ISSN 0826-9580
ISBN 0-7778-1220-7

THESE TERMS GOVERN YOUR USE OF THIS DOCUMENT

Your use of this Ontario Geological Survey document (the "Content") is governed by the terms set out on this page ("Terms of Use"). By downloading this Content, you (the "User") have accepted, and have agreed to be bound by, the Terms of Use.

Content: This Content is offered by the Province of Ontario's *Ministry of Northern Development and Mines* (MNDM) as a public service, on an "as-is" basis. Recommendations and statements of opinion expressed in the Content are those of the author or authors and are not to be construed as statement of government policy. You are solely responsible for your use of the Content. You should not rely on the Content for legal advice nor as authoritative in your particular circumstances. Users should verify the accuracy and applicability of any Content before acting on it. MNDM does not guarantee, or make any warranty express or implied, that the Content is current, accurate, complete or reliable. MNDM is not responsible for any damage however caused, which results, directly or indirectly, from your use of the Content. MNDM assumes no legal liability or responsibility for the Content whatsoever.

Links to Other Web Sites: This Content may contain links, to Web sites that are not operated by MNDM. Linked Web sites may not be available in French. MNDM neither endorses nor assumes any responsibility for the safety, accuracy or availability of linked Web sites or the information contained on them. The linked Web sites, their operation and content are the responsibility of the person or entity for which they were created or maintained (the "Owner"). Both your use of a linked Web site, and your right to use or reproduce information or materials from a linked Web site, are subject to the terms of use governing that particular Web site. Any comments or inquiries regarding a linked Web site must be directed to its Owner.

Copyright: Canadian and international intellectual property laws protect the Content. Unless otherwise indicated, copyright is held by the Queen's Printer for Ontario.

It is recommended that reference to the Content be made in the following form:

Breaks, F.W. and Bond, W.D., 1993. The English River Subprovince – An Archean Gneiss Belt: Geology, Geochemistry and associated mineralization; Ontario Geological Survey, Open File Report 5846, v.1, p.1-483, 884p.

Use and Reproduction of Content: The Content may be used and reproduced only in accordance with applicable intellectual property laws. *Non-commercial* use of unsubstantial excerpts of the Content is permitted provided that appropriate credit is given and Crown copyright is acknowledged. Any substantial reproduction of the Content or any *commercial* use of all or part of the Content is prohibited without the prior written permission of MNDM. Substantial reproduction includes the reproduction of any illustration or figure, such as, but not limited to graphs, charts and maps. Commercial use includes commercial distribution of the Content, the reproduction of multiple copies of the Content for any purpose whether or not commercial, use of the Content in commercial publications, and the creation of value-added products using the Content.

Contact:

FOR FURTHER INFORMATION ON	PLEASE CONTACT:	BY TELEPHONE:	BY E-MAIL:
The Reproduction of Content	MNDM Publication Services	Local: (705) 670-5691 Toll Free: 1-888-415-9845, ext. 5691 (inside Canada, United States)	pubsales.ndm@ontario.ca
The Purchase of MNDM Publications	MNDM Publication Sales	Local: (705) 670-5691 Toll Free: 1-888-415-9845, ext. 5691 (inside Canada, United States)	pubsales.ndm@ontario.ca
Crown Copyright	Queen's Printer	Local: (416) 326-2678 Toll Free: 1-800-668-9938 (inside Canada, United States)	copyright@gov.on.ca

Ministry of
Northern Development
and Mines
Ontario

Ontario Geological Survey
Open File Report 5846

The English River Subprovince – An Archean Gneiss Belt: Geology, Geochemistry and Associated Mineralization

Volume 1

1993

Ministry of
Northern Development
and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY

Open File Report 5846

The English River Subprovince—An Archean Gneiss Belt: Geology, Geochemistry and Associated Mineralization

Volume 1

By

F.W. Breaks and W.D. Bond

1993

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

Breaks, F.W. and Bond, W.D. 1993. The English River Subprovince—An Archean Gneiss Belt: Geology, Geochemistry and associated mineralization; Ontario Geological Survey, Open File Report 5846, v.1, p.1-483, 884p.

© Queen's Printer for Ontario, 1993

Ontario Geological Survey

OPEN FILE REPORT

Open File Reports are made available to the public subject to the following conditions:

This report is unedited. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Recommendations and statements of opinions expressed are those of the author or authors and are not to be construed as statements of government policy.

This Open File Report is available for viewing at the following locations:

Mines Library
Level A3, 933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5

Mines and Minerals Information Centre (MMIC)
Rm. M2-17, Macdonald Block
900 Bay St.
Toronto, Ontario M7A 1C3

The office of the Resident Geologist whose district includes the area covered by this report.

Copies of this report may be obtained at the user's expense from:

OGS On-Demand Publications
Level B4, 933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5
Tel. (705)670-5691 Collect calls accepted.

Handwritten notes and sketches may be made from this report. Check with MMIC, the Mines Library or the Resident Geologist's office whether there is a copy of this report that may be borrowed. A copy of this report is available for Inter-Library loan.

This report is available for viewing at the following Resident Geologists' offices:

Kenora, Box 5200, 808 Robertson St., Kenora P9N 3X9

Sioux Lookout, Box 3000, Court House Building, Sioux Lookout P0V 2T0

Red Lake, Box 324, Ontario Government Building, Red Lake P0V 2M0

The right to reproduce this report is reserved by the Ontario Ministry of Northern Development and Mines. Permission for other reproductions must be obtained in writing from the Director, Ontario Geological Survey - Geoscience Branch.

FOREWORD

Prior to 1974 there was very little geological understanding of the English River and Winnipeg River subprovinces. Their origin, tectonic setting, mineral potential and relations to the bounding Uchi and Wabigoon subprovinces were unknown.

Beginning in 1974 the Ontario Geological Survey undertook a four year helicopter supported reconnaisance mapping project covering 37000 square kilometers to improve on the geological data base.

The results of this study have greatly enhanced our understanding of the genesis of the metasedimentary subprovinces that flank the granite-greenstone dominated subprovinces. The present report describes the potential for metallic and industrial mineralization and building stone.

V.G. Milne
Director
Ontario Geological Survey

TABLE OF CONTENTS

VOLUME 1

ABSTRACT

CHAPTER 1 - INTRODUCTION....1
Location and Access....2
Present Geological Survey....3
Present Geological Report....6
Previous Investigations....7
Prospecting and Mining History....11
Natural Resources....12
Topography and Drainage....13
Acknowledgments....14

CHAPTER 2 - TERMINOLOGY....17
Major Divisions of the Superior Province....17
Subdivisions of the Subprovinces....17
Gneiss and Migmatite Terminology....19
Gneiss....19
Foliated to Gneissic....20
Foliation....20
Migmatite....21
Metamorphic Terminology....22
Cataclastic Terminology....22
Intrusive Rock Nomenclature....23

CHAPTER 3 - GENERAL GEOLOGY AND METAVOLCANIC ROCKS....26
Metavolcanic Rock Subdivision....31
Mapping Emphasis....32
Mafic to Intermediate Metavolcanic Rocks....33
Mineralogy....33
Massive Flows....35
Pillowed Flows....36
Pyroclastic Rocks....37
Gneissic Metavolcanic Rocks....37
Felsic to Intermediate Metavolcanic Rocks....38
Mineralogy....39
Pyroclastic Rocks....40
Massive and Porphyritic Flows....43
Specific Metavolcanic Belts....44
English River Subprovince....44
Separation Lake Belt....44
Modern Analogues....48
Eastern Extension of Separation Lake Belt....49
Uchi Subprovince....50

Dixie Lake Belt....51
Bruce Lake-Snakeweed Lake-Fredhart Lake Area....52
Mafic Metavolcanic Units....52
Felsic to Intermediate Metavolcanic Units....53
Slate Lake Area....56
Slate Lake to Papaonga Lake Area....57
Papaonga Lake....58
Badrock-Avis Lakes - Wassa Bay....59
Avis-Jubilee-Slate Lake Area....60
Papaonga Lake - Roadhouse River River - Root Bay Metavolcanic Belt....61
Lake St. Joseph Metavolcanic Belt....62
Wabigoon Subprovince....62
Tustin-Bridges Greenstone Belt....62
Dryden-Sioux Lookout Area....66
Sioux Lookout - Sturgeon Lake Belt....67
Savant Lake Greenstone Belt....68

CHAPTER 4 - METASEDIMENTARY ROCKS AND DERIVED MIGMATITES....71
Introduction....71
Lithological Composition....72
Inter- and Intra-subprovince Boundary Relationships....73
Northern Boundary....73
Boundary between Northern and Southern Domains....76
The Migmatite Problem....78
List of Notable Features of Metasedimentary Migmatites....82
Migmatite Stage....82
Protometatexite....82
Metatexite....83
Inhomogeneous Diatexite....83
Homogeneous Diatexite....83
Migmatite Constituents....83
Paleosome....83
Leucosome....83
Melanosome....84
General Types of Structures....85
Cataclastic Migmatitic Rocks....86
Map Coding....87
Classification of Metasedimentary Migmatites from the English River Subprovince: Concept of the Migmatite Continuum....87
Metatexite....88
Protometatexite....90
Diatexite....93
Inhomogeneous Diatexite....95
Homogeneous Diatexite....96
Wapesi Lake batholith....99

Churchill Lake batholith....100
Migmatite Constituents....101
Paleosome....101
Leucosome....103
Petrochemistry....107
K/Rb variation....112
Melanosome....112
Petrochemistry....114
Modal Features of Wacke and Pelitic Metasedimentary Rocks....115
Comparison to other Important Rock Groups
Hornblende-Bearing Sodic Granitoids....118
Potassic Granitoid Group....119
Petrochemistry of the Metasedimentary Rocks....120
K/Rb Variation....124
Origin of the Metasedimentary Rocks....125

CHAPTER 5 - SUBVOLCANIC INTRUSIVE ROCKS....133
Subvolcanic Intrusions....133
Subdivision of the Intrusive Rocks....135

CHAPTER 6 - MAFIC INTRUSIVE SUITE....141
Nature and Distribution....141
Stocks and Sills of the English River Subprovince....142
Isolated Plutons of Uncertain Origin....142
Muriel Lake pluton....143
Ena Lake pluton....144
Pakwash Lake pluton....145
Bruce Lake pluton....146
Stocks and Sills Associated with other Intrusive Suites....148
Broadcast Lake stock....149
Conifer Lake intrusive complex....149
Stocks and Sills of the Uchi Subprovince....151
Papaonga Lake pluton....152
Lake St. Joseph Layered Mafic intrusive complex....153
Plutons of the Wabigoon Subprovince....154
Mafic Dykes, Enclaves and Derived Amphibolite....156
Mafic dykes....156
Mafic Enclaves....157
Chemistry of the Mafic Intrusive Suite....158
Comparative Chemistry and Modern Analogues....158
Chemical Relationship of Dykes and Plutons....165
Age and Emplacement of the Mafic Intrusive Suite Relative to the Important Plutonic Suites....166
Summary....167

CHAPTER 7 - GNEISSIC GRANITOID SUITE....168
Introduction....168
Distribution and Nature....169
Map Associations....174
Ultramafic Association....175
Supracrustal Association....177
Amphibolite Units....177
Metasedimentary Units....178
Tonalite Association....178
Leucogranite Association....180
Leucocratic Biotite Trondhjemite....181
Holo-leucocratic Trondhjemite....182
Leucocratic Quartz Monzonite....182
Mafic Dyke Association....183
Potassic Granitoid Association....185
Other Minor Associations....186
Potassium Metasomatism....186
Biotite Schlieren....187
Tectono-Metamorphic Reworking of the Associations....187
Modal Variation....188
Origin of the Gneissic Suite....189
Summary....198

CHAPTER 8 - SODIC GRANITOID SUITE....200
Introduction....200
Mineralogy....202
General Lithic Groups of the Sodic Suite....206
Equigranular and Inequigranular Units....207
Porphyritic/Porphyroblastic (K-Feldspar) Units....208
Granitic Units....210
Hybrid Rocks and Enclaves....210
Cataclastic Units....211
Intrusion Types of the Sodic Granitoid Suite....211
Simple Homogeneous Plutonic Type....212
Dalles batholith....213
Campfire Lake and Daniels Lake plutons....216
Complex, Heterogeneous Plutonic Type....216
Sen Bay stock....218
Chemistry....220
Summary....223

CHAPTER 9 - POTASSIC GRANITOID SUITE....226
Introduction....226
Mineralogy and Modal Variation....230
Equigranular Units....231
Clotty Quartz Monzonite....233

Porphyritic Units....238
Lount Lake batholith....240
Mineralogy....243
Modal and Chemical Variation....246
Origin....247
Porphyritic, Contact-Controlled Sills....252
Trondhjemite to Granodiorite Units....254
Syenite Units....256
Pegmatite....257
Sharply-defined Sills and Dikes....258
Diffuse Veins and Sills....260
Pegmatitic Granite Border Unit....261
Consanguineous Pegmatite Pods....263
White Pegmatite....264
Potassium Metasomatism....268
Cataclastic Rocks....270
Summary....271

CHAPTER 10 - CHEMICAL VARIATION AND GENESIS OF THE IMPORTANT PLUTONIC SUITES....273
Introduction....273
Chemical Variation....273
Summary....275
Nature of the English River Subprovince Plutonism....278
Modern Analogues....286
Genesis of Plutonic Rocks of the English River Subprovince....288

CHAPTER 11 - NATURE OF PLUTONISM OUTSIDE THE ENGLISH RIVER SUBPROVINCE....293
Wabigoon Subprovince....293
Sturgeon Lake - Sioux Lookout Area....293
Mafic to Intermediate Intrusive Rocks....293
Intermediate to Felsic Intrusive Rocks....294
Yett Lake stock....294
Robinson batholith....294
Nagron Lake stock....295
Lake of Bays batholith....295
Other Areas in the Wabigoon Subprovince
Uchi Subprovince....297
Contact Relationships....298
Subprovince Boundaries....298
Wabigoon-English River Boundary....298
Uchi - English River Boundary....301
Northern - Southern Domain Interface....302

CHAPTER 12 - PLEISTOCENE GEOLOGY....304
Glacial History....304
Glacial Deposits....306
Terminal Morraines....306
Outwash Deposits....307
Glacio-Lacustrine Deposits....307
Kames and Eskers....308
Ribbed Morraines, Scouring/Drumlimoid Ridges....308
Recent....309

CHAPTER 13 - GEOPHYSICS....310
Correlation with aeromagnetic data....310
Correlation with radiometric data....311
Seismic data....312

CHAPTER 14 - METAMORPHISM....314
Introduction....314
Northern Supracrustal Domain....315
Lake St. Joseph Area
Southern Plutonic Domain....319
Low Pressure Granulite Facies Metamorphism....320
Metamorphic Conditions....323

CHAPTER 15 - STRUCTURAL GEOLOGY....325
Introduction....325
Northern Supracrustal Domain....325
Southern Plutonic Domain....331
Cedar - Clay Lakes Area....331
Tectonic Assemblage I....332
Tectonic Assemblage II....333
Tectonic Assemblage III....334
Kenora Area....335
Late Archean Faults....338
Sydney Lake Fault....338
Structural and Lithologic Features....339
Shearing and Flattening....341
Origin of the Faulting....341
Other Fault Systems....342
Origin and significance of pseudotachylite....343

CHAPTER 16 - METALLOGENY OF THE ENGLISH RIVER SUBPROVINCE...352
Introduction....352
Mineralization of the Lithophile Affinity....347
Beryllium....348
Sandy Creek Beryl Occurrence....348
Exploration History....349
Geology....349

Geochemistry....350
Cesium....352
Lithium....352
McCombe Property (Capital Lithium Mines Limited)....354
Exploration History....354
Geology....355
Geochemistry....356
Tot Lake Li-Cs-Rb-Ta Occurrence....357
Exploration History....357
Geology....358
Geochemistry....361
Mavis Lake Li-Be-Ta Pegmatite Dykes....365
Exploration History....365
Geology....366
Economic Geology....367
Distribution of Lithium in the Metamorphic and Anatectic Environments....368
Lithium in Anatectic Rocks....369
S-Type Granite - Rare-Element Pegmatite Association....371
Tantalum....375
Uranium....376
Metasedimentary Migmatite Association....377
Sydney Lake Fault Occurrences....377
Sydney Lake Fault Occurrences....377
Geological Setting....378
Radiometric Survey....378
Geochemistry....379
Umfreville Lake Uranium Occurrence....380
Exploration History....380
Geology....380
Geochemistry....381
Holunga Uranium Occurrence....384
Exploration History....384
Geology....384
Anderson Occurrence....385
Exploration History....385
Geology....385
Origin of the Type I Uranium-Bearing Granitic Pegmatites....386
Uranium Associated with the Potassic Granitoid Suite....388
Celyn Lake Occurrence....389
Exploration History....389
Geology....389
Geochemistry....390

Drope Township Uranium Occurrence....392
Exploration History....392
Geology....392
High Grade Zone....393
Low Grade Zone....394
Bluett-Gilbert Lakes Portage....395
Geochemistry....395
Davidson Uranium Occurrence....396
Exploration History....397
Geology....397
Geochemistry....401
Tourist Lake Occurrence....403
Exploration History....403
Geology....403
Geochemistry....405
Cameron-Alcock Occurrence....406
Exploration History....406
Geology....406
Perch Lake Occurrence....406
Exploration History....406
Geology....407
Geochemistry....407
Ena Lake Occurrence....407
Exploration History....407
Geology....408
Geochemistry....408
Mineralization of the Chalcophile Affinity....409
Massive Sulphide Mineralization....409
Minaki Pyrite Deposit....409
Exploration History....410
Geology....410

REFERENCES....419

VOLUME 2

TABLES

1-1 Classification of granulite rocks of the regional hypersthene zone.....484
1-2 Classification of plutonic rocks used by the Ontario Division of Mines.....485
2-1 Table of lithologic units for the English River Subprovince.....486
3-1 Chemical analyses of extrusive/intrusive rocks from Separation Lake.....492
3-2 List of localities representing the extension of Separation Lake Belt.....493
3-3 Chemical analyses of Chamberlain Narrows (Lac Seul) metavolcanic rocks.....494
3-4 Chemical analyses of Sioux Lookout amphibolites.....495
4-1 Lithological composition of the English River Subprovince.....497
4-2 Classification and general features of metasedimentary migmatites from the northern supracrustal domain, English River Subprovince.....498
4-3 Chemical and modal analyses of mafic diatexite from the English River Subprovince.....499
4-4 Modal analyses of leucosome from metasedimentary migmatites of the English River Subprovince.....500
4-5 Mean bulk chemical composition of metawacke from the English River Subprovince in comparison to various lithic groups from the literature.....509
4-6 Mean bulk composition of pelitic metasedimentary rocks from the English River Subprovince in comparison to various lithic groups from the literature.....510
4-7 Chemical analyses and selected element ratios for the leucosome constituent from metsedimentary migmatite of the English River Subprovince.....511
4-8 Chemical analyses and selected element ratios of mafic diatexites from the English River Subprovince.....522
4-9 Modal composition of the residual fraction derived from experimental partial melting of Harz Mountain greywackes at 700°C and pH_2O = 200 bars after Winkler and von Platen (1961).....526
4-10 Chemical analyses of the melanosome constituent from metasedimentary migmatite of the northern supracrustal domain.....527
4-11 Modal analyses of metawacke from the English River Subprovince.....528
4-12 Modal analyses of metapelite from the English River Subprovince.....535
4-13 Chemical analyses and selected element ratios of metawacke from the English River Subprovince.....539
4-14 Chemical analyses and selected element ratios of metapelite from the English River Subprovince.....560
4-15 Mean values and ranges of selected trace elements for metawacke, metapelite and various other Archean lithic groups.....575
4-16 Mean values and ranges of selected trace elements in metawackes from the English River Subprovince compared to those from the literature.....576

4-17 Mean values and ranges of selected trace elements in metapelites from the English River Subprovince compared to those from the literature....577
4-18 Mean composition of metawacke and metapelite from the English River Subprovince compared to the composition of the upper crust....578
6-1 Modal analyses from the Broadcast Lake pluton (after Desnoyers 1977, p.22)....579
6-2 Petrologic subdivision of Lake St. Joseph mafic layered sill (Smith 1977, p.1-39)....580
6-3 Chemical analyses of fine-grained amphibolites (Gower 1978, p.558-559)>....582
6-4 Chemical analyses of medium-grained amphibolites and mafic dykes form the Kenora area (Gower 1978, p.561-562)....583
6-5 Chemical analyses of Lac Seul mafic dykes....584
6-6 Chemical analyses of anorthositic, mafic and ultramafic enclaves, Lac Seul....585
6-7 Chemical analyses of mafic enclaves, Lac Seul....586
6-8 Range and mean values for various rocks of the mafic intrusive suite....587
6-9 Range and mean for Cr, Cu, Ni and Zn for various rocks of the mafic intrusive suite....589
7-1 Mappable rock associations within the gneissic suite (after Westerman 1977)....590
7-2 Petrographic differences between the fine-grained and medium-grained amphibolites in the Kenora area (Gower 1978, p.206)....591
7-3 Comparison of rock associations for Cedar Lake, Melick and Deception Bay gneissic suites....592
7-4 Important lithologic associations and possible genesis of the Cedar Lake gneiss....593
7-5 Lithological and genetic characteristics of the gneissic suite at Kenora summarized from Gower (1978)....594
7-6 Lithologic characteristics and associations of the Deception Bay - Lac Seul gneissic suite....595
7-7 Petrographic differences between fine-grained and coarse-grained amphibolites in the Kenora area (Gower 1978, p. 206)....597
8-1 Petrography of units from the Sen Bay stock....598
8-2 Chemical analyses of the Sen Bay stock....599
9-1 Chemical analyses of the matrix and clasts of the clotty quartz monzonite....600
9-2 Lithophile trace elements from pegmatitic granite mass north of Papaonga Lake. 10-1 Chemical analyses of the gneissic granitoid suite, Deception Bay area of Lac Seul....601
10-1 Chemical Analyses of the Gneissic Suite, Deception Bay Area....602
10-2 Chemical analyses of the Melick gneiss, Kenora area....604
10-3 Chemical analyses of the gneissic granitoid suite north of the Tustin-Bridges area....605

10-4 Chemical analyses of the gneissic granitoid suite from the Sioux Lookout area....606
10-5 Chemical analyses of Cedar Lake gneiss (Westerman 1977)....607
10-6 Chemical analyses of biotite tonalite gneiss from the Kenora area (Gower 1978, p. 567-568)....608
10-7 Chemical analyses of amphibole gneiss from the Kenora area (Gower 1978, p. 566)....611
10-8 Chemical analyses of sodic granitoid suite rocks from the Campfire Lake pluton....612
10-9 Chemical analyses of sodic granitoid suite rocks from the Bowden Lake and Daniels Lake plutons....613
10-10 Chemical analyses of miscellaneous rocks of the sodic granitoid suite emplaced in metasedimentary hosts....614
10-11 Chemical analyses of the Sen Bay stock....616
10-12 Chemical analyses of the Chamberlain Narrows intrusive complex....617
10-13 Chemical analyses of the Separation-Indian Lake intrusive complex....618
10-14 Chemical analyses of the Armit Lake intrusive complex....619
10-15 Chemical analyses of the Lount Lake batholith....620
10-16 Chemical analyses of miscellaneous units of the potassic granitoid suite....621
10-17 Chemical analyses of the Fletcher Lake batholith....623
10-18 Chemical analyses from the Lateral Lake area....624
10-19 Range and mean values of selected trace elements from the gneissic granitoid suite....625
10-20 Range and mean values of selected trace elements from the sodic granitoid suite....629
10-21 Range and mean values of selected trace elements from the potassic granitoid suite....633
10-22 Summary of the main features of the important plutonic suites of the English River Subprovince....635
10-23 Compilation of radiometric ages for the important plutonic suites of the English River Subprovince....636
11-1 Chemical analyses of the Robinson batholith....638
11-2 Chemical analyses of the Nagron Lake stock....639
11-3 Chemical analyses of the Lake of Bays batholith....641
11-4 Chemical analyses of the Sturgeon River Batholith....642
11-5 Chemical analyses of the Lewis Lake batholith....643
14-1 Metamorphic and deformation events in the Uchi and English River Subprovinces of Ontario (modified after McRitchie and Weber 1971)....644
14-2 Metamorphic mineral assemblages from the Lake St. Joseph and eastern Lac Seul areas....645
14-3 Metamorphic mineral assemblages in metasedimentary rocks from the Dryden-Eagle Lake area....646
15-1 Summary of structures and metamorphism in the nothern supracrustal domain of the English River Subprovince of Ontario and Manitoba....647

15-2 Summary of geological and tectonic-metamorphic history of the Cedar-Clay Lakes area (after Westerman 1977)....648
15-3 Summary of the structural and metamorphic history of the Kenora area (after Gower 1978; Gower and Clifford 1981)....650
16-1 Average crustal abundance of selected elements and ratios....651
16-2 Partial petrochemical analyses from the Sandy Creek beryl occurrence....652
16-3 Analysis of composite muscovite samples from the Sandy Creek and Tot Lake rare-element pegmatites....653
16-4 Selected mean ratios from beryllium, lithium and uranium pegmatite....654
16-5 Partial analyses and element ratios from spodumene pegmatite at the McCombe property....655
16-6 Partial petrochemical analyses from the Tot Lake Pegmatite....656
16-7 Analyses of columbite-tantalite group mineral from the Tot Lake Pegmatite (From Ucakuwun 1981, p.113)....659
16-8 Petrochemical analyses across Pegmatite #5 at the North Zone of the Mavis Lake property....660
16-9 Mean contents (ppm) of Li, Rb, Cs, Ba and U in metawacke and metapelitic rocks from the Lake St. Joseph area in relation to metamorphic grade....661
16-10 Mean contents (ppm) of lithium in muscovite and biotite from the study area and the literature....662
16-11 Classification of unzoned, uranium-rich granitic pegmatites of the western English River Subprovince....663
16-12 Partial petrochemical analyses from the Umfreville Lake uranium occurrence....664
16-13 Chemical analyses of metasedimentary rocks from the Umfreville Lake area which contain anomalous U and Th....669
16-14 Partial petrochemical analyses of granitic rocks from the Celyn Lake uranium occurrence....670
16-15 Partial petrochemical analyses of granitic rocks from the Drope Township uranium occurrence....671
16-16 Partial petrochemical analyses of granitic rocks from the Davidson uranium occurrence....675
16-17 Mean values of U, Th, K/Ba, K/Cs, K/Rb, K/Th, K/U, Ba/Rb, Mg/Li, and Th/U at the Main Zone of the Davidson uranium occurrence....680
16-18 Partial petrochemical analyses of various units at the Tourist Lake uranium occurrence....681
16-19 Chemical analyses and element ratios of granitic rocks from the Ena Lake and Perch Lake uranium occurrences....683

FIGURES

1-1 General location of areas covered by geological reconnaissance mapping projects in the English River Subprovince....685
1-2 Generalized geological aspect of the English River Subprovince, Northwestern Ontario....686
2-1 Geology of the English River Subprovince....687
3-0 Geology of the Separation Lake Belt....688
3-1 AFM diagrams of metavolcanic rocks....689
3-2 Jensen Cation Plot of Separation Lake mafic metavolcanic rocks, felsic volcanics, and mafic intrusive rocks....690
3-3 Chemical variation of Separation Lake mafic metavolcanic, extrusive and intrusive rocks....691
3-4 Chemical variation of Separation Lake mafic metavolcanic, extrusive and intrusive rocks....692
3-5 Chemical variation of Sioux Lookout mafic metavolcanic rocks....693
4-1 General geology and metallogeny of the English River and adjacent parts of the Uchi and Wabigoon Subprovinces....694
4-2 General geology of the English River-Uchi Subprovince interface in the Papaonga Lake area....695
4-3 General geology of the interface between Uchi Subprovince meta-volcanic rocks and northern supracrustal domain metasedimentary rocks in the western Lake St. Joseph area....696
4-4 Distribution of advanced stage metsedimentary migmatites (diatexites) in relation to low pressure granulite centres of the English River Subprovince....697
4-5 Modal variation of quartz-plagioclase-K-feldspar in leucosome from metasedimentary migmatite of the northern supracrustal domain....698
4-6 Modal variation of quartz-feldspar-colour index in leucosome from metasedimentary migmatite of the northern supracrustal domain as compared to S-Type granitoid rocks from the Kosciusko batholith, Australia....699
4-7 General modal variation trends in S-Type granitoid rocks (northern supracrustal domain and Kosciusko batholith) compared to I-Type granitoid rocks from the southern plutonic domain....699
4-8 Quartz-feldspar-colour index modal variation in metawacke and metapelitic rocks from the northern supracrustal domain....700
4-9. Comparison of the quartz-feldspar-colour index modal fields for metawacke, and metapelite of the northern supracrustal domain with biotite- and hornblende-bearing sodic granitoid suite rocks of the English River Subprovince....700
4-10 AFM and CNK plots (weight %) illustrating compositional variation of metawacke from the northern supracrustal domain. Ennumerated analyses correspond to mean lithic compostions selected from the literature as given in Table 4-5....701
4-11 AFM and CNK plots (weight %) illustraing composition variation

of metapelites from the northern supracrustal domain. Ennumerated analyses correspond to mean lithic compostions selected from the literature as given in Table 4-6 702
4-12 The Fe_{total}-Mg-Na+K (weight %) expression of metatexis-anatectic spitting of paleosome giving rise to melanosome and leucosome constituents 703
4-13 Variation of Fe_{total}-Mg-Na+K (weight %) in diatexites as possibly related to progressive fusion of a metasedimentary protolith. The curve interpreted as due to increasing anatexis was derived from this study supplemented with the data of Winkler (1979) 704
4-14 Variation of Ca-Na-K (weight %) in diatexites, illustrating the sodic and potassic leucosome trends 705
4-15 K_20 vs Na_2O variation in leucosome from metasedimentary migmatite of the study area in comparison to sodic and potassic granitoid suite rocks and Australian S-Type granitoids 706
4-16 Variation of Fe^{2+}-Fe^{3+}-Mg in leucosome from the northern supracrustal domain and equigranular and porphyritic divisions of the potassic granitoid suite from the southern plutonic domain 707
4-17 Histograms revealing frequency of $Fe^{3+}/Fe^{2+} + Fe^{3+}$ in leucosome from the northern supracrustal domain compared to potassic granitoid suite rocks from the southern plutonic domain 708
4-18 Normative quartz-albite-orthoclase for leucosome from the northern supracrustal domain. Isotherms and cotectic projection at P H_2O = 5 kbars from Winkler et al. (1975) 709
4-19 Normative anorthite-albite-orthoclase for leucosome from the northern supracrustal domain. Isotherms and cotectic projection at PH_2O = 5 kbars from Winkler et al. (1975) 710
4-20 K vs Rb variation in leucosome from metasedimentary migmatite of the English River Subprovince 711
4-21 K vs K/Rb variation in leucosome from metasedimentary migmatite of the English River Subprovince 712
4-22 Na_2O-K_2O variation in metasedimentary rocks from the English River Subprovince 713
4-23 Al_2O_3 vs K_2O+Na_2O variation in metasedimentary rocks of the English River Subprovince 713
4-24 Histograms revealing variation of CIPW normative corundum in metawacke and metapelite rocks of the English River Subprovince 714
4-25 FeO vs Fe_2O_3 variation in metawacke and metapelite rocks of the English River Subprovince 715
4-26 K vs K/Rb variation in metawacke rocks from the English River Subprovince 716
4-27 K vs K/Rb variation in metapelite rocks from the English River Subprovince 717
4-28 K vs Rb relationships as a function of metamorphism for metapelite and metawacke rocks of the English River Subprovince 718
4-29 MgO vs Ni variation in metasedimentary rocks from the English River Subprovince (123 analyses, this study) 719

4-30 MgO vs Cr variation in metasedimentary rocks from the English River Subprovince (132 analyses, this study).....720
4-31 Ni vs Cr variation in metasedimentary rocks from the English River Subprovince (123 analyses, this study).....721
4-32 MgO vs Ni diagram depicting the relationship of metasedimentary rocks of the English River subprovince with various, spatially associated lithic groups.....722
4-33 MgO-Cr diagram depicting the relationship of metasedimentary rocks of the English River Subprovince with various, spatially associated lithic groups.....723
4-34 Cr-Ni variation in meatavolcanic rocks from the Uchi and Wabigoon Subprovinces.....724
4-35 MgO-Ni variation in sodic granitoid suite rocks from the English River Subprovince.....725
4-36 MgO-Cr variation in sodic granitoid suite rocks from the English River Subprovince.....725
6-1 Location of the mafic intrusive suite in the English River Subprovince.....726
6-2 Modal analyses of various members of the mafic intrusive suite. Pillowed mafic metavolcanic rocks of the English River Subprovince are given for comparison (diagram #4).....727
6-3 Major, minor and trace element variation of the Lake St. Joseph layered mafic sill (Smith 1977) based upon 23 analyses. Dashed line divide undifferentiated metagabbro (Unit 3) from differentiated metagabbro (Unit 2).....728
6-4 TiO_2 vs FeO_{total}/MgO plot (Miyashiro and Shido 1975) for English River Subprovince amphibolites.....729
6-5 Zr-Ti/100-Sr/2 plot (Pearce and Cann 1973) for English River Subprovince amphibolites of varying origin. OFB = ocean basalts, CAB = calc-alkaline basalts and LKT = low K tholeiites.....730
6-6 Chemical variation of amphibolites in gneissic suite at Kenora. **missing figure**
6-7 Zr-Ti/100-Y.3 and Ti-Cr plots (Pearce and Cann 1973; Pearce 1975) for amphibolites of the English River and Wabigoon Subprovinces. OFB = ocean floor basalt, CAB = calc-alkaline basalts, LKT = low K-tholeiite, WPB = within plate basalts, IAB = island arc basalts.....731
6-8 K_2O-TiO_2-P_2O_5 plot (Pearce et al. 1975) for amphibolites hosted in the gneissic granitoid suite at Kenora and Cedar Lake.....732
6-9 K_2O-TiO_2-P_2O_5 plot (Pearce et al. 1975) for amphibolites in the Chamberlain Narrows (Lac Seul) area.....733
6-10 TiO_2-MnO-P_2O_5x10 plot (pearce et al. 1975) for English River Subprovince amphibolites of intrusive and extrusive origin.....734
6-11 AFM plots (weight %) of various amphibolitic rocks from the English River Subprovince.....735
6-12 Chemical variation of mafic intrusive suite rocks hosted in the gneissic granitoid suite.....736
7-1 Distribution of the gneissic granitoid suite in the English River Subprovince.....737

7-2 Classification of gneissic granitoid suite rocks in the Kenora area (Gower 1978, p.84)....738
7-3 Modal variation of the gneissic granitoid suite (Sioux Lookout gneiss, Lac Seul gneiss, Melick gneiss, Cedar Lake gneiss and Twilight gneiss....739
7-4 Sedimentary/igneous discrimination function analyses (Shaw 1972) for the gneissic granitoid suite (A and C: Melick gneiss; B: Kenora and Deception Bay gneiss)....740
7-5 TiO_2 - SiO_2 igneous/sedimentary discrimination diagram (Tarney et al. 1976) for the gneissic granitoid suite....741
7-6 Spatial relation between the gneissic granitoid suite and granulite grade zones....742
7-7 AFM-CNK (weight %) variation of Deception Bay (Lac Seul) gneissic granitoid suite. Unit number (see Table 7-6) indicates relative age of intrusion....743
8-1 Distribution of sodic and potassic granitoid suite stocks and batholiths in the northern supracrustal domain....744
8-2 Distribution of the sodic granitoid suite in the southern plutonic domain....745
8-3 Modal variation of specific sodic suite plutons in the northern supracrustal domain....746
8-4 Modal variation of the Separation-Indian Lakes Complex (sodic granitoid suite)....746
8-5 Modal variation of the Armit Lake Complex, Dalles batholith (Gower 1978) and miscellaneous plutons....747
8-6 Geological setting of the Sen Bay stock....748
8-7 Quartz-total feldspar-mafics modal variation of the Sen Bay stock....749
8-8 Quartz-plagioclase-K-feldspar) modal variation of the Sen Bay stock....750
8-9 AFM and Mg-Li variation of the Sen Bay stock....751
9-1 Distribution of potassic granitoid suite in the southern plutonic domain....752
9-2 Modal analyses of the potassic granitoid suite....753
9-3 Location of occurrences of clotty quartz monzonite....754
9-4 CNK plot (weight %) of the matrix of clotty quartz monzonite....755
9-5 FeO vs Fe_2O_3 variation for homogeneous diatexite and the matrix of the clotty quartz monzonite....756
9-6 AFM plot (weight %) for clots from clotty quartz monzonite....757
9-7 Geology of the Lount Lake batholith....758
9-8 Modal variation of early and late units of the Lount Lake batholith....759
9-9 CNK plot (weight %) of the early and late units of the Lount Lake batholith....759
9-10 Harker variation diagrams for Lount Lake batholith....760
10-1 AFM (weight %) variation of gneissic granitoid suite....761
10-2 CNK (weight %) variation of gneissic granitoid suite....762
10-3 AFM (weight %) variation of specific sodic granitoid suite plutons....763
10-4 CNK (weight %) variation of specific sodic granitoid suite plutons....764
10-5 AFM (weight %) variation of the sodic granitoid suite....765

10-6 CNK (weight %) variation of the sodic granitoid suite.....766
10-7 CNK and AFM (weight %) variation of the heterogeneous complexes of the sodic granitoid suite.....767
10-8 AFM and CNK (weight %) variation of the potassic granitoid suite. Numbers 1-15 are miscellaneous samples in Table 10-17.....768
10-9 AFM (weight %) variation of the major granitic suites.....769
10-10 CNK (weight %) variation of major granitic suites.....769
10-11 AFM-CNK (weight %) plots of average chemical analyses of other gneissic terrains compared to the average gneissic granitoid suite from the English River Subprovince (point 19). Points 9, 12, 13, 14, 15, 20 and 21 are averages of various metasedimentary rocks.....770
10-12 Chemical composition of various Archean complexes (Lambert et al. 1975, pp. 379, 381).....771
11-1 AFM - CNK (weight %) variation of the Wabigoon Subprovince intrusive rocks.....772
11-2 AFM and CNK (weight %) variation of Lewis Lake and Yett Lake stocks.....773
14-1 General distribution of metamorphic zones within the English River, Uchi and parts of the Berens River and Sachigo Subprovinces of northwestern Ontario (after Thurston and Breaks 1978).....774
14-2 Distribution of metamorphic zones, isograds, and migmatization stages at the Uchi-English River subprovincial boundary in the Lake St. Joseph area.....775
14-3 Inferred path of regional metamorphism across the Uchi-English River subprovincial boundary.....776
15-1 Geology of the Clay-Cedar Lakes area.....777
15-2 Vertical section of the important domal structures in the Cedar-Clay Lakes area.....Back pocket
15-3 Distribution of important fault systems in the English River Subprovince and adjoining parts of the Uchi and Wabigoon Subprovinces.....779
15-4 Geology of the Chase Lake area near the Sydney Lake Fault (after Stone 1981).....780
15-5 Contoured equal area stereoplot of slickensides from the Sydney Lake Fault between Sydney and Chase Lakes (after Stone 1981).....781
16-1 General geology near the Sandy Creek beryl occurrence.....782
16-2 Detailed geology of the Sandy Creek beryl dyke.....783
16-3 Distribution of rare-element pegmatites and isograds in the Dryden Pegmatite Field in relation to regional geology.....784
16-4 Detailed geology of the Roadhouse River spodumene pegmatite dykes.....785
16-5 Location of the Tot Lake Li- Cs-Rb-Ta Pegmatite, Webb Township.....786
16-6 Detailed geology of the Tot Lake Pegmatite.....787
16-7 K/Ba, K/Cs, K/Rb and Ba/Rb petrochemical relations and fractionation trends of spodumene pegmatites from the study area. Crustal abundance data for Ba, Cs, K and Rb from Table 16-1.....788

16-8 Profiles of Ba, Be, Cs, Li, Rb, Sr, Th and U variation in Trench 2 of the Tot Lake Pegmatite....789
16-9 Profiles of K/Ba, Rb/Sr, K/Cs, K/Rb, Mg/Li, and Ba/Rb variation in Trench 2 of the Tot Lake Pegmatite....790
16-10 Li vs. Mg variation in the Tto Lake Pegmatite....791
16-11 Comparison of Mg-Li variation in uranium pegmatites and spodumene-bearing, rare-element pegmatites from the study area....792
16-12 Th vs. U variation in spodumene-bearing rare-element pegmatites compared to that in a uranium-rich pegmatite....793
16-13 Geological setting of spodumene pegmatite dykes of the North and South Zones of the Mavis Lake (Fairservice) property....794
16-14 Profiles showing petrochemical variation of Ba, Cs, K, Li, Na, Rb, Sn, Sr and U and ratios K/Ba, K/Cs, K/Rb, K/Th, K/U, Th/U, Ba/Rb and Rb/Sr across Dyke #5 of the Mavis Lake spodumene pegmatite dyke swarm....795
16-15 Uranium mineralization associated with metasedimentary migmatite....796
16-16 Geology of the Sydney Lake uranium occurrence....797
16-17 Radiometric ground survey of the Umfreville Lake uranium occurrence. Contours represent total counts per second taken by an Exploranium scintillometer (model GRS-101) by Noranda Mines Limited in 1976....798
16-18 General geology and uranium mineralization in the Umfreville-Tourist Lakes areas....799
16-19 Detailed geology, location of trenches and assay samples at the Umfreville Lake uranium occurence....800
16-20 Petrochemical variation of K/Ba, K/Cs, K/Rb, and Ba/Rb at the Umfreville Lake uranium occurrence....801
16-21 Th vs. U relations in Type I uranium mineralization at the Umfreville Lake occurrence. Average Canadian shield Th/U ratios of 4 and 6.2 from Shaw et al. (1976) and Fahrig and Eade (1968), respectively....802
16-22 Mg vs. Li relations at Celyn Lake, Davidson, Drope Township, Tourist Lake and Umfreville Lake uranium occurrences....803
16-23 Distribution of Type II uranium mineralization and associated plutons of the potassic granitoid suite in the English River and Wabigoon Subprovinces....804
16-24 Geology, trench locations and assay sites at the Celyn Lake uranium occurrence....805
16-25 Petrochemical variation of K/Ba, K/Cs, K/Rb and Ba/Rb in potassic granitoid suite rocks from the Celyn Lake uranium occurrence....806
16-26 Th vs U relations at the Celyn Lake uranium occurrence....807
16-27 General geology of area around the Drope Township uranium occurrence....808
16-28 Location of "high grade" and "low grade" zones of Conwest Exploration Company Limited and other radioactive granitoid pegmatites, Drope Township uranium occurrence....809

16-29 Detailed geology, location of diamond drill holes of Conwest Exploration Company Limited and sample location from the "high grade" zone, Drope Township uranium occurrence....810
16-30 Geology and location of drill hole 3 and Pit #1 at the "low grade" zone of the Drope Township uranium occurrence....811
16-31 Petrochemical variation of K/Ba, K/Cs, K/Rb and Ba/Rb in uranium pegmatites of the potassic granitoid suite at the Drope Township uranium occurrence....812
16-32 Th vs. U relations in uranium pegmatites at the Drope Township uranium occurrence....813
16-33 Geology, location of trenches and assay samples from the Main Zone of the Davidson uranium occurrence....814
16-34 Petrochemical variation of K, U and Th in Trenches 1, 2, 3 and 4 at the Davidson uranium occurrence. Arrows indicate analyses with Th values below the 10 ppm detection limit....815
16-35 Petrochemical variation of K, U and Th in Trench 6 of the Davidson uranium occurrence. Arrows indicate analyses with Th values below the 10 ppm detection limit....816
16-36 Profiles showing petrochemical variation of K/Ba, K/Rb, K/U, Th/U, Ba/Rb, and Mg/Li along Trenches 1, 2, 3 and 4 at the Davidson uranium occurrence....817
16-37 Profiles showing petrochemical variation of K/Ba, K/Rb, K/U, Th/U, Ba/Rb and Mg/Li at Trench 6 of the Davidson uranium occurrence....818
16-38 K/Ba, K/Cs, K/Rb and Ba/Rb petrochemical variation at the Davidson uranium occurrence....819
16-39 Th vs. U petrochemical relations at the Davidson uranium occurrence....820
16-40 Li vs. SiO_2 relations in S-Type uranium-bearing granitic pegmatite rocks from the Umfreville Lake uranium occurrence....821
16-41 General geology, location of trenches and assay samples at the Tourist Lake uranium occurrence. Geological map after Can-Fer Exploration Syndicate (Fiale 2.307, AFRO, Toronto)....822
16-42 K/Ba, K/Cs, K/Rb, and Ba/Rb relations in metawacke, porphyritic quartz monzonite, porphyritic syenite and mafic-rich, biotite granodiorite at the Tourist Lake uranium occurrence....823
16-43 Th vs. U relations in rocks from the Tourist Lake uranium occurrence....824
16-44 Mineral occurrences in the Ena-Vermilion Lakes area....825

MAP

P.3091 Compilation map - English River Subprovince....Back pocket

PHOTOGRAPHS

3-1 Diffuse, magnetite-diopside-hypersthene-bearing felsic segregations (photo centre) contained within a magnetite-diopside-hypersthene-hornblende-plagioclase-bearing, possible mafic meta-volcanic host from Chamberlain Narrows, Lac Seul....826
3-2 Mafic tuff breccia from Troutfly Lake area in the Sioux Lookout greenstone belt....826
3-3 Gneissic mafic metavolcanic rocks from the Papaonga Lake-Lake St. Joseph greenstone belt. The banding is likely secondary but could also represent deformed tuffaceous bedding or pillow selvedges. Pencil = 22 cm....827
3-4 Intermediate tuff breccia containing fragments that are more mafic than the matrix. Outcrop located on the Ghost Lake road in south-west Webb Township....827
3-5 Contact between intermediate to felsic tuff (top of photo) and intermediate tuff breccia in the Lake St. Joseph greenstone belt....828
3-6 Felsic airfall tuff with mafic bomb (on left), situated about 3 km north of the eastern end of Gullwing Lake....828
3-7 Pillowed mafic metavolcanic rocks cut by quartz monzonite dyke in the Separation Lake greenstone belt near the Separation rapids....829
3-8 Complexely-deformed, thin dark bands in mafic metavolcanic rocks just south of Chamberlain Narrows. These bands possibly represent relict pillow selvedges....829
3-9 Diopside-hypersthene-bearing, mafic metavolcanic rock with possible partial melt of trondjemite composition from the Chamberlain Narrows area....830
3-10 Intermediate tuff breccia located just west of Fredhart Lake. The subtle fragments are slightly more felsic than the matrix....830
3-11 Porphyroblastic knots of andalusite in intermediate metavolcanic rocks southwest of Fredart Lake....831
3-12 Subvolcanic rock with brecciation possibly due to fumerolic degassing on the south shore of Fredhart Lake....831
3-13 Reworked tuffs and tuffaceous metasedimentary rocks from Upper Slate Lake....832
3-14 Cross-bedding in wacke metasedimentary rocks near Lower Slate Lake....832
3-15 Lit-par-lit injection of mafic metavolcanic rocks northeast of Papaonga Lake. The white bands consist of quartz monzonite....833
4-1 Multi-unit granitic rock exposure from the southern plutonic domain near Hudson....833
4-2 Inhomogeneous, meta-tonalite from the Sydney Lake area. Note the discrete to diffuse, mafic to ultramafic enclaves in varying states of reaction with the host and attendant, irregular zones of hybrid biotite-hornblende quartz diorite. Coin diameter = 2.3 cm....834

4-3 Multi-unit granitic exposure, west shore of Sydney Lake.....834
4-4 Protometatexite near Aerofoil Lake. Note the confinement of leucosome patches to the metamorphically coarsened pelitic paleosome layers. Metawacke layers have apparently resisted leucosome development and sporadically exhibit relict sedimentary laminae, as marked by hammer.....835
4-5 Detail of metapelitic layer in protometatexite, from the Wegg Lake area, which illustrates the abundance of cordierite and garnet porphyroblasts and intermingled patches of leucosome.....835
4-6 Combination of protometatexite and metatexite in metasedimentary migmatite at the Ear Falls damsite.....836
4-7 Metatexite metasedimentary migmatite, Ontario Hydro damsite at Ear Falls. Note the greater abundance of leucosome in the metapelitic paleosome (P) along the right. Metawacke paleosome (W) contains relatively sparse leucosome.....836
4-8 Inhomogeneous diatexite near Root Bay of Lake St. Joseph, illustrating the schollen structure. Bar = one metre.....837
4-9 Melanosome clot in the process of separation from a larger mass of restite to left of coin) contained within inhomogeneous diatexite of garnet-cordierite-biotite quartz monzonite composition. Treelined Lake. Coin diameter = 1.8 cm.....837
4-10 Transition from metatexite on right to inhomogeneous diatexite which contains twisted rafts of metawacke in cordierite-garnet-biotite leucosome at Treelined Lake.....838
4-11 Syenite leucosome from the Bear Narrows area of Lac Seul, exhibiting the large grain size range and hypidiomorphic-granular texture that is typical for the leucosome constituent.....838
4-12 Metatexite metasedimentary migmatite with exceptionally thick melanosome selvedges distributed only along one side of the leucosome. Ministry of Natural Resources warehouse site at Ear Falls. Coin Diameter = 1.8 cm.....839
4-13 Granite leucosome pod in protometatexite from the Wegg Lake area. The leucosome was apparently in the process of engulfing a large garnet porphyroblast (G) which lies adjacent to large cordierite poikiloblasts (C). Bar = 2 cm.....839
4-14 Dyke of "intrusive mobilizate" which sharpely truncates ptygmatically-folded leucosome in metawacke at Rao Lake. Coin diameter = 2.3 cm.....840
4-15 Apatite-biotite syenite leucosome in metatexite at the Ear Falls damsite. Note the symmetrical disposition of biotite-rich melansome selvedges along both leucosome contacts.....840
4-16 Biotite-cordierite-quartz clots in diatexite at Treelined Lake. Coin diameter = 1.8 cm.....841
4-17 Boudinage structure in metatexite metasedimentary migmatite, Wapesi Bay of Lac Seul.....841
4-18 Fibrous mat of sillimanite (S) associated with muscovite in

sillimanite-biotite-muscovite quartz monzonite in the Ghost Lake batholith. Highway 17 roadcut at Oxdrift. Coin diameter = 1.8 cm.....842
4-19 Cordierite-biotite quartz monzonite from Churchill Lake batholith near Sleen Lake. Euhedral cordierite indicated by arrow. Coin diameter = cm.....842
4-20 Hypidiomorphic-granular texture in homogeneous diatexite of biotite quartz monzonite composition at Jackson Lake. Bar = 2 cm.....843
4-21 Mafic diatexite of biotite tonalite composition near Conifer Lake. Bar = 1 cm.....843
4-22 Leucosome with abundant, euhedral cordierite, Ear Falls damsite. Coin diameter = 1.8 cm.....844
5-1 Medium-grained trondjemite, on right, intruded into quartz porphyry on Rexdale Property just southwest of Snakeweed Lake.....844
5-2 Irregular fracture pattern in subvolcanic intrusive (quartz porphyry) on the Rexdale Property.....845
6-1 Massive, medium-grained diorite at Muriel Lake, Kenora area.....845
6-2 Cataclastic quartz diorite of the Bruce Lake pluton situated about 8 km northwest of Bluffy Lake. Note the small, cross-cutting mass of pseudotachylite with well developed flow lines (centre).....846
6-3 Magmatic layering in unit 1D-i of the Lake St. Joseph mafic sill due to concentration of clots.....846
6-4 Clotty metagabbro of unit 1D-i of the Lake St. Joseph layered mafic sill. Note mafic-felsic mineral segregation suggesting top direction towards the photo top.....847
6-5 Mafic metagabbro dykes in the Bear Narrows area of Lac Seul.....847
6-6 Dykes of trondhjemite (T) and later quartz monzonite (Q) intruded into massive, coarse-grained, equigranular amphibolite (mafic intrusive suite). On the Minaki-Umfreville Lake road near Pistol Lake.....848
7-1 Gneissic granitoid suite with finely banded mafic aggregates, biotite tonalite, biotite trondhjemite and metasomatic K-feldspar (on left). Location is near the Wabigoon-English River subprovincial boundary at Kenora.....848
7-2 Intermediate gneiss from the Deception Bay area exhibiting diffuse, patchy hornblende diorite and small enclave of metaultramafic rock (on left).....849
7-3 Leucocratic trondhjemite gneiss, south of Bear Narrows, containing thin, continuous trains of biotite.....849
7-4 Gneissic granitoid suite at Deception Bay of Lac Seul. Rock contains foliated to gneissic biotite-hornblende diorite to quartz diorite and concordant trondjemite (T) which is discordantly intruded by fine-grained biotite trondhjemite.....850
7-5 Minor folds in gneissic granitoid suite from Pelican Lake near Sioux Lookout. Pen = 15 cm.....850
7-6 Rootless, intrafolial isoclinal folds in holo-leucocratic trondjemite constituent of a gneissic granitoid exposure on

Highway 105, just north of Vermilion Bay.....851
7-7 Rootless, intrafolial, isoclinal refolded fold defined by holo-leucocratic trondjemite and biotite-rich laminae in the Cedar Lake gneisses. Highway 105 roadcut near Cedar Lake. Ruler = 15cm.....851
7-8 Enclave of mafic metavolcanic or metagabbro rock in the gneissic granitoid suite, Deception Bay.....852
7-9 Highly disrputed, former dyke of mafic rock in intermediate gneiss from gneissic granitoid suite, Deception Bay area.....852
7-10 Interbanding in gneissic granitoid suite north of Tile Lake in the Deception Bay area. The main units comprise at least 3 units of trondjemite, 2 units of quartz monzonite and a mafic dyke. Arrows point to thin, biotite-rich selvedges along the margins of some concordant quartz monzonite units. Ruler = 15 cm.....853
7-11 Gneissic granitoid suite from the Deception Bay area, revealing interleaved biotite trondjemite, more leucocratic trondjemite (T) and quartz monzonite, marked by 15 cm-long ruler, with biotite-rich selvedges.....853
7-12 Gneissic granitoid suite near Wabigoon-English River subprovincial boundary, north shore of Pelican Lake.Outcrop contains several units of foliated biotite trondjemite interleaved with a more leucocratic trondjemite which are cut by a thin, discordant dyke of quartz monzonite. The mafic-rich enclaves may represent attenuated former dyke material. Pen = 15 cm.....854
7-13 An example of metamorphically-reworked mafic/felsic constituents in gneissic granitoid suite at Deception Bay.....854
7-14 Mafic to ultramafic enclaves (on right) from the gneissic granitoid suite, Deception Bay. The trondjemite unit (T) exhibits a wide colour index range.....855
7-15 Medium-grained, biotite-hornblende trondhjemite to quartz diorite unit of the sodic granitoid suite which contain a mafic band (on left) which is intruded by fine-grained, biotite trondjemite (right side) and by a discordant mass of inequigranular, quartz monzonite pegmatite. Outcrop is near the Wabigoon - English River subprovincial boundary just west of Highway 105. Ruler = 15 length.....855
7-16 Typical gneissose structure produced by interleaved, medium- to coarse-grained biotite-hornblende trondhjemite to quartz diorite, fine-grained biotite trondjemite, hornblende-rich mafic bands and minor, medium- to coarse-grained quartz monzonite. Photo located about 3 m from Photo 7-11.....856
7-17 Cataclastic quartz monzonite veins in gneissic granitoid suite north of Wabigoon - English River subprovincial boundary just west of Highway 105. Photo from same outcrop as Photos 7-15 and 7-16.....856
8-1 Foliated to gneissic, magnetite-diopside-hypersthene-biotite trondjemite near Chamberlain Narrows of Lac Seul. Coin diameter = 2.3 cm.....857

8-2 Stictolithic or fleck-textured hypersthene-biotite trondhjemite from just north of Chamberlain Narrows and marked by mafic segregations rich in magnetite enveloped by quartz-plagioclase leucocratic halos....857
8-3 Foliated to gneissose biotite trondhjemite (sodic granitoid suite) with diffuse, leucocratic, concordant, quartz monzonite vein of possible metasomatic origin. Bear Narrows area of Lac Seul....858
8-4 Kink bands in well foliated, hornblende-biotite trondhjemite to quartz diorite located on the Grassy Narrows-Oak Lake logging road, just north of Marshalok Lake....858
8-5 Porphyroblastic, medium- to coarse-grained, hornblende-biotite granodiorite on the Gordon Lake road north of the Grassy Narrows Reserve and south of Oak Lake. Coin diameter = 1.8 cm....859
8-6 Sodic granitoid suite near Chamberlain Narrows (Lac Seul), revealing a complex medley of units: Fine- to medium-grained biotite trondhjemite (unit A); medium- to coarse-grained hornblende-biotite trondhjemite to quartz diorite (unit B) intruded in order of decreasing relative agae by:....860
1) leucocratic trondhjemite (parallel to foliation of major units)
2) metagabbro dyke (parallel to widely-spaced, weak cleavage)
3) thin veins of leucocratic trondhjemite (parallel to cleavage)
4) late quartz monzonite (cross-cuts all units and structures).
8-7 Stictolithic quartz diorite of the Sen Bay stock intruded by trondhjemite (sodic suite) and quartz monzonite dykes....861
8-8 Medium- to coarse-grained magnetite-hornblende-biotite trondhjemite to quartz diorite from the Sen Bay stock with enclave of fine-to medium-grained biotite trondjemite (left corner) which is intruded by inequigranular, quartz monzonite (potassic suite)....861
9-1 Massive, medium-grained, equigranular, unmetamorphosed biotite quartz monzonite from the Nelson granite quarry near Vermilion Bay....862
9-2 Clotty quartz monzonite from Highway 105 roadcut at Perrault Falls....862
9-3 Clotty, garnet-bearing quartz monzonite northwest of Gymame Bay of Lac Seul....863
9-4 Equigranular, medium-grained quartz monzonite to granite (sensu stricto) with clots of garnet, quartz and biotite. Outcrop on the southern shore of Oak Lake....863
9-5 Inequigranular biotite quartz monzonite with clots of magnetite, cordierite and quartz located near Gymame Bay of Lac Seul. Note the concentration of clots adjacent to an enclave of trondjemite in the centre....864
9-6 Weakly cataclastic, porphyritic granodiorite sill at the Wabigoon-English River subprovincial boundary at Kenora Coin diameter = 1.8 cm....864
9-7 Possible rapakivi texture in porphyritic granodiorite of the Lount Lake batholith. Coin diameter = 1.8 cm....865
9-8 Porphyritic quartz monzonite from Lount Lake batholith in exposure

on the Kenora-Grassy Narrows road between Havik and Keys Lakes. Note the alignment of K-feldspar megacrysts which may relate to magmatic flowage....865
9-9 Dyke of magnetite-biotite syenite (potassic suite) intruded into foliated, biotite trondhjemite to quartz diorite, Chamberlain Narrows area of Lac Seul....866
9-10 Gneissic, leucocratic trondhjemite with amphibolite bands cut by zoned pegmatite-aplite dyke (marked by hammer), Anenimus Bay area of Lac Seul....866
9-11 Border unit of pegmatitic granite in batholith north of Papaonga Lake. Blade-like aggregates consist of magnetite, tourmaline and biotite....867
9-12 Medium-grained, equigranular, unmetamorphosed, biotite quartz monzonite to granite (sensu stricto) of the Tetu Lake Batholith containing consanguineous, quartz monzonite pegmatite pocket. Outcrop on the Minaki-Umfreville Lake road near Sashawa Lake....867
9-13 Pegmatite dyke in foliated hornblende-biotite trondhjemite. Note the perpendicular orientation of feldspar to the contacts and restriction of quartz masses to the dyke centre....868
10-1 Massive, fine-grained biotite trondhjemite (sodic granitoid suite) intruded in cataclastic, homogeneous diatexite. Outcrop on South Bay Mine road, northwest of Wenasaga Lake....868
10-2 Contact between the English River and Wabigoon Subprovinces at Kenora. The mafic metavolcanic rocks on left are intruded by a cataclastic, porphyritic granodiorite sill....869
10-3 Amphibolitic enclave of possible volcanic origin embedded in deformed inhomogeneous diatexite. Outcrop on island in Helder Lake about 100m north of boundary between northern and southern domains....869
14-1 Intense Fa_1 fold of originally discordant leucosome vein within garnet-sillimanite-cordierite-K-feldspar-biotite metapelite. Ministry of Natural Resources warehouse site at Ear Falls. Coin diameter = 2.3 cm....870
14-2 Fa_2 fold in metatexite metasedimentary migmatite on Wabaskang Lake....870
14-3 Leucosome distributed along the axial surface of Fa_2 open fold in metatexite metasedimentary migmatite on Wapesi Bay of Lac Seul....871
14-4 Interbedded fine-grained metawacke and highly porphyroblastic, andalusite metapelite near Temple Bay of Eagle Lake. Note the secondary planar fabric oriented at low angle to bedding, especially in metapelite layer to the left of the 4 cm long scale....871
14-5 Asymmetric Fa_1 folds in intrusive mobilizate vein which was initially discordant to metawacke (W)-metapelite (P) bedding in the sillimanite-K-feldspar-cordierite-garnet zone on Highway 17,

21 km west of Oxdrift. The left limbs of the two lowermost folds are almost detached along the strong axial planar fabric....872
14-6 Metatexite metasedimentary migmatite on the west shore of Pakwash Lake revealing arteritic leucosomes deformed by Fa_1 boudinage followed by Fa_3 open fold. Coin diameter = 2.3 cm....872
14-7 Fb_2 isoclinal folds in leucotrondhjemite layers in gneissic granitoid suite rocks in the Deception Bay area of Lac Seul. Coin diameter = 1.8 cm....873
14-8 Rootless, intrafolial Fb_1 fold of severely disrupted more mafic unit (possible former pillow selvedges) in granulite grade amphibolite of the Bear Narrows area of Lac Seul. Coin diameter = 2.3 cm....873
14-9 Isoclinal Fb_2 folds in holo-leucocratic trondjemite layers in amphibolite with superposed open fold (Fb_5?) from Deception Bay area. Coin diameter = 1.8 cm....874
14-10 Mylonite derived from homogeneous diatexite on the Sydney Lake Fault, south shore of Sydney Lake. Note the well developed fluxion structure composed of dark, quartz-rich bands and light, finely comminuted feldspar-rich bands. Porphyroclasts consist of K-feldspar, garnet and cordierite. Bar = 2 cm....874
14-11 Protomylonite derived from homogeneous diatexite at the Sydney Lake uranium occurrence, revealing the abundance of coarse porphyroclasts of quartz-feldspar and lack of a fluxion structure. Coin diameter = 2.3 cm....875
14-12 Pseudotachylite from the Sydney Lake Fault, south shore of Sydney Lake. Coin diameter = 1.8 cm....875
16-1 Sodic aplite from the Sandy Creek beryl pegmatite, revealing typical texture with megacrysts of euhedral beryl (near coin), quartz and books of muscovite. Coin diameter = 1.7 cm....876
16-2 Gradation between sodic aplite (A) and apatite-muscovite-rich pegmatite. Bar = 2 cm....876
16-3 Blocky K-feldspar in aplite unit of Dyke #2 at McCombe property. Coin diameter = 2.3 cm....877
16-4 Spodumene pegmatite unit of Dyke #1 at McCombe property. Note primary lineation defined by the near vertically-plunging K-feldspar megacrysts. Coin diameter = 2.3 cm....877
16-5 Spodumene-rich zone from Dyke #1 at the McCombe property. The relatively finer-grained spodumene exhibits a well defined linear fabric. Coin diameter = 2 cm....878
16-6 Longitudinal layering at the Tot Lake pegmatite, marked by the transition from pegmatite layers containing subhorizontally-aligned spodumene into finer-grained, equigranular, spodumene-poor layer (A). Quartz-rich core zone (Q) is situated along the upper left....878
16-7 Megacryst blades of spodumene near the northwestern end of the Tot Lake pegmatite....879

16-8 Partial replacement of pink spodumene megacryst (S) by lepidolite (L). Note the anhedral mass of pollucite (P) in contact with the spodumene. Coin diameter = 2.3 cm....879
16-9 Tantalite mineralization associated with quartz-rich (Q), albitized spodumene (S) - K-feldspar zone near the northwestern end of the Tot Lake pegmatite. The tantalite normally displays a marginal relationship to the albitized K-feldspar (A) megacrysts. Coin diameter = 2.3 cm....880
16-10 Blocky K-feldspar and local spodumene (S) in quartz-rich core zone (Q) at Pegmatite #1, Mavis Lake property. K-feldspar is partially enveloped by fine-grained green muscovite-albite aggregate (M). Coin diameter = 1.8 cm....880
16-11 Spodumene (S) rimmed by albite (A) in the quartz-rich zone of Pegmatite #1, Mavis Lake property. Coin diameter = 1.8 cm....881
16-12 Partially albitized K-feldspar in quartz-rich core zone of Pegmatite #1, Mavis Lake property. Albitization (A) tends to occur along the margins of the K-feldspar-rich (K) aggregate and commonly contains tantalite (T) as pointed by the arrows. Coin diameter = 1.8 cm....881
16-13 Porphyritic biotite quartz monzonite unit at the Tourist Lake uranium occurrence. Bar = 2 cm....882

ABSTRACT

This report describes a 1974-77 reconnaissance investigation of the English River Subprovince. The area is bounded by the Manitoba/Ontario boundary in the west, longitude 90°30'W in the east and north Latitudes 49°45' and 51°00'. All bedrock is Archean in age. The English River Subprovince consists of two major subdivisions: the **Southern Plutonic Domain,** a tract comprising plutonic rocks up to 3.02 Ga and derived orthogneisses, which forms a basement to the **Northern Supracrustal Domain**, dominated by high grade, migmatized clastic metasedimentary rocks younger than 2.74 Ga. Four classes of intrusive rocks are dispersed through the subprovince, i.e. the **gneissic granitoid suite,** metamorphosed plutonic rocks up to 3170 Ma and restricted to the Southern Plutonic Domain; a **mafic intrusive suite** comprising diorites, gabbros and ultramafic units which cut all supracrustal rocks; the syn- to post-tectonic, 2665 to 3002 Ma **sodic granitoid suite** (trondhjemite, tonalite and granodiorite) and the 2560 to 2702 Ma, dominantly post-tectonic, **potassic granitoid suite** (granite and granodiorite) which represents the majority of the youngest Archean rocks.

The Southern Plutonic Domain, forming the southern one-third of the subprovince, approximately consists of equal proportions of the sodic and potassic granitoid suites. The subordinate gneissic granitoid suite encompasses a broad compositional range, i.e. tonalite-trondhjemite-quartz diorite-diorite-ultramafic-anorthositic. These intensely deformed rocks display a banded or gneissic fabric and contain tectonically interleaved enclaves of metasedimentary and metavolcanic rocks and **lit-par-lit** injections of sodic and potassic suite rocks.

The Northern Metasedimentary Domain, which forms the northern two-thirds of the English River Subprovince, is dominated by a belt of wacke-pelite units of turbidite origin which is continuous for 700 km in Ontario. These rockshave been metamorphosed and partially melted at 2.68 Ga forming migmatites and S-type granites. Part of the southern boundary of the domain is marked by the Separation Lake metavolcanic belt, the eastern extension of the >2715 Ma Bird River greenstone belt of Manitoba. Scattered remnants of this belt, as enclave trains, occur over a distance of 250 km to the Lac Seul area to the east. It is inferred from stratigraphic relations near Uchi Lake that clastic metasedimentary rocks of the Northern Metasedimentary Domain are correlative with Uchi Subprovince metavolcanic rocks ranging from 2.9 to 2.7 Ga. Stratigraphic-structural relations of proximal facies metaconglomerates at Separation Lake suggest the Northern Domain and the Separation Lake volcanic belt are in part correlative.The division of the metasedimentary migmatite rocks was based on the concept of progressive migmatization with the following successive stages: protometatexite (incipient partial melting) -> metatexite -> inhomogeneous diatexite -> homogeneous diatexite (complete melting).

The sodic granitoid suite is widespread in the English River Subprovince. Two types of intrusive bodies were recognized: relatively early, heterolithic complexes and later, relatively simple, compositionally more uniform plutons. The early heterogeneous intrusive complexes comprise large, discrete batholiths or ill-defined masses which generally lie elongated subparallel to subprovince boundaries and are deformed by later intrusive rocks. Representative plutons such as the >3.02 Ga Sen

Bay stock comprise numerous units of gabbro-diorite-quartz-diorite-trondhjemite. Petrochemistry of this intrusive type is marked by depletion of Fe+Mg and enrichment of K with decreasing relative age of internal units. The simple pluton type, as exemplified by the Dalles batholith, is marked by relatively uniform compositions, generally 1-2 units of trondhjemite and granodiorite, which form discrete, commonly subcircular intrusions. These intrusions occur as diapirs which deflected host-rock structural fabrics.

The potassic suite culminated granitic igneous activity in the English River Subprovince and is mainly restricted to western part of the Southern Plutonic Domain. It forms large batholiths, up to 2200 km_2, marked by uniform compositions over a narrow range, i.e. granodiorite-quartz monzonite-granite.

The structural history of the area is protracted and involved three periods of folding (D_1, D_2 and D_3) and ensuing phases of kink-style folding, shearing, fracturing and faulting (D_4, D_5 and D_6) which partially form the north and south subprovince boundaries. Abukuma-type regional metamorphism followed D_2 and reached granulite facies conditions of >750°C and >2.5 kbar.

The English River Subprovince has a low mineral potential which is mainly relegated to various lithophile elements. From detailed mapping and geochemistry, methods are described for evaluation of the economic potential of rare-element pegmatites and U-Th deposits.

THE ENGLISH RIVER SUBPROVINCE - AN ARCHEAN GNEISSIC BELT: GEOLOGY, GEOCHEMISTRY AND ASSOCIATED MINERALIZATION

Frederick W.Breaks[1] and William D. Bond[2]

---

1. Geologist, Ontario Geological Survey, Mines and Mineral Research Centre, 933 Ramsey Lake Road, Sudbury, Ontario.
2. Geologist, Goldfields Canadian Exploration Limited, 100 Front Street West, Toronto

CHAPTER 1

INTRODUCTION

The division of the Superior Province of the Canadian Shield into several distinctive lithological-structural-metamorphic subprovinces was initially proposed by Stockwell (1964). However, the specific geological processes responsible for the characteristic stripped map pattern of contrasting granite-greenstone vs metasedimentary-rich subprovinces in northwestern Ontario continues to be an enigma and a topic of controversy. The lack of systematic mapping and a modern geological data base from the metasedimentary "gneiss" belts has hampered crustal modelling studies aimed at explaining this mega-belt pattern. In order to evaluate the origin and economic potential of one of these metasedimentary "gneiss" belts, the English River Subprovince, the Ontario Geological Survey undertook four, 1:63, 360 helicopter-supported, reconnaissance mapping programs (Figure 1). Reconnaissance mapping of the English River Subprovince was instigated with Operation Ignace- Armstrong (Sage and Breaks, in review). This present study examined a 400 km strike-length of the English River Subprovince including adjoining segments of the Uchi and Wabigoon Subprovinces and covered an area of approximately 37,000 km^2 and resulted in seventeen preliminary geological maps (Breaks, Bond et al. 1975a, b, c, d, e, f; 1976a, b, c, d, e, f; 1979a, b, c, d, and Breaks, Bond and Stone, 1980) and a 1:253, 440 compilation map (**Map 1, back pocket**). and Stone,

1978).

LOCATION AND ACCESS

The map area is bounded in the west by the Manitoba-Ontario boundary and in the east by Longitude 90°30'00"W. The north and south limits are north latitudes 49°45'00" and 51°00'00", respectively. The map area is mostly in the Kenora Mining Division. The extreme northeast corner, is in the Thunder Bay Mining Division.

In the study area there are several population centers: Kenora, Vermilion Bay, Ear Falls, Red Lake, Dryden and Sioux Lookout which are connected by major roads including the TransCanada Highway 17 which traverses the south part of the map area. Population density is greatest in the south. The northern half, except for the towns of Ear Falls and Red Lake, is sparsely populated with seasonal tourist lodges but otherwise is uninhabited. Important roads leading north from the TransCanada Highway include Highway 105 between Vermilion Bay and Red Lake, Highway 72 from Wabigoon to Sioux Lookout, Highway 599 which trends northeast from Ignace to Pickle Lake and the Dryden Airport Road that leads north to Williams Bay of Lac Seul. Secondary, gravelled roads extending north into the map area include the Jones Road extending northeast from Kenora to Maynard Lake, and the Minaki Lake Road extending north from Keewatin (Kenora) to Umfreville Lake. Additional secondary routes giving access to the area originate at Ear Falls where Highway No. 657 extends northeast to the South Bay Mine. Highway 804 extends west to west-northwest and has been extended to Long-Legged Lake. The Marchington Lake Road links Sioux Lookout with the town of Savant Lake.

The Canadian National Railway transects the southern part of the map area. An

extensive network of private and forest access

routes traverses the area between the Trans Canada Highway No. 17 and the Canadian National Railway in the southern part of the map area. All of these are gravel and/or sand-based.

The English River drainage basin including the Lac Seul Resevoir, English River, Wabigoon River, Marchington River, and Winnipeg River is an extensive lake-river system that affords relatively easy access to the southern half of the map area. It is possible, with only a few short portages, to travel by boat from the east boundary of the map area to the west boundary, a distance of 360 km. The most inaccessible areas are situated north of this drainage system.

Charter aircraft available at Red Lake, Ear Falls, Kenora, Vermilion Bay, Dryden, Sioux Lookout, Savant Lake and Pickle Lake provide access into the more remote northern part of the map area. Although there are several large lakes and a few interconnecting waterways, most of the interconnecting drainage patterns in the northern part are too small to be navigable by watercraft.

PRESENT GEOLOGICAL SURVEY

Field work for this survey was carried out during the field seasons of 1974 to 1977, inclusive. The crews for these four field seasons consisted of two staff geologists and, depending upon the size of the area, from one to four senior assistants accompanied by four to seven junior assistants.

At a mapping scale of 1 inch to 1 mile (1:63,360) outcrop examinations were made at intervals of approximately 0.4 to 0.8 km in readily accessible areas having abundant

outcrop. In areas of poor exposure and/or having poor access the data points were placed from 0.8 to 2.0 km apart. In some areas containing important geological contacts the interval of data points was decreased to more accurately trace these boundaries. The shorelines of all major lakes and rivers were examined as were the exposures along all roads. Locally mapping was done by pace and compass traverses at 0.8 to 1.6 km intervals. These traverses were designed for optimum coverage of outcrops in areas of concern and were run at or near right angles to the strike of the rock units. Brief attention was directed towards those segments of the map area that had previous, recent detailed geological mapping for comparative purposes and consistency. Where possible this previous information was integrated with the present study. The letter "I" preceeding a map code indicates data reinterpreted from compiled information. Some previously-mapped areas such as High Lake - Rush Bay (Davies, 1965) and Werner Lake (Carlson, 1957; Shklanka, 1967) were not reexamined but compiled directly. Emphasis in this project was placed upon those areas previously untouched by recent geological investigations. Most of the recent work has centered on the Wabigoon and Uchi Subprovinces. Except for parts of a survey done by Hudec (1965) northwest of Savant Lake, the English River Subprovince in northwestern Ontario had received virtually no significant previous mapping. In general, equal proportions of time were allotted to mapping of supracrustal and plutonic domains.

Mapping was done using vertical air photographs at a scale of 1 inch to 1 mile (1:63,360) supplied by the National Air Photo Library, Department of Energy, Mines and Resources, Ottawa. In most cases outcrops were sufficiently exposed or situated so as

to be readily apparent on the photograph. In a few localities, outcrops not apparent on the airphotos were related to recognizable topographic features by pace and compass lines. In areas underlain by iron-formation, structural trends and outcrop locations were approximated using the sun in conjunction with recognizable topographic features. Geological data were plotted in the field on transparent acetate overlays attached to the air photos and subsequently transferred to base maps prepared by the Cartographic Section, Lands and Waters Group, Ontario Ministry of Natural Resources.

Many of the examined outcrops were sampled and about 90 percent of these samples were cut using a diamond rock saw in the field. All plutonic samples were etched with hydrofluoric acid and stained for potassium feldspar. Nomenclature of all samples of plutonic rocks is after Ayres (1972). Results of staining were used to check field terminology. Modal analyses of some of the coarser-grained plutonic rocks were done on the stained slabbed surfaces. Samples selected for whole rock or trace element analyses had all weathered surfaces removed by the diamond saw. Samples submitted for analysis were regarded to be representative. Only those samples showing no signs of intense alteration and free of impregnation by extraneous dyke material were analyzed. All analyses, unless otherwise stated, were carried out by the Geoscience Laboratory of the Ontario Geological Survey. All analysed samples were thin sectioned.

Regular mapping was supplemented with the use of a helicopter in remote areas during all four years of the project. The helicopter was used strictly for reconnaissance geological mapping in remote areas not accessible by fixed-wing aircraft. Helicopter traverses were run at or near right angles to the strike of the geological formations. A

grid system of data points at intervals of 1.6 to 2.8 km was attempted in these remote areas having sufficient outcrop and suitable landing spots. Paucity of observation points is a direct reflection of poor exposure coupled with lack of the latter. A Bell G-4A was the model used in 1974, 1975 and 1976. In 1974 this model was occasionally supplemented with a Hughes 500 C. In 1977 a Bell 206 L was used. A few traverse parties were sent out using the helicopter. During an average 9 hour period approximately 25 to 45 individual stops were completed depending upon the geological complexity. An average period of 5 to 7 minutes were spent at each of the helicopter observation points. A total of 900 hours were flown during the four field seasons. About 5 percent of this time was used for ferrying.

The 1974 map area was divided into four parts with the program in each section directed by a geologist or senior assistant. A similar method was employed to a certain extent in the 1975 field season although with substantially greater exchange of information. The 1976 and 1977 operations were run from central base camps augmented by numerous fly camps. Fixed-wing aircraft were used to service the various camps in remote areas during all of the four field seasons.

PRESENT GEOLOGICAL REPORT

W.D. Bond was responsible for the introduction and sections on: metavolcanic rocks, plutonic rocks including the subvolcanic suite, mafic, gneissic, sodic and potassic suites, their chemistry and style of intrusion, correlation with aeromagnetic and radiometric data, and the Pleistocene section. F.W. Breaks was responsible for the remainder. The assessment work compilation was done by D. Stone, R. Zalnierunias and was rechecked

by A. Taylor. The abstract, sections on general geology and structure were written jointly by both authors.

PREVIOUS INVESTIGATIONS

The earliest survey in the map area was done by Robert Bell of the Geological Survey of Canada in his canoe journey on the English River and Albany River systems (Bell 1873). A second expedition of Bell (1886) traversed across the English River Subprovince, between Lonely Lake (now Lac Seul) and Lake St. Joseph via the Root River. Fawcett (1885) conducted a line survey using transit and micrometer from Rat Portage (Kenora) to Osnaburgh house returning via the Wenasaga River. According to Bruce (1924) the English River probably was not used extensively as a route to the west by fur traders due to the difficult route between Lake Superior and Lac Seul. Undoubtedly the more southern Rainy - Winnipeg River system was more extensively travelled and explored. A.C. Lawson (1885) conducted a survey of the Lake of the Woods area from 1883 to 1885. The first geological map of the subprovince was constructed by Dowling (1894) did geological exploration in the vicinity of Red Lake including the Trout Lake River. Wilson and Johnston (1904) made a reconnaissance traverse from Lac Seul to Cat Lake by way of the Wenassaga River in 1902. Burwash (1920) undertook a geological reconnaissance of the Wenasaga River northeast to Birch Lake in 1919. His report is accompanied by maps showing the geology of Whitemud Lake. Burwash (1921) also traversed the Ontario - Manitoba Boundary and his report is accompanied by map 32A (scale 1:126,720). All of these early surveys combined both geographical and

geological descriptions; geological maps of this early work was based on limited observations.

Most of the following previous work is confined to or near the margins of Uchi and Wabigoon Subprovinces. Until the present survey, previous geological exploration within the English River Subprovince proper is restricted to the following: Bruce (1924) conducted the first geological reconnaissance at a scale of 1:126,720 (map no. 33f) and included the area between Ball Lake and Pakwash Lake west of Highway 105. Gilbert (1927) examined the area around Sydney Lake and produced a map (36f) at a scale of 1:253,440. Derry (1930) subsequently mapped the region adjoining both of the above map areas at a scale of 1:190,080 (map no. 39g). All of these surveys were based on a limited number of observations restricted to major water-ways and were not successful in developing a regional geological picture. Similarly, Williamson and Hudec (1959) conducted a geological survey in the eastern end of Lac Seul but their mapping (scale 1:63,360) was also restricted to major water routes; Hudec (1965) completed the most comprehensive map of the English River Subprovince to date. His mapping examined the area between Savant Lake and Lake St. Joseph and was published at a scale of 1:63,360. Skinner (1969) made a reconnaissance survey in the same area and the resulting map (scale 1:253,440) concentrated on the greenstone belts with the intervening granitoid areas remaining largely unsubdivided.

Progressing from west to east the following surveys have been made within or adjacent to the Uchi Subprovince. In the Bee Lake - Werner Lake area, initial reconnaissance mapping by Gilbert (1927) was followed by detailed mapping (1:31,680)

by Carlson (1957) and Shklanka (1967). Further east near Highway 105, Shklanka (1970) reported on the geology of the Bruce Lake Area in the vicinity of the Griffith Iron Mine (scale 1:31,360). Wright (1936) and Bateman (1939) were early workers in the Slate - Papaonga Lakes area followed by Fenwick (1972). Bruce (1922 a,b,c) reported on the geology of the Lake St. Joseph area and indicated the approximate outline of the volcanic units. Later Clifford (1969) and Clifford and McNutt (1971) examined the greenstone belt between Root Lake and Lake St. Joseph in more detail (1:31,680). East of Lake St. Joseph, Dyer (1933) examined the Pashkokogan Lake area and produced a map (42e) at a scale of 1:253,440. Goodwin (1965) later restudied Pashkokogan Lake in more detail (scale 1:31,680).

In the south part of the map area, several workers have sporadically examined the Wabigoon-English River subprovincial boundary. These areas include, from west to east, recent detailed mapping (1:31,680) at the Manitoba - Ontario boundary by Davies (1965), at Kenora by King (1983) and near Vermillion Bay by Pryslak (1976). Moorhouse (1939) mapped the Eagle Lake area including the subprovince boundary between Dryden and Vermilion Bay at a scale of 1:63,360. Satterly (1941) examined the adjoining area to the east and produced an excellent map (scale 1:63,360) of the Dryden - Wabigoon Lake area. Harding's (1950) work adjoined Satterly's (1941) map area and was also done at a scale of 1:63,360. In response to the discovery of gold by A. Ward and R. Lundmark in 1941, Armstrong (1950) did a detailed study of Echo Township. Reconnaissance mapping in the Sioux Lookout area by Hurst (1932), Horwood (1937) and Skinner (1969) was augmented by later detailed mapping by Johnston (1969, 1972) and Palonen and

Speed (1974). Moore (1910, 1928) did the first complete geological study in the Savant Lake area and this work has recently been supplemented with detailed mapping by Bond (1977, 1979, 1980) and Trusler (1975).

Much of the early work cited above has been compiled at a scale of 1:253,440 by Davies and Pryslak (1967), Ferguson et al. (1970) and Davies et al. (1970). Since publication of these compilation maps, substantial new geological data contributed by recent detailed studies and this study have been made. These three compilation series are presently being recompiled and the work done in this study will be incorporated. Trowell et al. (1978) have undertaken a synoptic study of the Wabigoon Subprovince including the area from Kenora to Savant Lake and will serve to correlate and upgrade much of the previous geological survey work.

The aeromagnetic survey of the area was undertaken in 1961 and published jointly by the Ontario Department of Mines and the Geological Survey of Canada at a scale of 1:253,440 (ODM-GSC 1961). A joint federal-provincial airborne radiometric survey has recently been completed (OGS-GSC, 1976, 1977). Several interpretations of the magnetic data have been made by Kornik (1971), Wilson (1971), Hall (1968) and McGrath and Hall (1969).

Seismic signatures have been studied by Hall and Hajnal (1969), Hall (1971) and Brown (1968). The gravity high over the English River Subprovince was recognized by Innes (1960). Riley (1965) studied the gravity profile over the Kenora area. Barlow et al. (1975) and Gupta and Wadge (1978) have completed gravity surveys in the Red Lake area and Birch-Uchi Lakes area. Both of the latter included the northern boundary of the

English River Subprovince.

A substantial amount of work has been undertaken by various government surveys in the western extension of the English River Subprovince in Manitoba. No attempt is made herein to document all of this work but major contributions to the regional geology have been made by McRitchie (1971), McRitchie and Weber (1971) and Trueman (1978). Gower (1974, 1975, 1978) gives a more complete record of the work done in Manitoba and a more comprehensive synthesis of all of the above studies.

Various workers have engaged in thesis studies. Dwibedi (1966) made the first major contribution to the overall understanding of the subprovince and this was augmented by smaller scope studies by Hodgkinson (1968), Morin (1970) and Jones (1973). Westerman (1977) and Gower (in 1978) partly in conjunction with this survey, have made the most complete, comprehensive study to date. Other thesis work resulting from the present survey include Stone (1982), Panagapko (1976), Mathews (1975), Makepeace (1976), Kusmirski (1977), Desnoyers (1977), Smith (1977) and Bartlett (1978).

Wilson and Brisbin (1963a,b) and Wilson (1971) provided initial regional overviews of the structure of the Precambrian in northwestern Ontario. Morin (1977, 1979) has studied the nature of the granitic rocks across the Wabigoon - English River Subprovince boundary. Recent studies of segments of the map area by Harris and Goodwin (1976) and Beakhouse (1975, 1977) including geochronological work by Krogh et al. (1976) have also been made.

PROSPECTING AND MINING HISTORY

Until the recent interest in lithophile element mineralization, the gneissic terrains such

as the English River Subprovince were relatively unexplored. A few mining companies sporadically conducted exploration programs for uranium, basic metals and gold within the main part of the English River Subprovince (see summary of Assessment data in the Economic Geology this report) but most exploration efforts continued to emphasise the adjacent greenstone terrain. More recently exploration concerns have begun to examine the boundary or marginal area of the English River Subprovince for the possibility of distal facies volcanogenic massive sulphide areas.

The Griffith Mine (iron ore) on the west shore of Bruce Lake was the only producing mine in the map-area during the investigation period and has since closed. Several other iron prospects and deposits occur to the west just south of the Uchi-English River Subprovince boundary.

NATURAL RESOURCES

The map area is situated dominantly in the Boreal Forest Region as indicated by Rowe (1972). The southwest part of the map area from Minaki east to Eagle Lake is part of the Quetico district of the Great Lakes - St. Lawrence Forest Region (Rowe, 1972). There is a progressive change in vegetation cover from southwest to northeast. Mixed stands of dominantly deciduous species in the southwest gradually give way to dominantly coniferous varieties in the northeast. In the southwest mixed stands of trembling aspen, balsam fir, balsam poplar, white spruce and red and eastern white pine form the chief forest cover. Locally isolated clumps and pure to mixed stands of jack pine, white birch, black spruce, rare tamarack, green ash and white elm complete the forest cover. Eastern white and red pine are confined to well drained, rocky higher elevations and are favoured

in the Great Lakes - St. Lawrence Forest Region. Northeastwards mainly black spruce mixed with jack pine and tamarack in the poorly drained areas are dominant. In the north part of the map area forest fires have ravaged several large areas. Burned areas tend to favour jack pine and minor white birch. The largest forest fire was situated north of Lac Seul stretching from Ear Falls east-northeast to Lake St. Joseph and occurred in 1961.

Fish and game thrive throughout the area as testified by the numerous tourist camps. Most of the latter are situated in the south half of the map area. Northern pike and pickerel inhabit almost all of the lakes. Lake trout are found locally in some of the deeper lakes. Numerous outpost camps are spotted throughout the northern part of the map area.

Deer are most plentiful in the southwest part of the area near Kenora. Moose are most abundant in the northeast part of the map area; numerous sightings of full grown moose were made throughout most of the map area, exclusive of that part populated by deer. In addition, sightings or signs of black bear, beaver, wolf, rabbit, otter, weasel, red fox and skunk were noted throughout the map area.

TOPOGRAPHY AND DRAINAGE

The map area is situated within the headlands of the Arctic Watershed and is just north of the great divide separating the Arctic and Great Lakes drainage systems. About 90 percent of the map area is situated within the headwaters of the English River Drainage Basin. The extreme northeast part of the map area is situated within the headwaters of the Albany River Drainage Basin. The height of land separating these the latter two is situated north of Lac Seul and trends west-northwest from Armit Lake (25 km

northwest of the town of Savant Lake) to Otatakan Lake.

Most of the topography is fairly flat and lies between 335 and 366 m above sea level. Isolated hills generally up to just over 427 m above sea level are found throughout the map area. In the southwest the topography locally rises up to 900 m above sea level; in this area these highs are correlatable with plateau-like outcrop exposures that appear similar to a mesa-like topography.

In the north, hills are related to Pleistocene deposits such as the Lac Seul Morraine. Rare, isolated peaks of over 457 m are found locally at Conifer Lake, Keys Lake and most extensively

north of Wapesi Lake. The north part of the map area is generally more uniformly flat than the south, it is mantled by extensive drift deposits resulting in small exposures. For the most part, exposures in the north and east part of the map area are uniformly distributed. Poorest exposure (less than 0.5%) occurs in the area overlain by Lac Seul Morraine from Ear Falls to north of the Trout Lake River.

Lac Seul fluctuates up to 3 m annually but is generally at about 354 m above sea level. To the west, the English River drainage system drops down to 317 m near the Manitoba/Ontario boundary.

ACKNOWLEDGMENTS

Senior assistants conducting independant mapping for this project included G. McWilliams, C. Gower, D. Stone and D. Findlay in 1974; C. Westerman, N. Harris, D. Stone and D. Desnoyers in 1975; D. Stone and D. Desnoyers in 1976; and D. Stone in 1977. The following acted as junior assistants: J. Barclay, D. Desnoyers, W. Liebau, S.

Mathews, M. Tilkov, R. Tremblay and M. Walker in 1974; P. Banks, E. Hinchey, R. Kusmirski, A. LaLonde, D. Makepeace, D. Panagapko and D. Turgeon in 1975; R. Kusmirski, J. Reid, D. Smith and R. Zalnierunias in 1976; and J. Bartlett, J. Malczak, C. Revington and G. Wach in 1977.

Gower (1974) is acknowledged for a preliminary compilation of the previous work completed within the western part of the English River Subprovince. Gower (1975), McWilliams (1974),Westerman (1976) and Harris (1976) provided summary reports on their respective field areas. D. Stone in conjunction with his Ph.D. dissertation has been generous in supplying the authors with data on the Sydney Lake Cataclastic zone.

The authors wish to acknowledge the assistance provided by personnel of the district offices of the Ministry of Natural Resources (Forests Resources Group) in Kenora, Red Lake and Dryden. Ministry of Natural Resources (Division of Mines) regional staff members including R. Beard, W. Valliant, P. Palonen, L. Koskitalo, and A. Speed made available some field equipment and provided assistance in local knowledge of their respective regions.

The authors wish to thank personnel of Green Airways, Red Lake for contributing greatly to the course of the field work. The authors were received excellent service from Viking Helicopters Limited based out of Kenora in 1974, by pilots B. Tremble (1975) and M. Roach (1976) both of Great Lakes Helicopters Ltd. based in Toronto, and Heli-Voyageur based out of Val-d'or in 1977.

Barbara Moore and Dirk Septer contributed equally to the preparation of many of the figures. R. Zalnieriunas assisted in modal analysis and was responsible for much of the

processing of data include A. Taylor, R. Pichette, J. Malczak, L. Cymbalisty, M. Smith and J. Foster.

P.C. Thurston was helpful in communicating geological ideas and insight. N.F. Trowell was also very helpful in communicating geological ideas and data especially with respect to the volcanic rocks. The authors have utilized and drawn extensive material from the Ph.D. dissertation of Westerman (1977), Gower (1978), and Stone (1981).

CHAPTER 2

TERMINOLOGY

MAJOR DIVISIONS OF THE SUPERIOR PROVINCE

The study area is situated within the Superior Province of the Canadian Precambrian Shield and includes portions of three subprovinces: the Uchi Subprovince, the English River Subprovince and the Wabigoon Subprovince. The Wabigoon Subprovince was named by Wanless et al. 1968 and subsequently called the Kenora Block by Wilson (1971). These lithotectonic entities have been described as both belts and blocks in the literature. In this report the term "belts" is reserved for greenstone or metavolcanic-metasedimentary belts while the term subprovince will be used to designate component parts ofthe superbelt structure. The boundary of the Uchi and Wabigoon Subprovinces with the English River Subprovince is based on the first appearance of metavolcanic rocks. In some cases, as along the northern boundary, ther is coincidence with important cataclastic deformation zone, i.e. the Sydney Lake Fault.

SUBDIVISIONS OF THE SUBPROVINCES

The geological investigation for this report concentrated on the English River Subprovince and the metavolcanic-rich subprovinces were examined only briefly. No systematic subdivision of these metavolcanic subprovinces was attempted other than to designate the greenstone belts according to geographical location. From west to east these include (Figure 1-1A):

Uchi Subprovince

Bee Lake belt

Dixie Lake belt

Slate Lake area

Papaonga Lake area

Lake St. Joseph belt

Wabigoon Subprovince

Kenora belt

Tustin-Bridges belt

Dryden-Sioux Lookout belt

Savant Lake belt

The English River Subprovince is divisable into two lithologically-contrasting domains (Figure 1-2)[1]:

1) Northern supracrustal domain

2) Southern plutonic domain

A similar division was advanced by McRitchie and Weber (1971) and Beakhouse (1977). The Northern Supracrustal Domain correlates with the Manigotagan Gneiss Belt of McRitchie and Weber (1971), the Ear Falls - Manigotagan Gneiss Belt (Beakhouse 1977; Gower 1978) and the English River metasedimentary migmatite complex (Westerman 1977). The Southern Plutonic Domain is synonymous with the Winnipeg River Plutonic Complex (McRitchie and Weber 1971; Gower 1978), the Winnipeg River Batholithic Belt (Beakhouse 1977) and the English River Plutonic complex (Westerman 1977).

The Separation Lake greenstone belt, situated at the contact between the two domains

is a continuation of the Bird River greenstone belt of Manitoba.

---

1. Subsequent to the writing of this report, Hall and Brisbin (1982) and Card and Ciesielski (1986) proposed that the English River Subprovince (sensu lato) be divided into the English River (sensu stricto), the Bird River and the Winnipeg River Subprovinces. This terminology is currently used in the literature.

GNEISS AND MIGMATITE TERMINOLOGY

Gneiss

The A.G.I. Glossary defines gneiss (p.303) as: "a foliated rock formed by regional metamorphism in which bands or lenticles of granular minerals alternate with bands and lenticles in which minerals having flaky or elongate minerals show preferred parallel orientation".

The term gneissose is "said of a rock or its structure that resembles gneiss but that is not the result of metamorphic processes" (A.G.I. glossary, 303). The main confusion in the use of the term gneiss has arisen from its application to textures that are not of metamorphic origin. Banding in granitic rocks, as viewed by Stone (1969), Butler (1969) and Myers (1978) can originate from any of the following processes:

1) migmatitic - the **lit-par-lit** injection of a magmatic melt into an older rock commonly along existing anisotropies. For example, there is commonly a concentration of

potassium-rich veins and veinlets within the host-rocks of a quartz monzonite intrusive;

2) metasomatic - formation of a granitic rock by the injection of hydrothermal solutions into an older rock-type;

3) anatectic - partial melting;

4) deformation - transformed through strain;

5) primary - mineral banding;

For the purposes of this report, the term GNEISS describes a banded metamorphic rock consisting of holo-leucocratic to leucocratic layers alternating with mesocratic to melanocratic layers. The leucocratic portion commonly consists of an allotriomorphic-granular mixture of quartz and feldspar while the darker layers consist of an abundance of flaky or elongate minerals such as biotite. The gneissic banding in the English River gneissic granitoid suite (Chapter 7) is also considered as part gneissose and was developed from a combination of non-metamorphic processes.

Foliated to gneissic texture describes similar, mineralogically segregated rocks in which the banding is discontinuous. In this case the mafic minerals form as discontinuous diffuse lenticles, clots or "autoliths". Balk (1937) defined autoliths as simply an accumulation of Fe-Mg minerals of uncertain origin in granitoid rocks). The mafic clots are separated by wide patches of foliated or locally massive dominantly leucocratic allotriomorphic to hypidiomorphic-granular minerals. The accumulation of the mafic minerals is regarded as metamorphic but the texture may in part reflect a primary mafic mineral accumulation.

Foliation is defined as a subparallel to parallel arrangement of prismatic and platy

mafic minerals. In this case the platy minerals are dispersed evenly and exhibit no tendency to form lenticular concentrations.

In essence the melanocratic and leucocratic minerals are intensely segregated into well defined bands in a "gneiss" and only exhibit partial segregation in "foliated to gneissic" texture and are mostly unsegregated in foliated texture. The distinction between foliated, foliated to gneissic, gneissose, gneiss is arbitrary (Gower, 1978, p.96).

Migmatite

Migmatite as described by Mehnert (1971) is a megascopically composite rock consisting of two or more petrographically different parts. One is the country rock in a more or less metamorphic stage, the other is an igneous rock of granitoid or plutonic appearance. The later plutonic portion is regarded as a genetically related unit exsolved through partial melting (anatexis) from the metamorphic unit and occurs both in situ and as an intrusive unit.

With progressive anatectic degeneration of the metamorphic country rock, the rock passes through a succession of migmatite stages. The migmatite classification scheme includes (with increasing degree of partial melting): protometatexite -> metatexite -> inhomogeneous diatexite -> homogeneous diatexite. The scheme is adopted (with minor additions by the authors) from the work of Scheumann (1937), Mehnert (1971) and Brown (1973). The characteristics of each stage are described in Chapter 4. The use of these terms does not signify that the original rocks are metasedimentary. The term migmatite is used to infer only that the country rock has been partially melted (any country rock including metavolcanic and metagranitoid rocks can be partially melted if the P-T

conditions are adequate). **Mobilizate** refers to the new or plutonic rock unit that is generated during anatexis. Mobilizate in protometatexite is typically derived in situ. **Intrusive mobilizate** is regarded as genetically related to its country rock but is injected into its present setting. That is, intrusive mobilizate is envisaged as being developed at one set of P-T conditions but is mobilized upwards due to decreasing pressure and intruded into a setting characterized by entirely different P-T conditions. Aluminosilicate minerals associated with intrusive mobilizate are not indicative of metamorphic grade at its present setting and can not be used to determine P-T conditions.

Metamorphic isograds, where observed, are based on mica- and aluminosilicate-bearing assemblages in pelitic horizons and less commonly in in situ mobilizate.

Metamorphic Terminology

Metamorphic terminology is based on Winkler (1974). The terms low grade and medium grade correspond more or less with greenschist and lower amphibolite facies. All metamorphic isograds in the Lake St. Joseph and Dryden area are based on thin section examination, the isograd being defined by coexisting indicator minerals. Hypersthene-bearing units, where known to be present, are marked with an asterisk* on the maps.

Cataclastic Terminology

Cataclastic terminology is from Spry (1969, p.229). With increasing degree of deformation the terms protomylonite, mylonite and ultramylonite refer to the amount of crush "matrix" produced. In extremely deformed areas, pseudotachylite is developed. The modifiers "strongly foliated" and "weakly cataclastic" are used to refer to the presence

of a dominantly protomylonitic fabric (up to 50% matrix) but locally minor shear bands of mylonite and ultramylonite may be present.

Intrusive Rock Nomenclature

The plutonic rocks were classified (Table 1-2) from Ayres (1972). The amount of quartz and feldspar ratio were estimated in the field. Approximately 80 percent of all granitoid samples were slabbed and stained for potassium feldspar in the field. Initially, the feldspar ratio was estimated visually but about 150 typical slabbed and stained samples were modally analyzed to confirm these estimates. About 200 samples were also chemically analyzed for comparison to the field classification.

The Streckeisen (1970) classification of plutonic rocks had not been universally accepted during the survey period. The important differences between the two classifications are:

1) the change from quartz-poor to normal granitoid composition is marked at 20% by Streckeisen versus 10% by Ayres (1972). 2) most rocks classified as quartz monzonite by Ayres (1972) fall into the granite "b" field of Streckeisen (1976) and overlap into the granite "a" field.

3) the field of trondhjemite (Ayres, 1972) has been designated as tonalite in the Streckeisen classification. Trondhjemite is retained in the latter but is restricted to leucotonalite where M is less than 10 (M = mafic mineral %).

4) the change in limits of the quartz content does not affect the data in this report to any great extent. Out of a total of 58 modal analyses of the potassic granitoid suite, only 9 percent fall in the 5 to 20 percent quartz range of Streckeisen (i.e., fields 7*

and 8*). In the sodic granitoid suite only 1.5 percent of 65 modal analyses fall below the 20 percent division (i.e., field 10*) of Streckeisen. Thus, according to the Streckeisen (1976) classification, the potassic granitoid suite lies mostly in the granite "b" and "a" and granodiorite fields with minor overlap in the quartz monzonite field (field 8*, Streckeisen, 1976, p.8). The sodic granitoid suite is dominantly tonalite.

Other terms used include the following:

Leucocratic designates granitoid units with 5 and 35 percent mafic minerals. Holo-leucocratic refers to rocks with less that 5% mafic minerals. Granitoid is a loosely applied term to any light-coloured, fine- to coarse-grained plutonic rock.

During the initial stages of the fieldwork, the legend was set up to distinguish metamorphosed (recrystallized) from unmetamorphosed plutonic units. It became apparent, through thin-section examination, that this distinction could not always be made. There is a spectrum of metamorphic rocks, ranging from completely unmetamorphosed to strongly metamorphosed varieties. From the outset it was recognized that the latest intrusive units, based on field relations, were dominated by K-feldspar and tended to be unrecrystallized. The early sodic granitoid units were at least weakly recrystallized and exhibited a foliation. The igneous suites are for the most part compositionally and petrographically distinct and to some extent the suites have distinctive tectonic styles. The potassic granitoid suite is synonymous with the granodiorite-granite suite (Beakhouse, 1977, p.1483; Gower, 1978); the sodic granitoid suite is synonymous with the trondhjemite-granodiorite suite (Beakhouse), and tonalite-granodiorite suite (Gower, 1978);

the mafic intrusive suite is synonymous with the dioritic suite (Beakhouse, 1977) and diorite-granodiorite (Gower, 1978, p.469) suite. The term gneissic granitoid suite was applied by all of the above authors although Beakhouse (1977) refers to it as the early gneissic suite. Textures of the granitoid units are self explanatory except the terms defined below:

seriate - the texture of a subtly porphyritic rock in which there is a complete range in size of grains between groundmass and phenocrysts. Compare with porrphyritic granitoid rocks were there is a considerable difference in the dimensions of the smallest phenocryst and those constituting the matrix.

grain size - aphanitic - crystals cannot be distinguished in field.

fine-grained (1 mm)

medium-grained (1 - 5 mm)

coarse-grained (>5 mm)

pegmatitic (>2.5 cm or 1 inch)

Where more than one modifier mineral is associated with a particular granitoid unit, they are listed in order of increasing abundance such that the most abundant is nearest the rock name. In outcrops containing multiple units, all members are coded in order of decreasing abundance except for the type of enclave (given in brackets) which is placed immediately following its host.

CHAPTER 3

GENERAL GEOLOGY AND METAVOLCANIC ROCKS

GENERAL GEOLOGY

The map area includes the west part of the English River Subprovince in northwestern Ontario and portions of the north and south contact zones with the Uchi and Wabigoon Subprovinces, respectively. These three structural subprovinces, as defined by Stockwell (1970), lie within the Superior Province of the Canadian Shield. All rocks within the map area are of Precambrian (Archean) age. The three major subprovince belts strike east to east-northeast within the map area.

The English River Subprovince comprises two domains: the southern domain is underlain by mainly granitic intrusive rocks while a northern domain is dominated by metasedimentary rocks and derived migmatites. Figure 2-1 illustrates the general geology of the English River Subprovince. Both the Uchi and Wabigoon Subprovinces are characterized by metavolcanic assemblages. Table 2-1 presents the general rock units and their percentage in the English River Subprovince.

Metavolcanic rocks are rare in the English River Subprovince. The only major metavolcanic unit within the English River Subprovince occurs at Separation Lake and forms part of the northern-southern domain boundary. This 5 by 45 km belt comprises mainly pillowed mafic flows and is continuous with the Bird River greenstone belt (McRitchie and Weber 1971). East of this belt at least 16 isolated supracrustal rafts occur along the northern-southern domain boundary. It is suggested from this distribution that this greenstone belt possibly extended 160 km to the east.

The north half of the English River Subprovince is underlain by an extensive metasedimentary belt that has undergone regional migmatization. This metasedimentary belt is traceable for the full extent of this survey (310 km) and continues further west into Manitoba (McRitchie & Weber, 1971) and further eastward (Sage et al., 1974). The metasedimentary rocks occupy 67% of this northern domain. Locally, proximal facies conglomerated occur near the south margin of this former sedimentary trough, suggesting contemporaneity with the Separation Lake metavolcanic rocks. In localities such as at Avis- Papaonga-Root Lakes and the Lake St. Joseph area, contemporaneity of rock units in the Uchi Subprovince and the English River Northern Supracrustal Domain is also established. In most of these areas there is a gradual dimunition of volcanic facies to the south of the Uchi Subprovince. However along much of this northern margin, especially in the west, major faulting (the Sydney Lake Fault Zone) has substantially interrupted this volcanic-sediment continuity. Away from the margins of this sedimentary trough most of the units comprise wacke-pelite beds of turbidite origin.

Based on composition, texture and style of intrusion three major plutonic suites (gneissic, sodic and potassic) intrude the English River Subprovince. Collectively these suites comprise 98% of the Southern Plutonic Domain and 30% of the Northern Supracrustal Domain. The mafic intrusive suite comprises a minor group (gabbro-diorite-quartz diorite), forming only about 4% of the subprovince. It is noteworthy that the gneissic suite comprises only 19% of the Southern Plutonic Domain and overall constitutes less than 10% of the so-called "English River Gneiss Belt" (Wilson, 1971, p.45). The gneissic granitoid suite is mainly restricted to the west part of the English

River Subprovince (Figure 2-1) and, except for large segmented tracts of gneissic rocks in the Clay Lake - Cedar Lake area and in the central part of Lac Seul, occurs predominantly along the extreme southern contact adjacent the Wabigoon Subprovince. The relation of gneissic rocks to the contact with the Wabigoon Subprovince is uncertain as sodic and potassic suite intrusions commonly occur at the subprovincial boundary. The gneissic granitoid suite is the most structurally complex and has been affected by several periods of deformation. It is characteristically banded and comprises numerous, polycyclic, complexely intermixed and tectonically-metamorphically-reworked intrusive units ranging from ultramafic-gabbro-diorite-quartz diorite-trondhjemite-granodiorite. The gneissic suite tends to wrap around some of the later sodic and potassic suite batholiths.

The sodic granitoid suite is more uniformally distributed and comprises 38% of the southern Plutonic Domain and 29% of Northern Supracrustal Domain. The sodic granitoid suite forms two types of intrusions. There are complex heterolithic, multi-unit batholiths and simple, more uniform, homogeneous stocks and batholiths. The complex type has a wider compositional range (gabbro- diorite- quartz-diorite-trondhjemite-granodiorite) and similar to the gneissic granitoid suite. This complex type forms extensive, batholithic complexes generally oriented parallel to the east to east-north-east strike of the major subprovince belts. The heterolithic type of the sodic granitoid suite is most common in the Southern Plutonic Domain. The simple type of sodic plutonic rocks comprise a much more restricted range (dominantly trondhjemite) and form discrete, sub-circular stocks and batholiths throughout the English River Subprovince.

The potassic granitoid suite is the youngest of all intrusive rocks, accounting for 39%

of the Southern Plutonic Domain but is rare (1%) in the Northern Supracrustal Domain. The potassic granitoid suite comprises a restricted compositional range varying from granodiorite-quartz monzonite-granite and typically exhibits uniform composition over vast areas. Intrusions range from extremely thin apophyses to stocks and batholiths such as the 2701.9 +3.9/-3.0 Ma, 25 by 95 km Lount Lake batholith (Beakhouse and McNutt 1991) that occupies approximately 2,070 km^2.

Field relationships indicate the simple type of sodic suite plutons is intrusive into the gneissic suite, the complex, heterolithic type of sodic suite and the mafic intrusive suite. Several ages of mafic dykes intrude the gneissic suite and the complex style sodic suite. In contrast, most of the youngest plutons in the Wabigoon Subprovince belong to the sodic granitoid suite.

The Uchi-English River Subprovince boundary is gradational and represents a continuous progression from a volcanic regime to a sedimentary regime. Evidence for this contemporaneity is obscured in most of the western part of the subprovince due to major cataclastic zones (the Sydney Lake Fault) and local plutonic intrusion. Along most of the Wabigoon-English River Subprovince boundary granitic intrusions have obscured any evidence of major cataclasis.

The division of the English River Subprovince into a Northern Supracrustal Domain and Southern Plutonic Domain is based on the southward disappearance of metasedimentary units against granitic intrusions. No faulting has been observed along this interface. The abrupt increase in metamorphic grade across the Uchi-English River Subprovince boundary across the Wabigoon-English River Subprovince boundary imply

that the English River Subprovince has experienced an unknown magnitude of uplift in relation to the adjacent metavolcanic complexes.

Detailed structural studies in the area by Westermann (1977), Gower (1978) and Stone (1981) have been mainly used to document the structural history for the area. Westermann, in deciphering the structural history of the Cedar Lake area gneiss domes has postulated the following history:

1) emplacement of tonalite precursors to the Cedar Lake gneisses of the Southern Plutonic Domain.

2) D_1 deformation of pre-D_1 tonalites etc. producing rootless intrafolial folds of axial planar fabric

3) D_2 deformation of pre-existing compositional banding

4) intrusion of Clay Lake granitoid suite

5) structural discordance or disconformity

6) deposition of supracrustal rocks (2.59 Ga)

7) D_3 deformation and migmatization of metasedimentary rocks of the Northern Metasedimentary Domain

8) D_4 development of major domes through emplacement of sodic suite plutons

9) D_5 minor deformation of granitic dykes

10) development of major subprovince boundary faults such as the Sydney Lake Cataclastic Zone

11) regional Z-warping, conjugate joints, minor Z- and S-folds

12) development of linear mylonite - ultramylonite fabric on major subprovince boundary

faults

The metamorphic facies zonation of the area progresses from greenschist facies adjacent to the metavolcanic-rich subprovinces to small nodes of low pressure granulite facies rocks in the Northern Supracrustal and Southern Plutonic Domains.

The progression is smooth and uninterrupted south of Uchi Lake and Lake St. Joseph but substantial discontinuities in facies zonation occur elsewhere. This zonation helps demonstrate the correlation of the Northern Supracrustal Domain with the Uchi Subprovince.

There is good potential in the area for rare element and U-Th deposits. Through property descriptions and geochemical data we demonstrate methods for assessment of mineral potential of pegmatites. Measures of fractionation of pegmatites (K/Ba etc.) demonstrate the differing fractionation trends of U-Th-bearing and rare-element pegmatites.

METAVOLCANIC ROCK SUBDIVISION

The metavolcanic rocks were subdivided into two groups based on colour index: 1) mafic to intermediate metavolcanic rocks having a color index greater than 30 and dominantly basaltic to locally andesitic composition; 2) felsic to intermediate metavolcanic rocks having a color index of less than 30 and an andesitic to rhyolitic composition. Where possible the latter rocks were subdivided further into two categories: i) metavolcanic rocks of andesitic to dacitic composition (colour index about 18 to 30, map code 2a) and ii) metavolcanics of dacitic to rhyolite composition (color index less than 18).

Color index is the percentage of total mafic minerals including amphibole, biotite, chlorite and pyroxene present in the rocks.

At the 1: 63, 360 scale of mapping, the majority of the contacts within the metavolcanic sequences mark changes in composition that correspond to one of the two major subdivisions.

MAPPING EMPHASIS

Emphasis was placed on those metavolcanic belts that were either previously unmapped or had not received any relatively recent detailed examinations. The following areas (outlined in Figure 3-A) were not examined in any detail: the Bee Lake area (Shklanka 1967), Werner Lake area (Carlson 1957), the Doran Lake area (Goodwin 1965), the High Lake-Rush Lake area (Davies 1965), Kenora area (King 1983), Bruin Lake-Edison Lake area (Pryslak 1976), Dryden-Sioux Lookout area (Harding 1950; Hurst 1932; Moorhouse 1939; Palonen and Speed 1974; Page 1979a; Johnston 1969, 1972; Satterly 1941 and Page 1979b), and the Savant Lake area (Bond 1977, 1978, 1980). Those areas that were mapped include:

Uchi Subprovince

i) Dixie Lake Belt

ii) Bruce Lake-Snakeweed-Fredart Lake area (Fenwick, 1972)

iii) Slate Lake

iv) Kesaka-Papaonga Lakes area

v) Root Lake-Lake St. Joseph Area

Wabigoon Subprovince

i) Vermilion Bay area

ii) north of Dryden-the Gullwing Lake area

The mapping of the above areas was mainly for correlation with previously mapped metavolcanic-rich areas.

MAFIC TO INTERMEDIATE METAVOLCANIC ROCKS

Except for the Separation Lake belt including its eastern extension and the Ena Lake mafic metavolcanic lens, mafic metavolcanic rocks mainly occur in the adjacent Uchi and Wabigoon Subprovinces. In fact the sudden absence of mafic metavolcanic rocks is used to mark the boundary of the English River Subprovince.

Mineralogy

The mafic to intermediate metavolcanic rocks have been derived from rocks of predominantly basaltic to locally andesitic composition. These rocks weather light green to dark green to green-black. Fresh surfaces exhibit a similar hue. In low grade rocks the typical mineralogy includes actinolite, plagioclase (albite-oligoclase), hornblende, chlorite, epidote, clinozoisite, quartz, sericite and carbonate. In the almandine-amphibolite facies or medium grade (Winkler 1974) mafic to intermediate metavolcanic rocks contain hornblende, plagioclase, garnet, quartz, biotite and epidote. Medium-grade metamorphic conditions typify the Bruin Lake-Edison Lake area (Pryslak, 1976), the Fredart-Whitemud Lake area (Fenwick, 1972), the Snakeweed Lake and parts of the Dixie Lake belts. Pyrite, pyrrhotite, sphene and leucoxene are the common accessory minerals.

Actinolite occurs as single subhedral to anhedral prismatic crystals and as aggregates of randomly oriented prismatic crystals in low grade rocks. The latter locally forms mats

4-5 mm across. The actinolite is generally randomly oriented but is aligned in zones of shearing.

Hornblende is most prominent in medium metamorphic grade rocks where it forms single, prismatic, subhedral crystals. In areas of granulite grade metamorphism, the hornblende is completely anhedral and tends to occur as equidimensional crystals.

Plagioclase (albite-oligoclase) is the other main constituent and forms approximately 30-40 percent of these rocks. It is generally untwinned to locally twinned and is subhedral in flows metamorphosed under low grade conditions. In medium and higher (granulite) metamorphic grades the plagioclase is anhedral and recrystallized to a granoblastic mosaic. Locally in low grade conditions the original lath shape of the plagioclase is preserved.

Epidote, clinozoisite, sericite and carbonate are secondary minerals found during subsequent metamorphic alteration. The carbonate and some of the quartz is secondary, intruded as later veins. Chlorite is commonly a retrograde mineral.

Garnet is locally present in sequences metamorphosed to medium-grade metamorphic conditions.

Hypersthene, diopside and magnetite are common in mafic volcanic rocks metamorphosed to granulite high grade conditions and occur at Cedar Lake and Chamberlain Narrows (Photo 3-1). Mafic metavolcanic rocks at the latter locality contain diffuse, in situ, trondhjemite clots comprised of coarse-grained, hypersthene, diopside and magnetite (Photo 3-1). In general if these indicator minerals are present in the leucosome, they are also present in the host.

The mafic metavolcanic rocks are composed of fine to coarse-grained massive flows, pillowed flows, porphyritic (plagioclase) flows and porphyroblastic (amphibole) flows, (pillow) breccia and rare flow top breccia, gneissic mafic metavolcanic and pyroclastic rocks including tuff, lapilli-tuff and tuff-breccia.

Massive Flows

Massive fine to medium-grained flows (map code 1a) and medium to coarse-grained flows (map code 1b) and their derived amphibolites are the most common type of mafic metavolcanic rocks. They constitute at least 90 percent of most of the mafic metavolcanic belts near the margin of the Uchi and Wabigoon Subprovinces and in the Separation Lake Belt (English River Subprovince). The coarse-grained (4 mm) flows may in part be intrusive into the mafic metavolcanic rocks and represent feeder zones coeval with their extrusive equivalents. Grain size commonly varies from fine to coarse over single exposures. In most areas no contacts between individual flow units were observed and it is difficult to estimate the thickness of the flows. Mafic flow units range from 458 m thick northwest of Slate Lake to more than 6.4 km thick in the Savant Lake area (north of Kashaweogama Lake). These flow sequences undoubtedly comprise numerous, multiple flow units. Amphibole is the most prominent mineral observed in the field and was used as an indicator of grain size. It is generally randomly oriented to locally weakly lineated. Locally the amphibole forms single porphyroblastic or poikiloblastic, subhedral phenocrysts (map code 1m) that may be pseudomorphic after olivine.

Porphyritic (plagioclase) flows (map code 1j) are exceedingly rare in the areas that were reexamined but are significantly present in some of those areas compiled from

recent

detailed work including the Bruin-Edison Lake (Tustin-Bridges) area (Pryslak, 1976) the Savant Lake Greenstone Belt (Bond, 1977, 1978, 1980) and parts of the Sioux Lookout Greenstone Belt. Porphyritic plagioclase flows are most abundant in the mafic metavolcanic unit at Keikewabic and Kabikwabik Lakes just south of Minnitaki Lake in the southeast corner of the Sandybeach-Route Lake Sheet (Breaks et al. 1976f). The phenocrysts are commonly enveloped by randomly oriented, subrounded, lath-shaped plagioclase and suspended in a basaltic matrix. In places the phenocrysts are concentrated into narrow sill-like units and may be partly intrusive. Depending on their stratigraphic association, a number of mechanisms may be instrumental in their origin including flow differentiation, and flotation and/or gravity settling (Bond 1977, pg. 18-19).

Pillowed Flows

Pillowed flows (map code 1c) were locally observed at Separation Lake (see below) and are abundant at Lake St. Joseph and in the Jutten mafic volcanic sequence north of Kashaweogama Lake in the Savant Lake Greenstone Belt. The pillow lavas at Lake St. Joseph are well formed allowing numerous top determinations. Elsewhere, pillow lavas are a minor constituent of almost all of the metavolcanic belts lying along the margin of the English River Subprovince. In most cases the pillows are non-vesicular, closely packed with a minimum of interstitial material and average 0.9 to 2.5 m in length. Length to thickness ratios average from 1:1 to about 5:1 on plan surfaces. They are commonly bun to mattress-shaped.

Pillow and flow top breccia (map codes 1d, 1h) are rare features in the Savant Lake area, Sioux Lookout area and at one locality in the Separation Lake Greenstone Belt where the brecciation is possibly due to fumerolic action.

Pyroclastic Rocks

Pyroclastic rocks were subdivided into fine types (tuff, lapilli-tuff, map code 1f) and a coarser type (tuff-breccia, map code 1g). Pyroclastic rocks are much less abundant than flows but are a constituent of most of the mafic metavolcanic belts along the margin of the English River Subprovince. Commonly the fragments are easily observed, being slightly more felsic than the matrix but locally, as near Troutfly Lake (northeast of Dryden) there are porphyritic flow and tuffaceous mafic fragments in a mafic matrix (Photo 3-2).

The classification of mafic tuff units is tentative due to the difficulty in distinguishing them from mafic flows. In general, the mafic tuffs are more prominently foliated.

Gneissic Metavolcanic Rocks

Gneissic mafic metavolcanic rocks are found in many areas of medium- and high (granulite) grade metamorphism. This texture is especially common in the enclave population lying east of the Separation Lake belt, and in areas where the metavolcanic units were engulfed in granitoid intrusive rocks as near the margins of the Uchi and Wabigoon Subprovinces. This gneissic texture is characterized by leucocratic, sharply defined to diffuse, discontinuous veins and bands varying in composition from trondhjemite to quartz monzonite to quartz-epidote silicified zones. In some cases the banding may be deformed, primary layering or pillow selvages (Photo 3-3) but it is

regarded as dominantly due to secondary, granitoid or silicification processes. Locally some of the granitoid constituent possibly was derived by partial melting of the mafic metavolcanic host under granulite metamorphic conditions (Photo 3-1).

FELSIC TO INTERMEDIATE METAVOLCANIC ROCKS

Felsic to intermediate metavolcanic rocks form a thin wedge on the north side of the Separation Lake metavolcanic belt and occur as rare thin beds in a supracrustal enclave at Florence Lake (Table 3-2). Except for these occurrences all of the felsic metavolcanic rocks are situated outside the English River Subprovince in the Uchi and Wabigoon Subprovinces. In contrast to the English River-Wabigoon Subprovinces boundary, marked mainly by the appearance of mafic metavolcanic rocks, the northern interface (English River-Uchi Subprovince boundary) is commonly heralded by the appearance of felsic to intermediate metavolcanic rocks. Along the latter contact, only the portion situated at the western arm of Lake St. Joseph and between Lake St. Joseph and Doran Lake is marked by the appearance of mafic metavolcanic rocks.

In the Uchi Subprovince there are important felsic metavolcanic accumulations as in the Bee Lake area (Shklanka 1967), in the Maskooch Lake area (southwest of Slate Lake) and in the Lake St. Joseph area. In addition there are three significant felsic metavolcanic units in the Bruce Lake to Lake St. Joseph area:

1) a felsic unit running southwest from the Fredart Lake area (Fenwick, 1972) to and adjoining the Dixie Lake greenstone belt, correlative with Thurston's (1978) volcanic cycle III.

2) a felsic unit extending between north of Ben Lake to north of Bluffy Lake (Fenwick,

1972). This unit is equivalent to Thurston's (1978) volcanic cycle II.

3) an extensive felsic metavolcanic unit striking 70 km along the south side of the Uchi Subprovince between Badrock Lake and Lake St. Joseph.

The felsic metavolcanic rocks (map unit 2b) are generally white to light grey to light beige on the weathered surface and are typically light grey to dark grey and siliceous-appearing on fresh surface. The intermediate metavolcanic rocks (map unit 2A) are more varied in colour and weather light grey to light green to buff-brown and vary from grey to light green on the fresh surface.

Mineralogy

The felsic metavolcanic rocks are derived from compositions ranging from andesite to dacite to rhyolite. Typical mineralogy in low grade metamorphic conditions consists of quartz, plagioclase, biotite, muscovite, chlorite, secondary epidote, secondary calcite, minor to rare microcline, sphene, magnetite, pyrite and rare apatite and tourmaline. In medium grade metamorphic conditions the mineralogy consists of quartz, biotite, muscovite, hornblende, retrograde chlorite, epidote, apatite, sphene, staurolite, andalusite, sillimanite, cordierite and anthophyllite. The latter are mainly confined to the felsic unit striking southeast from Fredart Lake to the Dixie Lake Belt and correlates with Thurston's (1978) volcanic cycle III which hosts the South Bay Mine.

Quartz and plagioclase are the dominant constituents. In medium grade zones they occur as an anhedral granoblastic mosaic and are indistinguishable in thin section. In lower grade zones, the plagioclase locally retains its original subhedral to euhedral lath shape. In most cases the plagioclase is untwinned.

Biotite is most prominent in the intermediate units whereas muscovite is the dominant mica in the more felsic varieties. Both occur as single, aligned to sub-aligned crystals that locally deflect around crystals, crystal fragments and lithic fragments. Locally the biotite forms randomly oriented crystal aggregates that form clots sub-aligned to the foliation of the rock. Chlorite, some carbonate and epidote are commonly associated with the mafic clots.

Chlorite forms individual crystals that are locally discordant to biotite. Commonly it is complexly and conformably intergrown with biotite where it is probably a retrograde product. Hornblende is rare but occurs locally as subhedral porphyroblasts. Apatite, tourmaline, sphene and opaque minerals (mainly magnetite and pyrite) are accessory minerals.

The felsic to intermediate metavolcanic rocks are composed predominantly of pyroclastic rocks and subsidiary, commonly porphyritic flows. In medium-grade metamorphic zones the fine-grained felsic to intermediate tuffs are difficult to distinguish from flows of the same composition.

Pyroclastic Rocks

Pyroclastic rocks comprise the greater proportion of the intermediate to felsic metavolcanic units. They are subdivided into fine (tuff, lapilli-tuff: map code 2c) and coarse (agglomerate, tuff-breccia: map code 2d) types based on Fisher's (1961) classification. Other types are lapillistone (rare, characterized by little or no matrix: map code 2d), crystal tuff (map code 2g) and reworked or bedded pyroclastics (map code 2h). Tuff, lapilli-tuff and tuff-breccia are estimated to comprise about 95% of the felsic

metavolcanic sequences with tuff and lapilli tuff constituting the greater proportion (about 70-80% approximately). For example, most of the unit striking southeast from Fredart Lake to north of Pakwash Lake (the extension of volcanic cycle III) from Uchi Lake (Thurston 1978) comprises tuff and lapilli-tuff. In many areas due to extensive recrystallization and alteration, the unit could not be subdivided into tuff or flow.

In most cases the fragments are more felsic than their host matrix but rare cases of the reverse are locally observed (Photo 3-4). The fragments are commonly lensoidal having been tectonically deformed parallel to regional foliation. In most cases the regional foliation and elongation of fragments is parallel to the overall trend of units but, locally, in areas of folding, such as at Lake St. Joseph (Photo 3-5), the fragments are oriented parallel to a fold cleavage and elongated at a high angle to bedding. In most cases bedding is not obvious possibly due to the dominant fine fragmental nature of the rocks.

The coarsest intermediate to felsic fragmental rocks incurre by the present survey were found in the following localities:

1) in the felsic to intermediate metavolcanic sequence mapped as conglomerate by Harding (1950), situated between Bluett Lake and Vermilion Lake

2) locally interbedded with metasedimentary rocks in the unit (Uchi metavolcanic extension, cycle III) north of Bruce Lake.

3) as rare isolated areas in the same unit (as 2 above) in the vicinity of Fredart Lake.

4) as minor units in the large felsic accummulation situated between Slate Lake and Avis Lake.

5) as discontinuous thin lenses in the two felsic to intermediate metavolcanic units that border the metavolcanic belt in the vicinity of Papaonga Lake (specifically near the eastern border of the Papaonga-Wapesi Lake Sheet: Breaks et al. 1976b).

Almost all of the coarse pyroclastic rocks are matrix- supported, composed of a heterolithic population of fragments.

Crystal tuff, characterized by fractural subhedral laths of plagioclase and/or quartz fragments with or without lithic metavolcanic fragments, is fairly rare in those areas reexamined. It is locally present in the metavolcanic belt southeast of Slate Lake and in the felsic to intermediate metavolcanic unit along the north margin of the Papaonga Lake belt. Reworked and/or bedded tuffs (map code 2h) are typically fine-grained, bedded tuffs.

According to Pettijohn et al. (1973) volcaniclastic rocks are of two types each related to the dominant force acting in their production: 1) those of pyroclastic origin and 2) those of erosional origin. The dominant force in the first type is volcanic via exploded ejecta but were sorted in a medium of air or water and deposited as ash fall. The second type has been deposited during two separate periods involving two distinct forces: firstly, deposition by volcanic means and secondly erosion followed by redeposition as a tuffaceous rich sediment. As such, the second type commonly show primary sedimentary features. Bedded and/or reworked felsic to intermediate tuffs are most common in the

sequences southeast and south of Slate Lake, in the formation situated along the north margin of the Papaonga Lake Greenstone Belt and in the felsic to intermediate metavolcanic formation situated between Fredart Lake and Pakwash Lake (ie. the extension of Uchi volcanic cycle III of Thurston, 1978). Both generic types of bedded pyroclastic deposits cited above are present although the pyroclastic type would appear to be most prominent. Perhaps the best example of the volcanic type occurs north of Gullwing Lake in the felsic to intermediate metavolcanic sequence which contains a mafic bomb (Photo 3-6) in felsic ash exhibiting diffusely-defined bedding regarded as air fall in origin. In general, bedded tuffs of the volcanic type origin characteristically have diffusely defined bedding while the erosional type characteristically have sharply defined bedding planes.

Massive and Porphyritic Flows

Both massive, equigranular (map code 2j) and porphyritic (feldspar-map code 2k; quartz and feldspar-map code 2n) intermediate to felsic flows comprise only a small percentage of the intermediate to felsic metavolcanic belts. The massive equigranular flows are commonly difficult to distinguish from fine tuffs, however, porphyritic flows characterized by plagioclase and quartz phenocrysts (2 mm) are easily delimited. In general, the phenocryst population constitutes from 5 to 15 percent by volume of the rock. Many of the phenocrysts are fractured and occur as broken subhedral crystals. Matrix plagioclase is not visible in the field. In thin section this plagioclase is recrystallized to anhedral granules.

The feldspar-quartz porphyritic flows are similar to, but can be distinguished from,

porphyritic subvolcanic rocks by:

1) the maximum size of phenocrysts in flows (2 mm) is generally smaller than phenocrysts in intrusive rocks (2-4 mm).

2) flows generally have a more prominent foliation.

3) the phenocryst population in the flows tends to be less abundant than in the subvolcanic intrusions.

4) quartz phenocrysts in flows are generally less abundant than in intrusions.

5) locally the matrix of the subvolcanic intrusions is coarser- grained relative to that of the flow and appears almost granitoid.

6) in general the phenocryst population is evenly distributed in flows while the subvolcanic intrusions are texturally (both grain size, type and distribution of phenocryst) more variable.

The matrix of both the porphyritic and massive flows is similar. All primary textures have been obliterated and both

types are highly recrystallized to a granoblastic mosaic of quartz, plagioclase, biotite and muscovite.

Flow breccia is rarely observed but does occur locally within the felsic to intermediate belt southeast of Slate Lake and locally within cycle III (Thurston, 1978) in the unit striking between Fredart Lake to north of Pakwash Lake.

SPECIFIC METAVOLCANIC BELTS

ENGLISH RIVER SUBPROVINCE

Separation Lake Belt

The Separation Lake Belt, including scattered satellitic equivalents, is the only metavolcanic sequence entirely within the English River Subprovince. This belt is continuous with the Bird River Greenstone Belt in Manitoba (McRitchie and Weber, 1971; Trueman, 1975). The most extensive part of this greenstone belt is at Separation Lake. Further eastward, scattered enclaves of this belt have been mostly transported away from the contact by intrusive rocks.

At Separation Lake, the main part of the belt is up to 5 km wide and is enveloped by intrusions of the Umfreville Lake area. Further west, along much of its length, the belt is less than 30 m wide. The main part of the Separation Lake Belt (Figure 3-0) is dominated by mafic metavolcanic flows and subsidiary mafic intrusive rocks. Due to a lack of reliable, primary facing data, overall stratigraphy of the main part of the belt is ill-defined although Beakhouse (1975) indicates this belt is a north-facing homoclinal sequence. In general the north and west parts of the main belt are underlain by massive mafic metavolcanic flows. Pillowed flows are mainly concentrated in the southeast part of the belt (Figure 3-0).

The massive flows are usually fine to medium-grained and massive to locally foliated or lineated. Locally, rare zones of primary brecciation due either to degassing through fumerolic action or hyaloclastic mixing of magma and sea water are present. No flow contacts were observed in the field. A few minor pods of quartz and epidote are present but in general these massive flows are texturally featureless. Near the north contact and locally along the south boundary the mafic metavolcanic unit is strongly foliated to sheared. The shearing is discontinuous, restricted to zones separated by relatively

undeformed zones. Locally the shear zones are garnetiferous and contain concordant to discordant veins of quartz and epidote.

Pillowed flows (Photo 3-7) are bun to mattress-shaped, exhibit considerable size variation over single exposures (5 cm to tens of meters) and are generally elongate on outcrop surface in the direction parallel to the overall boundary of the belt. Individual pillows exhibit numerous re-entrant selvage edges and are almost invariably plastically deformed. No reliable top determinations could be made on this survey. The pillows have thick (2.5 to 4.0 cm), non-vesicular selvages that weather dark green. Near the northern boundary, thin (5-10 feet) pillowed units are interlayered with massive units. There, the pillows are highly stretched and locally cut by shear planes.

Both the massive and pillowed flows vary from massive to lineated and in thin section comprise hornblende, plagioclase, rare quartz and opaques. Hornblende (40 to 1%) occurs as single prismatic crystals and as rare porphyroblastic mats. Plagioclase is recrystallized to a granular mosaic and is untwinned but locally it's original lath shape is preserved.

Iron formation is locally present within the Separation Lake belt. The iron formation is up to 2.5 m thick and generally discordant to the strike of elongation of the pillows and or foliation. It is characterized by assemblages of magnetite, quartz, garnet and amphibole interlayed on a scale of 0.8 to 1.2 cm. Iron formation is locally observed within the metagabbro where it is always observed to be highly contorted. Based on aeromagnetic maps, iron formation probably occurs as a more extensive unit striking parallel to the eastern arm of the Separation Lake Greenstone Belt.

Two small massive to porphyroblastic metagabbro bodies intrude into the mafic metavolcanic rocks (Figure 3-0). Locally the gabbro - mafic metavolcanic contacts are partly gradational (grain size) but, in at least one locality, the contact is sharp, chilled over a width of 20 to 25 cm, sheared and is intruded by diopside-quartz-epidote veins of possible hydrothermal origin. The gabbro exhibits a typical ophitic texture composed of hornblende, plagioclase, opaque minerals, sphene and quartz. Hornblende occurs as single randomly oriented prismatic crystals and as coarse-grained, glomeroporphyritic crystal aggregates (4-6 mm across) that are locally porphyroblastic. Plagioclase (An_{50}) occurs as randomly oriented, well twinned, partly recrystallized grains interstital to the hornblende mats. It is possible that these intrusive rocks represent source magmas that are coeval with the mafic metavolcanic rocks.

Along the north contact of the belt lies a thin wedge of intermediate felsic metavolcanic rocks comprosed of an intermediate quartz-feldspar porphyritic flow that may in part be subvolcanic. At the contact the intermediate to felsic metavolcanic rock is fractured and weakly cataclastic. A minor unit within this felsic mwetavolcanic unit appeared very felsic and banded (due to quartz-rich laminae) and represent a welded tuff. The porphyritic unit consists of quartz, plagioclase, K-feldspar, biotite, retrograde chlorite and opaque oxides.

Chemistry

Table 3-1 lists chemical analyses of the Separation Lake metavolcanic and intrusive rocks. According to Irvine and Baragar (1971) as seen in Figure 3-1, diagram 2, the extrusive and intrusive rocks are all tholeiitic basalts. Based on the ratio of Al_2O_3 vs normative plagioclase the intrusives plot as calc-alkaline basalts. In the Jensen cation

plot (Figure 3-2) the extrusive rocks are dominantly high magnesium tholeiitic basalts whereas the intrusive metagabbro rocks vary from high magnesium tholeiitic basalts to calc-alkaline basalts. The felsic metavolcanic rocks plot as calc-alkaline dacites and on the border of calc-alkaline to tholeiitic rhyolite (Figure 3-2).

Modern Analogues

According to Floyd and Winchester (1975) and Winchester and Floyd (1977) the elements P, Zr, Ti, Y, Nr and the REE are relatively immobile. Discrimination diagrams based on modern day analogues using some of these elements have been proposed by various workers (Pearce 1975; Pearce et al. 1975; Pearce and Cann 1973; Davies et al. 1979). Discrimination plots of the Separation Lake metavolcanic and intrusive gabbro rocks (Figures 3-3; 3-4; diagram 4; Figures 6-5) suggest an oceanic or ocean floor basalt affinity. On the TiO_2-Y + Zr - Cr diagram (Figure 3-4, diagram 2) of Davies et al. (1979) the Separation Lake extrusive and intrusive rocks exhibit similar trends in the Archean magnesian tholeiitic field in agreement with the Jensen (1976) and Irvine and Baragar (1971) classifications. Based on similar geochemical trends the Separation Lake metavolcanic sequence is very similar to the Jutten Volcanic Sequence, Savant Lake area (N.F. Trowell et al., 1980; Bond 1978) and the Wapageisi Lake metavolcanic rocks (Trowell et al. 1980). These belts are characterized by thick piles of tholeiitic metavolcanic~~s~~ rocks of deep submarine origin with little or no metasedimentary interruptions. Trowell et al. (1980) regard the Jutten and Wapageisi Lake sequence as the most primitive in the Wabigoon Subprovince and probably represent "deep submarine fissure

outpourings" (Blackburn et al. 1978, p.7).

Virtually every chemical plot involving the Separation Lake metavolcanic rocks exhibit a very restricted field. Only Cr and TiO_2 (Figure 3-4, diagrams 2 and 3) exhibit some variation but this is probably due to differentiation. In all the other diagrams (Figures 3-2; 3-3; 3-1, 6-4; 6-5) involving elements such as K_2O, P_2O_5, CaO, MnO, Zr, TiO_2, Sr, FeOt, Mg, the Separation Lake metavolcanic and intrusive rocks plot in a relatively close cluster. The lack of mobility is striking if one considers that the metavolcanic belt is partially overprinted by the Umfreville-Conifer Lakes granulite zone. Chemically the intrusive rocks are locally distinguishable from the extrusive rocks: the intrusive gabbros plot more magnesian (i.e., lower on the differentiation trend) on the AFM trend (Figure 3-2), and on the TiO_2-FeO/MgO (Figure 6-4) are slightly more aluminous (Figures 3-4, diagram 1), richer in chromium (Figures 3-3; 3-4, diagrams 2 and 3) and slightly enriched in potassium (Figure 3-3). The close chemical correlation between the extrusive and intrusive rocks of the Separation Lake Belt suggests the two types are genetically related. In fact, the enrichment in Cr and magnesium in the gabbro suggests it may be a magma residuum more primitive than the extrusive equivalents. That is, the metavolcanic rocks may be differentiates from the gabbro both having originated in a common magma chamber.

Eastern Extension of Separation Lake Belt

East of Separation Lake, there are at least 16 localities of supracrustal rocks (Table 3-2) interpreted as enclaves of a formerly more continuous, 250 km-long metavolcanic belt. Most of the enclaves consist of massive to gneissic amphibolitic rocks of uncertain

origin. Locally, intercalated banded iron-formation, diffuse irregular pillow selvages and tuffaceous metasedimentary rocks (Table 3-2) support a supracrustal origin.

At Cliff Lake a large enclave of massive and pillowed metavolcanic rocks situated in the Cliff Lake porphyritic granodiorite (part of the Lount Lake batholith) was described in detail by Westerman (1977, p.51-53). At Chamberlain Narrows there are thin, very dark bands within the mafic metavolcanic rocks (Photo 3-8). These dark bands could represent deformed remnants of intrusive mafic to ultramafic dykes or relict pillow selvadges.

Most of the supracrustal localities (Table 3-2) are isolated rafts of limited extent. These enclaves rarely exceed 2,000 m in width and are generally less than 2.0 km in length, the most extensive being the Chamberlain Narrows enclave (at least 16 km in length). Most of the mafic metavolcanic rocks are massive, and mainly contain plagioclase and black hornblende. Locally the metavolcanic rocks are gneissic with diffuse leucocratic lenticles to bands composed of plagioclase, quartz, epidote, biotite and rare K-feldspar. At Chamberlain Narrows the mafic metavolcanic rocks are situated in a granulite metamorphic zone and are diffusely gneissose which may be a product of local partial melting (Photo 3-9). The mineralogy of the granulite grade mafic metavolcanic enclaves include hornblende, plagioclase, diopside, hypersthene and magnetite. Chemical analyses (Table 3-3) reveal a similarity between mafic metavolcanic rocks at Chamberlain Narrows and Separation Lake (Figure 3-1, Diagram 3).

UCHI SUBPROVINCE

Dixie Lake Belt

The Dixie Lake metavolcanic-metasedimentary belt branches into several prominent arms that extend south, southwest and west from a central mass at Dixie Lake. Two previously unmapped, isolated remnants of foliated to pillowed, amphibolitic mafic metavolcanic rocks that extend southwest to the southern end of Longlegged Lake probably represent a relict arm of this belt.

Exposure in the northern half of this belt and within the Bug Lake-Stone Lake extension is fair to moderate, but in the central, southeastern and southern parts is poor to non-existent. The Dixie Lake belt is dominantly composed of a thick sequence of pillowed to massive, mafic to intermediate metavolcanic flows. Individual flows are typically thin, varying between 2 and 9 m in thickness.. Metavolcanic rocks of intermediate composition constitute the second most abundant rock type and occur as finely laminated tuff units, massive flows, and local tuff-breccia units. A prominent, previously unmapped, predominantly tuffaceous unit occurs in the northern part of the Dixie Lake belt. This unit gradually widens eastward for at least 23 km, from just east of Bug Lake. This unit is at least 3 km wide near Rice Lake (local name). A quartz monzonite batholith near Stone Lake appears to have removed a small segment of this unit by stoping. Minor intercalated bands of greywacke, argillite and quartzite are also present. Oxide facies iron formation has been identified in diamond drill intersections and inferred from aeromagnetic data (File 63.3001 Diamond Drill Reports, Assessment Files Research Office, Ontario Geological Survey, Toronto). A small septum of metavolcanic rocks was traced along the western shoreline of Pakwash

Lake and represents a previously unknown southward extension of the Dixie Lake belt. This septum contains amphibolitic, foliated equigranular and pyroclastic mafic metavolcanics, dacitic tuff, lapilli tuff, and heterolithic tuff-breccia. Also notable is volcanogenic conglomerate containing exotic clasts of medium-grained massive leucocratic trondhjemite. Feldspar porphyry dykes are locally apparent, particularly within the intermediate metavolcanic rocks.

Bruce Lake-Snakeweed Lake-Fredart Lake Area

The area is underlain by two metavolcanic units both striking east-northeast to northeast (N65^0-70^{0}E) separated by granitoid intrusive rocks The area was previously mapped by Fenwick (1972) and the northeast part of this area has subsequently been mapped by Muir and Graydon (1982). The two major units consist of a northern, dominantly mafic unit and a felsic unit to the south. The latter is the extension of the Uchi Cycle III (Thurston, 1978).

Mafic Metavolcanic Units

The mafic metavolcanic unit runs from north of Pakwash Lake, past the north end of Fredart Lake to Uchi Lake, a distance of 32 km. The mafic metavolcanic formation varies in width from 0.5 km to 5-6 km in the southwest. The mafic metavolcanic rocks comprise dominantly massive medium-grained mafic flows. Locally these are well foliated to sheared or gneissose. The gneissose structure is due to small leucocratic veinlets (3-10 mm width) that are injected but may in part be metamorphic segregations. Locally the

amphibole is coarsely porphyroblastic. Pillow lavas were observed at two localities on the southwest Bay of Fredart Lake, but were plastically deformed and do not aid in determining tops. The metavolcanic rocks are locally garnetiferous.

Within this mafic metavolcanic formation, there are a few thin stringers of felsic to intermediate tuffs in the Snakeweed Lake area. The felsic metavolcanic rocks are highly recrystallized but appear to be mostly tuffaceous. In a few areas cordierite znd andalusite porphyroblasts (Photo 3-10) are present. Locally the pyroclastics are coarse tuff-breccias. In medium grade metamorphic zones where the composition of the fragments approximates that of the matrix, the fragments are ill-defined (Photo 3-11).

Felsic to Intermediate Metavolcanic Units

Uchi Volcanic Cycle III (Thurston, 1978) extends southwest to Pakwash Lake for a distance of about 42 km. It varies in width from 1-3 km and is interrupted by later granitic intrusives in at least one locality. The sequence is complex and is characterized by rapid alternation of mafic and felsic metavolcanic with minor amounts of associated metasedimentary rocks. This formation is composed of fine to medium pyroclastic rocks and subsidiary porphyritic flows, some of which may be subvolcanic. Near the Copper-Lode deposit just south of Fredart Lake (Breaks et al., 1975; Closs and Colvine 1975, 1976), the pyroclastic rocks are fine-grained, massive, locally bedded, tuffs and lapilli-tuffs. Due to their fine-grained size, they may have formed in a distal facies environment. By comparison, further southwest near Pakwash Lake, the pyroclastic rocks are coarser and appear to be more proximal. This formation is characterized by several

massive sulphide deposits (Closs and Colvine, 1975, 1976) including the Copper Lode Deposit. These deposits and showings are on strike with the South Bay Mine and are probably all genetically related.

South-west of Fredart Lake the unit dominantly consists of intermediate pyroclastic rocks but locally there are felsic tuff horizons (0.3 to 3 m thick). Numerous porphyroblasts, varying in size from 1.2 to 3 cm but averaging 2.5 cm, are present in the metavolcanic rocks and include staurolite, sillimanite, cordierite, andalusite and garnet. These minerals led Fenwick (1972) to suspect this formation was dominantly metasedimentary in origin but this interpretation is questioned by this study. Amphibole is absent to rare in the English River metasedimentary rocks. The abundance of amphibole in many of the units of this formation indicates a probable volcanic origin. The porphyroblasts are generally lobate in form, have diffuse contacts and are locally enveloped by foliation. Locally some appear to overgrow the foliation (Photo 3-10). A peculiar rock that appeared to be a mixed metavolcanic unit consisting of equal proportions of mafic and felsic constituents occurs 4 km southwest of the Copper Lake Deposit in the same formation (Breaks et al. 1976a, map P.1199). The mafic/felsic constituents form a continuous honeycomb network or deformed mesh-texture. The mafic portion is composed mainly of amphibole and subsidiary recrystallized plagioclase. The felsic portion comprises a highly recrystallized fine grained granoblastic mosaic of quartz, plagioclase andandalusite. Cordierite and staurolite also occur nearby in intermediate lapilli-tuff. The proportion of mafic/felsic units locally varies up to 80% felsic and 20% mafic material. It is unknown if this texture is a primary magma mixing phenomena or

whether it constitutes a large scale metamorphic segregation texture. Anthophyllite and sillimanite also occur locally in the same unit.

The aluminosilicate minerals are all regarded as alteration- related to the various massive sulphide volcanogenic deposits in the medium grade, felsic to intermediate metavolcanic unit.

Quartz and feldspar porphyry flows and/ or sills occur

as isolated conformable units throughout the felsic unit. According to Closs and Colvine (1976, p.166) the volume of porphyritic units in the "Copper Lode" area is considerably less than that to the northeast in the vicinity of the South Bay Mine. Some of the porphyry-types within this unit exhibit small breccia areas possibly due to fumerolic action suggesting they may in part be extrusive (Photo 3-12).

Locally there are metagabbro stocks associated with the metavolcanic formation in the Pakwash-Fredart Lakes area. The mafic intrusive rocks are fine- to medium-grained and compositionally vary from mainly gabbro to locally diorite. Commonly they exhibit original ophitic textures in which plagioclase phenocryst are suspended in an amphibole rich matrix. Rare andalusite occurs near the south contact within the metagabbro stock situated south of Fredhart Lake just north of the Copper Lode deposit. The andalusite (2 cm x 0.8 cm) is rectangular, weathers up and is easily distinguished in the field. Some of the metagabbros contain abundant magnetite.

Approximately 7 km west-southwest of Snakeweed Lake, a massive diorite-gabbro intrusion containing 5 percent magnetite is exposed in one outcrop. The intrusion is interpreted to extend northwest, coinciding with a magnetic high shown on the regional

aeromagnetic maps (ODM-GSC 1961).

Slate Lake Area

The Slate Lake area was previously mapped by Bateman (1939). Fenwick's (1972) and Muir and Graydon's (1982) mapping adjoined the western part of Bateman's mapping and included Ben Lake. The simplified geology of this part of the Uchi Subprovince including the English River-Uchi subprovincial boundary between Slate Lake and Papaonga Lake is illustrated in Figure 4-2.

Mafic metavolcanic units situated north and south of Slate Lake that join in the vicinity of Lower Slate Lake demarcate a fold structure. Top determinations in clastic metasedimentary rocks suggest Slate Lake is overprinted by an anticlinal axis. The mafic metavolcanic units are dominantly fine to coarse-grained mafic flows with local rare mafic pyroclastic beds. The mafic metavolcanic unit on the north side of Slate Lake is continuous to the Jubilee Lake area. This unit is commonly sheared and locally silicified.

North of the mafic metavolcanic unit on the north side of Slate Lake there is a thick sequence of intermediate to locally felsic tuffs and reworked tuffs (Photo 3-13). This sequence extends from Panama Lake to northwest of Upper Slate Lake where locally there are a few intrusive quartz-feldspar porphyry sills. These reworked tuffs grade into a dominantly metasedimentary sequence to the northwest (Thurston, 1978).

The metasedimentary rocks underlying the core of the anticlinal axis comprise well bedded (average between 5 and 35 cm) greywacke, and arkosic wacke with minor siltstone. These metasedimentary rocks are commonly graded and locally exhibit cross-bedding (Photo 3-14). Locally there are interbedded, intermediate tuff and crystal

tuff units within the metasedimentary rocks. Two types of conglomerate are exposed in Sawan Bay of Slate Lake: a lower polymictic paraconglomerate containing abundant, locally pink-weathering trondhjemite boulders and volcanic clasts and a volcanic conglomerate composed predominantly of volcanic clasts and minor quartz and iron formation pebbles. The two conglomeratic units are separated by about 150 m of massive, coarse-grained greywacke that is similar to the matrix of the granitoid boulder-bearing paraconglomerate. Several interbeds of greywacke also occur within the volcanic conglomerate. Both conglomerates locally exhibit inclined stratification. The conglomerate facies and presence of cross-bedding suggests these metasedimentary rocks are proximal and in a near shore environment. Thin bedded mudstone (slate) is interbedded with wackes and arkosic wacke and are peculiar to the metasedimentary unit on the southside of Sawan Bay.

South of the mafic metavolcanic unit at Sawan Bay the volcanics pass abruptly into metasedimentary rocks of the English River Subprovince but locally there are intercalated tuffs within the first 1 to 2 km of the metasedimentary sequence.

Slate Lake to Papaonga Lake Area

Metavolcanic and metasedimentary rocks underlying the Ben Lake-Slate Lake area extend eastward past Papaonga Lake to the east boundary of the map-area and are probably continuous with the Lake St. Joseph "greenstone" belt. The limits of the Papaonga Lake belt were first defined by Wright (1936) and are similar to that shown on the compilation map of the area (Ferguson et al. 1970). The metavolcanic rocks in the Papaonga Lake belt display a compositional layering which is complicated by intervening

metasedimentary accumulations and plutons. However, units are recognizable:

1) a dominantly mafic metavolcanic unit in the Papaonga area;

2) a dominantly metasedimentary and metatuffaceous sequence between Badrock Lake-Avis Lake and Wassa Bay (Slate Lake);

3) a dominantly intermediate pyroclastic accumulation from Kesaka Lake north to Jubilee Lake (just outside of the north boundary of the map area).

Papaonga Lake Area

This belt is composed predominantly of mafic metavolcanic flows and pillow lavas continuous with those exposed in the Slate Lake area. Pillow tops suggest the sequence faces south. At Papaonga Lake the sequence is approximately 5200 m thick but thins rapidly eastward to about 1500 m. The northern margin of the Papaonga Lake Belt is partly gradational in that it is injected by quartz monzonite sills (Photo 3-15). The mafic metavolcanic rocks overlie a thin lens (300 to 600 m) composed of metasedimentary rocks, reworked tuffaceous rocks and minor iron formation. At the top of the sequence the mafic metavolcanic rocks are interbedded with several lenses of metasedimentary rocks, intermediate tuff, lapilli tuff and,locally, tuff breccia and flows. These pyroclastic accumulations are generally fine in texture and are more abundant to the east, grading imperceptibly westward into dominant metasedimentary rocks at Papaonga Lake. Metasedimentary rocks at Papaonga Lake comprise a thin- to medium-bedded sequence of interbedded greywacke and siltstone which locally exhibit graded bedding.

Chert-magnetite iron formation is present on the south side of Papaonga Lake and is

up to 20 m wide. The uppermost (southern) unit of the belt comprises intermediate to felsic metavolcanic rocks overlying a thin layer of mafic metavolcanic rocks, and this unit can be traced beyond Badrock Lake, a distance of 40 km. Felsic metavolcanic rocks are most common in this uppermost intermediate to felsic metavolcanic unit and generally consist of fine pyroclastic material, commonly reworked, and subject to rapid facies change into more silica-deficient metasedimentary rocks. To the south the felsic tuffaceous rocks diminish, gradually being superceded by greywacke typical of the English River Subprovince (Figure 4-2).

Badrock-Avis-Wassa Bay (Slate Lake) Area

Relationship of this area with the Papaonga Lake area is difficult to establish in that the rocks are complexly folded and intruded by a small unmetamorphosed hornblende-biotite granodiorite pluton between Avis Lake and the Papaonga River. Northeast of Badrock Lake the area is dominantly underlain by metasedimentary rocks similar to the greywacke-siltstone sequence in the Papaonga Lake area. Distinct bedded units are traceable over single exposures and are generally thin- to medium-bedded. The complex folding observed within the metasedimentary rocks precludes any estimation of their true thickness. These metasedimentary rocks grade into a thick sequence of intermediate tuff and reworked tuffaceous metasedimentary rocks to the northeast of Badrock Lake. North of the metasedimentary and tuffaceous sequence a thin unit of mafic metavolcanic flows extends from Slate Lake to east of Papaonga Lake.

Avis-Jubilee-Slate Lake Area

A thick sequence of predominantly intermediate pyroclastic rocks occurs north of the aforementioned thin mafic metavolcanic unit. The pyroclastic sequence includes intermediate to felsic tuff, lapilli-tuff, tuff breccia, flows and flow top breccia, intermediate to mafic garnetiferous lapilli-tuff, thin gabbroic intrusive sills and conglomerate. The conglomerate is continuous with the Slate Lake conglomerate described by Bateman (1939, p.9-10). North of this sequence, mafic metavolcanic flows intruded by coarse-grained gabbroic sills are present. The mafic flows form a layer about 1200 m thick that is continuous from Ben Lake through the central portion of Slate Lake, northeast to Jubilee Lake where they curve southeastward, terminating 5 km east of Curie Lake. The eastern end of this mafic metavolcanic unit is marked by complex granitic contamination. Dikes, sills and small plugs of subvolcanic rocks (predominantly feldspar porphyry) intrude the sequence. At Kesaka Lake, iron formation occurs within intermediate lapilli tuff and reworked tuffaceous rocks and extends eastward to Crossley Lake. The iron formation is composed of thin-bedded, chert-magnetite layers interbedded with roughly equal amounts of garnetiferous metagreywacke.

Within the Slate Lake - Papaonga Lake belt the relationship of the Slate Lake area and the areas mentioned above is not entirely understood due to complex folding. Isoclinal folding occurs in the metasedimentary rocks at Papaonga Lake and west-southwest of Avis Lake and appears the result of the adjustment of these rocks to adjacent granitic intrusions. An anticlinal axis, indicated by opposite-facing sedimentary top directions, trends through the southwestern part of Slate Lake. Northwest from this axis, the map

units correlate with those of Thurston (1978) who also established a northwest-facing direction. However, the sequence of the map units southeast of Slate Lake is markedly dissimilar to that northwest of Slate Lake and top determinations are generally lacking. With minor exceptions the remainder of the Papaonga Lake sequence faces south towards the English River Subprovince. Thus, the dominantly intermediate to felsic pyroclastic sequence between Jubilee and Kesaka Lakes (see above) appears to underlie the dominantly metasedimentary sequence exposed south of Slate and Avis Lakes. Bedding tops suggest a synclinal fold axis between Badrock and Papaonga Lakes, however, the metasedimentary rocks along the south margin of the Papaonga Lake Belt (i.e., at the boundary between the Uchi Subprovince and English River Subprovince) appear to face south.

Papaonga Lake-Roadhouse River-Root Bay (Lake St. Joseph) Metavolcanic Belt

The supracrustal sequence at Lake St. Joseph extends westward to merge with the metavolcanic-metasedimentary sequence in the Papaonga Lake area. Part of this extension was also mapped by Clifford (1969). Stratigraphic relations within this sequence are grossly similar to those in the Papaonga Lake area: the majority of the sequence is composed of fine- to medium-grained mafic metavolcanic flows. These flows are flanked to the south and north by thin, fine-grained pyroclastic, in part metasedimentary units. Along the southern margin, the pyroclastic rocks form a continuous marker horizon while those in the north appear to form discontinuous lenses. Towards the Lake St. Joseph area the southern pyroclastic unit becomes more metasedimentary in character with thin beds of metagreywacke and metasiltstone

interrupted by arkosic and/or reworked felsic tuffaceous horizons. No primary top indicators were found to aid in stratigraphic determinations within this sequence.

Lake St. Joseph Metavolcanic Belt

The western portion of the Lake St. Joseph area was previously investigated by Bruce (1922c) and, more recently, by Clifford (1969) and Clifford and McNutt (1971). The greenstone belt comprises two major sequences:

1) a mafic metavolcanic rocks and 2) accumulation of felsic to intermediate metavolcanic rocks.

Examination of exposures along the western and northern shorelines of an unnamed bay containing Islands 70 and 81 (Clifford, 1969) revealed a metavolcanic succession composed of massive, medium-grained and fine-grained pillowed mafic flows, dacitic tuff to lapillistone (with lesser tuff-breccia and pyroclastic breccia) and a 1.5 m band of magnetite-siltstone iron formation.

The felsic to intermediate pyroclastic accumulation was accurately delineated by Clifford (1969). Unfortunately much of this mass lies beneath waters of Lake St. Joseph. On a group of islands just west of Eagle Island, coarse, generally monolithologic, pyroclastic breccia and tuff-breccia of dacitic composition are prominent and commonly exhibit bedding with tuff and lapilli-tuff of similar composition. Thin layers of mafic tuff are also discernable within this pile. The prevailing direction of fragment stretching of is normal to bedding.

WABIGOON SUBPROVINCE

Tustin-Bridges Greenstone Belt

This belt described by Pryslak (1976, p.4) is situated midway between the Kenora and the Sioux Lookout greenstone belts. Located at the north margin of the Wabigoon Subprovince, the northern boundary of the Tustin-Bridges greenstone belt marks the south boundary of the English River Subprovince. The main part of the belt is exposed over a strike-length of 51 km and varies in width from 30 m to 6 km. At Willard Lake the west extension of the belt splays into three thin (0.4 km) arms. Two of these segments extend discontinuously westward to Silver Lake. Except for a few discontinuities at Silver Lake, the Tustin-Bridges greenstone belt is nearly continuous with the Kenora greenstone belt. Segmentation of the belt at Willard Lake relates to emplacement of granitic plutons. The intrusions have deflected the metavolcanic units and these remnants tend to partially envelop certain intrusions. In general, the English-Wabigoon subprovincial boundary can be sharpely defined in this area. Only one partially digested metavolcanic enclave occurs north of the contact, 1 km northwest of Gordon Lake and defines the east margin of the Daniels Lake pluton. The thin segments marking the west continuation of the belt are generally foliated, amphibolitic mafic metavolcanic units that are texturally featureless and highly impregnated by granitic injections. East of Docker Township the belt extends a further 19 km, terminating just east of Wildrice Lake. Minor thin mafic metavolcanic segments occur just south of Rugby Lake in **???** Township, however, consanguinity with the Tustin-Bridges belt cannot be established.

Pryslak (1976) has estimated that the belt consists of about 75% metavolcanic and 20% metasedimentary rocks. Essentially the belt comprises a mafic metavolcanic sequence succeeded in turn by intermediate pyroclastic rocks that are gradational both

laterally and vertically with metasedimentary rocks. Mafic metavolcanic rocks, including mostly massive and pillowed flows, are confined to the northern part of the belt. Facing criteria are scarce as the area has been subject to medium grade metamorphic conditions and high strain. However, a few graded beds and rare undeformed pillow structures suggest that the belt is a homoclinal, south facing sequence (Pryslak 1976, p.31). Intrusive sills, ranging in composition from diorite through gabbro to ultramafic, interrupt the mafic metavolcanic sequence. Intermediate metavolcanic rocks, comprised largely of pyroclastic material, directly overlie the mafic metavolcanic sequence and are intercalated with the base of the metasedimentary succession where they form discontinuous lenses. The most extensive pyroclastic sequence is situated in Tustin Township where these rocks may be partially concentrated through folding about a 70^0 plunging, southwesterly trending fold axis (Pryslak 1976, p.31). There, the fold structure is consistent with wedging of the pyroclastic sequence between the Feist Lake pluton and the Dryberry dome. Metasedimentary rocks are exposed in the south part of the Tustin-Bridges Greenstone Belt and overlie the metavolcanic sequences. The margins of the belt and the thinner portions have been injected by concordant granitic dykes. This is especially evident in the road exposures along Highway 17. East of Docker Township, reconnaissance mapping indicates the same general sequence. From north to south the supracrustal rocks consist of mafic metavolcanics, intermediate metavolcanic (mostly pyroclastic) and metasedimentary rocks. Mafic metavolcanic rocks are strongly foliated, fine- to medium-grained, amphibolitic and locally garnetiferous. Commonly thin (2.0 to 5.0 cm) epidote-rich veins penetrate these rocks (Westerman, 1976, p.39). Locally

at Wildrice Lake the mafic metavolcanic rocks are coarse-grained and porphyroblastic with coarse hornblende crystals (4 mm) hosted within a finer-grained granoblastic matrix (1 mm) of untwinned plagioclase plus minor quartz. The porphyroblastic hornblende forms approximately 50% by volume of the rock.

Intermediate metavolcanic rocks are mostly pyroclastic. East of Docker Township, intermediate metavolcanic rocks occur in two associations: 1) as rare thin, intermediate to felsic units within the mafic metavolcanic sequence and 2) as a more extensive unit interposed between the metavolcanic sequence and the metasedimentary sequence. The former association is best exemplified on the exposure immediately south of the Wabigoon-English River subprovincial boundary (Breaks et al. 1978b, STOP 12) where thin crystal tuff and tuff breccia interrupt massive and pillowed mafic volcanic flows. Coarse pyroclastic rocks are more prominent in the second association. Fragments are generally more felsic than the matrix and constitute up to 60 percent by volume of the rock. Fragments have length:width ratios in the order of 4:1 but maximum dimensions with ratios of about 10:1 have been attained near the boundary of the subprovince (Westerman, 1976, p.39). According to Westerman (1978) a significant flattening deformation has affected the Tustin-Bridges Greenstone Belt. Westerman (1976) indicated that the degree of strain increases towards the Wabigoon English River Subprovince boundary as evidenced by change in dimensions of fragments and pillowed units. At Highway 105, Westerman (1978, p.208) documented ratio changes in stretched pillows from 12:1 to 200:1, respectively 450m and 120m south of the boundary. In addition to the coarse pyroclastics in association 2) above, a unique corundum-bearing

banded tuff or tuffaceous metasedimentary rock occurs 1.5 km southeast of Wildrice Lake (Westerman 1976, p.40). The banding varies from 2 mm to 2 cm in thickness. Corundum crystals are coarse (5-10 mm), weather positively and are surrounded by inner and outer reaction rims of muscovite and biotite respectively. The metasedimentary rocks in the eastern terminus of this belt are partially melted and exhibit textures and structures similar to those in the northern domain of the English River Subprovince.

Dryden-Sioux Lookout Area

Between Vermilion Bay and Sioux Lookout, portions of the Wabigoon Subprovince were previously mapped by Hurst (1932), Moorhouse (1939), Satterly (1941), Harding (1950), Johnston (1969, 1972), Skinner (1969), Palonen (1974), Page (1979, 1980, 1984). On the Sandy Beach-Route Lake Sheet (Breaks et al. 1976f) there are three major metavolcanic belts that strike approximately southwest, interfingering with metasedimentary rocks. North to south these belts are:

1) a dominantly mafic metavolcanic belt extending west-southwest along the north part of Vermilion Lake extending from Bluett Lake to Sioux Lookout. Immediately south of this mafic belt is a sequence of felsic to intermediate pyroclastic rocks between Bluett Lake and Vermilion Lake (Harding 1950; Johnston 1964, 1972 and Page 1980, 1984)

2) a dominantly mafic metavolcanic, south-facing belt with some intermediate to felsic metavolcanic rocks extending southwest from east of Sioux Lookout to Thunder-Ghost Lakes (Johnston 1969, 1972; Satterly 1941 and Palonen 1974).

3) a mafic metavolcanic belt extending from south of Sandy Beach Lake to northeast to Kabikwabik Lake and beyond (Johnston 1969, 1972 and Palonen 1974).

Several modifications were made in the area mapped by Harding (1950):

1) the conglomerate indicated by Harding (1950) between Bluett Lake and Vermilion Lake is reinterpreted as intermediate to felsic pyroclastic rocks. Some of this sequence is regarded as ash fall in origin (Photo 3-6).

2) the small quartzite lens (Harding 1950) on the southside of Gullwing Lake is intermediate tuff-breccia.

3) subsequent to this study, Page (1980; 1984) has shown that mafic metavolcanic rocks completely envelop the Lateral Lake stock which may represent the roof of a domal intrusion (Page 1979, p.95).

The three major volcanic formations correspond to the north, central and southern volcanic groups of Trowell et al. (1978). The entire area has been summarized by Trowell et al. (1978, p.30-32).

Sioux Lookout-Sturgeon Lake Belt

The three metavolcanic groups clearly coalesce at Sioux Lookout. This belt extends west to Nagron Lake where it is truncated by the Lake of Bays batholith (Breaks, Bond and Stone, 1980). The area from Botsford Lake to Zarn Lake is described by Page (1979). Several gabbroic stocks are spatially associated with the termination of both the Sioux Lookout and the Sturgeon Lake greenstone belts (Breaks et al. 1980).

The chemistry of the mafic metavolcanic rocks and the intrusive gabbroic bodies were compared in this part of the Wabigoon Subprovince (Table 3-4). The mafic metavolcanic rocks are classified as tholeiitic basalts (Figure 3-1, diagram 1). The extrusive rocks plot in the oceanic field of the K_20-$Ti0_2$-P_20_5 diagram, but show considerable scatter on the

Ti-Cr diagram (Figure 3-5). They also show a tendency to plot in the ocean floor basalt field on the Ti/100-Zr-Sr/2 (Figure 6-5).

Savant Lake Greenstone Belt

The area has been mapped in detail by Bond (1977, 1978, 1980), Trusler (1974) and Trowell et al. (1977, p.29-32). The part of the greenstone belt situated north of Kashaweogama Lake has received little or no detailed mapping prior to the present survey. Bond (1980) has correlated these rocks with the Jutten volcanic sequence exposed on the east side of Savant Lake (Bond, 1977, 1978). North and west of McCubbin Township the mafic metavolcanic rocks form a synclinal sequence opening to the east with the trace of the axial plane trending in a nearly east direction and plunging steeply to the southeast. The mafic metavolcanic rocks are composed predominantly of massive and pillowed flows. It should be pointed out that there are minor differences between this mafic metavolcanic sequence north of Kashaweogama Lake and east of Savant Lake (Jutten Township). Although both are essentially tholeiitic basalt (Bond 1978, Trowell & Blackburn, in prep.) the sequence north of Kashaweogama Lake differs in that:

1) it contains a substantially thick (400 m) band of intermediate to felsic tuffs and tuffaceous metasedimentary rocks between the Dickson Lake and Heron Lake plutons;

2) the amount of pillow lavas (most concentrated in McCubbin Township (Bond, 1977)) appears to be volumetrically less.

North of Kashaweogama Lake a magnetite-silicate iron formation lies near the base of this sequence. According to company reports (Assessment Files Research Office, Ontario Geological Survey, Toronto, File 63.2115) the iron formation beds are of

considerable continuity and can be traced for approximately 6 km. Most of the individual beds are less than 6 m thick but a maximum of 120 m is reached in one area. The magnetite content varies from approximately 10 to over 30 percent with the remainder being composed of chert and iron silicate minerals. According to the assessment file (63.2115): "The banding is often highly crenulated and contorted and in general gives the impression that it absorbed much of the movement during folding. Narrow sills and dikes of amphibolitized basic rock cut the iron formation".

The iron formation is fairly lean especially in the northern extension. Locally, beds of tuff are found below and associated with the iron formation but are exceedingly rare above the iron formation. This lean iron formation is probably continuous with the iron silicate formation found to extend northwest of (near the west end of) Kashaweogama Lake (Bond, 1980). The latter iron formation, also situated in mafic metavolcanic rocks, has been traced northwest to the southern end of Armit Lake.

The Savant Lake conglomerate, which is exposed in McCubbin Township (Bond, 1975), was traced along the north shore of Kashaweogama Lake and linked wth the conglomerate exposed in the Hough-Houghton Lakes area (Bond, 1974).

Davies et al. (1970) accurately delimited the mafic metavolcanic belt extending from Kashaweogama Lake to Winsom Lake. The present mapping indicates that the belt is predominantly composed of mafic metavolcanic rocks but towards the southwest a zone of felsic tuffs and minor metasedimentary units were also found. A felsite body approximately 1.5 km across was found on the north shore of Kashaweogama Lake near this same mafic metavolcanic lobe and may represent the volcanic source of these felsic

tuffs.

The ultramafic bodies at Armit Lake (Hudec 1965) are pyroxenite to peridotite in composition and are intrusive into the lower Jutten Volcanics (Trowell et al. 1977, p.31).

CHAPTER 4

METASEDIMENTARY ROCKS AND DERIVED MIGMATITE

INTRODUCTION

The northern supracrustal domain contains the most extensive and continuous geological unit within the English River Subprovince - a linear, east-striking belt of wacke-pelite metasedimentary rocks and derived migmatite, traced continuously for approximately 335 km. Coupled with previous geological mapping (McRitchie and Weber, 1971), this supracrustal complex has now been established as a major regional geological feature of the Superior Province, striking about 800 km east from Lake Winnipeg (the Manigotagan gneisses of McRitchie and Weber 1971) to the Paleozoic sedimentary overlap in the James Bay Lowlands. Eastward from longitude 90°30', the eastern boundary of this project area, Thurston and Carter (1970) and Sage, et al. (1974) previously mapped equivalent metasedimentary rocks and derived migmatite. Assuming a continuation of this domain to the Kapuskasing Structure, an ultimate strike length of 1200 km may be possible.

Width of the northern supracrustal domain is highly variable, ranging from 1.5 to 50 km, and averaging about 30 km. A pronounced constriction of the metasedimentary belt is conspicuous in the Miniss Lake - Pashkokogan Lake area and is possibly related to differential movement and uplift along a series of two major criss-crossing faults. This

particular area is unique as it represents the only known portion of English River Subprovince where faults actually cross the subprovince trend, in contrast to their usual sub-parallel orientation such as the Sydney Lake Fault.

LITHOLOGICAL COMPOSITION

Metasedimentary rocks and derived migmatites, termed the "Miniss Series" by Dyer (1933) dominate the northern domain (Figure 4-1 and Table 4-1), comprising about 67 percent of all generalized rock groups. Continuity of this predominantly east-west striking "cover" sequence is interrupted by numerous intra-belt granitoid stocks and batholiths, the largest being the 700 km^2 Bluffy Lake batholith. These plutonic complexes mainly comprise foliated to gneissic, metamorphosed trondhjemite-quartz diorite-diorite (24 percent) and subordinate massive to foliated quartz monzonite to granodiorite (approx. 6 percent). Several other salient lithological features include:

1) paucity of metavolcanic units (approximately 2 percent);
2) scarcity of mafic and ultramafic plutonic rocks (approximately 1.5 percent);
3) paucity of unmetamorphosed, late to post-tectonic, potassic granitoid intrusions,
4) widespread distribution of magnetite-wacke iron formation, adjacent to southern margins of metavolcanic-rich Uchi Subprovince.

The descriptive term "Northern Supracrustal Domain" was derived by the writers and is preferred over formal geographic terminology since the full eastern extent of this domain has not been strictly defined. Beakhouse (1977) proposed the name

"Manigotagan - Ear Falls Gneiss Belt", implying that "gneisses" of the northern domain have a distribution mainly limited between the Manigotagan Lake area in Manitoba and Ear Falls, Ontario. This name has become somewhat outmoded, however, as the northern supracrustal domain is now known to extend at least 300 km east of the Ear Falls area. Westerman (1978) also proposed a strictly descriptive name for the northern domain, the "English River Metasedimentary Migmatite Complex". Furthermore, as pointed out by Westerman (1978, p.11) the "Beakhouse terminology fails to emphasize the dominantly metasedimentary aspect of this unit".

INTER- AND INTRA-SUBPROVINCE BOUNDARY RELATIONSHIPS

NORTHERN BOUNDARY

The Uchi Subprovince-Northern Supracrustal Domain interface is characterized by a combination of abrupt, faulted contacts between metavolcanic-rich portions of the Uchi Subprovince and metasedimentary migmatite, and, subordinate areas between faults exhibiting an uninterrupted, preserved lithofacies and metamorphic transition between major lithic units of the Uchi Subprovince and Northern Supracrustal Domain. A significant proportion of this subprovince boundary is conspicuously defined by a 140 km long regional tectonic feature, the Sydney Lake Fault System which is described in detail in Chapter 15.

Two areas east of the Sydney Lake Fault System exhibit important lithofacies and metamorphic relationships between metavolcanic rocks of Uchi-Confederation belt and low to medium grade metasedimentary rocks of the Northern Supracrustal Domain. In

the Papaonga-Slate Lakes area (Figure 4-2) conformable, cataclastically uninterrupted, stratigraphic relations indicate that the subprovince interface represented a major lithofacies transition exhibiting a change from distally deposited metavolcanic rocks equivalent to Cycle I of Confederation Lake series to an overlying succession of wacke-mudstone metasedimentary rocks of the Northern Supracrustal Domain. This stratigraphic succession is substantiated by facing data from graded bedding and interdigitation of metasedimentary and metavolcanic units. Furthermore, thin metavolcanic units completely isolated in northern domain metasedimentary rocks are situated a short distance south of the interdigitating subprovince boundary at Whitemud and Otatakan Lakes also suggest a contemporaneity between volcanism and sedimentation. In Manitoba Campbell (1971) had earlier reported a similar equivalence along the northern boundary of the English River Subprovince between the Edmunds Lake Formation (Rice Lake group) and paragneisses of the Manigotagan Gneiss Belt.

This major stratigraphic 'break' often coincides with an abrupt increase in metamorphic grade (see Chapter 14). Such a metamorphic discontinuity led workers such as Wilson et al. (1971) to the generalization that the complete boundary length of the Uchi Sub-province - Northern Domain interface and Wabigoon Subprovince-Southern Plutonic Domain interface was marked by continuous fault zones. Hence, a block faulting model (horsting) of the English River Subprovince was developed by Wilson (1971) to explain the rapid increase in metamorphic grade across the fault system. However, data from this study demonstrates that this model is overly simplistic:

1) faulting is not continuous across either the Uchi-Northern Domain or

Wabigoon-Southern Domain boundaries, i.e., the English River Subprovince did not function as an independent "block" but rather was intimately connected stratigraphically and metamorphically with the adjoining Uchi and Wabigoon Subprovinces until onset of widespread post-metamorphic faulting.

a) the lithologic transition in the Slate Lake-Eargey Township area from thick bedded proximal turbidites (Thurston, 1985) to the submarine fan conglomerates and immature arenites of the Slate Lake area (Bowen, 1989)

b) the metamorphic-lithologic transition documented in the Dryden area (Bartlett, 1976)

c) the lithologic and metamorphic transition observed in the Lake St. Joseph area with progressive charge from distal turbidites in the south (this study) and proximal facies metasedimentary rocks at Lake St. Joseph coincides with a metamorphic transition without major discontinuities from greenschist to amphibolite and low pressure granulite facies (Fig. 4-3).

2) major fault zones along the northern boundary such as the Sydney Lake Fault System and Lake St. Joseph Fault appear to have developed at different crustal levels and contrast markedly in amount of interpreted dip-slip componental movement (see Chapter 15). In the Chase Lake (Figure 13-5) and Western Lake St. Joseph (Figure 4-3) areas, a general conformity of fault zones and gross stratigraphy is apparent which may suggest an initial guidance of faulting by this stratigraphy

3) boundary areas unaffected by major faulting as at Papaonga Lake (Figure 4-2), and boundary areas where the dip slip displacement of major faulting is insignificant (Western Lake St. Joseph area) coincide with intact metamorphic facies pattern,

featuring a progressive increase in grade from the Uchi Subprovince southwards into the Northern Supracrustal Domain.

4) the latest event of faulting is post-metamorphic as these faults overprint post-tectonic potassic granitoid suite intrusions (2.652 Ga: Krogh et al. 1976), leucosome in metasedimentary migmatite, in addition to inducing retrograde metamorphic in low to medium grade metasedimentary rocks (Lake St. Joseph area). The late, brittle dextral sense faulting may represent Proterozoic reactivation as has been demonstrated for the Sydney Lake Fault by Kamineni et al. (1990) who dated pseudotachylite at 2183+/-74 Ma.

BOUNDARY BETWEEN NORTHERN AND SOUTHERN DOMAINS

In general, this curvilinear boundary (Figure 4-1) is marked by the first continuous appearance of metasedimentary rocks and derived migmatite in traversing north from the Wabigoon-English River subprovincial boundary. This boundary is interpreted as produced through extensive batholith intrusion and stoping which originated in the Southern Plutonic Domain. Accordingly the intra-domain boundary was likely the locus of extensive modification by emplacement of late to post-tectonic potassic granitoid suite plutons as suggested by curvilinear to strongly embayed trend of this boundary. The role of batholith intrusion in modifying this boundary is especially evident in the Wabaskang Lake area, near Perrault Falls, where potassic granitoid suite material is complexly interdigitated with metasedimentary migmatite. Several large enclaves of northern domain metasedimentary rocks lie isolated in the granitoid complex of the

southern plutonic domain and may have been transported southwards through stoping or thrusting mechanisms. The largest tectonic enclave is found near Lac Seul Settlement and considerably smaller ones occur near Maynard Lake and in the Cliff Lake-Clay Lake area.

Vestiges of primary lithostratigraphic relations along the southern possibly basin margin of the northern domain exist at Perrault Lake and in Separation - Umfreville Lakes area. In both areas, however, lack of reliable facing data renders deductions of the primary nature of the intradomain boundary of the English River Subprovince in Ontario somewhat tenuous. However, we suggest this boundary marked the southern margin of an extensive linear clastic sedimentary trough. Similar metaconglomerates and associated lithic meta-arenite of the Flanders Lake Formation of the Bird River Greenstone Belt in Manitoba have been shown by Trueman et al. (1976) and Trueman (1980) to represent lateral equivalents of the high grade metasedimentary migmatites of the Manigotagan Gneiss Belt, i.e., Northern Supracrustal Domain. This is significant as the Separation Lake metavolcanic belt of the study area represents an easterly continuation (Lamprey Falls Formation of Trueman, 1980) of the Bird River Belt, and suggests a basin margin marked by metaconglomerate and underlying mafic metavolcanics, as also interpreted for the Perrault Lake area. The lack of gneissic granitoid suite and massive potassic granitoid suite boulders at the Perrault Lake metaconglomerate suggest development of this basin during a time after deformation event D_2 which produced Fb_2 folds in the gneissic granitoid suite as at Cedar Lake (see Westerman 1977 and Chapter 15) and prior to emplacement of the potassic granitoid

suite.

Faulting does not exercise an important role in controlling disposition of the intra-domain boundary in contrast to the Uchi-English River Subprovince interface. Local faults are evident, however, as at Separation Lake, however they are never traceable for significant distances.

THE MIGMATITE PROBLEM

Migmatitic rocks can be generally classified into the following contrasting categories (Ayres, unpublished information), despite the plethora of terminology and variation in usage of several terms that have emerged subsequent to Sederholm's (1907) early work:

1) migmatites derived by incorporation of granitoid material derived from a source area external to the host (granitoid migmatites, injection migmatites along greenstone belt margins, and "intrusive mobilizate" derived from metasedimentary migmatites), and;
2) migmatites derived by in situ segregation of a granitoid component (leucosome) produced by partial melting and/or metamorphic differentiation of the host (metasedimentary migmatites, possibly some high grade mafic to intermediate granitoid rocks and felsic to intermediate metavolcanics).

Migmatites of category one have resulted through post-tectonic intrusion of dykes and masses of a particular granitoid unit into an older granitoid or supracrustal host. A much more complicated situation is usually evident, however, due relatively long plutonic history and compositional variability of granitoid intrusive units. Furthermore, the effects of tectonic deformation intervening between emplacement of granitoid material may

sufficiently obscure intrusive relationships of pre-tectonic units to the host (Photo 4-1). These have been designated by a variety of terms such as "lit-par-lit injection migmatite" (e.g., Clifford 1909), "hybrid granite" (eg. Carlson 1957, p.16-18), "migmatitic gneiss", or simply as "migmatite" (eg. Goodwin 1965).

The major problem in the mapping of migmatitic rocks is a lack of precision in usage of the term "migmatite". The variation in terminology exemplified above makes it obvious that the general term migmatite has commonly been employed as a "sack term" within which the mapper found it convenient to classify any moderately to intensely intermixed rock possessing an array of plutonic units, with or without supracrustal constituents. For example, an inhomogeneous trondhjemite from the Eagle Lake area contains relatively abundant amphibolite enclaves in varying stages of assimilation (Photo 4-2) and is situated about 15 m from a similar, but enclave-free trondhjemite which is probably part of the same intrusive complex. It is possible that two rock units would have been mapped here even though in reality both rock units have a petrologic affiliation. In this context, the term "migmatite" ceases to become a useful term since a wide variety of lithologic will have been ultimately lumped into this category.

The writers thus suggest abolition of the term "migmatite" when applied to exposures exemplified by Photos 4-1 and 4-2. More information of the geologic history of an area can be obtained by treating each major lithology present as a separate entity, such as unravelling the succession of plutonic, i.e., emplacement events in a multi-unit granitic batholith complex or stages of leucosome generation within a metasedimentary migmatite complex. In addition, utilizing this system of mapping multi-unit granitoid exposures will

be of immense aid to the geological compilator, who although possibly unacquainted with a given map-area, would be able to more decisively subdivide granitoid rock units possessing a common genesis.

It is recommended that coding of the various rock types in granitoid "migmatite" exposures be arranged in order of decreasing abundance with each unit physically separated by commas. For example, the granitoid "migmatite" revealed in Photo 4-3, is mainly a weakly foliated, metamorphosed biotite trondhjemite (7a) carrying enclaves of more mafic hornblende-biotite trondhjemite (7c), biotite metawacke (3c), and metamorphosed, holo-leucocratic quartz monzonite (7d). The exposure is criss-crossed by two interconnected coarse-grained to pegmatite tourmaline quartz monzonite dykes (8a). In this case, coding would be as follows: 7a (3c, 7c, 7d), 8a.

The same procedure also applies to situations, as shown in this example, where several distinctive enclaves exist. These enclaves are enclosed within brackets immediately following the host-rock type, in order of decreasing relative abundance, in this case 3c > 7c > 7d for enclaves hosted in 7a. This procedure will be particularly useful in tracing the full extent of mobilized, relict mafic metavolcanic supracrustal sequences.

Migmatites of category two, derived via **in situ** anatexis are particularly widespread within the northern supracrustal domain. The metatexite and diatexite subdivisions of this category, described below, are based upon definitions by Scheumann (1936, 1937) and later modifications by Mehnert (1971) Brown (1973) and by this study.

In this group petrologic relationships between granitoid material (leucosome) and protolith (host) are commonly obvious in the field. Migmatites of this group are thus

included under metasedimentary legend subdivisions (e.g., "Metasediments and Derived Migmatites"), even though the leucosome constituent may predominate. The term "migmatite" is retained for these rocks so that the distinction between relict supracrustal belts (e.g., northern supracrustal domain) and muilti-unit, granitic batholiths remains unequivocal. As emphasized by Mehnert (1968, p.231) if one simply focuses upon a classification scheme utilizing only the petrological character of the paleosome a "break in the classification of the development of migmatites occurs about half-way", corresponding to the transition from host-dominated migmatites to leucosome-dominated rocks. In actuality, a continuum exists in which a gradation from unmigmatized and locally migmatized wacke-pelite assemblages to neosome-dominant stages (homogeneous diatexite) has been documented within the Northern Supracrustal Domain (Table 4-2), the total sequence has been designated the "Metasedimentary Migmatite Continuum" in this report. The neosome-dominated migmatitic stages in the past have commonly been cast into granitoid legend subdivisions variously described as hybrid (e.g., Hudec 1959), schlieritic, xenolithic, or nebulitic types, thus unfortunately obscuring a possible genetic relationship. Brown (1973), however has argued for exclusion of neosome-dominant stages from the migmatite continuum, stemming from a highly restricted definition of the term "migmatite".

As detailed below, petrological and chemical attributes of these granitoid dominant migmatitic stages are distinctive and such rocks can readily be classified in the field as related to the process of **in situ** anatexis from the nearby host-rocks. Recently, similar granitoid rocks having a metasedimentary origin have been recognized by various

workers in Australia (Chappell and White 1974, Flood and Shaw 1975), and have been designated as S-type granitoids.

Similar migmatitic stages will develop within any lithology of appropriate bulk chemistry able to foster varying degrees of partial melting under conditions of high grade regional metamorphism. Included here as possibilities are relatively mafic, biotite trondhjemites and intermediate metavolcanic rocks.

LIST OF NOTABLE FEATURES OF METASEDIMENTARY MIGMATITES

The following check-list is intended to instill some consistency and completeness in descriptions of the highly variable metasedimentary migmatites that may be encountered in future mapping projects undertaken in high grade gneissic terrains by other workers. This guide was devised and modified during four field seasons of reconnaissance mapping in the English River Subprovince in order to systematize observations and nomenclature. It facilitated regional interpretation (e.g., delineation of relict supracrustal belts, and discrimination between S-type and I-type granitoids). This list is by no means complete and future work will hopefully allow it to be even more comprehensive. Please refer to the various Photo numbers referenced in the guide for representative examples of the various migmatite stages, constituents, structures and other important idiosyncrancies.

I. Migmatite Stage

A. Protometatexite - locally migmatized medium-to coarse-grained porphyroblastic metapelitic units characterized by discontinuous, podiform leucosome development.

Intercalated with fine-grained generally non-leucosome-bearing metawacke. See Photos 4-4, 4-5 and 4-6. Generally <10% leucosome in metapelitic part.

B. Metatexite - conspicuously layered metasedimentary migmatite generally containing between 10 and 50 percent stromatically disposed leucosome (Photos 4-6, 4-7).

C. Inhomogeneous Diatexite- leucosome constituent begins to dominate such that between 5 and 40 percent of surviving metasedimentary sequence occurs as enclaves and/or schlieren (Photos 4-8, 4-9, 4-10).

D. Homogeneous Diatexite - complete domination of leucosome constituent, metasedimentary enclaves rare and usually <5 percent (Photo 4-11).

II. Migmatite Constituents

A). Paleosome - the unaltered or only slightly modified parent rock or country rock" Mehnert, 1971, p.7).

1) percent of outcrop occupied by paleosome

2) lithology (-ies) apparent and relative abundance of each (wacke, pelite, arkose)

3) megascopic mineral assemblage, listed in order of increasing relative abundance, eg. garnet-biotite-quartz-plagioclase metawacke

4) texture - granoblastic, porphyroblastic, cataclastic, etc.

5) grain size - average and range

6) color index

7) accessory phases, e.g., apatite, tourmaline, magnetite, etc.

8) relict bedding or other sedimentary structures present?

B). Leucosome - that part of the neosome or "newly formed rock containing more light

minerals with respect to the paleosome" Mehnert (1971, p.8). See Photos 4-4, 4-5, 4-7, 4-8, 4-12 and 4-13.

1) percent of outcrop occupied by leucosome

2) modal composition

3) megascopic mineral assemblage, listed in order of increasing abundance of accessory minerals, eg. biotite-garnet quartz monzonite leucosome cordierite-garnet-biotite pegmatitic leucosome, hydrothermal leucosome (quartz rich veins occurring in low to medium grade metasedimentary rocks

4) texture - hypiomorphic-granular, allotriomorphic-granular, recrystallized, unrecrystallized (unpolygonized), incipiently recrystallized.

5) grain size - average and range

6) color index

a) holo-leucocratic (color index <5)

b) leucocratic (color index 5-35)

c) mesocratic (color index 35-65)

7) accessory mineralogy: eg. apatite, muscovite, biotite, almandine, sillimanite, cordierite, allanite, dumortierite, beryl (present individually in amounts <0.5 percent)

8) presence of dykes or masses of intrusive leucosome (Photo 4-14). Note percent of outcrop, orientation of dykes.

C). Melanosome - that part of neosome "containing mainly dark (mafic) minerals" (see

Photos 4-12, 4-15, and 4-16 and Mehnert, 1971, p.8).

1) percent of outcrop

2) megascopic mineral assemblage if possible, e.g., quartz-sillimanite -plagioclase-biotite melanosome

3) mode of occurrence

a) continuous to discontinuous selvadges developed along leucosome/paleosome interface in metatexites (Photos 4-13 and 4-15)

b) ovoid to irregular clots occurring within diatexite (Photo 4-16).

4) thickness of melanosome selvadges - average and range. Average dimensions of clotty melanosome in diatexite

5) color index

6) accessory mineralogy

7) presence of late to post-tectonic garnets overgrowing melanosome.

III. General Types of Structures

A) stromatic - relatively undeformed (Photos 4-7 and 4-13) or contorted (Photo 13-6, below)

B) phlebitic

C) folded - ptygmatic (Photo 4-14), flowage folds, convolute folds, gleitbretter, etc. (Photos 13-1, 13-2, 13-5 and 13-6, below).

D) agmatite - only rarely observed in metasedimentary migmatite

E) dilatational structure - boudinage (Photos 4-6 and 4-17)

F) schollen (raft) structure - commonly occurs in inhomogeneous diatexites (Photo

4-8)

G) cataclastic structure - Photos 13-10, 13-11, 13-12, below.

Cataclastic Migmatitic Rocks

Cataclastic features are best discerned in the leucosome constituent of metatexite and diatexite exposures. Several idiosyncrasies of such rocks are:

1) "banded" character of overall outcrops caused by alternating protomylonite, mylonite, and ultramylonite;
2) presence of several generations of cataclastic foliation surfaces, with low-angle truncations;
3) virtual universal presence of muscovite as single conspicuous "button" shaped grains or as light-yellow weathering wispy "schimmer" aggregates, both within surface of maximum compression;
4) augen or opthalmitic structure especially commonplace in medium- to coarse-grained pegmatitic diatexitic cataclastic zones. Shape varies from ovoid to sigmoidal;
5) development of slender masses of smoky grey to rusty brown weathering aphanitic pseudotachylite disposed along and crossing late cataclastic foliation surface;
6) common obliquity of cataclastic foliation to general trend of cataclastic zone.

The paleosome constituent tends to disguise cataclastic features owing to original fine-grain size and abundance of phyllosilicates which permit glide rather than brittle

deformation. Occasionally relatively large idiomorphic to subidiomorphic blastic K-feldspar crystals are present, growing across foliation surfaces.

Map Coding

If modal composition of the leucosome has been verified by field or laboratory staining, specific rock composition is placed in the map code in squared brackets. Abbreviations of granitoid rock compositions utilized in the coding are as follows:

GR Granite (sensu stricto)

QM Quartz Monzonite

GD Granodiorite

TR Trondhjemite

QD Quartz Diorite

SY Syenite

MZ Monzonite

DI Diorite

For example, a metatexite containing quartz monzonite leucosome would be coded 3j[QM]. If a range in granitoid composition is encountered, coding could reflect this variation by placement of an arrow between the effected modal class end-members. A homogeneous diatexite exhibiting a range between quartz monzonite and granodiorite would be coded 3m[QM->GD].

<u>CLASSIFICATION OF METASEDIMENTARY MIGMATITES OF THE ENGLISH RIVER SUBPROVINCE: CONCEPT OF THE MIGMATITE CONTINUUM</u>

The delineation of the migmatized metasedimentary belt comprising most of the northern domain required special attention. During the field studies it became evident that rigorous classification of the derived migmatite strongly depended upon recognition of a mutliplicity of migmatite stages which, collectively, represent a continuum fashioned by progressive anatectic destruction of a metasedimentary precursor. Bearing these difficulties in mind, a system was developed (Table 4-2) during the study in part stemming upon the works of Mehnert (1971) and Brown (1973) which respectively produced results in the Black Forest Massif of Germany and the Amorican Massif of France.

As indicated in Table 4-2, classification of metasedimentary migmatites is primarily based upon leucosome/leucosome + paleosome ratio, coupled with diagnostic migmatitic structures. This system was of value in effective reconnaissance delineation of this high grade metasedimentary migmatite belts. The ensuing text will now focus petrological, petrochemical and megascopic idiosyncrasies of the various migmatitic stages.

Metatexite

Metatexite represents the commonest migmatite type occurring within the English River Subprovince, although considerable megascopic variation is often evident, depending upon particular combination of interpenetration structures and degree of partial melting and/or metamorphic segregation. Metatexis refers to a "process of segregation (usually of quartz and feldspar) by metamorphic differentiation or partial melting" (Brown 1973, p.374). Thus a metatexite "is a rock produced by metatexis and in which migmatitic banding (stromatic structure) is evident" (Brown, ibid).

When essentially undistorted and well developed a conspicuous banded appearance, or stromatic structure represents the prime criterion of metatexites, and is manifested by the interlayering of wacke paleosome and granitoid to pegmatoid leucosome commonly in a pervasive manner (Photo 4-7). Generally, between 10 and 60 percent of metatexite outcrops consist of leucosome.

In many cases, metatexites have been generated by the intrusion process, i.e., the leucosome is of allochthonous origin, having travelled some distance from its site of fusion and amalgamation leaving the relatively higher density melanosome behind. Emplacement of the partial melt is usually guided by paleosome anisotropies such as bedding and foliation. This type of metatexite is exemplified by Plate 13-6 (see below) and is typically identified by the following criteria:

1) lack of melanosome along paleosome/leucosome interface;
2) presence of relatively thick leucosome [contrast Photos 13-6 (below) with Photo 4-12)
3) common presence of local discordancies to paleosome foliation or preserved bedding between leucosome and paleosome verifyng an intrusive origin.

Deformation in the form of flowage folding, boudinage, buckling, and shearing which occurred contemporaneously with formation of the granitoid and pegmatoid metatects, commonly contributes to obscuring of this characteristic banded appearance. In addition, injections of "intrusive mobilizate" are common and contribute towards this observation. **Intrusive mobilizate** is defined in this study as mobile leucosome emplaced at a

relatively late stage in the migmatitic evolution of high grade English River Subprovince metasedimentary rocks. These leucosomes typically discordant and undeformed intrusive have relations with earlier derived leucosomes (Photo 4-14), marked by varying styles of deformation. This type of leucosome can occur on all scales from the filling of heterokinetic spaces[1] between boudins of metawacke paleosome to relatively extensive allochthonous anatectic plutons emplaced within low and medium grade metasedimentary rocks. Compositionally, intrusive mobilizate is virtually identical to leucosome derived **in situ**, most commonly consisting of quartz monzonite. This material also intrudes older metamorphosed trondhjemitic rocks such as the Bluffy Lake batholith in zones adjacent to the metasedimentary migmatite belt contact, and low to medium metavolcanic-metasedimentary sequences found along the inter- or intra-domain boundaries.

---

1. This term (Sander 1948, 1950) refers to low pressure areas between boudins.

Protometatexite

The term "protometatexite" was coined by the writers to account for a particular variant of metatexite, that evolved during incipient stages of migmatization. This possibly may reflect a process of "selective anatexis", and is characterized by small quantities of irregular, podiform and lensoidal leucosome specifically confined to pelitic horizons (Photos 4-4, 4-5 and 4-6). These segregations have not amalgamated into continuous leucosome layers as is the case in metatexites displaying stromatic structures. Nevertheless, a layered distribution is apparent since the leucosome is specifically

confined to pelitic layers intercalated with leucosome-free wacke units. Good examples of protometatexite can be found in the Churchill, Aerofoil, Pakwash, and Wegg Lake areas.

Experimental work (Winkler and von Platen 1961, and von Platen 1965) on natural greywackes and pelitic rocks offers insight into the major petrochemical and mineralogical parameters controlling P-T conditions of leucosome development. Variation in the bulk, normative Ab/An ratio has a major effect in governing both temperature and pressure at which partial melting initially occurs, in addition to composition of the engendered melt. At constant vapor phase pressure = load pressure, increase in Ab/An ratio decreases temperature of minimum melt formation, and this variable decreases relatively amounts of quartz and orthoclase in the melt produced; it also increases albite content of plagioclase (Winkler 1979). In other words, in a gneiss complex, anatexis, due to temperature rise in high grade metamorphism, begins first in those layers having the most albite-rich plagioclase. The higher the anorthite content of plagioclase in a gneiss, the higher the temperature of the beginning of anatexis (Winkler, 1979, p.298).

Another important variable is availability of water-rich vapor phase under high grade conditions. Metapelitic rocks are again favored to become the first composition to melt due to generally higher contents of the $(OH)^-$ radical structurally-bound in phyllosilicate phases such as muscovite and biotite relative to metawackes.

Below are listed some important fundamental differences between pelitic and wacke components in protometatexites from Aerofoil and Carling Lake areas.

	39-8-7		5-165-3		35-8-2	
	Wacke	Pelite	Wacke	Pelite	Wacke	Pelite
Ab/An	2.51	4.28	1.51	2.96	1.78	3.51
H_20^+	0.52	0.96	0.19	0.88	0.33	1.04
Biotite	15.8	23.6	N.D.	N.D.	21.0	N.D.

N.D. = not determined

Metapelites generally have higher Ab/An ratios structurally-bound water, the latter owing to higher modal biotite and in some cases, muscovite. Sample 35-8-2 originates from the medium grade zone at western Lake St. Joseph, and offers some estimate of phyllosilicate mineralogy and levels of H_20^+ prior to anatexis. The Ab/An and levels of H_20^+ are 2 and 3 times higher, respectively, in the metapelitic constituent relative to metawacke.

Temperature of initial partial melting will also be governed to some extent by presence or absence of muscovite. If muscovite is absent from the pre-anatectic mineral assemblage then biotite is forced to supply all of the potash for K-feldspar component and water for the granitic melt. Higher temperatures under granulite facies conditions are thus required to initially decompose the biotite and melt an appreciable amount of paragneiss commonly containing 15 to 25 percent biotite. If, at most, only 2 percent water can be supplied by decomposition of biotite, the temperature of melts must exceed 900^{0}C at pressures greater than 5 kbars" (Winkler, 1979, p.319).

These observations have been experimentally substantiated on natural muscovite-free

greywackes (Knabe 1970b in Winkler 1979, p.321). Absence of muscovite in many metawackes of the medium-grade metamorphic zones of the Lake St. Joseph facies series taken in light of the experimental findings is probably one of the chief factors (besides the low amount of H_2O^+) in explaining the widespread preservation of this rock type in the northern supracrustal domain. Metawacke is commonly observed with nil to low volumes of leucosome and commonly represents the only widespread rock type forming enclaves in diatexite units. The original extent of muscovite-free metawackes in the English River subprovince can never be known, however, Winkler (1979, p.320-324) considers this wacke variant to be common than plagioclase-quartz- biotite-muscovite wackes.

Diatexite

Diatexis refers to "high grade anatexis in which fusion may be complete" and therefore diatexite is a "rock produced by diatexis and in which there is no continuous migmatitic banding" (Brown 1973, p.375). This rock type possesses a plutonic, granitoid appearance and understandably has been commonly included in legend subdivions of granitic rocks, as for example, Hudec (1957) and Skinner (1969). However, it must be emphasized that in our view diatexites represent an integral and final stage in the evolution of migmatitic metasedimentary rocks of the English River Subprovince and probably elsewhere (Mehnert 1971). In contrast, some workers such as Brown, 1973, have not included the term diatexite in the migmatite spectrum, stemming from a highly restricted definition of term migmatite.

Granitoid rocks similar to the diatexites of English River Subprovince have been

observed by the writers in various high grade metasedimentary-rich areas of the God's Lake, and Quetico Subprovinces and in the Grenville Province. Bailes and McRitchie (1978) have described and presented photographic documentations of identical rocks in the File Lake area of the Kisseynew Sedimentary Gneiss Belt in the Churchill Province of northern Manitoba. In short, diatexites appear to be a common granitoid rock type in the Superior Province, at least, and is the inevitable consequence of advanced high grade metamorphic conditions imposed upon metasedimentary terranes.

Several important field characteristics serve as a rapid means of identification of diatexite compared to other common plutonic rocks elsewhere in the English River Subprovince and are as follows:

1) remnants of paleosome are nearly always present but vary greatly in quantity (Photos 4-8 and 4-9);
2) evidence of varying degrees of mobility especially with respect to inhomogeneous diatexites. The rocks have a 'turbulent' character with abundant contorted, plastically deformed enclaves are commonly notable (Photo 13-10, below).
3) a wide range in grain size, even within a hand specimen. A medium- to coarse-grained average size is most prevalent, although pegmatitic equivalents are quite common (Photo 4-14);
4) the rocks mostly consist of distinctive earthy white-weathering, generally massive granitoid material, and usually exceeding 70 percent of a given outcrop.
5) the sporadic presence of accessory minerals uncommon in most granitic rocks such as garnet, cordierite or sillimanite (Photos 4-18 and 4-19);

6) absence of stromatic structure.

Two transitional subdivisions of diatexite can be effected in the field based upon volume of remnant material:

1) inhomogeneous diatexite.

2) homogeneous diatexite.

Inhomogeneous Diatexite

The overwhelming impression of this type of diatexite is that of a unoriented "mess" with 10 to 40 percent, paleosome and melanosome "debris" resulting respectively from mechanical incorporation during mobilization and incomplete fusion (Photos 4-9 and 4-10).

The most prevalent kinds of enclaves are listed below.

1) metatexitic rafts, occasionally with reaction rims.

2) non-mobilized, possibly stoped, fine-grained wacke schollen.

3) mechanically incorporated (by intrusion process) clots, clusters and/or schlieren containing generally haphazardly oriented biotite, minor garnet, cordierite, quartz, and plagioclase.

The composition of diatexite ranges between granite (sensu stricto) and trondhjemite. However, more mafic diatexite having a trondhjemite to granodiorite composition does exist within the region on a restricted basis.

Amphibolite enclaves (up to 2 by 3 m) and quartz fragments (up to 15 cm x 15 cm) have been rarely noted. The latter may represent former silica-rich quartz core zones in

pegmatitic diatexites which became later disrupted via mobilization. A moderate variation in grain size typically occurs, varying from medium- to coarse-grained. Textures are characteristically hypidiomorphic-granular in which idiomorphic to subidiomorphic feldspars formed prior to quartz (Photo 4-20).

Homogeneous Diatexite

As this term implies, this type of diatexite correspond to "granitoid rocks mainly without schlieren or inclusions" (Mehnert 1971, p.276). The transitional division between inhomogeneous and homogeneous diatexite was arbitrarily established at 10 percent of combined paleosome, and melanosome constituents. In essence, the same petrological attributes characterizing the leucosome from inhomogeneous diatexites applies to this category as well.

Between Ontario-Manitoba boundary and longitude $89^0 00'$ the total area underlain by diatexitic masses is approximately 3600 km^2, slightly in excess of the largest reported locale of S-type granitoid rocks in the literature, viz, the New England batholith of New South Wales, Australia (Flood and Shaw, 1975). Geographical distribution of the major diatexitic masses in the English River Subprovince is bimodal. As indicated in Figure 4-4, the great majority of these advanced stage migmatites are situated either within or near the two major low pressure granulite centres. The largest area of diatexite diatexite is related to the Eastern Lac Seul granulite centre and is mainly concentrated within two discrete masses:

1) Wapesi Lake batholith, and;

2) St. Raphael Lake batholith.

Within or proximal to the major low pressure granulite centres (Figure 4-4) it is plausible that higher ambient temperatures of metamorphism led to very extensive anatexis of metasedimentary protoliths. Relatively advanced anatexis should theoretically yield higher contents of ferromagnesian components which resulted from the destruction of the paleosome through reactions such as incongruent melting of Fe-rich biotite (Winkler 1979, p.323). Within the map area, relatively scarce, mafic leucosomes with colour indices between 10 and 33 (Table 4-3) are interpreted to have crystallized from relatively advanced anatectic melt and are termed "mafic diatexites" (Photo 14-21). Modal compositions plot in quartz monzonite, granodiorite, and trondhjemite fields of Figure 4-5. However, there is a strong tendency for domination by plagioclase (Table 4-3), as reflected by the relative common granodiorite compositions. Evidence regarding the relatively advanced nature of the anatectic process is presented by the close modal and petrochemical compositional similarities between some mafic diatexites and potential metawacke starting materials (see Figures 4-7, 4-8, 4-9 and 4-13, below).

A rarer diatexite variety, which also exhibits a general spatial restriction to granulite zones, is marked by syenite to monzonite compositions (Photo 4-11). These rocks were encountered, in particular, within the Eastern Lac Seul granulite centre, viz, at Scaler Lake and along Lac Seul west of Bear Narrows. An excellent example occurring in high grade rocks at Ear Falls and contains continuous, relatively thick melanosomes in metawacke paleosome (Photo 4-15), and importantly demonstrates that both quartz-rich and quartz-depleted leucosomes can be developed **in situ** within the same metasedimentary sequence. A hypidiomorphic-granular texture is widespread (Photo

4-20), as is the persistent large grain size variation, a petrographic feature characteristic of diatexitic rocks. The cause of the extreme quartz depletion **vis-a-vis** the normal, high quartz contents of diatexites is not easily explicable in terms of application to experimental anatectic systems, as no documentation regarding derivation of haplosyenitic liquids from a metasedimentary precursor has been encountered in the literature. Alternatively, these rocks could represent feldspar-rich cumulates.

Recent work in the Phanerozoic batholiths of eastern Australia has revealed two distinctive suites of granitoid rocks, already briefly mentioned which are interpreted as reflective of the lithic character of the respective source regions (Chappell and White, 1974, Flood and Shaw, 1975, Hine et al. 1978, Chappell, 1978). These granitoids have been subdivided by Chappell and White (1974):

1) I-Type granitoids, derived by partial melting of igneous source material

2) S-Type granitoids which originated by partial melting of sedimentary source material

The S-type granitoids, of particular interest here, have many field and petrochemical features that renders relatively easy identification:

1) high normative corundum, peraluminous (Shand 1950) where molar Al/Na+K+Ca > 1

2) accessory cordierite, muscovite, garnet, aluminosilicate polymorphs and tourmaline. Absence of hornblende.

3) high initial Sr ratios

4) general dominance of Fe^{2+} over Fe^{3+}

5) high 0^{18} isotope values

6) distinct modal trends in QFM plot (this study)

7) varying amounts of metasedimentary enclaves and restite.

Many of these petrochemical and petrological features characterize the diatexites from the northern supracrustal domain and Dryden area of southern plutonic domain.

Modal data of leucosomes from the English River Subprovince in Tables 4-3 and 4-4 have been plotted in the QFM diagram (Figure 4-6). In addition, data from a suite of S-type granitoids (Kosciusko batholith, southeast Australia) studied by Hine et al. (1978) have been plotted in the same diagram. Leucosomes from both study areas document a similar trend of increasing colour index at essentially constant quartz levels (generalized in Figure 4-7), although the Australian rocks contain slightly higher quartz contents. These trends suggest increasing anatexis in the metasedimentary source area since Fe-Mg components required to crystallize up to 33 percent biotite in leucosome from the study area can only derived from pre-existing biotite and/or amphibole in the paleosome. The S-type granitoid trend is clearly antipathetic to the I-type gabbro-diorite-quartz diorite-trondhjemite trend found in the sodic granitoid suite of the southern plutonic domain which, contrastingly show rapid decrease in modal quartz with increasing colour index (Figure 4-7). This distinctive S-type granitoid trend may thus serve as an additional criterion to facilitate recognition of granitoid rocks derived from metasedimentary precursors.

Wapesi Lake batholith

The Wapesi Lake batholith (Figure 4-4) covers an area of approximately 635 km^2 (77 km long and 19 km width) and comprises a discrete, southwesterly-tapering mass of

massive, coarse-grained to pegmatitic muscovite-biotite and biotite-muscovite quartz monzonite diatexite. Enclaves are extremely widespread in the batholith; non-migmatized metasedimentary enclaves are relatively rare except in a narrow zone along the eastern contact.

Accessory tourmaline and garnet are ubiquitous. The general absence of inhomogeneous diatexite stage, and smooth curvilinear contacts with the host metatexitic metasedimentary migmatites suggests that masses of anatectic melt have risen some distance beyond the site of fusion and amalgamation to a higher crustal level. In this process the higher density melanosome and paleosome enclaves would tend to remain largely deeper crustal levels. Winkler (1979, p.323) stated that both components "would be expected to underlie the large granitic and granodioritic (anatectic) plutons".

Cann (1971) pointed out that relatively wet anatectic liquids have a physical inability to rise to extremely high crustal levels, due to the thermodynamic "barrier" effect imposed by the granite liquidus to most paths of normal adiabatic cooling. Cann (1971) argued that most granitic magmas formed via anatexis of a sedimentary terrane at conditions near the liquidus in the haplogranite system af high grade metamorphism were able to rise only a short distance in the crust prior to solidification. Primary muscovite in this batholith infers that pH_20 was at least 4 kbars (14 kms depth) based upon intersection of the reaction Muscovite + Quartz --> K-feldspar + Sillimanite + H_20 (Kerrick 1972) with the granite minimum melting curve (Tuttle and Bowen 1958) as seen in Figure 12-3, below.

Churchill Lake batholith

The Churchill Lake batholith represents one of the largest granitoid masses within the English River Subprovince, covering an area of about 2070 km^2 (Figure 4-4). This mass exhibits complicated, interdigitating contact relations with host-rocks of the northern and southern domains. This feature, in addition to a high proportion of inhomogeneous diatexite, suggests a deeper crustal level relative to the Wapesi Lake batholith. The homogeneous diatexite unit exhibit widespread hypidiomorphic-granular textures and ubiquity of garnet. Euhedral to subhedral cordierite is also rather common, particularly in the Jackson Lake area. Several, small, highly recrystallized trondhjemite masses are completely surrounded and marginally intruded by the unmetamorphosed diatexite of this batholith. These trondhjemitic rocks, which sporadically contain orthopyroxene, may possibly represent of a former sialic basement to metasedimentary rocks prior to the extensive diatexis event.

MIGMATITE CONSTITUENTS

Three migmatitic constituents are developed through **in situ** metatexis and diatexis. The discussion will now focus on the petrographic and petrochemical attributes of these constituents in all migmatitic stages.

Paleosome

Two distinct metasedimentary rock types constitute the surviving paleosome and also may represent the progenitor of leucosome in the various migmatitic stages apparent in the northern supracrustal domain. During field work, these rock types were distinguished as "wacke" and "pelite" and respectively correspond rather closely in chemistry to average greywackes and mudstones from the literature (Tables 4-5 and 4-6). Wacke paleosome

is exceedingly widespread relative to pelitic paleosome, particularly in high grade metamorphic zones. Areas characterized by low and medium grade metamorphism generally exhibit greater preservation of pelitic material. The pelites may have been substantially obliterated under high grade metamorphic conditions by partial melting. During conditions of incipient anatexis, pelitic layers invariably represent the initial site of partial melting (Photos 4-4 and 4-5).

The wacke paleosome is fine-grained, moderately well foliated, equigranular, granoblastic to occasionally porphyroblastic, and is typified by a colour index between 15 and 30. In contrast, pelitic paleosome units are medium to coarse grained, strongly porphyroblastic, well foliated to schistose, and contain abundant aluminous metamorphic minerals and have a higher colour index and lower quartz content than the wacke paleosome (Figure 4-8, based upon 128 samples). Weathered surfaces of the wacke and pelitic paleosome are almost universally rusty to light brown and such a colour is related to preferential dissolution of biotite. Where weathering is not excessively intense, fresh surface colours are medium grey.

In Table 4-5, the mean bulk composition of wacke and pelitic paleosome from the northern domain is compared to several rock groups similar in composition mainly of Early Precambrian (Archean) age. These rock groups are also plotted in Figures 4-10 and 4-11. In the Na+K-Mg-Fe diagram (Figures 4-10 and 4-11), the wacke and pelite paleosomes each comprise well defined compositional fields. Most analyses of the two paleosome groups mutually overlap although the metawacke field exhibits a greater compositional variation. It can also be demonstrated that a closer chemical similarity

exists between various average greywacke suites from the literature and wacke paleosomes from the study area (Table 4-5). Also, wackes tend to be compositionally distinct from the average arkose, dacite, and trondhjemite groups in the FMA and CNK diagrams (Figure 4-10).

Metapelitic paleosome invariably have Na:K ratios of less than one (Table 4-6) and tends to form a field chemically distinct from that of the wacke paleosome (Figure 4-11) with only limited overlap with the wacke field of Figure 4-10. Note also that average metapelite and mudstones from the literature (Table 4-6) plot within or very close to the metapelite field of the study area (Figures 4-10 and 4-11).

The development of metatexite from a metasedimentary protolith can be considered a geochemical "splitting" process. The starting material represented by metawacke and metapelite fields in terms of Na+K-Mg-Fe in Figure 4-12 undergoes transformation via anatexis into a melt phase now represented by the leucosome and a mafic-rich residue termed the melanosome. Each of these migmatitic constituents thus lies separated from that of the paleosome field by a compositional hiatus.

Leucosome

In typical metatexite, the granitoid leucosome exhibits a characteristic massive, holo-leucocratic, earthy white-weathering appearance. Pale pink and brick-orange weathered surfaces are considerably less common. Colour index is normally less than

five and very commonly between one and two. Grain size usually ranges between medium and coarse, although pegmatoid segregations are widely present. Alkali feldspar and plagioclase feldspar are characteristically earthy-white on weathered surfaces rendering it difficult to estimate composition during outcrop examination. Rock composition should be verified in the field by hydrofluoric acid-etching and feldspar-staining.

Leucosomes from both metatexites and diatexites exhibit a wide range in K-feldspar total feldspar ratios, generally varying between granite (sensu stricto) to trondhjemite, based upon approximately 200 modal analyses (Figure 4-5). Rarely, syenitic leucosomes have been recognized but are restricted to within or proximal to low-pressure granulite centres, particularly in the Bear Narrows area of eastern Lac Seul. However, the vast majority of modally analysed specimens are quartz monzonite.

Most leucosome in the English River Subprovince is interpreted as crystallized anatectic melts because of the following attributes:

1) the bulk composition falls within the field of S-type granites (White and Chappell 1974) shown to originate by anatexis of metasedimentary rocks.
2) trace element chemistry of the leucosome is consistent with petrogenesis by partial melting of metasedimentary rocks (Westerman, 1979)
3) occurrence of melanosomes and enclaves of metasedimentary rock, logically interpreted as products from partial melting of a metasedimentary precursor
4) cordierite-sillimanite-garnet-biotite segregations in the Perrault Falls granite inferred by Morin 1971 and Morin and Turnock 1976 as restite from partial melting

5) textural evidence of partial melting, e.g., the progression from proto-metatexite to diatexite based upon classical studies of Sederholm (1902) and Brown (1973).
6) the generally peraluminous chemistry is permissive of an anatectic origin and is characteristic of S-type granites (cf. White and Chappell 1974).

The documented petrological diversity of the leucosome (Tables 4-3 and 4-4) may in part, be related to distinct paleosome compositional fields. Field staining studies reveal that pelitic paleosomes tend to contain strongly potassic leucosome (granite and quartz monzonite), whilst the more feldspathic wackes are commonly associated with sodic leucosomes (granodiorite and trondhjemite). Some experimental verification of this possibility has been given by Kilinc (1972), although the composition of his greywacke and pelitic starting materials do not exactly correspond to respective averages from the English River Subprovince. Accessory minerals include biotite, garnet, cordierite (Photo 4-22), and sillimanite. One feature of the leucosome of English River Subprovince metasedimentary migmatites is the virtual universal occurrence of garnet.

Garnets in granitic rocks of the Superior Province of northwestern Ontario are normally quite rare, as noted in granitic terranes in several widely separated areas of the following subprovinces: Uchi (Sage and Breaks, 1982), English River (this study), God's Lake and Berens (Bond and Breaks 1978), and Wabigoon (this study). The ensuing explanation qualitatively reconciles the ubiquity of garnet within leucosome of the various types of metasedimentary migmatite of the study area.

During an event of medium to high grade regional metamorphism, nucleation of garnet porphyroblasts was initiated in compositionally favourable rock types such as relatively

iron-rich metawacke and metapelites. The pre-migmatite appearance of garnet can be inferred, for example, as within the medium grade staurolite zone at the western end of Lake St. Joseph (Thurston and Breaks 1978, p.54). In the higher grade zones comprising metatexitic and diatexitic stages of migmatization, such blastic garnet would expectedly behave as a relatively resistant metastable phase during the fusion of the paleosome. Subsequently, diminutive garnet xenocrysts could have become incorporated within granitic melts, thereby acting as nucleation centres or "seeds". Epitaxial addition of components to such xenocrysts ensued forming idiomorphic to subidiomorphic, relatively homogeneous, garnet crystals which are very commonly observed in leucosome from the study area.

This type of garnet strongly contrasts with spongy, garnet-quartz aggregates which developed after formation of diatexites as these aggregates have overgrown contacts between diatexite and associated metatexitic rafts. Some evidence for this particular mode of origin is shown in Photo 4-13, a close-up of a leucosome pod in protometatexite from the Wegg Lake area. This plate documents garnet porphyroblasts being partially engulfed by leucosome during incipient anatexis. If the volume of partial melt were to expand to 50-60 percent (inhomogeneous diatexite stage) one would observe leucosome with xenocrysts of aluminous minerals garnet, cordierite and sillimanite. This is perhaps one reason for the diagnostic accessory mineralogy of corundum-normative granitoids derived by anatexis of clastic metasedimentary rocks. In English River Subprovince metatexites it is typical to observe the same aluminous minerals in surviving pelitic paleosome coexisting leucosome. This observation even applies to some low-pressure

granulite facies amphibolites such as in the eastern Lac Seul area which exhibit small, podiform, partial melt textures typified by hypersthene, diopside and hornblende in both the paleosome and mesocratic leucosome constituents.

Petrochemistry

Presented in Tables 4-7 and 4-8 are 32 analyses of leucosome from metatexite and diatexite of the study area. Modal analyses corresponding to the majority of these analyses can be obtained from Tables 4-3 and 4-4.

All analyses express a calc-alkaline chemistry, however, extreme enrichment in Na_20 or K_20 can occur as in the syenitic leucosomes (e.g., 41-2-21 and 43-4-1 in Table ?). generally holo-leucocratic leucosome has very low levels of Mg0, Fe0, Fe_20_3, and $Ti0_2$, relative to the mafic diatexite (Table 4-8) and forms a tight clustering of data points near the alkali apex in the FMA diagram of Figure 4-13. $Si0_2$ commonly exceeds 70 percent. The previously mentioned range in K-feldspar/Total Feldspar ratios is chemically reflected by a large dispersion in Na/K ratios which lie between 0.3 and almost 3. Most of Na/K ratios fall below 1.0 and dominantly correspond to quartz monzonite (Figure 4-5). A slightly peraluminous aspect of the leucosome is indicated by appearance of normative corundum in most analyses of Tables 4-7 and 4-8 and by positive molar Al/Na+K+Ca ratios ($mean_{23}$ = 1.156; range = 1.175-1.363). The mafic leucosomes (Table 4-3), representing greater degrees of partial melting or retention of greater amounts of restite (Chappell et al. 1987) are shown in Figure 4-13 and have generally higher A/CNK_{mol} ($mean_7$ = 1.415; range = 1.217-1.496).

The FMA plot indicates rapid increase in total iron and slight increase in Mg levels.

In the CNK diagram, a correlation exists with the normative anorthite-albite-orthoclase diagram for English River Subprovince leucosomes (Figure 4-19, below). The sodic leucosome trend shows increasing Ca and Na in contrast to the potassic leucosome trend which leads to high K levels and lower Ca + Na. Mafic leucosomes, which are predominantly granodiorite to trondhjemite, chemically correspond to the sodic leucosomes while leucosomes marked by lower quartz contents and high K-feldspar (i.e., syenite leucosomes) define the potassium leucosome trend. The FMA diagram (Figure 4-13) only reveals the sodic leucosome trend as Na and K are combined. This trend of increasing total iron and Mg corroborates with experimental studies on variation in compositions of anatectic melts as a function of increasing degree of partial melting (Winkler 1979).

The sodic leucosome trend follows a similar compositional path as that experimentally determined by Winkler (1979, p.311) in which a paragneiss containing very low amounts of K-feldspar produced a trend of leucosome compositions from granite to granodiorite to almost trondhjemite, as a function of increasing temperature of anatexis. A gradual rise in both the anorthite component (4 to 19 percent) and Fe + Mg in the melt phase with increasing anatexis are other features revealed in the work of Winkler (1979).

The relatively high K_2O in the analyses is due to high modal biotite which in turn contributes to high normative corundum values (maximum of 5.87 percent). Hornblende is never found in the mafic leucosomes and relates to relatively low CaO levels. This is normally not the case with trondhjemitic rocks of probable I-type origin containing similar SiO_2 levels from the southern plutonic domain (see Chapter 8).

The K_20 vs Na_20 diagram (Figure 4-15) is of limited usefulness in geochemical discrimination between the English River Subprovince I-type and S-type granitoids. This contrasts with the Australian counterparts (Hine et al. 1978). This diagram does, however, render a reasonably clear separation between the English River Subprovince S-type leucosomes and I-type granitoids of trondhjemite, quartz diorite, and diorite composition. There is minimal overlap with this field at the sodic end of the leucosome field (Figure 4-15). It should be additionally noted that the S-type granitoids of the study area encompass a much wider compositional spectrum than the Australian counterparts, the latter field never recording Na/K ratios exceeding 1.0 (Hine et al. 1978).

The widespread potassic granitoid suite rocks of the English River Subprovince (porphyritic and equigranular variants) significantly overlap with the leucosome field as shown in Figure 4-15. Age relationships and mineralogical parameters however can be utilized to distinguish between these two similar bulk chemical groups.

The almost universal white colouration of fresh surfaces of the leucosome constituent possibly relates to the oxidation state of iron. S-type granitoid rocks tend to show $FeO>Fe_2O_3$ (Figure 4-16). As a result, the usual pink colouration of alkali feldspar, in the I-type potassic granitoid rocks likely caused by submicroscopic hematite inclusions and limited substitution of Fe^{3+} for Al^{3+} in the lattices, is almost virtually absent in leucosomes associated with metasedimentary migmatites. As shown in Figure 4-17 leucosomes typically possess much lower Fe^{2+} than the later, cross-cutting, equigranular, quartz monzonite dykes and masses. There is some degree of overlap with the porphyritic quartz monzonite and granodiorite-trondhjemite groups (Figure 4-17), however,

discrimination between the two groups is readily accomplished on the basis of mineralogical parameters, and, secondly, by virtue of a lack of porphyritic textures in leucosomes. Most leucosomes also exhibit higher Mg levels than that of equigranular potassic granitoid suite field.

Predominance of Fe^{2+} in the leucosome constituent may reflect inheritance from wacke-pelitic metasedimentary precursors, particularly if graphite was originally present in these metasedimentary rocks. This mineral could have had a controlling influence in the establishment of reducing conditions during anatexis of metasedimentary rocks as conversion of graphite into CH_4, C0, and $C0_2$ gaseous species can have a drastic effect in lowering the $f0_2$ (Eugster, 1972), and hence lead to concentration of Fe^{2+} over Fe^{3+} in leucosomes. Graphite has been recognized in this study within low and medium grade metasedimentary rocks at Lake St. Joseph.

Normative proportions of felsic components in leucosome (including unpublished analyses from Operation Ignace-Armstrong) have been projected on to the ternary quartz-albite-orthoclase and anorthite-albite-orthoclase planes of the haplogranite system ($Si0_2$-$NaAlSi_30_8$-$KAlSi_30_8CaAl_2Si_20_8$-H_20) in Figures 4-18 and 4-19. The cotectic valley at 650^0C and isotherms at 670^0 and 700^0C (pH_20 = 5 Kilobars) from Winkler et al. (1975) have also been plotted. In both projections it can readily be observed that a significant number of leucosome analyses lie in scattered array along the cotectic curve. Granitoid rocks crystallizing from eutectic minimum melt systems commonly express a strong chemical homogeneity marked by close clustering of data points within such projections. Winkler et al. (1975) have experimentally studied low temperature melt evolution in these

systems and determined that rocks crystallizing from anatectic melts characteristically display lack of clustering in proximity to an eutectic or a thermal minimum at pressures exceeding about 4.5 Kbars. If a rise in temperature occurs in a terrane undergoing high grade metamorphism, composition of derived anatectic melts readily depart from the cotectic valley to one of the cotectic surfaces. According to Winkler (1979) only the earliest, incipient stage of anatexis will produce leucosomes of minimum melt composition along the thermal valley. In the quartz-albite-orthoclase system in Figure 4-18, approximately 60 percent of analyses plot sufficiently close to the univariant cotectic curve at 5 Kilobars as to be tentatively classified as cystallization products of minimum melt systems. This system, however, does not take into account influence of the anorthite component. The evolution of leucosome melt composition appears to have followed two distinct paths, which is more apparent in the Anorthite-Albite-Orthoclase system:

1) trend towards increasing orthoclase and decreasing anorthite, albite and quartz (potassic leucosome trend, Figure 4-19)
2) trend towards increasing quartz anorthite, and decreasing orthoclase (sodic leucosome trend in Figures 4-18 and 4-19)

In the anorthite-albite-orthoclase system of Figure 4-19, only about one-third of all analyses fall reasonably close to minimum melt compositional region of the cotectic curve which characterize incipient anatectic melts. Figure 4-19, in addition, shows that a significant number of analyses lie considerably removed from the univariant cotectic curve in two distinct trends oriented at high angles. These two paths of anatectic liquid evolution advance either to higher anorthite or orthoclase, and may in part reflect the

generally dual petrochemical character of the metasedimentary protolith. If alkali feldspar was sparsely present or absent in the protolith as in the case of wacke compositions, then disappearance of this phase during anatexis would advance leucosome compositions toward more sodic compositions. Contrastingly, pelitic paleosomes generally contain an abundance of alkali feldspar and phyllosilicate minerals (muscovite and biotite) with evolving melts tending to be very potassic with lower plagioclase.

K/Rb Variation in the Leucosome

In general the leucosomes are not highly fractionated as indicated in Figures 4-20 and 4-21. Most K/Rb ratios of leucosomes considerably exceed the average and range of most crustal materials as shown in these diagrams. Only about 20 percent of analyses reside within the K/Rb crustal limits of 150-300. Rubidium prefers to substitute for potassium in octahedrally-coordinated sites in biotite, and this mineral usually concentrates this element by a factor of 3 to 4 over potassic feldspar (White 1966). At first sight it would appear that the moderately high K/Rb ratios of the leucosome are controlled by the general paucity of biotite and general abundance of potassic feldspar. However, even the relatively mafic leucosomes containing 20-30 percent biotite which virtually lack K-feldspar have high K/Rb ratios as well. It is thus conceivable that significant levels of Rb were expulsed from evolving leucosomes in metasedimentary rocks undergoing migmatization and possibly concentrated either into a residual pegmatitic melt such as those containing rare-element mineralization or into a biotite-rich restite constituent.

Melanosome

The melanosome or restite constituent typically forms a meager percentage of most **in situ** metatexites. In diatexites, clots interpreted as restite are widely distributed, particularly near the inter-domain boundary as at Perrault Lake. In relatively undeformed exposures the melanosome is normally preserved as thin, continuous to partially continuous mafic selvedges, symmetrically distributed along the interfaces between paleosome and leucosome constituents (Photo 4-15). Such an observation normally supports an anatectic origin for the leucosome constituent and was first termed **veinite** by Holmquist (1916), i.e., **in situ** exudation of leucosome from the paleosome with the melanosome representing the residuum from the partial melting event. In rare cases, melanosome has been developed only along one side of leucosome layers (Photo 4-12), and the mechanism responsible for this unusual asymmetry is not totally understood, although it should be noted that the biotitic selvedge here is considerably thicker than normal. Mafic-rich rims have also been observed distributed in a continuous peripheral fashion around metatexitic enclaves within inhomogeneous diatexite.

Mineralogically, the metatexitic melanosomes dominantly comprise medium to coarse-grained biotite, which commonly exhibits a haphazard orientation in contrasts with the fine-grained, foliate biotites of the adjacent paleosome. Subordinate amounts of plagioclase, sillimanite, quartz, garnet and cordierite may also be present. The melanosome is of particular petrologic importance in that the metamorphic mineral assemblage in equilibrium with coexisting the melt phase (leucosome) may yield P-T-X data for the anatectic event.

Melanosome found in diatexites appears as generally ovoid-shaped entities (Photo

4-16), commonly varying between 1.3 and 15 cm in length and up to 2.5 cm in width. The clots consist of a fine- to medium grained granoblastic to diablastic aggregate generally enriched in quartz (approximately 60 percent) and depleted in biotite relative to metatexitic melanosome. Other minerals present, as listed in order of decreasing relative abundance, include garnet, cordierite, sillimanite, muscovite and very scant plagioclase and K-feldspar. A well-known locality is situated at Perrault Falls on Highway 105 and has been described in detail by Morin (1970).

Winkler and von Platen (1961) conducted partial melting experiments on greywackes from the Harz Mountains, Germany which vary in Ab/An ratio from 1.6 to 5.8. Their results indicated a considerable variation in modal composition of the restite constituent, reproduced in Table 4-9. This compares with the general modal diversity of melanosomes of the northern supracrustal domain. Two of the melanosomes produced by Winkler and von Platen (1961) contained very high quartz (72-81 percent) and subordinate cordierite (12.5 to 13.5 percent) which compare favourably with the quartz-cordierite clots found in diatexites of the study area. Melanosomes containing relatively low levels of quartz (11 to 24 percent) were encountered by Winkler and von Platen (1961) and better compare with melanosomes from metatexites of the northern supracrustal domain. However, a major disparity is reflected in the much higher biotite contents and general lack of cordierite from the latter (50-60 percent).

Petrochemistry

Due to difficulty in obtaining samples of the thin, restite selvages, only one analysis of a biotite-rich selvedge from metatexite was obtained. Material from three clotty

diatexites are also included in Table 4-10. In both instances, the melanosome was separated from adhering paleosome and leucosome constituents with a diamond saw.

A significant difference in major element chemistry is obvious between the biotite-rich melanosome selvadges from metatexites and quartz-rich restite clots from diatexites (Table 4-10). The latter show considerably higher SiO_2, and lower Al_2O_3, FeO, MgO, CaO, K_2O, Na_2O, and TiO_2 which mainly relates to relative paucity of biotite in the clots. The melanosome selvedges also exhibit enrichment in Ba, Cr, Ni, V, Rb, Sr, and Zr relative to the clots. Notably high concentrations of lithium (180-310 ppm) and Be (15-35 ppm) to levels significantly above their respective clarke values of 12 and 2 ppm is apparent in the clots.

MODAL FEATURES OF WACKE AND PELITIC METASEDIMENTARY ROCKS

Presented in Tables 4-11 and 4-12 are results of modal analyses of 85 metawackes and 48 metapelites, the vast number being from the northern domain. In addition, 32 modal analyses on metawackes which resulted from reconnaissance work in the English River Subprovince east of Longitude 90°30' (unpublished analyses from Operation Ignace-Armstrong) were used in the construction of modal variation plots. All modal analyses were conducted on thin-sections stained for plagioclase and K-feldspar (Boone and Wheeler, 1968). At least 500 points were tallied per slide, based upon a 1 mm x 1 mm grid system.

Several important general mineralogical features of the two major metasedimentary bulk compositional groups are readily apparent in the QFM plot (Figure 4-8). Taken

together, modal data of the metawackes and metapelites form a continuum, which defines a systematic decrease in quartz content with increasing colour index. The autonomy of the metawacke and metapelite fields is, nevertheless, relatively intact as only a small percentage of observations overlap.

The petrochemical expression of this continuum is evident in Figures 4-10 and 4-11, respectively relating Ca:Na:K and Fe:Mg:Na+K ratios. This general negative correlation between colour index and quartz is highly characteristic of most sodic granitoid suites in the English River Subprovince which exhibit a mafic to felsic differentiation trend (see Chapter 8). This feature in itself may imply that part of the provenance of sedimentary debris now occupying much of the northern domain, consisted of sodic granitoid suite rocks. Evidence supporting this contention will be discussed below.

Metawackes generally exhibit a higher quartz content and significantly lower colour index relative to the pelitic metasedimentary rocks (Tables 11 and 12). Colour index of the metawacke field ranges between 15.4 and 34.6, with the vast majority of specimens being closely bracketed between 15 and 30 (Table 4-11). Metapelites, contrastingly, show a considerably higher and more dispersed colour index, ranging from 28.6 to 71.2 with the majority clustering within the 35 to 60 percent range (Table 4-12). This group exhibits a tendency toward low quartz contents, although the wide range here (0 to 30 percent) overlaps with a significant number of quartz-poor metawackes, rendering this parameter a poor means of discriminating between the two major rock types. Total feldspar content of both lithic groups is largely similar, although approximately 30 percent of the metapelites show a tendency toward depletion in total feldspar, which significantly

departs from the metawacke field. Metapelites also differ in containing significant amount of K-feldspar in the total feldspar fraction, in the K-feldspar-Cordierite-Garnet and K-feldspar-Sillimanite-Garnet high grade metamorphic zones (Figure 12-2, below). Only coexisting metawackes within these metamorphic zone contain K-feldspar.

COMPARISON TO OTHER IMPORTANT ROCK GROUPS

In terms of major mineral composition, the metawackes most closely approach the biotite trondhjemite group (Figure 4-22 and both groups essentially comprise the simple assemblage quartz - plagioclase - biotite. In the field it is possible that some uncertainty may arise in distinguishing fine-grained, foliated, highly recrystallized biotite trondhjemite from metawacke which exhibit comparable petrographic characteristics. This quandary may be particularly evident in areas of the southern plutonic domain isolated from the large continuous metasedimentary migmatite belt comprising most of the northern domain.

Fortunately, several modal parameters aid in the discrimination for the majority of analyzed specimens. There is minimal overlap of these lithic fields in terms of total feldspar as indicated in Figure 4-22. The wackes and pelites both display a significantly lower relative amount of total feldspar than either the biotite trondhjemite or hornblende-bearing sodic granitoid fields, marking this as one of the salient modal discrimination features. Only about 11 percent of biotite trondhjemites from the southern domain, fall within the wacke field and even a lesser proportion (6 percent) of the wackes exhibit the opposite characteristic. In terms of colour index, only about 13 percent of the wackes overlap on Figure 4-22 with the biotite trondhjemites. This represents another prime modal feature: for a given quartz content, the metawackes almost invariably exhibit

appreciably higher colour indices.

The remaining wackes show much higher colour indices and compare more closely to the hornblende-bearing sodic granitoid field, although other major differences disclosed in the ensuing section allow rapid discrimination between these two lithic groups. In addition, the metawackes show a trend towards moderate quartz enrichment as about 27 percent of specimens lie above highest quartz values registered in the biotite trondhjemite field.

Biotite trondhjemite must be considered as one possible source for sedimentary debris for metawackes. This is suggested by abundant biotite trondhjemite clasts in a metaconglomerate at Perrault Lake situated at the intradomain boundary. The modal differences discussed above could be engendered by a dilution-effect involving intermixing of a mafic constituent such as tholeiitic basalt with biotite trondhjemite debris thus raising colour index and lowering total feldspar. However, feldspar would also expectedly undergo some authigenic conversion into clay minerals which would also lower the total feldspar fraction.

Hornblende-Bearing Sodic Granitoids

Some of the quartz-poor wackes possess similar colour indices to the quartz-rich portion of the hornblende-bearing sodic granitoid field, i.e., hornblende-biotite trondhjemite. Several features allow rapid discrimination here:

1) hornblende-bearing sodic granitoids have higher total feldspar whereas only 2 percent of all the wackes plot in this field (Figure 4-9);
2) hornblende is not present in wackes from the English River Subprovince.

Distinguishing between hornblende-bearing granitoids and metapelitic rocks is also readily accomplished despite a similarity in colour index. Due to the general extreme impoverishment in CaO, pelitic rocks do not develop phases such as hornblende during regional metamorphism. Therefore, no confusion can develop between metapelites and highly metamorphosed, foliated, recrystallized hornblende-bearing trondhjemites, in terms of modal composition. Only one specimen (31-10-15) in Table 4-12 contained hornblende out of approximately 200 meta-pelitic thin-sections examined from the English River Subprovince.

If any of the variants of the sodic granitoid group served as sources for wacke and mudstone debris, a thorough mechanical and authigenic destruction of hornblende would have to be an initial requirement, as no record of detrital hornblende has been recorded in these rock types. However, these rocks should not be discounted as minor clasts of biotite-hornblende tonalite have been identified in conglomerates associated with wackes and pelitic metasedimentary rocks at Perrault Lake.

Potassic Granitoid Group

Metasedimentary rocks of the wacke-pelitic type do not compare well to this lithic group owing to low colour index of these granitoid rocks and lack of K-feldspar in metawackes and in low to medium grade metapelites. At high grades of regional metamorphism, metapelites generally have appreciable amounts of K-feldspar (maximum of 31.4 percent) plausibly derived via devaporization/decomposition reactions involving muscovite (Winkler 1979). Also these potassic granitoids do not constitute a factor in the

provenance as such granitoids were emplaced after the 2.68 Ga migmatization (Krogh et al. 1976) of the northern domain metasedimentary rocks and are widely evident as dykes cross-cutting these migmatites. The 2.652 Ga granitic rocks (Krogh et. al. 1976) also does not occur as clasts in metaconglomerate bordering the northern domain metasedimentary rocks (as at Perrault Lake) and hence these rocks are concluded to have been absent in the provenance area.

PETROCHEMISTRY OF METASEDIMENTARY ROCKS

In Tables 4-13 and 4-14 are presented 128 analyses of metasedimentary rocks, which mostly constitute the surviving paleosome in the high grade metamorphic zones of the northern supracrustal domain. These tables include major, minor, and trace dements in addition to selected element ratios of 50 metapelites and 78 metawackes. Corresponding modal analyses for a large number of the analyzed specimens are presented in from Tables 4-11 and 4-12. Mean bulk compositions of metapelitic and metawacke rocks from the English River Subprovince are compared to various major sandstone and mudstone lithic groups of varying geological age but largely of Precambrian age in Tables 4-5 and 4-6. With respect to metawackes a geochemical similarity exists between the metawacke paleosome and various greywackes groups as shown by comparing Figures 4-10 and 4-11. In terms of Na+K:Fe:Mg and Ca:K:Na ratios, both the metawackes and metapelites of study area define reasonably discrete fields, marked by transitional geochemical relationships. Metapelites tend to have higher total Fe and Mg, coupled with lower total alkalies than the metawackes. In the CNK diagram the sodic nature of metawackes contrasts quite strongly with the highly potassic,

low calcic nature of most metapelites. The various average greywacke suite of Table 4-5 exhibit similar ratios and plot well within the English River Subprovince metawacke field. These rocks chemically are distinct from other sandstone and mudstone compositional groups.

The dominance of sodic plagioclase coupled with generally higher quartz levels and lower ferromagnesian minerals in the metawackes produces a chemistry characterized marked by high Na, Si, Ca, and lower Al, K, Fe_{total} and Mg relative to the metapelites. The metapelites exhibit an antipathetic, major element trend compared to the metawackes and relates to a higher biotite and/or muscovite content plus tendency towards low quartz and low total feldspar. Both metasedimentary groups display an overall trend towards Fe enrichment in the AFM diagram without an accompanying significant increase in Mg levels. Only three specimens (8-12-7A, 35-8-17 and 39-2-39 in Tables 4-13 and 4-14) exhibited appreciable Mg enrichment (>6 %) and are conspicuously isolated from the strong clustering of English River Subprovince metasedimentary analyses portrayed in Figure 4-9. Highest total iron content level was recorded in a wacke (41-3-13A: Table 4-13) although, in general, metapelites exhibit higher total contents of this element.

Several bulk chemical features characterize both major paleosome groups. With respect to the greywackes, the foremost feature is the excess of Na_20 over K_20, regarded by Pettijohn (1963, p.57) as "one of the most singular attributes of greywacke". As indicated in Table 4-13 and Figure 4-22, Na_20/K_20 ratios only rarely fall below unity and levels of Na_20 are comparatively constant in all average greywacke suites tabulated. Also a transitional petrochemical behavior is once more apparent between the two

metasedimentary groups. Arkoses and subgreywackes all exhibit Na/K ratios less than unity and considerably removed from most wacke analyses in Figure 4-9. Metapelites exhibit only limited chemical overlap with metawacke field and with exception of specimen 38-7-9A plot close to Na_2O:K_2O ratio of 1:1 (Figure 4-22). Also note the fairly limited K_2O range (1.3 to 3.1 percent) which reflects the relatively limited range in biotite content, invariably the sole potassic phase. Metapelites, on the other hand, owing to a greater diversity and modal variation in the potassic phases, exhibit a wide range in K_2O (1.6 to 6.9 percent).

Greater abundance of Al_2O_3 in metapelites vs metawackes is a generally distinctive petrochemical feature. Although minor overlap of these two fields is evident in Figure 4-23, metawackes generally fall below 17% Al_2O_3 whereas metapelites always exceed this value, even though total alkali contents are generally similar. The latter also exhibit a greater range of Al_2O_3 values (17-25.3 percent).

A petrochemical transition between the two compositional fields is again evident in this diagram. In particular, normative corundum is an excellent means of discriminating between metawackes and metapelites, this variable being a function of increased aluminum concentration through sedimentary fractionation (Wedepohl 1968). Weathering of sedimentary detritus results in progressive accumulation of Al_2O_3 through removal of alkalis primarily effected by feldspar breakdown, such that corundum appears in significant amounts in the normative calculation for the more highly weathered, mature pelitic metasedimentary rocks. Metawackes display a strong clustering of normative corundum between 2 and 4 percent (mean = 3.31 percent). There is generally a clear

separation between the wacke and pelite fields with only a few percent of observations mutually overlapping (Figure 4-24). Pelites show a considerably greater dispersion about the mean value (10.08 percent) and, in general, any metasedimentary rock with normative corundum exceeding 8 percent was originally relatively clay-rich and those with normative corundum values falling below 5 percent probably represent wackes.

The dominance of Fe^{2+} is another bulk chemical feature of the metawackes and metapelites, although Pettijohn (1963) cautioned that this relationship is generally found in most metasedimentary rocks and thus may not have sedimentological significance. Although some overlap is obvious in the FeO vs Fe_2O_3 diagram (Figure 4-25) between 4 and 6 percent FeO, the metapelites generally contain substantially higher FeO levels, reaching a maximum of 9.5 percent. Lesser variation in Fe_2O_3 is apparent in both groups. This dominance of FeO in metapelites is likely inherited in the anatectically derived white leucosome constituent in the metasedimentary migmatites, although mineralogical factors such as presence of graphite can exert strong controlling influences in lowering the fO_2 during anatexis of the metasedimentary rocks and hence favour concentration of Fe^{2+} over Fe^{3+} (Eugster 1972). Leucosome analyses always show excess of FeO over Fe_2O_3 (Tables 4-7 and 4-8).

The average English River Subprovince metawacke compares in most respects to average Canadian Shield composition of Shaw et al. (1967, 1976), which would be expected of sedimentary detritus derived from a diverse "granite-greenstone" provenance. Some disparity is met, however, in the higher K_2O content of the average Canadian Shield

crust. This average undoubtedly was influenced by the voluminous post-tectonic potassic granitoid igneous activity with an emplacement age of about 2.652 Ga (Krogh et al. 1976) which post-dates migmatization of the metasedimentary rocks at 2.68 Ga. The potassic granitoid suite was likely absent during derivation of the sedimentary detritus, as also suggested by absence of potassic plutonic clasts in metaconglomerates of the study area. No computation of the pre-Kenoran crustal composition in the Superior Province has been attempted due to incompleteness of mapping in gneissic/granitoid terrains and, secondly, owing to paucity of meaningful geochronological data.

K/Rb VARIATION IN METASEDIMENTARY ROCKS

Variation of Rb and K, two lithophile elements which typically exhibit a strong geochemical coherence (Goldschmidt 1954) is examined for metawackes and metapelites from the study area (Figures 26 and 27). Metawackes have an unusually wide range in ratios (mean = 322; range = 80 to 1300) which is maintained at a generally constant level of K (Figure 4-26). In contrast, the Archean greywackes from Wyoming (Condie 1968) exhibit a much more confined compositional field which expresses the more common crustal pattern of increasing K/Rb with decreasing K (Shaw 1968).

K/Rb ratios in the metapelitic rocks display a slightly more limited range (98 to 1005) and higher mean of 430. These rocks, however, show a general increase in K/Rb ratios with slightly increasing K contents (Figure 4-28), a trend that has been rarely reported in the literature. Heier and Thoresen (1971) documented this trend in mangerites from northern Norway although the controlling geological processes are not yet understood.

The observed variation in K/Rb ratios with general metamorphic grade of the

metasedimentary rocks shows no systematic patterns. There is a tendency in the high grade and granulite metapelites to exhibit the highest K/Rb ratios (Figure 4-28) as most samples of these grades exceed values of 450. However, note here that little difference exists between high grade and granulite K/Rb ratios which is typical for low pressure regional metamorphic facies series documented for other Precambrian areas (Lambert and Heier 1968, Heier 1973).

ORIGIN OF METASEDIMENTARY ROCKS

One of the foremost problems confronting workers in the English River Subprovince concerns the inference of the lithogic nature of the source region from which the voluminous quantities of clastic sediment now comprising the northern domain supracrustal rocks. Unravelling this fundamental problem is fraught with difficulties. These problems mainly relate to ambient high grade metamorphic and tectonic destruction of almost all sedimentary structures and textures which could have provided important clues bearing upon the provenance and the sedimentology of the rocks. Minimal evidence exists sporadically along the Uchi Subprovince-English River Subprovince interface in localities characterized by low and medium grade metamorphism. In suchlocalities interbedded pelitic and wacke units, coarse framework grains in wackes and graded bedding have managed to survive metamorphic effects.

As a provisional model, the authors interpreted that the northern domain comprises an extensive, linear metasedimentary trough rimmed by two contemporaneous island-arc volcanic complexes, now respectively the Uchi and Separation Lake Belts. These volcanic complexes, in turn, were positioned along the flanks of older sialic forelands,

and dominated by calc-alkalic granitoid complexes of trondhjemite-quartz diorite composition. Juxtaposition of such diverse rock types could engender a mixed-source provenance for the ubiquitous wacke constituent in the northern domain. The ensuing discussion will attempt to demonstrate that this interpretation best fits the model and the following salient attributes of the wacke paleosome:

1) the moderate enrichment in sand size quartz, commonly in the range 25 to 35 percent (Figure 4-8);
2) the bulk composition exhibits Na:K ratios in excess of one.
3) the moderate concentrations of the lithophile elements barium, rubidium, and zirconium, lithium;
4) the relatively high iron, magnesium, chromium, nickel and vanadium supportive of a mafic-ultramafic legacy.

Although dacitic and rhyodacitic rocks approximate the paleosome compositional field in Figures 4-10 and 4-11, several critical factors, dealt with below, militate against appealing to these rock types as the sole source material for the wacke paleosome. This statement is not meant to totally disregard dacite and rhyodacite material as sources of detritus. At certain localities along the Uchi Subprovince-English River Subprovince interface, dacitic to rhyodacitic rocks stratigraphically underlie the metasedimentary rocks of the Northern Supracrustal Domain,e.g., at Papaonga Lake and Lake St. Joseph. Firstly, if the preserved proportions of various cyclical volcanic deposits can be construed to represent a rough guide to initial abundances during Early Precambrian times, it becomes obvious that a lack of felsic to intermediate metavolcanic material now exists in contrast

to the extensive quantity of wacke within the northern supracrustal domain.

A planimeter survey by Goodwin (1976) established the following proportions of mafic to intermediate and felsic to intermediate metavolcanic rocks within the supracrustal areas of the Wabigoon and Uchi Subprovinces:

Uchi Subprovince:

Mafic to intermediate, 90 percent

Felsic to intermediate, 10 percent

Wabigoon Subprovince:

Mafic to intermediate, 92 percent

Felsic to intermediate, 8 percent

It is noteworthy that between Longitude 89^{0}00' and the Ontario-Manitoba boundary, the areal extent of the metasedimentary migmatite belt exceeds the total area of metavolcanics within the Uchi Subprovince almost by a factor of two, based upon planimeter analysis during the present study.

Secondly, trace element data (Table 4-15, 4-16 and 4-17) do not appear to solely favour a cratonic sialic provenance over a volcanic source region. Trace element data pertaining to major sandstone classes are generally scant in the literature (cf. Pettijohn, 1963). However, such data may provide important constraints regarding chemical constitution of a particular source region as exemplified by the study of Condie et al. (1970) of Early Precambrian greywackes from the Fig Tree Group, Republic of South Africa. In Table 4-15, average concentrations and abundance range of several potentially

useful "indicator" trace elements are listed for the following: (1) various sandstone suites; (2) greywacke paleosome of the English River Subprovince; and, (3) data for Archean rock types that plausibly occurred in the source region for wacke and pelite metasedimentary rocks.

Metawackes from the study area exhibit a significant enrichment in Mg, Fe, Cr, Co, Cu, S, Zn, Ga, Li and Cs relative to composition of the average upper continental crust (Table 4-18). Wedepohl (1968, p.1003), pointed out that the much smaller scatter in abundance ratios (log average abundance sediment/ average abundance in upper continental crust) in greywackes, compared to chemical sediments, for example, testifies to the very limited degree of sedimentary chemical fractionation for the former. The average enrichment of elements in greywackes which are also concentrated in basaltic rocks (Mg, Fe, Cr, Co, Cu, Zn) and depletion of lithophile elements K, Rb, Ba (Table 4-18) was suggested by Wedepohl (1968, p.1004) to "be due to an abnormal contribution of volcanic debris to greywacke formation". English River Subprovince metapelites exhibit even greater enrichment in Mg, Fe, Cr, Co, Cu, S, Zn, Ga, Li, and Cs in addition to Ni, V, Ga, Zr, and Pb relative to average upper continental crust composition (Table 4-18).

Metawackes and metapelites together define distinct positive correlations in the Ni-Mg, and Cr-Mg diagrams in (Figures 4-29 and 4-30). Correlation between Ni and Cr in these metasedimentary rocks (Figure 4-31) is also apparent but somewhat more diffuse than that between Ni-Mg and Cr-Mg. This coherence in Archean metasedimentary rocks was first pointed out by McPherson (1958).

Figures 4-32 and 4-33 respectively depict generalized Ni-Mg and Cr-Mg compositional

fields from metavolcanic-sequences of the bordering Wabigoon and Uchi Subprovinces and are compared to metasedimentary and sodic granitoid suite metaplutonic rocks from the English River Subprovince. Sodic suite granitoid rocks are also included in these variation diagrams as such rocks constitute a widespread and important constituent of sialic crust in the Superior Province of northwestern Ontario and therefore must be considered in sedimentary provenance studies. In both of these diagrams a significant overlap of the metasedimentary fields with the mafic metavolcanic and felsic to intermediate metavolcanic and metaplutonic compositions is notable as is a similarity in the inferred mean slope of the positive correlation line between Ni-Mg and Cr-Mg in the metasedimentary and mafic metavolcanic fields.

Turekian (1963) has pointed out a marked covariance between Cr and Ni based upon global sampling of Phanerozoic basaltic rocks and studies of fractionally crystallized mafic-ultramafic igneous rocks such as the Stillwater Complex. A strong positive correlation is also evident in most Archean metavolcanic compositions as indicated by sequences bordering the English River Subprovince (Figure 4-34).

Average Cr and Ni values of both the wacke and pelite metasedimentary groups (Table 4-15) appreciably exceed that for average metatrondhjemite and metadacites from the Uchi and Wabigoon Subprovinces. Metapelites generally contain higher levels of Cr and Ni, although a considerable interspersion of data is obvious in Figure 4-31. Highest levels of these elements (Cr= 980 ppm and Ni = 270 ppm) were in fact recorded in a low-grade metawacke overlying pillowed mafic metavolcanic rocks collected from the northern subprovince boundary in the Lake St. Joseph area (35-8-2A

in Table 4-13). Such high levels of Ni and Cr, which significantly exceed the mean abundance of Archean tholeiitic metabasalts (Table 4-15), suggests that ultramafic rock types may have locally supplyed detritus. Condie (1970) concluded that similar values of Ni in greywackes from the Sheba Formation, Fig Tree Group (average = 290 ppm) in the Barberton Belt of South Africa necessitated a significant, although subordinate ultramafic constituent in the source area.

Levels of Mg and Ni comparable to those in most English River Subprovince metawackes and metapelites exist in some metadiorite and metagabbro rocks from the study area (Figures 4-29 and 4-35). However, in the Mg-Cr diagrams (cf. Figures 4-30 and 4-36), most of these rocks plot significantly above the metasedimentary field. As these mafic rocks comprise a relatively meager portion of the granitoid terrain in the Southern Plutonic Domain (Table 4-1) or in the adjoining Uchi Subprovince (Sage and Breaks, 1982), they likely contributed very little detritus to the English River Subprovince metasedimentary rocks.

Presence of positive Ni-Mg, Cr-Mg, and Cr-Ni correlations in the English River Subprovince metasedimentary rocks are thus interpreted as preservation of similar geochemical relationships that were inherent in the source area. This could be effected by mixture of appreciable quantities of relatively unweathered tholeiitic basaltic detritus with that from provenance units having a felsic to intermediate composition.
These strong correlations would likely be obscured if significant sedimentary geochemical fractionation had occurred.

Felsic rocks in the source area must also be considered as average contents of Ba,

Cs, Li, Rb, and Zr in the metasedimentary rocks are significantly higher than that encountered in average Archean tholeiitic basalt compositions (Table 4-15).

These elements posses pronounced lithophile tendencies and thus are notably incompatible with the crystal-chemistry of most basaltic rocks. Barium exhibits a wide range of abundance, varying from 60 to 780 ppm in metawacke (mean value = 297 ppm) and from 210-1400 ppm in metapelite (mean value = 489 ppm). The mean value of metawacke, in particular, closely approximates that of the metamorphosed trondhjemite group (222 ppm) in addition to showing significant overlap of ranges. Mean abundance of zirconium in both the metawacke and metapelite is significantly higher than that of the average tholeiitic basalt or metamorphosed trondhjemite groups, and more clearly compare to the dacites (Table 4-14). Rubidium appears generally depleted in both the metawacke and metapelite with mean concentrations of 58 and 79 ppm versus the mean crustal abundance of 91 ppm (Heier and Adams, 1963). The relatively low levels of rubidium may be consequent upon derivation of wacke and pelitic metasedimentary detritus from a source area exhibiting similarly depleted Rb levels.. Average rubidium content of metamorphosed trondhjemitic rocks (Table 4-14) also indicate depleted levels and are even more depressed than that of the metasedimentary groups.

Direct evidence that involvement of both basalt and trondhjemite groups occurred during sedimentation stems from a critical series of outcrops in the Perrault Lake area, situated at the southern margin of the northern supracrustal domain. Here, amphibolitic mafic metavolcanic flows within enclaves situated to the east of the Separation Lake Belt are overlain by a clast-supported, cobble to boulder, polymictic conglomerate succeeded

by migmatized wacke of the northern domain. Clasts of massive to foliated, coarse-grained, biotite and hornblende-biotite trondhjemite predominate although subordinate mafic metavolcanic clasts are apparent. No strongly deformed clasts comparable to the rocks of the nearby gneissic granitoid suite in the nearby Cedar Lake area were apparent. Nevertheless, this exposure reveals the following important information:

1) trondhjemitic and basaltic constituents were simultaneously deposited in the northern domain basin,
2) granitic terrain of unknown extent must have been proximally situated in order to supply the coarse granitoid clasts.

Thus, the trace element character of wacke paleosome from the northern domain appears explicable if consideration is given to a heterolithic provenance. This source area must have significant quantities of tholeiitic basalt and trondhjemitic granitoid material, the latter group probably augmented by felsic to intermediate metavolcanic rocks. A felsic rock must have been present in order to provide an ample supply of sand size quartz for the wacke paleosome. Basaltic rock types are necessary for moderate chromium, vanadium, nickel, iron and magnesium levels but cannot fulfill the requirements for a relatively high quartz content.

CHAPTER 5

SUBVOLCANIC INTRUSIONS AND SUBDIVISION OF THE INTRUSIVE ROCKS

SUBVOLCANIC INTRUSIONS

Subvolcanic intrusions are a minor to rare constituent in the Uchi and Wabigoon Subprovinces but were not encountered within the English River Subprovince. The largest subvolcanic sequence occurs north of Ben Lake in Bowerman Township (Muir and Graydon 1982). This mass surrounds a tonalitic batholith, is spatially on strike with the intermediate to felsic formation at Fredart Lake and is the lateral extension of Thurston's (1978) cycle III volcanism. Muir and Graydon (1982) indicated that a portion of this felsic unit is locally pyroclastic. The east boundary of this felsic mass is very siliceous and schistose and contains quartz, minor muscovite and chlorite. It is possible that this schistosity represents a continuation of the Sydney Lake Fault. Locally this subvolcanic rock grades into a fine-grained chlorite-biotite trondhjemite (map code 6h).

Minor subvolcanic units are also present in the volcanic sequences at Fredart Lake and Snakeweed Lake. In both of these areas, many of the normal plutonic units are very fine-grained and are easily confused with subvolcanic rocks. The porphyritic mass north of Ben Lake and those in the Snakeweed Lake area occur as enclaves within later granitoid rocks (Photo 5-1). Locally some of the porphyritic rocks

resemble the South Bay Mine porphyry. South of Fredart Lake thin sills of quartz feldspar-porphyry are less abundant than those near the South Bay Mine (Closs and Colvine, 1976, p.166). They stated that "The porphyritic unit is discontinuous, has a maximum apparent thickness of 30-50 m (100-150 feet), and is interlayered with intermediate to felsic tuffs and flows, thus suggesting, in part, an extrusive mode of formation. The porphyritic member is, however, spatially related to a majority of the sulphide showings in the field area and therefore may constitute a useful guide for prospecting."

The subvolcanic rocks are aphanitic to very fine-grained, commonly exhibit a brittle fracture pattern (Photo 5-2) and contain quartz and feldspar phenocrysts. Where quartz and feldspar phenocrysts are conspicuous, the 2-4 mm diameter quartz is commonly subrounded and locally iridescent blue to clear grey. The feldspar weathers white and is subhedral and is less abundant and conspicuous. This subvolcanic mass weathers white to light greenish-white (in chloritic parts).

In thin section quartz is the most abundant phenocryst. The quartz and feldspar phenocrysts are set in a quartzofeldspathic granular matrix. The quartz phenocrysts vary from single unrecrystallized grains to highly recrystallized composite grains. Plagioclase phenocrysts are commonly sericitized. The matrix is composed of quartz, plagioclase, muscovite, biotite, and chlorite.

A thin lens of cataclastically deformed, fine-grained equigranular subvolcanic biotite trondhjemite borders the northeast part of the Bruce Lake Pluton. The fine-grain size may have been tectonically produced and thus the unit may more aptly belong to

the sodic granitoid suite.

A small intrusive body of unknown dimensions occurs at Maskooch Lake (southeast of Upper Slate Lake). This massive rock is characterized by quartz and saussuritized feldspar phenocrysts (2-4 mm) embedded in a matrix of quartz, plagioclase, biotite, chlorite and calcite. It is more intermediate in composition than the large felsic subvolcanic mass north of Ben Lake.

In the Wabigoon Subprovince, small bodies of subvolcanic rocks are associated with the three volcanic units at Sioux Lookout, described by Johnston (1969, 1972) and Page (1978). The small, apparently circular, subvolcanic quartz porphyry plug situated midway along Kashaweogama Lake in the Savant Lake area (Wabigoon Subprovince) is mineralized with pyrite and chalcopyrite in a quartz vein near its south margin. Interestingly, this body exhibits thin (1-2 cm) layering that could have been bedding.

For the most part these subvolcanic units are regarded to be mainly intrusive but locally some portions may have reached surface, vented and gave rise to local extrusive features.

SUBDIVISION OF THE INTRUSIVE ROCKS

Intrusive rocks within the English River Subprovince comprise four principal suites. Characterization of the suites is based upon a number of parameters including chemical and modal composition, structural style, tectonic style and field relationships. The four groups are:

1) gneissic granitoid suite
2) sodic granitoid suite
3) mafic intrusive suite
4) potassic granitoid suite

The mafic intrusive suite forms a minor constituent within the subprovince while the other three major suites which comprise substantial volumes. Except for minor discrepancies the rock suites strike approximately parallel to the overall boundaries of the English River Subprovince. West of Highway 105 the suites strike roughly east-west. East of Highway 105, from Vermilion Bay northeast to Sioux Lookout the trend is deflected further northeast to Pashkokagan Lake, where east-west strikes are again apparent. The northeast strike from Sioux Lookout to Pashkokogan Lake is related to the Miniss River Fault. The batholiths near the centre of this portion of the belt strike east but nearer the fault system these trends are deflected progressively north.

Planimetric calculations (Table 2-1) indicate the four suites comprise 98% by volume of the Southern Plutonic Domain and 31% of the Northern Domain. Ironically the gneissic granitoid suite comprises only 19% of the Southern Plutonic Domain and less than 10 percent of the English River Gneiss Belt (Wilson, 1971, p.45). The usage of the term gneiss to the subprovince name thus appears a misnomer.

The subdivision of the plutonic suites is somewhat conjectural. Whereas the rock groups of the metasedimentary association from a genetically related, clearly defined migmatitic spectrum, those of the plutonic suites are less clearly genetically related. That is, as yet the suites remain as individual unassociated groups. With further

investigation it may become apparent that these groups constitute an interdigitated and gradational series. The problem of association lies in the definition of what clearly constitutes an Archean magmatic suite and the lack of an overall general classification scheme for plutonic rocks. It is only recently that White (1979) and Chappell (1979) have attempted to relate tectonic setting and chemical classification of granitic magmas in general.

Most subdivisions have been based on distinctive field characteristics (Hubbard, 1975; Gorbatschev, 1975) that other investigators include structural features, contact relations and mode of emplacement (Archibald et al. 1978). Clearly the most obvious field characteristics include spatial and temporal relationships (Hudson, 1979) and lithologic association (Gaal et al. 1978).

McRitchie (1971) first recognized definite plutonic suites in the Wanipigow-Winnipeg Rivers Region. The Manigotagan gneissic belt, Pine Falls plutonic complex, Bird River Greenstone Belt, Lac du Bonnet Pluton and Winnipeg River plutonic complex collectively constitute the western extension of the English River Subprovince in Manitoba. The plutonic suites were based on the recognition of granitic rocks of varying processes including magmatic, metasomatic, anatectic and/or metamorphic. Other workers incuding Dwibedi (1968), Jones (1973) regarded the granitic units as dominantly derived by anatexis of a metasedimentary progenitor. Ermanovics (1971, 1974) recognized two major rock groups: an early deformed cycle and a later massive undeformed cycle. At Kenora Hodgkinson (1968) recognized similar textural differences and devided the plutonic rocks into two groups: 1) a deformed Melick Gneiss Group and

2) a less deformed Melick granodiorite.In the Cedar-Clay Lakes area Westerman (1977) recognized two dominant tectonic assemblages: 1) a gneissic assemblage and 2) a later massive plutonic assemblage. He subdivided two age groups of gneissic rocks and indicated the later massive plutonic assemblage may in fact be comprised of as many as three sub-assemblages. Gower (1978) indicated two gneissic plutonic cycles and three granitoid suites in agreement with this survey. Beakhouse's (1975) classification is based on the lithologic breakdown of the English River initially set up in the field legends for this report and, except for terminology differences, concurs with the suite subdivision in this report.

Approximately 40 individual plutonic units have been recognized in association with the three major suites. These units have been identified on the basis of easily distinguishable field parameters including differences in:

1) texture;

2) type and abundance of accessory minerals;

3) colour index;

4) grain size;

5) modal composition after Ayres (1972)

6) degree of recrystallization

The initial results of this project suggested that the potassic and sodic suites could be subdivided on the basis of presence or absence of metamorphism. Ayres (1978, p.33) considered that most of the granitoid batholiths show evidence of pervasive recrystallization but are unmetamorphosed. Subsequent investigation showed the degree

of recrystallization is highly variable. In fact there is a complete spectrum ranging from highly recrystallized to weakly recrystallized to unrecrystallized varieties. The end-members of this spectrum are easily classified but recognition of the moderately to weakly recrystallized units is subjective depending on whether the primary or secondary textures is more pronounced. Allotriomorphic-granular, fine-grained-textures are enigmatic in that the texture could be metamorphic or primary (microgranite). According to Spry (1969) fine-grained rocks are more easily recrystallized than coarse-grained rocks. Generally, regional metamorphism can be regarded as strain-induced during which highly strained grains are transformed into small unstrained grains thus producing a recrystallized equigranular mosaic. Voll (1960) indicated that quartz is the most easily recrystallized of all the rock forming minerals. Higgins (1971) stated that quartz is one of the first rock-forming minerals to be affected by cataclasis. Another factor includes the trace amounts (at least 1000 ppm) of OH. Hobbs (1968) revealed that dry quartz does not recrystallize except at temperatures close to its actual melting point. Table 5A-1 summarizes field criteria used to distinguish degrees of metamorphism. Most of the potassic granitoid suite is undeformed and weakly recrystallized to unrecrystallized whereas the sodic granitoid suite shows evidence of weak recrystallization. Besides those factors listed in Table 5A-1, other evidence of metamorphism in thin-section includes:

1) presence of blastic growth

2) concentration of biotite in aligned clots

3) presence of epidote and/or sericite associated with plagioclase

4) recrystallization around margins of crystals

5) presence of retrograde chlorite after biotite

6) charge in grain size of crystals along with the development of a granular matrix

7) development of a common foliation trend in two separate units which is discordant to the contact of these two units (Ayres, 1978, p.33). This is common occurrence in the Sen Bay stock (sodic suite).

Except for the presence of heterolithic banding and tectonic reworking criteriaused to divide the gneiss suite, the differences in textural, compositional and degree of recrystallization criteria used to separate out the other suites is not entirely exclusive. There are however gross similarities in composition, texture, emplacement tectonics and relative ages of intrusion that allow the subdivision to be set up in this manner.

CHAPTER 6

MAFIC INTRUSIVE SUITE

NATURE AND DISTRIBUTION

There is little detailed knowledge of the nature and relationship of the mafic plutonism relative to the remaining three more abundant intrusive suites in the English River Subprovince. The suite itself constitutes only a minor part of the English River Subprovince (0.2 percent of the Northern Metasedimentary Domain and 2.5 percent of the Southern Plutonic Domain, Table 2-1) and partly for this reason is relatively less understood.

The mafic intrusive suite has compositions ranging mainly from gabbro to diorite to quartz diorite; local compositional extremes including ultramafic (or hornblendite) and anorthositic gabbro are reached. Locally, more intermediate compositions (quartz diorite to trondhjemite) are present and overlap the compositional gamut expressed by the sodic suite and some members the gneissic suite. Final classification of these intermediate units into one of the above is based on compositional range and structure of the associated rock types.

In the field, these rocks were subdivided into recrystallized and unrecrystallized varieties but there tends to be a continuous spectrum between those two extremes and this classification is subjective. Both the recrystallized and unrecrystallized

Members of the mafic intrusive suite are typically uniform in composition, massive to locally weakly foliated, medium- to coarse-grained and relatively unrecrystallized; characteristically, hornblende is the dominant mafic mineral present. In general, the suite has a colour index greater than 25. Weathered and fresh surfaces are coloured similarly and vary from dark grey to green-black to black. Based on style of emplacement the mafic suite may be subdivided into two dominant types:

1) stocks and sills intrusive into all of the Subprovinces (English River, Uchi and Wabigoon Subprovinces).
2) mafic dykes intrusive into the sodic and gneissic suites in the English River Subprovince only.

STOCKS AND SILLS OF THE ENGLISH RIVER SUBPROVINCE

Plutons of the mafic suite form only a few major intrusive bodies within the English River Subprovince. Based largely on spatial association there are two major types: 1) those intrusives forming isolated bodies whose original or genetic relationship is enigmatic to a certain extent and 2) those bodies spatially and probably genetically related to the sodic granitoid suite.

Isolated Plutons of Uncertain Origin

In this group are four major intrusions within the English River Subprovince: Muriel Lake and Ena Lake intrusions (just north of Kenora, described by Gower (1975, 1978, p.437), Bruce Lake pluton (Figure 6-1) and the Pakwash Lake pluton (Figure 6-1). These intrusions tend to be oblate in form; elongation is generally conformable to

the overall trend of the subprovince in the vicinity. Contacts with the country rocks tend to be conformable and sharply defined. Commonly they contain enclaves of the surrounding host lithologies. Essential mineralogy includes mainly plagioclase, hornblende, biotite, K-feldspar and quartz. Both quartz and mafic minerals exhibit considerable, sympathetic variation in abundance. K-feldspar also exhibits a considerable modal range; its distribution and concentration is chaotic unrelated to the quartz/mafic mineral variations. Except for the Pakwash Lake pluton which is slightly recrystallized, all of these plutons are generally unrecrystallized and are dominantly quartz diorite in composition. Compositional differences arising from variations in the quartz/mafic mineral/K-feldspar content are chaotic and the changes occur gradationally.

Muriel Lake pluton

This pluton is a east-to southeast-trending, massive to moderately foliated stock that extends from just north of Kenora west to the Manitoba-Ontario border. The intrusion is dominantly quartz diorite in composition; modal analyses are given in Figure 6-2, Diagram 1. In its western part it intrudes members of the sodic granitoid suite but is intruded by units of the potassic granitoid suite. It commonly contains hornblendite enclaves. Gower (1978, p.43) studied the southeast end of the pluton in some detail and described four main rock types:

1) the main most extensive unit varies from quartz diorite to diorite to locally gabbro (Photo 6-1); this phase exhibits a wide range in texture and composition and includes leucocratic, mesocratic, melanocratic, fine-, medium- and coarse-grained varieties.

Grain size is commonly 3 to 4 mm but locally plagioclae altains measurements of 5 by 8 mm.

2) a secondary unit of granodiorite (Gower, 1978, p.438) is also present.
3) locally this second unit grades into a third characterized by magacrysts of K-feldspar.
4) a fourth unit comprised of hornblendite occurs only as enclaves (1 to 2% by volume) throughout the intrusive.

The hornblendite is composed of very coarse-grained (10 by 15 mm) hornblende crystal aggregates and interstitial plagioclase that locally exhibits a cumulate texture. The contacts of the intrusion with the host-rock are generally sharp. Gower (1978, p.438) suggests this is a cumulate unit genetically related to the intrusion that was disrupted and carried up as enclave during the intrusion. The mineralogy of the intrusion is characterized by plagioclase (An_{23-38}), hornblende, biotite, quartz, K-feldspar, sphene, allanite, apatite, epidote (mantles allanite), pyrite, retrograde chlorite and carbonate (Gower, 1978, p.40?). Plagioclase is subhedral to euhedral, well twinned and exhibits strong, normal, local oxillatory zoning. Hornblende is poikiloblastic with inclusions of quartz and apatite.

Ena Lake pluton

The Ena Lake pluton is triangular in plan and intrudes a synformal structure within the gneissic suite (Gower, 1975, p.54) just north of Kenora (Figures 6-1). The intrusion is moderately foliated and contains essential minerals plagioclase, quartz and hornblende

and accessories biotite, K-feldspar, epidote, apatite, sphene and magnetite. The Ena Lake Intrusion is petrographically similar to the Muriel Lake intrusion but chemically is more magnesium rich (Figure 6-1, Diagram 1). K-feldspar megacrysts (1.5-2.0 cm) are common along the south margin of the intrusion. There are two thick wedges of mafic volcanics just north of the Ena Lake pluton. The metavolcanic rocks and the Ena Lake pluton may be genetically related but whether they were once part of the Wabigoon Subprovince is not known.

Pakwash Lake pluton

The Pakwash Lake pluton is situated between an enechelon offset or splay of the Sydney Lake cataclastic zone at the northern border of the English River Subprovince (Figure 6-1). The 5 by 11 km, oblate pluton was first described by Shklanka (1970, p.9-10). The pluton contains enclaves of metapelite, metawacke and amphibolite. According to Shklanka (1970, p.10): "The pluton is composed of rocks that range from quartz diorite to diorite, with the latter more prevalent in the northern part. Mineralogically, it resembles the Bruce Lake pluton, but quartz, usually in the 5 to 10 percent range, is less abundant and mafic minerals, usually in the 10 to 25 percent range, are more abundant. Myrmekite, present in both plutons, is more pronounced in the Pakwash Lake pluton.

Rocks of the Pakwash Lake pluton commonly possess a marked mineral lineation defined mainly by the alignment of amphibole grains. Orientations range from gentle to moderate angles plunging to the north-northeast in the northern part of the pluton, to

moderate to steep angles plunging to the southeast in the southern part. A primary foliation is rarely developed; in some places, a secondary foliation can be recognized.

Contacts of the pluton with the host-rocks are usually sharp and generally conformable; some are marked by slight feldspathization or a narrow injection zone. Enclaves are not numerous in the pluton, but amphibole-rich 'clots' are common."

In the field the rocks appear to be recrystallized but this was not confirmed by thin section examination. The pluton intrudes metasedimentary migmatites of the northern domain. A fine-grained trondhjemite sill trends along the western margin of the pluton; its genetic relation to the mafic pluton is unknown.

Bruce Lake pluton

The Bruce Lake pluton was also partly mapped by Shklanka (1970, p.9). This pluton also intrudes clastic metasedimentary rocks near the north contact of the English River Subprovince (Figure 6-1). The 6 by 27 km pluton is conformable to the east-northeast trend of the English River Subprovince. Compositionally the rock varies from medium-grained diorite to quartz diorite to locally syenodiorite and gabbro (Ayres, 1972). Compositional variation is chaotic and gradational, no contacts between the above phases were obvious in the field. The pluton possesses a weakly developed internal foliation. Enclaves of mafic metavolcanic rocks and hornblendite are common whereas intermediate metavolcanic and trondhjemite to quartz diorite enclaves are rare. Shklanka (1970, p.9) also noted enclaves of iron formation at Bruce Lake.

The main rock type contains plagioclase (An_{33}), K-feldspar, quartz, hornblende, biotite,

apatite, and minor epidote, sericite, chlorite, allanite (with epidote rims), zircon and sphene. Locally plagioclase exhibits a subtle porphyritic texture. Shklanka (1970, p.9) also noted that quartz and K-feldspar show considerable modal variation and are responsible for the main compositional variation:

"The rocks are medium-grained, light- to medium-grey and mainly massive. Locally, a weak foliation is present and in one area a swirled layering was noted. A porphyritic facies, with medium- to coarse-grained plagioclae phenocrysts, occurs in places. The rocks are composed mainly of plagioclase (oligoclase-andesine); microcline or perthite forms up to 25 percent of the volume, but is erratic in development; quartz forms from 5 to 18 percent of these rocks by volume; hornblende and biotite make up about 15 percent of the rock volume; sphene, apatite, and zircon are minor accessory minerals; and secondary epidote, sericite, or chlorite were noted but not in abundance. Myrmekite is common along plagioclase grain boundaries."

Plagioclase is medium-grained (locally it forms laths up to 7.5 mm giving it a subporphyry texture), exhibits myrmekitic textures at grain boundaries, is poorly twinned and moderately sericitized. Quartz is mostly unrecrystallized but locally shows granular development at the margins. In the cataclastic units the quartz is completely granulated.

The extension of the Sydney Lake Fault passes through the northeast margin of the Bruce Lake pluton. There, the fault zone is at least 1 km in width. Cataclastic deformation is intense, causing the local development of pseudotachylite (Photo 6-2). Plagioclase is the least commuted by the cataclastic deformation; it remains

medium-grained in a fine to very fine-grained cataclastic matrix and gives the rock a porphyritic texture (Photo 6-2).

Stocks and Sills Associated With Other Intrusive Suites

Several mafic intrusions are spatially associated with other major rock suites. Their close spatial link implies a possible genetic link. These intrusives include:

1) Adamhay Lake pluton (see Figures 6-1, 2-1);
2) Celt Lake on southwest corner of Bluffy Lake Batholith (Figures 6-1, 2-1);
3) Broadcast Lake stock;
4) Conifer Lake intrusion;
5) India Lake intrusion;
6) Hooker Lake stock in the Armit Lake complex;
7) Miniss River sill;
8) Chamberlain Narrows Complex

The India Lake, Hooker Lake and Miniss River masses occur in the Southern Plutonic Domain; the remainder intrude the Northern Metasedimentary Domain (Figure 6-1). In general these intrusions differ from the previous bodies in being recrystallized and slightly more mafic with less modal K-feldspar.

The close spatial relationship of the Adamhay Lake, Celt Lake, and Chamberlain Narrows mafic intrusives to members of the sodic suite suggests they may be older, genetically related units similar to the older mafic unit of the Sen Bay stock (see Chapter

8). The field classification legend is strictly lithological, based on colour index; as a result these units were placed in the mafic suite due lacking evidence of a genetic kink with the early sodic granitoid suite. The Adamhay Lake pluton locally contains clinopyroxene and rare orthopyroxene (hypersthene). The India Lake and Hooker Lake stocks and the Miniss River sill all intrude the sodic granitoid suite. All of the above intrusives vary in composition from diorite to quartz diorite and are recrystallized.

Broadcast Lake stock

This sill-like pluton, emplaced mainly within migmatized metasedimentary rocks, extends for 32 km with an average width of 4 km and strikes northeast. Desnoyers (1977, p.19) mapped a border unit of foliated to gneissic biotite trondhjemite and a centre composed of quartz diorite. The rock is dominantly recrystallized quartz diorite with a colour index of 30 to 35. Internal fabric is variable from massive to strongly foliated. Modal analyses of the pluton and associated amphibolite inclusions are given in Fig. 6-2 (Diagram 3).

Mineralogically the pluton comprises plagioclase (oligoclase-andesine), hornblende, biotite, quartz, K-feldspar, sphene, magnetite, retrograde chlorite, apatite and allanite. K-feldspar varies from 0 to 12.5% (Table 6-1) and is regarded as partly secondary (metasomatic).

Conifer Lake intrusive complex

The Conifer Lake intrusion was studied in detail by Panagapko (1976). The complex forms a circular structure 1200 m in diameter that is evident on the aerial photograph and is expressed as a small, oval negative anomaly (aeromagnetic map 850G; Panagapko,

1976, p.4). The complex is situated in the center of small quartz-monzonite (potassic suite) intrusion (Figure 6-1) about 10 km north-northeast of the Campfire Lake pluton within the Northern Metasedimentary Domain.

The complex comprises:

1) a core of intermediate to felsic plutonic rocks that range in composition from trondhjemite to granite, dominantly granite (see Panagapko 1976; p.34);
2) this core is mantled by a continuous rim of meladiorite (less than 10% feldspar) that changes outwards to an outer discontinuous marginal zone of diorite.

The core of intermediate to felsic plutonic rocks contains garnet and sillimanite (Panagapko, 1976, p.34). The presence of the aluminosilicate minerals, Fe_2O_3/FeO ratios (Panagapko, 1976, p.20) locally less than 0.58 (Figure 9-4, this report) and the dominant quartz monzonite to granite composition all suggest some of this unit is homogeneous diatexite - i.e., a partial melt derived from metasedimentary rocks.

The relation between the (ultramafic) meladiorite and mafic (diorite) is unknown as no sharp contacts were observed due to poor exposure (Panagapko, 1976, p.9). The meladiorite has a variable colour index of 70-90, is medium- to coarse-grained (1-9 mm) and massive. The diorite occurs as discontinuous isolated patches. According to Panakapko (1976, p.10) the granitoid rocks clearly intrude the diorite unit. The diorite is medium-grained, massive to locally foliated and has a colour index of 65.

The meladiorite and diorite unit is composed of olivine, augite, hypersthene, hornblende, biotite, plagioclase (An_{35}) as reported by Panakapko, 1976, p.11-13. The plagioclase varies from 5-25 percent and ranges in size, from 0.1 to 5.0 mm; it exhibits

good albite twinning, is subhedral to anhedral and is interstitial. Accessory minerals include epidote and opaque minerals. The mafic minerals do not appear to be recrystallized.

According to Panagapko (1976, p.iv) chemical analyses indicate:

"that the Conifer Lake meladiorites are richer in total iron and alkalis than the average peridotite or pyroxenite (Nockolds and Allen, 1954), whereas the diorites are richer in Mg and poorer in alkalis than an average diorite. The granitic rocks have equal amounts of Na_2O and K_2O and are low in CaO. Trace element data show that the meladiorites are high in Ba, Be, Li, and Rb and the diorites are high in Cr and Cu with respect to similar rock types from other sources".

Panagapko (1976, p.28) was unable to postulate a genetic relationship between the central granitoid core rocks and the mafic to ultramafic rim. The granitoid rocks are intrusive into the mafic to ultramafic rim (Panagapko, 1976, p.28) and the former are regarded to be probably diatexite that resulted from partial melting of the metasedimentary rocks.

Stocks and Sills of the Uchi Subprovince

There are only four major mafic intrusions distributed within the Uchi Subprovince portion of this survey:

1). three metagabbroic sills:

a). a coarse-grained magnetite-bearing metagabbro to locally ultramafic sill in part geophysically interpreted to occur near the Trout Lake river about 25 km northeast

of Bruce Lake.

b). a long metagabbro to metadiorite sill conformable with the supracrustal sequence north of Ben and Slate Lakes.

c). a large body associated with the western extension of the Dixie Lake Greenstone Belt.

All of these may represent material coeval with the extrusives.

2). Papaonga Lake pluton situated northwest of Papaonga Lake;

3). a layered anorthositic gabbro sill within the Lake St. Joseph Greenstone Belt.

Papaonga Lake pluton

The Papaonga Lake pluton is a 5 by 13 km, east-northeast-striking, egg-shaped body which intrudes metavolcanic and unmigmatized metasedimentary rocks of the Uchi Subprovince. The intrusion is medium-grained to coarse-grained, equigranular and massive to locally weakly lineated at the margins. Minor enclaves of metasedimentary rocks and diorite to gabbro are present. The rock is petrographically similar to the individual intrusions in the English River Subprovince in that the (colour index), quartz and K-feldspar contents are highly variable. In general the color index is slightly lower and the K-feldspar content is slightly higher than the other mafic intrusions in the English River Subprovince. Compositions varyfrom diorite to mostly quartz diorite to extremes of syenodiorite and andesine monzonite. In thin section the pluton is comprised of plagioclase (andesine), quartz, biotite, antinolite, K-feldspar, hornblende, retrograde chlorite, epidote (mantles allanite), sphene, zircon, allanite, carbonate and opaque oxides.

Plagioclase is mostly untwinned to localy well twinned, heavily sericitized locally exhibits normal zoning and is characterized by irregular, ragged margins suggesting recrystallization has occurred. K-feldspar is highly variable in occurrence and grain size; it tends to be absent in the marginal unit. Baced on examination of a few outcrops, it is apparent that the margin of the pluton is dominantly diorite to quartz diorite while the interior is progressively enriched in potassium and attains syenodiorite and andesine monzonite (in abundant K-feldspar zones) compositions.

The Lake St. Joseph Layered Mafic Complex

The mafic sill within the Lake St. Joseph Greenstone Belt (Figure 6-1) was studied in detail by Smith (1977) and is is interpreted as synclinally folded. Structural interpretation is based on the fact that the southeast-striking sill is situated between an east-northeast facing mafic metavolcanic sequence to the west and a southwest-facing metasedimentary sequence to the east.

Smith (1977, p.ii, 6) indicates the sill was intruded in three stages; the first stage can be subdivided into six distinct layers. Table 6-2 summarizes the petrography and facing criteria of the layered sill (Smith, 1977, p.1-39). The sill shows spectacular mafic/felsic segregations in the layering (Photo 6-3), clots of mafic minerals (Photo 6-4) and dikes. Most of the layering and clots show normal segregation; i.e., the mafic minerals have sunk while the felsic (mainly plagioclase) unit has risen. The components faces indicate the layering dominantly northeast but locally unit 1B-ii (Table 6-1) exhibits southwest-facing reverse layering. The clots tend to be slightly coarser-grained than that

of their host.

Chemical analyses (Figure 6-3) indicate the metagabbro unit of stage I exhibits a normal tholeiitic Fe-enrichment differentiation pattern while the later two stages, although probably related to the same magma chamber do not show the strong differentiation trend exhibited by the first intrusion. With increasing height up the layered sill, the strongly differentiated intrusive (No. I) stage shows (p.41):

i) increasing SiO_2, P_2O_5, and Na_2O.

ii) decreasing MgO, CaO, Cr and Ni.

According to Smith (1977, p.41) the increasing P_2O_5 indicates fractional crystallization as it tends to concentrate in residual liquids crystallizing out abundant apatite late in the magma's history. The trend of SiO_2 shows a near mirror image but opposite to the trend of $FeO + Fe_2O_3$.

The pegmatite pods or patches probably represent an iron and volatile rich residual phase that collected near the center of the predominantly crystalline magma chamber (Smith, 1977, p.54).The coarser-grained clots represent very late products of crystallization from liquid pools of residuum that were trapped in the crystalline rocks (Smith, 1977, p.57). The lack of a chilled contact in the second stage suggests it was still warm and was probably intruded earlier than the third intrusive stage which does have a chilled margin (Smith, 1977, p.60-61). The second stage formed a plagioclase-rich crystal mush at the top of the chamber (Smith, 1977, p.62).

Plutons of the Wabigoon Subprovince

There are two areas in the Wabigoon Subprovince within the limits of the Survey that are intruded by mafic plutonism. Briefly these are:

1). Sturgeon Lake area (near Kenora).

Modal analyses are given in Figure 6-2, Diagram 2. The intrusive is part of the Scovil Lake Batholith (Gower; 1975, p.76) and it varies from quartz diorite to granodiorite with colour index between 19 and 24. This intrusion is probably most closely related to the sodic intrusives.

2). east of Minnis River Fault

Irregularly shaped, both unmetamorphosed and metamorphosed metagabbro to metadiorite, locally with rare anorthositic pods and bands intrude the Wabigoon Subprovince succession east of the Miniss River fault (see Figure 8-5 for location; also Breaks et al. 1980). In general those rocks are medium to coarse-grained, massive and characterized by the following essential minerals: plagioclase (oligoclase/andesine), hornblende and minor quartz. Locally there are coarse-grained to very coarse-grained clots of plagioclase and hornblende whose growth is probably due to metamorphic recrystallization. The close spatial association of some of these intrusives to the terminations of the Sioux Lookout and Sturgeon Lake Greenstone Belt suggest they maybe related to the volcanic rocks of the belt. Chemical analyses (Table 3-3) indicate the Sioux Lookout gabbroic intrusives are more alkali rich on an AFM diagram (Figure 3-1, Diagram 1) than their associated mafic volcanics. Unlike the Separation Lake intrusions which possibly differentiated to give rise to the volcanic sequence, the gabbroic intrusives at Sioux Lookout appear to be a later differentiate than their spatially associated

volcanic counterparts. However, on the TiO_2-K_2O-P_2O_5 (after Pearce et al. (1975)) the Sioux Lookout intrusions plot towards the K_2O apex in the non-oceanic field similar to the Separation Lake intrusives (figure 3-5). The Ti-Cr diagram (Figure 3-5) after Pearce (1975) for the Sioux Lookout intrusive and extrusive rocks shows considerable scatter.

Mafic Dykes, Enclaves and Derived Amphibolite

Amphibolite lenses and bands occur within the gneissic, sodic and potassic granitoid suites throughout the English River Subprovince. These lenses and bands are observed both discordant dykes and concordant masses (in which case their origin is questionable). Understanding their origin is critical to the overall history of development of the English River Subprovince. Note that no genetic link is implied in grouping these amphibolite lithologies with the mafic plutons of the mafic intrusive suite.

Amphibolite units are an essential part of the Cedar Lake Gneisses (Westerman, 1977, p.43), the Kenora Gneisses (Gower, p.199, 377) and in fact are found throughout the gneissic portion of the subprovince. The main problem with the amphibolite units lies in the interpretation of their origin; ie. they represent either one of two possibilities:

1). a previous volcanic terrain that was obliterated during later plutonic intrusion of the gneissic, sodic and potassic granitoid suites, i.e., they predate the plutonism).

2). deformed and undeformed dykes intruded into the plutons, i.e., post-dating the plutonism).

<u>Mafic Dykes</u>

Gower (1978, p.377) has documented about 60 occurrences of amphibolite dykes

in the Kenora Gneissic Suite and the authors have mapped numerous mafic dykes in the Chamberlain Narrows-Sioux Lookout region where they intrude both the gneissic (see Photo 7-6 in later text), sodic granitoid suites (Sen Bay stock) and the metasedimentary migmatites (Photo 6-5). Most of the dykes are narrow (less than 0.3 m) but locally some are reach to 2 or 3 m in the metasedimentary migmatite rocks, i.e., Chamberlain Narrows, Lac Seul: Photo 6-5 and Miniss Lake). In all the above cases the dykes exhibit discordant contacts and their intrusive origin is indisputable. The dykes within the gneissic and sodic suites are generally highly discontinuous over lengths of 4 to 5 m maximum due to offset. However, in other areas such as the Cedar Lake gneisses concordant amphibolite units and mappable for up to 1 km lengths. In places these form linear trains (Photo 7-5) of deformed, boudined, mafic enclaves (Westerman 1977, p.43) that are suspected of representing original dykes intrusive into the protolith of the gneissic suite (Westerman, 1977, p.45). The mafic dykes within the gneissic suite are described in detail within the section on the Gneissic Suite (Chapter 7).

Mafic Enclaves

The mafic enclaves are found in all of the major (gneissic, sodic and potassic) suites. They are isolated, conformable rafts varying in length from several cm to several meters and generally have widths comparable to that of the mafic dykes. The larger more extensive amphibolite rafts occurring near or along the Northern-Southern Domain Interface are regarded to be part of a once more extensive greenstone belt continuous from Separation Lake Belt. The smaller isolated enclaves that occur elsewhere

throughout the English River Subprovince remain problematical with respect to origin.

CHEMISTRY OF THE MAFIC INTRUSIVE SUITE

The dykes and enclaves of amphibolite representing the extension of the Separation Lake Belt are all characterized by a similar mineralogy: hornblende, plagioclase, quartz and minor hypersthene, diopside and magnetite in the granulite areas. Chemical analyses of the Kenora amphibolites (from Gower, 1978, p.559-562, 578), Chamberlain Narrows (Lac Seul) - Sioux Lookout mafic dykes and enclaves are given in Tables 6-3, 6-4, 6-5, 6-6 and 6-7 respectively. In addition the chemical analyses of the amphibolites described by Westerman (1977, p.279, 280) in the Cedar Clay Lakes area are also utilized. Westerman (1977, p.111) subdivides the amphibolites into two groups: group I amphibolites occur as enclaves within the gneissic suite and he suspects these represent original dykes. Westerman's second group of amphibolites occur as enclaves in the sodic and potassic granitoid suites; Westerman (1977, p.111) suspects these to be mainly of extrusive origin. Chemical analyses of the above types have been plotted on various diagrams in order to discern if any of the mafic groups (volcanic, mafic stocks, dykes and enclaves) has any distinct chemical signature or affinity.

COMPARATIVE CHEMISTRY AND MODERN ANALOGUES

The usefulness of discrimination diagrams lies in the nature or degree of immobility of the elements chosen. According to Floyd and Winchester (1975, 1978) elements such as Ti, Zr, Y, Nb, P and REE are relatively immobile. Pearce et al. (1975) use incompatible elements TiO_2-K_2O-P_2O_5 and indicate Archean basalts and dyke swarms fall

within the oceanic field. Pearce and Cann (1973) utilize the elements Ti, Zr, Y, Sr, Nb indicating Ti, Zr, Y and Nb are fairly stable and represent the best selection of immobile elements; both Sr, and Ti can exhibit some mobility. According to Gill (1979) Archean tholeiitic basalts have uniformly lower Ti, Zr and P than those in modern suites. Gill (1979) also points out that Cr, Ni and Co in Archean tholeiitic rocks are distinctly higher than island arc tholeiitic rocks. he suggested that the Archean basalts are a separate entity and that the differences in chemistry do not allow comparison to modern analogous. Nevertheless the following diagramatic plots are given for comparative reasons; no absolute genetic implications are meant.

From the previous diagrams (Figures 3-1, 3-2, 3-3, 3-4) and the following chemical plots it is obvious that the Separation Lake Volcanic and intrusive mafic rocks are essentially unaltered. Suc data will in part be used for comparative chemical models.

The following abbreviations are used in the diagrams:

OFB = ocean floor basalt

CAB = calc-alkaline basalt

LKT = Low K-tholeiite (island arc environment)

WPB = Within Plate Basalts

IAB = Island Arc Basalts

The Separation Lake volcanic and intrusive rocks form a fairly tight cluster partly within the abyssal tholeiitic field of Miyashiro (1974) and Miyashiro and Shido (1975) (Figure 6-4, diagram 1). The Separation Lake intrusive rocks show a distinctly lower TiO_2/FeO(Total)/MgO ratio than their extrusive counterparts. By comparison the Sioux

Lookout extrusive and intrusive rocks show a chaotic scatter (Figure 6-4; Diagram 2). The amphibolite phases that occur as both extrusive rocks, intrusions, and inclusions (Figure 6-4; Diagrams 3, 4, 5) in the English River Subprovince also plot near the abyssal tholeiitic field and, similar to the Separation Lake Rocks, are characterized by lower abundances of TiO_2 than recent abyssal tholeiitic rocks having comparable FeO total/MgO ratios. The lower TiO_2 of Archean amphibolites in comparison to recent oceanic tholeiites was first noted by Glikson (1972). The only other pattern discernable is in the amphibolites in the Cedar-Clay Lakes area: Westerman's group I amphibolite enclaves in the gneiss (which he possibly regards as original dykes) have higher $TiO_2/FeO_{total}/MgO$ ratios than the enclaves in the sodic/potassic suites (which he regards as extrusive). This trend is in direct contrast to the Separation extrusive/intrusive trend. The amphibolite extrusives/intrusive dykes and enclaves (Figure 6-4, diagrams 3, 4, and 5) exhibit considerable more variations in the TiO_2/FeOtot/MgO ratio than that indicated by the Separation Lake Sequence.

On the Pearce and Cann (1973) Ti/100-Zr-Sr/2 diagram both the extrusive and intrusive rocks of the Separation Lake Belt and the Sioux Lookout metavolcanic rocks plot in the OFB field (Figure 6-5, diagram 2). The Sioux Lookout metagabbroic rocks plot in the calc-alkaline basalt (CAB) field (Figure 6-5; Diagram 1). Mafic metavolcanic rocks from the granulite metamorphic zone at Chamberlain Narrows (Lac Seul) show a tendency to plot in the OFB field similar to the other volcanic areas while enclaves and dykes tend to plot in the CAB field (Figure 6-5, Diagram 3). The fine-and medium-grained amphibolites in the Kenora area (Gower, 1978) plot in both the OFB and Low K-tholeiite

amphibolites in the Kenora area (Gower, 1978) plot in both the OFB and Low K-tholeiite (LKT fields) while the dykes plot in the CAB field (Figure 6-5, Diagram 4).

Geochemical plots on other diagrams including the Ti/100-Zr-Y.3 diagram (figures 6-6, 6-7 after Pearce and Cann, 1973), the TiO_2-P_2O_5-K_2O diagram (Figures 6-8, 6-9 after Pearce et al., 1975) and the log-log Ti-Cr (Figure 6-7 after Pearce 1975) give a similar relation. That is, in all of these discriminatory diagrams there is a general trend that:

1). the extrusive rocks exhibit a tendency to plot within the oceanic basalt field;

2). the enclaves and dykes tend to plot within the non-oceanic (continental) basalt field;

3). the dykes plot furthest away from the oceanic basalt field.

Whether these are truly magmatic chemical variation or later metamorphic processes is uncertain. Gower (1978, p.215) interpreted the potassium enrichment trend of the amphibolites in the Kenora area (Figure 6-8) as being due to metamorphic effects. Westerman (1977, p.112) regarded that the higher K_2O/TiO_2 ratios of his amphibolites (Figure 6-8) as due to metamorphism. Floyd and Winchester (1978) have indicated phosphorous is fairly immobile and on the TiO_2-P_2O_5-K_2O diagrams this appears to be substantiated. However, in a TiO_2-P_2O_5 x 10 - MnO (also incompatible elements) diagram (Figure 6-10) phosphorous in enclaves does in fact show considerable variation.

From the previous chemical plots the following points are apparent:

1). metavolcanic rocks from Separation Lake, Sioux Lookout greenstone belt and Chamberlain Narrows plot entirely within or close to OFB (oceanic field) the

following diagrams:

TiO_2/100-Zr-Sr/2 (Pearce and Cann, 1973)

$Ti0_2$-K_20-P_20_5 (Pearce et al. 1975)

Ti/100-Zr-Y.3 (Pearce and Cann)

2). the Separation Lake gabbros also plot within the OFB field in all the above plus one Ti-Cr diagram (Pearce, 1975). This suggests the gabbroic rocks are genetically related to the metavolcanic rocks especially considering the low scatter (immobility or analytical/sampling errors) evident in most diagrams.

3). Sioux Lookout gabbroic rocks plot outside the OFB field in all the above. They plot in the CAB field or continental basalt field. This suggests perhaps the.PA gabbroic rocks are not related to the metavolcanic rocks.

In all pertinent diagrams the mafic dykes (of known intrusive origin) in the English River Subprovince are chemically distinct and plot away from the OFB field. The only exception to this is the Ti-Cr (Figure 6-7) diagram after Pearce (1975). In most cases there is a tendency for these dykes to plot in the CAB field (Figures 6-5, 6-6, 6-7), or in the non-oceanic field (Figure 6-9) suggesting an intrusive origin.

The fine-grained enclaves of amphibolite in the Kenora area (Gower, 1978) also plot in the oceanic field ($Ti0_2$-K_20-P_20_5) or the OFB to LKT field suggesting they also are extrusive. By comparison the medium-grained amphibolites at Kenora tend to plot in the CAB fields or non-oceanic fields, similar to the dykes, suggesting an intrusive origin. Perhaps the variation here is metamorphic but Gower (1978, p.217) did not indicate a possible genetic link between the medium grained amphibolites and the dikes.

Westerman's (1977) mafic enclaves in the gneisses (group I) plot further away from the oceanic field (Figure 6-8) in comparison to the group II amphibolite enclaves in the sodic and potassic granitoid suites. Both types plot in the continental basalt field suggesting an intrusive origin. However, this may be due to the effects of metamorphism. Even so chemistry indicates there is a greater possibility that the group II are in fact more extrusive in character while the group I, which do plot further away from the OFB similar to the dykes, are more intrusive in origin.

Both the inclusions and the dykes in the Chamberlain Narrows-Sioux Lookout area show a tendency to plot in the CAB fields or continental (non-oceanic) fields. The only exception to this is the Ti-Cr diagram after Pearce (1975).

In summary, it is uncertain what degree of the chemical variation in the amphibolite rocks is due to metamorphic processes or to primary magmatic activity as envisaged by Gill (1979). However, the previous diagrams do appear to be able to discriminate between extrusive and intrusive amphibolites. The mafic metavolcanic rocks tend to plot in the ocean floor basalt field for modern basalts; the dykes tend to plot in the calc-calc-alkali or continental fields for modern basalts. The enclaves are intermediate between these two groups, most appear to plot in the non-oceanic fields similar to and suggesting many may be dykes transposed conformably by later tectonics but some (fine-grained amphibolites at Kenora etc.) may be originally extrusive.

Lithophile trace element chemistry tends to concur with the above relationships (Table 6-8). In nearly all cases the intrusive rocks, relative to their extrusive counterparts, are enriched in Ba, Rb, Sr and to some extent K. Base metal chemistry is less conclusive

(Table 6-9). The Separation Lake intrusive rocks are enriched in Cr relative to the extrusives and this is an expected trend if the latter did in fact differentiate from the former. The Sioux Lookout intrusive rocks with respect to their extrusive counterparts are depleted in Cr. The Lac Seul mafic enclaves, dykes and extrusive rocks all exhibit similar Cr, Cu, Ni, Zn values. Except for decrease in Cu, these values most closely approximate the volcanics at Sioux Lookout and Separation Lake.

In general the AFM element plot (Figure 6-11) indicates the amphibolite enclaves and dykes are chemically similar to the extrusive rocks of the Separation Lake, Chamberlain Narrows and Sioux Lookout areas (Figure 3-1). The enclaves in the gneissic suite of the Cedar Clay Lakes area (Westerman 1977) (Figure 6-11, Diagram 1) are more alkalic than enclaves in the sodic and potassic granitoid suites, i.e., those in Westerman's (1977, p.111), Group 2 amphibolites which he regards to be extrusive. This trend concurs with the intrusive/extrusive alkalic trend exhibited by the Sioux Lookout rocks (Figure 3-1, diagram 1). Gower's (1978) medium-grained amphibolites plot slightly more magnesian than the fine-grained amphibolites (Figure 6-11; diagram 2). It has been suggested based on the previous discrimination diagrams that the medium-grained amphibolites are possibly intrusive in that they plot outside the oceanic field. If so, on the basis of their more magnesian character, they may represent the original magma from which the fine-grained Kenora amphibolites differentiated. The mafic dykes, enclaves and extrusive rocks (Figure 3-1: diagram 3) of the Lac Seul area exhibit similar chemical plots on the AFM diagram but do not show any chemical distinction themselves. The above relationship concurs with both the discriminatory and lithophile trace element chemical

trends.

CHEMICAL RELATIONSHIP OF DYKES AND PLUTONS OF THE MAFIC INTRUSIVE SUITE

The AFM and CNK element (weight %) plots of the Lac Seul dykes, Sioux Lookout and Muriel Lake plutons (Figure 6-12) indicates possible chemical distinctions between rocks of the mafic intrusive suite and dykes. On the AFM (element wt %) diagram the dykes are Fe-Mg rich and may have differentiated from a more primitive magma. The gabbroic stocks in the Sioux Lookout to Sturgeon Lake area plot further along the calc-alkaline trend on the AFM diagram. The Muriel Lake intrusion, typical of the mafic plutons in the English River Subprovince, is even more alkaline. The CNK element plot for the same suites (Figure 6-12) indicates a progressive potassium enrichment concomittant with this Fe-Mg depletion. It will be shown that this overall potassium enrichment-Fe/Mg depletion trend is a common evolutionary pattern both within and across the major (gneissic, sodic and potassic) plutonic suites. The Li/Mg ratio has been shown to increase with differentiation (Nockolds and Allen, 1953; 1954; 1956; the increase in this ratio Figure 6-12) concurs with the above Fe-Mg depletion trend.

It is not intended to imply that the mafic dykes are genetically linked with the plutons of the mafic suite. All that is meant is that the dykes are chemically distinct from the plutons. The dykes appear to have been generated from a more primative magma source as a possibly earlier differentiate while the latter were generated from a much more evolved magma source. Whether these magma sources are related is not known but in

all probability they are not. It is interesting to note that the two areas where mafic dykes are observed (the Kenora and Chamberlain Narrows - Sioux Lookout area) also appear to have the greatest number and volume of mafic plutons (although in the Sioux Lookout area most of these stocks intrude into the Wabigoon Subprovince).

The fact that the dykes are metamorphosed and deformed while many of the stocks are unrecrystallized also suggests the former are older and this concurs with their AFM-CNK element trends.

AGE AND EMPLACEMENT OF THE MAFIC INTRUSIVE SUITE RELATIVE TO THE IMPORTANT PLUTONIC SUITES

Gower (1978, p.479) indicated that plutons of the mafic suite in the Kenora area, on the basis of structure, post-date the sodic and potassic granitoid suites and this may well be the case elsewhere. This is not the case with respect to the mafic dykes and enclaves. There are numerous examples of mafic enclaves and dykes being intruded by dykes of the sodic and potassic granitoid suite (Photo 6-6). The fact that there are both conformable (highly deformed, mafic bands suspected as dykes) and disconformable mafic dykes (that are relatively undeformed) suggests there are at least two ages of emplacement of mafic dykes: an early deformed set and a later undeformed set.

To the authors' knowledge the dykes are only present in the gneissic suite and in the heterolithic sodic suite complexes. There are no known mafic dykes in any of the diapirs of the sodic and potassic granitoid suites. The fact that there are both undeformed and deformed dykes in these two suites suggests their emplacement duration lasted a time

span at least equivalent to the time of exolution of the heterolithic complexes which date back to at least 3.3 Ga (Sen Bay stock: Hinton & Long, 1979). The diapiric event probably began at around 2.65 Ga and this suggests an emplacement interval for the mafic dykes of up to 700 Ma.

SUMMARY

Within the English River Subprovince, the mafic intrusive suite comprises amphibolite enclaves, dykes, sills and stocks. Relative to the gneissic, sodic and potassic suites this is volumetrically minor. The mafic dykes and sills intruded the gneissic and sodic suites appear to be possibly earlier than the major mafic plutons; whether these two groups are genetically related or not is unknown. Some of the amphibolite enclaves within the major intrusive suites are chemically similar to the dykes and may represent disrupted dyke segments. Other examples such as the fine-grained amphibolites at Kenora (Gower, 1978 and Westerman's Group II amphibolites) may possibly be extrusive and represent relicts from an unknown early volcanic pile or are rafts of the Separation Lake Greenstone Belt or the Wabigoon Subprovince.

CHAPTER 7

GNEISSIC GRANITOID SUITE

INTRODUCTION

Although commonly postulated to be a major constituent of Archean high-grade terrains (Windley and Bridgewater, 1971, p.39), the gneissic granitoid suite is the least abundant of the major rock units of the English River Subprovince. Due to its complexity and extreme variability in both composition and fabric, the gneissic suite is the least understood of the rock units in the English River Subprovince. One of the most longstanding and intriguing problems in Archean terranes concerns the relationship between the gneissic (high grade) and greenstone-granite (low grade) terranes. Parts of the problem stem from the fact that it has become popular in recent years to regard the high grade terranes as representing the oldest rock association in the Archean (Windley, 1973; Beakhouse, 1977, p.1484). Another misleading assumption is that if high grade terranes are older than the greenstone belts, then the gneissic rocks must be basement to the latter (Gower, 1978, p.27). Evidence of actual basal unconformities such as documented in Rhodesia (Bickle et al., 1975) appear to be quite rare. As reviewed by Gower (1978, p.1-43) two main hypotheses concerning the high-low-grade terrain relationship are indicated in the literature:

1). the gneissic terranes represent sialic basement upon which the greenstones were deposited (Stowe, 1971; Archibald et al. 1978; Hunter, 1970, 1974; Windley, 1971; Windley and Bridgwater, 1971; Anheuser et al. 1969). The ubiquitous mafic inclusions commonly observed in these terrains are regarded to be relics of an earlier greenstone

assemblages as described in West Greenland (McGregor 1973; Bridgwater et al. 1973). In effect the development of these gneissic complexes predates the development of the greenstone assemblages.

2). the gneissic terranes developed synchronously or later than the greenstone areas and are subsequent sites of high heat flow. Viljoen and Viljoen (1969), Glikson (1972) and others contend the gneissic complexes represent the root zones of greenstone belts that were intensely injected by granitoid magmas.

Westerman (1977, p.5) suggested that the gneissic terranes represent sedimentary depositional areas that developed synchronous with the greenstone areas. Subsequently they became sites of high heat flow and were intruded by abundant granitoid material. As documented by Gower (1978, p.28) additional processes involving variations of 1) include: a) rifting (Hunter, 1974; Condie and Hunter, 1976) b) plate tectonic (continental margin subduction) models (Windley and Smith, 1976).

The resolution of the above hypotheses can, in part, be made if the origin of the layering can be deciphered.

DISTRIBUTION AND NATURE

The gneissic suite is restricted to the Southern Plutonic Domain of the English River Subprovince. Although there are large tracts of the gneissic suite preserved in the Cedar-Clay Lakes area and in the Lac Seul area there is a concentration of the gneissic rocks near the southern contact of the English River Subprovince, adjacent to the Wabigoon Subprovince (Figure 7-1). The gneissic suite is discontinuously exposed

rocks near the southern contact of the English River Subprovince, adjacent to the Wabigoon Subprovince (Figure 7-1). The gneissic suite is discontinuously exposed between the Manitoba-Ontario boundary and Sioux Lookout; a few small occurrences including a dome structure are found north of Savant Lake. Continuity of the gneissic suite is mainly disrupted by later potassic granitoid intrusions (Figure 9-1) and to a minor extent by plutons of the sodic granitoid suite (Figure 8-1).

The gneissic suite is characteristically compositionally banded or layered which is a prerequisite in its classification. The banding varies from continuous over tens of meters to discontinuous over tens of millimeters; width varies from a few millimeters or less up to more than a meter. Contacts of the individual bands vary from sharp and well defined (Photo 7-1) to gradational or diffuse (Photo 7-2) depending upon the degree of tectonic-metamorphic reworking. In general, the layering, except for local discordancies, is generally concordant to the fabric of the surrounding host-rocks including the metavolcanic rocks exposed along the north margin of the Wabigoon Subprovince. Grain size and textural inhomogeneities serve to further accentuate the banding as do the later intrusive units as also observed by Hunter (1974, p.265). The internal fabric of many of the lithological units comprising the gneissic suite varies from massive to foliated to lineated; gneissic fabric within individual phases is actually quite rare.

Although it will be shown that the gneissic suite is compositionally similar to and partly gradational into the sodic granitoid suite, several differences occur amongst the two groups:

1). the gneissic suite is banded;

2). in thin section the mineral components of the gneissic suite are approximately equigranular and anhedral (including plagioclase) and typically display an allotriomorphic granular texture. In the sodic granitoid suite plagioclase is commonly inequigranular and subhedral to euhedral, i.e. hypidiomorphic-granular textures prevail.

The gneissic suite is the most complex of all of the suites and comprises a medley of plutonic units and subordinate, rare units of possible supracrustal origin. These assemblages are tightly and conformably interleaved and characteristically display a banded (layered) or gneissic to gneissose fabric. Heterogeneity within the suite is influenced by complex intermixing of numerous polycyclic intrusive units and by changes in structure produced by chaotic differences in the following:

1) degree of development of layering and/or foliation;

2) continuity of layering;

3) thickness of layering;

4) percentage and homogeneity of distribution of complementary mafic and felsic constituents.

The most difficult problem in deciphering the genesis of the gneisses is in the implementation of a consistently valid mapping procedure. Initial unfamiliarity with the complexity of the gneissic suite during the first field season (Operation Kenora-Sydney Lake), led to a rather simplified classification based upon dominant accessory mineral. This classification included:

1) amphibole gneiss (25 percent of bands contain >10 percent amphibole);

2) biotite gneiss (50 percent of bands contain >10 percent biotite);

3) potassic feldspar gneiss (25 percent of bands contain >10 percent K-feldspar);

4) leucogneiss (essentially quartz and plagioclase);

5) migmatitic gneiss (rafts of amphibolite in foliated to gneissic trondhjemitic host).

Westerman (1977) studied the gneissic suite in the Cedar-Clay Lakes area and established mappable units based on associations of dominant constituents:

1) amphibolite.
2) mafic hornblende-biotite gneiss.
3) foliated biotite-hornblende quartz diorite to trondhjemite.
4) trondhjemitic and granodioritic gneiss.
5) foliated to gneissic trondhjemite and granodiorite.
6) leucotrondhjemite.
7) leucocratic quartz monzonite to granite (sensu stricto).
8) biotite trondhjemite gneiss (strongly banded on a scale of mms).

From these constituents, Westerman (1976) arrived at the mappable associations for Operation Kenora-Ear Falls as outlined in Table 7-1. Also, all of the associations listed, contain variable proportions of constituents 6 and 8 above which are related to the sodic and potassic granitoid suites, respectively. Locally the associations outlined in

Table 7-1 are complexly interlayered, in which case, due to the reconnaissance scale, only broadly defineable associations are indicated. All of the constituents composing the various associations are conformable except for 6 and 7 above. Furthermore, where these major mapable associations are intermixed, they are also conformably interleaved.

In the Kenora area Gower (1978, p.80, 84) classified the gneisses in terms of three fundamental, significant end members:

1) amphibolite, 2) tonalite gneiss and 3) granitic pegmatitic gneiss. Gower's (1978) mapping was based on these and transitional types (Figure 7-2) which form mappable, non-genetic associations.

With accummulated experience coupled with geochronological data (Krogh et al. 1976; Gower 1978) the authors ultimately concluded that the gneissic suite was, in part, a more deformed compositional equivalent of the sodic granitoid suite. Consequently, in the Deception Bay - Lac Seul area (Breaks et al. 1980) the gneissic suite was classified into three main types based on dominant overall or average colour index:

1) leucocratic granitoid gneiss (CI<5)

2) intermediate granitoid gneiss (CI 5 to 35)

3) mafic granitoid gneiss (CI 35 to 65)

Following this system, the individual units collectively present at a given station were classified according to the other major rock subdivisions. These were coded in [square brackets] following the map code 4. In effect the map code 4 has designated areas that are extremely complex due to structural tight interleaving of numerous phases.

MAP ASSOCIATIONS

Detailed mapping (Gower, 1978; Westerman, 1977) and detailed examination at a reconnaissance scale by the authors indicate that the following major rock types are consistently associated in the areas underlain by gneissic rocks:

1) ultramafic association;

2) supracrustal association;

3) tonalite association; (colour index >5)

4) leucocratic (dominantly tonalite) association (colour index <5)

5) mafic dyke association;

6) potassic granitoid suite association;

Table 7-3 is a comparison of association types and nomenclature used for the gneissic suite for the Cedar Lake area (Westerman, 1977), Kenora area (Gower, 1978) and the Deception Bay-Lac Seul area. Tables 7-4; 5 and 6 give detailed gelogical desriptions and relations for each rock unit within the respective rock associations. Figure 13-1 illustrates the geology of the Cedar-Clay Lakes area after Westerman (1977). Individual rock units within the associations are generalized according to composition. It was not possible at the present scale of mapping to exhaustively code every lithology in an exposure. The map legend allows classification of rocks into compositional ranges. Constituents characterized by similar composition but differing in texture or grain size were not separated out in the legend. For example, some of the rock units such as leucocratic trondhjemite (map code 7d) or quartz monzonite (map code 9a) may only appear once

in the map code at a given station even though, based on subtle differences in texture and grain size, there may be as many as 4 separate units of each.

As a first approximation, based on field relationships, the individual rock types (above), apeear in the following decreasing order of age: supracrustal, tonalite gneiss, leucogranitoid (tonalite), mafic dyke and potassic granitoid suite. This age relationship of each major rock type is not entirely exclusive; undoubtedly there is considerable overlap between the initiation and termination of each successive rock type.

ULTRAMAFIC ASSOCIATION

Ultramafic rocks are in the gneissic suite (Tables 7-4, 5 and 6). They occur as minor small enclaves mostly within units of the tonalite gneiss association in the Cedar Lake gneisses (Westerman, 1977, p.44), and the Deception Bay (Lac Seul) gneisses. At Kenora, Gower (1978, p.186) indicates three types:

1) an ultramafic sill associated concordantly with metasedimentary rocks. The sill displays weak layering suggesting an intrusive origin and is characterized by essential minerals clinoamphibole, plagioclase and clinopyroxene (Gower, 1978, p.186).
2) porphyroblastic hornblende mafic rock characterized by porphyroblastic hornblende megacrysts in a matrix of plagioclase (An_{60}), epidote, clinopyroxene, actinolite, minor sericite, carbonate, biotite and microcline (Gower, 1978, p.188).
3) foliated biotite-clinoamphibole schist.

Gower (1978, p.191) suggests the ultramafic rocks at Kenora may be modified komatiites

but textural evidence is lacking.

Ultramafic and anorthositic gabbro are restricted to the Tile Lake-Bindo Lake area of the Deception Bay (Lac Seul) gneissic zone. The ultramafic constituent occurs as small (3 cm to 0.6 m) lenticular hornblende-rich enclave within the more mafic (biotite-hornblende quartz diorite) units of the tonalite gneiss association; the ultramafic clots (Photo 7-2) are restricted to the gneissic suite, they are not present as inclusions in any of the nearby sodic granitoid members. Minor phlogopite and plagioclase accompany the hornblende. The anorthositic unit (Photo **7-3**) , not seen elsewhere in the gneissic suite, occurs as a remobilized sill consisting of 30 percent angular to rounded enclaves or cumulate globs of coarse-grained, massive to lineated, gabbroic anorthosite interlayered within anorthositic gabbro and minor gabbro all situated within a 6 m wide layer of medium to coarse-grained holo-leucocratic trondhjemitic leucosome. The trondhjemite is regarded to be a partial melt derived from the anorthositic suite. The gabbroic anorthosite comprises plagioclase (oligoclase to mostly andesine), hornblende, sphene, minor quartz, Fe-Ti opaques, rare relict olivine, retrograde epidote, biotite, chlorite, clinozoisite. The crystals are all allotriomorphic-granular and exhibit a good recrystallized texture. Due to its concordant relationship and uniqueness, it is unknown if the sill is intrusive or represents an in situ differentiated residue that accumulated at deep levels.

Although Gower (1978) leans towards supracrustal association for the ultramafic units, in the Deception Bay (Lac Seul) gneissic zone, the authors are uncertain whether the ultramafic enclaves represent a supracrustal unit or a deep seated mafic-rich residue

transported via intrusive units of the gneissic suite.

SUPRACRUSTAL ASSOCIATION

Amphibolite

Scattered screens of possible relict supracrustal rocks are found throughout the gneissic suite. There is no apparent distribution pattern except north of the Sioux Lookout area where Harris (1975) noted the contact of the English River and Wabigoon Subprovinces is gradational, marked by a decrease in the number of volcanic enclaves northwards, away from the contact. Except for rare enclaves of possible metasedimentary origins, it is noteworthy that nearly all of these are volcanic and tend to be mafic in composition.

At Kenora Gower (1978, p.199-208) describes fine-grained (1mm) and coarse-grained (2-3 mm) varieties of amphibolite (see Table 7-6a). The fine-grained variety varies from massive to foliated to strongly banded; banding is marked by a combination of i) mineral and or grain size heterogeneity, ii) mafic mineral concentrations (hornblende veneers) and iii) leucogranitoid veining. In addition the fine-grained variety contain calcic pods which he interprets as either interpillow accumulation or deposition from calcium-rich fluid metasomatism. Gower (1978) interprets the fine-grained variety as original mafic volcanic flows. The coarse-grained variety are interpreted as the central cores of thick flows or cogenetic intrusives. In the Cedar-Clay Lakes area, Westerman (1977, p.43-46; p.50-52) describes both massive and weakly to strongly banded amphibolites and interprets only the latter as being originally supracrustal (see Table 7-4). In the Hudson-Sioux Lookout

area, Harris (1975, p.41, 42) indicates fine-grained inclusions of unknown origin are generally concentrated along the contact between the gneissic suite and plutons of the other suites. These enclaves are similar to the amphibolitic mafic metavolcanic rocks of the Wabigoon Subprovince; this fact along with their increasing abundance towards the southern margin of the English River Subprovince supports a probable supracrustal origin.

All of the amphibolite units described above also occur as enclaves within the members of the sodic and potassic granitoid suites throughout the Southern Plutonic Domain.

Metasedimentary Units

Metasedimentary rocks are rare in the gneissic suite and have only been observed in the Melick gneisses at Kenora (Gower, 1978, p.235). Gower (1978) describes four types:

1) metamorphosed banded chert iron formation thinly (2-3 mm) to thick (10 mm) bedded;
2) metaarkose
3) metawacke or tuffaceous wacke
4) metaargillite

Locally the above units are associated with the fine-grained amphibolites confirming the latter's supracrustal origin.

TONALITE ASSOCIATION

This association is the most widespread and abundant within the gneissic suite and appears to be the host for the other associated rock types. The dominant composition

of the tonalite association ranges from quartz diorite to trondhjemite (ie. tonalite). Westerman (1977, p.41, 43) indicates a compositional range of tonalite to granodiorite (Table 7-4) but admits the granodiorite composition is in part a function of mixing of later potassic granitoid units. In both the Kenora area Gower (1978, and Table 7-5 this report) and the Deception Bay (Lac Seul) area (Table 7-6), the units can be separated into hornblende- and biotite-bearing members.

The fabric of the tonalite constituent can be described as massive, weakly foliated, foliated and foliated to gneissic (Photo 7-4). True gneissic texture within individual tonalite layers is rare but is locally present in the Melick Gneiss (Kenora) on the Kenora-Minaki Road. Members of the tonalite association are generally light grey to dark grey on the weathered surface. Grain size is also variable from fine to coarse-grained, equigranular to subtly inequigranular to inequigranular; medium-grained units are most common.

Plagioclase (oligoclase, locally albite, rare andesine), quartz, biotite, hornblende are the essential mineral constituents. In thin section plagioclase and quartz are invariably anhedral and the overall texture is nearly always allotriomorphic-granular. Plagioclase is poor to well twinned after the Albite, Pericline and Carlsbad Laws, is only weakly sericitized and/or saussuritized and exhibits sharp boundaries. This is markedly at variance with plagioclase of the sodic granitoid suite which is commonly subhedral, dominantly untwinned to poorly or hazily twinned, lightly to moderately sericitized and exhibits serated to diffuse boundaries. Quartz is invariably anhedral, with inequigranular subgrain growth. Biotite occurs as single, isolated, red-brown subhedral crystals and as

randomly oriented crystal aggregates that form clots with associated epidote, sphene, opaque minerals and hornblende. If a foliation is present it is due to the alignment of biotite; the individual biotite varies from randomly oriented to well aligned. Biotite also forms clots; the biotite is generally randomly oriented but the clots themselves are commonly aligned defining a foliation. Magnetite, typically associated with sphene, is the most abundant opaque mineral. Hornblende commonly alters to biotite. Gower (1978, p.257) found a gradation between biotite-rich and hornblende-rich rock types both along and across strike.

A leucocratic, foliated to gneissic biotite trondhjemite occurs in both the sodic and gneissic suites in eastern Lac Seul (Photo 7-4). The rocks are characterized by biotite to leucocratic biotite trondhjemite (CI 4-7). The foliated to gneissic texture results from the presence of long, very thin (<0.5 mm) strings of subaligned biotite flakes that form in "trains".

LEUCOGRANITE ASSOCIATION

In this report the leucocratic granitoid associations include mainly trondhjemite compositions and rare, white-weathering, recrystallized, leucocratic quartz monzonite. Both Westerman (1977) and Gower (1978) include a potassium granitoid unit which the authors believe is genetically tied to the potassic suite. All of the rock types in this association weather white to locally greyish-white; in the field they are massive and occur as thin, concordant veins (2 m up to 1 m, Photo 7-5) or bands. The association includes the following groups:

1). leucocratic biotite trondhjemite (CI generally <5)

2). hololeucocratic trondhjemite (CI <0.5 to almost nil)

3). leucocratic quartz monzonite

Leucocratic Biotite Trondhjemite

This unit is the most abundant rock type in this association. It occurs throughout all of the major gneissic areas and is described by both Westerman (1977, p.42), and Gower (1978, p.343-349). The leucocratic bands have sharp contacts (Photos 7-1 and 7-5) and are fairly continuous across single exposures. Locally the bands are deformed and form isoclinal rootless folds (Photo 7-6) and possible refolds (Photos 7-7 and 8). The leucocratic trondhjemite forms both fine to medium-grained and medium-to coarse-grained varieties but in general the two grain sizes are not intergradational. That is the grain size tends to remain uniform and equigranular along the strike of individual bands. Mineralogically this unit comprised 97% combined plagioclase (oligoclase) and quartz. Both of these characteristically form an allotriomorphic-granular texture; the plagioclase is unsericitized and poorly twinned and is difficult to distinguish from quartz. Biotite occurs as subaligned to randomly oriented, evenly distributed, isolated single crystals. Minor to rare epidote, muscovite, allanite and opaques are accessory minerals.

In places the boundaries of these leucocratic bands are gradational, marked by a gradual increase in mafic mineral content suggesting reworking in the form of hybridization or solid state metamorphic differentiation. Leucocratic biotite trondhjemite bands or layers with sharp boundaries, although mostly concordant to the gneissic fabric,

are interpreted by Westerman (1977) and Gower (1975) to be dominantly intrusive in origin.

Holo-leucocratic Trondhjemite

This unit is associated most commonly with amphibolite (Photo 7-9) and rarely with ultramafic and anorthositic gabbro in Deception Bay (Lac Seul) contained within the gneissic suite (also Gower, 1978, p.202). Typically this rock type weathers white, is inequigranular and varies from medium to coarse-grained to very coarse-grained. It occurs as pods, irregular patches, and locally discontinuous bands that are generally in sharp contact with the host amphibolite. This rock type is composed almost entirely of plagioclase (oligoclase) and quartz (35-40%) that exhibit similar petrography to that described for leucocratic biotite trondhjemite. Rare biotite, epidote and opaque accessories may be present. The fact that the hololeucocratic trondhjemite is spatially associated with and is the expected composition (Arth et al. 1978) suggests it is a partial melt of the amphibolite.

Leucocratic Quartz Monzonite

This unit is less common than leucocratic biotite trondhjemite, although the two are indistinguishable in the field. Leucocratic quartz monzonite is found in the Kenora area (Gower, 1978, p.346-349) and in the Deception Bay (Lac Seul) gneissic zone. This conformable rock type differs from later granitic injections in that it is consistently equigranular, very fine-grained to fine-grained (locally medium-grained), weathers white, and is allotriomorphic granular. In thin section microcline is interstitial and locally replaces plagioclase. The veins of leucocratic quartz monzonite are sharply defined and tend to

be thinner (<15 mm) that veins of leucocratic biotite trondhjemite.

MAFIC DYKE ASSOCIATION

Understanding the origin of the amphibolite enclaves is critical to the unravelling the genesis of the gneissic granitoid suite. Locally within the gneissic suite some amphibolites exhibit mild discordant contacts and are interpreted as dykes similar to those described by Bridgewater et al. (1973) in the early gneissic suite in Greenland. Mafic dykes have been recognized at the following localities:

1) at Kenora, Gower (1978, p.377) recognizes two groups of amphibolite dykes: i) severely deformed mafic amphibolitic dikes, and ii) weakly deformed intermediate dikes Both types are characterized by unequivocal discordant relationships to their host-rock types; the dykes are usually narrow (<0.3 m), rarely exceeding 1 m, and are discontinuous due to complex disruption by plutonic intrusion.
2) in Gundy Township (Davies, 1965) near the Manitoba/Ontario boundary: Gower (1978, p.381) noted fairly wide equigranular and porphyritic (plagioclase) amphibolite dikes within the western extension of the Melick gneiss.
3) Westerman (1977, p.43) described medium-grained amphibolite enclaves that occur as boudins and semicontinuous linear trains concordant to the gneissosity. Both equigranular and porphyritic (plagioclase crystals up to 1.5 cm x 0.7 cm) varieties are present.
4) highly discordant equigranular and porphyritic (epidotized and/or saussuritized plagioclase) amphibolite dykes occur within the gneisses at Deception Bay (Lac Seul)

(Photo 7-10 and 7-11).

5) Gower (1978, p.386, 401) describes several minor occurrences of miscellaneous diorites whose relation to the dykes is unknown.

Except for the intermediate dykes in the Melick Gneisses at Kenora, nearly all of the dykes are amphibolite. A few in the Deception Bay area have greater than 5% quartz and are diorite. Two dominant types are present: equigranular and porphyritic. Mineralogically the amphibolite dikes comprise hornblende, plagioclase (oligoclase), biotite, opaque minerals, sphene and quartz. In the Cedar-Clay Lakes area the dykes are locally characterized by hornblende, hypersthene, magnetite, diopside and plagioclase. Megacrystic plagioclase (An_{55-60}) occurs as a glomeroporphyritic texture. In the Deception Bay area the porphyritic plagioclase is heavily saussuritized and/or sericitized, is randomly oriented, and occurs as single crystals 2-5 mm in length.

Amphibolite bands with discordant relationships signifying a definite intrusive origin are much less abundant than those concordantly interleaved in the gneissic suite. As noted by Westerman (1977) and in the Deception Bay (Lac Seul) area (Photo 7-10), many of the amphibolite units form concordant, linear, disrupted blocks and boudins that form semicontinuous trains. These are similar to the discordant types and are also suspected to be dykes. Both Westerman (1977) and Gower (1978) indicate the intrusive amphibolites are medium- to coarse-grained and massive. They differ petrographically from finer-grained and banded varieties (see geochemistry, mafic enclaves in metavolcanics) and are regarded as supracrustal in origin. Westerman (1977) did not observe any discordant relationships of the massive amphibolite bands but suspected

they represented dykes based on their continuity and linearity. In the Deception Bay (Lac Seul) area many of the concordant mafic bands are suspected as dykes because less deformed petrological equivalents occur as discordant dykes within the nearby Sen Bay stock. Many of the concordant dykes are highly reworked and contain intercalated granitoid units of metamorphic, hybrid, metasomatic and anatectic origin. Commonly the concordant amphibolites have diffuse contacts, appear partly digested and are locally agmatized by leucocratic trondhjemite of possible anatectic origin.

POTASSIC GRANITOID ASSOCIATION

This association is second in abundance to the tonalite association of the gneissic suite. It occurs as pink weathering, concordant and discordant veins and bands that locally give the outcrop a phlebitic and/or stromatic structure. Both Gower (1978) and Westerman (1977) include this association as part of their leucogranitoid association. We believe that much of the potassic granitoid association of the gneissic suite is genetically related to emplacement of the potassic granitoid suite. The gneissic fabric is highly accentuated by the pink colouration of the potassic grantoid units and constituted the most obvious and easily recognizable lithologic component of the gneissic suite.

The potassic granitoid association ranges from mainly quartz monzonite to locally granite and syenite. Grain size varies from aphanitic (rare) to fine- to medium-grained, and medium to coarse-grained to pegmatitic. These units occur both as discordant and concordant (Photo 7-11) veins, bands, sills and dikes. Up to 4 or 5 successive ages of emplacement have been observed in the Deception Bay (Lac Seul) area. The field

characteristics of the concordant and discordant types are given in Table 7-6.

Gower (1978, p.332) describes a mixed biotite tonalite and granitic pegmatite gneiss (Table 7-5) unit peripheral to the Dallas granodiorite and observed that the unit has a complete gradation by intimate mixing of the two end members (tonalite and granite) in various proportions (Photo 7-11).

The sills occur as deformed and undeformed, unrecrystallized to weakly recrystallized to locally intensely recrystallized veins and bands that commonly exhibit diffuse contacts. Alternatively, the crosscutting dykes are sharply defined and unrecrystallized. In places the margins of the potassic granitoid sills with diffuse contacts are mantled with biotite-rich selvedges (Photo 7-12) suggesting such units are anatectic. The segregation of such rock units could also be due to replacement through metamorphic differentiation as described in the Precambrian gneisses in Sweden (Gavelin, 1975). However, the potassic granitoid association is largely regarded as intrusive.

OTHER MINOR ASSOCIATIONS

Potassium Metasomatism

The mobility of potassium is discussed to some extent in Chapter 9. Potassium metasomatism commonly occurs within the leucogranitoid (trondhjemite) association (Photo 7-1). In the Kenora area, Gower (1978, p.178-182) noted that the potassium metasomatism is indicated by the "presence of microcline porphyroblasts showing a systematic distribution" in the gneissic suite. He found a general, albeit sporadic, increase in abundance and size of the microcline porphyroblasts within the gneissic suite

towards the Dallas granodiorite. Their appearance is not due to contact metamorphic/metasomatic effects from the intrusion but instead is related to an overall higher grade of metamorphism with the potassium being added from an external (possible granulite) domain at depth. Gower (1978, p.183) also found that garnet and progressively lower Fe_2O_3/FeO values correlaed with the zone of potassium metasomatism.

Biotite Schlieren

Biotite-rich schlieren occur sporadically as thin, generally discontinuous lenses or layers throughout the gneissic suite (Photos 7-12 and 7-13). The biotite schlieren are characterized by both diffuse and sharp contacts. Locally they complement leucocratic trondhjemite or quartz monzonite lenses (Photos 7-7, 7-8). Their origin remains enigmatic in that they could be:

1) enclaves of mafic-rich metasedimentary rocks;

2) in situ restite;

3) allochthonous enclaves of restite.

Field characteristics suggest a combination of all three relations are present.

TECTONIC-METAMORPHIC REWORKING OF THE ASSOCIATIONS

Heterogeneity and complexity of the gneissic suite is influenced by the degree of reworking in the form of processes such as solid state metamorphic differentiation (Photo 7-14) hybridization or a combination of these two processes (Photo 7-15), potassium.PA metasomatism (Photo 7-1) and physical deformation. In many cases evidence of all four

processes can be observed on single exposures. Evidence of solid state metamorphic differentiation is mainly observed through diffuse, chaotic redistribution of hornblende. Evidence of hybridization is texturally and petrographically similar to that of metamorphic differentiation except the process of hybridization is spatially associated with mafic enclaves or dykes.

MODAL VARIATION

The compositions comprising the gneissic suite include gabbro, diorite, quartz diorite, trondhjemite, minor granodiorite and rare ultramafic and anorthositic rocks (Figure 7-30. On the QPK diagrams most of the analyses fall into the trondhjemite field. Except for the trend of the Cedar Lake rocks (Westerman, 1977) which probably reflect some enclaves of the potassic granitoid association, the modal analyses were done mainly on rocks of the the tonalite association. The line on the QFM diagram approximately separates dominantly sedimentary rocks (towards the quartz apex) from dominantly igneous rocks (see Beakhouse, 1979; Gower, 1978, Westerman, 1977). Some of the Twilight gneisses plot on the sedimentary side and are regarded as sedimentary (Westerman, 1977, p.113) and similar to metasedimentary rocks of the Northern Supracrustal Domain. In effect Westerman (1977, p.114-115) indicates two types of gneisses in the Twilight Lake Dome: Group A are petrologically similar to metasedimentary rocks of the Northern Supracrustal Domain. A discriminant analysis of their chemistry suggests a sedimentary protolith and that of Group B gneisses suggests an igneous parentage. The trend of the Lac Seul (Deception Bay). QFM variation is probably most representative ranging from mafic-rich

ranging from mafic-rich gabbro, anorthositic gabbro to trondhjemite.

ORIGIN OF THE GNEISSIC SUITE

The origin of the gneissic suite is controversial. Many investigators plausibly would would suggest a sedimentary origin but most contend the gneissic terrains are igneous origin (Gower, 1978, p.274). The gneissic granitoid suite is considered by the authors as a catazonal, granitoid intrusive complex composed of numerous early granitoid constituents which have been severely deformed and have suffered intense normal flattening which were intimately penetrated by lit-par-lit injected units originating in part from the sodic and potassic granitoid suites. Unlike the essentially closed system expressed by the metasedimentary migmatite spectrum, the gneissic suite has behaved as an open system whereby magmatic material has been added over time and episodically reworked by tectonism and metamorphism. The following evidence helps support athis interpretation:

1) the gneissic rocks (tonalite association) are fairly homogeneous with no interleaved apparent shale or conglomeratic units (Gower, 1978);
2) discriminant function analysis similar to that of Shaw (1972), de la Roche (1972) and Weisbrod (1969) all indicate igneous parentage;
3) extensive partial melting of metasedimentary rocks gives rise to a dominantly K-enriched magma (see Arth and Hanson 1972) and metasedimentary migmatite generation this report) and;
4) oxygen and Sr isotope data for the Melick gneiss compare favourably with plutonic

rocks in general.

Figure 7-4a,b,c shows plots of Zr versus Niggli Si for the Melick gneiss (A), Cr versus Niggli Mg for the Deception Bay (Lac Seul) gneises (B), and Niggli Si versus Niggli Mg for the Melick gneisses (C). According to Van de Kamp et al. (1976, p.209) Zr values increase with differentiation while Cr values decrease with differentiation. The Zr/Niggli Si (Figure 7-4a) for the Kenora Melick gneisses shows a scatter of plots with a tendency for the hornblende (more mafic) gneisses to plot with lower Niggli Si values. The Cr/Niggli Mg of the Deception Bay (Lac Seul) gneisses (Figure 7-4aa) shows a well defined negative correlation indicative of igneous differentiation.

Niggli Mg plotted against Niggli Si for the (Kenora) Melick Gneisses also gives a very well defined igneous trend with the expected negative correlation as indicated by Van de Kamp and Beakhouse (1979).

Figure 7-5 shows a Ti02-Si02 diagram for discriminating igneous and sedimentary parentage for gneissic rocks from Tarney (1976). The line on Fig. 7-5 separates igneous rocks (lower field) from sedimentary rocks. The majority of the data fall below the line on the igneous side of the diagram. However, the reliability of this plot may be questionable: The average of 21 wackes from the Northern Supracrustal Domain (Breaks et al. 1978, Table 3, p.10) plot above the line in the sedimentary field while the average of 15 pelite from the same area (Breaks et al. 1978, Table 3, p.10) plot below the line in the igneous field. Also the Twilight gneiss group "A" (Figure 7-5, No. 3) which is regarded to be metasedimentary plots just below the line in the igneous field. The authors agree with Westerman (1977) that a good portion of the Twilight gneisses are metasedimentary in

in origin similar to the metasedimentary migmatites of the Northern Domain.

The authors concur with Westerman (1977, p.116) and Gower (1978, p.274) and advocate that the most likely protolith for the felsic portion of the gneissic suite is an intrusive granitoid complex. Using REE patterns to model the conditions of magma formation Gower (1978, p.274-326) indicated the most likely source rock for the leucocratic tonalite association is generated by melting 10% by volume of a 2-pyroxene mafic garnet granulite of tholeiitic composition. McCarthy and Kable (1978, p.26) studied a suite of leucocratic gneisses from South Africa and reported large Eu anomalies and strong LREE enrichment. The leucogranitoid (types) associations at Kenora however exhibits unique LREE depletion and HREE enrichment (Gower, 1978, p.367-368), giving an overall fairly flat pattern.

Both the potassic and trondhjemite leucogranitoid rocks at Kenora exhibit similar REE patterns and apparently the presence or absence of K-feldspar does not influence the depletion-enrichment REE trends (Gower, 1978, p.367). Based on microprobe analyses on allanite in tonalitic gneiss, Morin (1977) indicated that the margins of such grains are depleted in LREE due to leaching possibly related to high grade metamorphism. As pointed out by Gower (1978, p.370), it would be unusual to expect only the leucogranitoid association to be affected by high rank metamorphism as the tonalite association is enriched in LREE and contains abundant allanite. The mixed biotite tonalite-pegmatoid gneiss presents a further problem in that the LREE's are enriched (Gower, 1978, p.362) above those of the tonalite association (p.310) when one would expect intermediate values between the two end members. Gower (1978, p.375) indicates:

"The mixed biotite tonalite - granitic pegmatoid gneiss, from its major and LIL trace element chemistry, could be a mixture of the two end-members. The average composition closely approximates to a 1:1 mix, though there are departures in some components. The REE patterns do not confirm this simple scheme and a model is developed whereby an original tonalite magma is permitted to 70% fractionally crystalline (with accessory phases remaining in the liquid), and the 30% residual liquid is mixed 1:1 with previously crystallized unfractionated tonalite."

The retention of the accessory phases is used to explain low Zr, P_2O_5 and TiO_2 major chemistry in the above rock type. The reason for the enriched LREE in the mixed gneiss is not known. Only clinopyroxene and to a much lesser degree biotite can concentrate the LREE. Biotite selvadges around the potassic granitoid units are common in this mixed tonalite-granite pegmatoid gneiss but whether they are abundant enough to sufficiently enrich the LREE pattern that Gower (1978, p.342) portrays is not known. McCarthy and Kable (1978, p.29) concluded "the behavior of REE in granitic systems may be highly variable" in part dependant on the presence or absence of very minor minerals and as such "their usefullness in granitic rocks might be severely restricted". Gower (1978, p.iv) concludes that for the granitoid pegmatoid gneisses:

"Bulk compositional data are compatible with fractionation from a tonalitic magma but unusual LREE-depleted REE patterns indicate that this mechanism is only possible if LREE-bearing accessory phases precipitate before residual liquid crystallizes."

Essentially Gower (1978) envisages the leucogranitoid association as being derived by fractionation of tonalitic magmas in part similar in composition to the tonalitic

association which they intrude. This may explain why some of the potassic and tonalitic leucocratic granitoid units are complemented by biotite-rich schlieren along their margins suggesting in situ anatexis. Westerman (1977, p.107) feels much of the potassic units are intrusive into the gneisses at their present setting.

The origin of the banding is also controversial. Banding in granitoid rocks as viewed by Stone (1969) and Butler (1969) can originate from any of the following processes:

1) magmatic injection; intrusion of a magma into an older rock commonly along planes of weakness or lithostructural discontinuities;
2) metasomatism; formation of a granitoid phase by the injection of hydrothermal solutions into an older phase;
3) anatexis; in situ partial melting of biotite-rich granitoid units resulting in interlayering of holo-leucocratic melt with granitoid paleosome and possible restite (locally west of Daniels Lake and north of Kenora on the Minaki Lake road, the leucocratic trondhjemite is regularly interbanded with mafic-rich biotite bands suggesting the two units are complimentary, anatectic derivatives).
4) metamorphic differentiation; separation of mafic/felsic components through solid state reactions (as opposed to anatexis in which the separation occurs in liquid reactions (Gavelin, 1975);
5) primary; depositional or flowage controlled mineral banding as could be set up during emplacement.

Processes 1, 2, 3 and 4 above have all been shown to be active within the gneissic suite of the English River Subprovince especially in regard to the leucocratic granitoid

(leucotonalite and potassic) association. Process 5, although possible, has not as yet been identified. A sixth process is however indicated: mechanical or tectonic. The mechanical production of metamorphic banding, although recently criticized by Shelley (1974), has been recently proposed as a possible method of formation of the banded gneisses in Greenland by Myers (1978, 1980). Both Westerman (1977, p.87) and Gower (1978, p.280) concur that some of the banding is the result of an extreme layer normal compressive deformation of an igneous suite. Indications through age dating are that the gneissic suite may be coeval with the sodic suite, i.e., the former represents in part a deformed version of the latter. Evidence that the two are coeval and that the banding is tectonic in origin include the following observations:

a) the gneissic suite is locally observed to be texturally gradational with the gneissic suite;

   i) Gower (1978, p.462) indicates the Melick tonalite is locally gradational into the biotite tonalite gneiss at Kenora.

   ii) locally gradations between the two suites were apparent to the authors north of the Tustin Bridges area.

b) Westerman (1977, p.47) reports: "When traced northeastwards into the Mystery Dome area the Clay Lake granitoid suite rocks undergo a change of character. The essential compositional characteristics remain unchanged but the rocks are more severely foliated and locally develop a compositional banding".

   Westerman (1977, p.117) believes the Clay Lake granitoid suite is intrusive into the Cedar Lake gneisses. Although he originally places the Clay Lake granitic rocks

into the gneissic suite, Gower also (1978, p.475) equates the Clay Lake granitoid suite with the Kenora gneisses) a brief reconnaissance visit to the Clay Lake area by the authors in 1977 indicated that much of the Clay Lake granitoid suite is similar to the sodic suite.

c) modal and chemical analyses of the gneissic suite (excluding the intrusive potassic association) are similar to and overlap those of the sodic granitoid suite.

Figure 7-7 shows variation in the Deception Bay (Lac Seul) gneissic suite in terms of AFM and CNK diagrams. The AFM diagram shows a similar calc-alkaline (trondhjemite) trend to the Sen Bay Stock (Figure 8-8) including the alkalic cyclicity.

d) minimal radiometric age determinations suggests the two suites overlap in age (see Chapter 10).

e) at Kenora there is a spatial correlation in which the most well-banded rocks are found in the deepest structural level (Gower, 1978, p.281).

f) numerous examples of intensely flattened discordant veins are common throughout the gneissic areas (Gower, 1978, p.281). Several periods of folding have been recognized by Westerman (1977) and Gower (1978) within the gneissic granitoid suite.

g) there are rare, commonly rootless, intrafolial folds (Westerman, 1977, p.234; Gower, 1978, p.281) indicative of tight isoclinal folding.

h) the Cedar Lake gneisses have undergone the most extensive structural history in the Cedar-Clay Lakes area (Westerman, 1977, p.68).

i) there are patches of much less complex rocks (ie. sodic suite) within the Deception Bay (Lac Seul) Gneisses (Breaks, Bond and Stone 1980).

Mechanical processes responsible for production of the banding would seem more important than high heat flow. Figure 7-6 shows the spatial relation of the Gneissic suite to outlined areas that have been subjected to low-pressure granulite metamorphism. Except for the Clay Lake area, the granulite metamorphism does not overprint any of the gneissic suite and therefore the banding can not be generally linked to high heat flow.

The compositional variety within the gneissic suite cannot relate to simple tectonics. Windley and Bridgewater (1971, p.40) indicate that McGregor considers the early gneissic suite in West Greenland was developed by deformation and metamorphic differentiation of an originally homogeneous granodiorite rock. The authors feel, however, that the protolith to the gneissic suite must, at least in part, represent a heterolithologic assemblage of rocks ranging in composition from rare anorthositic gabbro or at least gabbro to trondhjemite to minor granodiorite. The authors envisage the Sen Bay batholith, approximately 3.3 +/- 0.1 Ga (Hinton and Long, 1979), as a comparable pregneissic terrane.

The conformable interleaving of rock assemblages must have occured during the strong flattening deformation and this could have coincided with subhorizontal thrusting in the Cedar-Clay Lakes area (Westerman, 1977, p.117, 120). Evidence for the conformable interleaving was found on a single exposure just west of Highway 105 about 2 miles north of Vermilion Bay. Photos 7-16, -17 and -18 are a sequence of photos taken from this single outcrop. Photo 7-16 shows a typical sodic granitoid suite exposure composed of 4 major units:

1) biotite-hornblende trondhjemite to quartz diorite (medium to coarse grained texture);

2) fine-grained foliated biotite to leucocratic biotite trondhjemite;

3) metagabbro (dark) possibly a mafic dyke (mafic intrusive suite)

4) medium to coarse-grained to pegmatitic quartz monzonite (potassic granitoid suite).

Photo 7-17 is taken 10 feet perpendicular to strike from Photo 7-16 and shows the same 4 major units tightly and conformably interleaved. With a little further reworking by previously discussed processes this photo is typical of many gneissic exposures. Evidence of cataclastic deformation on this exposure is sparse but is observed as augen-bearing, weakly cataclastic, quartz monzonite veins. Only such veins exhibit the weak cataclasis and not all rock types are deformed. The cataclasis that in part accompanied the deformation which caused the interleaving was probably not penetrative, i.e., it was probably confined to assemblage boundaries or other lithostructural weaknesses. High grade metamorphism caused recrystallization which obliterated much of this evidence.

A glance at Figures 7-1 and 9-1 indicates a good portion of the gneissic suite is disposed around the batholiths of the potassic granitoid suite in the west: specifically the Tetu and Lount Lake batholiths (Chapter 9). Intrusion of such large batholiths is envisaged to have inflicted tremendous strain on the pre-existing rocks. The only major dome and basin structural style (see Photo 13-7, below) observed within the English River Subprovince occurs within the gneissic suite at the eastern periphery to this batholith.

The potassic granitoid suite and some portions of the sodic granitoid suite form the major diapiric event (Gower, 1978, p.475, 479). This diapiric event is regarded to be the main driving force for the deformation which caused the development of the layering or

banding in the gneissic suite. This strong flattening deformation that caused conformable interleaving of assemblages is equivalent to Westerman's (1977, p.117) D_3 event. Westerman (1977, p.120) indicates the subhorizontal thrusting that caused the major dome and basin topography in the Cedar Clay Lakes area probably occured during the same D_3 event. Hunter (1974, p.270) also describes banding in gneissic which becomes increasingly deformed nearer the contact of diapirs.

SUMMARY

The gneissic suite is interpreted as a catazonal, polymigmatitic, polydeformed, heterolithic granitoid complex composed of a medley of plutonic assemblages which were conformably interleaved by a major layer-normal compressive deformation possibly related to the large scale diapiric intrusion of the potassic granmitoid suite. The gneissic suite is in part coeval with, may be genetically related to and is possibly just a more deformed version of the sodic granitoid suite. Subsequently the gneissic suite suffered extensive and intimate penetration by lit-par-lit injected units originating in part from the later sodic and potassic granitoid units. The layering controlled emplacement and each successive intrusive unit gave rise to increasingly complex layering providing additional emplacement sites. The intrusions were possibly emplaced over a considerable amount of time and were severely complicated by reworking in the form of metamorphism, anatexis, metasomatism, and hybridization. The potassic granitoid association does not represent a single widespread episode of plutonism but, based on field relations in the Deception Bay (Lac Seul) area, a series of at least 3 or 4 pulses. The spacing and age

range of these pulses is not known. In effect, unlike the closed system represented by the metasedimentary migmatite spectrum of the Northern Suparacrustal Domain, the gneissic suite is an open system whereby plutonic material has been deformed, reworked and intruded by fresh magmatic additions originating externally in part from the other igneous suites. As indicated by Watson (1973, p.445) the formation of the banding is due to a combination of all of the reworking processes cited above.

The structure, texture and complexity of the English River Subprovince gneissic suite is not unlike the gneisses described in other areas such as West Greenland (McGregor, 1973) and the Kaapvaal Craton (Hunter, 1974, p.264-268).

CHAPTER 8

SODIC GRANITOID SUITE

INTRODUCTION

The sodic granitoid suite is the most widespread of all the igneous suites in the English River Subprovince. The suite is found in both northern and southern domains and constitutes 25% and 38%, respectively (Table 2-1). In the southern domain the sodic suite is about as abundant as the potassic granitoid suite. In the northern domain individual plutons form discrete, distinctive areas within their metasedimentary migmatite hosts (Figure 8-1) while in the southern domain (Figure 8-2) the plutons tend to coalesce to form extensive linear batholith belts. These batholith belts are linear, straight to curvilinear, and roughly subparallel to the overall trend of the southern domain (Figure 8-2). However, locally individual intrusions are outlined in the south.

The compositional spectrum of the sodic granitoid suite includes diorite, quartz diorite, trondhjemite and granodiorite. The earliest rock units tend to be more mafic and are exemplified by the multi-unit Sen Bay stock. With decreasing absolute age the units tend to become increasingly felsic.

In relation to the gneissic suite, the sodic suite is compositionally more uniform, less complex and is relatively non-migmatized on the scale of single exposures. These rocks are moderately but not severely deformed; their most common characteristic is the development of a secondary metamorphic foliation. The foliation is imparted by the common orientation of platy mafic minerals, elongation of quartz and diffuse linear

patches of feldspar. Where enclaves are present they are commonly aligned parallel to foliation direction. Rocks within the sodic suite are typically white to grey on both the weathered and fresh surface; with increasing mafic mineral content the colour becomes progressively darker grey.

Intrusions of the sodic granitoid suite range from small stocks to large batholithic complexes of about the same order of magnitude as those of the potassic granitoid suite. The two largest complexes are (Figure 8-2):

1) the Separation-Indian Lakes Complex extending from Oak Lake to Umfreville Lake.
2) the area collectively underlain by the Chamberlain Narrows, Armit Lake and Sen Bay complexes.

These two batholith complexes occupy between 1550 to 2070 km^2. The two main batholiths strike approximately east-northeast parallel to the trend of the southern domain. Although there are numerous local discordances, the internal foliation or fabric of the batholiths generally conforms to the regional trend. The batholiths are composed of numerous intrusive units but only the most compositionally and/or texturally distinct have been distinguished at the reconnaissance scale of mapping. Minor, more subtle igneous units may become apparent with follow-up detailed investigations. As a rule and in direct contrast to the potassic granitoid suite, members of the sodic suite do not tend to form dykes or apophyses. The batholiths are more continuous and are not disrupted into dyke swarms at their margins.

Foliation ranges from weakly to strongly developed but some units are massive suggesting they may be syn-tectonic and slightly later in age than the foliated varieties.

Foliated biotite trondhjemite with a colour index of 6-12 is the most widespread, abundant unit.

MINERALOGY

Nearly all units of the sodic granitoid suite are dominated by essential plagioclase (oligoclase), quartz, biotite, microline, and hornblende. Colour index ranges from less than 1 up to a maximum of 20 but commonly lies between 6 and 12. Hornblende is generally associated with the more mafic units (colour index 14 to 20). Together these essential minerals constitute at least 95% of the mineralogy of all members. Modal variation (Figures 8-3, 8-4 and 8-5) indicates the sodic suite varies from dominantly trondhjemite to granodiorite in composition and exhibits a fairly narrow range in potassium feldspar: total feldspar. On Streckeisen's (1976) classification scheme most of the sodic suite falls in the tonalite-granodiorite fields with minor to rare overlap into the quartz monzodiorite/quartz monzogabbro (9*) and the quartz diorite/quartz gabbro/quartz anorthosite (10*) fields. The texture of these rocks varies from allotriomorphic-granular to mostly hypidiomorphic-granular; medium-grained inequigranular varieties are most common.

The mineralogy of the sodic suite consists of plagioclase (oligoclase), quartz, biotite, K-feldspar, hornblende, sphene, apatite, allanite, zircon and opaque oxides and retrograde epidote, chlorite and muscovite/sericite. Hypersthene, diopside, magnetite, and hornblende are also present in those rocks that have been metamorphosed to the regional hypersthene zone of high grade metamorphism.

Plagioclase is mostly oligoclase and weathers white to light grey. It is mostly subhedral, but anhedral and euhedral forms are observed. Grain size is commonly inequigranular from fine matrix-size granular plagioclase to medium-grained phenocrysts (3 to 4 mm to locally 6 or 7 mm). The plagioclase is mostly untwinned to poorly twinned and exhibits some sericitic alteration. The crystals boundaries are sharp but more commonly are diffuse and shows the effects of marginal recrystallization. Subhedral to euhedral forms tend to be randomly oriented to locally lineated (especially near the Miniss River Fault near Sioux Lookout). The plagioclase may or may not be antiperthitic.

Quartz is invariably interstitial and varies (depending on degree of recrystallization) from a fine granular (recrystallized) matrix mosaic that is hard to distinguish from plagioclase to coarse, weakly fractured, anhedral, single, interstitial grains with broken undulose extinction. The quartz weathers from translucent grey (unrecrystallized) to cloudy whitish grey (recrystallized).

In distinct contrast to the potassic suite, K-feldspar is late and is almost never observed to form single euhedral crystals. In its most common form it is anhedral, interstitial, and is in most cases only a minor constituent. It is locally porphyroblastic forming broad, anhedral, interlocking plates containing inclusions of biotite and plagioclase. Flame, vein and string perthite are commonly present; myrmekitic textures are common along the margins at the grains.

Biotite occurs as single crystals and as crystal aggregates or clots. Single, evenly distributed biotite crystals may or may not be aligned defining foliation. The biotite clots are visible as negative-weathering pits on the weathered surface. In thin-section the clots

are comprised of randomly oriented biotite crystals; commonly the clots themselves are aligned imparting a weak foliation.

Hornblende occurs as anhedral prismatic and locally poikilitic, randomly oriented crystals. When present in the biotite clotty phase, it is spatially associated with the clots. Accessory minerals including sphene, apatite, zircon, magnetite, almandine and epidote are also associated with the biotite clots. Garnet is present in recrystallized, fine-grained trondhjemite locally in the Horse Creek pluton (Figure 4-1) and near the west shore of Anishinabi Lake and is generally a rare.

Epidote is commonly mantles allanite and is common in all members of the sodic granitoid suite having a colour index greater than 5. Epidote, chlorite and muscovite are common products of retrograde metamorphism as they are often observed to be fine grained mantling or intergrown with biotite. Sphene is commonly associated with opaque minerals (mainly magnetite) and increases in abundance with increasing mafic mineral content. Zircon commonly exhibits complex multiple overgrowths in many sodic suite members and U/Pb age dating should be approached with some caution (see Hinton and Long, 1979).

Some of the sodic suite members such as the Campfire Lake and Chamberlain Narrows plutons (Figure 8-1) have been metamorphosed to the granulite metamorphic facies. In the granulite metamorphic areas the sodic suite is characterized by hypersthene, diopside, magnetite and hornblende. Hypersthene is brown to redish-brown in the field and characteristically is most abundant in the more mafic compositions. Granulite metamorphic grade in the sodic suite is conspicuously marked in the field by

the presence of a yellow-grey, dull to vitreous lustre. This distinct colour change has been noted in other granulite areas (Hubbard, 1975, p.227). Apparently, along with the mineralogical change of primary mafic minerals to hypersthene, diopside, hornblende, biotite and magnetite there is a change in composition and alteration of plagioclase; it is this change which causes the yellow vitreous luster. The fabric of these rocks is invariably granoblastic (Photo 8-1). The mafic minerals tend to form diffuse gneissoid, aligned clots and porphyroblasts. Diopside may or may not be present, it commonly occurs in present in thin discontinuous, leucogranitoid veins of unknown or possibly late stage, metasomatic origin. At least some of this granitoid material is suspected of being in situ melt component; diopside and hypersthene are commonly associated with this leucocratic phase. Magnetite is commonly present in granulite facies trondhjemites and is undoubtedly a product of the reaction:

hornblende + quartz --> orthopyroxene + diopside + plagioclase + magnetite + melt.

Locally in the hypersthene-bearing trondhjemite to quartz diorite Chamberlain Narrows pluton (Lac Seul), magnetite is found suspended in leucocratic quartz-plagioclase halos (Photo 8-2). Similar magnetite with complimentary leucocratic halos has been noted in a hypersthene-bearing wacke bed in English River metasedimentary rocks just south of Bear Narrows (Lac Seul). The texture is similar to stictolithic (flecky) gneiss (Mehnert, 1971, p.38); the complimentary mafic-elsic clots obviously represent a metamorphic reaction but whether it took place in a solid state (ie. metamorphic differentiation) or liquid state is unknown although the former seems more plausible. In most cases the presence of hypersthene is not accompanied by gneissose textures. Besides their characteristic

mineralogy, the granulite grade units are typically fine-grained and completely granoblastic. This and the presence of the vitreous lustre are the two dominant field traits used to recognize the presence of this metamorphic grade.

Within the granulite areas not all of the sodic granitoid suite members contain hypersthene; it occurrence is based on bulk chemistry and water content (Watson, 1973, p.444). In most of the granulite zones recognized thus far in the English River Subprovince hypersthene is common only in the more mafic end members. In other cases, especially in the sodic suite members of intermediate composition, an individual unit may contain diopside- or hypersthene-diopside-bearing assemblages within the space of 30 m. The trondhjemite units within the Chamberlain Narrows complex is typical in this manner; the thermal fronts producing the granulite metamorphism were obviously not completely penetrative or uniformly distributed. In general (unless part of the mafic suite post dates the granulite metamorphic episode which does not appear to be the case), if the mafic units do not contain hypersthene than the more intermediate compositions will not contain hypersthene either.

GENERAL LITHIC GROUPS OF THE SODIC SUITE

Based on the major minerals in conjunction with minor textural changes there are, as approximately 30 units recognized within the sodic suite. The mineralogy has been described above and based on major petrographic traits the sodic suite members can be subdivided into the following groups:

1) equigranular and inequigranular units;

2) porphyritic/porphyroblastic units;

3) potassic units;

4) hybrid units;

5) cataclastic units.

EQUIGRANULAR AND INEQUIGRANULAR UNITS

These units constitute about 80-90% of the sodic granitoid suite. Grain size ranges from fine- to coarse-grained varieties but a medium-grain size is the most widespread. Inequigranular units tend to be subtle, ranging from fine-grained (matrix) to medium grained (plagioclase phenocrysts) but more commonly are medium-grained. Massive units that exhibit weak recrystallization tend to be equigranular while foliated phases that are recrystallized tend to be slightly inequigranular. In general the inequigranularity is not marked enough to be termed porphyritic.

Besides the above textural differences the individual units are distinguished by the presence or absence of accessory minerals recognized in the field including, in order of decreasing abundance: biotite, hornblende, magnetite, epidote, chlorite and garnet. The last three are rarely present in sufficient quantities to be observable in the field. Further subdivisions were based on the presence or absence of foliation, gneissic foliation, lineation and on the K-feldspar to total feldspar ratio. In foliated to gneissic biotite and/or hornblende biotite trondhjemite to quartz diorite (Photo 8-3) the mafic minerals are typically concentrated into diffuse, linear trains or clots. Besides the presence of secondary foliation and recrystallization, these rocks locally show evidence of other structural reworking (Photo 8-4).

PORPHYRITIC/PORPHYROBLASTIC (K-FELDSPAR) UNITS

Unlike the potassic granitoid suite, porphyritic porphyroblastic (K-feldspar) units are relatively rare members of the sodic suite. Porphyritic/porphyroblastic units occur:

1) as a major part in the Separation Indian Lakes Complex, forming a linear, conformable lens (20 by 43 km wide) between Ball Lake and Aerobus Lake;
2) sporadically in several intrusions in the Rugby Lake area and north of Centerfire Lake near the south boundary of the English River Subprovince between Dryden and Sioux Lookout;
3) as local minor occurrences in the Armit Lake complex (Figure 8-2).

Westerman (1977, p.61) placed some of the porphyritic (K-Feldspar) rocks disposed around the northeast part of the Cedar Lake dome within the sodic granitoid suite partly as they possess a secondary foliation marked by alignment of both K-feldspar-megacrysts and mafic accessory minerals. However, the authors believe this unit is part of the Lount Lake batholith (Potassic Suite) that was deformed during the horizontal tectonic event that produced the dome-basin structures in this area. Westerman (1977, p.61) indicated that this area is an extension of the Cliff Lake porphyritic granodiorite (ie. part of the Lount Lake batholith), and that the development of foliation in the later granitic intrusives is common in marginal units of larger bodies and throughout areas which branch out as thin arms.

In the Separation-Indian Lakes complex, the porphyritic/porphyroblastic granodiorite is characterized by anhedral, porphyroblastic, inequigranular megacrysts of potassium feldspar (1.5 to 5 or 6 mm in length) situated concordantly in a medium- to

coarse-grained biotite to hornblende-biotite trondhjemitic to granodioritic matrix (Photo 8-5). The matrix is characterized by plagioclase (oligoclase), quartz, K-feldspar, biotite, hornblende, opaque oxides and retrograde chlorite, epidote, leucoxene and zircon (commonly with overgrowths). Quartz is variably fractured to recrystallized while the hornblende is associated with biotite in lenticular clots (Photo 8-5). Locally the K-feldspar apparently deflected the mafic mineralogy during growth; such megacrysts have grown along the fabric and include patches of linear quartz or mafic minerals concentrations. The term porphyritic/porphyroblastic was used in that the growth of such K-feldspar anhedra has long been controversial centering on the problem of granitization (Marmo, 1971, p.58-81). Recently Ferguson and Harte (1975) studied the textural patterns of porphyroblasts to determine their time of relative growth. They concluded (p.478) that truncation of fabric at porphyroblastic margins, whether they exhibit matrix fabric deflection or not, is not sufficient criteria for a replacement (secondary) origin. In the absence of internal "S" (S_1) patterns it is extremely difficult to determine if the porphyroblasts are pre-, syn- or post-fabric growth. The time of growth of these K-feldspars remains unknown. The fact that rare quartz ribbons do penetrate the K-feldspar anhedra and the lack of pressure shadows does suggest post fabric growth. They do not appear to contain biotite inclusions as exemplified by the Lount Lake batholith but the mafic minerals do appear to have been shunted aside.

GRANITIC UNITS

Rare granitic units show evidence of weak to strong recrystallization including the local development of foliation and on this basis were included within the sodic suite. However, in some cases, e.g., the fine-grained quartz monzonite at the east end of Oak Lake. Thin section examination indicates this recrystallized texture consists of anhedral grains of K-feldspar, quartz and plagioclase. Due to the very fine grain size, it is difficult to infer if the texture is primary or secondary. Elsewhere this unit is a minor constituent recognized locally in the Miniss-Tully Lakes area but essentially it does not form major intrusives.

HYBRID ROCKS AND ENCLAVES

Hybrid units marked by anomalous diffuse mafic concentrations are locally present throughout the sodic suite. Hybridization is common around many of the enclaves. Enclaves within the sodic granitoid suite include mafic volcanic rocks (from the Wabigoon Subprovince or extension of the Separation Lake Belt), other sodic suite members, locally gneissic suite members and metasedimentary rocks (near the northern-southern domain interface). The enclaves are invariably parallel to the internal fabric (if present in the host) and tend on the whole to be more mafic than their host. Overall, inclusions tend to me more abundant in the sodic suite than in the potassic suite and are found throughout the batholiths. There is no tendency for the enclaves to be restricted to the margins of the intrusives.

CATACLASTIC UNITS

Cataclastic textures are not as conspicuous in the sodic suite relative to the potassic suite. The reasons for this lie in the tendency for the potassic suite to develop coarse textures (especially coarse porphyritic K-feldspar) and the lack of mafic, micaceous, foliated minerals. The greater abundance of mafic minerals and the common presence of foliation inhibits the development of cataclastic textures to a certain extent in that some of the strain can be taken up by gliding along these previously developed micaceous foliation plains. Higgins (1971, p.59-60) indicates both micas and quartz are the first minerals to be deformed while feldspar resists crushing; feldspar comprises the most common porphyroclasts preserved in deformed rocks and generally exhibits textures indicative of cataclastic deformation. According to Higgins (1971, p.59) micas are the first minerals to be deformed. If they are present in abundance, the deformation will continue to grind these down and will not effect the feldspar initially. Thus, as a rule the sodic suite rocks do not appear as intensely deformed as those of the potassic suite.

The Miniss River fault and the Sydney Lake cataclastic zone both affect members of the sodic suite but in general the sodic suite is not overly abundant in these areas.

INTRUSION TYPES OF THE SODIC GRANITOID SUITE

There are two general types of sodic granitoid suite plutonism:

1) simple, homogeneous plutons, and

2) complex, heterogeneous, intrusive complexes.

SIMPLE, HOMOGENEOUS PLUTONS

Stocks, large sills and batholiths exemplifying this type are characterized by relatively homogeneous composition and were intruded as relatively competent, single diapirs or rare phacoliths. In general these intrusions are characterized by a single dominant sodic unit upwards to 2 or 3 units with one unit still dominating. In certain cases the major single unit may be shown to be divisible into 2 or 3 units based on very subtle differences in texture such as: i) minor differences in equigranularity of grain size; ii) habit of a major minerals or iii) subtle variation in fabric. In general however the intrusions consist of one or two dominant units intruded by later members of the potassic granitoid suite. These intrusions tend to be circular to oval to elongate, large sill-like bodies that are possibly phacoliths. Contacts with the country rock are sharp and commonly the structure of the host rocks are bent into concordance thus wrapping around the intrusions. Locally the host-rocks also exhibit minor fold warps near the contact of the intrusion, e.g., Daniels Lake pluton, Figure 8-2, but these fade away from the contact. Enclaves of country rock tend to be confined to the outer margins of the intrusions but generally are not overly abundant. Near the contact of the intrusives, fabric tends to parallel and undulate with margins but in the interior tends to be consistent and subparallel to either the trend of the intrusive itself or the regional trend of that portion of the English River Subprovince. In most cases elongate intrusions tend to parallel and accentuate the regional approximate east-west trend of the English River Subprovince. Commonly the fabric is more pronounced near the margin of the intrusions a feature also noted by Gower (1978, p.406) who reports the development of vaque banding near the contact of the Dalles

batholith. In the simple intrusive style, dikes extending out into the country rocks are rare. Except for this last fact this simple intrusive style most closely approximates that of the potassic granitoid suite. Both of these styles are regarded to be diapiric in accordance with the criteria set forth by Stephansson and Johnson (1976) and Stephansson (1977).

Examples of the simple intrusive type are found mainly in the Northern Metasedimentary Domain and more locally in the Southern Plutonic Domain. The Dalles batholith (Gower, 1978, p.403-433), Daniels Lake pluton (Figure 8-2) are typical examples in the south while the Campfire Lake pluton, Gone Lake batholith, Rowdy Lake batholith, Aerial Lake pluton, Adamhay Lake pluton (Figure 8-1) are typical examples in the northern domain. The Ear Falls sill is an example of a simple intrusion that may be a phacolith (Desnoyers, 1977, p.11). The Dalles batholith, Daniels Lake pluton and Campfire Lake pluton are the most characteristic examples.

Dalles batholith

The Dalles batholith has been studied by Gower (1978, p.403-433) in some detail and much of the following is summarized from his description. This batholith occupies 450 km^2 and according to Gower (1978, p.403) and conceivably was the dominant force controlling the disposition and fabric of the gneissic suite at Kenora. About 95 percent of the batholith comprises medium-grained weakly foliated to massive biotite tonalite (trondhjemite by the Ayres (1972) classification) to granodiorite. Modal analyses (Figure 8-5, No. 2) indicate a tight cluster on the QFM diagram and a slightly less concentrated cluster on the QPK diagram. The remaining 5 percent of the batholith comprises of granodiorite to granite (quartz monzonite after Ayres (1972) that occurs as both irregular,

diffuse, gradational patches (ie. gradational into the main phase locally) and as sharply defined veins and dikes (typical of the potassic suite). Foliation is weakly developed to nonexistent in the main unit. Near the margin the foliation becomes more prominent and vague banding that locally exhibits minor fold structures is also developed.

Gower (1978, p.407) described the mineralogy in detail. Plagioclase (An_{17-23}) is anhedral, poor to moderately twinned, unzoned to weakly zoned, is slightly saussuritized in the core area and sericitized at the margins. Microcline feldspar is anhedral, interstitial and exhibits rare flamme and string perthite. Both polygonized and unpolygonized quartz are presentin the same thin section again reflecting the difference in the effect of metamorphism exhibited even within single samples. The only mafic mineral is olive-green biotite. Apatite, allanite, sphene, muscovite, magnetite, zircon and chlorite are all accessory minerals. The granitic unit is typical of members from other potassic granitoid suites and includes well twinned, unzoned plagioclase (An_{14-18}), K-feldspar and pink quartz, the pink being due to a coating of hematite). Locally, there are amphibolite enclaves that may or may not represent former dykes.

Gower (1978, p.407) interpreted that severe strain related to emplacement of the Dalles batholith as revealed by deformation in the outer shell including:

1) minor tight folds in the foliation and vague banding;

2) buckled fine-grained granite veins;

3) the development of the gneissic fabric.

The presence of marginal deformation as stated above, the oval shape, conformable marginal fabric, and the warping of the gneissic suite around it (the degree of deformation

in the gneissic suite increases in intensity toward the batholith) all suggest a diapiric intrusive process was active (Stephansson, 1977). Gower (1978, p.407), however, suggested that the margin was solid while the interior continued to be intruded by magma causing further expansion which produced shortening normalto the contact.

The REE data (Gower, 1978, p.417 and p.422) indicate typical LREE enrichment-HREE depletion with a flat to positive Eu anomaly. Gower (1978, p.427) suggested derivation of the batholith by 10% partial melting of a basaltic source rock (a hornblende-bearing garnet granulite) or, if the positive Eu anomaly is to be believed, a quartz eclogite. The derivation of the Dalles batholith from basaltic source rocks concurs with the generation of trondhjemitic-tonalitic magmas from partial melting of rocks of basaltic composition proposed by Barker and Arth (1976). Gower (1978, p.419, pg.419) indicates the melting must have taken place under equilibrium conditions to give such a homogeneous magma. The authors believe the overall style of intrusion of these bodies to be diapiric; whether the magma rose as a single entity or continued to be nourished from below after intrusion causing further expansion is unknown. Of interest is the fact that Gower (1978, p.431) regards the granitic unit as cogenetic with the main phase of the Dalles batholith and is either:

1) a partial melt derivative, or more probably,
2) a residual liquid concentration which separated during the final stages of crytallization.

He suggested derivation of the granitic unit by 70 percent fractional crystallization of the main unit. This may explain the gradational patches but the authors are unsure that such

a process should be used to explain the granite veins and dykes.

Campfire Lake and Daniel Lake Plutons

The Daniels Lake and Campfire Lake plutons are similar to the above. The west half of the Campfire Lake pluton contains diopside and minor hypersthene and has been metamorphosed to the granulite metamorphic grade. The mineralogy of the Campfire Lake pluton includes plagioclase (An_{33}), quartz, biotite, diopside, hypersthene, actinolite, K-feldspar, epidote, chlorite, muscovite, opaque minerals, sphene and apatite. Quartz, plagioclase and biotite compose at least 97% of the pluton. The Daniels Lake pluton consists of plagioclase, quartz, biotite, K-feldspar, opaque oxides, zircon, apatite, sphene, epidote, chlorite and allanite. Both of these plutons are leucocratic with less than 5% combined mafic minerals. The country rocks are deflected and wrap around both plutons; minor shallow dipping crenulation folds are apparent in the country rocks along the eastern periphery of the Daniels Lake pluton.

COMPLEX, HETEROGENEOUS PLUTONS

This type directly contrasts with the simple plutons described above. These intrusions tend to be larger, forming discrete batholiths and ill-defined intrusive complexes. The discrete batholiths may have risen as diapirs similar to those of the simple type. Heterogeneity of the complexes ranges from fairly simple such as the Separation-Indian Lakes complex where mappable units are separable at the present scale to the complexity exhibited by the Sen Bay-Armit Lake complex where the numerous units are so chaotically mixed as to prohibit meaningful separation at the present map scale.

These intrusions tend to be elongated, subparallel to the overall trend of the English River Subprovince and not circular like those of the simple intrusive style. These multi-unit intrusives are characterized by up to 10 identifiable igneous units. Some of these units are internal, found only within the limits of the individual intrusive complex proper; others are found both intruding the batholth and its host rocks and are considered to be external. Intrusive units of this group are less deformed and less reworked than the gneissic suite; cross-cutting relationships allow one to work out the sequence of intrusive development (Photo 8-6). Contacts with the country rock can be sharp such as the Bluffy Lake batholith (Figure 8-1) but tend to be gradational. Local warping of the country rocks around the intrusions is not as pronounced as the simple diapiric intrusive style. Enclaves are not confined to the margins but may be found throughout the intrusives. Fabric is more variable than exhibited by the simple diapiric style intrusives; minor contortions are common and probably reflect individual, internal magmatic intrusives within the complexes. Dyke apophyses are still as rare as that of the simple intrusive style.

These heterogeneous, multicyclic intrusives and intrusive complexes are mainly found in the southern domain. The Bluffy Lake batholith is the only example of a heterogeneous, elongate, discrete batholith in the northern domain. It is the largest batholith in the northern domain and occupies 706 km^2. The intrusive history of the Bluffy Lake batholith is only generally understood but based on differences in grain size and fabric the igneous units present include massive and foliated biotite-hornblende diorite, several units of massive, foliated, foliated to gneissic, biotite,

hornblende-biotite and leucocratic trondhjemite to quartz diorite.

Not all of the units in these complex intrusives are cross-cutting, some are conformable in which case the history of intrusion cannot be worked out. In most cases there is a decrease in mafic mineral abundance in successively younger units.

Sen Bay stock

One of the older units of the Sen Bay stock has a minimum age of 3.3 +/- 0.1 Ga (Krogh et al. 1976, modified by Hinton and Long, 1979) and is the oldest dated rock in the English River Subprovince and indeed in the Superior Province of northwestern Ontario. The Sen Bay stock is a heterogeneous, polyphase intrusive situated within the Sen Bay - Armit Lake complex (Figure 8-2) which is part of the sodic suite, situated just north of Sioux Lookout (Figure 8-6).

In the field up to ten identifiable units are present but only about half of these belong to the stock proper. The external units are also common to the region outside the limits of the stock. The contact of the stock (Figure 8-6) is irregular; it cuts across the fabric of the host complex and is in part gradational into the sodic suite host. Limits of the stock are approximate based on the general absence or disappearance of the internal units characteristic of the intrusive. Internal fabric (mainly a northeast foliation and lineation) tends to cross the elongated (east) axis of the batholith complex and does not parallel the outline of the stock itself (Breaks et al. 1980).

Table 8-1 is a summary including relative sequence of intrusion and age relationships amongst the ten (internal and external) units that constitute the stock. Modal analyses (Figures 8-7 and 8-8) indicate that the younger intrusive units show an increase in quartz

(accompanied by a slight increase in K-feldspar) concommitant with a decrease in mafic mineralogy. The units vary with decreasing age from diorite to quartz diorite to trondhjemite to leucocratic trondhjemite to granodiorite.

All of the units indicated in Table 8-1 are not present in every outcrop. The oldest dated unit was a diorite to quartz diorite that showed field evidence of reworking in the form of metamorphic differentiation and/or hybridization (Krogh et al. 1976). Another phase of similar diorite to quartz diorite composition was characterized by a stickolithic (flecky) texture (Photo 8-7) (see Mehnert, 1971, p.37) evidence of considerable anatectic reworking. This partial melting event was not observed in the dated diorite to quartz diorite unit and may suggest the stictolithic unit is the older of the two. The stictolithic texture is described Mehnert (1971, p.38) as coarse grained clots of complimentary mafic/felsic minerals - the flecks are formed by segregation of the dark component from the intermediate (paleosome) parent leaving the leucocratic halo behind. The clots (Photo 8-7) form as discrete or diffuse aggregates. Photo 8-8 shows the relationship of units C and D (Table 8-1) intruded by unit I (Table 8-1). Nearly all of units are characterized by inequigranular grain size (mostly in the medium-grained size range) and anhedral mineral constituents. Twinning is mostly destroyed in plagioclase; the plagioclase margins are diffuse but on the whole not strongly recrystallized or altered to sericite. Magnetite is a common opaque accessory. Chlorite and epidote, in association with hornblende, are mainly retrograde metamorphic products. Sphene commonly is observed to mantle magnetite. Diopside is locally present in the more mafic phases (A and D specifically) and is undoubtedly related to the granulite metamorphic zone situated

just north of the stock (Figure 7-6). Units F, G, H and I, found throughout the Deception Bay (Lac Seul) gneissic suite, correlate with the units documented in Table 7-6 (Nos. 11, 10, 9, 12 respectively).

Chemistry

Chemical analyses from the Sen Bay stock are presented in Table 8-2 and plotted on the AFM diagram (Figure 8-9). Both the internal and external units show a typical trondhjemite trend (Barker and Arth, 1976, p.598) and exhibit iron-magnesium depletion/potassium enrichment with decreasing age (AFM diagrams 1, 2 - Figure 8-9). Whether the internal units (essentially a diorite-quartz diorite-trondhjemite suite) represent a genetically related, continuous differentiated igneous series or is a result of partial melting of rocks of basaltic composition is unknown (Barker and Arth, 1976; Arth et al. 1978). The fractional crystallization mechanism mainly involves the removal of hornblende (Arth et al. 1978, p.314). Nockolds and Allen (1953, 1954, 1956) show that the Li/Mg ratio increases with differentiation and is a common feature in many magmatic rock suites. However the absolute amount of Li decreases in the most differentiated rocks due to i) decrease in overall abundance of Mg-bearing minerals, and ii) during fractional crystallization Li tends to be concentrated in biotite which is depleted in the later phases. The Sen Bay stock shows an increase in Li/Mg ratio up to unit 2; thereafter the ratio decreases (Figure 8-9). The Li/Mg cycle and the trondhjemite (potassium enrichment - Fe/Mg depletion) trend (AFM diagram #2 in Figure 8-9) appears repeated for the external units (# 5, 6, 7, 8, Figure 8-9). In accordance with Arth et al. (1978, p.314) the presence of successive, cumulatively less mafic rocks (compositions vary

continuously from 44.7 to 74.4 SiO_2 suggests fractional crystallization may have been the dominant mechanism.

Barker and Arth (1976) and Barker et al. (1976) recognize two types of trondhjemite: a high Al_2O_3 type (greater than 15%) and a low Al_2O_3 type (less than 15%). Based on Al_2O_3 values greater than 15% (15.3 to 19.0%) and low Rb values (all less than 100 ppm) the Sen Bay Stock is the high Al_2O_3 type. In fact, most of the Archean trondhjemite suites are the high aluminum-type (Barker and Arth, 1976, p.596).

Other heterogeneous intrusives such as at Chamberlain Narrows (Lac Seul) show a similar mafic depletion with age. The Chamberlain Narrows Complex (Figure 8-2) consists of the following units (Photo 8-6 in part) in order of decreasing age:

a) coarse-grained, hypersthene-biotite-hornblende quartz diorite (with minor metagabbro enclaves)

b) foliated to gneissic, magnetite-hornblende-biotite trondhjemite to quartz diorite (minor hypersthene and diopside). Mafics occur in clots, locally massive to gneissose (local metagabbro enclaves): Unit B in Photo 8-6,

c) massive to weakly foliated magnetite-biotite trondhjemite; fine-grained , colour index 8-12: Unit R in Photo 8-6,

d) foliated biotite trondhjemite with colour index = 6-8,

c) leucocratic biotite trondhjemite, fine-grained, contorted, colour index <5: Unit 1 - in Photo 8-6,

f) metagabbro as thin, shallowly discordant dykes: Unit 2 in Photo 8-6,

g) medium-grained leucocratic trondhjemite to granodiorite with local

metagabbro enclaves: Unit 3 in Photo 8-6,

h) fine to medium-grained and medium to coarse-grained quartz monzonite as thin veins and dykes commonly associated with Unit C.

i) very fine-grained massive biotite trondhjemite as minor narrow dykes

j) medium- to coarse-grained, cross-cutting quartz monzonite (Unit 4 - Photo 8-6) to locally biotite-magnetite syenite (Photo 9-9).

This progression in sequence of intrusion from mafic-rich, sodic compositions to mafic-poor/potassic compositions in magmatic cycles is the most widely encountered evolutionary pattern described in high-grade terrains throughout the world. However, opposite trends have been cited in the literature and include:

i) mafic enrichment/quartz depletion, potassium enrichment (Emmermann and Rein, 1976).

ii) potassium depletion (Kesler and Sutter, 1979).

The mafic depletion-potassic enrichment trend is regarded to be a very general perhaps oversimplification of the evolution of these batholiths.It is clear for instance that the fine-grained to very fine-grained massive biotite trondhjemite dykes in the Chamberlain Narrows Complex are late and intrude potassic units while in the Sen Bay stock they predate the potassic granitoid suite intrusions (Table 8-1). Similarly, it is evident that the sequence of intrusion of the external units of the Sen Bay stock (ie. the units common to the rocks outside the stock including the gneissic suite progresses as follows: metagabbro, fine-grained trondhjemite, holo-leucocratic biotite trondhjemite, and leucocratic biotite quartz monzonite (Table 8-1) while the order of intrusion for

compositionally similar unitss in the Deception Bay (Lac Seul) gneissic suite progresses hololeucocratic trondhjemite, fine-grained trondhjemite, metagabbro and leucocratic quartz monzonite (Table 7-6). The apparent discrepancy in composition and relative age of intrusion of the metagabbro dykes and fine-grained biotite trondhjemite dykes indicates there may have been several mini-cycles of granitoid intrusion or there may have been considerable overlap in orogenic emplacement activity. In all likelihood the time-space complexity of Archean plutonism is due to episodic development of calc-alkaline differentiation. Episodicity in plutonism is a common phenomena in many of the more recent plutonic belts (Hudson, 1979). The Sen Bay stock appears to have undergone at least two periods of magma generation.

SUMMARY

Two types of intrusive rocks comprise the sodic suite in the English River Subprovince: a simple, homogeneous, diapiric style and complex, multi-unit, intrusive complexes. The simple intrusion type is characterized by fairly uniform, homogeneous compositions typically comprise one or two main igneous units and one or two subordinate later units. These intrusions tend to be oval in form, contain few enclaves and typically do not generate dykes. This simple type of intrusion is envisaged as being forceful causing deflection of the host lithologies and is similar to the intrusive style of the potassic suite. The uniformity of the composition and texture in the simple style suggests intrusion in the solid state. The tendency for enclaves to occur along outer margin and the warping of the host rocks suggests a diapiric style of intrusion (Stephansson and Johnson, 1976;

Lindh (1977, p.264-266). Magmatic differentiation has probably played an important part in the formation of some of those intrusions that have 2 or 3 igneous units but partial melting of basaltic compositions as proposed for the Dalles granodiorite cannot be ruled out. There does not appear to be any systematic spatial zoning of the few successive units and it is not known whether these later units (which tend to be more potassic) are a product of magmatic differentiation of the main unit or were intruded from an external source at a much later date.

The heterogeneous complexes comprise numerous igneous units, show no evidence of deflection of the host-rocks but according to Lindh (1977, p.264) its absence should not be the sole criteria for eliminating a diapiric model. The heterogeneous complexes are dominantly conformable in broad outline to the trend of the English River Subprovince. Internal units may or may not be conformable; they are haphazardly oriented and show no systematic spatial pattern. The complexes contain enclaves which are found throughout which combined with the lack of dykes in surrounding rocks suggest passive intrusion by stoping and piecemeal assimilation. Chemistry indicates the heterogeneous sodic complexes undergo episodic periods of magma differentiation characterized by cycles of potassium enrichment/mafic (Fe/Mg) depletion.

Diapiric tectonics may have marked the final stages of plutonism in the English River Subprovince. The simple diapiric style of the sodic suite is similar to the potassic intrusive style and the two may be approximately related to the same tectonic event. Conformability of the heterogeneous sodic complexes into linear patterns signifies tectonic adjustment and a greater age than the sodic diapirs. The differences in tectonic style

between the simple (diapiric) and heterogeneous types may be due to difference in intrusive mechanism (style) or a difference in age or combination of both It is possible the simple type of sodic plutons may be younger than the heterogeneous complexes The the diapirism may in fact be part of the driving force that caused the linear conformity of the heterogeneous plutonic complexes

CHAPTER 9

POTASSIC GRANITOID SUITE

INTRODUCTION

The potassic granitoid suite is the youngest of the intrusive suites and culminated Early Precambrian (Archean) igneous activity in the English River Subprovince. This suite underlies approximately 40 percent of the Southern Plutonic Domain (Table 2-1) where it is roughly as abundant as the sodic suite. The major batholiths are mainly restricted to the western portion of the Southern Plutonic Domain (Figure 9-1). Within the Northern Metasedimentary Domain, the potassic granitoid suite is considerably less abundant and overall occupies about 6 percent of the area. Most of these rocks are concentrated within the Great Falls - Davidson Lake and the Fletcher Lake Batholiths (Figure 8-1).

The potassic grantoid suite is characterized by a granodiorite-quartz monzonite-granite (sensu stricto) assemblage that ranges from syn- to- post-tectonic. Earliest units within the suite are represented by the Lount Lake batholith which is predominantly porphyritic granodiorite. Later units tend to increase in alkali feldspar content. Members of the potassic suite are typically of uniform composition over extensive areas, undeformed, massive and relatively unrecrystallized. In general they contain pink alkali feldspar evident on the weathered and fresh surfaces. On more extensively weathered outcrops the rocks are brick-red with some of the colouration due to hematite-bearing quartz. More extensively weathered outcrops the rocks tend to be brick red. The overall massive texture implies that almost magmatic flowage had essentially ceased prior to crystallization.

The form of potassic granitoid suite intrusions range from thin apophyses to stocks to large batholiths (more than 2000 sq. km). West of Highway 105, two major batholiths linked by granite apophyses dominate the Southern Plutonic Domain. These two batholiths, the Lac de Bonnet batholith (corresponds to the west extension of the Lac de Bonnet Pluton/Winnipeg River Plutonic Complex (McRitchie, 1971) and the Lount Lake batholith (Figure 9-1), are linked by narrow apophyses which together form an elongate, rectilinear potassic mass at least 2700 km^2 in area. The overall trend of this batholith is easterly, parallel to the that of the Southern Plutonic Domain. Unlike the sodic granitoid suite, the potassic suite characteristically has apophyses branching out into the country rock in the form of dykes and sills. The volume of these potassic injections decreases proportionately away from the major intrusive centres. Other major plutonic centres occur at Thaddeus Lake, Ryan Lake and Anishinaki Lake and these are also connected by similar apophyses. Due to the proportionate increase of potassic injections near the major centers, the margins of major batholiths such as the Tetu, Thaddeus Lake, and Ryan Lake are approximated by the change in dominant rock composition from granite to tonalite. The Lount Lake batholith is an exception to this and in general did not generate dykes into the surrounding host-rocks.

Generally the potassic granitoid suite forms extensive dyke-like swarms within all surrounding rock units including diatexite derived from metasedimentary rocks. These dikes and sills generally take advantage of any pre-existing zones of weakness or structural avenues such as lithological contacts. The dykes and sills range from 1 cm wide ribbons to extensive, probably composite, coalescing sills such as between Helder

Lake and Oak Lake. Contacts of the dykes and sills are generally sharp, unchilled and exhibit little if any reaction with their host rock. Local potassium-rich dykes infiltrate shear zones; and in places such rocks are notably foliated to weakly protocataclastic at their margins. Development of this planar fabric is especially prevalent in relatively thin tentacles as in the Cedar-Clay Lakes area (Westerman, 1977).

Within the gneissic granitoid suite, alkali feldspar-dominant intrusive units are both discordant and concordant to the gneissic fabric. Concordant sills tend to thicken and thin and are locally discontinuous, forming isolated patches. Where there is significant concentration of the potassic granitoid units within the gneissic suite, Gower (1977, p.349-350) classified the rocks as granitic pegmatoid gneiss. Concordant potassic granitoid units parallel all contortions, including isoclinal folds (Westerman, 1977, p.188) within tonalitic gneiss but rarely cut across the fabric. Margins of these granite intrusions are diffuse, uneven or locally hybrid. The latter may have originated via potassium metasomatism (Photo 7-1). Locally the concordant potassic units within the gneisses are complimented by marginal biotite-rich melanosome (Westerman, 1977, p.188) layers suggesting an **in situ** anatectic origin similar to diatexite. Discordant dikes of the potassic composition are more continuous and of consistent thickness along their strike length. Their margins are generally sharply-defined, enclave-free, uncontaminated and locally mimic contortions of the gneissic fabric. The dykes intrude the fabric of the gneissic and sodic granitoid suite units at shallow to high angles. Locally near major structural-lithologic features such as the Archer Lake (Sen Bay) Dome (Figure 8-2), the dikes are commonly oriented along radial, perpendicular fractures.

It is apparent from the above field evidence that several relative ages of intrusion of potassic granitoid dykes/sills are present. The concordant, contorted potassic granitoid units with diffuse margins emplaced in the gneissic suite are definitely cut by later dike typical members of the potassic granitoid suite. Therefore a considerable chronological gap remains a possibility. Whether or not this earlier potassic granitoid component in the gneisses is genetically and chronologically related to the main event of potassic granitoid suite magmatism or to a tectonic event germane to the tonalitic gneissic is currently uncertain. Elsewhere the relation is not as clear. In some cases the concordant phases appear to have nucleated from nearby discordant dykes. Based upon grain size and accessory minerals, there can be up to six separate potassic suite units within a given exposure. In places, age relationships are complexly intertwinned: a fine-grained potassic unit may cut an earlier pegmatoid unit which may in turn be found to be intruded by a similar pegmatoid unit along strike. Commonly, many outcrops of the sodic granitoid suite are intruded by one to two units of the potassic granitoid suite. Within the gneissic granitoid suite there are generally two and in many cases three ages of injection of potassic granitoid suite rocks. Locally the oldest of these three units exhibits modification in the form of hybridization, metasomatism or weak recrystallization.

Grain size of the potassic granitoid units is more variable than that of the sodic granitoid suite and ranges from fine-grained to pegmatite. Fine-grained quartz monzonite is rare but is generally found to be the latest unit and locally cuts even the pegmatite units which also tend to be late. Generally the potassic granitoid units are medium-grained (1 to 4 mm) and equigranular. Coarse-grained and pegmatoid units tend to be more

inequigranular. For the most part, individual members of the potassic granitoid suite exhibit a constant medium-grain equigranular texture and relatively homogeneous compositions over vast areas which is interpreted to signify uniform homogeneous equilibrium conditions during crystallization. Porphyritic units generally represent the oldest members of the suite. Textures are mainly hypidiomorphic-granular and most of the exposures are massive albeit transected by minor, widely spaced, fractures or joints. The fractures are generally clean, uncontaminated but locally exhibit a pink weathering rind (up to 5 cm away from the fracture), the pink reflecting a combination of hematized or iron oxide-stained quartz and metasomatic growth of pink alkali feldspar. Locally, especially in the Tustin-Bridges area, the fractures are epidote-filled. Most of the fracturing is approximately vertical but horizontal jointing with a spacing of 5-8 cm, is locally prominent as at Maynard Lake.

MINERALOGY AND MODAL VARIATION

Members of the potassic granitoid suite are mineralogically less variable than the sodic or gneissic granitoid suites. All units of the potassic suite are dominated by a relatively simple mineralogy consisting of potassium feldspar (microcline), plagioclase, (oligoclase to minor albite) and quartz which in total constitute not less than 95% of the mode. The suite also exhibits the widest range in potassium feldspar to total feldspar ratio (Figure 9-2). Potassium feldspar content rarely exceeds 2/3 of the total feldspar. Except for variation in grain size and potassium feldspar content, the suite is petrographically uniform and most of the minerals exhibit a consistent habit. Potassium feldspar tends to be euhedral and early-forming; plagioclase is early to intermediate with quartz crystallizing

interstitially as the latest mineral. Most of the suite members are holo-leucocratic (less than 5% total mafic minerals). Biotite dominates but rare hornblende can occur in granodiorite members and in late metasomatic zones. In most cases the mafic minerals are evenly disseminated and rarely occur in podiform concentrations. Homogeneous distribution of all four major minerals (K-feldspar, plagioclase, quartz and biotite) is the norm. Potassium feldspar is the only major mineral of the potassic granitoid suite that exhibits inhomogeneous distribution patterns.

Unlike the batholiths of the sodic granitoid suite, the potassic granitoid suite batholiths tend to be less complex and comprise only a few units. In general the main unit constitutes at least 75% of a typical outcrop with ancillary units forming only a minor percentage. An approximate systematic age relationship is apparent at many exposures: in order of decreasing age the units most commonly encountered include i) porphyritic granodiorite; ii) equigranular biotite quartz monzonite; iii) holo-leucocratic, equigranular, biotite quartz monzonite; iv) pegmatitic quartz monzonite.

Based on major traits there are seven major rock units comprising the Potassic Suite: 1) equigranular units, 2) clotty quartz monzonite, 3) porphyritic units, 4) granodiorite to trondhjemite units, 5) syenitic units, 6) pegmatite-aplite units, and 7) cataclastic units.

EQUIGRANULAR UNITS

Equigranular potassic granitoid suite units (Photo 9-1) range from fine to coarse-grained. These are ubiquitous through the English River but are most prominent in the Southern Plutonic Domain forming dykes and sills that intrude all other rock types

and represent the most abundant widely recognized member of the potassic suite. It is the major component of all major batholiths (Figure 9-1) except for the Lount Lake batholith and also forms numerous, smaller stocks.

Mineralogically the equigranular units are composed of potassium feldspar, quartz, plagioclase (oligoclase), biotite, muscovite, hornblende (rare) , opaque oxides (mostly magnetite), retrograde chlorite, diopside, hypersthene, sericite (alteration of plagioclase), zircon, allanite, sphene, and apatite. Potassium feldspar is mostly subhedral, and less commonly anhedral or euhedral, perthitic and/or myrmekitic. It may occasionally display inclusions of biotite and/or quartz. Quartz is invariably interstitial, forms coarse irregular subgrains showing variable degrees of fracturing (the fractures are frequently evident in hand specimen). It is commonly grey and translucent in the field and is mainly unrecrystallized. In thin section plagioclase is mostly untwinned; albite twinning, if present, is hazy and ill-defined. Plagioclase forms generally unzoned, subhedral to anhedral crystals; euhedral crystals are present but are not common. The plagioclase is lightly altered to sericite and in some cases the sericitic alteration is compositionally selective with respect to twins. Myrmekitic texture is present most frequently in the Oak Lake area and is most common where plagioclase abutts against potassium feldspar. Biotite is brown and typically disseminated evenly. Hornblende is exceedingly rare and is present in the quartz-poor units. Diopside is rare as a late stage hydrothermal accessory. Magnetite is the most common accessory and is concentrated locally up to 5 percent. All the accessory minerals tend to concentrate near biotite but they are not nearly as abundant as in the sodic or gneissic granitoid suites. Zircon overgrowths are

fairly common. Muscovite is both interleaved with and cuts across biotite. Sphene is often found to mantle the opaque minerals. These accessories show incipient stages of recrystallization around margins of crystals (mainly quartz and feldspar) but in general are well preserved.

CLOTTY QUARTZ MONZONITE

Clotty quartz monzonite (Photo 9-2) is perhaps the most peculiar rock type occurring within the English River Subprovince. The rock varies in composition from dominantly quartz monzonite to locally granite (sensu stricto) and typically contains clots characterized by assemblages of quartz, biotite, garnet, cordierite, sillimanite and minor potassium feldspar, chlorite and magnetite. Assemblages containing quartz, biotite and garnet is by far the most common mineralogy of the clots. The most notable example occurs at Perrault Falls (Morin 1970). The present survey has shown this peculiar rock type is commonly distributed proximal to the regional contact between the northern and southern domains of the English River Subprovince (Figure 9-3). Regional distribution of the clotty rocks is imperfectly known due to lack of detailed mapping but have been recognized east of the study area near Souter Lake, north of Armstrong.

The matrix of the clots is pink-weathering, medium-grained, hypidiomorphic granular quartz monzonite composed of nearly equal amounts of quartz, potassium feldspar, and plagioclase (An_{20-25}), up to 5 percent brown to rare green biotite, minor muscovite, minor retrograde epidote and chlorite, rare accessory apatite, allanite and zircon. Morin (1970) found the green biotite to be spatially associated with garnet (in the matrix) and the clots

themselves. The difference in colour is related to the oxidation state of Fe, the ratio of Fe^{3+} and Fe^{2+} and the TiO_2 content (Morin, 1970, p.42). In hand specimen the matrix is texturally and mineralogicaly identical to massive equigranular quartz monzonite of the potassic suite. In thin section, however, the clotty quartz monzonite differs in that it locally contains rare, microscopic crystals of cordierite and sillimanite. Cordierite is commonly heavily altered to serpentine and pinite and is traversed by fractures coated with iddingsite or related hydrous iron oxides. The matrix comprises 55 percent microcline, 15-20 percent quartz and 20 percent plagioclase (Desnoyers, 1977, p.10). Morin (1970) reported up to 75 percent microcline in the matrix of the Perrault Falls clotty granite.

The clots are the most distinctive part of the rock, commonly weathering as pits. They comprise from 1 to 10 percent by volume of the clotty rock. In localities with low concentrations the clots tend to be clustered in irregular patches; in higher concentrations, as at Perrault Falls, the clots tend to be evenly distributed. At Perrault Falls, two types of clots are observed: most commonly the clots are subrounded (1 to 4 cm), have sharp to locally diffuse margins, and are characterized by a simple assemblage (garnet - quartz or garnet - quartz - biotite). Garnet locally occurs as single euhedral crystals and as symplectic intergrowths with quartz. The second type of clot is highly irregular in shape and somewhat lensoidal with diffuse boundaries with the matrix. These clots are 1 to 15 cmm in long axis and are 2-3 cm thick; they are weakly aligned and locally exhibit flexures possibly due to magmatic flow. More complex mineral assemblages typify this clot variant as shown below.

The following assemblages have been documented within the clots from various areas as indicated in Figure 9-3:

Simple Assemblages

a) garnet (Oak Lake, Northwestern Lac Seul: Photo 9-3)

b) garnet - quartz (most common, Oak Lake: Photo 9-4)

c) garnet - quartz - biotite (Oak Lake, Anishinabi Lake)

d) quartz - biotite - magnetite (Oak Lake)

Complex Assemblages

a) biotite - quartz - albite - sillimanite - cordierite - retrograde muscovite - garnet - magnetite [Perrault Falls, Morin and Turnock (1975) : Photo 9-2]

b) biotite - garnet - sillimanite - muscovite (retrograde?) - quartz (western Lac Seul, Desnoyers, 1977, p.11)

c) biotite - quartz - cordierite (Anenimus Bay, northeast Lac Seul: Photo 9-5)

d) quartz - cordierite (Iran Lake)

e) biotite - quartz - magnetite - cordierite (south of Anenimus Bay, Lac Seul, Photo 9-5)

f) quartz - biotite - garnet - muscovite.

South of Anenimus Bay of northeastern Lac Seul, the clots are concentrated around inclusions of diorite and quartz diorite to trondhjemite (Photo 9-5). Locally the clots are are surrounded by leucocratic halos (Perrault Lake: Morin, 1970). The leucocratic aureoles may have developed: i) through mutual exchange of mafic/felsic constituents due to partial melting of the clots similar to the development of stictolithic structure Mehnert (1971, p.37). ii) by precipitation of an aqueous fluid at the margins of the foreign

clots (Morin, 1970, p.37) or; iii) in the presence of an aqueous phase, metasomatism due to reaction of the foreign (restite) clots with the cooling igneous body (Jahns and Burnham, 1969, p.855).

The origin of the clotty quartz monzonite is speculative but may be a product of processes active in both the northern and southern domains. The matrix of the clotty rocks is texturally similar to the units of the potassic suite but resembles diatexite in that it contains freely incorporated garnet and other aluminum silicate minerals. However, its texture is equigranular and thus differs from typical inequigranular homogeneous diatexite. Clotty quartz monzonite most closely resembles the fine to medium-grained diatexite (map code 3D) except the latter is invariably white, commonly contains apatite, and is more variable in composition (trondhjemite to granite).

Chemical analyses of the matrix (# 1 to 7) and clots (# 8 to 11) are given in Table 9-1. On both the CNK and AFM ternary diagrams (Figure 9-4) the compositional field of the potassic suite and the potassic portion of the compositional field of homogeneous diatexite exhibit almost complete overlap. On the CNK ternary (Figure 9-4) the matrix of the clotty quartz monzonites tend to be slightly less calcic than the diatexites. The only notable major element distinction between the potassic granitoid suite and homogeneous diatexite noted to date is the Fe_2O_3/FeO ratio (Figure 9-5). Potassic granitoid suite members have Fe^{3+}/Fe^{2+} mostly greater than 0.59 while homogeneous diatexite generally have Fe^{3+}/Fe^{2+} less than 0.59 with no sharp boundary between the two populations. Analyses of the matrix of the clotty quartz monzonite plots within the field of the homogeneous diatexite. The reason for the low Fe^{3+}/Fe^{2+} ratio in diatexites of S-type

affinity may lie in more areduced conditions prevalent in the zone of magma generation relative to the potassic granitoid suite. This could conceivably relate to presence of graphite in shale-wacke precursors and its known effect upon derivative magmas (Eugster 1972). According to Mueller (1970, p.26-M-2) studies of metamorphic schists and gneisses indicate that their oxidation state can be inherited from an earlier period. Shaw (1956) indicates a tendency for gradual reduction of iron with increasing metamorphism. Gower (1978, p.183) indicates low values of Fe_20_3/FeO for amphibolites and granitoid gneisses in the Kenora area correlate with high metamorphic grades confirming increasing reducing conditions in higher metamorphic grades. Recent sediments have a general higher Fe^{3+}/Fe^{2+} ratio than their source materials due to oxidation during weathering (Berner, 1970, p.26-K-1). Perhaps the low Fe^{3+}/Fe^{2+} ratio is related to i) the accepted lack of oxygenating atmosphere in the Early Precambrian at the time of deposition of metasediments and at the time of their partial melting and ii) reduction of iron during metamorphism. Based on the Fe^{3+}/Fe^{2+} ratio the clotty quartz monzonites have a chemical affinity to the peraluminous diatexite rocks. Discriminating functions (DF3 and DF4) of Shaw (1972) indicate igneous parentage for both homogeneous diatexite and clotty quartz monzonite.

White and Chappell (1977) introduced "I" (Igneous) and "S" (Sedimentary) type granitoid rocks. In accordance with Chappell (1979) the high K^20/Na_20 ratio, low CaO and low Fe^{3+}/Fe^{2+} ratio suggest the clotty quartz monzonite is an "S" type or diatexitic in origin. However the fact that this type of equigranular clotty rock is not found throughout the mobilizate of the northern domain suggests it is not true diatexite.

The authors agree with Morin and Turnock (1975) that the clots represent refractory metasedimentary relics of anatexis. They indicated that assemblages in the clots at Perrault Falls were stable in the presence of a granitic liquid under conditions varying from 650 to 700°C at PH_20 1 to 5 kb. Whether the matrix originated through partial melting of metasedimentary rocks as suggested by the ratio of oxidation states of iron or by differentiation of crustal material is not known. Restriction of many clotty quartz monzonite units proximal to the boundary of the northern and southern domains suggests it to be a product of processes active in both domains in which partially melted metasedimentary residuum (northern domain) was accidently incorporated in quartz monzonite (potassic granitoid suite-southern domain) sheets localized along the contact zone.

Analyses of the clots (Table 9-1, Figure 9-6) plot within or along the path of anatectic degeneration of metasedimentary paleosome to melanosome, their position varying according to the extent of partial melting. Complete analysis of two of the clots indicate particularly high lithium (130 and 310 ppm) versus a mean of 18 ppm (98 analyses, see Table 4-11) for most of the wacke paleosome and a mean of 36 ppm (49 analyses Table 4-12) for the pelite constituent). Lithium is likely contained in the biotite where it substitutes for Mg^{2+} and Fe^{2+} (Heier and Billings, 1970, p.3-0-1) but conceivably could also occur within cordierite. Stavrov (1978) indicated that cordierite can contain up to 2000 ppm Li. The potassic suite is the youngest of the intrusive suites and possibly produced a concentration of Li through late differentiation.

PORPHYRITIC UNITS

These rocks are much less common than equigranular units and are most abundant in the southwest part of the English River Subprovince. As a rule porphyritic textures commonly occur in the earliest units of the potassic magmatic cycle. Porphyritic units dominate the Lount Lake batholith and the Fletcher Lake batholith but are also found at the following localities:

i). a cataclastically deformed porphyritic granodiorite sill (Photo 9-6) at the contact of the Wabigoon/English River Subprovince boundary at Kenora (Gower 1978, p.444-446; Matthews, 1975);

ii). porphyritic granodiorite sill at the contact of the Wabigoon/English River Subprovince boundary at Linklater Lake (Tustin-Bridges Area);

iii).marginal border zones of small stocks at Lost Lake and Grassy Bay (Lac Seul area: Harris, 1976, p.24);

iv). porphyritic quartz monzonite sills within the Lount Lake batholith;

v). a large body of porphyritic quartz monzonite to granite centered on Bornite Lake and part of the Anishinabi Lake complex (Westerman, 1977, p.196-198);

vi). subtely porphyritic granodiorite stock intrusive into the Wabigoon Subprovince in Docker Township (just west of Vermilion Bay).

All of the above are characterized by porphyritic textures in which megacrysts of potassium feldspar are contained within in a finer-grained, equigranular matrix. Except for units iv) and v) above the matrix is typically impoverished in potassium feldspar. Subtely porphyritic texture indicates a progressive variation in grain size is present whereby matrix-size potassium-feldspar grades imperceptibly up to porphyritic megacryst

size. In general, porphyritic units are characterized by a simple bimodal grain size: matrix composed of mostly medium-grained minerals and a megacryst population composed of coarse-grained minerals. Porphyritic units are mineralogically similar to the equigranular ones except for the following:

1) porphyritic rocks generally have a lower potassium feldspar to total feldspar ratio;
2) epidote is a common accessory and;
3) hornblende is slightly more prominent.

Lount Lake batholith

The Lount Lake batholith, at 2070 km^2 is the largest discrete batholith in the western part of the English River Subprovince, situated between Kenora and Vermilion Bay and lies just north of the English River Subprovince - Wabigoon Subprovince interface. In plan the 24-34 by 95 km batholith is rectangular to oval (Figure 9-7); the long axis trends easterly, parallel to the overall trend of the English River Subprovince in this region. The contact of the batholith with the country rock is sharply defined and dykes intruding the country rocks are rare to absent. Along the north contact, enclaves of country rock are locally intermixed with the batholith; in most places the margins are non-hybrid.

Nature of Intrusive Units

Three major units comprise most of the batholith (Figure 9-7). Approximately 70% of the batholith is composed of porphyritic granodiorite characterized by megacrysts of potassium (microcline) feldspar (Photo 9-7). Dykes or sills of equigranular and porphyritic (microcline) quartz monzonite (Photo 9-8) having a common, consistent, east-northeast

strike (i.e. discordant to the easterly trend of the long axis of the batholith) intrude the central portion of the batholith. These dykes or sills are about 15 to 25 km in length and range from 1.6 to 3.2 km in average breadth. They apparently taper out and terminate within the confines of the batholith. The Cliff Lake porphyritic granodiorite described by Westerman (1977, p.58) marks the eastern terminus of the batholith while the Austin Granite (described by Gower, 1978, p.448) forms the southwestern part. Therefore, the Austin Granite and the Cliff Lake porphyritic granodiorite represent parts of the Lount Lake batholith.

Porphyritic granodiorite, the major unit, weathers white to grey to locally pink; fresh surfaces are characteristically grey to purple. Quartz monzonite compositions tend to be pink on weathered and fresh surfaces. It diagnostically contains randomly oriented, pink-to-white-weathering megacrysts of microcline suspended in a matrix of massive, equigranular trondhjemite to granodiorite. Megacrysts of microcline average 2.0 to 3.0 cm in length and are locally up to 4 or 5 cm. These are set in a medium-to coarse-grained (2 to 6 mm) matrix. Gower (1978, p.448) indicates there is rare increase in the size of the microcline megacrysts inwards from the south west margin; this increase was not observed elsewhere. The microcline megacrysts are generally evenly spaced within the porphyritic granodiorite but locally, irregular concentrations are apparent. Microcline is not abundant in the matrix and variations in composition are based solely on fluctuations in the megacrysts to matrix ratio. Within the major unit, the only significant change in concentration occurs locally along the north margin where the megacrysts are more sparse. Similarly, at Cliff Lake, thin injections of the rock exhibit a poorly defined

textural and compositional zoning: central portions of these arms are less foliated and are more abundantly populated with megacrysts than adjacent border zones (Westerman, 1977, p.59- 60). The matrix of the main porphyritic granodiorite unit is massive, equigranular and mostly unfoliated. Foliation where found is defined by a weak alignment of the mafic minerals and subtle preferred orientation of the microcline megacrysts. In the latter cases the microcline tend to approximate augen shapes and have indistinct margins. Foliation is mainly observed near the marginal zones or associated with the thinner intrusive arms.

Enclaves are not abundant but are generally associated with the main porphyritic granodiorite unit, especially near the margin of the batholith. The enclave population is dominated by mafic metavolcanic rocks but locally, quartz diorite, trondhjemite, porphyroblastic trondhjemite and rare trondhjemitic gneiss are present. In the southwest many of the enclaves are oriented parallel to the long axis of the batholith and the amphibolite enclaves are surrounded by reaction rims in which hornblende has been altered to biotite plus epidote (Gower, 1978, p.448). Enclaves observed near the central portion of the batholith are oriented parallel to the east-northeast trend of the sills. The largest example is composed of pillowed and massive mafic volcanics and occurs at Cedar Lake near the eastern terminus of the batholith.

Porphyritic quartz monzonite sills are characterized by abundant, primary, magmatic, flow-aligned megacrysts of microcline that volumetrically constitute about 50% of the rock (Photo 9-8). Although no statistical measurements were made, the microcline megacrysts within the porphyritic quartz monzonite sills were observed to be flow aligned in two main

directions: the majority are oriented in the horizontal plane parallel to the strike of the sills but a substantial number are oriented perpendicular to this direction with the long axis near vertical. This quartz monzonite unit is regarded to be a later, genetically-related concentrate, intrusive into the main porphyritic granodiorite unit. Subsequent sills of equal size, trending parallel to the east-northeast-trending porphyritic quartz monzonite sills, are composed of equigranular, massive quartz monzonite that are typical of the latest phases of the potassic suite observed as small dykes and sills throughout the Southern Plutonic Domain. Massive equigranular quartz monzonite also forms randomly oriented, minor dykes throughout the batholith's main unit.

Mineralogy

Porphyritic granodiorite is composed of microcline, plagioclase (oligoclase), quartz, biotite, hornblende, clinopyroxene (diopside), retrograde chlorite, muscovite, opaque (mainly magnetite), zircon, sphene, and rare epidote, apatite and allanite. Microcline forms large subhedral to enhedral megacrysts that commonly have biotite and plagioclase inclusions. The lack of quartz inclusions and the myrmekitic intergrowth of quartz around their margin suggests the microcline crystalized earlier than the quartz. Except for rare granular pockets of recrystallization along their margins, the microcline crystals are undeformed. Microcline also forms interstitial anhedra within the matrix where it is commonly associated with myrmekitic intergrowths. The matrix is hypidiomorphic, equigranular (2 to 6 mm), and is comprised of the following mineralogy: Plagioclase (An_{25}) is anhedral to subhedral, rarely enhedral; it is moderately to heavily sericitized, unzoned, untwinned, locally antiperthitic and is locally recrystallized around the margins.

It is commonly found as a myrmekitic intergrowth with quartz. Plagioclase weathers white in the field and frequently is observed as a rapakivi texture mantling the coarse microcline megacrysts. Quartz is unrecrystallized and varies from milky to clear and translucent grey in the field. It is commonly fractured, forming coarse subgrains and this fracturing is evident in hand specimen. The quartz is interstitial forming anhedral patches about 2 mm across, locally up to 4 to 5 mm by 7 mm. Brown-green biotite forms the dominant mafic constituent. Colour index averages 4 to 5 percent. Biotite is generally randomly oriented but locally forms a vague foliation; commonly it is randomly oriented in aggregates forming diffuse clots that are aligned. Pleochroic green to light greenish-yellow hornblende forms a lesser mafic constituent commonly associated with the biotite clots. Chlorite, carbonate and epidote are minor retrograde constituents also associated with the mafic clots. Chlorite is generally intergrown with biotite and is most abundant near the margins of the batholith. Muscovite is not a common constituent of the ground mass and where present occurs as interstitial anhedra associated with myrmekitic intergrowths. Clinopyroxene (probably green diopside) is locally present near the southwest and south central margin of the batholith. It forms anhedral grains associated with the mafic clots described above. Gower (1974, p.61) suggests the mafic clots may be pseudomorphic after clinopyroxene. Near the junction of the Red Deer Lake and Jones roads (northeast of Kenora), diopside is associated with the minor quartz-rich, late cross-cutting quartz monzonite dykes and may be hydrothermal in origin. Apatite, sphene, magnetite, zircon and rare allanite are common accessory minerals spatially associated with the mafic minerals.

Near the south margin, the batholith is locally strongly lineated. The linear fabric, defined mainly by elongated quartz (up to 30 mm long by 2 mm wide), is predominantly subhorizontal. Both plagioclase and microcline feldspar are oriented parallel to and complement the linear quartz. Gower (1974, p.60) indicated this zone to be between 0.5 to 1.0 km wide and attributed it to deformation through faulting. However, in thin section the quartz is completely unrecrystallized, unfractured and gives no indication of cataclasis. The linear fabric is probably primary in origin, related to movement during intrusion. The zone is not continuous around the south margin and appears to be most prominent in the southwest.

Porphyritic, flow-aligned quartz monzonite is similar to the above axcept that the essential minerals display a common preferred orientation. Myrmekitic quartz intergrowths are particularly prominent along the margin of the long axis of the microcline megacrysts, some of this myrmekitic quartz is granular possibly due to recrystallization. The restriction of the myrmekite to the margins of the long axis of the microcline megacrysts suggests its origin is post microcline feldspar development and occurred during the final stages of emplacement. Biotite forms a foliation and commonly occurs in long trains. In rare cases it occurs as flow-aligned enclave within the potassium feldspar megacrysts. Hornblende was not observed in either the late porphyritic quartz monzonite or equigranular quartz monzonite units.

Massive equigranular quartz monzonite is composed of microcline, quartz, plagioclase, biotite, opaque (magnetite), muscovite (primary), minor zircon, sphene and apatite and rare epidote and secondary chlorite. Microcline is subhedral to euhedral; the

other minerals are similar in habit to those in the matrix of the porphyritic granodiorite. Based on mafic content, two types of equigranular quartz monzonite sills were distinguished: a leucocratic variety with a colour index of 0 to 5 and a more mafic variety with a colour index of 5 to 8. Except for their difference in biotite content, both types are compositionally similar being composed of roughly equal amounts of quartz, microcline and plagioclase.

Modal and Chemical Variation

Modal analysis of the early (main porphyritic granodiorite) and the later intrusive units indicate the later memebers are enriched in potassium and exhibit a slight mafic mineral depletion (Figure 9-8). The main unit ranges from porphyritic trondhjemite to porphyritic granodiorite. Later units are mainly quartz monzonite to locally granodiorite. Chemical analyses (Table 10-16) support the above trends. On a CNK diagram (Figure 9-9) the later units are enriched in potassium relative to earlier ones. Harker variation diagrams (Figure 9-10) indicate similar overall mafic depletion and complimentary enrichment-depletion alkali trends between the early and later units. The marginal phase is enriched in silica but otherwise shows similar enrichment trends continuous with the main unit suggesting the two are related. The main porphyritic granodiorite unit has a fairly narrow tight pattern while the later equigranular quartz monzonite exhibits broader range and greater scatter. Locally the former shows some scatter on the potassium and aluminum plots no doubt related to concentration of microcline megacrysts. For the most part total FeO, MgO, and Na_2O in the main unit remain constant while CaO, K_2O and A_2O_3

show a slight initial decrease before leveling off with increasing SiO_2. Except for MgO the trend of the later porphyritic quartz monzonite sills is substantially removed from the trend of the main porphyritic granodiorite suggesting the two may not be differentiates from the same magma source. The former are enriched in total FeO, TiO_2 and K_2O and depleted in CaO, Na_2O and Al_2O_3. The slope and range of the various trends of the porphyritic quartz monzonite (later unit) are consistent with those of the main unit except for Fe_2O_3. If the equigranular quartz monzonite sills are later than and intrude the porphyritic quartz monzonite. Thus with decreasing age, K_2O has been progressively enriched concomitant with a progressive depletion of CaO and Na_2O. Except for FeO and MgO to some extent, chemical trends and slopes of the equigranular quartz monzonite do not coincide with the trend of the main batholith unit. Equigranular quartz monzonite exhibits a broader range in SiO_2, is enriched in K_2O and depleted in CaO, Na_2O and Al_2O_3. The slopes of the chemical trends for the main porphyritic granodiorite and the later porphyritic quartz monzonite agree except for Fe_2O_3. However, slight to dramatic changes in slopes of the variation trends of FeO, Fe_2O_3, Na_2O, K_2O and Al_2O_3 suggest the chemical history of the equigranular quartz monzonite differs from the other batholith units and is perhaps unrelated.

Origin

Due to its huge extent, an understanding of the origin of the batholith is fundamental to deciphering the Late Archean history of the Southern Plutonic Domain of the English River Subprovince. The origin of such porphyritic textures has in the past been in some dispute. Various workers (Marmo, 1971) have speculated on the problem of granitization

or potassium metasomatism. However, the lack of visible evidence of potassium-rich metasomatic fronts even along fractures within the main intrusive unit suggests the texture and potassium feldspar is magmatic in origin. Most workers have appealed to a two or multi-stage process where by early crystallizing phenocrysts are transported to new environments where rapid crystallization of the crystal-mush magma proceeds. Recently Swanson (1977, p.977) has indicated the development of porphyritic textures can occur as a one-step crystallization process. According to Swanson (1977, p.977) porphyritic textures are related to crystallization kinetics in which there is a low nucleation density associated with a rapid growth rate. A one-stage crystallization process is realized where larger grains of a faster-growing (potassium-rich) phase coexist with smaller grains of a slower growing phase (matrix). Swanson (1977) indicates the growth rate is dependent upon the amount of temperature change during crystallization (i.e. amount of undercooling) and water content. Swanson (1977, p.976) indicates porphyritic (alkali feldspar) textures occur in granite systems that crystallize with low amounts undercooling while equigranular textures result from system that have undergone large amounts of undercooling. Mineral inclusions such as biotite within the microcline megacrysts of the Lount Lake Batholith have been engulfed during advancing growth of the crystal face and indicates the latter developed when there was still some silicate liquid remaining.

The lack of any apparent flowage alignment of the microcline megacrysts in the main porphyritic granodiorite phase, the presence of inclusions within these megacrysts, and the presence of some potassium feldspar in the matrix indicate the microcline megacrysts were crystallizing along with the matrix components. This suggests a one-stage

crystallization process was operative during the formation of the main phase of the Lount Lake batholith. The main unit is regarded to have been intruded as a competent single crystalline diapir.

In accordance with the criteria of Stephannson and Johnson (1976, p.183) the following observations support a diapiric model:

1). a smooth outline conformable to the surrounding country rock and regional trend of the English River Subprovince;

2). lack of dykes;

3). restriction of a linear fabric to the outer margin of the batholith in the southwest;

4). lack of flowage alignment of the megacrysts of microcline (the above two points indicate intrusion in an almost to complete solid state).

5). low abundance of inclusions indicating intrusion by piecemeal stoping was not a process;

6) bending of previously deformed country rock (Cedar Lake Gneisses, Westerman, 1977) into concordance with the batholith margin.

7) development of dome and basin structures in the Cedar-Clay Lakes area (Westerman, 1977) at the east terminus of the batholith which is otherwise exceedingly rare throughout the rest of the English River Subprovince.

The fairly restricted, limited compositional range, low colour index, lack of associated more mafic intrusive units or enclaves, probable low degree of undercooling suggest the main units originated as a fairly low temperature magma within the upper crust (Wiebe, 1975, p.256). Based on REE patterns and chemical trends Gower (1978, p.456-458)

favours derivation of the Lount Lake batholith from a hydrous, two pyroxene granulite magma by fractional crystallization Due to a lack of agreement in REE patterns Gower is unable to model the batholith using a greywacke source The absence of obvious rocks of greywacke bulk compositions in the area and the absence of aluminosilicate minerals in the batholith substantiate this

Flowage alignment of the microcline megacrysts within the porphyritic quartz monzonite sills was imposed by confinement of the crystal-mush magma to a narrow conduit that may represent the original feeder zone to the batholith Time of intrusion of the porphyritic quartz monzonite must have been sufficiently late to allow cooling of the main unit The fact that myrmekitic intergrowths are restricted to the long axis of the flow aligned microcline megacrysts suggests this is a late stage reaction and indicates the presence of silicate fluid at the time of emplacement of the sills

The porphyritic texture and similar matrix composition suggest the late porphyritic quartz monzonite sills are genetically related to the main unit only the mechanism of emplacement differed The main unit is regarded to have intruded as an essentially crystalline, competent diapir The later porphyritic quartz monzonite sills are regarded to have been intruded as crystal-much magmas in which there was considerable silicate fluid remaining These porphyritic quartz monzonite sills were intruded near the end of crystallization probably along the main magma feeder zone and probably before or during the diapiric ascent The massive quartz monzonite sills are chemically similar to the porphyritic quartz monzonite They may be genetically related to the porphyritic phase but the difference texture, matrix composition and in slope and range of their Harker variation

trends suggests they may have a separate parent melt.

Intrusion of such a large body could theoretically inflict large strain on the host rocks. The consistent placement of the late equigranular quartz monzonite sills near the core of the batholith suggests a considerable measure of structural control clearly operated during emplacement, similar to that documented by Pitcher and Bussell (1977). Lack of continuity of this controlled expression outside the limits of the Lount Lake Batholith and absence of inclusions of deep-seated origin suggest the structural control may be related to intrusion of the batholith itself and not to a previous structure. If the equigranular quartz monzonite sills are intruded later than the flow-aligned porphyritic quartz monzonite sills, this preferred direction of emplacement was maintained during a substantial time interval. The pattern presented by the later quartz monzonite sills may reflect a late fracture pattern that was imposed internally on the batholith as a result of regional compression of country rocks. Continued intrusion in the core of this batholith would cause expansion of the main unit and place high strain on the surrounding host rocks. The linear fabric at the margin in the southwest is near horizontal and trends east to east-northeast parallel to the dominant alignment trend of the microcline megacrysts in the later porphyritic quartz monzonite sills and the two probably developed at approximately the same time. The only major dome and basin structural style observed within this part of the English River Subprovince occurs at the east periphery of the batholith and is also probably related to this east-northeast maximum strain direction associated with the batholith emplacement. The dome and basin structure is probably the result of thrust faulting (Westerman, 1977) similar to that advocated by Hamilton and

Myers (1974). Also of interest is the fact that this east to east-northeast maximum stress direction parallels the Miniss River Fault system (Breaks et al., 1978).

Porphyritic, Contact-Controlled Sills

Between the Manitoba/Ontario Boundary and Vermillion Bay and also in the vicinity of Sioux Lookout the gneissic granitoid suite of the English River Subprovince is in contact with metavolcanic rocks of the Wabigoon Subprovince. At several localities including Kenora (Photo 9-6), Tustin-Bridges Townships, and McIlraith Township (west-southwest of Sioux Lookout) the two subprovinces are separated by structurally-controlled thin sills of porphyritic granodiorite. At the latter locality (McIlraith Township), the Watch Lake Stock is compositionally related to the sodic granitoid suite. The remaining occurrences are unrecrystallized and are part of the potassic granitoid suite.

At Kenora, the sill has been termed the "marginal porphyritic granodiorite" (Gower, 1978, p.444-446). The sill is narrow (0.3 km) and extends for a distance of about 25 km. The south contact with the Wabigoon metavolcanic rocks is very sharp while the north contact is partially intrusive and partially gradational over a 300 m distance (Mathews, 1975; Gower, 1978, p.445). According to Gower the megacrysts decrease in size, and abundance towards the gneissic contact. The occurrence of gneissic zones, amphibolite and attenuated pegmatite increase in abundance toward the gneissic contact. The porphyritic sill is characterized by a strong protomylonitic fabric in which augens of potassium feldspar (Photo 9-6) megacrysts have a senusoidal to rotated habit.

Intensity of deformation varies with both cataclastically deformed and undeformed portions present. The fabric of the porphyritic granodiorite is best described as protomylonitic (Matthews, 1975, p.55). The most intense granulation occurs on the south side of the sill; the northern margin is apparently less severely deformed.

Modal analyses (Gower, 1978, p.89) of the marginal porphyritic sill overlap the granodiorite-quartz monzonite compositional fields. Gower (p.446) reports that plagioclase in the intensely deformed portions exhibits oscillatory zoning while in the less deformed parts it lacks zoning. Oscillatory zoning of plagioclase is not observed elsewhere in the English River Subprovince. At Kenora the mineralogy of the sill is potassium feldspar, plagioclase, quartz, biotite, epidote, sericite, chlorite, apatite, magnetite, carbonate and allanite.

Matthews (1975, p.56) also noted the central part of the sill, relative to the margins, is depleted in K-feldspar and muscovite due to alkali metasomatism initiated as a result of temperature gradients between a still hot core zone and the cooler margins. Mathews (1975, p.54) perceives the intrusion as emplaced along the structurally weak break provided by the Wabigoon-English River Subprovince interface. Crystallization of the granitic material occured after emplacement followed by cataclastic deformation due to tectonic adjustment along the boundary. Whether this movement was a reactivation of an earlier adjustment is not known. Gower (1978, p.117) envisaged the zone to be an area of intense and repeated movement. However, he had difficulty in modelling the origin of this sill but based on REE data concluded that the most favorable origin to be melting of a "hydrous two-pyroxene granulite wtih up to about 3% garnet permitted".

At the Tustin-Bridges occurrence the porphyritic sill varies from 0.4 to 1.6 km (at Linklater Lake) in width and continues for approximately 20 km. The sill contains a few mafic schlieren and volcanic enclaves but differs from the Kenora sill in that it is massive to weakly foliated. Also potassium feldspar megacrysts are not as uniform in size and range from almost-matrix size up to 2 cm. Mineralogy of this sill is nearly identical to the Kenora Sill. A chemical analysis (No. 7, Figs. ?, Table ?) indicates normal trace element abundances except for high barium (1200 ppm).

The cataclasis is restricted to the sills and has not been observed in adjacent gneissic granitoid suite rocks in the Kenora area either by the authors or Gower (1978). The restriction of the cataclasis to the sills suggests the deformation may have developed during intrusion as a response to dilation within the constrictive refines of the contact zone. Intrusion of these two sills was controlled along pre-existing linear zones of weakness. The massive texture, lack of a secondary fabric, or evidence of recrystallization suggests the sill at Linklater Lake is fairly young and may represent an early part of the potassic granitoid suite.

TRONDHJEMITE TO GRANODIORITE UNITS

The plutonic subdivisions of the English River area are based on a combination of parameters including composition, relative age, style of intrusion and degree of reworking (mainly through metamorphism). Locally there are more plagioclase-rich unitss (leucocratic trondhjemite to granodiorite) believed to be related to the potassic granitoid suite because of a generally unrecrystallized nature. Furthermore, they form dykes or sills

or late, compositionally uniform batholiths similar in habit and style to most other members of the potassic suite. As these sodic granitoid unitss can be unequivocally related to the potassic granitoid suite is revealed by sporadic trondhjemite units which exhibit a lack of K-feldspar megacrysts along the north margin of the Lount Lake Batholith. Unmetamorphosed sodic granitoid rocks equivalent in age to the potassic suite are fairly rare in the English River Subprovince proper; they are more prominent in batholiths within the adjacent Uchi and Wabigoon Subprovinces.

Unmetamorphosed to weakly metamorphosed trondhjemite to granodiorite comprise the following associations:

English River Subprovince

1). in thin concordant intrusions and rare dikes within the gneissic granitoid suite;

2). local units within the large concordant potassic granitoid intrusions within the English River Subprovince north of Vermillion Bay.

Uchi/Wabigoon Subprovinces

3). Bamaji-Blackstone batholith west of Lake St. Joseph (Uchi Subprovince).

4). the large batholith south of Minnitaki Lake (Wabigoon Subprovince);

5). Lewis Lake batholith, Yett Lake stock and Nagron Lake stock all situated southwest of the Minis-Tully Lakes fault in the Wabigoon Subprovince between Sioux Lookout and the Savant Lake Greenstone Belt.

These later sodic granitoid unitss are typically massive, leucocratic and medium-to

coarse-grained. The mineralogy consists mainly of subhedral to euhedral plagioclase (oligoclase), interstitial quartz with minor interstial K-feldspar, biotite and accessory minerals. Local variants include chlorite-biotite-bearing units and porphyritic phases.

SYENITE UNITS

Syenitic rocks are exceedingly rare and are restricted in occurrence to the English River Subprovince and occur as:

1). a small elliptical intrusion of porphyritic hornblende syenite at Willard Lake in MacNicol Township near the south boundary of the English River Subprovince (Pryslak, 1976, p.21);

2). a hornblende syenite forms the northeast part of a small quartz monzonite stock south of Slate Lake near the north margin of the English River Subprovince;

3). as rare, thin, hornblende syenite concordant intrusions within the gneissic granitoid suite north of the Tustin Bridges area (along the Gordon Lake Road) and north of Sioux Lookout. In places this latter association forms as small, isolate, irregular patches that grade into quartz monzonite;

4). minor magnetite-biotite syenite dykes (Photo 9-9) spatially associated with the granulite metamorphic zone in the Bear Narrows-Chamberlain Narrows (Lac Seul) area;

5). as rare, thin dykes intruding the sodic suite as at Wine Lake (Westerman, 1977, p.198).

6). as rare, diffuse consanguinous pods within equigranular quartz monzonite of the

potassic suite probably as a result of inhomogeneous distribution of quartz.

7). as rare inhomogeneous indiscernable diffuse pods in pegmatitic units of the potassic suite.

The reason for the occurrence type 4 is uncertain. Perhaps quartz is preferentially mobilized during the granulite metamorphism. Most of the syenitic units are comprised of potassium feldspar, hornblende, biotite, magnetite, minor plagioclase, quartz, and accessory minerals. The majority of these rocks are inequigranular and medium -to coarse-grained.

PEGMATITE

Very coarse-grained to pegmatite unitss of the potassic suite are relatively common throughout the map area but are most common in the Southern Plutonic Domain. In most areas these occur as quartz monzonite pegmatite dykes that represent the youngest intrusive rock. Locally fine to medium-grained equigranular quartz monzonite units do post date the pegmatite dykes. Pegmatite is defined as containing crystals of greater than 5 cm in cross section; all of the pegmatites are massive.

Based on color there are two major types of pegmatite in the English River map area: pink to red and rare white varieties. Pink to red-weathering pegmatite is most commonly found in the following four associations:

1) sharply defined, commonly cross-cutting, straight veins and dykes intruding all of the major plutonic suites and supracrustal rocks. In places these dykes are texturally, compositionally complexly zoned (Photo 9-10) but most are uniform in grain size.

2) as diffuse concordant and discordant veins, sills and dykes within the gneissic suite (Photos 7-6, 7-7 and 7-11).

3) as a major pegmatite border phase mantling a biotite granodiorite to quartz monzonite batholith north of Papaonga Lake in the (Uchi Subprovince (Photo 9-11).

4) as gradational, irregular consanquineous, pods within members of the potassic suite of similar composition (Photo 9-12).

Sharpely-Defined Sills and Dykes

Westerman (1977, p.60) indicated the pink to red pegmatite dykes are demonstrably later than the equigranular, pink, finer-grained quarz monzonite units and tend to be the youngest dyke system in the Cedar-Clay Lakes area. However the above relation is not valid in the rest of the English River Subprovince as numerous fine-to medium-grained and medium to coarse-grained equigranular potassic granitoid units are observed to cut the pegmatite dykes in the gneissic suite (Deception Bay (Lac Seul) and at Kenora (Gower, 1978, p.350). In their most mineralogically simple form the sharply-defined pegmatite dykes vary from quartz monzonite to granite (sensu stricto) and are comprised of euhedral K-feldspar (microcline), euhedral plagioclase and interstitial quartz. Complexities arise from chaotic textural and compositional variations causing local zonation. Changes in composition tend to be irregular with variations ranging from trondhjemite to quartz monzonite to granite to local syenite occurring along the strike length of the dykes. Compositional zonation is occasionally regular in which plagioclase crystallizes perpendicular (Photo 9-13) to the host wall while quartz and K-feldspar is

concentrated towards the central zone. Quartz is commonly confined to the central portion of the dyke (Photo 9-13). In all probability the marked segregation of the crystals is related to change in migration of the chemical components to preferred portions prior to precipitation and the fact that potassium appears to be more mobile or transferable than sodium in response to temperature gradients (Jahns and Burnham (1969, p.857)).

Textural variation mainly arises through changes in grain size. Although these changes can be irregular and chaotic, most commonly this divergence in grain size is regular. The two main variations in textures within dykes are:

1). fine- to medium-grained fairly thin border zones grading abruptly inwards to very coarse-grained to pegmatite central core zones. This texture may be due difference in cooling history related to chilling; this is the more normal, expected texture (Jahns & Burnham 1969, p.855).

2). coarse grained to pegmatitic border unit grading abruptly into a medium-to coarse-grained or fine- to medium-grained central core (Photo 9-10). This texture could be due to slow precipitous growth at the walls of the conduit along which the pegmatite fluid is flowing followed by an abrupt change in P-T conditions causing crystallization of the fluid phase.

In textural variant 1, the opposite scenario takes place where by precipitation of the crystallizing phase at the walls occurs due to chilling followed by slow crystal growth in uniform P-T conditions).

The pegmatite dykes are generally quartz monzonite to granite (sensu stricto) and are frequently inequigranular. The dykes are characteristically straight and regular, locally

offset by minor faults Commonly, sill-like veins concordant to the foliation or fabric of the host branch from the crosscutting dykes and in fact were themselves probably continuously nourished by the cross cutting dikes Accessory minerals associated with the pegmatites include, in order of decreasing abundance, are biotite, magnetite and muscovite, and rare hornblende and tourmaline The colour index in the pegmatoid phases never exceeds 5% by volume The coarsest dykes observed with microcline crystals up to 30 to 40 cm occur in the metasediments south of Gullwing Lake There are at least two ages of pegmatite injection in the Separation-Indian Lakes complex (sodic suite) and this is probably the norm for most of the remainder of English River Subprovince (there may be up to three ages of pegmatite intrusion in the gneissic suite) Peripheral to the Archer Lake dome (north of Sioux Lookout, Figure 8-2) the pegmatite dykes in places cut uniformly perpendicular to the domal structure having intruded along a previous fracture system probably related to the doming event Uranium-enriched pegmatites are especially common in the Tustin- Bridges area (Pryslak, 1976, p 34) and in the Umfreville-Separation Lake area (Breaks et al 1975) and is further documented in Chapter 16

Diffuse Veins and Sills

Veins and sills of coarse-grained to very coarse grained to pegmatitic quartz monzonite occur both concordantly and discordantly within the gneissic granitoid suite (Photo 7-6) Westerman (1977, and in Breaks et al (1978, p 25)) referred to these as "early" and "late" potassic granitoid units, respectively Where intimately interlayered

concordantly with the gneissic granitoid suite, Gower (1978, p.332) refers to these as a mixed "biotite tonalite-granitic pegmatoid gneiss". Due to rare discordancies Gower (1978, p.350) infers that this association is an intrusive phenomena.

Where as the previously mentioned pegmatite dykes tend to be straight, regular, and continuous, these units are characterized by diffuse, irregular borders; the sills thicken and thin at random and are discontinuous. At Kenora granite or quartz monzonite pegmatoid gneiss (Gower, 1978, p.349) occurs conformably as:

1) numerous (unmappable at the survey sacle) irregular lenses and;

2) a 4 km long marginal border unit of the Dalles granodiorite.

Both of these are interpreted to be deformed pegmatities both concordantly and discordantly injected into pre-existing tonalitic rocks (Gower, 1978, p.350). Gower modelled the granitic pegmatites and interpreted them as fractionated end-stage liquids which crystallized on the cotectic line near the center of the quartz-albite-orthoclase ternary diagram (Gower, 1978, p.364) but which "retained some residue crystals from a previous crystallization segment" (Gower, 1978, p.367). The authors concur that these pegmatites do appear to be intrusive into the gneissic suite. Other possible origins for the pegmatite associated with the gneissic suite are discussed in Chapter 7.

Pegmatite Border Unit

Similar to the pegmatoid gneiss bordering the Dalles granodiorite (Gower, 1976) there is a very coarse pink pegmatite that mantles a large equigranular granodiorite to quartz monzonite batholith north of Papaonga Lake in the Uchi Subprovince. The pegmatite

border unit is in contact with metavolcanic rocks of the Papaonga Lake - Lake St Joseph Belt to the south and is traceable for about 32 miles and averages 2 km in width The pink to locally pinkish white pegmatite is dominantly quartz monzonite Magnetite and locally anomalous percentages of apatite and tourmaline are accessories No lithium-bearing minerals were observed in the field and lithophile trace element analyses are impoverished (Table 9-2) The zone is on strike with the Root Lake lithium showing but on the basis of differences in texture, composition and accessory minerals this pegmatite border unit does not appear to be related Mineralogically the pegmatoid mass comprises K-feldspar, plagioclase, quartz, biotite, muscovite, tourmaline and apatite Reconnaissance mapping indicates the border pegmatite is continuous and texturally uniform (Photo 9-11) Grain size is very coarse-grained to pegmatitic and does not vary noticeably throughout the zone In general feldspar (both microcline and plagioclase) form evenly distributed megacrysts situated within slightly finer-grained interstitial material (Photo 9-11 quartz, K-feldspar and biotite)

In accordance with Jahns and Burnham (1969) the lack of textural inhomogeneities suggests the parent magma was unfractionated In effect crystallization of the granodiorite to quartz monzonite batholith proceeded almost to completion but just prior to complete crystallization the water saturated, volatile-rich residual silicate liquid was expelled from the parent batholith magma With complete expulsion this exsolved hydrous phase (ie the only unit with potential pegmatite constituents) crystallized, forming the pegmatite border unit The association of pegmatite at the margin of batholiths also occurs near the northern contact of the Feist Lake Pluton (Morin, 1979) in the Tustin-Bridges area The

pegmatite border unit may be in situ, situated in its original magma generation site but more plausibly was intruded into its present setting along the lithostructural break provided by the batholith/volcanic contact. The pegmatite's spatially close, concordant, association and similar composition suggests it is genetically related to the batholith. The pegmatites of association i) are probably similar in origin to this third association (iii) except the forms can not be directly genetically related to their hosts; that is they originated at some greater depth and were intruded into their present setting. The general lack of spatial concentration of the pegmatite dykes (association i) around specified intrusives precludes any possible specific genetic association.

Consanguineous Pegmatite Pods

Typically, the late-gradational, isolated pods of pegmatite (Photo 9-12) are found in the equigranular leucocratic quartz monzonite to granite (sensu stricto) unit of the potassic suite. Except for being slightly more quartz rich, the isolated, diffuse (ie. gradational contacts) pods are similar in composition to their hosts. These pegmatitic pods are regarded to be due to late stage crystallization of water-rich products in miarolitic cavities and indicates the water concentration in the original magma approached and locally exceeded its saturation level. Jahns and Burnham (1969, p.854, 855) suggest these isolated pegmatite patches occur when the late-stage water-rich "rest" or residual liquid is confined and crytallized within a single enclosed body, ie. it is not withdrawn away from the host as in the case of the border pegmatites. Equigranular potassic magmas that also do not contain the pegmatite pods:

i) not initially saturated with volatiles or;

ii) have undergone expellation of volatile components.

The expulsion of the water rich residual phase is probably related to depth (ie. confining pressure constraints) while retention occurs only in higher level granitoid magmas where confining pressure is much less.

Pink to red-weathering pegmatite differs from white homogeneous diatexite in colour, accessory minerals, variation in grain size and homogeneity of composition. Pink to red-weathering pegmatite is characterized by accessory minerals such as magnetite, tourmaline and apatite, is compositionally uniform (mostly quartz monzonite to granite (sensu stricto), and texturally is relatively uniform in grain size. On the other hand diatexite is characterized by varietal and accessory cordierite, sillimanite, garnet and rare and varies in composition from trondhjemite to granite to syenite even at the outcrop scale (8-10 cm). A further distinction of the diatexite pegmatites is the highly variable grain size ranging from 1-2 cm up to 30 cm within the space of a meter.

White Pegmatite

White-weathering pegmatite is rare in the English River area, but is important as it tends to be mineralized with lithophile elements such as lithium. If it were more abundant it be might be easily confused with homogeneous diatexite. White pegmatite occurs in only three known areas:

1). a uniformly coarse-grained pegmatite spatially related to porphyritic granodiorite occurs in the vicinity of Medicine and Lift Lakes in the Bruin Lake- Edison Lake area (Tustin-Bridges area); this pegmatite is characterized by perthite, quartz, biotite

and accessory minerals including black tourmaline, beryl, garnet, muscovite and rare tantalite (Pryslak, 1976, p.28).

2). pegmatites associated with clastic metasedimentary rocks at Sandy Creek (north of Ear Falls on Highway 105); beryl mineralization occurs with an asymetrically zoned white albite-rich pegmatite dike. The dike is concordant to medium-grade metasedimentary rocks of the English River Subprovince. According to Breaks (1979, p.7) the aplite unit comprises 80 percent of the dike and consists of subhedral to anhedral quartz phenocrysts in a matrix of felty, white to pink cleavlandite with accessory purpurite, beryl, muscovite and apatite. The pegmatite portion is mineralogically similar except modal percentage of muscovite, purpurite and apatite increases. It is unknown at present if this pegmatite is related to the partial melting event of the metasediments or was generated in similar form to the pink pegmatite.

3). an elliptical, zoned pegmatite intrudes mafic metavolcanics at Separation Lake (Figure 3-0). The pegmatite is complexly banded and characterized by both aplitic and megacrystic portions similar to the Sandy Creek pegmatite. The zonation is quite irregular, aplite constitutes about 40-50% by volume of the intrusive.

Four subtle mineralogical types were recognized within the third occurrence:

i). fine-grained (biotite - muscovite - garnet) granodiorite characterized by allotriomorphic-granular quartz (most abundant) - plagioclase - K-feldspar (30-35%)

ii). very fine-grained to aphanitic (muscovite - garnet) quartz-rich granodiorite to quartz monzonite characterized by green-yellow muscovite (1--15%),

iii). medium- to coarse-grained biotite - garnet trondhjemite to quartz monzonite (10%),

iv). coarse-grained pegmatite with biotite - muscovite - garnet - rare tourmaline (40%). This occurs as sharply defined dykes, as diffuse consanquinous pods and also tends to nucleate around the two finer-grained units (a & b above).

One minor occurrence of tapiolite was noted in unit d) but no other lithophile mineralization was observed with this pegmatite/aplite intrusive. Commonly the presence of green-yellow muscovite is an indicator that lithium mineralization may be present. The pegmatite/aplite is dominant granodiorite to quartz monzonite in composition; some of the coarser units vary to trondhjemitic composition. In areas where the coarser pegmatite constituents appear to be nucleating around the finer unit the coarse crystal growth is perpendicular to the margin. According to Makrygina (1979) an increase in sodium (ie. the formation of albite pegmatites) is accompanied by an increase in the amounts of Li, Rb, Cs and Be in pegmatites, of Rb, Sc, Be and F in the micas and of Rb and Sc in the feldspars from muscovite-bearing pegmatites of the andalusite-staurolite zone. Perhaps the general lack of albitic compositions in the zoned pegmatite at Separation Lake (ie. most of the units are granodiorite to quartz monzonite) explains the apparent lack of rare element concentrations.

All of the white pegmatites tend to be inhomogeneous, characterized and by discontinuous, irregular, complementary aplitic and pegmatitic layers, pods or segregation (see terminology of Jahns and Burnharn, 1969, p.853). The textural complexities of these white pegmatites indicate they have undergone successive withdrawals of increasingly fractionated residual, water-rich silicate liquids (Jahns and Burnham, 1969, p.855). If such is the case than each successive liquid silicate phase will be richer in water-volatile

component and will be correspondingly richer in true pegmatite constituent (Jahns and Burnham 1969 p.855) suggesting the coarser phases (c and d above) are later than the finer units (a and b above) verified by the field evidence.

White, pegmatite differs from homogeneous diatexite in accessory minerals; the main difference however is the characteristic banding or layering of aplitic and pegmatitic phases characteristic of the former.

As indicated in Chapter 16, the white pegmatites are the main hosts for rare-element and other lithophile mineralization. Pink- to red-pegmatites are hosts for uranium mineralization and minor tantalum. Cerny and Trueman (1978, p.368) have reported the tendency for mineralized pegmatites to occur in the gneissic areas. According to Cerny and Trueman (1978, p.370) the quartz monzonite units of the potassic suite are probable parental to such mineralized pegmatites. During ascent, the quartz monzonites, undergo "repeated cycles of decreasing temperature and pressure quenching thus promoting continuing fractionation".

Makrygina (1979, p.1140) indicates the overall total confining pressure (which effects the fluid or volatile pressure) and the composition of the volatile components are the dominant factors controlling the development of particular types of pegmatites. He indicates the rare metals tend to be concentrated only in the areas of low-pressure metamorphism. The English River Subprovince is dominantly a low pressure regime.

In summary, the red- to pink-weathering pegmatites are compositionally related to the potassium suite. They are texturally uniform indicating they are relatively unfractionated. They originate by withdrawal of residual, water-rich silicate liquids near the completion of

crystallization of members of the potassic suite. If constrained and not allowed to escape, possibly due to decreased confining pressure, this residual water-rich silicate liquid crystallizes in situ forming consanquinous pods within the host granitoid magma. The white pegmatite on the other hand is texturally complex signifying repeated fractionation from an unknwon source. The white pegmatite may be genetically related to the potassic suites. The difference in colour may be due to the Fe_{3+}-Fe_{2+} oxidation ratio similar to the homogeneous diatexite-potassic suite difference described in the clotty quartz monzonite section of this report. The white pegmatite, especially those with albitic compositions that evolved in low-pressure environments, may contain concentrations of rare metals in economic quantities.

POTASSIUM METASOMATISM

Evidence of potassium mobility is observed in all of the major plutonic suites within the English River Subprovince. These potassium "fronts", marked be abundant K-feldspar, have the following characteristics:

1) the potassic-rich fluids migrate through and adopt the texture and of the host rocks filling the interstices.
2) the metasomatism is marked by an intense pink colouration on both the weathered and fresh surfaces
3) the potassic injections have diffuse, ill-defined,irregular boundaries
4) the potassic rich fluids form whisps, lenses, diffuse veinlets that swirl and exhibit contortions unrelated to structural fabric
5) commonly the potassium metasomatism follow structural fabric such as fractures.

Potassium metasomatism, composed only of K-feldspar, adopts all traits of the host rock, texturally it looks identical except for the pink colouration In direct contrast, the intrusive potassic veins are sharply defined, composed of K-feldspar - plagioclase - quartz almost invariably these veins exhibit at least minor differences in texture, grain size and composition that distinguish them from their host Potassium metasomatism is found in the following associations

i) Most commonly it is found as discontinuous, concordant,thin veins throughout the gneissic suite, it tends to be mostly associated with the hololeucocratic and leucocratic trondhjemite bands (Photo 7-1)

ii) as diffuse lenticular swirls that start and terminate for no apparent reason within rocks of the potassic suite

iii) as linear veins and fronts within the sodic suite these are nearly always associated with intruding members of the potassic suite

iv) rarely within the mafic suite near eastern Lac Seul where it is locally observed migrating between amphibole crystals in amphibolites

Within the potassium metasomatic front euhedral potassium feldspar crytals greater than 0 5 to 1 0 mm were never observed In almost all cases the potassium metasomatism is spatially linked to large intrusive bodies of the potassic suite For example no potassium melasomatic veins were observed within the porphyroblastic/porphyritic (K-feldspar) granodiorite to quartz monzonite unit within the Separation-Indian Lakes complex There may be no great significance in the occurrences of potassium metasomatism other than to recognize that it exists and probably was

generated during intrusion of the potassic suite

Morin (1979) indicates alkali metasomatism is a common late event in the Fiest Lake pluton and the Crabcraw Lake batholith Both of these intrusives, although south of the Tustin-Bridges metavolcanic belt in the Wabigoon Subprovince, are typical late intrusives associated with the potassic suite diapirism Morin (1979) interprets the northern and eastern margins of the Feist Lake Pluton to have cooled earlier than the western margin and interior core He indicated the northern and eastern margin of the pluton is enriched in K_2O and depleted in Na_2O in comparison to the western margin and core area This migration of potassium to the cooler portions of a crystallizing magma accompanied by a complimentary exchange involving sodium migration to the hotter portions is consistent with experimental studies done by Orville (1963) It is interesting to note that nearly all of the known uranium mineralization in the Tustin-Bridges area is restricted to the south side of the greenstone belt specifically peripheral to the northern contacts of the Fiest Lake pluton and the Crabcraw Lake batholith of the Dryberry Dome Uranium concentration is probably related to late migrating fluids (especially water-rich phases (Bohse et al , 1974, Smithson and Decker 1973)

CATACLASTIC ROCKS

Where members of the potassic suite have been deformed the resulting cataclastic textures tend to be easily recognizable This is probably because potassium feldspar is not easily broken down and tends to form easily recognizable cataclastically-deformed phenocrysts Most commonly potassium feldspar forms sinuous augen

structures (Photos 7-13, 9-6) indicative of cataclasis, in some cases the phenocrysts display regular fracturing with minor offsets along each fracture The sense of movement along these fractures will give the sense of movement of the shear couple producing the fracture thus giving the approximate sense of movement in the cataclastic zone In addition to the deformed sill at Kenora, cataclastically deformed rocks occur

1) along the margin of the Mystery Lake Dome,

2) near the southeast margin of the Archer Lake Dome (Figure 8-2),

3) within the gneissic suite,

4) associated with thin potassic quartz monzonite veinlets within the sodic suite just north of the Wabigoon-English River Subprovince boundary near Highway 105

5) the St Raphael batholith (Figure 9-1) is extensively deformed by the Miniss River Fault zone

Most of these rocks are protomylonitic to mylonitic (Spry, 1969, p 229)

SUMMARY

The potassic granitoid suite is the youngest and culminated igneous activity in the English River Subprovince It varies from thin sills and dykes up to some of the largest batholiths known in northwestern Ontario The smaller sills and dykes are commonly structurally controlled along previous zones of weakness including fractures and thological boundaries From this it might be inferred that the batholiths are structurally controlled and that all evidence of this control has since been masked or affected by the intrusive event, a situation similar to that recognized by Brindley (1973) in the Pyrenees The

restricted modal and compositional chemistry suggests emplacement over a short interval of time The reason for the locus of such volumes of potassic magma in the western part of the subprovince is not known

The depth to which the potassic magmas extend is somewhat conjectural The authors have observed large, east-dipping (10-20^{0}E), metasedimentary enclaves in the western part of the Tetu Lake batholith suggesting it is a shallow east dipping mega sill-like structure Springer (1952) indicated in this same area a peculiar configuration in which metasedimentary enclaves follow the railroad tracks likely because these inclusions are only exposed in the rock cuts on vertical surfaces! On flat surfaces the enclaves do not show up due to subhorizontal attitudes also implying a sheet-like morphology In effect some of the potassic suite batholiths may not extend to any great depth, i e , they may be pancake-like intrusives Just how much of the potassic suite is intruded in this fashion is not really known

CHAPTER 10

CHEMICAL VARIATION AND GENESIS OF THE IMPORTANT PLUTONIC SUITES

INTRODUCTION

This chapter will summarize the chemistry of the important intrusive groups of the English River Subprovince and suggest petrogenetic mechanisms, partly in comparison to modern analogues, by which the intrusive rocks may have formed.

CHEMICAL VARIATION

Chemical analyses of the important intrusive groups are given in Tables 10-1 to 10-21, inclusive. The trondhjemite rock type within both the gneissic and sodic suites is dominantly the high Al_2O_3 type of (Barker and Arth, 1976; Barker et al, 1976). Locally there are examples that are of the low Al_2O_3 type (<15% Al_2O_3; >100 ppm Rb). The Cedar Lake gneisses (Westerman 1977; see Table 10-5, below) have Al_2O_3 values slightly less than 15 weight percent; examples where Rb is greater than 100 ppm are locally found throughout all of the sodic and gneissic suite.

The gneissic suite typically shows the trondhjemite trend of Baker and Arth (1976) as depicted in Figure 10-1. A potassium enrichment trend (Figure 10-2) is evident for some of the gneissic suite the most prominant being that exhibited by the Cedar Lake gneisses. This potassic enrichment trend may be a function of sampling technique (ie. exclusion of potassic units in the bulk sample - see Westerman, 1977, p.108). Due to inclusion of ultramafic-gabbro-anorthositic gabbro types, the Deception Bay gneisses show an extensive Fe/Mg differentiation trend. In general the compositional range

expressed by the gneissic suite is the most extensive and this is a reflection of its heterolithic nature.

The two types of the sodic granitoid suite (simple, compositionally uniform versus heterogeneous) are apparent in the AFM-CNK diagram (Figures 10-3, 4, 5, 6 and 7). The Daniels Lake pluton, Dalles batholith (Gower 1978, p.582) and the Campfire Lake pluton are typical examples of the former style. Even potassium does not show a wide compositional variation. The miscellaneous trondhjemite samples of various intrusives into the metasedimentary rocks of the Northern Domain are also representative of the simple style of sodic intrusions but further analyses are required to diagramatically represent this. The Campfire Lake pluton does show some variation along a trondhjemite trend; whether this is due to the presence of granulite metamorphism or not in this area is unknown. Except for samples 2 and 5 of the Campfire Lake pluton, hypersthene-bearing units tend to plot towards the Fe/Mg tie lines and the calcium apex. The marginal granodiorite (Figure 10-3 and 4; also Gower, 1978) is cataclastically deformed and may belong to either the sodic or potassic suites.

The heterogeneous complexes of the sodic granitoid suite (Figure 10-6) and batholiths (Figure 8-8) exhibit a much greater compositional range on the AFM and CNK diagrams, similar to the gneissic suite. The Bowden Lake pluton and the Chamberlain Narrows batholith (Figures 10-3, 10-4, 10-5 and 10-6) are heterogeneous intrusions however, the small compositional range expressed by these is a function of meager sampling.

Both the gneissic and complex sodic suites exhibit depletion of Fe and Mg concomittant with potassium enrichment. The Sen Bay stock (Figure 8-8) a typical

heterogeneous intrusion type exhibits such an evolutionary trend with decreasing relative age. Based on rare cross-cutting relationships in the Deception Bay (Lac Seul) area (see Table 7-6) the gneissic suite exhibits a similar chemical trend (Figure 7-7). The potassic enrichment trend is also present (Figure 7-7) but the trend is not as simple or as clearly defined.

The potassic granitoid suite (Figures 9-8 and 10-8) exhibits a similar potassium enrichment but less significant depletion in Fe-Mg (Figure 9-7). Excluding the rare syenitic unit (No. 15, Figure 10-8 lower diagram) and the more sodic/mafic granodiorite phases (Muriel Lake - No. 8 same diagram) most of the potassic members plot in a restricted field near the alkali end of the calc-alkaline trend.

Range and mean values of trace elements (Ba, Cs, Li, Rb, Sr,Y, Zr) for the various gneissic, sodic and potassic suites are given in Tables 10-19, 10-20 and 10-21, respectively. Overall trace values in the gneissic and sodic suites are approximately the same although the latter tends to be slightly lower in Ba, Rb, Zr and slightly higher in Li, Sr and Y. The potassic suite shows major increases in overall mean values of Ba and Rb. The increase in Ba is to be expected in that it is taken up in alkali feldspar (Arth, 1976; Anderson and Cullers, 1978) however the reason for the increase in Rb is unknown in that it tends to be concentrated in biotite, a mineral that is depleted in the potassic suite. If rocks of the potassic suite represent extremely fractionated liquids, this may explain the Rb enrichment.

SUMMARY

Modal variation of the three major suites (Figures 7-3, 8-2, 8-3, 8-4 and 9-2) indicates

the potassic suite exhibits the widest range in potassium feldspar to total feldspar ratio. On the quartz-total feldspar-mafic ternary there is a progressive shift of the composition away from the mafic component proceeding from the gneissic through sodic to potassic suites. Also, there is a progressive shift away from the trondhjemite sector to the quartz monzonite field. Chemical (element wt.%) variations (Figures 10-9 and 10-10) support the modal data. The CNK plot indicates the potassic suite is most enriched in potassium whereas the AFM (element wt.%) plot indicates progressive overall iron-magnesium depletion progressing from gneissic to sodic to potassic suites. Major chemistry of the suites exhibits considerable overlap but the limits and range of the compositions (expressed by the size of the field on Figure 10-9, and to a lesser degree in Figure 10-10) become increasingly restrictive from the gneissic through sodic to potassic suites respectively. The upper part of the potassic suite (Figure 10-10) delimits quartz monzonite compositions while the lower portion delimites granodioritic compositions. The mafic depletion-potassium enrichment evolutionary trend occurs as a major cycle across the major suites and as possibly numerous mini-cycles within the individual major suites.

The general potassium enrichment is a world wide recognized evolutionary trend in many Precambrian areas including West Greenland (McGregor, 1973), Africa (Anhaeusser, 1973) and Finland (Hietanen, 1975). More modern analogies have also been documented (Hietanen, 1975) and in fact "the trend from potassium-poor to potassium-rich silicic magmas seems to be repeated during each magmatic cycle through geological time (Hietanen, 1975, p.632)". Hietanen (1975) also reported an increase in

potassium content of plutonic magmas from south to north in Finland. However reversals have locally been documented. Kesler and Sutter (1979) report a decrease in K20 in intrusive magmas over a 40 m.y. period (average rate of change was - 0.06% K_20/Ma). Emmermann and Rein (1973) report an unusual chemical trend: with decreasing age there is a mafic mineral and potassium enrichment accompanied by a decrease in the quartz content in granitoid rocks of Hercynian age. Perhaps the most widely recognized potassium trend occurs in the batholithic belts of the southwestern United States (Miller, 1977). Systematic increases in K_20, $Si0_2$, K_20/Na_20 and $K_2O/Si0_2$ are reported across the Sierra Nevada batholith (Bateman and Dodge, 1970). In the same context Gastil et al. (1975) indicated there is no systematic variation in K_20 + $Na_20/Si0_2$ across the northern Baja California (Peninsular Ranges) batholith. However Gastil (1975) does indicate the Peninsular Ranges batholith is divisible intometamorphic, structural and petrologic zones that parallel the axis of the batholith. In effect the depth of burial and metamorphism increase eastwards and he relates this to subduction tectonics. As noted by Gower (1978), Saggerson and Turner (1976) describe an association of a sodic granitoid with lower metamorphic grades while the potassium-rich granitoids are associated with higher metamorphic grades. The eastward potassium enrichment of the Sierra Nevada batholith however is not linked to simple, uniformly decreasing ages but an eastward migration of plutonic centers (Kistler, 1974) possibly related to depth to (controlled by dip) the subducting lithosphere (Kieth, 1978).

Thus, in summary the potassium enrichment trend in Archean provinces tends to be

time-related; i.e., the older units are potassium-poor while the younger ones are potassium-rich. In some younger intrusions the potassic trend is linked to changes in island arc geometry. The potassic suite is late in the English Rivers, plutonic cycle; its restriction to the south domain, specifically the area west of Highway 105, may infer a more spatial genetic link.

NATURE OF ENGLISH RIVER SUBPROVINCE PLUTONISM

Table 10-22 summarizes the nature of the plutonism of the major (gneissic-sodic-potassic) suites in the English River Subprovince. Ideally the final subdivision would be based if possible on a spatial-time relationship. Hudson (1979, p.231) uses the term "magmatic arc" to designate igneous rock suites formed in response to specific episodes of plate convergence. In all probability the suites cannot be ascribed to simple orogenic events. Based on the data in Table 10-22 the suites can be subdivided into the present categories, however, the relationships listed are by no means entirely exclusive. The overall fundamental differences between the suites is based on degree of reworking, overall composition and tectonic style. It is on this basis that the suites are postulated to be logical subdivisions. These similarities reflect major magma-generation processes were operative but how these were interrelated in space and time is unknown.

Both Gower (1978) and Westerman (1977) indicate the possible existence of three volcanic-plutonic cycles or tectonic assemblages. Westerman (1977, p.230), on the basis of field relationships, postulates the following:

Tectonic Assemblage I: Comprised of the older Cedar Lake gneisses intruded by the younger Clay Lake gneisses (p.231).

Tectonic Assemblage II: Comprised of supracrustal assemblages exposed in the Twilight and Mystery Lake Domes.

Tectonic Assemblage III: Comprised of typical granitoid (quartz diorite to granite) rocks (in this report these would correlate with the mafic, sodic and potassic suites).

Gower (1978), on the basis of field relationships and age dating, proposes the following:

Volcanogenic-plutonic cycle I - Cedar Lake gneisses

Volcanogenic-plutonic Cycle II - Kenora gneisses* and Clay Lake gneisses (* 2760+/-50 Ma, Gower, 1978)

Diapiric event - emplacement of Dalles batholith and other plutons (2630+/-10 Ma, Gower 1978).

Gower proposed that the Kenora gneisses are time equivalent to the Clay Lake gneisses and both are younger than the Cedar Lake gneisses on the basis of similar chemistry (p.476) and correlation of his D_1 and D_2 events with Westerman's D_3events (Gower, 1978, p.478-479). The main reason for this correlation appears to be that Gower's (1978, p.471-472) D_2 event marks an interleaving of supracrustal/tonalite sheets while Westerman's (1977, p.88) D_2 marks an interleaving of basement (the Cedar Lake gneisses) and cover (metasedimentary rocks of the Twilight Lake dome). However, both of Gower's D_1 and D_2 events are marked by similar rootless isoclinal (refolded?) intrafolial folds of leucogranitoid constituents within the gneissic suite. Gower (1978, p.186)

indicates that the amphibolite lenses in the gneissic suite at Kenora are the oldest assemblage present. It is quite possible, if one considers the relatively young date obtained by Rb/Sr methods for the Kenora Gneisses (2760 +/- 50 Ma: Gower, 1978, p.266; also Table 10-22) that these are actually inclusion of the Wabigoon Greenstone Belt at Kenora. That is the Kenora gneisses represent an original heterolithic magma intrusive into the Wabigoon Greenstone Belt.

The authors differ from Gower's interpretation in the following:

1) The Clay Lake (Figure 13-1) granitoid suite appears to be part of the sodic suite. This interpretation is based on a brief reexamination of the area in 1977 and by Westerman's (1977, p.84) observation that: "the Clay Lake granitoid suite is much less deformed,lacking both isoclinal folds and a well developed compositional layering".
2) The Cedar Lake (Figure 13-1) gneisses may contain more potassic granitoid rocks which would explain their more potassic average composition; except for this the authors regard the Cedar Lake gneisses to be formed at the same time as the Kenora gneisses.
3) The Melick tonalite (Gower, 1978, p.268) is not part of the gneissic suite but is regarded as part of the sodic suite due to its lack of well defined compositional banding.

Based on field characteristics, chemistry (Fe^{2+}/Fe^{3+} ratios), REE patterns (Gower, 1978) and discriminatory diagrams (for the gneissic suite) the major suites (gneissic, sodic and potassic) are all wholly igneous in origin. That is, there are no indications that any of

these suites was derived by anatexis of metasedimentary rocks.

The gneissic granitoid suite is lithologically and chemically similar to the heterogeneous intrusive style of the sodic granitoid suite (Chapter 8). Together with the gneissic suite these rocks are characterized by an association of diorite-quartz diorite-trondhjemite-granodiorite units. Both the Sen Bay stock (sodic suite) and the gneissic suite display trondhjemite trends (Figure 8-9 and 10-1 respectively). The main difference between these two types is textural: the gneissic suite exhibits banding in which the assemblages are tightly interleaved and characteristically display a gneissic structure. The effect of the banding is further emphasized by migmatization involving later lit-par-lit conformable intrusions probably related to the later sodic and potassic suites. Heterogeneity and complexity is influenced by the number of intermixed phases and the degree of reworking. The heterogeneous intrusive style of the sodic suite is characterized by a mafic depletion-potassium enrichment variation trend (Figures 10-7 and 8-8) with decreasing age. This compositional variation trend is polycyclical and has probably been repeated several times. Each cycle may have overlapped in both time and space. That is there may or may not have been an interval between successive cycles.

At least two cycles have been indicated in the Sen Bay stock and with more detailed examination, more will probably come to light. The timing of these cycles is unknown. Hudson (1979) indicates the 10-30 Ma intervals are sufficient for the generation and emplacement of individual plutonic belts in southern Alaska. The age span of the major batholiths in the southwestern United States is in the order of 70 Ma.

There are indications that the Cedar Lake gneisses (Table 7-4) Kenora Gneiss (Table

7-5) and the Deception Bay (Sioux Lookout) Gneiss (Table 7-6) have undergone similar, cyclical mafic depletion-potassium enrichment with decreasing age although the lack of cross-cutting relationships has hampered reconstruction of the detailed history in these areas.

A comparison of the AFM and CNK averages of Englsih River Subprovince gneissic rocks with other gneissic and metasedimentary areas is given in Figure 10-11. Point number 19 is the average of 57 samples of the gneissic suite from the English River Subprovince. Also note the Cedar Lake gneisses plot much nearer the alkali apex of the AFM ternary than do the other English River gneissic areas suggesting a volumetrically more abundant leucocratic units of the potassic or sodic granitoid suites. There is some overlap in the sedimentary and gneissic average compositional fields but in general there is a tendency for the sedimentary rocks to plot towards the F-M side of the diagram (i.e., higher mafic content) and the K apex (due to abundant biotite). Figure 10-12 shows the AFM-CNK (oxide wt%) trend of other gneissic suites (Lambert et al. 1975, p.379, 381). The English River gneissic trend (Figures 10-9 and 10-10) does not coincide with any particular suite on both diagrams. On the CNK diagram the English River gneissic suite trend most closely approximates the Amitsoq gneisses; on the AFM diagram the English River gneissic trend most closely approximates the Lewisian and East Greenland gneisses.

The authors regard the gneissic suite to be primarily a more deformed version of the heterogeneous type of sodic suite intrusives. That is the gneissic suite is at least in part time equivalent to the sodic suite.The main evidence for this relationship includes similar

chemical trends (Figures 7-7, 8-8, 10-1 and 10-7) and documented gradational field relationships:

1) the Clay Lake intrusion (regarded by the authors as part of the sodic suite) becomes increasingly layered and deformed nearer the gneissic domes.
2) there are broad elliptical areas of the sodic suite whose axis is parallel to the gneissic banding that are situated within and are gradational (through development of heterolithic layering) with the gneissic suite (this is evident north of the Tustin-Bridges area).
3) the above two relationships are evident on the scale of single exposures in which lenses of unreworked uniform trondhjemite lenses are situated in and partly grade into the gneissic suite (Photos 7-11, 7-12, 7-13).
4) the mafic dykes are only present in the gneissic suite and in the heterolithic sodic suite complexes. That is, there are no known mafic dykes in any of he later sodic and potassic diapirs and this suggests the gneissic and heterolithic sodic complexes are roughly time equivalent.

Radiometric ages by Wooden (in Gower, 1978) confirm the gneissic suite at Kenora is not of great age (Table 10-23). The biotite tonalite gneiss at Kenora (2760 +/- 50 Ma is much younger than the Sen Bay stock (3.3 Ga: Hinton & Long, 1979) and not that much older than the Dalles batholith (2630 +/- 10 Ma). Furthermore, REE modelling by Gower (1978) suggested a somewhat similar generation process for both the gneissic suite at Kenora and the Dalles Batholith (sodic suite). Both plutons can be modelled by 10% partial melting of granulites; only the parent composition is slightly different: i) in the case

of the gneiss, a two-pyroxene garnet granulite of tholeiitic composition and ii) the Dalles parentage is either a hornblende-bearing garnet granulite (or if a modelled positive Eu-anomaly is ignored, a quartz eclogite).

The authors suggest the gneissic banding is due to deformation of an originally heterolithic batholith complex similar to the process recently suggested by Myers (1978). In this process of progressive deformation, units become tectonically interleaved; individual layering becomes thinner and more uniform with increasing intensity. The original heterolithic nature of the pre-gneissic terrain aided the deformation process by providing zones of weakness (contacts) along which the movement took place. Later intrusives were structurally tied to the developmed banding, and complicated the picture further. The Sen Bay stock, for which there is ample evidence of an early intrusive history, and the Clay Lake intrusion are typical protolithic examples of this pre-gneissic terrane.

The chemistry, compositional range and polylithic nature of the heterogeneous style sodic suite intrusives is similar to that of the gneissic suite. Both the gneissic suite and heterogeneous sodic intrusions are characterized by a wide compositional range (ie. trondhjemite trend) initiating towards the mafic end of this trend and both would appear to have long plutonic histories. On the other hand the simple sodic style, like the potassic suite, has a fairly narrow compositional range that tends to plot towards the alkaline end of the differentiation or calc-alkaline (trondhjemite) trend on an AFM diagram.

Based on the wide compositional range, extensive and repeated polycyclic plutonic history and the great age (3300 +/- 10 Ma, Table 10-23) of the Sen Bay stock, the

authors envisage the heterogeneous complexes as the older intrusive style of the two sodic granitoid suite types. Evidence for early diapirism of those intrusions is not observed - many now conform to their bounding rock units. The simple sodic suite diapirs such as the Melick tonalite and Dalles batholith (Table 10-23) appear to be younger intrusions. The 3300 Ma date for one of the older units of the Sen Bay stock (recall that there may be an older unit) is the age of one unit in one stock that forms part of the sodic suite. Photo 10-1 shows a trondhjemite dyke cutting cataclastic leucosome of the diatexite stage of the metasedimentary migmatite spectrum. Krogh et al. (1976) have dated the metasedimentary migmatization event at 2680 +/- 20 Ma. The age gap between the older phase of the Sen Bay stock and this dyke is in the order of 620 Ma. If Archean plutonism has behaved similarly to more recent plutonism where magma generation is on the order of 30 to 70 Ma pulses than there is potential room for numerous polycyclic magma sequences within the sodic suite.

Field relationships and radiometric ages indicate the potassic suite is the youngest of all suites. The potassic suite intrusions are structurally controlled and occur as spatially extensive dykes throughout the English River Subprovince and as huge batholith diapirs mainly confined to the Southern Plutonic Domain. REE modelling (Gower, 1978) in its simplest form suggests the potassic suite was generated by fractional crystallization of tonalitic magmas similar in composition to much of the sodic suite.

Partial melting of a sedimentary source will also give rise to a predominantly potassic magma. Therefore only the potassic suite could have such a parentage. However, field characteristics and chemistry (Fe^{2+}/Fe^{3+}) of the potassic suite are markedly different from

that of diatexites in the northern domain. Gower (1978) indicates the potassic phase in the Dalles batholith is cogenetic with and is a product of fractional crystallization of the main trondhjemite host. Just how much of the potassic phase in general is an in situ cogenetic phase is unknown but most of it is regarded to be intrusive into its present setting.

The ages of the potassic granitoid suite (Table 10-23) range from 2680 +/- 91 Ma (Lac De Bonnet Batholith in Manitoba) to about 2560 +/- 40 Ma for a pegmatite dyke in the Lac Seul area. This age difference (about 120 Ma) represents a much shorter period of evolution than that of the sodic suite. It should be noted that in the Kenora area, Gower (1978, p.479-481) indicates on the basis of structural considerations that some of the potassic granites precede the sodic suite suggesting a greater time span. The restricted, uniform compositional range (Figure 10-9), and lack of numerous compositional units for the potassic suite fit with this narrow age span. Gross similarities in composition, uniform textures and grain size over large batholiths suggest derivation from similar source materials under similar widely uniform conditions. The potassic suite marks the end stage of the major plutonism in the English River Subprovince. Also, if the chemical evolutionary trend is correct, the individual units of the potassic suite potentially mark the end of each heterolithic intrusive cycle.

MODERN ANALOGUES

The overall haphazard distribution of the major suites poses important problems. One fundamental problem requiring explanation is that if the gneissic suite is a deformed version of the sodic suite why was most of the compressive force which produced the

gneissic suite directed towards the south against the Wabigoon Subprovince, i.e., why do not gneisses occur north of the potassic suite batholiths west of Highway 599? The Wabigoon Subprovince must have behaved in part as a rigid block against which the gneissic suite was deformed.

There does not appear to be any regular spacing of the English River diapirs such as that described by Fyfe (1973a, 1974) in the Rhodesian craton. Fyfe (1973b) indicates the intrusive pattern there is a result of simple thermal convective motion in the upper crust. The irregularities of distribution of the diapiric bodies suggest this mechanism could not be applied.

Langford and Morin (1976) first proposed island arc tectonics in northwestern Ontario. However the basic symmetry noted in other conveying plate margins of rock chemistry (Bateman and Dodge, 1970; Miller, 1977) and metamorphic-structural and petrologic criteria (Gastil, 1975) is not present in the English River. Depth to the subduction zone related to the angle of inclination of the lithosphere i.e., island arc geometry, is accepted as one of the most fundamental factors affecting chemistry within the island arc system. Silver (1979) and Gromet (1979) indicate the Penninsular range batholith in southern California has a bipartite history. Although the Peninsular batholith is comprised of a uniform calcic plutonic suite in which major elements vary across it, several criteria suggest a two part history. The batholith ranges from 140 to 79 Ma with age decreasing from west to east. Across the axis marking 105 Ma, there are dramatic changes in petrologic diversity, pluton size and shape, gravity gradient, bulk volume, isotopic properties, trace elements and degree of REE fractionation. The 105 Ma axis is also

marked by a strong negative Bouger anomaly. Apparently the first 30-35 Ma were static while after the 105 Ma era the island arc migrated eastward and the locus of plutonism also migrated eastward. Three zones have been outlined based on REE fractionation trends. Fractional crystallization or contamination cannot be used used to explain the variations. Partial melting of source rocks can be used to explain the pattern on the static side of the batholith while partial melting in conjunction with prior variability in source region REE is used to explain the arc plutonism on the transgressive side. In Peru, Pitch and Taylor (1979) indicate the coastal batholith is similar to the Peninsular Range batholith; that is, the locus of intrusion was initially static but began moving eastward during the last 30 Ma. Pulses of magma generation comprise mafic to felsic sequences resulting from magma generation at progressively shallower depths in the subduction zone. Whether the present symmetry of the English River Subprovince can be related to subduction geometry combined with migrating loci of plutonism or perhaps a combination of convection and plate tectonics is not known. The distribution of the suites would appear to be too haphazard to adopt either model.

GENESIS OF ENGLISH RIVER SUBPROVINCE PLUTONIC ROCKS

In summary there are two major intrusive styles in the English River Subprovince: earlier intrusions tend to be complex, polycyclical, heterolithic, complexly reworked while the later intrusions are simple, compositionally uniform, mostly uncomplicated unreworked.

Based on texture, composition, and intrusive style there are three major intrusive suites in the English River Subprovince. The gneissic, sodic and potassic suites. The sodic suite can be subdivided further into heterolithic, complex, polycyclic intrusions and simple, compositionally uniform intrusions. The gneissic suite and heterolithic complex sodic suite are chemically and compositionally similar; they are characterized by an extensive, compositionally wide-ranging polyplutonic history that probably underwent numerous repeated cycles of magmatic differentiation from characterized by diminishing Fe-Mg and increasing K with time. The gneissic suite represents a possibly deeper, more strongly structurally modified, more reworked version of the heterolithic complex, sodic suite intrusives. These two suites are typical of the earlier intrusives. Grossly simplified the plutonism in the English River Subprovince was initially of a sodic nature that was subjected to extensive, cyclical differentiation, intrusion and reworking. A complex array of textures, structures and lithologies dating from the period of reworking of the sodic heterogeneous complexes was superimposed on and interfingered with the earlier generations. The extent to which these earlier features were modified vary from place to place; in the case of the gneissic suite the mofidication obliterated most of the earlier relations. With time the plutonism changed to a dominantly diapiric style involving both sodic and potassic units. The diapiric style was characterized by more uniform compositions and a much shorter evolutionary period. That is, with time the plutonism became more restricted in composition perhaps in part due to a shorter duration of plutonic evolution. The diapiric style plutonism became dominated by potassium compositions about 2650 Ma and was in the order of

100 Ma in duration. The heterogeneous intrusive style involving the sodic suite lasted for a much longer time period (approximately 650 Ma). A narrowing of compositional range accompanied by increase in potassium has also been noted in Sweden (Gorbatschev, 1975, p.109).

Mafic dykes are found only in the gneissic and heterolithic, complex sodic suites and were generated prior to the diapiric event. The fact that there are both undeformed and deformed dykes in these two suites suggests their emplacement duration lasted a time span at least equivalent to the time of exolution of the heterolithic complexes which date back to at least the 3.3 Ga Sen Bay stock (Hinton & Long, 1979). The diapiric event probably began at around 2.65 Ga and this suggests an emplacement interval for the mafic dikes of up to 700 Ma.

The major suites exhibit considerable overlap in time (Table 10-23) and in all probability the mini-cycles of potassic enrichment will eventually be shown to exhibit considerable time overlap. Perhaps this is the case at Kenora where Gower (1978, p.481) indicates the potassic granitoid intrusives predate the Dalles (simple sodic style) Batholith.

The fact that the earlier complex plutonism is comprised of numerous units with abundant enclaves throughout suggests passive intrusion in part by piece meal stoping. However, the true nature of the earlier plutonism is unknown in that the later diapiric event considerably structurally modified the earlier intrusions. Schwerdtner et al. (1979) report just the opposite effect in the Wabigoon Belt where several orders of initial gneissic diapirism are followed by a later intrusive event that did not disturb earlier plutonic structures.

The diapiric event in the English River Subprovince possibly provided the driving force behind the deformation of the gneissic suite. Evidence for this occurs in the Kenora and Clay Lake areas where deformation and development of banding increases towards the more homogeneous diapiric intrusives. There is no real overall symmetry to distribution of the major suites except: i) the gneissic granitoid suite is restricted to the Southern Plutonic domain mainly adjacent to the Wabigoon Subprovince and ii) the potassic suite including the huge Lount Lake batholith is also mostly restricted to the Southern Plutonic Domain, specifically the area west of Highway 105. In fact a large portion of the gneissic suite (Figure 7-1) surrounds the potassic suite (Figure 8-1) in this part of the map area. This association implies a link: deformation of the gneissic suite in part may be linked to distension caused by intrusion of the late diapirs. The only major dome and basin structural style (Westerman, 1977; see Photo 13-7) observed within the English River Subprovince occurs at the eastern periphery of this potassic mass. There, a structurally anomalous situation in which metasedimentary migmatitic assemblages (Twilight Lake and Mystery Lake Domes - Figure 13-1), anomalous to those in the Northern Metasedimentary Domain are structurally overlain by superincumbent highly deformed phases of the Cedar Lake gneissic suite (Figure 13-1). Westerman (1977) has proposed sub-horizontal sheet intrusion or a thrusting mechanism similar to that envisaged by Myers (1976) to produce this configuration. Myers (1976) indicated the emplacement of similar sheets is syntectonic associated with dilation processes. The authors have observed protomylonitic textures in the granitoid gneisses at the periphery of these domes adding support to the subhorizontal tectonic hypothesis. There is some

evidence that part of the Lac du Bonnet batholith was emplaced as large, shallow, east-dipping sills suggested by shallow dipping, large enclaves in the Manitoba extension of this batholith.

Brisbin (1975, p.726) indicated diapiric intrusion is accommodated by horizontal compression which in turn is compensated for by vertical and lateral extension. The east to northeast trend (seen at all structural scales from the internal fabric (foliation and gneissosity) of the suites to the elongation of individual sodic suite batholiths and complexes up to the megabelt trend of the major suites themselves) is a major structure that was probably a result of this horizontal compression. The east to northeast trend is a result of rebounding pressure which caused vertical/lateral extension (ie. distension) in this direction.

The gneissic suite in its entirely does not owe its existence to just diapirism though - there are areas of gneissic terrain where these appears to be little evidence of diapirism (for example central Lac Seul and north of Sioux Lookout). Undoubtedly there must still have been some form of layer normal compression.

CHAPTER 11

NATURE OF PLUTONISM OUTSIDE THE ENGLISH RIVER SUBPROVINCE

Gneissic rocks are absent along the subprovincial boundaries of the English River Subprovince with the Uchi and Wabigoon. However, Schwerdtner et al. (1979) described an early foliated to gneissic diapiric tonalite to granodiorite assemblage in the Wabigoon subprovince, intruded by later massive to foliated dioritic to granitic plutons.

WABIGOON SUBPROVINCE

STURGEON LAKE-SIOUX LOOKOUT AREA

In the Sioux Lookout and Sturgeon Lake area, the younger, massive plutons of the Wabigoon Subprovince strongly contrast with adjacent, more complex plutons of the English River Subprovince (Figure 8-5, above). The plutons are compositionally simple, massive, undeformed and generally exhibit $Na_2O>K_2O$. They generally range from gabbro and diorite to trondhjemite and granodiorite with minor potassium-rich variants. In general the earlier intrusive units within this part of the Wabigoon Subprovince are not nearly as complex as that of the English River Subprovince to the north. All of the plutons and batholiths described are located on Figure 8-5 and Map P.2293 (Breaks et al. 1980).

Mafic to Intermediate Intrusive Rocks

Weakly recrystallized to unrecrystallized, mafic to intermediate intrusive units within the Wabigoon Subprovince form small stocks at Marchington Lake, Stanzhikimi Lake and

in the central part of the Yett Lake stock. At least some of the coarse-grained gabbro and diorite found between Kinniwap Lake and the north end of Lake of Bays also belong in this group. These rocks vary from gabbro to diorite to quartz diorite.

Intermediate to Felsic Intrusive Rocks

Yett Lake stock

Emplacement of this ovoid stock has displaced the Savant Lake metavolcanic-metasedimentary belt between Schist Lake and Drive Lake. This pluton, mapped in part previously by Trusler (1975), has a compositional range between trondhjemite and granodiorite. The rock is massive, greenish-grey to moderate orange (fresh surface) and characterized by distinct, abundant opalescent blue coarse quartz (30 to 40 percent). Several massive exposures of orange granodiorite accessible on the Marchington River Road may have potential as an attractive building or lapidary stone.

Robinson batholith

A prominent, elongate, relatively high level granodiorite to trondhjemite batholith roughly straddles the Canadian National Railway line from Ekstrom Lake to beyond the eastern limits of the map area. This intrusion was initially mapped in part and named by Horwood (1937) as the Robinson stock. Recently, Dusanowskyj (1976) ammended this to the Robinson batholith after delineation of its full extent. Dusanowskyj and Barlow et al. (1975) also demonstrated a significant negative gravity anomaly associated with this intrusion. Gravity modelling indicated an estimated depth of 16 km (Dusanowskyj, 1976, p.63).

The major intrusive unit consists of a pale orange to pink (weathered surface),

medium- to coarse-grained, inequigranular, hypidiomorphic-granular, biotite trondhjemite to granodiorite. Staining studies on numerous slabbed specimens indicated an absence of quartz monzonite although Dusanoswkyj (1976, p.27) implied the contrary. Fine- to medium-grained, chilled units occur at the contact zones. Both the Yett Lake stock and Robinson batholith are post-dated only by coarse-grained to pegmatitic, holo-leucocratic quartz monzonite to granite (sensu stricto) dykes which form a minor unit.

The granitoid terrane between the Robinson batholith and the Yett Lake stock is mainly massive to moderately foliated, pink, weathering, medium to coarse-grained, inequigranular to occasionally porphyritic (plagioclase), biotite and hornblende- biotite trondhjemite. The Robinson batholith is bordered on the south by similar, metamorphosed, biotite to hornblende-biotite trondhjemite that locally grades into quartz/diorite.

Nagron Lake stock

The Nagron Lake stock is a medium- to coarse-grained, unmetamorphosed, equigranular, lineated biotite trondhjemite. Locally in the southwest it grades into a unit of chlorite-biotite trondhjemite of subvolcanic origin. This latter unit is characterized by subhedral to euhedral quartz phenocrysts and contains 5 to 7 percent disseminated pyrite.

Lake of Bays batholith

This pluton is the largest batholith in the area of which only half is indicated in Figure 8-5. The batholith is composed of massive, unmetamorphosed quartz monzonite that varies from equigranular to subtly porphyritic (potassium feldspar) and locally grades to

granodiorite. A marginal unit of unmetamorphosed hornblende-biotite to biotite-hornblende diorite to quartz diorite to possibly andesine quartz monzonite is exposed at Zarn and Nagron Lakes and Lake of Bays. Both the above main and marginal units are cut by rare, thin dykes of quartz monzonite. Dusanowskyj (1976, p.63) also modelled this batholith and computed an estimated depth of 16 km.

Chemical analyses of the Robinson Lake batholith, Nagron Lake stock, Lake of Bays batholith, Sturgeon River batholith, Lewis Lake batholith (Tables 11-1 to -5,) are plotted on AFM and CNK diagrams (Figures 11-1 and 11-2). These trends fall in the central range of the sodic granitoid suite (Figures 10-7, 10-8). The Robinson batholith and Lake of Bays batholith (Figure 11-1) exhibit a weak potassium-enrichment trend compared with the English River potassic suite. The Robinson batholith exhibits a fairly extensive compositional range; the other plutons have a restricted compositional range, similar to the potassic suite and simple intrusive type of the sodic suite in the English River Subprovince.

There are indications that this distinct compositional contrast is more widespread outside the English River Subprovince, i.e., the later plutons are more sodic in the Wabigoon Subprovince whereas the latest plutonic activity in the English River Subprovince is potassic. To the east (Sage et al. 1973; R.P. Sage, personal communication, 1980) has noted that the latest batholiths are mostly massive, calc-alkalic (trondhjemite-granodiorite), and are simple, compositionally uniform intrusions. Potassic granitic rocks are the latest unit but are volumetrically much less abundant (R.P. Sage, personal communication, 1980). The Aulneau batholith (Ziehlke 1974, p.156-161,

179) shows a similar weak potassium enrichment trend in the later units but is also dominantly sodic in composition. Elsewhere the intrusions between Kenora and Vermilion Bay including the Sturgeon Lake area (see mafic suite) and the Feist Lake pluton are dominantly either diorite or granodiorite. Only the Crabcraw Lake pluton is more potassic, i.e. quartz monzonite.

UCHI SUBPROVINCE

Much of the south margin of the Uchi Subprovince between the Manitoba/Ontario border and Pakwash Lake consists of batholiths composed of the sodic granitoid suite. Several elliptical structures, rendered conspicuous as ovoid magnetic anomalies (Aeromagnetic Maps 4010G and 4011G) and to a lesser extent by topographic features, are a striking feature in the Sydney Lake- Longlegged Lake-Medicine Stone Lake area:

1) Sydney Lake-Rainfall Lake dome, and;

2) Longlegged Lake dome

A third similar structure is probably centred between Medicine Stone and Upper Medicine Stone Lake, but this area was largely unexamined by the present survey. Domal tectonics, except for that described in the Cedar-Clay Lakes area of the English River Subprovince (Westerman, 1977), are generally rare to absent throughout the remainder of the survey area.

The 8 by 22 km Longlegged Lake overturned dome is composed of intercalated amphibolite, biotitic quartzo-feldspathic gneiss, hornblende-biotite quartzo-feldspathic gneiss and medium-grained biotite trondhjemite gneiss units mantling a core of foliated,

metamorphosed, homogeneous to gneissic and xenolithic trondhjemite. Massive to foliated, fine-grained to medium-grained, amphibolite units, commonly containing epidote, is especially prominent on the periphery of the dome. One amphibolite band was traced for about 64 km around the southern and northeastern periphery of the dome before widening and coalescing with amphibolitic, pillowed mafic metavolcanic rocks of the Dixie Lake metavolcanic-metasedimentary belt. The fine-grained biotitic quartzo-feldspathic gneisses probably represent greywacke that has undergone metatexitic migmatization. Several small, massive, metamorphosed, medium- to coarse-grained, gabbro to hornblendite intrusive bodies occur both within and proximal to the Sydney Lake-Rainfall Lake and Longlegged Lake domes.

The 8 by 31 km Sydney Lake-Rainfall Lake dome exhibits quaquaversal (dome-like) dips ranging between 35 and 50 degrees. This antiformal dome plunges at the southwest, under the north end of Sydney Lake, and terminates to the northeast near Bug Lake.

Both the core and mantle zones of the Longlegged Lake and Sydney Lake-Rainfall Lake structures were the loci of numerous late-tectonic stocks and dikes of unmetamorphosed, medium- to coarse-grained, leucocratic biotite quartz monzonite (potassic units) which have obliterated the original core-mantle relations in many areas.

CONTACT RELATIONSHIPS

SUBPROVINCE BOUNDARIES

Wabigoon-English River Subprovincial Interface

Wilson (1971) proposed that a fault zone marked the southern contact of the English

River Subprovince based on coincident, strong linear magnetic features and topographic lineaments. No evidence of major cataclasis occurs along the west portion of this boundary or along several lineaments including a notable lineament at Canyon Lake. This lineament, 40 km in length and averaging 0.3 km in width, has proved to be neither fault-controlled nor lithologically-controlled, but instead may relate to late fracturing with no apparent movement.

The geological maps (Figures 2-1 and 7-1) show the gneissic suite of the Southern Plutonic Domain in contact with the Wabigoon Subprovince. At several localities including Kenora, Tustin-Bridges Townships, Vermilion Bay and the Gilbert-Islay Lake area (north of Dryden), the gneissic granitoid suite is separated from the Wabigoon Subprovince by structurally controlled, thin 0.4 km to 1.6 km, intrusive sills genetically related to the later sodic and potassic plutonic suites. At Kenora and in the Tustin-Bridges area, the contact is sharp, it has been intruded by porphyritic granodiorite (Photo 11-1), characterized by microcline augen hosted within a protomylonitic fabric (Photo 9-6). The cataclastic fabric is restricted to the sills and is not apparent in either the adjacent mafic metavolcanic rocks or in the gneisses suggesting that the cataclasis may have developed during intrusion as a response to dilation within the constrictive confines of the contact zone. The contact is inferred as of intrusive origin, however whether these intrusions have obscured evidence of cataclasis is unknown. Westerman (1977, p.195) indicated that amphibolite enclaves in the intrusive rocks of the Vermilion Bay area are clearly derived from metavolcanic rocks of the Wabigoon Subprovince. North of Vermilion Bay and in the Gilbert-Islay Lakes area, the intrusions along the contact are more extensive, massive,

and undeformed. In other areas such as the High Lake-Rush Bay area near the Manitoba-Ontario boundary, and north of Hudson, the contact appears to be gradational. Harris (1976) indicated that the gneissic granitoid suite passes into the mafic metavolcanic rocks. The position of the contact is arbitrarily drawn on the basis of dominant rock type, but according to Harris (1976) the gneissic interlayers within the Wabigoon Belt disappear approximately 100 m south of the contact. Within the gradational area, the gneissic fabric has been reworked along with the volcanic fabric so that both are conformably interleaved.

Further east, the boundary is marked by cataclasis of the Miniss River Fault Zone and the sudden appearance of metavolcanic assemblages of the Wabigoon Subprovince. Both Morin (1979) and Gower (1978, p.483) argued that the Dryberry Dome is part of the English River Subprovince:

1) the magnetic signature of this area as described by McGrath and Hall (1969) and Hall (1968, 1971) is similar to that of the Southern Plutonic Domain.

2) high grade, partially melted metasedimentary rocks occur on the north margin of the Wabigoon Subprovince (Bartlett, 1978) and also extend around the southern flanks of the Dryberry Dome (Gower, 1978, p.483).

In this survey, boundary limits for the Wabigoon Subprovince at the eastern end are defined by metavolcanic assemblages. The volcanic stratigraphy is nearly continuous between Kenora and Vermilion Bay. The circular nature of the Dryberry Dome suggests the northeast contact is in the area between Vermilion Bay and the main portion of Eagle Lake. No mafic metavolcanic vestiges are known in this vicinity but if present then the

Dryberry Dome would unequivocally reparesent an intravolcanic belt plutonic mass similar to the Aulneau batholith. Whether this plutonic mass is related to the Southern Domain of the English River Subprovince or the intravolcanic belt plutonism is not known. Between Dryden and Sioux Lookout the three major volcanic formations and metasedimentary rocks interfinger. The southern contact (Figures 7-1 and 8-1) follows this interfingering in that the contact is marked by the appearance/disappearance of the volcanic assemblages. The contact, as it strikes west from Dryden, follows the appearance/disappearance of metavolcanic rocks and therefore circles the Dryberry Dome entirely and emerges on the south side of the Tustin-Bridges greenstone belt. The presence of partially melted metasedimentary rocks around the Dryberry Dome is not reason enough to include this area in the English River Subprovince. Structural boundaries are also viewed with apprehension as certainly the Sydney Lake fault does not completely follow the Uchi-English River boundary.

Thus, in northwestern Ontario within the confines of this survey, the Wabigoon-English River Subprovince is marked by the disappearance of metavolcanic assemblages. In the west part of the area, the boundary is intrusive. The presence of highly reworked gneissic suite rocks to the north in the English River Subprovince versus simple, mostly unreworked plutonic rocks to the south (Wabigoon Subprovince) suggests a tectonic break in the form of faults (Gower 1978, p.481).

Uchi-English River Subprovincial Interface

The contemporaneity of volcanism in the Uchi Subprovince and sedimentation in the northern metasedimentary domain of the English River Subprovince has been inferred for

several areas. Stratigraphic continuity between the two subprovinces is apparent: i) locally at Pakwash Lake, ii) throughout the Slate-Papaonga Lake-Root Bay area (Figure 4-2); and iii) in the Lake St. Joseph area. In these areas the stratigraphy simply passes from dominantly metavolcanic to dominantly metasedimentary marked by a high temperature-low pressure metamorphic gradient (see Chapter 15). South of the Slate Lake-Papaonga Lake area, fine distal facies felsic to intermediate tuffs and reworked tuffs interfinger with and occur as isolated lenses within the metasedimentary rocks of the English River Subprovince (Figure 4-2). Most of these continuous supracrustal sections are present in the eastern part of the Uchi-English River boundary zone..

The stratigraphic continuity across much of the western portion of the interface is interrupted by the Sydney Lake Fault system (Stone 1977; Schwerdtner et al. 1979; Stone 1982). This is regarded as a late fault system that was superimposed on and perhaps initially guided by the facies change corresponding to the present boundary between subprovinces. The fault zone does not consistently occur within the area of the facies transition. At Pakwash Lake the fault cuts across metasedimentary rocks and demarks a change from medium-grade on the north to high-grade (partially melted) rocks to the south suggesting the latter metamorphic zone may have been displaced upward.

Interface Between the North and South Domains

The northern-southern domain interface is an intrusive contact, marking the southern limit of metasedimentary rocks and migmatitized equivalents. To the south the plutonic domain largely consists of the sodic and potassic intrusive suites. At Separation Lake,

the contact between the two domains is marked by a predominantly metavolcanic supracrustal sequence. East of the Separation Lake Belt, spaced almost regularly along or near the contact at intervals of 6 to 13 km, there are some 20 discrete units of amphibolite varying in thickness from tens of meters to hundreds of metres. These units may be discontinuously traced about 180 km eastward. However, supracrustal remnants occur at the inter-domain boundary at only five localities and the remaining remnants apparently have been transported away by intrusive rocks (Table 3-2). Therefore, although the contact is locally marked by the remnants of the extension of the Separation Lake Belt, it is predominantly intrusive. At Helder Lake there are metavolcanic enclaves of the Separation Lake Belt extension within inhomogeneous diatexite (Photo 11-2). The intrusive rocks along the inter-domain boundary are mainly affiliated with the sodic and potassic granitoid suites.

CHAPTER 12

PLEISTOCENE GEOLOGY

The Pleistocene geology of the map-region has been previously mapped by Zoltai (1961, 1965a,b) and the Pleistocene history has been summarized by Prest (1970). The discussion that follows is largely a summary from these two sources.

GLACIAL HISTORY

Scattered glacial striae measurements taken during the present survey vary widely:

i) dominantly N45-50^{0}E in the southwest (near Kenora)

ii) dominantly N70-80^{0}E in the northwest (west of Highway 105);

iii) dominantly N70-80^{0}E in the area north of Lac Seul;

iv) dominantly N45 to 70^{0}E south of Lac Seul;

v) dominantly N30 to 50^{0}E in the Miniss-Tully Lakes-Savant Lake area.

The glacial striae mark the latest movement of the Wisconsin glaciation which was dominantly northeast to southwest. Whether the more westerly to west-southwest trends (ii and iii above) reflect minor deflections in the latest ice advance or indicate a previous ice advance direction is unknown. Zoltai (1961, p.64) does indicate two previous ice directions one in Kakagi Lake area being at S50^{0}W to S64^{0}W.

During Pleistocene time the map area was covered by at least four ice advances (Zoltai, 1961, p.63) the last being the Wisconsin Sheet which began retreating between

14,000 and 13,000 years ago (Prest, 1970). According to Prest (1970) the margin of the ice mass remained fairly stagnant south of the map area until 12,800 to 12,700 years age when the ice front began retreating north and the southwest part of the map area was covered by glacial Lake Agassiz. By 12,200 years ago the ice front had retreated to the vicinity of Lac Seul. Between then and 11,800 years the ice readvanced as indicated by overridden varved clays in the Lac Seul area (Zoltai, 1965). Between 11,800 years ago and 11,500 years ago the ice retreated leaving in its wake the first of three major morrains: The Eagle-Finlayson Morraine (Zoltai, 1961, p.68) which trends southeast from Canyon Lake to Vermilion Bay. From 11,600 years to 11,500 years age the ice again retreated followed by a readvance which deposited the Hartmann Morrain which is curvalinear southeastwards from Anishinabi Lake to southeast of Sandybeach Lake. From 11,200 to 10,900 years ago the ice retreated followed by another advance at around 10,600 years ago. The subsequent retreat (10,300 years ago) this time left in its wake the Lac Seul Morraine. During all of the above retreats and advances, glacial Lake Agassiz remained in contact with the icefront. In fact all of the portions of the morraines in the limits of the map-area were produced beneath and modified by lake action (Prest, 1970, p.731). Commencing at 10,300 years B.P. the ice retreated although there was a minor readvance east of Lac Seul about 10,000 years ago. Beginning about 10,300 years ago glacial Lake Agassiz began to drain east-southeast through the Dog River Spillway and by the period 9,000 yers ago the ice had retreated and glacial Lake Agassiz had completely drained from the map area. The outlets of Lake Agassiz were controlled by the position of the ice front and by topography (Prest, 1970, p.732). The final

discharge of Lake Agassiz in this part of the map area took place via the Nipigon Basin outlet.

GLACIAL DEPOSITS

Terminal Moraines

Three moraines cross the area in a curvalinear fashion. They have all been modified by glacial Lake Agassis; they trend from near south to east-southeast and were constructed during readvance stages during retreat of the Wisconsin Ice Sheet.

The most southerly is the Eagle-Finlayson Lake morraine (Zoltai, 1961, p.68). Accordng to Zoltai this morraine locally rises to over 100 feet above the surrounding topography. It is fairly continuous within the map area and occurs as a single ridge; it is fairly narrow up to 1.6 km in maximum width. Near Eagle Lake the crest has been peneplained and is quite level.

The Hartmann moraine is (Zoltai 1961, p.69) continuous from Dryden north to just south of Mystery Lake and thereafter to the north it is discontinuous. There is a continuous 24 km section west of Aerobus Lake and another 38 km continuous section west of and north of Pakwash Lake. The northwest part of this moraine, s in the map area, is compresed of a single ridge "composed of stratified sand and gravel, overlain by 0.6 to 0.9 m of loose till" (Zoltai, 1961, p.69). This moraine is mostly modified by glacial lake Agassiz but south of Sandybeach Lake it is unmodified. The Hartmann moraine curves north to north-eastwards at Pakwash Lake until it is truncated by the younger Lac Seul Moraine (Prest, 1970, p.731).

The Lac Seul Moraine is the most northern in the map-area; it is nearly continuous

from north of Lac Seul to Kerkewabick Lake (south of Sioux Lookout) but locally there are minor discontinuous portions. The north part of the moraine is the most prominent and is marked on the map (Breaks, et al. 1976a). The moraine rises sharply to 270 feet above the topography on the northeast side (ice side) but on the distal (Lake Agassiz) side it slopes more gently and displays relict beaches and terraces (Prest, 1970, p.731).

Outwash Deposits

The only major lacustrine outwash deposits are generated from the Lac Seul Moraine north of Dryden where there are broad sandy areas. The outwash deposits are southwest of and slope gently away from the moraine. Vegetation, mainly coniferous trees, is both sparse and stunted in this area.

GLACIO-LACUSTRINE DEPOSITS

Glacio-lacustrine deposits, mainly varved clays and silt are extensive and spatially associated with the moraines. Much of the English River-Wabigoon River-Clay Lake and Pakwash-Lac Seul area is covered with varved clays. In part the deposition in these areas (covered by Lake Agassiz) was controlled by the ice front (to the northeast) and an extensive topographic high comprised of denuded rocks to the southwest (diagonally from Umfreville Lake to Vermilion Bay - the area to the southwest has extensively exposed outcrop areas). The varved clays are restricted to the lower areas (Zoltai, 1961, p.71). According to Zoltai (1961, p.71) the thickness of the varved clays varies both regionally and locally; in Lake of the Woods they are 1.2 m thick but are up to 3 m thick in the Wabigoon River Basin. In the Lac Seul area the clays vary from 2 m to up to 6 m

thick. The varved clays are generally thinly layered (less than 0.8 cm). The clays are usually grey but locally south of the Hartmann Moraine the clays are red (Zoltai, 1961, p.72).

Kames and Eskers

Numerous eskers are found throughout the northeastern part of the map area and generally trend west-southwest parallel to the ice movement direction. Except for an esker on the south side of Lake St. Joseph these eskers are all modified by Lake Agassiz and are highly discontinuous. Small kettle lakes are commonly associated with the Eskers.

Numerous kames of varying extent are found throughout the area. According to Zoltai (1961, p.70) they vary in size from hills of stratified sand and gravel several square miles in extent to small accumulations of the same material, set against the side of rock knolls".

Ribbed Moraines, Scouring/Druminoid Ridges

Ribbed moraines (Prest, 1968, p.6) are common north of Lac Seul and north of Fairchild Lake and are mainly restricted to the area northeast of the Lac Seul Moraine. They are discontinuous and trend parallel to the ice direction.

Drumlinoid ridges, marked mainly by adjacent glacial fluting (Prest, 1968, p.9) are rare but are locally present northeast of Lac Seul (Zoltai, 1961, p.1965a).

BEDROCK, GLACIAL TILL

Large denuded bedrock areas occur in the west part of the map area:

i) west and northwest of Sydney Lake;

ii) west Umfreville Lake

iii) sporadic to continuously southwest of a diagonal line from Umfreville Lake to Vermilion Bay;

iv) as minor small pockets extending above the glacial till irregularly scattered throughout the remaining areas

The rest of the area is covered by a thin veneer of silty to sandy glacial till.

RECENT

Redistribution of the Pleistocene deposits is locally evident in the map area. Sand, silt and gravel deposited locally by streams and organic mud deposits associated with decomposition of muskeg and vegetation constitute the recent material. Locally sand deposits are concentrated through wave action and form beach accumulations along lake shores.

CHAPTER 13

GEOPHYSICS

CORRELATION WITH AEROMAGNETIC DATA

The aeromagnetic expression of the map area is shown on various maps (ODM-GSC, 1961) published jointly by the Ontario Department of Mines and the Geological Survey of Canada in 1961 at a scale of 1:63,360 (1 inch to 1 mile). The Geological Survey of Canada also published maps of the area at a scale of 1:253,440 or 1 inch to 4 miles (7122G, 7123G, 7124G, 7105G, 7106G).

The following observations can be made:

1). the intrusive rocks are generally magnetically noisy ,i.e. closely-spaced contour intervals. The contours tend to conform to and outline the margins of plutons in the northern supracrustal domain. In the southern domain the contours are chaotic and lithologic contacts are generally not discernible.

2). the metasedimentary rocks normally exhibit more uniform, linear, conformable east-west trends. The metasedimentary rocks in the northern domain (especially east of Highway 105) are much less noisy (wide-spaced contour intervals) than the plutonic rocks.

3). the homogeneous diatexite bodies tend to exhibit the least magnetic noise.

4). the plutonic rocks exhibit weak, magnetic high responses whereas the metasedimentary rocks and especially the homogeneous diatexites exhibit magnetic lows.

5). west of Highway 105, the northern domain is marked by linear areas versus more chaotic contour patterns in the southern plutonic domain. However both the north and

south domains in this area are magnetically noisy due to the greater abundance of granitic plutonic rocks. Therefore, although the major plutons are weakly outlined in the northern domain, they are not as prominent as those in the large area of metasedimentary rocks east of Highway 105, as, for example, the Bluffy Lake batholith and Otatakan Lake stock.

6). the various plutonic suites do not exhibit unique or conspicuous signatures although there is a vaque tendency for the gneissic suite to be slightly less noisy than the other plutonic suites.

7). the Sydney Lake fault appears as a weak magnetic low due to the intrusion of homogeneous diatexite along its length.

8). the bending of lithologic trends near the Miniss River fault zone is very evident. The warping actually is not suggestive of right-lateral motion.

9. the dome structures at Longlegged and Clay Lakes are conspicuous.

10). the volcanic terranes are magnetically noisy and also record the highest values.

The boundary between northern and southern domains of the English River Subprovinces is strikingly outlined on the regional magnetic anomaly map of Hall (1971).

CORRELATION WITH RADIOMETRIC DATA

Airborne radiometric maps were published jointly by the Ontario Geological Survey and the Geological Survey of Canada in 1977 (OGS-GSC, 1977) at a scale of 1:253,440 (1 inch to 4 miles). The potassium and total count contour maps have some correlation with geology:

1). areas underlain by the potassic granitoid suite generally coincide with specific contours

2). the large homogeneous diatexite batholiths such as at Wapesi Lake are also clearly correlative with specific (potassic,total count) contours. The metasedimentary rocks, metatexites and inhomogeneous diatexites are fairly low in total counts.

3). some of the sodic granitoid plutons in the northern domain exhibit a slight increase in contour density compared to the metasedimentary rocks.

4). the total count contours are chaotic in the western part of the English River Subprovince and do not follow lithologic contacts.

The uranium contour maps do indicate the three principle uraniferous areas within the western part of the subprovince:

1). Sydney Lake cataclastic zone locally exhibits high nodes;

2). Separation Lake area

3). southern boundary of the Tustin Bridges contact.

The flight lines, for example, pass near but miss several uranium occurrences such as the Richard Lake prospect (Tustin-Bridges Area) and consequently, these do not appear on the maps.

SEISMIC DATA

Seismic data for the English River Subprovince has been adequately summarized by Gower (1978, p.48-52).

"Seismic studies in northwest Ontario (Hall and Hajnal, 1968, 1973; Hall, 1971) have demonstrated the presence of a two-layer crust. A crustal structure anomaly, with thicker upper crust, attenuated lower crust, and thinner total crust, correlates with the position of

the "Ear Falls - Manigotagan Gneiss Belt" (ie. the English River Subprovince). Though Hall (1971) claims the gradient is steep near the margins of the subprovince; suggesting steep, possibly faulted, boundaries, the data do not make this obvious (Figures 2.4, 2.5, 2.6). Hall and Hajnal (1973) suggest the presence of a further discontinuity at 50 km but do not explain its significance. Hall and Hajnal (1973) and Hall (1971) consider the English River Subprovince to be in isostatic equilibrium over a uniform upper mantle. Their comparison of the seismic profile with the Donets-Dnieper basin, which is interpreted as an aulacogen, is difficult to reconcile with the overall subprovince geometry of northwest Ontario, and the existence of older sialic crust (Krogh et al., 1976) in the Winnipeg River Plutonic Complex."

Gower (1978, p.52) also writes:

"It should be noted that the seismic model is not compatible with hypotheses that explain the gravity highs and higher grade of metamorphism as due to elevation of a crustal block bringing denser and higher grade rocks closer to the surface. This implies that both the Intermediate and Moho discontinuities should be elevated, whereas the Intermediate discontinuity is depressed".

CHAPTER 14

METAMORPHISM

INTRODUCTION

The tectono-metamorphic evolution of the Uchi and Northern Supracrustal Domain of the English River Subprovince is quite similar and has involved five metamorphic events (Table 14-1). This interpretation is similar to McRitchie and Weber (1971) for the Manigotagan Gneissic Belt and has been established the Uchi and English River Subprovinces (Thurston and Breaks 1978). The general distribution of metamorphic zones within these two subprovinces and parts of the Cross Lake, Wabigoon and Berens River Subprovinces are outlined in Figure 14-1. Classification of metamorphic zones in this report is after Winkler (1979).

The major regional metamorphism, M_{1A}, formed porphyroblasts of almandine garnet, andalusite, biotite and staurolite. These porphyroblasts record an earlier M_1 planar fabric of quartz, biotite and feldspar inclusion trains which underwent rotation by the ensuing D_2 deformation. Metamorphic event M_2 resulted in matrix coarsening of the matrix, especially in metasedimentary rocks and growth of biotite and muscovite coplanar with D_2 fold axial surfaces. Metamorphic event M_3 was mainly retrograde as reflected in widespread pinitization of cordierite, sericitization of andalusite and local chloritization of biotite, garnet and amphiboles. The M_4 metamorphic event is essentially associated with major fault movement along the Uchi-English River Subprovince boundary and various major strike slip faults in the Uchi Subprovince (Thurston 1978). Metamorphic features

include recrystallization of chlorite and muscovite and formation of hematite, carbonate, epidote and minor pyrite. Relatively late recrystallization along late transcurrent faults such as the Bear Lake Fault in the Confederation Lake Belt of Uchi Subprovince may reflect a fifth metamorphic event (Thurston 1978).

METAMORPHISM OF THE NORTHERN SUPRACRUSTAL DOMAIN

The transition from Uchi Subprovince metavolcanic-metasedimentary belt into the Northern Supracrustal Domain is marked by a rapid southward increase in regional metamorphic grade (McRitchie and Weber, 1971; Jones 1973, Dwibedi 1966 and this study). This study substantiates that this pattern of increasing regional metamorphic grade is a widespread phenomenon involving at least 470 km of the subprovince boundary in Ontario. The progressive regional metamorphic patterns are commonly seriously interrupted by extensive post-regional metamorphic fault systems apparently guided by the stratigraphic interface between the two subprovinces. The Sydney Lake Fault records an abrupt "jump" from medium-grade low pressure assemblages to zones of widespread migmatization of clastic metasedimentary rocks. At Pakwash Lake this is exemplified by juxtaposition of sillimanite-muscovite bearing metapelite and metatexitic metasedimentary migmatite.

The Bee Lake metavolcanic-metasedimentay belt along this fault zone separates andalusite-bearing metapelites from migmatized equivalents. At Pashkokogan Lake, approximately 320 km east of Sydney Lake, the Miniss River - Pashkogan Lake Fault system marks an even greater sudden metamorphic grade separating low grade mafic

metavolcanic assemblages from metatexitic metasedimentary migmatites.

Relatively intact regional metamorphic zones are, however, only apparent in certain localities such as at western Lake St. Joseph (Figure 14-2). Five metamorphic zones have been delineated in the Lake St. Joseph area mainly based upon assemblages recorded in pelitic and wacke compositions:

LOW GRADE

Chlorite-Biotite Zone

MEDIUM GRADE

Staurolite-Chlorite-Biotite Zone

Sillimanite-Muscovite Zone

HIGH GRADE

Sillimanite-Potassic Feldspar Zone

Cordierite-Almandine-Potassic Feldspar Zone

A plausible reaction for the formation of M_{1A} staurolite may be similar to that experimentally determined by Hoschek (1969): Chlorite + Muscovite -> Staurolite + Biotite + Quartz + Vapour. Chlorite and muscovite are widespread in pelitic rocks of the chlorite-biotite zone of low grade metamorphism which immediately adjoins the staurolite zone to the north. Chlorite, biotite and muscovite also represent integral phases in the S_2 foliation of the staurolite zone.

Prior to the elimination of M_{1A} staurolites with increasing grade, cordierite makes its

initial appearance as porphyroblasts aligned within S_2 foliation surfaces and coexisting with sillimanite, muscovite, garnaet and biotite. The experimentally determined reaction (Hirschberg and Winkler 1968): Chlorite + Muscovite + Quartz -> Cordierite + Biotite + Sillimanite + Vapour appears to be applicable. Relicts of staurolite occur in the centres of some cordierites, however, the nature of possible involvement of staurolite in cordierite paragenesis is unclear. It is also uncertain whether M_{1A} staurolites developed under P-T conditions within the sillimanite or andalusite field. These staurolites have not been noted to coexist with any of the aluminosilicate species. Further east in the Soules Bay area (Lake St. Joseph) coexisting staurolite and andalusite porphyroblasts have been encountered (Sage and Breaks 1982). It seems plausible that the path of metamorphism breached the andalusite-sillimanite boundary within the staurolite zone prior to the first appearance of cordierite. It should be mentioned that a zone of cataclastic deformation crosses the staurolite zone (Lake St. Joseph Fault Zone). This zone of brittle deformation post dates regional metamorphism and the youngest Archean granitoid rocks in the area (leucocratic quartz monzonite), although no significant change in metamorphic grade is apparent across the fault. The main effect of this fault likely caused H_20 ingress into wall rocks causing retrogression of M_2 metamorphic assemblages, as exemplified by the complete replacement of staurolite by chlorite and muscovite. Obliteration of primary structures and a large portion of pelitic rocks occurred in the high grade zone related to anatexis and pervasive matrix coarsening.

Mineral assemblages corresponding to each of the zones as listed in Table 14-2, appears explicable by experimentally and/or petrographically validated metamorphic

reactions from the literature. The observed increase in grade also corroborates with a transition from non-migmatized metasedimentary assemblages in the medium grade zones to an orderly succession of migmatitic stages prevailing at high grade. Within the medium grade zones P-T conditions were inadequate to foster partial melting of compositionally appropriate rock types. Thus, sedimentary bedding structures and framework grains in wackes generally exhibit some degree of preservation. Layers, boudins and rootless intrafolial folds of quartz veins are, however, evident in the transitional area between the staurolite-chlorite-biotite and sillimanite-muscovite zones. The transition from medium to high grade metamorphism corresponds to the disappearance of M_2 muscovite and entry into P-T conditions conducive to widespread in situ anatectic melts (metatexis). The metatexitic stage of migmatization generally corresponds to the sillimanite-K-feldspar zone. Stromatic leucosomes of granitic and pegmatitic rock are predominant. Dykes and discordant masses of tourmaline-muscovite leucosome derived from this zone at depth invaded the lower grade sillimanite-muscovite zone to the north. Sizeable masses of this allocthonous material can exist as are shown in Figure 14-2.

Near the cordierite-almandine-potassic-feldspar isograd, the metatexite zone yields to higher grade conditions promoting an advanced stage of fusion (diatexis). The reaction, Biotite + Sillimanite + Quartz + Vapour -> Cordierite + Almandine + Melt (Grant 1973) therefore may be important. On the higher grade size of the isograd, metastable sillimanite is widely observed in the cores of cordierite. Further south the assemblage biotite-K-feldspar-cordierite-almandine is widespread in surviving metapelitic horizons.

The proportion of metapelitic paleosome decreases rapidly southwards from the second sillimanite isograd.

METAMORPHISM OF THE SOUTHERN PLUTONIC DOMAIN

The variation of regional metamorphic grade within the Southern Plutonic Domain of the English River Subprovince is considerably more enigmatic, mainly related to two factors:

(1) scarcity of bulk compositions necessary to record useful metamorphic assemblages.

(2) widespread late Archean invasion by post metamorphic potassic granitoid suite rocks which has effectively reduced the areal extent of pre-Kenoran metamorphosed foliated and gneissic granitoid rocks.

Amphibolite enclaves are widespread as exemplified by those within the Deception Bay Gneiss Belt (Breaks and Bond 1977). However, these bulk compositions are notoriously insensitive to changes in metamorphic conditions under medium to high grade regional metamorphism. Thus, only ubiquitous biotite-hornblende-plagioclase-quartz-Fe-oxide assemblages commonly occur in these rocks. It does appear that P_{total} was insufficient to stabilize garnet-producing reactions in most of these mafic compositions, in contrast to the omnipresence of this mineral in the Northern Supracrustal Domain.

Load pressures of at least 4 kbs at 500°C are generally required to initially stabilize almandine garnet, depending upon amount of the spessartine component, in common rock types according to Winkler (1979).

Temperatures and vapour pressures appear substantial enough to have caused local anatexis of some amphibolite gneiss units, as in the Deception Bay area. Pods and small masses of white, holo-leucocratic and leucocratic quartz-poor trondhjemite and biotite-hornblende diorite exhibit a close, carapace-type relationship with incompletely degraded amphibolite paleosome. This leucosome megascopically resembles the widespread leucosome prevalent in metasedimentary migmatite of the Northern Supracrustal Domain.

Nature of regional metamorphism at the Wabigoon-English River subprovincial boundary, however, can be better evaluated in the Eagle Lake - Dryden area due to presence of well preserved clastic metasedimentary rocks in the English River Subprovince. As delineated by Bartlett (1978) and Breaks (1989) major isograds tend to parallel the subprovince boundary and several of the delineated zones are very similar to those at Lake St. Joseph (Tables 14-2 and 14-2). Metamorphic conditions in the Eagle Lake area were deduced by Bartlett (1978) between 600-750°C and 3-4 kilobars pressure. Thus, a bilateral metamorphic symmetry is apparent along an oblique cross-section of the English River Subprovince between the Dryden area and Lake St. Joseph which achieves maximum conditions of low pressure granulite grade approximately midway. Whether this bilateral metamorphic pattern prevailed on a regional basis cannot be confidently evaluated due to factors reasons presented at the beginning of "Metamorphism in Southern Plutonic Domain".

LOW PRESSURE GRANULITE FACIES METAMORPHISM

Several large areas of the English River Subprovince in Ontario have been affected by granulite facies regional metamorphism. At least three principal areas, intermittently spaced along a strike length of 315 km, have been delineated as indicated in Figure 14-1 as follows:

1) Umfreville Lake-Conifer Lake Zone,
2) Cliff Lake-Clay Lake Zone (Westerman 1978), and,
3) Eastern Lac Seul Zone (Urquhart 1976; Breaks and Bond 1977).

It is revealed by field evidence that the granulite facies zones overprint developed during the Kenoran tectonic-metamorphic episode. The individual zones vary in scale from singular occurrences to rather extensive, ovoid areas, the latter exemplified by the 30 by 85 km Eastern Lac Seul Zone. The various zones are either superimposed upon the interdomain boundary or entirely isolated within the northern or southern domains. In the central Manigotagan gneissic belt of adjacent Manitoba, Trueman et al. (1975) have documented a further orthopyroxene zone of unspecified dimensions.

Several field and mineralogical features of the English River Subprovince granulites indicate that these assemblages originated under P-T conditions of the low pressure subdivision of Green and Ringwood (1967):

1) domination by felsic rocks; low quantities of intermediate and mafic compositions,
2) presence of cordierite, biotite, and almandine garnet.
3) orthopyroxene is mainly confined to mafic and intermediate rocks and is rarely found in felsic compositions.
4) no evidence of tectonic uplift of the granulite zone, but instead marked by a

metamorphic transition from high grade into low pressure granulite conditions.

5) no associated anorthositic suite members or rocks of charnockitic affinities.

The coexistence of cordierite and orthopyroxene is evident, albeit rare, in certain metasedimentary layers. The assemblage cordierite-almandine-quartz-plagioclase-K-feldspar is more common Orthopyroxene and/or diopside are much more widespread in rocks of mafic and intermediate bulk composition. It is clearlya noted from field evidence that reactions leading to elimination of hornblende constituted an important prograde reaction in amphibolite horizons of the Eastern Lac Seul area and may have originated by the following reaction:

Hornblende + Quartz --> Orthopyroxene + Diopside + Plagioclase + Iron-oxide (magnetite) + Melt

Furthermore, the development of diopside and/or orthopyroxene-bearing, medium- to coarse-grained, leucocratic granitoid units of plausible partial melt origins in amphibolite and intermediate granitic units attests to physical conditions in which P_{total} approximates P_{vapour} under these conditions. Binns (1969) has experimentally documented that appearance of a melt phase in quartz in quartz-bearing amphibolite and hornblende-pyroxene gneiss can occur at minimum temperatures of 770°C and pressures exceeding about 2.5 kilobars.

Hornblende decomposition, however, cannot be considered a widespread process in the ubiquitous wacke and pelitic bulk systems, as this mineral is extremely uncommon in lower grade equivalents due to relatively low calcium contents (typically <3.5 % CaO). The appearance of orthopyroxene in some wackes may be explicable in terms of the

semi-quantitative univariant reaction (Grant 1973, p.508): Biotite + Garnet --> Orthopyroxene + Cordierite + Potassic Feldspar + Melt.

The zone of granulite metamorphism in the Eastern Lac Seul area, situated about 30 km south of the Lake St. Joseph facies series (Figure 14-1) may actually represent a spatial continuation of the interpreted path of metamorphism as outlined in Figure 14-3, and as such, is reminiscent of the thermal anticline model proposed by Richardson (1970). Progressive removal of fluid phase components via anatectic melts engendered by the intersection of the path of metamorphism with melt-producing divariant reactions under high grade conditions may ultimately yield relatively anhydrous bulk compositions capable of yielding granulite assemblages.

METAMORPHIC CONDITIONS

The delineation of the path of progressive regional metamorphism southwards from across the Uchi Subprovince-English River subprovincial boundary (Figure 14-3) may be estimated in conjunction with the aforementioned isograds as well as the following important observations:

1) high pressure phases such as kyanite or high temperature-high pressure phases such as sapphirine are unknown in the English River Subprovince.
2) cordierite is a widespread phase in the northern supracrustal domain especially in high grade metamorphism zones.
3) decomposition of staurolite does not coincide with the sudden appearance of the stromatic migmatites. The stability of staurolite, in other words, does not

extend into regions where M_2 muscovite (sillimanite-K-feldspar zone) is absent (P_{total} < 4.5 kilobars; Winkler 1979).

4) the disappearance of M_2 muscovite in the presence of quartz generally coincides with pervasive metatexitic migmatization of pelitic-wacke assemblages (P_{total}> 3 kilobars).

5) appearance of leucosome-dominant migmatite stages resulting from advanced stage fusion (diatexis) approximately coincides with the cordierite-almandine-potassic feldspar zone.

6) garnet becomes widespread only in the high grade zones suggesting increasing pressure for the facies series represented in the Lake St. Joseph area.

7) localized partial melting of amphibolite bulk compositions under low pressure granulite conditions indicates P_{total} approximates P_{vapour} and P_{total} then >2.5 kilobars, T >770°C.

Assuming $P_{total} = P_{vapour}$, estimates of P-T conditions are as follows:

Medium Grade = 550-650°C, 3-4.5 kilobars

High Grade = 650-790°C, 3-7.5 kilobars

Granulite = >770°C, >2.5 kilobars

These conditions are indicative of an average geothermal gradient between 35°C/km and 50°C/km, possessing mineralogical characteristics of the low pressure-intermediate series of Miyashiro (1961, p.283 and 303).

CHAPTER 15

STRUCTURAL GEOLOGY

INTRODUCTION

Detailed structural studies of the English River Subprovince in Ontario have been undertaken in only two areas of the southern plutonic domain. Westerman (1977) studied the Cedar Lake-Clay Lake area, unique for the dome and basin structures, and Gower (1978) examined the Melick area near Kenora which contains part of the southern subprovince boundary. A less detailed structural analysis was only possible in the remainder of the English River Subprovince, mainly related to the large scale of mapping. Structural data from the above studies are also augmented by an earlier study in the Manigotagan Gneissic Belt of Manitoba by McRitchie and Weber (1971).

NORTHERN SUPRACRUSTAL DOMAIN

Definitive work by McRitchie and Weber (1971) unravelled a complex and protracted tectono-metamorphic history (Table 15-1) for a paragneiss-pluton-rich area in the Clearwater-Flintstone Lakes region of the Manigotagan gneissic belt. The paragneiss sequence which represents a continuation of the northern supracrustal domain, was subjected to four periods of folding, and two periods of fracturing and cataclasis, with intensity of deformation diminishing with time (McRitchie and Weber 1971, p.238). A similar progression of structures has been partly recognized in metasedimentary migmatite by this study and Westerman (1978) in the Wabaskang and Twilight Lakes

area. D_1, the earliest recognizable deformation in the Manigotagan gneissic belt, produced macroscopic isoclinal folds with vertical axial surfaces parallel to the belt margins and low plunge values to the WNW or ESE (McRitchie and Weber 1971, p.239-243). These workers remarked that major folds of this generation rarely have preserved closures, and, as such, the resulting planar fabric (S_1) is only rarely recognized since axial planar foliation is parallel to the gneissosity of enveloping paragneisses and migmatites.

The major folds are best delineated on basis of bedding reversals and hence would be poorly defined in high grade areas. In low and medium-grade metasedimentary rocks such as in the Eagle River-Dryden area, one major isoclinal fold with an axial surface coplanar with sedimentary bedding was defined by graded bedding reversals (Breaks in press) and probably relates to the D_1 event. In the high grade zones of the northern supracrustal domain, macroscopic tight to isoclinal folds as at Miniss Lake, south of Longlegged Lake may also have developed during D_1 event. Minor folds of the D_1 episode are also not common (McRitchie and Weber 1971, p.239; this study and Westerman 1978). These may involve intense buckling of initially discordant (to layering) leucosome veins (Photo 15-1). Boudins of thin, amphibolite and metasedimentary migmatite leucosomes concordant to compositional banding in metasedimentary migmatites was interpreted by Westerman (1978, p.204) as D_1 (= Fa_1 fold group of Westerman, Table 15-2).

A well developed planar fabric is commonly observed in concordant to bedding (S_0) low- to medium-grade metasedimentary rocks as in the Dryden-Eagle River area. This

structure, which is readily recognized by parallelism of phyllosilicate minerals to bedding, probably developed during the D_1 event. Blackburnet al. (1982) have also recognized tight isoclinal folding about subhorizontal axes in this area which also quite plausibly were generated during D_1.

Concomitant with the D_1 deformation is a major metamorphic event (M_1) which was mainly responsible for regional, low pressure metamorphic patterns coinciding with the transition from Uchi to English River Subprovince (McRitchie and Weber, 1971, p.240-243). Where the metamorphic zones are completely uninterrupted, a southwesterly increase from low grade at the subprovince boundary through medium and high grade zones into the Manigotagan gneissic belt, is observed. The diagnostic low pressure metamorphic assemblages documented by McRitchie and Weber (1971, p.242) and by Thurston and Breaks (1978, p.54) in Table 15-1 were recognized on the basis of chlorite, biotite, hornblende, garney, andalusite, sillimanite and cordierite porphyroblasts containing a preserved internal planar fabric.

D_2 deformation in the Manigotan Gneissic Belt and northern supracrustal domain is characterized by regional, intensely asymmetrical, intrafolial, tight to close S- and Z-folding (Photo 15-2) with moderate E to SE plunges and steep axial surfaces (McRitchie and Weber 1971, p.244). Development of an epitaxial muscovite-biotite axial planar fabric in D_2 folds is another important structure documented by these workers. This fabric has controlled emplacement of some mobile pegmatitic leucosome in the Manigotagan Gneissic Belt (McRitchie and Weber 1971, p.245, 276) and in the map area (Photo 15-3). McRitchie and Weber (1971, p.244) also consider boudinage as D_2 based upon

concordancy of the boudinage axis with D_2 fold axes.

As pointed out by McRitchie and Weber (1971, p.244) the axial planar foliation of D_2 and D_1 layering are typically indistinguishable unless distributed at discordant angles (10-25 degrees). In the Eagle River area a secondary foliation containing apparently rotated M_1 andalusite porphyroblasts lies at a low angle to regional foliation strike which in the case is parallel to bedding (Photo 15-4). Such a discordant foliation could represent a D_2 axial planar fabric although no minor fold evidence was available for verification.

Severe transposition of leucosome layers along S_2 during asymmetrical folding of metasedimentary migmatites can produce "pseudoconglomerates", characterized by complete isolation of more competent, ovoid-leucosomes embedded in a less competent metasedimentary host (McRitchie and Weber 1971, p.245).

An approach to this condition is seen in Photo 15-5 of high grade metasedimentary rocks in the Dryden area. The two lowermost ovoid leucosomes exhibit almost complete detachment. McRitchie and Weber (1971, p.245) state that this process may cause regional scale segmentation of pegmatitic layers resulting in round to ovoid plutonic-appearing stocks.

Matrix-coarsening of M_1 assemblages and reorientation of M_1 porphyroblasts were the main effects of metamorphism associated with the D_2 deformation which McRitchie and Weber (1971, p.246-247) interpret to represent a continuation of P-T conditions established during M_1. Evidence for the M_2 metamorphism is idioblastic staurolite and garnet which microscopically show no evidence of preserved S_1 internal foliation.

Replacement and flattening of faserkiesel by muscovite porphyroblasts and later overprinting by fibrolite is another observation made by McRitchie and Weber (1971, p.246, 280).

Extensive anatexis is considered by McRitchie and Weber (1971, p.246-247) to have occurred during the higher temperature M_2 metamorphic event (ibid p.261-262). These diatexite zones may contain paleosome enclaves exhibiting D_2 folds and a strong S_2 fabric (McRitchie and Weber ibid, p.245 and 280). Westerman (1978, p.205) considered the leucocratic diatexite zones to have emerged previous or synchronous with Fa_2 folding (= D_2).

The D_3 deformation event is attributed by McRitchie and Weber (1971, p.247) to waning of D_2. This is reflected by its variability in fold style. This event tends to produce asymmetric, broad open, concentric S-folds which plunge steeply NW with incipient development of strain-slip cleavage in highly schistose units (McRitchie and Weber ibid). Locally the folds may be disharmonic, intrafolial, and similar.

These folds have also been sporadically observed in the map area and correlate with Fa_3 folds of Westerman (1978, p.205) who described concentric close to open folds with upright, NW-SE axial planes with steeply plunging fold axes and 60°-110° interlimb angles, apparently associated with or predating intrusion of granite and granodiorite plutons. Folds of D_3 generation occur elsewhere as in the Pakwash Lake area. In Photo 15-6 metatexitic metasedimentary migmatite with arteritic leucosomes have been exposed to two deformation events. Early boudinage (D_1?) was followed by D_3 open, disharmonic folding which has resulted in partial rotation of some boudins (especially that immediately

below the coin).

Metamorphism associated with D_3 deformation is marked by overprinting of S_2 foliation by muscovite porphyroblasts aligned with basal cleavages parallel to axial surfaces of D_3 folds and annealing of the strain slip cleavage (McRitchie and Weber 1971, p.248). Retrograde metamorphism was also variably imposed upon cordierite, andalusite, tourmaline, garnet and biotite during this time (McRitchie and Weber ibid).

The D_4 deformation event represents the first recognizable period of cataclasis and is marked by broad, highly schistose, curvilinear shear zones (up to 915 m width) which are apparently controlled by S_3 strain slip cleavage (McRitchie and Weber ibid, p.248-249). Development of major faults such as the Moose River Fault (at least 120 kilometres length in Manitoba) mark the first stage in development of structural boundaries between the high grade Manigotagan gneissic belt and lower grade metavolcanic-metasedimentary sequences of the Uchi Subprovince (Rice Lake and Bee Lake Belts). These workers (ibid p.250) noted that relative movement in D_4 shear zones were commonly small compared to later D_6 fault lateral displacement. Associated metamorphism (M_4) mostly consists of retrograde chlorite and muscovite confined to the sheared zones (McRitchie and Weber 1971, p.249).

Deformation D_5 in the Manigotagan gneissic belt is represented by regional Z-warping (with associated Z- and S-kinks) which deflect the early D_4 mylonite zones and conjugate N and NE sheared and brecciated zones (McRitchie and Weber 1971, p.249). Metamorphic event M_5 is represented by retrogressive quartz, carbonate and chlorite D_5

fracture zones or parallel to D_5 axial planes (McRitchie and Weber 1971, p.239, 249).

D_6, the last period of cataclasis was marked by significant dextral movements. These structures are preferentially guided by S_0-S_1 layering, D_1 axial traces, S_2 schistosity and D_4 shear zones according to McRitchie and Weber (1971, p.250). A fault along the Manigotagan River has recorded an apparent detral movement of approximately 26 km (McRitchie and Weber ibid). The D_6 event also probably correlates with major movement along the Sydney Lake Fault which can be continuously traced for about 210 km from Black Lake, Manitoba to east of Pakwash Lake. This fault system has been studied by Stone (1981) and will be described below in this detail.

SOUTHERN PLUTONIC DOMAIN

The structural relationships in two separated parts of the southern domain will now be described.

CEDAR LAKE-CLAY LAKE AREA

This area, studied by Westerman (1977), is a particularly significant in that lithologic units characteristic of northern supracrustal domain metasedimentary migmatites are structurally interleaved with highly deformed gneissic granitoid rocks forming "paragneiss domes and basins" (Figure 15-1). Westerman (1977, p.230-238) defined three tectonic assemblages based upon detailed geological, geochemical, metamorphic and structural analysis of this area:

1) Tectonic Assemblage I - highly deformed gneissic granitoids basement sequence)

2) Tectonic Assemblage II -metasedimentary migmatite (cover sequence)

3) Tectonic Assemblage III-plutonic granitoid rocks (quartz diorite to granite)

His work indicated a more protracted tectono-metamorphic history for the southern plutonic domain relative to the northern supracrustal domain which has scant geochronological support.

The characteristics of folds involved in structural evolution of these three tectonic assemblages are summarized in Table 15-2 and correlated wherever possible with accompanying metamorphism. The fold groups of Westerman (1977) in Table 15-2 are arranged in order of decreasing severity and in apparent order of decreasing relative age.

Tectonic Assemblage I

Tectonic assemblage I is equivalent to the gneissic granitoid suite defined on a reconnaissance basis by this study, and quite possibly contains the oldest rocks in the English River Subprovince. The severely deformed Cedar Lake gneisses, the only rocks containing Fb_1 and Fb_2 folds are lithologically and structurally similar to gneissic granitoid rocks in the Deception Bay gneissic belt (Breaks et al. 1981), in the central part of Lac Seul and in the Kenora area (Gower 1978). It is possible that the Deception Bay gneisses are the oldest units in the subprovince as these rocks are host to a circa 3 Ga sodic granitoid plutonic complex (Sen Bay stock) which is considerably less deformed. Early structures similar to Fb_1 and Fb_2 fold groups defined by Westerman (1977) in the Cedar Lake gneisses also are developed in gneisses and significantly in possible mafic metavolcanic supracrustal remnants of the Deception Bay area (Photos 13-7, 15-8 and

15-9).

Westerman (1977, p.231) interpreted the Cedar Lake gneisses as derived from the early granitoid plutons. Amphibolite encalves within these gneisses have not convincingly been proven as definitely supracrustal and could very well represent mafic dyke swarms emplaced prior to the Fb_2 fold event which caused severe segmentation of these relatively competent units (Westerman 1977, p.68).

The Clay Lake granitoid suite of Westerman (1977, p.46-48 and 231) is also included in Tectonic Assemblage I. These rocks consist of strongly foliated to locally gneissic biotite tonalite and granodiorite equivalent to the sodic granitoid suite of this report. Westerman (1977, p.85-88) concluded that the Clay Lake suite was intruded into the Cedar Lake gneisses after development of Fb_2 folds and prior to deposition to the clastic sedimentary precursors to the Twilight Gneiss.

Fb_1 and Fb_2 folds possibly had recumbent or gently inclined axial surfaces with subhorizontal axes trending WNW-ESE preceeding development of the Cedar Lake Dome (Westerman, 1977, p.70). This implies a period of horizontal tectonic deformation prior to D_3, the event responsible for interleaving of basement and cover rock units and subsequent development of major domal structures. No major Fb_1 or Fb_2 structures were observed byWesterman (1977, p.71) which could provide more information on the macroscopic implications of this early event of horizontal tectonics.

Tectonic Assemblage II

Tectonic assemblage II comprises the Twilight gneiss, relatively rare mafic to intermediate metavolcanic rocks and meta-orthoconglomerate. The Twilight gneiss is

equivalent to metatexitic metasedimentary migmatites of the northern supracrustal domain and is situated 17 km northeast in the Perrault-Wabaskang Lakes area. In the Cedar Lake area, Twilight gneiss is only found in the core zones of the Mystery Lake and Twilight Lake Domes (Figure 15-1 and 15-2). There is an absence of Fb_1 and Fb_2 folds in the well developed compositional banding in the Twilight gneiss, thus making the earliest recognized fold generation (Fa_1 in Table 15-1) in the northern supracrustal domain coeval with D_3 of the Cedar-Clay Lakes area (Westerman 1977, p.86). Contemporaneous with Fb_3 structures which deformed the Twilight is a high grade to granulite regional metamorphic event. This metamorphic event (M_3) is associated with penetrative linear and planar fabric developed during D_3 and hence such metamorphic conditions accompanied the horizontal tectonic event (Westerman 1977, p.88).

The age of Tectonic Assemblage II must lie between 2.68 and 2.952 Ga, the respective ages of migmatization (Krogh et al. 1976) and Cycle I volcanism in the Confederation Lake area (Nunes and Thurston 1980), i.e., contemporaneous with clastic metasedimentary rocks of the northern supracrustal domain.

Tectonic Assemblage III

The structural history of this tectonic assemblage characterized by major domes commenced with a relatively early event (D_3) responsible for interleaving of basement (Cedar Lake gneisses) and cover Twilight metasedimentary gneisses) via thrusting or recumbent nappes accompanied by high grade to granulite regional metamorphism (Westerman 1977, p. 129, 234-235). An ensuing deformation (D_4) resulted in macroscopic doming of the D_3 structurally interleaved units and is due to diapiric emplacement of

potassic granitoid suite plutonic rocks, i.e., Cliff Lake porphyritic granodiorite (Westerman 1977). The Cliff Lake granodiorite is the extreme eastern end of the large Lount Lake batholith described in this report. Emplacement of these rocks occurred at about 2635 +/- 56 Ma (Beakhouse and McNutt 1981). Critical evidence for attributing the early development of Tectonic Assemblage III to horizontal tectonics was documented by Westerman (1977, p.83-89) at the Mystery Lake Dome (Figure 15-2). Here the Twilight gneiss and Clay Lake granitoid suite not only structurally underlie the Cedar Lake gneisses contained within the Transitional Sequence, but show a complete absence of Fb_1 and Fb_2 fold groups which typify the Cedar Lake gneisses.

KENORA AREA

This 470 km^2 area of the English River Subprovince situated at the English River-Wabigoon subprovincial boundary immediately north of Kenora, was studied in detail by Gower (1978) and recently proposed as a type area for the Kenoran Orogeny (Gower and Clifford 1981). Gower (1978) unravelled a complex plutonic-deformational-metamorphic sequence of events marked by seven deformation episodes subdivided into three events of penetrative folding and four periods of faulting and shearing (Table 15-3). Geochronological control was provided in Gower's study by Rb/Sr dating of various intrusive events interspersed between three periods of folding after initial movement in the Kenora and Rabbit Lake Faults.

Remnants of a supracrustal sequence constitute the oldest rocks recognized by Gower (1978) and are mainly pillowed to massive mafic metavolcanic rocks with minor

ultramafic, felsic to intermediate metavolcanic and metasedimentary rocks including banded chert-magnetite iron formation.

The earliest deformation event (D_0) produced a foliation in these supracrustal remnants followed by injection of leucogranitoid veins both of which are truncated by plutonic precursors to the biotite tonalite gneisses (Gower and Clifford 1981, p.1078).

D_1 deformation ensued producing the major gneissosity trends and isoclinal to tight single layer folds which are typically intrafolial, rootless with axial surfaces coplanar with the enclosing gneissosity. These folds are best recognized in strongly flattened leucogranitoid veins in a homogeneous biotite tonalite host but may also occur within interbanded amphibolite-tonalite units. The 2760 Ma Marginal granodiorite was emplaced after D_1 along a linear zone which Gower and Clifford (1981, p.1078) interpreted to represent early existence of the Kenora Fault.

D_2 deformation led to formation of multiple layer folds in gneissosity with a gradation from tight-to-close into close-to-open types. Interfering relations between D_1 and D_2 deformation events as at Middle Lake established refolding of F_1 intrafolial folds refolded by a close-to-open F_2 fold (Gower and Clifford 1981, p.1080-1081).

Major F_2 synforms and antiforms produced during D_2 are adjacent to the east - southeast and of the Dalles granodiorite. Emplacement of the Melick tonalite succeeded D_1 but not D_2 suggested by common F_2 folds, and Gower (1988) interpreted a major F_2 antiform over the northern part of the Melick tonalite.

Following D_2 was an igneous plutonic episode marked by emplacement of the Lulu granodiorite, Lount Lake batholith (Austin granite) and mafic dykes. The calc-alkaline

mafic dykes are important in that they allowed Gower and Clifford (1981, p.1083) to separate D_2 and D_3 events.

Contemporaneous with the D_1 and D_2 events was a major high grade regional metamorphism (M_1) with P-T conditions estimated by Gower (1978) at 650-750°C and 4-7 kbars.

The D_3 event is most conspicuously related to diapiric emplacement of the Dalles granodiorite (2630 Ma) and is associated with a low grade retrograde metamorphic event (M_2) (Gower and Clifford 1981, p.1089).

This pluton produced a F_3 major synform in host-rocks immediately adjacent to its east-southeast rim which not only refolded major F_2 folds in this region but also caused plunge reversals in F_2 major-minor folds and the F_3 rim synform due to uplift of the gneissic host-rocks (Gower and Clifford, 1981,
p.1086).

Major dextral displacement on the Rabbit Lake Fault probably occurred during two periods in the D_3 deformation episode (Gower and Clifford 1981, p.1087):

1) an apparent 2.5 km displacement prior to emplacement of Dalles granodiorite, and

2) a succeeding 3.3 km movement in response to uplift of gneissic host-rocks by this pluton.

The en-echelon Kenora Fault which forms the subprovince boundary in this region was also a zone of repeated movement which Gower and Clifford (ibid) also relate to in part to Dalles granodiorite-induced uplift.

The D_4 deformation event produced open, NE-trending upright folds, and buckling of some pegmatites, in addition to final movement on the Kenora and Rabbit Lake Faults (Gower and Clifford 1981, p.1088).

Deformation events D_5 and D_6 include pre- and post-diabase dike fault minor faulting and jointing.

LATE ARCHEAN FAULTING

Several important Late Archean fault systems overprint various areas of the English River Subprovince (Figure 15-3). The fault zones were first noted by Parkinson (1962). These deformation systems are the final significant structural event in the Archean and apparently represent late displacement of large rigid crustal blocks (Stone 1982).

Differential displacement between such blocks appears to have been dissipated by mylonitic flow concentrated in finite linear deformation zones. In general, the fault systems, which tend to follow regional structural trends, are superimposed and thus apparently controlled by major geological boundaries.

The time interval involved in the faulting episode is unknown but may be considerable. Gower and Clifford (1981, p.1087) interpreted that the Kenora Fault existed prior to the 2735 +/- 65 Ma Marginal granodiorite and represented a "zone of repeated andintense movement" which terminated prior to injection of rectiplanar, undeformed granitic pegmatites.

In other areas, these fault systems represent the only tectonic deformation which overprints the youngest members of the potassic granitoid suite which may imply a maximum age of 2.65 Ga (Krogh et al. 1976) at least for the Sydney Lake Fault.

SYDNEY LAKE FAULT

One of the most important of these late Archean deformation systems is the arcuate Sydney Lake Fault. The most intensely developed part of this fault system in Ontario is continuously traceable between Sydney Lake and the Ontario-Manitoba border (185 km). McRitchie and Weber (1971, Map 69-4) delineated a further 36 km in Manitoba (between Octopus Lake and north of Black Lake) and further continuation along the Black River to Winnipeg Lake is possible.

East of Pakwash and Wenasaga Lakes the fault system is only intermittantly traceable due to very poor exposure and may ultimately extend northeast into the Confederation - Uchi Lakes Metavolcanic-Metasedimentary Belt as the Uchi Lake Fault of Thurston (1976, 1978). An ultimate length of 450 km is thus postulated for the Sydney Lake Fault.

Between Pakwash Lake and the interprovincial boundary the fault represents, in certain areas, an abrupt lithologic discontinuity between low to medium grade metavolcanic-metasedimentary assemblages of the Uchi Subprovince (Bee Lake and Dixie Lake Belts) and high grade metasedimentary migmatites and metaplutonic rocks of the English River Subprovince. In the area between the Bee Lake and Dixie Lake, there is no significant contrast in metamorphic grade across the fault zone. However, there is a sharp lithologic change from felsic to intermediate granitoid rocks in the Uchi Subprovince to metasedimentary migmatite of the Northern Supracrustal Domain.

Structural and Lithologic Features

This following text of the Sydney Lake Fault System is summarized from Stone (1981). The fault is a 1 to 2 km wide zone of protomylonitic and mylonitic equivalents of metatexite and diatexite metasedimentary migmatites (Plates 15-10 and 15-11) felsic to

intermediate metaplutonic and metavolcanic rock types.

Important units such as the Pineneedle Lake pluton and Bee Lake metavolcanic belt can be traced into the fault zone, and the offset of these indicates right-handed strike separation. Asymmetrical Z-type drag folds within the fault zone support this sense of movement. Based upon observed slickenside attitudes (Figure 15-4) the direction of the last observable displacement on the fault is approximately horizontal. Consequently, strike separation on the fault may be equivalent to the net slip.

A large number of smaller shear zones characterize the fault zone, varying from microfractures to structures 20 cm wide exhibiting horizontal offsets in excess of 30 m. These shear zones are arranged in a braided pattern, in which later shears transect and displace earlier systems. The displacement direction on all these features is statistically horizontal based on tracing map units. Consequently, the fault was a locus for horizontal movements for a protracted part of its history and not necessarily involving merely the last increment of time.

Development of mylonites (Plate 15-10) is most prevalent along the contact between migmatized metasedimentary rocks of the English River Subprovince and metavolcanic or granitoid rocks of the Uchi Subprovince. The widest extent of cataclasis is developed in metasedimentary migmatites along the southern edge of the fault. A bulge-like structure is evident in the Pineneedle Lake area due to a local bifurcation which rejoins, thus enclosing a lensoid area of largely undeformed diatexitic metasedimentary migmatite.

In the Chase Lake area, several distinctive metavolcanic units as delineated by Stone (1981) and in Figure 15-5 can be traced into the fault zone. A unit of amphibolitic mafic

metavolcanic rock has been recognized with the fault 6 km west from the point of initial disruption of the unit (point A in Figure 15-5) which would represent a minimum value of dextral displacement of the faulting was due to simple shear.

Shearing and Flattening

Several features indicate that the main part of the fault zone has a high component of shearing relative to flattening. Rock units are highly attenuated parallel to the fault as are dikes, veins and mineral grains. Asymmetrical Z-type drag folds are common in the mylonite. Obliquity of cataclastic foliation and rigid feldspar crystals to the general strike of the fault zone suggests rotation. Deformation within the northeasterly-striking splays of the fault zone is markedly different. Folds within the mylonite are predominantly "M" type with no consistent asymmetry. rock unit contacts commonly observed strike at high angles to the mylonitic foliation. Mineral grains do not exhibit consistent rotation, but appear to have been flattened in situ.

Slickensides are poorly developed and cataclastic foliation is generally parallel to the fault trend. These characteristics are consistent with a high component of flattening relative to shearing. The northeasterly segments of the fault dominated by flattening and the dominantly sheared main part suggest a regional compression from the northwest.

An estimate of the amount of shearing was made by Stone (1977) from the reorientation of linear elements within the fault zone.

Origin of the Faulting

Displacement of all parts of the Sydney Lake Fault is right lateral. Elsewhere in the

Superior Province work by Bau (1975) and Mackasey et al. (1974) indicates a similar sense of displacement along the Quetico Fault. Similarly, right lateral displacement has been recently described for the Lake St. Joseph Fault Zone and the Miniss River Fault Zone (Breaks and Bond 1977). McRitchie and Weber (1971) documented right lateral movement on the Wanipigow-Wallace Lakes Fault (in Manitoba). It is possible that all of these deformation zones, which appear to have evolved quasi-contemporaneously, were caused by the same regional stress. Stone (1976, 1977) examined three possible models of fault formation applied to the Sydney Lake Fault and contended that the fault zone formed first in the central region under the influence of the regional stress. Subsequently the fault propagated, splayed, and curved under the influence of regional stress, the local secondary stresses, and the anisotropy of the rock.

OTHER FAULT SYSTEMS

The Miniss River Fault (Hudec 1965) comprises another important fault system within the English River ubprovince. In contrast to the Sydney Lake and Lake St. Joseph Fault Zones, this fault strikes northeasterly across the English River Subprovince, transecting the northern and southern domains. Pronounced convergence of the northern domain is apparent in the Miniss Lake-Pashkokogan Lake area, probably caused by the intersection of the Miniss River Fault with the Lake St. Joseph Fault. Slickensides ("a" lineations) on both systems indicate that the displacement has been dominantly horizontal strike slip. On the Miniss River Fault Zone, these structures plunge northeast at about 15°, identical to those on the Sydney Lake Fault Zone. The sense of displacement is right-handed based upon asymmetrical "Z" folds, clockwise rotation of pegmatite boudins,

feldspar megacrysts and by right-hand offset of mafic enclaves by late minor faults. The amount of strike slip displacement is estimated at 10 km, assuming that the biotite-hornblende trondhjemite to quartz diorite unit on the northwest side of the fault at Miniss Lake is correlative with a diorite unit on the southeast side.

The Miniss River Fault partly represents the boundary between the northern and southern domains. Rock types southeast of the fault zone are dominantly granitoid plutonic rocks and polycyclic granitoid gneiss. Restricted areas of metasedimentary migmatite from the northern domain extend easterly beyond the fault in the Miniss Lake and DeLesseps Lake area. The fault, however, marks an abrupt change between different stages in the migmatization of metasedimentary rocks. Metatexites exhibiting relatively low degrees of partial melting occur along the northwestern side of the fault zone. Accross the fault are advanced stage metasedimentary migmatites (homogeneous and inhomogeneous diatexites). It is estimated that the granitoid terrain along the southeastern side of the Miniss River Fault has been uplifted or tilted by at least 2.2 km. This value for the dip slip component of movement is computed utilizing the aforementioned strike slip value and average 'a' lineation plunge of 15 degrees. This estimation is, in part, supported by the sudden appearance of abundant diatexite and sporadic orthopyroxene-bearing tonalites which testifies to a higher metamorphic grade and possibly deeper crustal level compared to the southeastern side of the Miniss River Fault.

ORIGIN AND SIGNIFICANCE OF PSEUDOTACHYLITE

Pseudotachylite is apparent in all the major fault systems delineated in the English

River Subprovince. Characteristically the pseudotachylite occurs in the youngest shears within a given cataclastic zone and tends to develop more readily in relatively siliceous rocks such as metawacke, granitoid gneisses and homogeneous diatexite. On weathered surfaces the pseudotachylite varies from khaki to rusty brown. The striking, bifurcated mass of pseudotachylite shown in Photo 15-12, the largest single mass observed to date, occurs in metasedimentary migmatites at Sydney Lake. The disposition of the pseudotachylite is partially controlled by contact between medium-to coarse-grained, protomylonitic, tourmaline-muscovite quartz monzonite leucosome and fine-grained, phyllonitic metapelitic paleosome (paleosome occupies lower one-third of photo). In terms of the morphological classification of Francis and Sibson (1973), this example would comprise a combination of subconcordant pinch-swell lensing (in lower and upper branches) emanating from a central discordant bleb. Note the fragmentary material in the form of metapelitic paleosome and individual crystals and wispy asymmetrical internal "onion-skin" structure which may have been induced by viscous flowage or convective cooling. Development of pseudotachylite in fault systems of the English River Subprovince post-dates the mylonitic foliation as observed in the granitoid leucosome of this photo and marks a fundamental change from Sibson's (1977) Quasi-Plastic (QP) regime of homogeneous aseismic shear flow in host material to an Elastico-Frictional (EF) regime at higher crustal levels distinguished by brittle seismic deformation marked by widespread pseudotachylite generation.

The studies of Sibson (1977) and Grocott (1977) have stated that the generation of pseudotachylite is typically confined to upper levels of fault systems and is

accompanied by cataclasite exhibiting a general lack of ductile, homogeneously deformed gneiss. In the case of Sydney Lake Fault this suggests a later reactivation signifying a drastic change to more brittle, structural mileau, likely a consequence of erosion, uplift and decrease in ambient temperature.

CHAPTER 16

METALLOGENY OF THE ENGLISH RIVER SUBPROVINCE

INTRODUCTION

The various mineral occurrences and deposits of the English River Subprovince and adjacent parts of the Uchi and Wabigoon Subprovinces documented in Map **?** (back pocket) generally fall into two classes;

1) mineralization of lithophile affinity, and,

2) mineralization of chalcophile affinity.

The English River Subprovince is a sialic terrain in which the lithophile mineralization predominates over that of the chalcophile class.

Mineral exploration in the English River Subprovince has largely been desultory, in part possibly due to poor geological data base prior to the present survey. Mineral production to date has only occurred in the Werner Lake area (Cu, Ni, Platinum group elements) and at the Griffith iron mine near Ear Falls. In general, the lack of cyclical metavolcanic sequences implies little possibility of massive sulfide deposits. However, one should bear in mind the possibility of the sediment-hosted massive sulphide ore deposits in the subprovince boundary regions. All assessment work submitted to date has been summarized in Appendix I and located in Map **?** (back pocket). Average crustal abundance data used to compute various element ratios in the chemical diagrams and tables of this chapter are given in Table 16-1.

MINERALIZATION OF THE LITHOPHILE AFFINITY

Elements of this class have ionic radius, valence state and partition coefficients are compatible with the mineralogy of sialic rocks. Economic concentration of such metals as Be, Cs, Li, Ta, Rb, and Sn are hence almost exclusively associated with granitoid rocks of various types, particularly the granitic pegmatites. Thus, detailed knowledge regarding mode of occurrence, geochemistry and genesis of granitoid rocks which comprise significant portions of high grade gneissic belts such as the English River Subprovince will be critically important in the conception of future mineral exploration programs designed to search, in particular, for Ta-, Li- and Cs-bearing rare-element pegmatites. One of the world's premiere tantalum deposits and the largest concentration of pollucite yet discovered, the Bernic Lake Mine of Tantalum Mining Corporation Limited, is situated in the English River Subprovince of Manitoba, a short distance west of the project area. This area contains a high concentration of rare-element pegmatites of extremely varied metallogenic characteristics (Cerny et al. 1981). Similar pegmatitic deposits in the project area are scattered, although most occurrences are west of longitude 93°30'. Chemical similarities between the Bernic Lake pegmatite and one spodumene pegmatite in the map-area (see Tot Lake Li-Cs-Rb Occurrence, below) suggest a strong mineral potential for certain parts of the study area.

Restriction of rare-element granitoid pegmatites to the peripheral lower P-T metamorphic zones of gneissic belts is a well known metallogenic feature of the Superior Province of northwestern Ontario and adjacent Manitoba (Cerny and Trueman 1978). Lithophile mineralization is generally lacking in adjacent metavolcanic-rich subprovinces

such as the Uchi Subprovince. Rare-element granitic pegmatites typically exhibit a spatial restriction to the lower grade, margins of metavolcanic-rich belts which contact the high grade gneissic subprovinces. This is exemplified by the English River - Wabigoon subprovincial boundary in the Dryden-Vermilion Bay area and the Uchi -English River subprovincial boundary in the Root Lake - Pashkokogan Lake region.

BERYLLIUM

Rare-element pegmatites containing beryllium as an important metal are scarce in the English River Subprovince of Ontario (Map ?, back pocket) in contrast to the westward extension of the subprovince in Manitoba (Cerny and Turnock, 1971, 1975). Beryl-type pegmatites occur in the Medicine Lake area of Tustin Township (Pryslak, 1976), north of Ear Falls near Sandy Creek and in the Separation Lake area. The Medicine Lake occurrence has been described by Pryslak (1976, p.40-41) and will not be discussed further. Beryl-bearing granitic dykes were noted by Wright (1932) to have intruded metavolcanic and metasedimentary rocks in the Separation Lake-Oneman Lake area. These occurrences could not be located by the present survey and were possibly innundated by the damming of Umfreville Lake by Ontario Hydro subsequent to Wright's work. Accessory beryl occurs in the spodumene pegmatites near Mavis and Tot Lakes and will be discussed below in the section under "Lithium".

Sandy Creek Beryl Occurrence

This beryl occurrence is approximately 10 km north of Ear Falls and a short distance

by trail east of Highway 105 (Figure 16-1).

Exploration History

The property was investigated by Madsen Red Lake Gold Mines Limited which staked a group of 41 claims in 1962 over the showing and undertook some shallow trenching (Resident Geologist's Files, Ontario Ministry of Natural Resources Red Lake).

Geology

Sparse beryl occurs in a narrow dyke (5.5 m by 52 m), striking N90E and hosted by metasedimentary rocks of the Northern Supracrustal Domain. This dyke is situated very close to the southern contact of the Wenasaga Lake batholith (Figure 16-1) in an area of poor outcrop. This pluton is an S-type biotite-muscovite granite mass approximately 260 km^2 in area and is postulated as the parent granite for the beryl dyke. Tourmaline, an important accessory in the Sandy Creek dyke, is also found in several parts of the Wenasaga Lake batholith, most notably proximal to its southern contact with migmatitic metasedimentary rocks (Figure 16-1).

The dyke is largely concordant to foliation of the host metasedimentary rocks which are mainly medium grade, muscovite-biotite metapelites and minor metawackes. Dip of the contact is generally steep, varying between 65^0 and 85°N. Near the western end of the dyke, a branching into a discordant southwest-trending arm is obvious (Figure 14-2).

As shown in Figure 16-2, the dyke comprises aplitic and pegmatitic units forming a crude asymmetric zonal relationship. This asymmetry is caused by the vertical restriction of the 0.3 m to 0.9 m wide pegmatitic unit to the northern contact. Within this narrow band of pegmatite, a local zonation also occurs, marked by aplite pods enveloped by the

pegmatitic unit. Near the eastern limit of exposure, the narrow pegmatitic zone deflects into the dyke centre, forming a core zone 15 m in length. The aplite unit comprises approximately 80 percent of the dyke and consists of subhedral to anhedral, vitreous quartz megacrysts embedded in a matrix of felty, white to pink cleavelandite, accompanied by accessory beryl, muscovite, purpurite and apatite (Photo 16-1). The fine cleavelandite plates are oriented parallel to the dyke contacts thus defining a subtle internal foliation.

The pegmatitic unit (Photo 16-2) essentially contains the same megascopic mineralogy, however, modal percentage and coarseness of muscovite, purpurite and apatite tend to be greater. Beryl is also more concentrated in the pegmatitic unit with maximum crystal diameters up to 7.5 cm.

According to Palache et al. (1944, p.668) purpurite (Mn^{3+}, Fe^{3+}) $P0_4$ is formed by pseudomorphic alteration of huhnerkobelite and varulite (minerals of the triphylite group) by meteoritic waters in the weathering zone. This process involves oxidation of Fe^{2+} to Fe^{3+} and Mn^{2+} to Mn^{3+} with valence balancing achieved by leaching of Na. Extensive weathering may form "brown to black friable pseudomorphs composed of hydrous oxides and manganese oxides" (Palache et al. 1944, p.668).

Metasomatic replacement of the host metapelites by black, coarse-grained tourmaline occurs along the northern contact. These pod-like masses, up to 3 m by 0.8 m (Figure 16-2), are strictly related to the pegmatitic unit.

Geochemistry

In Table 16-2, partial major and trace element analyses are presented for 15 grab

samples. Samples SC 13, SC 14, SC 15, and SC 16 for which more complete major element data are presented, reveals several chemical characteristic of the aplitic unit. This rock is enriched in Na_2O and depleted in CaO, K_2O, MgO and total Fe as Fe_2O_3 reflecting the predominance of cleavelandite and paucity of ferromagnesian phases. Na/K ratios which range between 8.5 and 26.7 for this unit do not, however, reach the extreme values recorded in similar rocks of the Tot Lake pegmatite-aplite dyke (Table 16- 6, below). Most of the inter-element ratios exhibit large variationand their mean values ratios (Table 16-2) indicate a lower extent of chemical fractionation than the Tot Lake pegmatite. The average K/Ba ratio is lower than the Tot Lake pegmatite and compares more closely with the Mavis Lake spodumene pegmatite (Table 16-5, below). A notable exception, however, is the low K/U and K/Th ratios of the Sandy Creek beryl pegmatite in comparison to spodumene pegmatites. The spodumene pegmatites have higher Th than U and although this is also apparent in the Sandy Creek beryl pegmatite (mean Th/U = 2.13), most samples in Table 16-2 reveal uranium values above the average crustal value of 2.5 ppm. Slight enrichment of Cs, Li and Sn is also evident. Although minerals of the columbite-tantlite group were not isolated, one anomalous Ta value of 240 ppm (sample SC-3: Table 16-2) and low Nb/Ta (0.3) suggest sporadic tantalite.

Analysis of a composite sample of muscovite from the pegmatitic unit is given in Table 16-3 and compares well to the muscovite from the Tot Lake pegmatite. However, the amount of Rb present in the muscovite from Tot Lake is 15,400 ppm, 11 times higher than in the Sandy Creek muscovite, indicating the much higher degree of fractionation. Similarly, the Cs content of the Sandy Creek muscovite is about an order of magnitude

lower than that in the Tot Lake pegmatite.

In terms of the classification of granitic pegmatites of Cerny (1989), the Sandy Creek beryl pegmatite best fits the beryl-columbite-phosphate subtype of the rare-element class. Enrichment in phosphorous is a diagnostic feature of muscovite-albite-beryl pegmatites according to Burnol (1974) and the low levels of fluorine typically found in these pegmatites have been regarded by Kovalenko et al. (1977) as a major difference from lithium pegmatites which usually do not contain significant syngenetic beryl. Beus (1967) suggests that the high fluorine content of lithium-bearing pegmatitic melts lead to formation of stable fluorine-beryllium complexes which largely prevented precipitation of beryl with lithium-rich phases. The distribution coefficients of Be between groundmass and phenocrysts of albite, K-feldspar, quartz and mica in fluorine-rich ongonite sikes as determined by Kovalenko et al. (1977), favor retention of Be in the fluid phase.

CESIUM

This rare element typically shows anomalous trace level concentration in both uranium and spodumene pegmatites of the study area. However, exceptional concentrations in pegmatitic systems necessary to foster crystallization of the rare mineral pollucite is only exemplified by the Tot Lake spodumene pegmatite (see below).

LITHIUM

Granitic pegmatites in the project area which contain lithium as the principal rare element are confined to the lower grade subprovince interface zones:

1). northern supracrustal domain - Uchi Subprovince boundary in the Root Lake area and at East Pashkokogan Lake, and,

2). southern plutonic domain - Wabigoon Subprovince interface zone in the Dryden area.

These pegmatites are typically accompanied by variable, trace level concentrations of Rb, Cs, Sn, Ta, Nb, Be, and Mn.

In the Dryden area, the various rare-element granitic pegmatites lie within and proximal to the eastern termination of the Ghost Lake batholith (Figure 16-3), an S-type granitoid complex covering approximately 280 km^2. This complex comprises cordierite-biotite and biotite-muscovite, homogeneous to inhomogeneous diatexite primarily of quartz monzonite to granite (sensu stricto) composition. Accessory tourmaline, apatite, garnet and sporadic beryl, dumortierite and sillimanite occur throughout the batholith. The surrounding metasedimentary host-rocks to the pegmatites commonly have metasomatic halos marked by tourmaline enrichment, first described by Satterly (1940, p. 26, 39-40) which are spatially related to the B-rich pegmatites. A regional zonation in pegmatite types (Cameron et al. 1949; Heinrich 1953) is marked by beryl in pegmatites within or close to the batholith-metavolcanic contact succeeded by spodumene pegmatites (with sporadic tantalite) approximately 1.6 km east of this contact. The Tot Lake Li-Cs-Rb pegmatite, 16 km northeast of the batholith, contact may not be related to the Ghost Lake batholith but, nevertheless, appears represent a further stage in this zonation sequence.

Data of Stewart (1963) and Jahns and Burnham (1958) synthesized in Cerny and Turnock (1971) indicate that the spodumene pegmatites of the study area belong to the low-temperature, high-pressure type, characterized by primary, green spodumene and

lacking petalite ($LiAlSi_4O_{10}$).

McCombe Property (Capital Lithium Mines Limited)

The McCombe Property is located about 0.4 km north of the Roadhouse River at a point 8 km downstream from McCombe Lake (local name). Root Lake is situated about 3 km south of the main showing. Access is relatively difficult by canoe, since the section of Roadhouse River between McCombe Lake and this property is commonly interrupted by rapids, isolated boulders, and shallow stretches. Quick access is best gained by helicopter.

Exploration History

In the mid-1950's, Capital Lithium Mines Limited discovered spodumene-bearing pegmatitic dykes in the Root Lake area. This group of patented claims, known as the McCombe Property, lies in the Root Lake Field of Mulligan (1965, p.64-65). Capital Lithium Mines Limited undertook detailed geological mapping (1 inch to 200 feet or 1:2,400 scale), magnetometer and resistivity surveys and a program of diamond drilling marked by 6 holes totalling 817 m (Resident Geologist's Files, MNDM, Red Lake). An estimated 2.3 million tons averaging 1.3 percent Li_2O has been outlined to the 150 m level (Skinner, 1969, p.8). Approximately 1525 m east of the main showing of Capital Lithium Mines Limited several spodumene-bearing dykes were investigated in 1956 by Consolidated Morrison Exploration Limited. Drilling totalling 1930 m in 16 holes outlined a zone 1220 m in length and up to 14.3 m. No tonnage figures are known and the only available analyses indicate 2:63% Li over 13.0 feet and 1.86% Li over 17.5 feet (Resident

Geologist's Files, MNDM, Red Lake).

Geology

The McCombe Property comprises two subconcordant dykes at the No.1 showing, herein distinguished as Dyke 1 and Dyke 2 (Figure 16-4). Dyke 1, striking N90E is more extensive, being intermittantly exposed over a length of 176 m and attaining a maximum width of 15 m. Both ends are covered by glacial overburden. Dyke 2, striking N80E is a 19 by 87 m lensic mass. The eastern end western terminations are geologically well defined (Figure 16-4). These dykes occur in highly deformed, pillowed mafic metavolcanic rocks and subordinate massive, medium-grained mafic flows containing low grade regional metamorphic assemblages. Holmquistite $Li_2(Mg, Fe^{2+})_3 (Al, Fe^{3+})_2 [Si_8O_{22})(OH, F)_2$ first observed by Mulligan (1965) and tourmaline are locally developed in the mafic metavolcanic host-rocks, indicating restricted contact metasomatism.

A characteristic petrographic feature of these dykes is the conspicuous presence of euhedral to subhedral, white, blocky alkali feldspar megacrysts which achieve maximum dimensions of 15 cm x 15 cm (Photo 16-3). Variation in grain size and mineralogy of the matrix has resulted in two porphyritic textural types:

1) Porphyritic Texture with coarse-grained to pegmatitic matrix (Pc), abundant spodumene and K-feldspar phenocrysts, minor beryl, and rare lepidolite (Photo 16-4)..

2) Porphyritic Texture with aplitic to medium-grained matrix (Pa), with meagre spodumene phenocrysts and common, fine-grained, accessory tourmaline (Photo 16-3).

The distribution of these textural variants has produced simple zoning patterns in both dikes. The western 60 m of Dyke 1 is dominated by the Pc type which envelops Pa pods (up to 18 m by 4.6 m). The latter accounts for approximately 10 percent of the dyke in this area and is symmetrically disposed about the dyke centre. Spodumene can comprise up to 50 percent (Photo 16-5). In the eastern portion of Dyke 1, both textural types are present in approximately equal amounts. The Pa type appears to envelop Pc along the western extremity of the latter (Figure 16-4), although outcrop was not continuous.

Dyke 2 is characterized by several, small, asymmetrically distributed, Pc zones. These masses are partially to completely enveloped by th Pa type, the latter comprising about 70 percent of the dyke. The largest Pc zone abuts against the southern host-rock contact and measures 27 m by 9 m.

The southern contacts of both dykes are marked by a zone of tourmaline-enrichment. These zones (maximum width 0.7 m) consist of fine-grained black tourmaline in an anastomosing vein system and medium to coarse grained individual crystals which tend be oriented normal to the contact. Spodumene is typically white to faint-green on fresh surfaces and only rarely exhibits alterations. Flesh-coloured spodumene intermittently occurs near the southern contact. In Dyke 1, spodumene in the Pc type shows a progressive coarsening towards the northern contact where crystals up to 2.5 cm x 20 cm were noted. Near the northern contact, spodumene, alkali feldspar and tourmaline define a down-dip lineation with plunge varying between 30 and 70 degrees. This lineation (Plates 14-4 and 14-4A) may represent a magmatic flow feature.

Geochemistry

Analyses of Li, Cs, Be, Rb, Sn on three grab samples of spodumene pegmatite are given in Table 16-5. A high degree of chemical fractionation is indicated by extremely low K/Rb, K/Cs and Ba/Rb, all of which are comparable to the Tot Lake pegmatite (Table 16-6, below).

Tot Lake Li-Cs-Rb Occurrence

This pegmatite is situated in Webb Township, approximately 1.3 km S30W of the most southerly part of Tot Lake. Access is gained by travelling 27.4 km along the Ghost Lake Road from its termination at Highway 601 to an easterly junction with a gravelled former logging access road, the latter allowing vehicle access within about 2.6 km of the showing (Figure 16-5).

Exploration History

Initial work was undertaken in 1964 by J.A. Donner who carried out a magnetometer survey, diamond drilling (4 holes totalling 223 m) and geological mapping. (Assessment Files Research Office, Ministry of Natural Resources, Toronto). Three of the diamond drill holes probed the southeast extension of the dyke under overburden (Figure 14-6). In 1973, A Kozowy did a limited amount of trenching (Assessment Files Research Office, Ministry of Natural Resources, Toronto). Recently in 1979, Tantalum Mining Corporation investigated by diamond drilling, nature of the dyke both down dip and to the northwest (D. Janes, personal communication, 1979, Resident Geologist, Ministry of Natural

Resources, Sioux Lookout).

Geology

Regionally, the Tot Lake pegmatite is situated within Wabigoon Subprovince metavolcanic rocks, near the interdigitating contact of with a metasedimentary-rich segment of the Southern Plutonic Domain (Figure 16-3). The general area is covered by extensive glacio-lacustrine clay sediments which dominate the Pleistocene of the Dryden area. In general the massive resistant nature of pegmatitic granite masses and dykes causes local topographic elevations. This particular exposure is only slightly elevated in comparison to similar pegmatitic dykes at Mavis Lake and Roadhouse River.

The Tot Lake pegmatite dyke (Figure 16-6) strikes about E50S and dips 80NE lying sharpely discordant to foliation in mafic metavolcanic host. It is exposed for about 46 m and achieves a maximum width of 7 m at the southeastern end. Host-rocks consist of mainly of low grade well-foliated, fine-grained mafic metavolcanic rocks with subordinate massive rocks of similar composition.

The assemblage biotite-chlorite-amphibole-plagioclase-(-quartz) is typical in these rocks with occasional calcite-rich lenses. A 10.6 m thickness of massive mafic metavolcanic rocks containing medium-grained, hornblende porphyroblasts lies in sharp contact with the fine-grained variety near the southeastern part of the main outcrop. This rock type could represent coarse-flow center material. At the extreme southeastern part of the outcrop, the dyke is in contact with meta-ultramafic rocks. Within 2 cm of the contact, the ultramafic rocks contain profuse, haphazard, accicular, purple holmquistite.

This mineral is strikingly evident especially on wet surfaces along the western contact of the dike. Its distribution suggests that the holmquistite originated by contact metasomatic processes. This rare mineral apparently only occurs near metasomatically-altered rare element pegmatite dykes (Heinrich 1965). Its distribution in the immediate host rocks of Tot Lake pegmatite also strongly suggests a similar exomorphic origin.

The pegmatite dyke is characterized by zonation which is particularly obvious at the extreme southeastern face (Photo 16-6). Here, alternation between spodumene-rich pegmatite layers and medium to fine-grained spodumene-impoverished layers forms strikingly evident zones. This alternation is symmetrically disposed about a central core comprised mainly of milky quartz. This persistant, gradually tapering, central quartz core, having a maximum width of about 3 cm, is traceable for about 18 m northwestwards, from the extreme southeastern outcrop edge and constitutes approximately one-half of the exposed length of the dyke. A small but genetically significant pollucite-rich pod about 1 m in diameter lies along the northeastern contact near Trench 2. This zonation does not continue along the entire dyke length as the aplite unit assumes predominance towards the northwestern end.

Zones in contact with the country rock are usually marked by a fine to medium-grain size and a paucity of spodumene. In certain areas, coarse reddish spodumene occurs at the contact and are oriented perpendicular to the host-rocks. Extremely coarse spodumene crystals measuring up to 110 cm in length occur within the central dyke, especially towards the northwestern end (Photo 16-7). Spodumene crystals are typically light pink on fresh surfaces and weather to a light pinkish grey, the pink colouration likely

due to trace levels of manganese and low Fe:Mn ratios in the crystal structure (Claffy 1953). Towards the northwestern end, spodumene crystals tend to be more friable and vary from lime-green to moderate orange. The orange may reflect ferric oxide absorbed from ground water. Spodumene apparently has an affinity for iron as evidenced at the Bernic Lake Mine in Manitoba, where spodumene-quartz intergrowths were noticeably encrusted after dewatering of underground workings (P. Cerny, University of Manitoba, personal communication, 1980). K-feldspar is generally white and perthitic. A characteristic accessory is vivid yellow-green muscovite which varies from fine-grained patches to books of pegmatitic grain size. Black tourmaline is only scantily apparent usually as fine grains in the aplite unit, as fine-grained veinlets in contact zones (including the host rocks), and as scarce needles oriented normal to the wall rocks.

This yellow-green colour of muscovite is apparent in many spodumene pegmatites examined by the writers and according to Skosyreva and Nikol'skaya (1978) this colour is due to presence of significant trace levels of Fe^{2+} in the crystal structure. Lepidolite is sporadically present, mainly as fine-grained veinlets up to 1 cm thick. Munoz (1965) has experimentally determined that such probably formed by subsolidus decomposition of spodumene in presence of a volatile phase enriched in presence of a volatile phase enriched in fluorine. Lepidolite also occurs as pseudomorphs after spodumene (Photo 14-7) which strongly suggests a subsolidus derivation. Other minor minerals include blue-green apatite, brown phosphate (possibly of the sicklerite series), and minerals of the columbite-tantalite group. The latter show locally impressive concentrations (Photo 16-9) and have maximum dimensions of 1 x 2 cm. According to Ucakuwun (1981, p.110)

the latter correspond to the disordered ixiolite-type structure and reported four electron microprobe analyses in which a considerable disparity in Nb/Ta ratios is apparent. Three analyses (Table 16-7) are rich in tantalum enrichment while a fourth is enriched in niobium. Ucakuwun (1981) does not indicate exact location of the columbite-tantalites with respect to pegmatite assemblage. It is suspected by the authors that analyses 1, 2, and 3 in Table 16-7 originate from the highly albitized northeastern end of the pegmatite where locally impressive tantalite concentrations have been observed. Much rarer, possibly syngenetic columbite-tantalite up to 4x10x>2 mm have been observed in the pink spodumene-pollucite zone in Trench 2 and would most likely correspond to the high niobium type of analysis 1 in Table 16-7.

Geochemistry

Chemical analyses undertaken on 24 pegmatite samples (1-2 kg weight range) for major, minor, and selected lithophile trace elements (Table 16-6) along with some inter-element ratios. In Trenches 2 and 3, the entire dyke width was sampled at 60 cm intervals commencing at the southwest contact, in order to discern possible cryptic chemical fractionation trends.

A distinctive sodic, alkalic chemistry marked by high alumina contents is obvious in Table 16-6. Calcium is less than 0.5 percent except near the southwestern contact where possible introduction of this element from calcite stringers in mafic metavolcanic host rocks may have occurred. The overall high alumina and sodium contents is likely due to the considerable cleavlandite, especially in Trench 4 where Na_2O reaches 11.6 weight

percent. Petrochemical zonation is evident particularly with respect to abundances of Na, K, Li, Cs, Rb, and various ratios and also supports a crystallization sequence from external contacts to core.

The ratio Na/K shows a wide range in values from 0.43 to 80.7 (average = 9.8) reflecting the chemical differences between highly sodic aplite and the more potassic spodumene-bearing pegmatite. The latter tends to be confined to the central dyke area in Trenches 2 and 3 (Table 16-6), and generally coincides with the lowest Na/K ratios. Trench 4 is highly sodic and contains amongst the highest Na/K ratios in the dyke.

As indicated in Figure 16-7, the whole rock K/Ba, K/Cs, K/Rb, Ba/Rb and Mg/Li all are reliable indications of the degree of fractionation. Figure 16-8 shows profiles of variation of Ba, Be, Cs, Li, Rb, Sr, Th, and U and Figure 16-9 reveals inter-element ratios Ba/Rb, K/Ba, K/Cs, K/Rb, Mg/Li, and Rb/Sr across Trenches 2 and 3 from southwest to northeast. The Mg/Li ratio represents the most sensitive indicator of fractionation of all inter-element ratios studied. This ratio indicates a conspicuous, trough-like, symmetrical depression of values coincident with dyke center in both Trenches 2 and 3 (Figure 16-9). The core zone relative to contact zone exhibits a decrease by more than 2 orders of magnitude in Trench 3. Nockolds and Allen (1953, 1954, 1956) have shown that Mg/Li ratios decrease regularly with magmatic differentiation, even though the level of lithium may actually diminish (Heier 1960). Both of these geochemical features are generally exhibited by Type I and II uraniferous pegmatites (see below) an contrasts greatly with the trend of Mg/Li fractionation in volatile-rich rare-element pegmatite systems from the study area (Figure 16-11). Lithium abundances in the Tot Lake pegmatite increase

rapidly to 24,000 ppm at essentially constant Mg levels (Figures 16-9 and 16-10).

Ba/Rb and K/Ba ratios are useful petrogenetic indicators and respectively decrease and increase with advancing geochemical fractionation (Taylor 1965). Ba/Rb exhibits a tendency for decrease in values towards the core zone of this pegmatite, however, distribution of values is more erratic and less symmetric than Mg/Li. This erratic nature also reflects K/Ba ratios which show a general increase towards the core. Both ratios define fractionation fields progressing sharply away from the average crustal ratio line in Figure 16-7 and contrast in this regard with K/Cs and K/Rb. Some Ba/Rb ratios of the Tot Lake occurrence show extreme values lying more than 3 orders of magnitude lower than average crustal values (Figure 16-7).

K/Cs ratios behave in a less orderly fashion. In Trench 2, Cs levels are higher adjacent to the wall rocks which produces higher K/Cs ratios towards the centre. The reverse patterns are apparent across Trench 3. In Figure 16-7 positive correlation of K and Cs paralleling the average crustal ratio but 3 orders of magnitude lower is evident for most samples. This pattern of increasing Cs with increasing K is generally different from relations in uranium pegmatites from the study area which exhibit increasing Cs at constant or decreasing K (Figures 16-20 and 38, below). The relationship of increasing Cs with decreasing K may represent a trend for Cs-rich pegmatitic zones at Tot Lake occurrence (Figure 16-7), however, insufficient data points here render this observation somewhat tenuous.

Fractionation within the rare-element pegmatites from the study area is marked by a general concentration of Th relative to U, defining a field removed from most uranium

pegmatitic rocks. In Figure 16-12 a notable increase in Th/U ratios is evident in progressing from the uranium pegmatites, exemplified by the Davidson Occurrence (see below) to rare-element pegmatites. The highly fractionated Tot Lake Li-Cs-Rb-Ta pegmatite contains the highest Th/U ratios and is generally depleted in U relative to average Canadian Shield crustal rocks. Th/U ratios, although erratic, tend to achieve highest values towards the dyke centre (Table 16-6) with a very high mean of 22.8 and a considerable range (2.8 to 112.5). The abundance of Th is more symmetrically distributed about the core zone than U (Figure 16-8).

The Mavis Lake Li-Be-Ta pegmatites are not as chemically fractionated as the Tot Lake pegmatite as revealed by the mean values of various ratios (Table 16-4) and this lesser extent of fractionation is also exhibited by generally lower Th/U ratios which partially overlap with the low uranium end of the Davidson Occurrence field. Rb/Sr ratios in the Tot Lake pegmatite show a well defined increase towards the center of Trench 3 although this increase is not as apparent in Trench 2. Overall this ratio also indicates extreme fractionation, having a very high mean of 27.7 relative to the average crust (0.2) and a large range (from 5.8 to 84.8).

K/Rb ratios, although anomalously low relative to the mean and range for crustal materials, indicate extreme fractionation. Nevertheless, the ratio is not a good indicator for discerning fractionation trends within the dyke (Figure 16-9) as it produces a relatively flat profile. In Trench 3 a very slight depression of values towards the certain is apparent.

Extreme enrichment of Rb and Cs suggests that the Tot Lake spodumene pegmatite the most fractionated rock within the project area. Levels of Rb reach distinctively high

levels of 9,500 ppm within the central pegmatite unit in Trench 3. Elsewhere in the Superior Province, pollucite is only found at the Bernic Lake pegmatite of Tanco (Cerny et al., 1981), Valor deposit in Quebec (Mulligan 1965) and Lily Pad Lake area pegmatites (Wallace, 1978). In terms of Rb and Cs enrichment in alkali feldspar the Tot Lake pegmatite approaches the extreme values attained by the Tanco pegmatite (Cerny et al. 1981). Rb and Cs contents of the composite muscovite sample (Table 16-3, above) lie just within the Bernic Lake pegmatite field of Cerny et al. (1981).

Although the Tot Lake dyke appears to disappear along strike and at depth, its significance should nevertheless be emphasized. Exploration programs should consider the possibility that more extensive, consanguineous pegmatite dykes could well be present within the general Mavis Lake - Tot Lake region. Rare-element pegmatites typically occur in en-echelon swarms as exemplified by the Mavis Lake property and thus exploration efforts should be initially concerned with establishing additional dykes lying beneath the pervasive overburden in vicinity of the Tot Lake pegmatite. A combined program of overburden drilling, lithogeochemistry, and heavy mineral analysis in basal till represent a possible means of achieving this end.

Mavis Lake Li-Ta-Be Pegmatite Dykes

Exploration History

During the mid-1950; discovery of the Mavis Lake spodumene pegmatite dykes in Brownridge Township spurred exploration activity in the Dryden area. These dykes were

investigated in 1956 by Lun-Echo Gold Mines Limited. Forty diamond-drill holes totalling 1,968 m established widespread lithium mineralization, albeit discontinuously, over a strike length of 915 m (Mulligan 1965, p.64). Widths of individual dykes varied between 1.5 and 11 m. The best intersection recorded 2.76 percent Li_2O over 2.9 m (Assessment Files Research Office, MNDM, Toronto). Recent interest in the Mavis Lake pegmatites has focused upon their tantalum potential. In 1979, this spodumene pegmatite dike group was optioned from Mr. Robert Fairservice by Selco Exploration Ltd., who conducted a lithogeochemical survey for Li, Cs and Rb over the North and Northeast Zones (AFRO, Toronto). During August of 1980, diamond drilling had commenced on several Li anomalies to test for possible tantalum-bearing spodumene pegmatite dykes at depth (A.P. Pryslak, Selco Exploration Ltd., personal communication, 1980).

Geology

Fifteen known spodumene pegmatite dykes are emplaced in low-grade foliated to gneissic mafic metavolcanic rocks immediately south (North and South Zones) and southeast (Northeast Zone) near Mavis Lake (Figure 16-13). With exception of the single dyke at the Northeast Zone (strike 160°) and two narrow dykes on claim 489173 (Figure 16-13), the dykes strike east and are generally concordant to host-rock foliation or gneissosity. Widths of the dykes vary between 4 m and 19 m with dips ranging between 30° and vertical. The dykes are unzoned with randomly oriented, light-green euhedral to subhedral spodumene crystals generally distributed from wall to wall. Coarse spodumene laths up to 5 cm x 97 cm typify primary high-pressure, iron-rich phenocryst variant of

Heinrich (1975). In part of a 13 m wide dyke of the North Zone (Pegmatite No.1) vague development of a quartz-rich core zone is apparent. This zone, which is most plausibly interpreted as a silica-rich, supercritical igneous fluid (Stewart 1978), contains well developed blocky K-feldspar up to 22 cm^2 (Photo 16-10), faint blue to white euhedral to subhedral beryl up to 7 cm x 12 cm and spodumene crystals with partial to continuous albite-rich coronas (Photo 16-11) which may signify late disequilibrium with sodic-rich fluids. Tantalite crystals and clusters, commonly less than 1.5 cm x 0.5 cm, occur in local domains, particularly within albitized rims of coarse K-feldspar masses (Photo 16-12) or along contacts between such albitized K-feldspar and quartz-rich masses. A few tantalite crystals were also noted within the albite-rich coronas around spodumene. The tantalite crystals are commonly surrounded by a slight iron-stained halo. Variable amounts of saccaroidal, sodic aplite of replacement origin occur in most spodumene dykes of the Mavis Lake area and are characterized by white anhedral to subhedral, white generally smaller beryl up to 3 cm diameter. No megascopic Ta-Nb group minerals could be identified in the saccaroidal aplite.

A notable feature in the mafic metavolcanic wall-rocks of several spodumene pegmatite dykes in the Mavis Lake area is conspicuous, medium to coarse-grained, black tourmaline porphyroblasts, generally occurring within 3 m of the contact.

Economic Geology

Mr. Robert Fairservice had assays undertaken on 17 grab samples from Pegmatite No.1 and an en-echelon dyke lying immediately south and reported an average Ta = 150 ppm and range of 2 to 260 ppm. Pegmatite No.5, the second most easterly of the North

Zone (Figure 16-13) averaged 125 ppm Ta and ranged 33-200 ppm Ta (Table 16-8) on the basis of 36 grab samples (R. Fairservice, Dryden, personal communication 1980). Eight grab samples taken across 4.5 m from the same dyke were analyzed by this study and registered a similar average of 110 ppm Ta with a range of 33 to 200 ppm. Profiles of selected elements and ratios across Pegmatite Dyke #5 is given in Figure 16-14.

Distribution of Lithium in the metamorphic and anatectic environments

The fate of lithium in the metamorphic-anatectic part of the geochemical cycle is much less known than its behaviour in the igneous, surficial and sedimentary environments (Heier and Adams 1964; Ronov et al. 1970; Heier and Billings 1972). The data base has, however, been somewhat improved for Rb, K and Na in the years subsequent to publication of the extensive review of Heier and Adams (1963). Shaw (1954, 1956) found that average Li contents of metapelites of the Littleton Formation New Hampshire, do not change significantly in the low, medium, and high grade zones. Several studies, however, have demonstrated a general decrease in Li content with increasing metamorphism. Sighinolfi and Gorgoni (1978) encountered a depletion pattern of Li in metasedimentary rocks of the Western Italian Alps, marked by an 80 percent decrease of Li contents in progressing from amphibolite to granulite facies. Metapelites and metawackes of the Lake St. Joseph metamorphic zones at the Uchi-English River subprovincial boundary exhibit a systematic decrease in average Li contents in the progression from low to high grade zones (Table 16-9). This depletion trend also involves Rb, Cs, and U. Evans (1964) documented a substantial decrease in Li content of pelitic hornfelses in contact with mafic

and ultramafic rocks from Connemara, Ireland compared to unhornfelsed pelites. Virtually no Li was found in unmigmatized pelitic xenoliths. Depletion Ba, Rb, La, Cs, Si, Al, K, Na and H_2O was also observed in the Irish metapelites. Kesler's (1976, p.49) postulated a mechanism which involved leaching of loosely bonded Li from pelitic metasedimentary rocks via volatiles for the Kings Mountain area of North Carolina. This process may have have some validity in effecting pre-anatectic concentration of lithium.

There are presently no known data on the partitioning of Li between coexisting biotite-muscovite, and muscovite-chlorite in metapelites and metawackes as a function of increasing metamorphic grade and type of metamorphism. It is known from mineral chemistry studies on muscovites and biotites from granitoid rocks (Table 14-6) that substantial trace levels of Li can be accommodated by such minerals. In particular, the Li content of muscovites in such metasedimentary rocks presents a major unknown variable in application of S-type derivation for rare-element pegmatites. In two-mica granitoid rocks of the Preissac-Lamotte-Lacorne region of Quebec, Siroonian et al. (1959) showed that primary muscovites contain Li levels comparable to those of coexisting biotites (Table 16-10). Muscovites from various rare-element pegmatites in that area not containing biotite curiously show lower average Li contents (Table 16-10). According to Gordiyenko (1970) entry of lithium into the muscovite lattice is governed by the substitution sequence: $Li^+ + (Mg, Fe)^{2+} \rightarrow Fe^{3+} \rightarrow Al^{3+}$.

Lithium in anatectic rocks

The general concentration of Li and other rare elements in average metapelitic rocks

to the extent of 6 times greater than the average crust (Heier and Billings 1972) suggests that metapelitic rocks in the anatectic environment could serve as important protoloiths in the evolution of Li-enriched granitoid rocks and pegmatitic affiliates. There is a common association of two-mica granitic rocks and rare-element pegmatite fields with the peripheral parts of high grade metasedimentary-rich subprovinces in noarthwestern Ontario (Pye 1965, 1968; Breaks 1980, 1981, 1989). Several workers such as Stewart (1978) and Norton (1973, 1975) contend that partial melting of Li-enriched metasedimentary sequences and subsequent strong fractionation of Li into a late pegmatitic phase is the only feasible process for formation of spodumene/petalite pegmatites. Holland and Lambert (1972) suggested that anatectic fractionation of plutonic gneisses and metasedimentary rocks would produce a leucosome depleted in Li and a corresponding biotite-rich restite enriched in Li. These workers assume that most lithium is retained within biotite which typically dominates the restite constituent of migmatites. Hence granulite facies metamorphic conditions would be necessary release most of th Li to anatectic melts. These workers neglect the possible implications of pre-anatectic vapor phase transport (Evans, 1964; Kesler, 1976) and the likelyhood that, in pelitic metasedimentary rocks, at least, muscovite could contain significant levels of Li which could be released to leucosomes generated above the second sillimanite isograd, by reactions modified after Winkler 1979, p.320:

Li-enriched Muscovite + Quartz + Plagioclase --> Melt (Li^+) + K-feldspar + Sillimanite + An-richer Plagioclase

In the Lake St. Joseph metamorphic zones (Figures 12-2, and 12-3) a drastic decrease in Li is obvious in the surviving metawacke and metapelitic paleosome of migmatitic rocks which contain low amounts of leucosome compared to their unmigmatized counterparts. Although these high-grade and granulite metapelites reveal high biotite (30-40 percent), the rock as a whole contains less than half of the Li of the low-to medium-grade equivalents. Here it may be tentatively concluded that greater than 50 percent of the Li was released to the leucosome through muscovite dehydration reactions.

In order to release Li substituting for Mg in the biotite lattice to anatectic melts, conditions of granulite facies are required and are probably governed by reactions similar to (after Winkler 1979, p. 321):

Biotite + Sillimanite + Quartz --> K-feldspar + Almandine Garnet + Melt + Li^+

Although a granulite grade zone exists in this facies series, the metamoarphic rocks in many lithium pegmatite districts do not approach such conditions (e.g. Black Hills district, Cerny and Trueman 1978).

S-Type granite - rare-element pegmatite association

The elucidation of the source of granitic pegmatites enriched in Be, Cs, Li, Rb and occasionally Ta and Sn has proven to be a difficult task in several pegmatite districts (eg. Cerny et al. 1981). One reason for the elusive genesis of pegmatitic systems is that the

highly evolved major, minor and trace element compositions recorded in such rocks typically deviate significantly from that of the parental source area. In addition, rare-element pegmatites are commonly physically removed from a given source-area due to their lower solidus temperatures, large volatile content and consequent enhanced mobility. Various subsolidus mineral reactions also contribute difficulties in the isotopic characterization of rare-element pegmatites and in Rb/Sr dating which could shed light on nature and age of the precursor.

On geologic grounds, a synmetamorphic petrogenetic model of lithium pegmatite formation involving affiliation with metasedimentary migmatite is favoured in this study. The postulated metasedimentary protoliths and derived S-Type granites are common rock units proximal to rare element pegmatite districts of the Superior Province of Ontario such as in the Dryden area, Roadhouse River area, Georgia Lake area (Breaks 1980) and Crescent Lake area (Breaks 1981). This model for rare-element pegmatites of the English River Subprovince suffers at present from a paucity of whole rock and mineral chemical data, along with U/Pb geochronological work for various pegmatites and prospective source regions.

Involvement of Li-enriched metapelitic rocks in extensive regional anatexis, typified by the Northern Supracrustal Domain of the English River Subprovince (average Li = 65 ppm, range = 15-185 ppm) and, in particular, the close association of advanced stage anatexis with low pressure granulite centres, could conceivably lead to higher than average Li concentrations in the associated S-type granites. If an anatectic granitic mass initially contains a higher than average content of rare elements, it follows that further

concentration via partitioning into a volatile-enriched supercritical phase (Jahns 1982) or by crystallization-induced distillation (Gordiyenko et al. (1981) may be enhanced. As indicated by Jahns and Burnham (1969) the aqueous rich phase of pegmatitic magmatite systems is a "powerful scouring agent and transporting medium". The favoured crystallization of spodumene and K-feldspar, for example, in quartz-rich cores of rare-element pegmatites, zones interpreted as a former supercritical aqueous phase (Stewart 1978), points to strong partitioning of Li and K in this phase relative to the viscous silicate rest-melt. Element partition data are lacking for rare-element pegmatitic systems, however, Kovalenko et al. (1977, 1978) have reported results for ongonites from the South Gobi igneous belt in Mongolia. These rocks represent subvolcanic analogues of Li-F granites and contain the highest known F content (maximum 3.5%) of any natural granitic melt. Distribution coefficients derived for Be, Cs, Li, Rb indicate a strong preference for these rare-elements to be concentrated in the fluorine-enriched fluid phase. Many rare-element pegmatites are suspected to have contained high fluorine contents during crystallization based of the presence of fluorine-rich minerals and/or greisen. Accurate and representive data on fluorine contents of such pegmatites are, however, seldom reported in the literature (Bailey 1977, p.18-20). Thus there may be a general similarity in distribution coefficients computed for ongonites and parental Li-F granites and those for certain fluorine-enriched, rare-element pegmatites.

Rare-element pegmatitic magmatic systems by virtue of greatly depressed liquidus temperatures relative to lower volatile contents of parental granites could remain fluid for a considerable time subsequent to solidification of the parental anatectic granitoid mass

under a regime of slow crustal cooling following the peak of metamorphism such as that characterizing the Superior Province. Wyllie and Tuttle (1961, 1963), van Groos and Wyllie (1968), Kovalenko (1977), Glyuk and Trufanova (1977) have demonstrated that small additions of HF and Li_2O both depress the solidus in the haplogranite system to a significant degree. Chorlton and Martin (1978) have shown that addition of boron to a water-saturated granitic system lowers the solidus at 1 kbar by 125°C and modifies the structure of the granitic melt in a fashion completely different from that of HF and Li_2O such that the effects of B together with HF and Li_2O will result in a cumulative lowering of melting temperatures. HF has the additional effect of greatly increasing water solubility in a granitic melt (Bailey, 1977, p.27-28). These pegmatitic masses would consequently have time to migrate outward from the parental mass into available dilatational or other late structural environments in the lower grade metamorphic zones thus obscuring genetic relations with the parental mass.

The beryl-bearing pegmatites of the English River Subprovince are not as fractionated as the spodumene types on the basis of K/Ba, Ba/Rb, K/Cs and K/Rb (Table 16-4) possibly due to relatively higher liquidus temperatures. The beryl pegmatites consequently are restricted to within or very near associated S-type granitic plutons such as the Ghost Lake batholith (Figure 14-3). This type of regional zoning is recorded in numerous pegmatite districts such as at Preissac-Lacorne (Mulligan, 1965), Black Hills (Cerny and Trueman, 1978) and in the Yellowknife district (Hutchinson, 1955).

Some important differences in pegmatites of S-type affiliation vs those of potassic granitoid suite of probable I-type origin are outlined below:

1) spatial relation of muscovite-bearing S-type granitic masses and metasedimentary migmatite terrains, to rare-element pegmatites.
2) aluminous accessory minerals such as sillimanite, cordierite, garnet and tourmaline in the S-type granites, which are attributed to a metapelitic source area, are not found in I-type pegmatites
3) pegmatites of potassic granitoid suite, post-date the S-type granites, and invariably contain biotite as the major mica. Uranium and molybdenum represent the only economically important elements concentrated in these pegmatites.
4) the lithium and beryllium-pegmatites invariably contain white K-feldspar which contrasts with the pink to red K-feldspar from pegmatites of the potassic granitoid suite association. This may reflect fundamental differences in $f0_2$ regimes (Breaks 1982).

TANTALUM

Tantalum concentrations, found mainly in minerals of the columbite-tantalite group, occur in erratic fashion in the spodumene pegmatites at Mavis Lake and Tot Lake. Columbite-tantalite is also associated with beryl in a small, white, muscovite pegmatitic granite stock in the Bruin lake-Edison Lake metavolcanic belt, west of Vermilion Bay (Pryslak, 1976, p.40-41). The origin of this stock is not understood at present. Erratic high values of tantalum in the Sandy Creek beryl pegmatite also probably indicates Ta-Nb oxide minerals, however, identification of the mineral(s) was not positively made in the study.

URANIUM

Uranium-enriched granitic pegmatites constitute the largest class of lithophile mineralization in the western English River Subprovince and adjacent Wabigoon Subprovince in terms of the number of occurrences. As indicated in Figure 4-1 (above0, the number of occurrences in this region could render this area a potentially important future exploration area in the search for large tonnage, low grade deposits, the "porphyry uranium" deposits of Armstrong (1974). One particular showing (see Celyn Lake Occurrence, below) has an average uranium content approximately twice that of the Rossing deposit of Southwest Africa, currently the lowest grade uranium deposit being mined in the world. Locations of these occurrences have been extracted from assessment reports, Ontario Geological Survey reports, and observations of radioactivity and uranium staining by the present survey. Although uranium mineralization associated with granitoid pegmatites has been described in the literature (e.g., Little 1974, MacMillan, 1977), possibly due, in part, to the importance of the former producing Bancroft Camp, very little chemical data is available to allow comparison and contrast between pegmatitic units within a given uranium district. These data would not only aid in the classification of various pegmatitic uranium deposits but may also place contraints regarding source of the granitoid material. In this study uranium-bearing pegmatitic rocks, loosely classified by Little (1974) as unzoned red or white pegmatites, have been subdivided according to geological association and petrography (Table 16-11). Two distinct types of uraniferous granitic pegmatitic rocks have been recognized by the present survey:

Type I: Metasedimentary Migmatite Association (northern supracrustal domain); and;

Type II: Potassic Granitoid Suite Association (southern plutonic domain and adjoining Wabigoon Subprovince).

This classification is also applicable elsewhere in the Superior Province of northwestern Ontario, where uranium-bearing granitic rocks of both types were recognized ,for example,in the Favourable Lake area (Bond and Breaks, 1978).

I. Metasedimentary Migmatite Association

Uranium mineralization of this type is principally confined to the northern supracrustal domain (Figure 16-15) and hosted in white-weathering, coarse-grained to pegmatitic, inhomogeneous and homogeneous diatexite. The first occurrence known to receive exploration attention is situated on Umfreville Lake (see Umfreville Lake Occurrence, below). The important occurrences exemplifing this association will now be described in detail.

Sydney Lake Fault Occurrences

Numerous occurrences of uranium staining have been observed during the present study within the Sydney Lake fault zone between Confusion Lake and the Ontario-Manitoba border. All of these occurrences are situated within an extensive narrow band of mylonitic to protomylonitic, garnet-biotite-muscovite homogeneous diatexite unit (0.4-2 by 90 km). Interestingly, McRitchie and Weber (1971) report presence of further occurrences in adjacent Manitoba within the same fault system.

Sydney Lake Occurrence

The only evidence of exploration activity prior to 1974 consists of a series of small pits

and trenches exposed on the eastern side of Sydney Lake. Specifically, the area of uranium staining (Latitude 50°37'40" and Longitude 94°26'35") lies along the southern edge of a large point extending westward below the mouth of Pineneedle Creek (Figure 16-16). This occurrence was discovered by A. Kostynuk and T. Kostynuk in 1972 (A. Kostynuk, prospector, Red Lake, personal communication 1980) and these prospectors were responsible for the trenching.

Geological setting: The uranium mineralization occurs within the protomylonitic, homogeneous diatextites (see Photo 14-11, above) situated within the Uchi-English River subprovincial boundary. Rocks immediately north of the contact are mylonitic quartz monzonites of the Pineneedle Lake pluton which do not contain anomalous amounts of radioactive minerals. Several narrow bands of protomylonitic to mylonitic metatexite are present along the inter-belt contact. These rocks do not appear to contain anomalously high uranium.

Radiometric survey: A hand-held ACR model 661 Geiger Counter was used to check a number of outcrops along the shoreline and inland from the shoreline. The geiger counter was held about 10 cm from the rock surface and moved slowly over the outcrop surface. Typical background readings for rocks in the area are recorded below:

Rock Type	Counts Per Minute
Quartz monzonite	100-125
Cataclastic quartz monzonite of Pineneedle Lake pluton	100-125
Metatexite	50-75

Cataclastic metatexite	50-75
Diatexite	50-75

The only anomalous radiometric readings (greater than 2 times background) occur within the cataclastic (protomylonitic) diatexite. In nearly all cases a yellowsecondary uranium stain was present in areas of anomalous readings.

The radioactivity is hosted by a coarse grained, protomylonitic, muscovite homogeneous diatexite. Many feldspar porphyroclasts are up to 20 cm across. Yellow stain indicative of the secondary U minerals on these porphyroclasts suggests that the primary source of the uranium may lie within the large feldspar crystals. Only a few (5% of total) feldspar porphyroclasts appear to contain uranium. Most of the porphyroclasts are not radioactive and do no exhibit yellow secondary uranium staining. Small blebs of radioactive stain may be found in the coarse-grained cataclastic material surrounding the large feldspar porphyroclasts. These blebs may be mechanically broken down feldspars or hydrothermal concentrations of uranium oxide. In a typical outcrop the best radiometric readings are obtained over the coarsest diatexite that has not been severely mylonitized.

Geochemistry: A chemical assay undertaken on a grab sample by the Geoscience Laboratory, Ontario Geological Survey registered 0.11 percent U_3O_8. X-ray powder studies identified the yellow radioactive material as Beta Uranotil ($CaO.2UO_3.2SiO_2.6H_2O$) a secondary mineral possibly after uraninite. No primary mineral could be isolated. The radioactive assay (0.07 percent U_3O_8 equivalent) was appreciably less than the chemical result principally because the Beta Uranotil is out of equilibrium with the daughter

elements that normally produce the radiometric measurements.

Umfreville Lake Uranium Occurrence

This uranium occurrence is situated on a small penninsula which protrudes south into the eastern expanse of Umfreville Lake. Access is achieved via boat from Caribou Falls landing.

Exploration History

Initial work on this property was recorded by Bralorne Can Fer Mines Limited who in 1968 undertook trenching and geological mapping. In 1976, Noranda Exploration Company Limited conducted a detailed group scintillometer surface survey (total counts per second) and established an east-west trending radioactive zone 183 m in length and about 18 m in width (Figure 16-17).

Geology

This occurrence represents one of the best examples of Type I uranium mineralization (Table 16-11) in the English River Subprovince and is associated with diatexite approximately 1.6 km north of the interdomain boundary (Figure 16-18). Immediately north lies a narrow, concordant unit of metamorphosed biotite trondhjemite.

The local area is characterized by high grade regional metamorphism which passes into low-pressure granulite conditions about 6.4 km north of the uranium zone (Figure 16-18). Specifically, the mineralization occurs in weakly foliated to massive medium grained to pegmatitic, inhomogeneous and homogeneous diatexite of quartz monzonite composition (Figure 16-19). The inhomogeneous diatexite is usually white on fresh

surface, however, towards western end of trenched zone a subtle gradation into light-pink (fresh surface) homogeneous diatexite is apparent. Minor metatexite and amphibolite also occur on the property.

The inhomogeneous diatexite unit contains about 30 percent oriented enclaves of fine-grained biotite metawacke paleosome and grades into homogeneous diatexite normal to strike of foliation due to decrease in metasedimentary enclaves. Biotite is the sole ferromagnesian accessory, occurring as disseminated grains and books, or, more commonly, in clusters and schlieren. Biotite tends to be rather inhomogeneously distributed in both diatexite stages, varying from less than one percent to 15 percent but probably averaging around 5 percent. Trace quantities of blue-green apatite, allanite, muscovite and pyrite are sporadically. Notable are the high local concentrations of medium to coarse-grained apatite (up to 5 percent) as in Trenches 5 and 7. Such concentrations are generally associated with biotite-rich clots possibly of restite origin. In Trench 5 very sparse molybdenite flakes up to 5 mm diameter were noted. The major uranium-bearing phase is principally uraninite, as determined through X-ray diffraction work. Autoradiographs indicated that the uraninite occurrs as diminutive grains disseminated within biotite. Secondary uranium minerals are abundant as patches over most of the ridge, but achieve their highest concentration near Trenches 6 and 7.

Geochemistry

In Table 16-12, 52 petrochemical analyses for Ca0, K_20, Na_20, and Mg0 and lithophile trace elements Ba,, Be, Cs, Li, Nb, Rb, Sn, Sr, Ta, Th, and U are presented for the Umfreville Lake uranium occurrence as selected from all trenched areas in Figure 16-19.

Average U and Th values for samples are 52 ppm and 108 ppm, repectively, yielding one of the highest Th/U ratios of any uranium occurrence in the project area. Only metawacke and porphyritic biotite quartz monzonite from the Tourist Lake occurrence surpass this value.

The diatexitic host-rocks of this occurrence are not significantly fractionated (Figure 14-20) as revealed not only by average K/Rb, K/Ba, Ba/Rb and K/Cs (Table 16-4) with all ratios lying near or coinciding with average crustal values in Table 16-1, and differing in trend from the Davidson or Celyn Lake occurrences. Average abundances of Ba, Li, Rb and Sr also do not markedly deviate from the average crustal levels in Table 16-1. The K/Cs ratios (average K/Cs = 6,751 in Table 16-12) compares most closely with the "Low Grade" Zone of the Drope Township occurrence. This average ratio is not quite as fractionated, however, as the Celyn Lake occurrence, Drope Township High Grade Zone, or biotite-rich granodiorite at Tourist Lake. K/Cs ratios comprise two distinct fields in Figure 16-20, both which exhibit generally decreasing K/Cs with increasing Cs contents. The high-potassium field comprises rocks averaging approximately 5 percent K and a relatively greater variation in Cs content (1-50 ppm) than the low-potassium field which averages approximately 1 percent K and a more limited range in Cs (1-20 ppm).

Th/U ratios are mostly between 4 and 0.4 (Figure 16-21) and lie essentially parallel to the average Canadian Shield crust (Eade and Fahrig 1971 and Shaw et al. 1976). Enrichment of radiogenic elements in the diatexites most plausibly relates to metapelites containing anomalous levels of U and Th. The metapelite from Trench 1 (Table 16-13) contains U and Th levels respectively about 30 and 6 times above the average crustal

concentration

It was postulated earlier that the white diatexites crystallized under lower fO_2 conditions than the pink potassic granitoid suite rocks Lower fO_2 may account for the generally higher Th/U ratios for the Type I uranium pegmatites Thorium only exists in the tetravalent state and thus is commonly incorporated into primary, early magmatic minerals such as allanite, zircon, thorianite, etc (Rodgers and Adams, 1969a) Contrastingly uranium may exist in the +4 or +6 valence state (Rodgers and Adams, 1969b) and if fO_2 is relatively high in a pegmatitic magma then some oxidation to the hexavalent state is possible Subsequent incorporation of U^{6+} into the fluid phase of fractionating pegmatites would effect separation U from Th and hence cause deviation of Th/U ratios from normal Canadian Shield values of 4 to 6 The commonlly low Th/U ratios in Type II uranium pegmatites from the study area (e g , Figure 16-39, below) provide some support for this hypothesis Type I uranium pegmatites on the other hand have Th/U ratios which cluster near the average Canadian Shield values (Figure 16-21)

Mg and Li exhibit a well defined linear correlation somewhat similar to that described for the Davidson and Tourist Lake uranium occurrences (Figures 16-22) Although similar controlling mineralogical influence on Li abundances is present in the diatexite and the potassic granitoid suite rocks (i e , variation in modal biotite abundance), the average Mg/Li ratio from the Umfreville Lake occurrence is at least one order of magnitude higher than that of the Davidson occurrence (Table 16-16, below) Mg/Li ratios from the Umfreville Lake occurrence are closer to the average crustal value than any of the other occurrences with exception of the "High Grade" Zone from Drope Township (Table 16-15,

below) which has Mg/Li of 610

Holunga Uranium Occurrence

This uranium occurrence is located mainly along the shoreline of Davidson Lake commencing about 400 m east of the Manitoba-Ontario boundary The Werner Lake road allows access to Davidson Lake at a point just west of the trenches

Exploration History

The work of W Holunga represents the only development recorded to date, which consisted solely of 12 blast pits sporadically situated over 6 claims (K203386-203389 203390 203391 241979)

Geology

Uranium mineralization is situated within the same area of granitoid rocks mapped by Carlson (1955) as the Anderson showing (see below) On claim 241979 weak radioactivity is associated with very coarse-grained to pegmatitic, biotite quartz monzonite to granite (sensu stricto) hosted in a massive, medium- to coarse-grained, white (weathered surface) homogeneous diatexite unit This rock type is noticeably schlieritic and grades into the pegmatitic granite without any sign of abrupt contact relations Radioactivity mainly coincides with biotite which is invariably apparent as randomly oriented coarse clusters Secondary uranium minerals commonly coincide with the biotitic clusters Traces of pyrite and molybdenite the latter as individual grains and clusters, were also observed Hornblende-biotite metawacke enclaves are sparsely evident In the southwest portion of claim K203387, approximately 15 m of trenching perpendicular to the southern shore of Davidson Lake contained higher radioactivity (up to 450 cps,

This white to light pink (fresh surface) leucosome contains melanosome clots rich in medium-grained biotite and lies in contact striking at E15S and dipping 70 degrees north with fine-grained biotite metawacke. Secondary uranium minerals are locally present.

Anderson Uranium Occurrence

This property is generally located between Reynar Lake and the Werner Lake road, about 10 km east of Werner Lake (AFRO). The occurrence, however, could not be exactly located by the present survey.

Exploration History

The sole record of investigation of this radioactive zone was carried out by Mr. E. Anderson in 1969. Five Winkie diamond drill holes probed a 38m strike length on claim K 43996 and 43993 and encountered some interesting U_3O_8 values but over very narrow widths.

Geology

The occurrence is situated within a zone of granitoid rocks mapped by Carlson (1956) which appear to be dominantly diatexites based upon several scattered helicopter stops made by the present survey in this area. In the drill logs of E. Anderson (Diamond Drill Report, Assessment Files Research Office, Ministry of Natural Resources, Toronto) the rock types descriptions also appear to resemble those of metasedimentary migmatite.

Uranium is largely associated with white pegmatites, with the following assays reported:

Hole Number	U_3O_8 %	Width (m)

reported:

Hole Number	U_3O_8 %	Width (m)
2	0.05	0.6
4	0.10	0.45
5	0.07	0.30
5	0.04	0.30
5	0.03	0.60
6	0.15	0.60

In hole 3, a 0.31 m width of 0.11 percent U_3O_8 was reported in "pinkish" pegmatite. Three narrow sections of massive sulfide totalling 1.7 m were also intersected in Hole 1 conntaining chalcopyrite, assayed 0.09 to 0.12 percent Cu and traces of Ni (AFRO, Toronto).

Origin of the Type I uranium-bearing granitic pegnmatites

The following discussion postulates the origin of uranium concentrated in S-type granitic rocks of the study area. Prior to high grade metamorphism and attendant anatectic conditions, uranium-bearing horizons were possibly intermittently present within the sedimentary trough now represented by the northern metasedimentary migmatite domain. Initial mode of uranium concentration in this sedimentary environment is vaguely understood. However, it would appear that either detrital concentration of uranium minerals and/or absorption by clay minerals constitute plausible mechanisms controlling

original distribution of U and Th within the clastic metasedimentary basin. This absorption of U and Th is partially supported by high uranium content of some metapelites from the Umfreville Lake area (e.g., 30 ppm U and 25 ppm Th, Table 16-13. During anatexis of the wacke-pelite metasedimentary rocks at about 2.68 Ga (Krogh et al. 1976) this uranium was possibly released to ubiquitous minimum melt anatectic systems, now represented by the leucosome. In particular the Umfreville Lake, Davidson and some Sydney Lake Fault occurrences are situated very near the orthopyroxene isograd of the Umfreville-Conifer Lakes granulite zone. Such metamorphic conditions would imply relatively extensive partial melting and expulsion of lithophile elements such as U, Th, and Rb outwards to lower P-T areas. Although very little comparative data are available for these elements within and adjacent to this granulite centre, this possibility is however, suggested on basis of data from the Lake St. Joseph facies series (Table 16-10). Uranium shows a significant decrease in granulite zone metawackes and metapelites to levels one-third and two-thirds that of the medium grade lithic counterparts, respectively. Within these anatectic systems uranium complexes would be concentrated within the volatile-rich pegmatitic melts. Zones of potential mineralization of this type may be revealed by reconnaissance lithogeochemical programs particularly if airborne radiometric response is muted due to either heavy forest cover or relatively poor exposure.

Association of uranium mineralization with the diatexis stage of migmatization in the northern supracrustal domain may importantly render a vast belt, at least 1200 km in strike length, favorable for exploration consideration.

Uranium associated with the potassic granitoid suite

Several uranium occurrences of this association have been investigated during the past years (Pryslak, 1972; Beard 1977). The vast majority of known mineralization is situated in two areas (Figure 16-23):

1) along contact between English River and Wabigoon Subprovinces in Vermilion Bay-Willard Lake area (Vermilion Bay pegmatite field: Breaks 1982), and,
2) north of Kenora between Ena Lake and Umfreville Lake.

Several features serve to distinguish between host rocks of Type 1 and 2 uranium deposits, despite a gross similarity in that both type typically contain coarse-grained to pegmatitic, holo-leucocratic granitic rocks:

1. Type 2 deposits generally do not contain metasedimentary paleosome and melanosome constituents;
2. pink colours characterize host-rocks of Type 2 deposits whereas white is pervasive for granitic host-rocks of Type 1 deposits, and;
3. Type 2 granitic host-rocks lack the unusual accessories sillimanite, cordierite and garnet that distinguish in Type 1 host-rocks.

Most exploration activity has focused upon the Bruin Lake-Edison Lake area between Kenora and Vermilion Bay (Pryslak, 1972). Many of these occurrences appear geologically controlled by the northern, northeastern, and northwestern contact zones of the Dryberry Dome and Feist Lake pluton with supracrustal rocks of the Vermilion Bay metavolcanic belt. The deposit of New Campbell Island Mines Limited on Richard Lake represents the largest outlined to date, estimated at 650,000 tons grading 0.10 percent

U_3O_8 (Pryslak, 1972, p.46). The uranium minerals isolated from this deposit are uraninite, uranothorite, allanite and beta-uranotil (Robertson, 1968, p.58).

Celyn Lake Uranium Occurrence

As indicated in Figure 16-18, this uranium occurrence is situated between Celyn Lake and two smaller lakes lying approximately 1 km to the north. The mineralization is exposed in an area exhibiting a high percentage of outcrop and shallow overburden.

Exploration History

There is little record of uranium exploration in the Celyn Lake area although the base-metal occurrences have been investigated by C. Alcock in 1948. In 1976 Noranda Exploration Company Limited evaluated a zone of uraniferous granitic pegmatites, although several test pits had been previously established by an unknown party (L. Kaye, Noranda Exploration Co. Ltd., personal communication, 1976).

Geology

Uranium mineralization occurs in coarse-grained to pegmatitic granitic rocks of the Patterson Lake batholith, a mass contiguous to a north-striking contact with fine-grained, foliated to gneissic, amphibolitic mafic metavolcanic unit which is probably a remnant of the nearby Separation Lake belt (Figure 16-24). The amphibolites are severely deformed and banded with relatively open Z-folding of banding. The dominant granitic rock is a coarse-grained to pegmatitic biotite quartz monzonite. Highest radioactivity readings coincide with biotite-rich masses in this quartz monzonite as indicated by samples Trench

1-#2, Trench 2-#1 (Table 16-14).

Trenches along the western contact zone contain a porphyritic biotite-hornblende syenite as in samples Trench 1-#3, and Trench 2-#3. Phenocrysts of subhedral hornblende, mineral that is unusual for potassic granitoid suite rocks of the English River Subprovince, achieve a maximum diameter of 2.5 cm. These syenites may represent cumulate rocks as also may be the case for biotite syenites of the Tourist Lake uranium occurrence (see below). Such rock types were not encountered in trenches situated along the eastern contact area. Radioactivity associated with the syenite, however, was not especially high, as revealed by scintillometer readings taken by this survey.

The average of 11 samples arbitrarily selected from the trenches revealed mean U and Th of 768 ppm and 130 ppm, repectively and represents the highest average U grade and lowest Th/U ratio of any occurrence examined in the project area. In view of theses values, such aa occurrence may have potential as a future low grade deposit if substantial tonnages can be delineated. A detailed trenching and sampling program is required to establish surface dimensions of the uranium mineralization. It is interesting to note that the average grade of the Celyn Lake uranium occurrence more than twice exceeds that of the low grade Rossing deposit of Southwest Africa which is currently in production (average U = 325 ppm: MacMillan 1977). The Rossing deposit has been classified by some workers as the classical "porphyry" uranium deposit (Armstrong, 1974).

Geochemistry

In Table 16-14 partial major element analyses of the host-rocks for K_2O and MgO are presented in addition to selected lithophile trace elements. Overall the granitoid rocks

have been moderately fractionated (Figure 16-25) as indicated by fairly low K/Rb (mean = 141), K/U (mean = 418), K/Cs (mean = 3019), Ba/Rb (mean = 2.26) and K/Th (mean = 807). The biotite-hornblende syenite contains high K_2O and Ba (820-1320 ppm) resulting in the lowest K/Ba and highest Ba/Rb ratios. K/Rb, K/U and K/Th ratios are also clearly amongst the highest for the syenite. In terms of Ba/Rb, K/Ba, K/Cs, and K/Rb there appears to be two distinct populations of data, related to the dichotomy of granitoid rock types. The biotite quartz monzonite represents the most highly fractionated group, exhibiting the lowest K/Cs ratios found within any of the uranium-bearing pegmatites (range 231 - 6,142), K/Rb ratios below 150, Ba/Rb trending toward 0.44 and K/Ba near the average crustal ratio of 53. These rocks also contain the highest uranium contents, six values of which exceed 700 ppm. The anomalous trace concentrations of Be, Cs and Li are also notable in most samples. Sn shows high trace levels up to 45 ppm in 3 specimens. Mg/Li ratios in Figure 16-22, illustrate a unique trend of nearly constant Li with decreasing Mg, a trend clearly distinct from the Drope Township, Umfreville Lake, Davidson and Tourist Lake occurrences which exhibit a correlation marked by decreasing Li with decreasing Mg.

The important Th/U ratio indicates similarities between the Celyn Lake and Davidson occurrence. Both occurrences contain abnormally low, average Th/U ratios and a fractionation trend of U increasing at much greater rate than Th (Figures 16-26 and 16-39, below). Most analyses have Th/U (0.4-0.04) significantly removed from the average crustal ratio lines (Th/U = 4.2 and 6.2). The Celyn Lake field shows a tendency for much higher uranium abundances. These trends contrast dramatically with Type I

uranium mineralization which is derived from a crustal metasedimentary protolith as reapresented by the Umfreville Lake occurrence (Figure 16-21).

Drope Township Uranium Occurrence

Several radioactive coarse-grained to granitic pegmatite dykes are situated between Bluett and Gilbert Lakes in north-central Drope Township (Figures 16-27 and 16-28). Easiest access is by traversing for approximately 400m southwest from midway along from the Gilbert Lake-Bluett Lake portage. Secondary roads in highly variable condition lead to both Bluett and Gilbert Lakes.

Exploration History

Initial work was undertaken in 1968 by Conwest Exploration Company Limited which involved limited stripping, trenching, and diamond drilling (4 holes totalling 360.5 feet: Private File, Conwest Exploration Company Limited). Most of the investigation occurred on claim PA 38756. The claim group lapsed in 1970 and was subsequently staked by R. Knappet who optioned the property to Kirkland Townsite Gold Mines Limited.

In 1974 F.O.B. Mining Company staked the property (P. Palonen, Ministry of Natural Resources, London, Ontario, personal communication, 1977). Most recent record of ownership involved R. Fairservice, who staked the property in 1977 (R. Fairservice, Sioux Lookout, personal communication, 1977).

Geology

As indicated in Figure 16-27, this uranium occurrence is situated near the western limits of the Sioux Lookout metavolcanic-metasedimentary belt (Wabigoon Subprovince)

where interdigitating relations with the southern plutonic domain of the English River Subprovince are apparent. The mineralized area consists of several northeast-trending unzoned granitic pegmatite dykes emplaced in amphibolitic mafic metavolcanic host, varying in width from 3 to 18 m. Two particular dykes received the majority of exploration attention by Conwest Exploration Company Limited, designated by this firm as the "high-grade" and "low-grade" zones (Figure 16-28). Both of these granitic pegmatites are generally concordant to host-rock foliation although local discordances are most apparent with respect to the "high grade" zone pegmatite.

High Grade Zone : Two small pits about 1.3 m in depth have exposed uranium mineralization across a narrow pegmatite dyke averaging approximately 2.4 m in width (Figure 16-29). There appears some lateral zonation in the dominant granitoid rock type. In Pit 2, a medium to coarse-grained, allotriomorphic-granular, light-pink (fresh surface), holo-leucocratic albite trondhjemite is dominant, although highest radioactivity here is associated with a coarse-grained to pegmatitic, biotite, albite quartz monzonite. In Pit 3, about 6 m southwest, however, coarse-grained to pegmatitic biotite, albite quartz monzonite is the dominant rock type. Both rock types are allotriomorphic-granular and appear largely unrecrystallized. Coarse biotite aggregates tend to occur inhomogeneously distributed in the quartz monzonite. Scarce flakes and clusters of molybdenite also tend to be associated with this rock type. Weathering of fine-grained pyrite has resulted in local rusty patches, especially associated with "Pit 2 - maximum radioactivity" grab specimen". Diminutive fractures filled with hematite pervade both rock types. Highest radioactivity readings in this zone occurs proximal to the southeastern pegmatite-amphibolite contact.

In Pit 2, specimens from this study averaged 1197 ppm U and 1343 ppm Th over 0.6 m. A 0.9 m chip sample taken by Conwest Exploration Company Limited registered a similar value of 0.102 percent U_3O_8 (AFRO). U and Th analyses from Pit 3 were somewhat lower although the tendency towards higher values near the southeastern amphibolite contact is once again apparent. U and Th in this study respectively averaged 127.5 ppm and 77.5 ppm over a four foot interval along a section extending northwest from this contact (Table 16-15). Three diamond-drill holes of Conwest Exploration Company Limited probed a 15 m strike length of this dyke although no assay values on the core were reported (AFRO, Toronto). The uranium-bearing mineral was not isolated but is likely uraninite.

Low Grade Zone : This 21 m wide zone constitutes the largest uraniferous pegmatitic dyke delineated in the area and is situated about 72 m southeast of the high grade zone (Figure 16-30). The sole rock type is a holo-leucocratic pegmatitic, biotite, albite quartz monzonite which weathers to a light pink apparent on fresh surfaces. Allotriomorphic-granular textures prevail, with granophyric textures more obvious than is the case with the high grade zone. Most of the work undertaken by Conwest Exploration Company Limited was near a small pit exposing abundant, deep yellow coatings of secondary uranium mineralization on fracture surfaces. A bulk chip sample from the pit revealed only 34.5 ppm U and 25 ppm Th (Table 16-15). Semiquantitative U_3O_8 values of 0.02 and 0.03 percent were established on chip samples over 1.5m by Conwest Explorations Company Limited. A grab sample near this pit registered 17 ppm U and 30 ppm Th (Table 16-15).

Bluett-Gilbert Lakes Portage : Radioactivity readings of 2 to 10 times background was also encountered by this survey on this portage near the crest of a southwest trending ridge. A grab sample taken by Conwest Exploration Company limited from a 6m wide pegmatite registered 0.045% U_3O_8 (Private File, Conwest Explorations Company Limited). Less radioactive pegmatites occur immediately northwest of this dyke. One grab sample recorded only 7.4 ppm U and 25 ppm Th (Table 16-15).

Chemistry

In Table 16-15, partial major element analyses are presented for CaO, K_2O, Na_2O and MgO, accompanied by selected trace elements (Ba, Be, Cs, Li, Rb, Sn, Sr, Th and U). One of the prime chemical features is the alkaline character of the granitic rocks, marked by considerable range in Na/K ratios accompanied by generally very low CaO contents. Compared to the most other uraniferous pegmatites in the project area, the Drope Township pegmatites are relatively more fractionated (Table 16-4) especially in terms of K/Ba and Ba/Rb. Considering only the high-grade zone pegmatite, which represents the majority of data in Table 16-15, the relatively high degree of fractionation is indicated by the very low Ba/Rb, K/U and K/Th ratios. These values are only lower in the biotite-rich granodiorite unit at Tourist Lake. The K/Ba ratios of both zones are the highest of any of the uraniferous pegmatites studied and the majority of K/Ba, K/Cs, K/Rb and Ba/Rb ratios in Figure 14-31 lie considerably removed from their respective average crustal ratios (Table 16-1). Other indicators used to access magmatic fractionation such as Mg/Li and Th/U appear to be more enigmatic. In terms of Th/U (Figure 14-32), correlation between these elements, although removed from the average Canadian Shield

crustal ratio estimates of 4.2 to 6.2 (Table 16-1), nevertheless, bears resemblance to this ratio lines with no obvious departure towards excessive concentrations of U over Th as is the case with the Davidson occurrence, for example. Trend of Th vs U fractionation pattern greatly resembles that of the Umfreville Lake occurrence (Figure 16-21, above). Mg/Li ratios (Figure 16-22) depict the usual fractionation trend of decreasing Li with decreasing Mg accompanied by a mild departure from average crustal ratio in the more Mg-deficient rocks. The Drope Township uranium pegmatites are characterized by the lowest lithium contents of any uranium-bearing pegmatite studied, ranging from 3 ppm to 20 ppm, and invariably less than 10 ppm, slightly depleted relative to the average crustal abundance of 12 ppm (Heier and Billings 1972), Barium is also considerably depleted, particularly in the albite trondhjemite where it varies between 40 and 70 ppm. This results in a net concentration of Rb over Ba and the majority of Ba/Rb ratios thus lie clustered near a ratio about an order of magnitude lower than the average crustal value.

Origin of the Drope Township uranium-bearing pegmatites is uncertain at present, mainly due to a lack of petrochemical data from nearby granitic plutons which would enable one to constraint genetic hypotheses. Two extensive granitic masses could have engendered moderately fractionated uraniferous magmas:

1) Islay batholith, and, 2) Gullwing Lake batholith

Davidson Uranium Occurrence

This uranium zone is accessible by boat from Umfreville Lake. A short trail of 360 m from the southeastern end of a small bay leads to the trenched zone (Figure 16-18).

Exploration History

This property is termed the "Davidson Occurrence" in this report, named after the discoverer, P. Davidson, who initially staked the zone in 1954 (Resident Geologist's Files, MNDM, Kenora). In 1955, Mr. Davidson optioned the property to Pancer Exploration Limited. During 1968-70 activity resumed when Tudale Exploration Limited undertook trenching, sampling, ground scintillometer surveys and diamond drilling. The later investigation disclosed that radioactivity was concentrated in two main zones, approximately 390 m apart, both of which were trenched, sampled and probed by diamond drill holes (AFRO, Toronto):

1) No. 1 Zone - south-central portion of claim K 40681

2) No. 2 Zone - northeastern portion of claim K 40675

Ten holes totalling 920m were drilled in 1970. Seven holes (675 m) focused on the No.1 Zone at depth and the remaining three diamond drill holes (244 m) were examined the No.2 Zone. Location of these diamond drill holes could not be ascertained by the present survey. No record of exploration activity has been documented in recent years.

Geology

As indicated in Figure 16-18, the 0.5 by 1 km mineralized zone occurs within a pegmatitic granite mass emplaced within metasedimentary rocks and derived migmatites of the Northern Supracrustal Domain. The pegmatitic granite mass is marked by a distinct rise in topography due to its more resistant nature relative to the metasedimentary migmatites of the surrounding area. Local relief reaches approximately 15 m.

Figure 16-33 gives detailed geology and location of trenches and pits in the No. 1

Zone. The No. 2 Zone could not be located by this survey. Two distinct types of granitoid rocks are present in this zone, marked by a gradational contact which rendered it impossible to assess age relations. Trenches 1, 2, 3 and 4 are excavated in light-pink (weathered surface), to deep pink (fresh surface) medium-grained to pegmatitic biotite quartz monzonite to granite (sensu stricto). The granitic rocks surrounding Pits 1, 2, 3 and Trenches 5 and 6 also encompass this compositional and grain-size range but are distinctly porcellaneous white on weathered surface. Another distinctive feature is sporadic blue-grey K-feldspar which is common in leucosomes in the Northern Supracrustal Domain. Both granitoid rock units are generally massive although a weak foliation is intermittantly apparent. The foliation is likely related to a late period of weak cataclasis as revealed by protomylonitic fabric striking between 70 and 80 degrees.

Shallow plunging slickensides, varying from 5 to 30 degrees west, are subtly evident on biotite-rich aggregates. In th No.1 Zone, radioactivity is present over a strike width of at least 162 m and strike length of about 45 m with the northern limit covered by swampy ground. Highest radioactivity measurements correlate with granitoid samples containing greatest amount of biotite. X-ray diffraction studies on coarse-grained biotite separated from Trench 1 revealed the major uranium-bearing phase is uraninite. Eight consecutive 1.5 m chip samples taken by Mr. J.W. Campbell of Kerr Addition Mines Limited from trenches across the No.1 Zone in 1968 averaged 0.035 percent U_20_8 (range 0.002 to 0.077 percent). The highest U_3O_8 content of 0.065 percent over 4.5 m. A grab sample from the No.2 Zone described by Mr. Campbell as a "grey granite gneiss intruding metasediments" exhibited "much radioactivity across 60 feet". A grab sample selected

by Mr. Campbell from a 2.3 square metre trenched area yielded 0.38 percent U_3O_8, the highest value from the property (Private Kerr Addison Limited Files, Kenora, Ontario).

Trench 3 contains a fine-grained, light pinkish-grey (fresh surface), aplite containing meager amounts of fine-grained disseminated pyrite. Aplite also appears between Trenches 3 and 4 but in this area it contains lensic, magnetite-biotite streaks up to 2 cm by 4 cm. These aggregates consist mostly of magnetite and comprise about 5 percent of the rock. Radioactivity measurements over both aplite zones were very low. In Trench 4 local segregations of fine- to medium-grained apatite was notable.

Secondary uranium minerals were not conspicuously concentrated in the pink quartz monzonite to granite occupying the northern half of the No.1 Zone. Specks of such yellow mineral species are typically associated with the biotite-rich segregations.

Trenches and pits excavated in the white, biotite quartz monzonite to granite phase occupying the northern half of No.1 Zone contrastingly contain abundant yellow secondary uranium minerals which coat various fractures. Rare, lensic garnet-biotite aggregates occur in this unit could represent melanosome clots similar to those in leucosomes of metasedimentary migmatites of the northern domain. The accessory garnet represents a distinct feature unknown in the pink quartz monzonite unit.

Fine-grained, yellow-green sericite marks the surfaces of thin shears occurring in this part of the No. 1 Zone. In the No. 1 Zone it is possible that that two distinct, potassic granitoid magmatic systems were responsible to the petrographic diversity. Petrographic features of the pink quartz monzonite to granite zone suggest a relation with the pegmatitic affiliates of the potassic granitoid suite, which are extremely abundant to the

south of the property. The southern portion of this zone, on the other hand, compares more closely to leucosome derived through partial melting of metasedimentary rocks (diatexite stage of migmatization) which is common in the surrounding area of the Northern Supracrustal Domain. The main petrographic characteristics of the homogeneous diatexite unit at the Davidson occurrence are:

1) absence of aplite in leucosome of metasedimentary migmatite;
2) presence of garnet in melanosome clots in association with biotite;
3) presence of blue-grey K-feldspar;
4) presence of enclaves of metasedimentary rock;
5) presence of white colouration, virtually an universal feature of metasedimentary migmatite leucosomes in the English River Subprovince.

It would appear fortuitous that two distinct magmatic systems (i.e., originating from different source regions) would both be enriched in similar levels of U and Th at the present level of exposure. It may be possible that metasedimentary rocks in the area contiguous to the Patterson Lake batholith were initially enriched in these elements by sedimentary processes. Subsequently, under high grade to granulite P/T conditions, U and Th were scavenged by S type and I-type granitic magmas evolving in this thermal-tectonic regime. A metapelitic sample collected by Mr. H.L. King south of the No.1 Zone in 1970 exhibited moderately strong radioactivity, thus allowing some credence for high initial radiogenic element concentration in the metasedimentary rocks, although no analyses were undertaken on this specimen (H.L. King, former resident geologist, Kenora, personal communication, 1974).

Geochemistry

In Table 16-16, partial analyses for K_2O and MgO, and Ba, Be, Cs, Li, Rb, Sn, Th, and U are presented. The majority of these samples were selected at 0.6 and 1.5 m intervals in all major trenches across the No.1 Zone (Figure 16-33). Trench Plan profiles of variation in U, Th and K abundance (Figures 16-34 and 16-35) and K/Ba, K/Rb, K/U, Ba/Rb, Mg/Li and Th/U (Figures 16-36 and 16-37) are given for all trenches in this zone. General indices of fractionation such as K/Rb, K/Ba, Ba/Rb and Mg/Li are strikingly constant across the entire trenched section underlain by pink quartz monzonite. Th/U and K/U ratios, however, are characterized by "saw-tooth" style variation with no indication of any systematic pattern of magmatic fractionation. This erratic pattern also characterizes Th and U abundances, making it difficult to establish zones of uniform grade. The best mineralization in the No.1 Zone registered 205 ppm U and 33 ppm Th over 4.6m (Trench 4). Average Th/U of each trench indicates, however, a general pattern of decreasing values to the south (Figures 16-36 and 16-37).

The various ratios in Figure 16-38 generally do not indicate that the granitic rocks underwent extreme fractionation. Well defined fields in the K/Rb, K/Ba and Ba/Rb diagrams fall on or near average crustal values for these ratios. Evidence for some degree of differentiation is, however, apparent in K/Cs plots. Two cesium fractionation patterns are possible, both leading to K/Cs ratios approaching 1000 which is considerably lower than the average crustal ratio of 7000. The upper field involving of high K contents broadly shows increasing Cs at relatively constant K, although a minor bifurcation into a region of increasing Cs with decreasing K is apparent. The lower field again illustrates

increasing Cs at constant K.

When the two distinctive granitoid types are compared (Table 16-17) some striking differences emerge and indicate that the white, quartz monzonite homogeneous diatexite is more fractionated. This is especially indicated by the lower K/Rb, K/Th, K/U and Ba/Rb and higher K/Ba coupled with an average uranium content of 236 ppm, nearly twice that of the pink quartz monzonite zone. Th/U, K/Cs, and Mg/Li are marginally lower in the homogeneous diatexite. The highest grade section in the No.1 Zone established 292 ppm U and 37 ppm Th over 14m (Trench 6). Slope of the Th profile is generally very flat and not subjected to erratic fluctuation characteristic of Trenches 1 to 4.

Mg/Li ratios and lithium content also indicate a moderate level of fractionation. In Figure 16-22, Mg/Li ratios comprise a well defined, positive linear field situated well below the average crustal ratio of 1742. Li and Mg are mainly partitioned into the biotite structure, evidenced by fact the biotite separates contain highest levels of these elements in Figure 16-22, all other rocks show a progressive decrease in these elements whilst maintaining an essentially constant Mg/Li. As magmatic systems become more fractionated and ferromagnesian minerals decrease (represented only by biotite in the uranium pegmatites of the study area), less Li enters into the more siliceous residual compositions, as exemplified by the Umfreville Lake occurrence (Figure 16-40). This pattern contrasts strongly with that for spodumene pegmatites such as the Tot Lake occurrence (Figure 16-11). Lithium averages 54 ppm overall, more than four times that of the average crustal abundance of Heier and Billings (1972). A fairly wide range (3-300

ppm) is also apparent.

Tourist Lake Uranium Occurrence

The Tourist Lake uranium zone (Figure 16-18) commences approximately 610 m northeast of Tourist Lake and is readily accessible by a good 1500 m long trail which leads from the lake.

Exploration History

Initial work on this uranium property was undertaken in 1970 by Can-Fer Exploration Syndicate. This involved an integrated program of geological mapping (1 inch to 200 feet, detailed radiometric and magnetic surveys, extensive trenching (31 trenches), and limited diamond drilling (3 holes) totalling 45 m. Recently, in 1976, this 16 claim property was optioned to Consolidated Summit Mines by Huronian Mines which specifically involved further diamond drilling (R.C. Beard, Regional Geologist, Ministry of Natural Resources, 1976 personal communication).

Geology

The general geology is given in Figure 16-41 which subdivides the immediate area into three principal units:

1) metawacke;
2) white, porphyritic (K-feldspar) biotite quartz monzonite, and,
3) pink, inequigranular to porphyritic (K-feldspar) biotite quartz monzonite.

As shown in Figure 16-41, white porphyritic biotite quartz monzonite is confined to an elongate unit up to 3.3 km in breadth situated between Tourist Lake and a small unnamed

lake to the northeast. This rock type is coarsely porphyritic, hypidiomorphic-granular (Photo 16-13) and contains between 10 and 15 percent biotite. This unit contains two slender (less than 30 m width) foliated metawacke horizons which strike N45E to N80E. These fine-grained biotite-rich rocks weather rusty-brown to ochre, owing to the significant sulfide content. The metawacke is the oldest rock type and is injected by both pink and white quartz monzonite dykes. Sulfides consist mainly of pyrite and pyrrhotite which and sporadic chalcopyrite. Uranium mineralization is proximal to the contact zones of the northernmost metawacke horizon, along which the vast majority of trenches have been established. Although this zone is approximately 600 m in length, highest radioactivity is confined to the westernmost 240 m, as marked by the most intense trench development.

Minor units include fine-grained amphibolite which occurs intercalated with metawacke as in Trench D and medium to coarse-grained, mafic, quartz-rich, biotite granodiorite also occurring in the metawacke horizon. The latter rock is highly uraniferous and appears to have been the main stimulus for exploration in the area. Drilling from the Consolidated Summit Mines program intersected 15 cm band carrying a radioactive equivalent of 3 lb U_3O_8 per ton (R.C. Beard, Regional Geologist, Ministry of Natural Resources, personal communication, 1976), which probably came form the mafic unit. K-feldspar cumulate domains of syenite composition occur in the white porphyritic quartz monzonite and tend to contain slightly more uranium in comparison to their quartz-rich counterparts (Table 16-18). These syenites are also conspicuous petrochemically by virtue of high K and Ba and low Ca.

Geochemistry

Grab samples from all major units were selected from 5 different trenches within this part of the uranium zone and chemical data are presented in Table 16-18. All samples with exception of the amphibolite contain U values in excess of the average crustal abundance of 2.5 ppm. However, all rock types exclusive of the mafic, quartz-rich, biotite granodiorite contain uranium values that are far below even the average grade of the world's lowest grade uranium mine, i.e., Rossing deposit averaging 325 ppm U. Average uranium contents increase in the order: metawacke (9.0 ppm), white porphyritic quartz monzonite (12.5 ppm), white biotite syenite (23.5 ppm), pink quartz monzonite (40.9 ppm), mafic, biotite-rich granodiorite (675 ppm) although the hiatus between the latter and other rock types is considerable.

In terms of most interelement ratios in Table 16-18, the mafic granodiorite demonstrates differences compared to all other rock types and exhibits modest fractionation with respect to K/Rb, K/Ba, K/Cs, Ba/Rb (Figure 16-42), K/U and K/Th. The fractionation of the remaining rock types from this property is towards Th concentration at greater rate than U resulting in Th/U exceeding unity and lying close to average crustal ratio of 4 (Figure 16-42, Table 16-1). Interestingly, the mafic granodiorite exhibits an opposite fractionation pattern, with a mean Th/U = 0.50. In Figure 16-42 K/Rb, K/Ba, K/Cs and Ba/Rb ratios demonstrate that the mafic granodiorite bears the closest relationship to the metawacke field. This situation is, however, not apparent in the Th vs U or Mg vs Li diagrams (Figures 16-43 and 16-22).

Cameron-Alcock Occurrence

This uranium occurrence is located near the western end of a small unnamed lake four miles north of Ena (Figure 16-44).

Exploration History

The showing was first reported by Chisholm (1950) and subsequently has been known as the Cameron - Alcock Occurrence (Robertson 1968, p.60-61). M.Y. Cameron and C. Alcock excavated some pits in 1952 (Ontario Geological Survey Mineral Deposit Files, Toronto).

Geology

Radioactive quartz monzonite to granite pegmatitic dykes occur in pillowed amphibolitic mafic metavolcanic rocks near the eastern contact with granitoid rocks of the Tetu batholith (Figure 16-44). According the Chisholm (1950, p.2), the radioactivity exhibits a patchy distribution in a 3m wide dike with a chemical assay registering 0.14 percent U_3O_8. Monazite is the chief radioactive mineral, augmented by small quantitites of uraninite (Chisholm, 1950, p.2). Sporadic molybdenite is also apparent.

Perch Lake Occurrence

This radioactive occurrence is situated near the western shore of Perch Lake which is accessible via portages from Sand Lake or Ena Lake.

Exploration History

The party responsible for the limited amount of developmental work (several small

blast pits) is unknown but may have been J. Zivyone who investigated sulfide occurrences in the area (AFRO, Toronto).

Geology

The main area of radioactivity is situated a short distance west of Perch Lake (Figure 14-44) and adjacent to the eastern extremity of the Vermilion Lake - Perch Lake mafic metavolcanic enclave. Uranium mineralization occurs in massive, holo-leucocratic, coarse-grained, inequigranular granite to quartz monzonite possibly consanguineous with the Lount Lake batholith.

Geochemistry

Chemical analyses of 2 grab samples representative of typical radioactive material are shown in Table 16-19. General similarities to the Ena Lake occurrence are evident, with exception of higher Ba/Rb, higher average U and Th lower K/Ba in the Perch Lake rocks.

Ena Lake Occurrence

This occurrence is readily accessible by boat from Ena Lake. A well maintained secondary road leads to Ena Lake from the Redditt-Kenora Highway. The trenched area is a short distance northeast of Ena Lake (Figure 16-44).

Exploration History

In 1967 Headvue Mines Limited carried out an airborne radiometric survey between Ena Lake and Vermilion Lake covering the No.1 showing only. A ground magnetometer survey was also undertaken by this company (AFRO, Toronto). The relatively recent trenches and blast pits were possibly undertaken by this firm, although no record of this

excavation activity is available.

Geology

Uranium mineralization is situated along the southwest contact of a curvate enclave of pillowed, amphibolitic mafic metavolcanic rocks. A series of 5 shallow blast pits appear to have been excavated in radioactive granitic rocks over an interval 65m parallel to the amphibolitic contact. The granitic rocks consist of a coarse-grained to pegmatitic derivative of fine to medium-grained, inequigranular, massive biotite granite to quartz monzonite. Enclaves of amphibolite in the radioactive zone are sparse (less than 1 percent) and strike N50E to N55E and dip vertically. Proceeding towards the uranium zone, the grain size becomes perceptibly coarser and is marked by an abundance of pegmatitic "pools" possessing gradational contacts with its medium-grained host. Highest radioactivity coincided with coarse-grained irregular patches containing magnetite and biotite. Magnetite grains vary up to 5 cm diameter. Biotite books oriented at random are also conspicuously evident. Light blue quartz is a characteristic feature in the pegmatitic patches.

Secondary uranium minerals are especially evident in Trench 3, coating fracture surfaces.

Geochemistry

Three grab samples of highest radioactivity were analyzed for major elements and selected trace elements in Table 16-19. These rocks record a moderate degree of fractionation as indicated by the low Ba/Rb, Mg/Li, Th/U, K/U and K/Th and relatively high K/Ba and Rb/Sr. The K/Rb ratios, however, lie within normal crustal limits. Source of the

U-Th-rich magma was most likely the Tetu Lake batholith (Figure 16-44), which borders the entire western contact of the Vermilion Lake - Ena Lake mafic metavolcanic enclave.

MINERALIZATION OF THE CHALCOPHILE AFFINITY

Mineralization exhibiting chalcophile affinities in the English River Subprovince are relatively scarce, mainly related to a paucity of sulfur-rich host-rocks of mafic to ultramafic composition. Metasedimentary migmatite of the northern domain only rarely contain sulfide minerals, mainly as pyrite in disseminated concentrations as on Pakwash, Delesepps and Wegg Lakes. The more important occurrences of chalcophile mineralization are listed below:

1) Cu-Ni-Co-PGE in metaperidotite at Werner Lake (Carlson 1957).
2) Cu-Ni-Mo in mafic metavolcanic rocks, Bury-Moose Lakes area (Hudec 1965)
3) Zn-Au in mafic metavolcanic rocks, Umfreville Lake (Thompson,1947).
4) Cu-Ni in mafic intrusive rocks near Redditt (Shklanka 1969).
5) pyrite deposit at Vermilion Lake ("Minaki Pyrite Mine")
6) massive sulfide deposit near Ryerson Lake.

The first four properties have been adequately described in the designated references and will not be mentioned further.

MASSIVE SULPHIDE MINERALIZATION

Minaki Pyrite Deposit

This deposit is located near the eastern termination of a 600 m portage between.

Sand Lake and Vermilion Lake (Figure 14-44). Access may also be gained through the Ena Lake - Vermilion Lake portage. A well maintained secondary road leads west to Ena Lake from the Kenora - Redditt Highway.

Exploration History

This deposit has been termed the "Minaki Pyrite Mine" even though no record of production exists (Private File, Kerr Addison Mining Company Limited). Most of the ensuing text has been extracted from this report. The only record of development was that undertaken by the Minaki Mining and Development Company in 1937. This program involved excavation of 22 deep pits plus a few shallow trenches, 26 diamond drill holes, an adit driven 27m. A large bulk unspecified size was selected from an open cut and shipped via railway. Main development of the deposit focused on a section having a strike length of about 300 m. The diamond drill program mainly evaluated mineralization to a 75 m depth although one vertical hole of 122m was terminated still within an apparent excellent grade of material. No record of diamond drill location, description of core material or geological sections are available on the work performed by Minaki Mini Mining and Development Company as this activity preceeded the time it was mandatory to submit such records for assessment work credits. An estimate of 1,432,400 tons to the 75 m depth was given by this company (Private File, Kerr Addison Mining Company Limited).

Geology

Massive sulfide mineralization occurs in pillowed, amphibolitic mafic metavolcanic rocks of the Vermilion Lake - Perch Lake enclave (Figure 14-44). The actual mineralized

zone is highly conspicuous due to a deep red residual soil, at least 7.5 m in depth. No doubt presence of this gossan was responsible for the naming of Vermilion Lake and may have once served as a source paint pigment for native peoples residing in the area. The deposit is bounded along the south by pink, porphyritic biotite quartz monzonite, typical of the material exposed along the shoreline of Vermilion Lake and perhaps related to the Tetu Lake batholith.

The massive sulfide consists mostly of pyrite, accompanied by minor pyrrhotite. Low amounts of gold and silver were detected in grab samples analyzed by the Geoscience Laboratory of the Ontario Geological Survey:

	Au[1]	Ag[1]	Cu[2]	Ni[2]
Grab #1	0.01	0.10	ND	ND
Grab #2	0.02	0.50	ND	ND
Grab #3	Nil	Trace	0.05	0.01

1 = ounces per ton; 2 = in weight percent ND = not determined

An error has been made in the page numbering of this report. Although page numbers 412 to 418 are missing, no text or information is missing. The references should have started on page 412.

REFERENCES

A.G.I. Glossary of Geology

1973: American Geological Institute, Washington, 1973 edition.

Anderson, J.L. and Cullers, R.L.

1978: Geochemistry and evolution of the Wolf River batholith, a Late Precambrian rapakivi massif in North Wisconsin, U.S.A.; Precambrian Research, **7**, 287-324.

Althaus, E., Nitsch, K.H., Karotke, E., and Winkler, H.G.F.

1970: An experimental re-examination of the upper stability limit of muscovite plus quartz; Neues Jahrbuch fur Mineralogie Monatshefe No.7, 325-336.

Anhaeusser, C.R.

1973: The evolution of the Precambrian crust of southern Africa, Philosophical Transactions Royal Society of London, A, **273**, 359-388.

Anhaeusser, C.R., Mason, R., Viljoen, M.J. and Viljoen, R.P.

1969: A reappraisal of some aspects of Precambrian shield geology, Geological Society of America Bulletin **80**, 2175-2200.

Archibald, C.W.

1970: Summary report on Copper-Lode Mines Limited, Red Lake-Uchi Lake area, Resident Geologist's Files, Red Lake, Ontario, 8p.

Archibald, N.J.; Bettenay, L.F., Binns, R.A., Groves, D.I. and R.J. Gunthorpe

1978: The evolution of Archean greenstone terrains, eastern

Goldfields Province, Western Australia; Precambrian Research, **6**, 103-131.

Armstrong, H.S.

1950: Geology of Echo Township; Ontario Department of Mines, **59**, Part 5, 1-40.

Arth, J.G.

1976: Behavior of trace elements during magmatic processes - a summary of theoretical models and their applications; Journal of Research, United States Geological Survey, **4**, 41-47.

Arth, J.G. and Hanson, G.N.

1972: Quartz diorites derived by partial melting of eclogite or amphibolite at mantle depths; Contributions to Mineralogy and Petrology **37**, 161-174.

Arth, J.G., Barker, F., Peterman, Z.E., and Friedman, I.

1978: Geochemistry of the gabbro-diorite-tonalite-trondhjemite suite of southwest Finland and its implication for the origin of tonalitic and trondhjemitic magmas; Jounrnal of Petrology **19**, Part 2, 289-316.

Ayres, L.D.

1972: Guide to granitic rock nomenclature used in reports of the Ontario Division of Mines; Ontario Division of Mines, Miscellaneous Paper 52, 14p.

1974: Geology of the Trout Lake area, District of Kenora (Patricia Portion); Ontario Division of Mines Geological Report 113, 197p.

1978: Metamorphism in the Superior Province of northwestern Ontario and its relationship to crustal development; **in** Metamorphism in the Canadian Shield, Geological Survey of Canada Paper 78-10, 25-36.

Bailes, A.H.

1978: The transition from low to high grade metamorphism in the Kisseynew sedimentary gneiss belt, Manitoba; **in** Metamorphism in the Canadian Shield, Geological Survey of Canada Paper 78-10, 155-177.

Bailey, J.C.

1977: Fluorine in granitic rocks and melts: a review; Chemical Geology **19**, 1-42.

Balk, R.

1937: Structural behavior of igneous rocks (with special reference to interpretation by H. Closs and collaborators), Geological Society of America Memoir 5, 177p.

Baragar, W.R.A. and Goodwin, A.M.

1969: Andesites and Archean volcanism of the Canadian Shield; **in** Proceedings of the Andesite Conference, Oregon Department of Mineral Industries Bulletin **65**, 121-142.

Barker, F. and Arth, J.G.

1976: Generation of trondhjemite-tonalitic liquids and Archean bimodal trondhjemite-basalt series; Geology **4**, No.10, 596-600.

Barker, F., Arth, J.G., Peterman, Z.E. and Friedman, I.

1976: The 1.7-1.8 b.y. old trondhjemites of southwestern Colorado and northern New Mexico: geochemistry and depth of genesis; Geological Society of America Bulletin **87**, 189-198.

Barlow, R.B., Wadge, D.R. and Dusanowskyj, T.H.

1975: Bouguer gravity map of the Sturgeon Lake area, Districts of Kenora and Thunder Bay; Ontario Division of Mines, Preliminary Map P. 1050.

Barth, T.F.W.

1952: Theoretical Petrology; John Wiley and Sons, New York, 387p.

Bartlett, J.

1978: Metamorphic trends in the metasedimentary rocks north of Eagle Lake, Ontario; unpubl. B.Sc. thesis, Universituy of Western Ontario, London, Ontario, 92p.

Bateman, P.C. and Dodge, F.C.W.

1970: Variations of major chemical constituents across the central Sierra Nevada batholith; Geological Society of America Bulletin **81**, 419-420.

Bateman, J.D.

1939: Geology and gold deposits of the Uchi-Slate Lakes area; Ontario Department of Mines **48**, pt.8, 1-43.

Bau, A.S.

1975: Structures in the Kashabowie-Upsala region, northwest Ontario; **in** 1975 Superior Geotraverse Conference Proceedings, University of Toronto, 258p

Beakhouse, G.P.

1974: Geology of the Pakwash Lake area, northwestern Ontario; **in** 1974 Annual Report of the Centre for Precambrian Studies, University of Manitoba, Part 2 Research, 240-245.

1975: The English River Subprovince; **in** 1975 Annual Report for the Centre for Precambrian Studies, University of Manitoba, Part 2 Research, Paper 11, 51-66.

1977: A subdivision of the western English River Subprovince; Canadian Journal of Earth Sciences **14**, 1481-1489.

1983: Geological, geochemical, and Rb-Sr and U-Pb zircon geochronological investigatioins of granitoid rocks from the Winnipeg River Belt, northwestern Ontario and southeastern Manitoba; unpublished Ph.D. thesis, McMaster University, Hamilton, Ontario.

Beakhouse, G.P. and McNutt, R.H.

1980: Rb-Sr isotopic systematics of granitoid rocks from the English River Subprovince at Redditt, N.W. Ontario; **in** 1980 Meeting, Geological Association of Canada, Program with Abstracts **5**, 48.

1991: Contrasting types of Late Archean rocks in northwestern Ontario: implications for crustal evolution in the Superior Province; Precambrian Research **49**, 141-165.

Beakhouse, G.P., McNutt, R.H. and Krogh, T.E.

1988: Comparative Rb-Sr and U-Pb zircon geochronology of late- to post-tectonic plutons in the Winnipeg River belt, northwestern Ontario, Canada; Chemical Geology (Isotope Geology Section) **72**, 337-351.

Beard, R.C.

1977: Uranium deposits of the Kenora area; **in** Proceedings of the 23rd Annual Institute on Lake Superior Geology, 53p.

Beard, R.C. and Garratt, G.L.

1976: Gold deposits of the Kenora-Fort Frances Area, Districts of Kenora and Rainy River; Ontario Division of Mines, Mineral Deposit Circular 16, 46p.

Bell, R.

1873: Report on the country between Lake Superior and Lake Winnipeg, Geological Survey of Canada, Report of Progress, 1872-1873, 87-111.

Berner, R.

1970: Abundance of iron in common sediments and sedimentary rock types; **in** Handbook of Geochemistry, Springer-Verlag, New York, p.26-K-1 to 26K-4.

Beus, A.A.

1960: Geochemistry of beryllium and genetic types of beryllium deposits; Academy of Science of the U.S.S.R., Moscow, English Translation (1966), Freeman and Company, 401p.

Bickle, M.J. Martin, A. and Nesbet, E.G.

1975: Basaltic and peridotitic komatiites and stromatolites above a basal unconformity in the Belingue greenstone belt, Rhodesia; Earth and Planetary Science Letters **27**, 155-162.

Binns, R.A.

1969: Hydrothermal investigations of the amphibolite-granulite

facies boundary; Geological Society of Australia Special Volume 2, 341-344.

Blackburn, C.E., Trowell, N.F., Edwards, G.R.

1978: Bilateral symmetry of Archean volcano-sedimentary sequences, western Wabigoon belt, Ontario; 1978 Annual Meeting, Geological Association of Canada-Mineralogical Association of Canada-Geological Society of America, Program with Abstracts **?**,

Blackburn, C.E., Breaks, F.W., Edwards, G.R., Poulsen, K.H., Trowell, N.F. and Wood, J.

1982: Stratigraphy and structure of the western Wabigoon Subprovince and its margins, northwestern Ontario; 1982 Meeting of Geological Association of Canada-Mineralogical Association of Canada, Field Trip Guidebook 3, 105p.

Blue, Archibald

1893: The gold fields of Ontario; Ontario Bureau of Mines, **3**, 11-61.

Bohse, H., Rose-Hansen, J., Sorensen, H., Steenfelt, A., Lovborg, L. and Kunzendorf, H.

1974: On the behavior of uranium during crystallization of magmas with special emphasis on alkaline magmas; **in** Formation of Uranium Ore Deposits, International Atomic Energy Agency Proceedings, Series No. ST1/- Pub 374, 49-60.

Bond, W.D.

1971: Geology of McCubbin, Poisson and McGillis Townships

(Savant Lake Area), District of Thunder Bay; **in** Ontario Department of Mines and Northern Affairs Miscellaneous Paper 49, 36-41.

1972: Conant, Jutten and Smye Townships (Savant Lake Area), District of Thunder Bay; **in** Ontario Division of Mines Miscellaneous Paper 53, 38-43.

1973: Houghton-Hough Lakes Area (Savant Lake Area), District of Thunder Bay;**in** Ontario Division of Mines Miscellaneous Paper 56, 25-31.

1975: Geology of McCubbin, Poisson and McGillis Townships (Savant Lake Area), District of Thunder Bay; Ontario Division of Mines Open File Report 5120, 168p.

1976: Geology of Conant, Jutten, and Smye Townships (Savant Lake Area), District of Thunder Bay; Ontario Division of Mines Open File Report 5213, 186p.

1977: The Geology of McCubbin, Poisson and McGillis Townships (Savant Lake Area), District of Thunder Bay; Ontario Division of Mines Geological Report 160, 78p.

1978a: Regional geological synthesis of the English River Subprovince, a high grade Archean gneissic belt. Part II The Southern Plutonic Domain; **in** Program with Abstracts, 1978 Joint Annual Meeting, Geological Association of Canada-Mineralogical Association of Canada-Geological Society of America, Program with Abstracts **Vol. ?, P. ?**

1978b: Geology of the Houghton-Hough Lakes area, District of Thunder Bay; Ontario Geological Survey Open File Report

5237, 192p.

1979: Geology of Conant, Jutten and Smye Townships (Savant Lake Area), District of Thunder Bay; Ontario Geological Survey Report 182, 113p.

Bond, W.D. and Breaks, F,W,

1978: Ground evaluation of airborne radiometric anomalies in northwestern Ontario; **in** Ontario Geological Survey Miscellaneous Paper 82, 22-27.

Boone, G.M. and Wheeler, E.P.

1968: Staining for cordierite and feldspars in thin section; American Mineralogist **53**, 327-331.

Bowen, R.P.

1989: Geology of the Slate Lake area, District of Kenora; Ontario Geological Survey Report 256, 82p.

Breaks, F.W.

1979: Lithophile mineralization in northwestern Ontario, rare-element granitoid pegmatites, **in** Ontario Geological Survey Miscellaneous Paper 90, 5-7.

1980: Lithophile mineralization in northwestern Ontario:rare-element granitoid pegmatites; **in** Ontario Geological Survey Miscellaneous Paper 96, 5-9.

1982: Uraniferous granitoid rocks from the Superior Province of northwestern Ontario; **in** Uranium in Granites, Geological Survey of Canada, Paper 81-23, 61-70.

1983: Lithophile mineralization in the Dryden Pegmatite Field;

Ontario Geological Survey Miscellaneous Paper 116, 15-20.

1989: Origin and evolution of peraluminous granite and rare-element pegmatite in the Dryden area, Superior Province of northwestern Ontario; unpubl. Ph.D. thesis, Carleton University, Ottawa, 594p.

Breaks, F.W., Bond, W.D., McWilliams, G.H. and Gower, G.

1974: Operation Kenora-Sydney Lake, District of Kenora; **in** in Ontario Division of Mines Miscellaneous Paper 59, 17-36.

Breaks, F.W., Bond, W.D., McWilliams, G.H., Gower, C.F., Findlay, D. and Stone, D.

1975a: Eagle-Sydney Lakes Sheet, Operation Kenora-Sydney Lake; Ontario Division of Mines Preliminary Map P1026.

1975b: Pakwash-Longlegged Lakes Sheet, Operation Kenora-Sydney Lake; Ontario Division of Mines Preliminary Map P.1027.

1975c: Umfreville-Separation Lakes Sheet, Operation Kenora-Sydney Lake; Ontario Division of Mines Preliminary Map P.1028.

1975d: Oak-Indian Lakes Sheet, Operation Kenora-Sydney Lake; Ontario Division of Mines Preliminary Map P.1029.

1975e: Kenora-Minaki Sheet, Operation Kenora-Sydney Lake; Ontario Division of Mines Preliminry Map P.1030.

1975f: Gordon-Big Canyon Lakes Sheet, Operation Kenora-Sydney Lake; Ontario Division of Mines, Preliminary Map P.1031.

Breaks, F.W. and Bond, W.D.

1976: Operation Miniss-Tully Lakes, District of Kenora; **in** Ontario Division of Mines Miscellaneous Paper 67, 17-36.

1977: English River Subprovince (Marchington Lake area), District of Kenora; **in** Ontario Geological Survey Miscellaneous Paper 75, 16-75.

1977: Manifestations of recent reconnaissance investigations in the English River Subprovince, northwestern Ontario; Proceedings 1977 Geotraverse Conference, University of Toronto, 170-211.

Breaks, F.W., Bond, W.D., Harris, N., and Westerman, C.

1975: Operation Kenora-Ear Falls, District of Kenora; **in** Ontario Division of Mines Miscellaneous Paper 63, 19-33.

Breaks, F.W., Bond, W.D., Harris, N., Westerman, C.J., Stone, D., and Desnoyers, D.W.

1976a: Bruce-Bluffy Lakes Sheet, Operation-Kenora Ear Falls; Ontario Division of Mines Preliminary Map P.1199.

1976b: Papaonga-Wapesi Lakes Sheet, Operation-Kenora Ear Falls; Ontario Division of Mines Preliminary Map P.1200.

1976c: Perrault Lake Sheet, Operation-Kenora Ear Falls; Ontario Division of Mines Preliminary Map P.1201.

1976d: Operation Kenora-Ear Falls, Lac Seul Sheet, District of Kenora; Ontario Division of Mines Preliminary Map P.1202.

1976e: Dryden-Vermilion Bay Sheet, Operation-Kenora Ear Falls; Ontario Division of Mines Preliminary Map P.1203, scale 1

1976f: Sandy Beach-Route Lakes Sheet, Operation-Kenora Ear Falls; Ontario Division of Mines Preliminary Map P.1204,

Breaks, F.W., Bond, W.D., and Stone, D.

1978a: Preliminary geological synthesis of the English River

Subprovince, northwestern Ontario and its bearing upon mineral exploration; Ontario Geological Survey Miscellaneous Paper 72, 55p.

1981: Precambrian geology of the English River-Marchington Lake area, Kenora District (Patricia Portion); Ontario Geological Survey Preliminary Map P. 2293.

Breaks, F.W., Bond, W.D. Bartlett, J.R. and Facca, F.

1978b: The English River Subprovince, An Archean Gneissic Belt. Its Characteristics and Associated Mineral Deposits; 1978 Joint Annual Meeting, Geological Association of Canada-Mineralogical Association of Canada-Geological Society of America Field Trips Guidebook, 220-236. A.L. Currie and W.O. Mackasey, p.220-236.

Breaks, F.W., Bond, W.D., Stone, D. and Desnoyers, D.W.

1979a: Root Lake Sheet, Operation Miniss-Tully Lakes; Ontario Geological Survey Preliminary Map P.2215.

1979b: Miniss Lake Sheet, Operation Miniss-Tully Lakes, Ontario Geological Survey Preliminary Map P.2216.

1979c: Chamberlain Narrows (Lac Seul) Sheet, Operation Miniss-Tully Lakes; Ontario Geological Survey Preliminary Map P.2217.

1979d: Hooker-Fitchie Lakes Sheet, Operation Miniss-Tully Lakes; Ontario Geological Survey, Preliminary Map P.2218.

Bridgewater, D. and Collerson, K.

1976: The major petrolaogical and geochemical characteristics of

the 3,600 m.y. Uivak gneisses from Labrador; Contributions to Mineralogy and Petrology **54**, 43-59.

Bridgwater, D., Watson, Janet, and Windley, B.F.

1973: The Archean craton of the North Atlantic region; Philosophical Transactions of the Royal Society of London **A273**, 493-512.

Brindley, J.C.

1973: Some aspects of batholithic intrusion; Geological Society of South Africa Special Publication 3, 35-44.

Brisbin, W.C.

1975: Granitic diapirism and deformation in the Superior Province, northwestern Ontario; Geological Society of America Meeting, Program with Abstracts **7**, No.6, 726.

Brown, M.

1973: The definition of metatexis, diatexis and migmatites; Proceedings of the Geological Association **84**, 371-382.

Bruce, E.L.

1922a: Iron formation of Lake St. Joseph; Ontario Department of Mines **31**, pt.8, 1-32.

1922b: Eastern part of Lake St. Joseph; Ontario Department of Mines **31**, pt.8, 33-38.

1922c: Area south of the west end of Lake St. Joseph; Ontario Dept. Mines **31**, pt.8, 39-40.

1924: Geology of the upper part of the English River valley; Ontario Department of Mines **33**, pt.4, 1-11.

Burnol, L.

1974: Association des caracteristiques et l'evolution petrographiques et geochemiques des leucogranites de la partie nord-ouest du Massif central francais avec les differents types de concentration en W, Be, Li etain et niobium-tantale; **in** Metallization Associated with Acid Magmatism, Geological Survey, Prague, 237-248.

Burwash, E.M.

1920: A geological reconnaissance into Patricia; Ontario Department of Mines **29**, part 1, 157-192.

1921: Geology of Ontario-Manitoba boundary, Winnipeg River to Bloodvein River; Ontario Department of Mines **32**, part 2, 1-48.

Butler, J.R.

1969: Origin of Precambrian granite gneiss in the Beartooth Mountains, Montana and Wyoming; **in** Igneous and Metamorphic Geology, Geological Society of America Memoir, 73-101.

Caby, R., Dostal, J and Dupuy, C.

1977: Upper Proterozoic volcanic greywackes from the northwestern Hoggar (Algeria) - geology and geochemistry; Precambrian Research **5**, 283-297.

Cameron, E.N., Jahns, R.H., McNair, A.H. and Page, L.R.

1949: Internal structure of granitic pegmatites; Economic Geology Monograph 2, 115p.

Campbell, F.H.A.

1971: Stratigraphy and sedimentation of part of the Rice Lake

Group, Manitoba; unpublished Ph.D. thesis, Universtiy of Manitoba, Winnipeg, Manitoba.

Cann, J.R.

1970: Upward movement of granitic magma; Geological Magazine **107**, 335-340.

Card, K.D. and Ciesielski, A.

1986: DNAG #1. Subdivisions of the Superior Province of the Canadian Shield; Geoscience Canada **13**, 5-13.

Carlson, H.O.

1957: Geology of the Werner Lake-Rex Lake area; Ontario Department of Mines **66**, part 4, 30p.

Cerny, P.

1989: Characteristics of pegmatite deposits of tantalum; **in** Lanthanides, Tantalum and Niobium, Springer-Verlag, Berlin, 192-236.

Cerny, P. and Turnock, A.C.

1971: Pegmatites of southeastern Manitoba; Geological Association of Canada Special Paper 9, 119-127.

Cerny, P and Turnock, A.C.

1975: Beryl from granitic pegmatites at Greer Lake, southeastern Manitoba; Canadian Mineralogist **13**, 55-61.

Cerny, P. and Trueman, D.L.

1978: Distribution and petrogenesis of lithium pegmatites in the western Superior Province of the Canadian Shield; Energy **3**, 365-377.

Cerny, P., Trueman, D.L., Ziehlke, D.V. Goad, B.E. and Paul, B.J.

1981: The Cat Lake-Winnipeg River and the Wekusko Lake Pegmatite Fields, Manitoba; Manitoba Department of Energy and Mines Economic Geology Report ER80-1, 216p.

Chappell, B.W.

1978: Granitoids from the Moqnbi district, New England batholith, eastern Australia; Geological Society of Australia Journal **25**, part 5, 267-283.

Chappell, B.W.

1979: Granites as images of their source rocks; 1979 Annual Meeting Geological Society of America Abstracts with Programs **11**, No.7, 400.

Chappell, B.W. and White A.J.R.

1974: Twp contrasting granite types; Pacific Geology **8**, 173-174.

Chappell, B.W, White, A.J.R and Wyborn, D.

1987: The importance of source material (restite) in granite petrogenesis; Journal of Petrology **28**, 1111-1138.

Chinnery, M.A.

1966: Theory of secondary faulting; Canadian Journal of Earth Sciences **3**, 163-174.

Chisholm, E.O.

1950: Preliminary report on radioactive occurrences in the Kenora area; Ontario Department of Mines Preliminary Report 1950-1, 5p.

Chorlton, L.D. and Martin, R.F.

1978: The effect of boron on the granite solidus; Canadian Mineralogist **16**, 239-244.

Claffy, E.W.

1953: Composition, tenebrescence, and luminescence of spodumene minerals; American Mineralogist **38**, 919-931.

Clark, G.S., Bald, R. and Ayres, L.D.

1981: Geochronology of orthogneiss adjacent to the Archean Lake of the Woods greenstone belt, northwestern Ontario: a possible basement complex; Canadian Journal of Earth Sciences **18**, 94-102.

Clifford, P.M.

1969: Geology of the western Lake St. Joseph area, Districts of Kenora and Thunder Bay; Ontario Department of Mines Geological Report 70, 61p.

Clifford, P.M. and McNutt, R.H.

1971: Evolution of Mount St. Joseph - an Archean volcano; Canadian Journal of Earth Sciences **8**, 150-161.

Closs, L.F. and Colvine, A.C.

1975: Geology and geochemistry of pyritic and graphitic volcanogenic sediments and their relationships to massive sulphide deposits; Ontario Division of Mines Miscellaneous Paper 63, 146-149.

1976: Geology and geochemistry of pyritic and graphitic volcanogenic sediments and their relationship to massive sulphide deposits; Ontario Division of Mines Miscellaneous Paper 67, 165-168.

Cocco, G., Fanfani, L. Zanazzi, P.F. Heier, K.S. Billings, G.K. and Steinnes, E.

1970: Cesium; **in** Handbook of Geochemistry **II/I**, Springer-Verlag.

Coleman, A.P.

1898: Fourth report on the west Ontario gold region; Ontario Bureau of Mines **7**, part II, 109-206.

Condie, K.C.

1967: Geochemistry of early Precambrian greywackes from Wyoming; Geochimica Cosmochimica Acta **31**, 2135-2149.

Condie, K.C. and Hunter, D.R.

1976: Trace element geochemistry of Archean granitic rocks from the Barberton region, South Africa; Earth and Planetary Sciences Letters **29**, 389-400.

Condie, K.C., Mackie, J.E., and Reimer, T.O.

1970: Petrology and geochemistry of early Precambrian greywackes from the Fig Tree Group, South Africa; Geological Society of America Bulletin **81**, 2759-2776.

Corfu, F.

1988: Differential response of U-Pb systems in coexisting accessory minerals, Winnipeg River Subprovince, Canadian Shield: implications for Archean crustal growth and stabilization; Contributions to Mineralogy and Petrology **98**, 312-325.

Dana, J.D. and Dana, E.S.

1951: The System of Mineralogy, Volume 2:Halides, Nitrates, Borates, Carbonates, Sulfates, Phosphates, Arsenates, Tungstates, Molybdates; 7th Edition, John Wiley and Sons

Davies, J.C.

1965: Geology of the High Lake-Rush Bay area, District of Kenora; Ontario Department of Mines Geological Report 41, 57p.

Davies, J.F., Grant, R.W.E., and Whitehead, R.E.S.

1979: Immobile trace elements and Archean volcanic stratigraphy in the Timmins mining area, Ontario; Canadian Journal of Earth Sciences **16**, 305-311.

Davies, J.C. and Pryslak, A.P.

1967: Kenora-Fort Frances sheet, Kenora, Rainy River Districts; Ontario Department of Mines Map 2115.

Davies, J.C., Pryslak, A.P. and Pye, E.G.

1970: Sioux Lookout-Armstrong sheet, Kenora and Thunder Bay Districts; Ontario Department of Mines Map 2169.

Davies, J.C., Pryslak, A.P., Ferguson, S.A. and Brown, D.D.

1968: Red Lake-Birch Lake sheet; Ontario Department of Mines Map 2175.

De La Roche, H.

1972: Geochemical characters of the metamorphic domains: survival and testimony of their premetamorphic history. Proceedings of the International Congress I.A.G.C., Moscow.

Derry, D.R.

1930: Geology of the area from Minaki to Sydney Lake, District of Kenora; Ontario Department of Mines **39**, part 3, 25-41

Desnoyers, D.W.

1977: Geology of the northwestern portion of Lac Seul (Northwestern Ontario); Unpublished B.Sc. thesis, Carleton

University, Ottawa, Ontario, 40p.

Dieterich, J.H.

1970: Computer experiments on mechanics of finite amplitude folds; Canadian Journal of Earth Sciences **7**, 467-476.

Dowling, D.B.

1894: Report on the country in the vicinity of Red Lake and part of the basin of Berens River, Keewatin; Geological Survey of Canada **7**, part F, 5-54.

Dusanowskyj, T.H.

1976: A gravity study of the Sturgeon Lake metavolcanic - metasedimentry belt; Unpublished M.Sc. thesis, University of Toronto, Toronto, Ontario, 75p.

Dwibedi, K.

1968: Petrology of the English River Gneissic Belt, northwestern Ontario and southeastern Manitoba; Unpublished Ph.D. thesis, University of Manitoba, Winnipeg, Manitoba.

Dyer, W.S.

1933: Geology of the Pashkokogan-Misehkow area; Ontario Department of Mines **42**, part 6, 1-20.

Eade, K.E. and Fahrig, W.F.

1971: Geochemical evolutionary trends of continenetal plates - a preliminary study of the Canadian Shield; Geological Survey of Canada Bulletin 179, 49p.

Emmermann, R. and Rein, G.

1973: Genesis of granite by anatexis and differentiation (Southwestern Blackforest, Germany); Geological Society of

South Africa Special Publication **3**, 25-33.

Ermanovics, I.

1971: Granites, granite gneiss and tectonic variation of the Superior Province in southeastern Manitoba; Geological Society of Canada Special Publication 9, 79-81.

1974: Archean crust in northwestern Superior Province; 4th Annual Geotraverse Workshop, University of Toronto.

Eugster, H.P.

1972: Reduction and oxidation; **in** Metamorphism II, 24_{th} International Geological Congress, Section 10, 4-11.

Evans, B.W.

1964: Fractionation of elements in the pelitic hornfelses of the Cashel-Lough Wheelan intrusion, Connemara, Eire; Geochimica et Cosmochimica Acta **28**, 127-156.

Fahrig, W.F. and Eade, K.E.

1968: The chemical evolution of the Canadian Shield; Canadian Journal of Earth Sciences **5**, 1247-1252.

Farquharson, R.B.

1975: Revised Rb-Sr age of the Lac Du Bonnet quartz monzonite, southeastern Manitoba; Canadian Journal of Earth Sciences **12**, 115-118.

Farquharson, R.B. and Clark, G.S.

1971: Rb-Sr geochronology of some granitic rocks in southeastern Manitoba; **in** Geoscience Studies in Manitoba, Geological Association of Canada Special Paper 9, 111-117.

Fawcett, T.

1885: Annual Report; Deptartment of the Interior, part 2, 30-38.

Fenwick, K.G.

1972: Geology of the Fredart-Whitemud Lakes area, District of Kenora (Patricia Portion); Ontario Department of Mines and Northern Affairs Open File Report 5095, 131p.

Ferguson, S.A., Brown, D.D., Davies, J.C. and Pryslak, A.P.

1970: Red Lake - Birch Lake sheet, Kenora District; Ontario Department of Mines Map 2175.

Ferguson, S.A. Groen, H.A. and Haynes, R.

1971: Gold deposits of Ontario; Ontario Department of Mines and Northern Affairs Mineral Resources Circular No. 13, Part 1, 315p.

Ferguson, C.C. and Harte, B.

1975: Textural patterns at porphyroblast margins and their use in determining time relations of deformation and crystallization; Geological Magazine **112**, No.5, 467-480.

Fisher, R.V.

1961: Proposed classification of volcaniclastic sediments and rocks; Geological Society of America Bulletin **72**, 1409-1414.

Flood, R.H. and Shaw, S.E.

1975: A cordierite-bearing granite suite from the New England batholith, N.S.W., Australia; Contributions to Mineralogy and Petrology **52**, 157-164.

Floyd, P.A. and Winchester, J.A.

1975: Magma type and tectonic setting discrimination using

immobile elements; Earth and Planetary Science Letters **27**, 211-218.

1978: Identification and discrimination of altered and metamorphosed volcanic rocks using immobile elements; Chemical Geology **21**, 291-306.

Francis, P.W. and Sibson, R.H.

1973: The Outer Hebrides thrust; **in** The Early Precambrian of Scotland and Related Rocks of Greenland; University of Keele, 95-104.

Fyfe, W.

1973a: The granulite facies, partial melting and the Archean crust; Philosophical Transactions of the Royal Society of London **272**, 457-462.

1973b: The generation of batholiths; Tectonophysics **7**, 273-283.

1974: Archean tectonics; Nature **249**, 338.

Gaal, G., Mikkola, A. and Soderholm, B.

1978: Evolution of the Archean crust in Finland; Precambrian Research **6**, 199-215.

Gastil, R.G.

1975: Plutonic zones in the Peninsular Ranges batholith of Southern California and northern Baja California; Geology **3**, part 7, 361-363.

Gastil, R.G., Phillips, R.P., and Allison, E.C.

1975: Reconnaissance geology of the State of Baja, California; Geological Society of America Memoir 140, 170p.

Gavelin, S.

1975: Replacement veins in gneiss from the Precambrian of southeastern Sweden; Geol. Foreningens i Stockholm Forhandlingar **97**, 56-73.

Gilbert, G.

1927: Gammon River area and Ricaby Lake schist belt, District of Kenora (Patricia Portion); Ontario Department of Mines **36**, part 3, 73-84.

Gill, R.C.O.

1979: Comparative petrogenesis of Archean and modern low-K tholeiites: a critical review of some geochemical aspects; **in** Origin and Distribution of the Elements, 431-447, Pergamon Press, Toronto.

Glikson, A.Y.

1972: Early Precambrian evidence of a primitive ocean crust and island nucleii of sodic granite; Geological Society of America Bulletin **83**, 3323-3344.

Glyuk, D.S. and Trufanova, L.G.

1977: Melting at 1000 kg/cm^2 in a granite-H_2O system with the addition of HF, HCl and Li, Na, and K fluorides, chlorides and hydroxides; Geochemistry International **14, 28-36.**

Goldich, S.S., Hedge, C.E. and Stearn, T.W.

1970: Age of the Morton and Montevideo gneisses and related rocks; Southwestern Minnesota Geological Survey Bulletin **81**, 3671-3696.

Goldschmidt, V.M.

1954: Geochemistry; Oxford University Press.

Goodwin, A.M.

1965: Geology of Pashkokogan Lake-Eastern Lake St. Joseph area, Districts of Thunder Bay and Kenora; Ontario Department of Mines Geological Report 42, 58p.

1966: Archean protocontinental growth and mineralization; Canadian Mining Journal **87**, 57-60.

1968: Archean protocontinental growth and early crustal history of the Canadian Shield; 23rd International Geological Congress **1**, 69-89.

1976: Lithologic and major element compositions, Superior Geotraverse; 1976 Geotraverse Conference, University of Toronto, 7-16.

Gorbatschev, R.

1975: Fundamental subdivisions of Precambrian granitoids in the Amal mega-unit and the evolution of the south-western Baltic Shield, Sweden; Geologiska Foreningens i Stockholm Forhandlingar **97**, 107-114.

Gordiyenko, V.V.

1971: Concentration of Li, Rb and Cs in potash feldspar and muscovite as criteria fpr predicting the value of rare metal ore deposits in granitic pegmatites; International Geological Review **13**, No.2, 134-142.

Gower, G.F.

1975: The English River gneiss belt, Kenora District: field

characteristics and petrography; Unpublished Ontario Geological Survey field report, 98p.

1975: The geology and tectonic evolution of the English River gneiss belt in the Jaffray-Melick Area, near Kenora, northwestern Ontario; Unpublished Technical Memo 75-8,, McMaster University, Hamilton, Ontario, 54p.

1978: The tectonic and petrogenetic history of Archean rocks from the Kenora area, English River Subprovince, northwestern Ontario; Unpublished Ph.D. Thesis, McMaster University, Hamilton, Ontario, 622p.

Gower, C.F. and Clifford, P.M.

1981: The structural geometry and geological history of Archean rocks at Kenora, northwestern Ontario - A proposed type area for the Kenoran orogeny; Canadian Journal of Earth Sciences **18**, 1075-1091.

Grant, J.A.

1973: Phase equilibria in high grade metamorphism and partial melting of pelitic rocks; American Journal of Science **273**, 289-317.

Green, D.H. and Ringwood, A.E.

1967: An experimental investigation of the gabbro to eclogite transformation and its petrological applications; Geochimica et Cosmochimica Acta **31**, 767-833.

Grieg, J.W.

1927: Woman and Narrow Lakes area, District of Kenora (Patricia Portion); Ontario Department of Mines Annual Report **36**,

Part 3, 85-119.

Grocott, L.P.

1977: The relationship abetween Precambrian shear belts and modern fault systems; Journal of the Geological Society of London **133**, 257-262.

1979: Zonation of REE characteristic in the Peninsular Ranges batholith, southern and Baja California, and their implication for magmatic arc petrogenesis; **in** Annual Meeting, Geological Society of America, Program with Abstracts, 436.

Gupta, V.K. and Wedge, D.R.

1978: Bouguer gravity and generalized geological map of the Red Lake area, District of Kenora, Patricia Portion; Ontario Geological Survey Preliminary Map P. 1248.

Gupta, V.K., Thurston, P.C. and Dusanowskyj, T.H.

1982: Constrainsts upon models of greenstone belt evolution by gravity modelling, Birch-Uchi greenstone belt, nothern Ontario; Precambrian Research **16**, 233-255.

Hall, D.H.

1968: Regional magnetic anomalies, magnetic units and crustal structure in the Kenora District of Ontario; Canadian Journal of Earth Sciences **5**, 1277-1296.

1971: Geophysical determination of deep crustal structure in Manitoba; Geological Association of Canada Special Paper 9, 83-88.

Hall, D.H. and Hajnal, Z.

1973: Deep seismic crustal studies in Manitoba; Seismological Society of America Bulletin **63**, 885-910.

Hall, D.H. and Brisbin, W.C.

1982: Overview of regional geophysical studies in Manitoba and northwestern Ontario; Canadian Journal of Earth Sciences **19**, 2049-2059.

Hamilton, W. and Myers, W.B.

1974: Nature of the Boulder batholith of Montana; Geological Society of America Bulletin **85**, 365-378.

Harding, W.O.

1950: Geology of the Gullwing Lake - Sunstrum area, District of Kenora; Ontario Department of Mines **59**, part 4, 1-29.

Harris, N.B.W.

1975: Geology of the Wapesi Lake-Eastern Lac Seul-Route Lake area, Operation Kenora-Ear Falls; Unpublished Ontario Geological Survey field report, 53p.

Harris, N.B.W. and Goodwin, A.M.

1976: Archean rocks from the eastern Lac Seul Region of the English River Gneiss Belt, northwestern Ontrio, part 1: Petrology; chemistry and metamorphism; Canadian Journal of Earth Sciences **13**, No.9, 1201-1214.

Hart, S.R., Brooks, C., Krogh, T.E., Davis, G.L. and Nava, D.

1970: Ancient and modern volcanic rocks: a trace element model; Earth Planetary Science Letters **10**, 17-28.

Heier, K.S.

1960: Petrology and geochemistry of high-grade metamorphic and

igneous rocks on Langoy, northern Norway; Norges Geologiske Undersoekelse **207**, 246p.

Heier, K.S.

1973: The geochemistry of granulite facies rocks and problems of their origin; Philosophical Transactions of the Royal Society of London, Series A, **273**, 429-442.

Heier, K.S. and Adams, J.A.S.

1964: The geochemistry of the alkali metals; **in** Physics and Chemistry of the Earth **5**, 253-381.

Heier, K.S. and Thoresen, K.

1973: Geochemistry of high-grade metamorphic rocks, Lofoten-Vesteralen, north Norway; Geochimica et Cosmochimica Acta **35**, 89-99.

Heinrich, E.W.

1953: Zoning in pegmatite districts; American Mineralogist **38**, 68-87.

1965: Holmquistite and pegmatitic lithium exomorphism; Indian Mineralogist **6**, 1-13.

1975: Economic geology and mineralogy of petalite and spodumene pegmatites; Indian Journal of Earth Sciences **2**, No. 1, 18-29.

1978: Mineralogy and structure of lithium pegmatites; Journal de Mineralogia, Recife **7**, 59-65.

Henderson, J.B.

1972: Sedimentology of Archean turbidites at Yellowknife, Northwest Territories; Canadian Journal of Earth Sciences

9, 882-902.

Hewitt, D.F.

1967: Pyrite deposits of Ontario; Ontario Department of Mines Mineral Resources Circular No.5, 64p.

Hietanen, A.

1975: Generation of potassium-poor magmas in the Northern Sierra Nevada and the Svecofennian of Finland; United States Geological Survey Journal of Research **3**, No. 6, 631-645.

Higgins, M.W.

1971: Cataclastic rocks; United States Geological Survey Professional Paper 687, 96p.

Hine, R., Williams, I.S., Chappell, B.W. and White, A.J.R.

1978: Contrast between I- and S-type granitoids of the Kosciusko batholith; Journal of the Geological Society, **25**, part 4, 219-234.

Hinton, R.W. and Long, J.V.P.

1979: High-resolution ion-microprobe measurement of lead isotopes: variations within single zircons from Lac Seul, northwestern Ontario; Earth and Planetary Science Letters **45**, 309-325.

Hirschberg, A., and Winkler, H.G.F.

1968: Stabilitatsbeziehungen Zwischen Chlorit, Cordierit, und Almandin Bei Der Metamorphose; Contributions to Mineralogy and Petrology **18**, 17-42.

Hobbs, B.E.

1968: Recrystallization of single crystals of quartz;

Tectonophysics **6**, No.5, 353-401.

Hodgkinson, J.M.

1968: The geology of the Kenora airport area; Unpublished M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Holdaway, M.J.

1971: Stability of andalusite and the aluminum silicate phase diagram; American Journal of Science **271**, 97-131.

Holland, J.G. and Lambert, R.St.J.

1972: The geochemistry of lithium in the mainland Lewisian of Scotland; 24th International Geological Congress, Section 10, 169-178.

Holmquist, P.J.

1916: Swedish Archean structures and their meaning; Bulletin of the Geological Institute of Uppsala **15**, 125-148.

1921: Typen unt Nomenklatur der Adergesteine; Geologiska Foreningens Stockholm Forhandlingar **43**, 612-631.

Hopkins, Percy E.

1921: Ontario gold deposits, their character, distribution and productiveness; Ontario Department of Mines **30**, Part II, 73p.

Horwood, H.C.

1937: Geology of the Superior Junction - Sturgeon Lake area; Ontario Department of Mines **46**, part 6, 1-25.

Hoschek, G.

1969: The stability of staurolite and chloritoid and their significance in metamorphism of pelitic rocks;

Contributions to Mineralogy and Petrology **22**, 208-232.

Hubbard, F.H.

1975: The Precambrian crystalline complex of south-western Sweden. The geology and petrogenetic development of the Varborg Region; Geologiska Foreningens i Stockholm Forhandlingan **97**, 223-236.

Hudec, P.P.

1965: Highstone Lake-Miniss Lake area, Districts of Kenora and Thunder Bay; Ontario Department of Mines Geological Report 32, 28p.

Hudson, T.

1979: Mesozoic plutonic belts of southern Alaska; Journal of Geology **7**, 230-234.

Hunter, D.R.

1970: The ancient gneiss complex of Swaziland; Geological Society of South Africa **73**, 107-150.

1974: Crustal development in the Kaapvaal Craton, I. The Archean; Precambrian Research **1**, No.4, 259-294.

Hurst, M.E.

1932: Geology of the Sioux Lookout area; Ontario Department of Mines **41**, part 6, 1-33.

Hutchinson, R.W.

1955: Regional zonation of pegmatites near Ross Lake, District of Mackenzie, Northwest Territories; Geological Survey of Canada Bulletin 34, 50p.

Innes, M.J.S.

1960: Gravity and isostasy ub northern Ontario and Manitoba; Publication of the Dominion Observatory **21**, 263-337.

Irvine, T.N. and Baragar, W.R.A.

1971: A guide to the chemical classification of the common volcanic rocks; Canadian Journal of Earth Sciences **8**, 523-548.

Jahns, R.H. and Burnham, C.W.

1969: Experimental studies of pegmatite genesis: a model for the derivation and crystallization of granitic pegmatites; Economic Geology **64**, No.8, 843-864.

Jensen, L.S.

1976: A new cation plot for classifying subalkaline volcanic rocks; Ontario Division of Mines Miscellaneous Paper 66, 22p.

Johnston, F.J.

1968: Molybdenum deposits of Ontario; Ontario Department of Mines Mineral Resources Circular No.7, 98p.

1969: Geology of the western Minnitaki Lake area, District of Kenora; Ontario Department of Mines Geological Report 75, 28p.

1972: Geology of the Vermilion-Abram Lakes area, District of Kenora; Ontario Division of Mines Geological Report 101, 51p.

Jones, R.B.

1973: Metamorphism across the English River gneissic belt, along the Red Lake road; Unpublished M.Sc. Thesis,

University of Manitoba, Winnipeg, Manitoba.

Kamineni, D.C., Stone, D and Peterman, Z.E.

1990: Early Proterozoic deformation in the western Superior Province, Canadian Shield; Geological Society of America Bulletin, **102**, 1623-1634.

Keith, S.B.

1978: Paleo-subduction geometries inferred from Cretaceous & Tertiary magmatic patterns in southwestern North America: Geology **6**, 516-521.

Kerrick, D.M.

1972: Experimental determination of muscovite and quartz stability with P $H_2O < P_{total}$; American Journal of Science **272**, 946-958.

Kesler, S.E. and Sutter, J.F.

1979: Compositional evolution of intrusive rocks in the eastern Greater Antilles Island area; Geology **7**, 197-200.

Kesler, T.L.

1976: Occurrence, development and long range outlook of lithium pegmatite ore in the Carolinas; United States Geological Survey Professional Paper 1005, 45-50.

Kilinc, I.A.

1972: Experimental study of partial melting of crustal rocks and formation of migmatites; 24th International Geological Congress, Section 2, Petrology, 109-113.

King, H.L.

1983: Precambrian geology of the Kenora-Keewatin area, District

of Kenora; Ontario Geological Survey Preliminary Maps 2617 and 2618.

Kistler, R.W.

1974: Phanerozoic batholiths in western North America: a summary of some recent work on variations in time, space, chemistry and isotopic composition; Annual Review, Earth and Planetary Science Letters **2**, 404-418.

Koster van Gros, A.F. and Tuttle, O.F.

1968: Melting relationships in the system $NaAlSi_3O_8$-NaF-H_2O to 4 kilobars pressure; Journal of Geology **76**, 50-70.

Koster van Gros, A.F. and Wyllie, P.J.

1969: Melting relationships in the system $NaAlSi_3O_8$-NaCl-H_2O at one kilobar pressure, with petrological applications; Journal of Geology **77**, 581-604.

Kovalenko, V.I.

1977: Measurement of the Li and Rb distributions in the ongonite-H_2O-HF system; Geochemistry International **14,** No. 3, 133-140.

1978: Distribution ratios of lithium, rubidium and cesium in ongonites; International Geology Review **22**, No. 6, 718-730.

Kovalenko, V.I., Antipin, V.S., Konusova, V.V., Smirnova, V.V., Petrov, L.L., Vladykin, N.V., Kuznetsova, A.I., Kostyukova, Y.S. and Disarskaya, V.A.

1977: Partition coefficients of fluorine, niobium, tantalum, lanthalum, ytterbium, tin and tungsten in ongonite; Academy of Sciences, U.S.S.R. Doklady **233**, No. 5, 951-953.

Kovalenko, V.I., Antipin, V.S. and Petrov, L.L.

1977: Distribution coefficients of beryllium in ongonites and some notes on its behaviour in the rare-metal lithium-fluorine granites; Geochemistry International **14**, No. 4, 129-141.

Kretz, R.

1967: Granite and pegmatite studies at northern Indian Lake, Manitoba; Geological Survey of Canada Bulletin 148, 42p.

Krogh, T.E., Harris, N.B.W. and Davis, G.L.

1976: Archean rocks from the eastern Lac Seul region of the English River Gneiss Belt, northwestern Ontario, part 2. Geochronology; Canadian Journal of Earth Sciences **13**, No.9, 1212-1215.

Kusmirski, R.T.

1970: Petrology and geochemistry of the Heron Lake stock, Superior Province, northwestern Ontario; Unpublished B.Sc. thesis, McMaster University, Hamilton, Ontario.

Lambert, I.B. and Heier, K.S.

1968: Geochemical investigations of deep-seated rocks in the Australian shield; Lithos **1**, No.1, 30-53.

Lambert, R.St.J., Chamberlain, V.E. and Holland, J.G.

1976: The geochemistry of Archean rocks; **in** The Early History of the Earth, 377-388, John Wiley and Sons.

Lang, A.H.

1952: Canadian deposits of uranium and thorium; Geological Survey of Canada Economic Geology Series No.16, 173p.

p.173.

Langford, F.F. and Morin, J.A.

1976: The development of the Superior Province of Northwestern Ontario by merging island arcs; American Journal of Science **276**, 1023-1034.

Lawson, A.C.

1885: Geology of the Lake of the Woods region with special reference to the Keewatin (Huronian) belt of Archean rocks; Geological and Natural History Survey of Canada Annual Report 1885, **1**, Part cc, 151p.

Lewis, J.D. and Spooner, C.M.

1973: K/Rb ratios in Precambrian granulite terrains; Geochimica Cosmochimica Acta, **37**, 1111-1118.

Lindh, A.

1977: The Blomskog granite - a possible diapiric structure; Precambrian Research **5**, 261-282.

Little, H.W.

1974: Distribution of types of uranium deposits and favourable environments for uranium exploration; **in** Uranium Exploration Geology, Panel Proceedings Series, International Atomic Energy Agency, ST1/PUB/277, Vienna, 35-49.

Mackasey, W.O., Blackburn, C.E., and Trowell, N.F.

1974: Regional approach to the Wabigoon-Quetico belts and its bearing upon mineral exploration in northwestern Ontario; Ontario Division of Mines Miscellaneous Paper 58, 30p.

MacPherson, H.G.

1958: A chemical and petrographic study of Precambrian sediments; Geochimica et Cosmochimica Acta **14**, 73-92.

Makepeace, D.K.

1976: The geology of the Aerofoil Lake pluton, northwestern Ontario; Unpublished B.Sc. thesis, Queen's University, Kingston, Ontario, 58p.

Makrygina, V.A.

1979: Role of metamorphic zonation in distribution of pegmatites and migmatites of different composition. International Geology Review **19**, No.10, 1133-1141.

Marmo, V.

1971: Granite petrology and the granite problem; Elsevier Publishing Company, New York, 244p.

Mason, B.

1966: Principles of Geochemistry; New York, John Wikley and Sons, 329 p.

Matthews, S.R.

1975: The contact nature of the Darlington Bay porphyritic granodiorite: Kenora-Keewatin; Unpublished B.Sc. Thesis, Queen's University, Kingston, 61p.

McCarthy, T.S. and Kable, E.J.D.

1978: On the behavior of rare-earth elements during partial melting of granitic rocks; Chemical Geology **22**, 21-29.

McGrath, P.H. and Hall, D.H.

1969: Crustal structure in northwestern Ontario: regional magnetic anomalies; Canadian Journal of Earth Science **6**, 101-107.

McGregor, V.R.

1973: The Early Precambrian gneisses of the Godthab District, West Greenland; Philosophical Transactions of the Royal Society of London Series A, **273**, 343-358.

McMillan, R.H.

1977: Metallogenesis of Canadian uranium deposits - a review; **in** Geology, Mining and Extraction Processes of Uranium, Institute of Mining and Metallurgy, London, United Kingdom, 43-55.

McRitchie, W.D.

1971: The petrology and environment of the acidic plutonic rocks of the Wanipigow-Winnipeg Rivers region southeastern Manitoba (Project Pioneer); Manitoba Mines Branch Publication 71-1, 7-62.

McRitchie, W.O., and Weber, W.

1971: Metamorphism and deformation in the Manigotagan gneissic belt, southeastern Manitoba; **in** Geology and Geophysics of the Rice Lake Region, Southeastern Manitoba (Project Pioneer), Manitoba Department of Mines and Natural Resources, Mines Branch Publication 71-1, 235-284.

Mehnert, K.R.

1971: Migmatites and the origin of granitic rocks; Elsevier Publishing Company, New York, 405p.

Merrill, R.B., Robertson, J.K. and Wyllie, P.J.

1970: Melting relations in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O to 20 kilobars compared with results for other Feldspar-Quartz-H_2O and Rock-H_2O systems; Journal of Geology **78**, 558-569.

Middleton, G.V.

1960: Chemical composition of sandstones; Geological Society of America Bulletin **71**, 1011-1026.

Miller, C.F.

1977: Early alkalic plutonism in thwe clac-alkalic batholithic belt of California; Geology **5**, 685-688.

Misch, P.

1968: Plagioclase compositions and the non-anatectic origin of the migmatitic gneisses in the northern Cascade Mountains of Washington State; Contributions to Mineralogy and Petrology **17**, 1-70.

Miyashiro, A.

1961: Evolution of metamorphic belts; Journal of Petrology **2**, No.3, 277-311.

Miyashiro, A. and Shido, F.

1975: Tholeiitic and calc-alkaline series in relation to the behavior of titanium, vanadium, chromium and nickel; American Journal of Science **275**, 265-277.

Moore, E.S.

1928: Lake Savant area, District of Thunder Bay; Ontario Department of Mines **37**, part 4, 52-82.

Moorhouse, W.W.

1939: Geology of the Eagle Lake area; Ontario Department of Mines **48**, part 4, 1-31.

Morawski, F.P., Jeffries, J.D., Wilson, D.M., Schelske, J.E., Geddes, J.R. and Eberts, B.R.

1970: The Griffith Mine story; Canadian Institute of Mining and Metallurgy Bulletin **63**, No.703, 1271-1288.

Morin, J.A.

1970: The clotty granite at Perrault Falls, Ontario. Unpublished M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba, 63p.

1977: Allanite in granitic rocks of the Kenora-Vermilion Bay Area, northwestern Ontario, Canadian Mineralogist **15**, 297-302.

1979: A study of the petrology of granitic rocks in the Tustin-Bridges area, Northwestern Ontario; Unpublished Ph.D. Thesis, University of Saskatchewan, Saskatoon.

Morin, J.A. and Turnock, A.C.

1975: The clotty granite at Perrault Falls, Ontario, Canada; Canadian Mineralogist **13**, 352-357.

Mueller, R.F.

1970: Abundance of iron in common metamorphic rock types; **in** Handbook of Geochemistry, p. 26M-1 to 26M-5, Springer-Verlag, New York.

Muir, T.L. and Graydon, J,W,

1982: Precambrian geology of Belanger and Bowerman Townships,

Kenora District; Ontario Geological Survey Preliminary map P. 2571.

Mulligan, R.

1961: Pollucite (caesium) in Canada; Geological Survey of Canada Paper 61-4, 4p.

1965: Geology of Canadian lithium deposits: Geological Survey of Canada Economic Geology Report 21, 131p.

Munoz, J.L.

1969: Stability relations of $LiAlSi_2O_6$at high pressures; Mineralogical Society of America Special Paper **2**, 203-209.

Myers, J.S.

1976: Granitoid sheets, thrusting and Archean crustal thickening in West Greenland; **in** Geology **4**, 265-268.

1978: Formation of banded gneisses by deformation of igneous rocks; Precambrian Research **6**, No.1, 43-64.

1981: The Fiskenaesset anorthositic complex - a stratigraphic key to the tectonic evolution of the West Greenland gneiss complex 3000-2800 m.y. ago; **in** Geological Society of Australia Special Publication **7**, 351-360.

Nanz, R.H.

1953: Chemical composition of Precambrian slates with notes on the geochemical evolution of lutites; Journal of Geology **61**, 51-64.

Neiva, A.M.R.

1975: Geochemistry of muscovite in the pegmatites of nothern Portugal; Fortschritte der Mineralogie **52**, 303-315.

Newton, R.C.

1972: An experimental determination of the high-pressure stability limits of magnesian cordierite under wet and dry conditions; Journal of Geology **80**, 398-420.

Newton, R.C., Charles, T.V. and Kleppa, O.J.

1974: A calorimetric investigation of the stability of anhydrous magnesian cordierite with application to granulite facies metamorphism; Contributions to Mineralogy and Petrology **44**, 295-311.

Nockolds, S.R. and Allen, R.

1953: The geochemistry of some igneous rock series; Geochimica et Cosmochimica Acta **4**, 105-142.

1954: The geochemistry of some igneous rock series. Part II; Geochimica et Cosmochimica Acta **5**, 245-285.

1956: The geochemistry of some igneous rock series. Part III; Geochimica et Cosmochim Acta **9**, 34-77.

Norton, J.J.

1973: Lithium, cesium and rubidium - the rare alkali metals; **in** United States Mineral Resources, United States Geological Survey Professional Paper 820, 365-378.

1975: Mineral and water resources of South Dakota; United States Senate Committee on Interior and Insular Affairs, 313p.

Nunes, P.D. and Thurston, P.C.

1980: Two hundred and twenty million years of Archean evolution: a zircon U-Pb age stratigraphy study of the Uchi-Confederation Lakes greenstone belt, northwestern Ontario;

Canadian Journal of Earth Sciences **17**, 710-721.

Olsen, S.N.

1985: Mass balance in migmatites; **in** Migmatites, Blackie Publishing, Glasgow, 145-179.

Ontario Department of Mines-Geological Survey of Canada

1961: Various aeromagnetic maps covering the map area: Ontario Department of Mines - Geological Survey of Canada, Aeromagnetic Series, Maps (inclusive), 1128G, 1129G, 900G, 901G, 890G, 891G, 1138G, 1139G, 880G, 881G, 1146G-1148G, 870G, 871G, 1155G-1157G, 860G, 861G, 1163G-1165G, 851G, 850G, 1171G-1173G, 4010G, 4011G, 1179G-1181G, 4029G, 4028G, 1187G-1189G, 4048G, 4047G, 1192G-1194G, scale 1 inch to 1 mile.

Ontario Geological Survey - Geological Survey of Canada

1976: Airborne gamma-ray spectrometry survey, Sioux Lookout Sheet, Maps P.1112-P.1146, inclusive.

1977: Airborne gamma-ray spectrometry survey, Pointe Du Bois Sheet, Maps P.1220-1354, inclusive; Kenora Sheet, Maps P.1355-P.1389, inclusive; Lac Seul Sheet, Maps P.1425-P.1459, inclusive; Dryden Sheet, Maps P.1460-1494, inclusive.

Orville, P.M.

1963: Alkali ion exchange between vapour and feldspar phases; American Journal of Science **261**, 201-237.

Page, R.O.

1978: Zarn Lake area, District of Kenora; Ontario Geological

Survey Miscellaneous Paper 82, 45-48.

1979: Zarn Lake area (northern part), District of Kenora; Ontario Geological Survey Preliminary Map 2233.

1979: Lateral Lake area, District of Kenora; Ontario Geological Survey Miscellaneous Paper 90, 92-96.

1984: Geology of the Lateral Lake area, District of Kenora; Ontario Geological Survey Open File Report 5518, 175p.

Palache, C., Berman, H. and Frondel, C.

1944: The System of Mineralogy of J.W. Dana and E.S. Dana - Volume I (Elements, Sulfides, Sulfosalts, Oxides); 7th Edition, John Wiley and Sons, 834p.

Palonen, P.A. and Speed, A.A.

1974: Sandybeach Lake area, District of Kenora, Patricia Portion; Ontario Division of Mines Miscellaneous Paper 59, 48-51.

Panagapko, D.A.

1976: The geology, petrology and chemistry of the Conifer Lake Igneous Complex, District of Kenora, Ontario. Unpub. B.Sc. Thesis, Carleton University, Ottawa.

Parkinson, R.N.

1962: Operation Overthrust; **in** The Tectonics of the Canadian Shield, Royal Society of Canada Special Publication No.4, 90-107.

Parsons, A.L.

1911: Gold fields of Lake of the Woods, Manitou and Dryden; Ontario Bureau of Mines **20**, 158-198.

Pearce, J.A.

1975: Basalt geochemistry used to investigate part tectonic environment on Cyprus; Tectonophysics **25**, 41-67.

Pearce, J.A. and Cann, J.R.

1973: Tectonic setting of basic volcanic rocks determined using trace element analyses; Earth Planetary Science Letters **19**, 290-300.

Pearce, T.H., Gorman, B.E., and Birkett, T.C.

1975: The TiO_2-K_2O-P_2O_5 diagram; a method of discriminating between oceanic and non-oceanic basalts; Earth Planetary Science Letters **24**, 419-426.

Peterman, Z.E., Goldich, S.S., Hedge, C.E. and Yardley, D.M.

1972: Geochronology of the Rainy Lake region, Minnesota-Ontario; Geological Society of America Memoir 135, 193-215.

Pettijohn, F.J.

1963: Chemical composition of sandstones-excluding carbonate and volcanic sands; **in** Data of Geochemistry, 6th Edition, United States Geological Survey Professional Paper 440-5, S-1 to S-21.

Pettijohn, F.J., Potter, P.E. and Sieyer, R.

1973: Sand and Sandstone; Springer-Verlag, New York, 618p.

Pitcher, W.S. and Bussell, M.A.

1977: Structural control of batholithic emplacement in Peru: a review; Journal of the Geological Society of London, **133**, 249-256.

Pitcher, W.S. and Taylor, W.P.

1979: The episodic generation of magma sequences in the Coastal Batholith of Peru; **in** Geological Society of America Annual Meeting, Book of Abstracts, 496.

Prest, V.K.

1963: Red Lake-Lansdowne House area, northwestern Ontario; Geological Survey of Canada, Paper 63-6.

1968: Nomenclature of moraines and ice-flow features as applied to the glacial map of Canada; Geological Survey of Canada Report 67-57, 32p.

1970: Quaternary geology of Canada; **in** Geology and Economic Minerals of Canada, Geological Survey of Canada, Economic Geology Report No.1, 676-758.

Pryslak, A.P.

1972: Geology of the Tustin-Bridges area, District of Kenora; Ontario Department of Mines and Northern Affairs, Open File Report 5075, 94p.

1976: Geology of the Bruin Lake-Edison Lake area, District of Kenora; Ontario Division of Mines Geological Report 130; 61p.

1981: The Rafter Lake Project-Fairservice option No. 1 report; Assessment Files Research Office, Ontario Geological Survey Toronto.

Pye, E.G.

1965: Georgia Lake area; Ontario Department of MInes Geological Report 31, 113p.

1968: Crescent Lake area; Ontario Department of Mines Geological

Report 55, 72p.

Ramberg, H.

1949: The facies classification of rocks: a clue toa the origin of quartzo-feldspathic massifs and veins; Journal of Geology **57**, 18-54.

1952: Origin of metamorphic and metasomatic rocks; University of Chicago Press, Chicago, 317p.

Ramsay, J.G.

1967: Folding and fracturing of rocks; McGraw-Hill, 586 p.

Reitan, P.

1952: Pegmatite veins and the surrounding rocks. I. Petrography and structure; Norsk Geologisk Tiddskrift, **36**, 213-239.

Richardson, S.W.

1968: Staurolite stability in a part of the system Fe-Al-Si-O-H; Journal of Petrology **9**, Part 3, 467-488.

1970: The relationship between petrogenetic grid, facies series, and the geothermal gradient in metamorphism; Fortschritte der Mineralogie **47**, 65-76.

Riley, C.

1965: A gravity survey of the Kenora area, Ontario; unpublished M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba.

Rivalenti, G. and Sighinolfi, G.P.

1969: Geochemical study of greywackes as a possible starting material of para-amphibolites; Contributions to Mineralogy and Petrology **23**, 173-188.

Robertson, James A.

1968: Uranium and thorium deposits of northern Ontario; Ontario Department of Mines, Mineral Resources Circular No.9, 106p.

Rodgers, J.J.W. and Adams, J.A.S.

1969a: Thorium; Handbook of Geochemistry II/1, Springer-Verlag.

1969b: Uranium; Handbook of Geochemistry II/1, Springer- Verlag.

Rowe, J.S.

1972: Forest regions of Canada; Department of Environment, Canadian Forestry Service, Publication No. 1300, 172p.

Sage, R.P. and Breaks, F.W.

1982: Geology of the Cat Lake-Pickle Lake area, Districts of Kenora and Thunder Bay; Ontario Geological Survey Report 207, 238p.

Sage, R.P., Breaks, F.W., Stott, G., McWilliams, G., and Bowen, R.P.

1974: Operation Ignace-Armstrong, Pashkokogan-Caribou Lakes sheet, District of Thunder Bay; Ontario Division of Mines, Preliminary Map P.962.

Sage, R.P., Breaks, F.W. and Troup, W.

1976: Cat Lake-Pickle Lake Sheet, Kenora and Thunder Bay District; Ontario Division of Mines Map 2218.

Saggerson, E.P. and Turner, L.M.

1976: A review of the distribution of metamorphism in the ancient Rhodesian craton; Precambrian Research **3**, 1-53.

Sander, B.

1948, 1950: Einfuhrung in die Gefugekunde der Geologischen

Korper, 1 und 2; Springer, Wien, 215 und 409 S.

Satterly, J.

1941: Geology of the Dryden-Wabigoon area; Ontario Department of Mines **50**, Part 2, 1-57.

Sawyer, E.W. and Robin, P.Y.F.

1986: The subsolidus segregation of layer-parallel quartz-feldspar veins in greenschist to upper amphibolite facies metasediments; Journal of Metamorphic Geology **4**, 237-260.

Scheumann, K.H.

1936: Sur Nomenklatur Migmatitischer and Verwandter Gesteins; Tschmermaks Mineral. Petrogr. Mitt. **48**, 297-302.

1937: Metatexis und Metablastesis; Tschermaks Mineral. Petrogr. Mitt. **48**, 402-412.

Schreyer, W. and Seifert, F.

1969: Compatibility relations of the aluminum silicates in the systems $MgO-Al_2O_3-SiO_2-H_2O$ and $K_2O-MgO-Al_2O_3-SiO_2-H_2O$ at high pressures; American Journal of Science **267**, 371-388.

Schwerdtner, W.M., Stone, D., Osadetzok, Morgan, J. and Stott, G.M.

1979: Granitoid complexes and the Archean tectonic record in the southern part of northwestern Ontario, Canadian Journal of Earth Sciences **16**, 1965-1977.

Sederholm, J.J.

1907: On granite and gneiss; Bulletin de la Commission Geologique de Finlande **23**, 1-110.

Selwyn, A.R.C.

1873: Report of progress, on a preliminary reconnaissance from Lake Superior by the English and Winnipeg Rivers to Fort Garry; Geological Survey of Canada, 1872-73, 8-18.

Sergiades, A.O.

1968: Silver, cobalt, calcite vein deposits of Ontario; Ontario Department of Mines Mineral Resources Circular No.10, 498p.

Shand, S.J.

1950: Eruptive rocks; 4thedition, John Wiley and Sons, New York.

Shaw, D.M.

1954: Trace elements in pelitic rocks: Parts I and II; Geological Society of America Bulletin **65**, 1161-1182.

1956: Geochemistry of pelitic rocks: Part III; Geological Society of America Bulletin **67**, 919-934.

1968: A review of K-Rb fractionation trends by covariance analysis; Geochimica et Cosmochimica Acta **32**, 573-601.

1972: The origin of the Apsley gneiss, Ontario; Canadian Journal of Earth Sciences **9**, 18-35.

Shaw, D.M., Reilley, G.A., Muysson, J.R., Patterson, G.E. and Campbell, F.E.

1967: An estimate of the chemical composition of the Canadian Shield; Canadia Journal of Earth Sciences **4**, 829-853.

Shaw, D.M., Dostal, J and Keays, R.P.

1976: Additional estimates of continental surface Precambrian Shield composition in Canada; Geochimica et Cosmochimica Acta **40**, 73-83.

Shelly, D.

1974: Mechanical production of metamorphic banding - a critical appraisal; Geological Magazine **111**, No.4, 287-292.

Shklanka, R.

1967: Geology of the Bee Lake area, District of Kenora; Ontario Department of Mines Geological Report 47, 42p.

1968: Iron deposits of Ontario; Ontario Department of Mines, Mineral Resources Circular No. 11, 480p.

1969: Copper, nickel, lead and zinc deposits of Ontario; Ontario Department of Mines, Mineral Resources Circular No. 12, 394p.

1970: Geology of the Bruce Lake area; Ontario Department of Mines Geological Report 82, 27p.

Sibson, R.H.

1977: Fault rocks and fault mechanisms; Journal of the Geological Society of London **133**, 157-176.

Sighinolfi, G.P. and Gorgoni, C.

1978: Chemical evolution of high grade metamorphic rocks - anatexis and remotion of material from granulite terrains; Chemical Geology **22**, 157-176.

Silver, I.T.

1979: Peninsula-Ranges batholith: a case study in continental margin magmatic arc setting, characteristics and evolution; **in** Geological Society of America Annual Meeting, Book of Abstracts, 517.

Sirhoonian, H.A., Shaw, D.M. and Jones, R.E.

1959: Lithium geochemistry and the source of the spodumene pegmatites of the Preissac-Lamotte-Lacorne region of western Quebec; Canadian Mineralogist **6**, 320-338.

Skinner, R.

1969: Geology of the Sioux Lookout map-area, Ontario, a part of the Superior Province of the Precambrian shield (52J); Geological Survey of Canada, Paper 68-45, 10p.

Skosyreva, M.V. and Nikol'skaya, L.V.

1978: Causes of the color of muscovite from rare-metal pegmatites; Geokhimiya, No. 3, 437-442.

Slaght, A.

1892: Report of the inspector of mines; Ontario Bureau of Mines **2**, 231-254.

Smith, D.A.

1977: The geology of the Lake St. Joseph layered mafic intrusive complex, northwestern Ontario; Unpublished B.Sc. Thesis, Queen's University, Kingston, Ontario, 77p.

Smithson, J.B. and Decker, E.R.

1973: K, U and Th distribution between dry and wet facies of a syenitic intrusion and the role of fluid content; Earth and Planetary Science Letters **19**, No.2, 131-134.

Springer, G.D.

1952: Geology of the Rennie-West Hawk Lake area, Lac Du Bonnet Mining Division; Manitoba Mines Branch Publication 50-6, 24p.

Spry, A.

1969: Metamorphic Textures; Pergamon Press. Toronto, 350p.

Starmer, I.C.

1969: The migmatite complex of the Risor area, Aust-Agder, Norway; Norsk Geologisk Tidsskrift **49**, No.I, 3-56.

Stavrov, O.D.

1978: The geochemistry of lithium, rubidium and cesium in the magmatic process; Nedra, Moscow.

Stephanson, O.

1977: Granite diapirism in Archean rocks; Journal of the Geological Society of London **133**, 357-361.

Stephansson, O. and Johnson, K.

1976: Granite diapirism in the Rum Jungle area, northern Australia; Precambrian Research **3**, 159-185.

Stewart, D.B.

1963: Petrogenesis and mineral assemblages of lithium-rich pegmatites; **in** Geological Society of America Special Paper 76, 159.

1978: Petrogenesis of lithium-rich pegmatites; American Mineralogist **63**, 970-980.

Stockwell, C.H.

1964: Fourth report on structural provinces, orogenies, and time-classification of rocks of the Canadian Precambrian Shield; **in** Age Determinations and Geological Studies, Part II. Geological Studies, Geological Survey of Canada Paper 64-17, 1-21.

Stone, M.

1969: Nature and origin of banding in the granitic sheets; Tremear Porthleven, Cornwall; Geological Magazine **106**, No.2, 142-158.

Stone, D.

1976: The Sydney Lake cataclastic zone; **in** Geotraverse Conference, 1976, University of Toronto, 89-90.

1977: The Sydney Lake Fault Zone; **in** Geotraverse Conference, 1977, University of Toronto, 94-108.

1978: Major faults in northwestern Ontario; Joint Annual Meeting of Geological Association of Canada-Mineralogical Association of Canada-Geological Society of America Program with Abstracts **?????**

1981: The Sydney Lake Fault Zone in Ontario and Manitoba; Unpublished Ph.D. Thesis, University of Toronto, Toronto, Ontario, 146p.

Storre, B. and Karotke, E.

1971: An experimental determination of the upper stability limit of muscovite + quartz in the range 7-20 kb. water pressure; Neues Jahrbuch fur Mihneralogie Monatshefe No. 5, 237-240.

Stowe, C.W.

1971: Summary of the tectonic development of the Rhodesian Archean craton; Geological Society of Australia, Special Publication 3, 377-384.

Streckeisen, A.

1967: Classification and nomenclature of igneous rocks; Neues Jahrbuch fur Mineralogie Abhandlungen **107**, 144-240.

1976: To each plutonic rock its proper name; Earth Science Reviews **12**, 1-33.

Swanson, S.E.

1977: Relation of nucleation and crystal-growth rate to the development of granitic textures; American Mineralogist **62**, 966-978.

Tarney, J.

1976: Geochemistry of Archean high-grade gneisses with implications as to the origin and evolution of the Precambrian crust; **in** The Early History of the Earth John Wiley and Sons Ltd., 405-417.

Tarney, J., Skinner, A.C. and Sheraton, J.W.

1972: A geochemical comparison of major Archean gneiss units from northwest Scotland and east Greenland; 24th International Geological Congress, Precambrian Geology, Section 1, 162-174.

Taylor, S.R.

1965: The application of trace-element data to problems in petrology; Physics and Chemistry of the Earth **6**, No.2, 133-214.

Taylor, S.R. and Heier, K.S.

1960: The petrological significance of trace element variations in feldspars; **in** 21st International Geological Congress, Norden, **14**, 47-61.

Thomson, J. E.

1936: Geology of the north central part of the Lake of the

Woods; Ontario Department of Mines **45**, Part III, 59p.

Thomson, Jas. E., and Ferguson, S.A., Johnston, W.G.Q., Pye, E.G., Savage, W.S., and Thomson, Robert

1957: Copper, nickel, lead and zinc deposits in Ontario; Ontario Department of Mines, Mineral Resources Circular No.2, 126p.

Thomson, R.

1947: Report on sulfide occurrences at Helder Lake, Kenora Mining Division, September 25, 1947; Assessment Files, Regional Geologist's Office, Kenora, Ontario, 6p.

1948: Showings in the vicinity of Oneman Lake, District of Kenora; Ontario Department of Mines Preliminary Report 1948-6, 5p.

Thurston, P.C.

1973: Earngey-Costello Townships area, District of Kenora, Patricia Portion; **in** Ontario Division of Mines Miscellaneous Paper 56, 8-15.

1976: Confederation Lakes synoptic project, District of Kenora, Patricia Portion; **in** Ontario Division of Mines Miscellaneous Paper 67, 8-15.

1985: Geology of the Earngey-Costello area, District of Kenora; Ontario Geological Survey Report 234, 125p.

Thurston, P.C. and Breaks, F.W.

1978: Metamorphic and tectonic evolution in the English River and Uchi Subprovinces; **in** Metamorphism in the

Canadian Shield, Geological Survey of Canada, Paper 78-10, 49-62.

Thurston, P.C. and Carter, M.W

1970: Operation Fort Hope; Ontario Department of Mines and Northern Affairs Miscellaneous Paper 42, 64p.

Timmins, E.A., Turek, A. and Symons, D.T.A.

1985: U-Pb zircon geochronology and paleomagnetism of the Bird River greenstone belt, Manitoba; **in** Program with Abstracts, Geological Association of Canada-Mineralogical Association of Canada, **10**, A62.

Trowell, N.F., Blackburn, C.E., Edwards, G.R., and Sutcliffe, R.H.

1977: Savant Lake - Crow Lake special project, District of Thunder Bay and Kenora; **in** Ontario Geological Survey Miscellaneous Paper 75, 29-50.

Trowell, N.F., Blackburn, C.E., Edwards, G.R., and Bartlett, J.R.

1978: Sioux Lookout - Gullwing Lake area, District of Kenora; **in** Ontario Geological Survey Miscellaneous Paper 82, 28-33.

Trueman, D.L.

1975: Bird River - Winnipeg River area; **in** Manitoba Department of Mines, Resources & Environmental Management, Geological Services Branch, Geological Paper 2175.

1978: Exploration methods in the Tanco Mine area of southeastern Manitoba; Energy **3**, 293-298.

1980: Stratigraphic, structural and metamorphic petrology of the Archean greenstone belt at Bird River, Manitoba;

Unpublished Ph.D. thesis, University of Manitoba, Winnipeg, Manitoba.

Trueman, D.L., Posehn, G.A. and Stoeterau, W.

1975: Metamorphism, structure, and stratigraphy in the Rice Lake-Manigotagan gneiss belt-Bird Lake areas of southeastern Manitoba and northwestern Ontario; **in** 1975 Annual Report of Centre for Precambrian Studies, University of Manitoba, 67-79.

Trusler, J.R.

1974: Farrington Lake area, District of Kenora; **in** Ontario Division of Mines Miscellaneous Paper 59, 41-47.

1975: Farrington Lake area, District of Kenora; Ontario Division of Mines Preliminary Map P.996. Geology 1974.

Turekian, K.K.

1963: The use of trace element geochemistry in solving geological problems; **in** Studies in Analytical Geochemistry, University of Toronto Press, 3-24.

Turekian, K.K. and Kulp, J.L.

1956: The geochemistry of strontium; Geochimica et Cosmochimica Acta **10**, 245-296.

Turekian, K.K. and Carr, M.H.

1960: The geochemistries of chromium, cobalt,and nickle; 21st International Geological Congress, Part 1, 14-26.

Turekian, K.K. and Wedepohl, K.H.

1961: Distribution of the elements in some major units of the earth's crust; Geological Society of America Bulletin **72**,

175-192.

Tuttle, O.F. and Bowen, N.F.

1958: Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O; Geological Society of America Memoir 74, 153p.

Ucakuwun, E.K.

1981: The pegmatites and granitoid rocks of the Dryden area, northwestern Ontario; Unpublished M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba.

Urquhart, W.E.S.

1976: Investigation of the geological significance of linear aeromagnetic anomalies in the English River gneissic belt; Unpublished M.Sc. thesis, University of Toronto, Toronto, Ontario.

van de Kamp, P.C.

1974: Paragenesis in the English River gneiss belt; **in** Centre for Precambrian Studies, University of Manitoba, Unpublished Report, 10p.

van de Kamp, P.C. and Beakhouse, G.P.

1979: Paragneisses in the Pakwash Lake area, English River gneiss belt, northwestern Ontario; Canadian Journal of Earth Sciences **16**, 1753-1763.

van de Kamp, P.C., Leake, B.E. and Senior, A.

1976: The petrography and geochemistry of some Californian arkoses with application to identifying gneisses of metasedimentary origin; Journal of Geology **84**, 195-212.

Viljoen, M.J. and Viljoen, R.P.

1969: The geochemical evolution of the granitic rocks of the Barberton region; Geological Society of South Africa Special Publication **2**, 189-218. p.189-218.

Voll, G.

1960: New work on petrofabrics; Liverpool-Manchester Geological Journal **12**, 503-

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Edmonds, C.M.

1968: Age determinations and geological studies, K-Ar isotopic ages; Geological Survey of Canada Paper 67-2, Report 8.

Wallace, H.

1978: Geology of the Opikeigen Lake area, District of Kenora (Patricia Portion); Ontario Geological Survey Report 185, 58p.

Watson, J.V.

1973: Effects of reworking on high-grade gneiss complexes; Philosophical Transactions of the Royal Society of London **273**, 443-455.

Wedepohl, K.H.

1968: Chemical fractionation in the sedimentary environment; **in** Origin and Distribution of the Elements, Pergamon Press, Oxford, 999-1016.

Westerman, C.J.

1976: Geology of the Anishinabi Lake-Eagle Lake subarea, Operation Kenora-Ear Falls; Unpublished Ontario

Geological Survey field report, 65p.

1977: Tectonic evolution of a part of the English River Subprovince, northwestern Ontario; Unpublished Ph.D. Thesis, McMaster University, Hamilton, Ontario, 292p.

White, A.J.R.

1966: Genesis of migmatites from the Palmer region of South Australia; Chemical Geology **1**, 165-200.

1979: Sources of granite magmas; Annual Meeting, Geological Society of America, Book of Abstracts, 539.

White, A.J.R. and Chappell, B.W.

1977: Ultrametamorphism and granitoid gneiss; Tectonophysics **43**, 7-22.

Whitney, P.R.

1969: Variations of the K/Rb ratio in migmatitic paragneisses of the northwest Adirondacks; Geochimica et Cosmochimica Acta **33**, 1203-1211.

Wiebe, R.A.

1975: Origin and emplacement of Acadian granitic rocks, northern Cape Breton Island; Canadian Journal of Earth Sciences **12**, No.2, 252-262.

Williamson, W.R.M. and Hudec, P.P.

1959: Geology of the Wapesi-Tully Lakes area; Ontario Department of Mines **67**, Part 4, 1-12.

Wilson, A.W.G. and Johnston, J.F.E.

1904: Report on a traverse through the Severn River; Geological Survey of Canada **16**, Part A, 143-152.

Wilson, H.D.B.

1971: The Superior Province in the Precambrian of Manitoba; **in** Geological Association of Canada Special Paper No. 9, 41-49.

Wilson, H.D.B. and Brisbin, W.C.

1963: Nature of the granitic crust in the Superior Province; **in** Annual Meeting Geological Society of America, Abstract, 180.

Wilson, H.D.B., Andrews, Peter, Moxham, R.L. and Ramlal, K.

1965: Archean volcanism in the Canadian Shield; Canadian Journal of Earth Sciences **2**, 161-175.

Winchester, J.A. and Floyd, P.A.

1977: Geochemical discrimination of different magma series and their differentiation products using immobile elements; Chemical Geology **20**, 325-343.

Windley, B.F.

1973: Crustal development in the Precambrian; Philosophical Transactions of the Royal Society of London, A.273, 321-341.

Windley, B.F. and Bridgwater, D.

1971: The evolution of Archean low and high-grade terrains; **in** Geological Society of Australia Special Volume **3**, 33-46.

Windley, B.F. and Smith, J.V.

1976: Archean high grade complexes and modern continental margins; Nature **260**, 671-675.

Winkler, H.G.F.

1979: Petrogenesis of Metamorphic Rocks; 5th edition, Springer-Verlag, New York, 348p.

Winkler, H.G.F. and von Platen, H.

1958: Experimentalle Gesteinemetamorphose II; Geochimica Cosmochimica Acta **15**, 91-112.

1961: Experimentalle Gesteinemetamorphose IV. Bildung Anatektischer Schmelzen aus Metamorphisierten Grauwacken; Geochimica et Cosmochimica Acta **24**, 250-259.

Winkler, H.G.F., Boese, M. and Marcopoulos, T.

1975: Low temperature granitic melts; Jahrbuch fur Mineralogie Monatshefe **6**, 245-267.

Wooden, J.L. and Goodwin, A.M.

1980: A Rb-Sr isotopic study of the Archean rocks of the eastern Lac Seul region, English River Subprovince, northwestern Ontario; Canadian Journal of Earth Sciences **17**, 569-576.

Wright, J.F.

1936: Geology and mineral deposits of a part of southeastern Manitoba; Manitoba Department of Mines and Resources, Mines and Geological Branch Memoir 169, 150p.

Wright, W.I.

1936: Papaonga area, Kenora District (Patricia Portion); Geological Survey of Canada Map 347A.

Wyllie, P.J. and Tuttle, O.F.

1961: Experimental investigation of silicate systems containing two volatile components. Part II. Effects of NH_3 and HF, in addition to H_2O on the melting temperature of albite and

granite; American Journal of Science **259**, 128-143.

1964: Experimental investigation of silicate systems containing two volatile components, Part III. The effects of SO_3, P_2O_5, HCl and Li_2O, in addition to H_2O on the melting temperatures of albite and granite; American Journal of Science **262**, 930-939.

Ziehlke, D.V.

1974: The Aulnean batholith project; **in** 1974 Annual Report, Centre for Precambrian Studies, University of Manitoba, 150-184.

Zoltai, S.C.

1961: Glacial history of part of northwestern Ontario; Proceedings of the Geological Association of Canada **13**, 61-83.

1965a: Surficial geology of the Kenora-Rainy River area; Ontario Department of Lands and Forests Map S-165.

1965b: Glacial features of the Quetico-Nipigon area, Ontario; Canadian Journal of Earth Sciences **2**, No.4, 247-269.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0 039 37	inches	1 inch	**25.4**	mm
1 cm	0 393 70	inches	1 inch	**2.54**	cm
1 m	3 280 84	feet	1 foot	**0.304 8**	m
1 m	0 049 709 7	chains	1 chain	20 116 8	m
1 km	0 621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0 155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10 763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0 386 10	square miles	1 square mile	2 589 988	km^2
1 ha	2 471 054	acres	1 acre	0 404 685 6	ha
		VOLUME			
1 cm^3	0 061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35 314 7	cubic feet	1 cubic foot	0 028 316 85	m^3
1 m^3	1 308 0	cubic yards	1 cubic yard	0 764 555	m^3
		CAPACITY			
1 L	1 759 755	pints	1 pint	0 568 261	L
1 L	0 879 877	quarts	1 quart	1 136 522	L
1 L	0 219 969	gallons	1 gallon	**4 546 090**	L
		MASS			
1 g	0 035 273 96	ounces (avdp)	1 ounce (avdp)	28 349 523	g
1 g	0 032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2 204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0 001 102 3	tons (short)	1 ton (short)	**907 184 74**	kg
1 t	1 102 311	tons (short)	1 ton (short)	**0 907 184 74**	t
1 kg	0 000 984 21	tons (long)	1 ton (long)	**1016 046 908 8**	kg
1 t	0 984 206 5	tons (long)	1 ton (long)	**1 016 046 908 8**	t
		CONCENTRATION			
1 g/t	0 029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34 285 714 2	g/t
1 g/t	0 583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1 714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20 0	pennyweights per ton (short)
1 pennyweight per ton (short)	0 05	ounces (troy) per ton (short)

Note Conversion factors which are in bold type are exact The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by the Mining Association of Canada in co-operation with the Coal Association of Canada

3268
ISSN 0826-9580
ISBN 0-7778-1220-7

Ministry of
Northern Development
and Mines
Ontario

Ontario Geological Survey
Open File Report 5846

The English River Subprovince – An Archean Gneiss Belt: Geology, Geochemistry and Associated Mineralization

Volume 2

1993

Ministry of
Northern Development
and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY

Open File Report 5846

The English River Subprovince—An Archean Gneiss Belt: Geology, Geochemistry and Associated Mineralization

Volume 2

By

F.W. Breaks and W.D. Bond

1993

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

Breaks, F.W. and Bond, W.D. 1993. The English River Subprovince—An Archean Gneiss Belt: Geology, Geochemistry and associated mineralization; Ontario Geological Survey, Open File Report 5846, v.2, p.484-884, 884p.

© Queen's Printer for Ontario, 1993

Ontario Geological Survey

OPEN FILE REPORT

Open File Reports are made available to the public subject to the following conditions:

This report is unedited. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Recommendations and statements of opinions expressed are those of the author or authors and are not to be construed as statements of government policy.

This Open File Report is available for viewing at the following locations:

Mines Library
Level A3, 933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5

Mines and Minerals Information Centre (MMIC)
Rm. M2-17, Macdonald Block
900 Bay St.
Toronto, Ontario M7A 1C3

The office of the Resident Geologist whose district includes the area covered by this report.

Copies of this report may be obtained at the user's expense from:

OGS On-Demand Publications
Level B4, 933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5
Tel. (705)670-5691 Collect calls accepted.

Handwritten notes and sketches may be made from this report. Check with MMIC, the Mines Library or the Resident Geologist's office whether there is a copy of this report that may be borrowed. A copy of this report is available for Inter-Library loan.

This report is available for viewing at the following Resident Geologists' offices:

Kenora, Box 5200, 808 Robertson St., Kenora P9N 3X9

Sioux Lookout, Box 3000, Court House Building, Sioux Lookout P0V 2T0

Red Lake, Box 324, Ontario Government Building, Red Lake P0V 2M0

The right to reproduce this report is reserved by the Ontario Ministry of Northern Development and Mines. Permission for other reproductions must be obtained in writing from the Director, Ontario Geological Survey - Geoscience Branch.

FOREWORD

Prior to 1974 there was very little geological understanding of the English River and Winnipeg River subprovinces. Their origin, tectonic setting, mineral potential and relations to the bounding Uchi and Wabigoon subprovinces were unknown.

Beginning in 1974 the Ontario Geological Survey undertook a four year helicopter supported reconnaisance mapping project covering 37000 square kilometers to improve on the geological data base.

The results of this study have greatly enhanced our understanding of the genesis of the metasedimentary subprovinces that flank the granite-greenstone dominated subprovinces. The present report describes the potential for metallic and industrial mineralization and building stone.

V.G. Milne
Director
Ontario Geological Survey

TABLE OF CONTENTS

VOLUME 1

ABSTRACT

CHAPTER 1 - INTRODUCTION....1
- Location and Access....2
- Present Geological Survey....3
- Present Geological Report....6
- Previous Investigations....7
- Prospecting and Mining History....11
- Natural Resources....12
- Topography and Drainage....13
- Acknowledgments....14

CHAPTER 2 - TERMINOLOGY....17
- Major Divisions of the Superior Province....17
- Subdivisions of the Subprovinces....17
- Gneiss and Migmatite Terminology....19
  - Gneiss....19
  - Foliated to Gneissic....20
  - Foliation....20
  - Migmatite....21
- Metamorphic Terminology....22
- Cataclastic Terminology....22
- Intrusive Rock Nomenclature....23

CHAPTER 3 - GENERAL GEOLOGY AND METAVOLCANIC ROCKS....26
- Metavolcanic Rock Subdivision....31
- Mapping Emphasis....32
- Mafic to Intermediate Metavolcanic Rocks....33
  - Mineralogy....33
  - Massive Flows....35
  - Pillowed Flows....36
  - Pyroclastic Rocks....37
  - Gneissic Metavolcanic Rocks....37
- Felsic to Intermediate Metavolcanic Rocks....38
  - Mineralogy....39
  - Pyroclastic Rocks....40
  - Massive and Porphyritic Flows....43
- Specific Metavolcanic Belts....44
  - English River Subprovince....44
    - Separation Lake Belt....44
      - Modern Analogues....48
    - Eastern Extension of Separation Lake Belt....49
  - Uchi Subprovince....50

Dixie Lake Belt....51
Bruce Lake-Snakeweed Lake-Fredhart Lake Area....52
Mafic Metavolcanic Units....52
Felsic to Intermediate Metavolcanic Units....53
Slate Lake Area....56
Slate Lake to Papaonga Lake Area....57
Papaonga Lake....58
Badrock-Avis Lakes - Wassa Bay....59
Avis-Jubilee-Slate Lake Area....60
Papaonga Lake - Roadhouse River River - Root Bay Metavolcanic Belt....61
Lake St. Joseph Metavolcanic Belt....62
Wabigoon Subprovince....62
Tustin-Bridges Greenstone Belt....62
Dryden-Sioux Lookout Area....66
Sioux Lookout - Sturgeon Lake Belt....67
Savant Lake Greenstone Belt....68

CHAPTER 4 - METASEDIMENTARY ROCKS AND DERIVED MIGMATITES....71
Introduction....71
Lithological Composition....72
Inter- and Intra-subprovince Boundary Relationships....73
Northern Boundary....73
Boundary between Northern and Southern Domains....76
The Migmatite Problem....78
List of Notable Features of Metasedimentary Migmatites....82
Migmatite Stage....82
Protometatexite....82
Metatexite....83
Inhomogeneous Diatexite....83
Homogeneous Diatexite....83
Migmatite Constituents....83
Paleosome....83
Leucosome....83
Melanosome....84
General Types of Structures....85
Cataclastic Migmatitic Rocks....86
Map Coding....87
Classification of Metasedimentary Migmatites from the English River Subprovince: Concept of the Migmatite Continuum....87
Metatexite....88
Protometatexite....90
Diatexite....93
Inhomogeneous Diatexite....95
Homogeneous Diatexite....96
Wapesi Lake batholith....99

Churchill Lake batholith....100
Migmatite Constituents....101
Paleosome....101
Leucosome....103
Petrochemistry....107
K/Rb variation....112
Melanosome....112
Petrochemistry....114
Modal Features of Wacke and Pelitic Metasedimentary Rocks....115
Comparison to other Important Rock Groups
Hornblende-Bearing Sodic Granitoids....118
Potassic Granitoid Group....119
Petrochemistry of the Metasedimentary Rocks....120
K/Rb Variation....124
Origin of the Metasedimentary Rocks....125

CHAPTER 5 - SUBVOLCANIC INTRUSIVE ROCKS....133
Subvolcanic Intrusions....133
Subdivision of the Intrusive Rocks....135

CHAPTER 6 - MAFIC INTRUSIVE SUITE....141
Nature and Distribution....141
Stocks and Sills of the English River Subprovince....142
Isolated Plutons of Uncertain Origin....142
Muriel Lake pluton....143
Ena Lake pluton....144
Pakwash Lake pluton....145
Bruce Lake pluton....146
Stocks and Sills Associated with other Intrusive Suites....148
Broadcast Lake stock....149
Conifer Lake intrusive complex....149
Stocks and Sills of the Uchi Subprovince....151
Papaonga Lake pluton....152
Lake St. Joseph Layered Mafic intrusive complex....153
Plutons of the Wabigoon Subprovince....154
Mafic Dykes, Enclaves and Derived Amphibolite....156
Mafic dykes....156
Mafic Enclaves....157
Chemistry of the Mafic Intrusive Suite....158
Comparative Chemistry and Modern Analogues....158
Chemical Relationship of Dykes and Plutons....165
Age and Emplacement of the Mafic Intrusive Suite Relative to the Important Plutonic Suites....166
Summary....167

CHAPTER 7 - GNEISSIC GRANITOID SUITE....168
Introduction....168
Distribution and Nature....169
Map Associations....174
Ultramafic Association....175
Supracrustal Association....177
Amphibolite Units....177
Metasedimentary Units....178
Tonalite Association....178
Leucogranite Association....180
Leucocratic Biotite Trondhjemite....181
Holo-leucocratic Trondhjemite....182
Leucocratic Quartz Monzonite....182
Mafic Dyke Association....183
Potassic Granitoid Association....185
Other Minor Associations....186
Potassium Metasomatism....186
Biotite Schlieren....187
Tectono-Metamorphic Reworking of the Associations....187
Modal Variation....188
Origin of the Gneissic Suite....189
Summary....198

CHAPTER 8 - SODIC GRANITOID SUITE....200
Introduction....200
Mineralogy....202
General Lithic Groups of the Sodic Suite....206
Equigranular and Inequigranular Units....207
Porphyritic/Porphyroblastic (K-Feldspar) Units....208
Granitic Units....210
Hybrid Rocks and Enclaves....210
Cataclastic Units....211
Intrusion Types of the Sodic Granitoid Suite....211
Simple Homogeneous Plutonic Type....212
Dalles batholith....213
Campfire Lake and Daniels Lake plutons....216
Complex, Heterogeneous Plutonic Type....216
Sen Bay stock....218
Chemistry....220
Summary....223

CHAPTER 9 - POTASSIC GRANITOID SUITE....226
Introduction....226
Mineralogy and Modal Variation....230
Equigranular Units....231
Clotty Quartz Monzonite....233

Porphyritic Units....238
Lount Lake batholith....240
Mineralogy....243
Modal and Chemical Variation....246
Origin....247
Porphyritic, Contact-Controlled Sills....252
Trondhjemite to Granodiorite Units....254
Syenite Units....256
Pegmatite....257
Sharply-defined Sills and Dikes....258
Diffuse Veins and Sills....260
Pegmatitic Granite Border Unit....261
Consanguineous Pegmatite Pods....263
White Pegmatite....264
Potassium Metasomatism....268
Cataclastic Rocks....270
Summary....271

CHAPTER 10 - CHEMICAL VARIATION AND GENESIS OF THE IMPORTANT PLUTONIC SUITES....273
Introduction....273
Chemical Variation....273
Summary....275
Nature of the English River Subprovince Plutonism....278
Modern Analogues....286
Genesis of Plutonic Rocks of the English River Subprovince....288

CHAPTER 11 - NATURE OF PLUTONISM OUTSIDE THE ENGLISH RIVER SUBPROVINCE....293
Wabigoon Subprovince....293
Sturgeon Lake - Sioux Lookout Area....293
Mafic to Intermediate Intrusive Rocks....293
Intermediate to Felsic Intrusive Rocks....294
Yett Lake stock....294
Robinson batholith....294
Nagron Lake stock....295
Lake of Bays batholith....295
Other Areas in the Wabigoon Subprovince
Uchi Subprovince....297
Contact Relationships....298
Subprovince Boundaries....298
Wabigoon-English River Boundary....298
Uchi - English River Boundary....301
Northern - Southern Domain Interface....302

CHAPTER 12 - PLEISTOCENE GEOLOGY....304
Glacial History....304
Glacial Deposits....306
Terminal Morraines....306
Outwash Deposits....307
Glacio-Lacustrine Deposits....307
Kames and Eskers....308
Ribbed Morraines, Scouring/Drumlimoid Ridges....308
Recent....309

CHAPTER 13 - GEOPHYSICS....310
Correlation with aeromagnetic data....310
Correlation with radiometric data....311
Seismic data....312

CHAPTER 14 - METAMORPHISM....314
Introduction....314
Northern Supracrustal Domain....315
Lake St. Joseph Area
Southern Plutonic Domain....319
Low Pressure Granulite Facies Metamorphism....320
Metamorphic Conditions....323

CHAPTER 15 - STRUCTURAL GEOLOGY....325
Introduction....325
Northern Supracrustal Domain....325
Southern Plutonic Domain....331
Cedar - Clay Lakes Area....331
Tectonic Assemblage I....332
Tectonic Assemblage II....333
Tectonic Assemblage III....334
Kenora Area....335
Late Archean Faults....338
Sydney Lake Fault....338
Structural and Lithologic Features....339
Shearing and Flattening....341
Origin of the Faulting....341
Other Fault Systems....342
Origin and significance of pseudotachylite....343

CHAPTER 16 - METALLOGENY OF THE ENGLISH RIVER SUBPROVINCE...352
Introduction....352
Mineralization of the Lithophile Affinity....347
Beryllium....348
Sandy Creek Beryl Occurrence....348
Exploration History....349
Geology....349

Geochemistry....350
Cesium....352
Lithium....352
McCombe Property (Capital Lithium Mines Limited)....354
Exploration History....354
Geology....355
Geochemistry....356
Tot Lake Li-Cs-Rb-Ta Occurrence....357
Exploration History....357
Geology....358
Geochemistry....361
Mavis Lake Li-Be-Ta Pegmatite Dykes....365
Exploration History....365
Geology....366
Economic Geology....367
Distribution of Lithium in the Metamorphic and Anatectic Environments....368
Lithium in Anatectic Rocks....369
S-Type Granite - Rare-Element Pegmatite Association....371
Tantalum....375
Uranium....376
Metasedimentary Migmatite Association....377
Sydney Lake Fault Occurrences....377
Sydney Lake Fault Occurrences....377
Geological Setting....378
Radiometric Survey....378
Geochemistry....379
Umfreville Lake Uranium Occurrence....380
Exploration History....380
Geology....380
Geochemistry....381
Holunga Uranium Occurrence....384
Exploration History....384
Geology....384
Anderson Occurrence....385
Exploration History....385
Geology....385
Origin of the Type I Uranium-Bearing Granitic Pegmatites....386
Uranium Associated with the Potassic Granitoid Suite....388
Celyn Lake Occurrence....389
Exploration History....389
Geology....389
Geochemistry....390

Drope Township Uranium Occurrence....392
Exploration History....392
Geology....392
High Grade Zone....393
Low Grade Zone....394
Bluett-Gilbert Lakes Portage....395
Geochemistry....395
Davidson Uranium Occurrence....396
Exploration History....397
Geology....397
Geochemistry....401
Tourist Lake Occurrence....403
Exploration History....403
Geology....403
Geochemistry....405
Cameron-Alcock Occurrence....406
Exploration History....406
Geology....406
Perch Lake Occurrence....406
Exploration History....406
Geology....407
Geochemistry....407
Ena Lake Occurrence....407
Exploration History....407
Geology....408
Geochemistry....408
Mineralization of the Chalcophile Affinity....409
Massive Sulphide Mineralization....409
Minaki Pyrite Deposit....409
Exploration History....410
Geology....410

REFERENCES....419

VOLUME 2

TABLES

1-1 Classification of granulite rocks of the regional hypersthene zone.....484
1-2 Classification of plutonic rocks used by the Ontario Division of Mines.....485
2-1 Table of lithologic units for the English River Subprovince.....486
3-1 Chemical analyses of extrusive/intrusive rocks from Separation Lake.....492
3-2 List of localities representing the extension of Separation Lake Belt.....493
3-3 Chemical analyses of Chamberlain Narrows (Lac Seul) metavolcanic rocks.....494
3-4 Chemical analyses of Sioux Lookout amphibolites.....495
4-1 Lithological composition of the English River Subprovince.....497
4-2 Classification and general features of metasedimentary migmatites from the northern supracrustal domain, English River Subprovince.....498
4-3 Chemical and modal analyses of mafic diatexite from the English River Subprovince.....499
4-4 Modal analyses of leucosome from metasedimentary migmatites of the English River Subprovince.....500
4-5 Mean bulk chemical composition of metawacke from the English River Subprovince in comparison to various lithic groups from the literature.....509
4-6 Mean bulk composition of pelitic metasedimentary rocks from the English River Subprovince in comparison to various lithic groups from the literature.....510
4-7 Chemical analyses and selected element ratios for the leucosome constituent from metsedimentary migmatite of the English River Subprovince.....511
4-8 Chemical analyses and selected element ratios of mafic diatexites from the English River Subprovince.....522
4-9 Modal composition of the residual fraction derived from experimental partial melting of Harz Mountain greywackes at 700°C and pH_2O = 200 bars after Winkler and von Platen (1961).....526
4-10 Chemical analyses of the melanosome constituent from metasedimentary migmatite of the northern supracrustal domain.....527
4-11 Modal analyses of metawacke from the English River Subprovince.....528
4-12 Modal analyses of metapelite from the English River Subprovince.....535
4-13 Chemical analyses and selected element ratios of metawacke from the English River Subprovince.....539
4-14 Chemical analyses and selected element ratios of metapelite from the English River Subprovince.....560
4-15 Mean values and ranges of selected trace elements for metawacke, metapelite and various other Archean lithic groups.....575
4-16 Mean values and ranges of selected trace elements in metawackes from the English River Subprovince compared to those from the literature.....576

4-17 Mean values and ranges of selected trace elements in metapelites from the English River Subprovince compared to those from the literature....577
4-18 Mean composition of metawacke and metapelite from the English River Subprovince compared to the composition of the upper crust....578
6-1 Modal analyses from the Broadcast Lake pluton (after Desnoyers 1977, p.22)....579
6-2 Petrologic subdivision of Lake St. Joseph mafic layered sill (Smith 1977, p.1-39)....580
6-3 Chemical analyses of fine-grained amphibolites (Gower 1978, p.558-559)>....582
6-4 Chemical analyses of medium-grained amphibolites and mafic dykes form the Kenora area (Gower 1978, p.561-562)....583
6-5 Chemical analyses of Lac Seul mafic dykes....584
6-6 Chemical analyses of anorthositic, mafic and ultramafic enclaves, Lac Seul....585
6-7 Chemical analyses of mafic enclaves, Lac Seul....586
6-8 Range and mean values for various rocks of the mafic intrusive suite....587
6-9 Range and mean for Cr, Cu, Ni and Zn for various rocks of the mafic intrusive suite....589
7-1 Mappable rock associations within the gneissic suite (after Westerman 1977)....590
7-2 Petrographic differences between the fine-grained and medium-grained amphibolites in the Kenora area (Gower 1978, p.206)....591
7-3 Comparison of rock associations for Cedar Lake, Melick and Deception Bay gneissic suites....592
7-4 Important lithologic associations and possible genesis of the Cedar Lake gneiss....593
7-5 Lithological and genetic characteristics of the gneissic suite at Kenora summarized from Gower (1978)....594
7-6 Lithologic characteristics and associations of the Deception Bay - Lac Seul gneissic suite....595
7-7 Petrographic differences between fine-grained and coarse-grained amphibolites in the Kenora area (Gower 1978, p. 206)....597
8-1 Petrography of units from the Sen Bay stock....598
8-2 Chemical analyses of the Sen Bay stock....599
9-1 Chemical analyses of the matrix and clasts of the clotty quartz monzonite....600
9-2 Lithophile trace elements from pegmatitic granite mass north of Papaonga Lake. 10-1 Chemical analyses of the gneissic granitoid suite, Deception Bay area of Lac Seul....601
10-1 Chemical Analyses of the Gneissic Suite, Deception Bay Area....602
10-2 Chemical analyses of the Melick gneiss, Kenora area....604
10-3 Chemical analyses of the gneissic granitoid suite north of the Tustin-Bridges area....605

10-4 Chemical analyses of the gneissic granitoid suite from the Sioux Lookout area....606
10-5 Chemical analyses of Cedar Lake gneiss (Westerman 1977)....607
10-6 Chemical analyses of biotite tonalite gneiss from the Kenora area (Gower 1978, p. 567-568)....608
10-7 Chemical analyses of amphibole gneiss from the Kenora area (Gower 1978, p. 566)....611
10-8 Chemical analyses of sodic granitoid suite rocks from the Campfire Lake pluton....612
10-9 Chemical analyses of sodic granitoid suite rocks from the Bowden Lake and Daniels Lake plutons....613
10-10 Chemical analyses of miscellaneous rocks of the sodic granitoid suite emplaced in metasedimentary hosts....614
10-11 Chemical analyses of the Sen Bay stock....616
10-12 Chemical analyses of the Chamberlain Narrows intrusive complex....617
10-13 Chemical analyses of the Separation-Indian Lake intrusive complex....618
10-14 Chemical analyses of the Armit Lake intrusive complex....619
10-15 Chemical analyses of the Lount Lake batholith....620
10-16 Chemical analyses of miscellaneous units of the potassic granitoid suite....621
10-17 Chemical analyses of the Fletcher Lake batholith....623
10-18 Chemical analyses from the Lateral Lake area....624
10-19 Range and mean values of selected trace elements from the gneissic granitoid suite....625
10-20 Range and mean values of selected trace elements from the sodic granitoid suite....629
10-21 Range and mean values of selected trace elements from the potassic granitoid suite....633
10-22 Summary of the main features of the important plutonic suites of the English River Subprovince....635
10-23 Compilation of radiometric ages for the important plutonic suites of the English River Subprovince....636
11-1 Chemical analyses of the Robinson batholith....638
11-2 Chemical analyses of the Nagron Lake stock....639
11-3 Chemical analyses of the Lake of Bays batholith....641
11-4 Chemical analyses of the Sturgeon River Batholith....642
11-5 Chemical analyses of the Lewis Lake batholith....643
14-1 Metamorphic and deformation events in the Uchi and English River Subprovinces of Ontario (modified after McRitchie and Weber 1971)....644
14-2 Metamorphic mineral assemblages from the Lake St. Joseph and eastern Lac Seul areas....645
14-3 Metamorphic mineral assemblages in metasedimentary rocks from the Dryden-Eagle Lake area....646
15-1 Summary of structures and metamorphism in the nothern supracrustal domain of the English River Subprovince of Ontario and Manitoba....647

15-2 Summary of geological and tectonic-metamorphic history of the Cedar-Clay Lakes area (after Westerman 1977)....648
15-3 Summary of the structural and metamorphic history of the Kenora area (after Gower 1978; Gower and Clifford 1981)....650
16-1 Average crustal abundance of selected elements and ratios....651
16-2 Partial petrochemical analyses from the Sandy Creek beryl occurrence....652
16-3 Analysis of composite muscovite samples from the Sandy Creek and Tot Lake rare-element pegmatites....653
16-4 Selected mean ratios from beryllium, lithium and uranium pegmatite....654
16-5 Partial analyses and element ratios from spodumene pegmatite at the McCombe property....655
16-6 Partial petrochemical analyses from the Tot Lake Pegmatite....656
16-7 Analyses of columbite-tantalite group mineral from the Tot Lake Pegmatite (From Ucakuwun 1981, p.113)....659
16-8 Petrochemical analyses across Pegmatite #5 at the North Zone of the Mavis Lake property....660
16-9 Mean contents (ppm) of Li, Rb, Cs, Ba and U in metawacke and metapelitic rocks from the Lake St. Joseph area in relation to metamorphic grade....661
16-10 Mean contents (ppm) of lithium in muscovite and biotite from the study area and the literature....662
16-11 Classification of unzoned, uranium-rich granitic pegmatites of the western English River Subprovince....663
16-12 Partial petrochemical analyses from the Umfreville Lake uranium occurrence....664
16-13 Chemical analyses of metasedimentary rocks from the Umfreville Lake area which contain anomalous U and Th....669
16-14 Partial petrochemical analyses of granitic rocks from the Celyn Lake uranium occurrence....670
16-15 Partial petrochemical analyses of granitic rocks from the Drope Township uranium occurrence....671
16-16 Partial petrochemical analyses of granitic rocks from the Davidson uranium occurrence....675
16-17 Mean values of U, Th, K/Ba, K/Cs, K/Rb, K/Th, K/U, Ba/Rb, Mg/Li, and Th/U at the Main Zone of the Davidson uranium occurrence....680
16-18 Partial petrochemical analyses of various units at the Tourist Lake uranium occurrence....681
16-19 Chemical analyses and element ratios of granitic rocks from the Ena Lake and Perch Lake uranium occurrences....683

FIGURES

1-1 General location of areas covered by geological reconnaissance mapping projects in the English River Subprovince....685
1-2 Generalized geological aspect of the English River Subprovince, Northwestern Ontario....686
2-1 Geology of the English River Subprovince....687
3-0 Geology of the Separation Lake Belt....688
3-1 AFM diagrams of metavolcanic rocks....689
3-2 Jensen Cation Plot of Separation Lake mafic metavolcanic rocks, felsic volcanics, and mafic intrusive rocks....690
3-3 Chemical variation of Separation Lake mafic metavolcanic, extrusive and intrusive rocks....691
3-4 Chemical variation of Separation Lake mafic metavolcanic, extrusive and intrusive rocks....692
3-5 Chemical variation of Sioux Lookout mafic metavolcanic rocks....693
4-1 General geology and metallogeny of the English River and adjacent parts of the Uchi and Wabigoon Subprovinces....694
4-2 General geology of the English River-Uchi Subprovince interface in the Papaonga Lake area....695
4-3 General geology of the interface between Uchi Subprovince metavolcanic rocks and northern supracrustal domain metasedimentary rocks in the western Lake St. Joseph area....696
4-4 Distribution of advanced stage metsedimentary migmatites (diatexites) in relation to low pressure granulite centres of the English River Subprovince....697
4-5 Modal variation of quartz-plagioclase-K-feldspar in leucosome from metasedimentary migmatite of the northern supracrustal domain....698
4-6 Modal variation of quartz-feldspar-colour index in leucosome from metasedimentary migmatite of the northern supracrustal domain as compared to S-Type granitoid rocks from the Kosciusko batholith, Australia....699
4-7 General modal variation trends in S-Type granitoid rocks (northern supracrustal domain and Kosciusko batholith) compared to I-Type granitoid rocks from the southern plutonic domain....699
4-8 Quartz-feldspar-colour index modal variation in metawacke and metapelitic rocks from the northern supracrustal domain....700
4-9 Comparison of the quartz-feldspar-colour index modal fields for metawacke, and metapelite of the northern supracrustal domain with biotite- and hornblende-bearing sodic granitoid suite rocks of the English River Subprovince....700
4-10 AFM and CNK plots (weight %) illustrating compositional variation of metawacke from the northern supracrustal domain. Ennumerated analyses correspond to mean lithic compostions selected from the literature as given in Table 4-5....701
4-11 AFM and CNK plots (weight %) illustraing composition variation

of metapelites from the northern supracrustal domain. Ennumerated analyses correspond to mean lithic compostions selected from the literature as given in Table 4-6 702
4-12 The Fe_{total}-Mg-Na+K (weight %) expression of metatexis-anatectic spitting of paleosome giving rise to melanosome and leucosome constituents 703
4-13 Variation of Fe_{total}-Mg-Na+K (weight %) in diatexites as possibly related to progressive fusion of a metasedimentary protolith. The curve interpreted as due to increasing anatexis was derived from this study supplemented with the data of Winkler (1979) 704
4-14 Variation of Ca-Na-K (weight %) in diatexites, illustrating the sodic and potassic leucosome trends 705
4-15 K_20 vs Na_2O variation in leucosome from metasedimentary migmatite of the study area in comparison to sodic and potassic granitoid suite rocks and Australian S-Type granitoids 706
4-16 Variation of Fe^{2+}-Fe^{3+}-Mg in leucosome from the northern supra-crustal domain and equigranular and porphyritic divisions of the potassic granitoid suite from the southern plutonic domain 707
4-17 Histograms revealing frequency of $Fe^{3+}/Fe^{2+} + Fe^{3+}$ in leucosome from the northern supracrustal domain compared to potassic granitoid suite rocks from the southern plutonic domain 708
4-18 Normative quartz-albite-orthoclase for leucosome from the northern supracrustal domain. Isotherms and cotectic projection at P H_2O = 5 kbars from Winkler et al. (1975) 709
4-19 Normative anorthite-albite-orthoclase for leucosome from the northern supracrustal domain. Isotherms and cotectic projection at PH_2O = 5 kbars from Winkler et al. (1975) 710
4-20 K vs Rb variation in leucosome from metasedimentary migmatite of the English River Subprovince 711
4-21 K vs K/Rb variation in leucosome from metasedimentary migmatite of the English River Subprovince 712
4-22 Na_2O-K_2O variation in metasedimentary rocks from the English River Subprovince 713
4-23 Al_2O_3 vs K_2O+Na_2O variation in metasedimentary rocks of the English River Subprovince 713
4-24 Histograms revealing variation of CIPW normative corundum in metawacke and metapelite rocks of the English River Subprovince 714
4-25 FeO vs Fe_2O_3 variation in metawacke and metapelite rocks of the English River Subprovince 715
4-26 K vs K/Rb variation in metawacke rocks from the English River Subprovince 716
4-27 K vs K/Rb variation in metapelite rocks from the English River Subprovince 717
4-28 K vs Rb relationships as a function of metamorphism for meta-pelite and metawacke rocks of the English River Subprovince 718
4-29 MgO vs Ni variation in metasedimentary rocks from the English River Subprovince (123 analyses, this study) 719

4-30 MgO vs Cr variation in metasedimentary rocks from the English River Subprovince (132 analyses, this study).....720
4-31 Ni vs Cr variation in metasedimentary rocks from the English River Subprovince (123 analyses, this study).....721
4-32 MgO vs Ni diagram depicting the relationship of metasedimentary rocks of the English River subprovince with various, spatially associated lithic groups.....722
4-33 MgO-Cr diagram depicting the relationship of metasedimentary rocks of the English River Subprovince with various, spatially associated lithic groups.....723
4-34 Cr-Ni variation in meatavolcanic rocks from the Uchi and Wabigoon Subprovinces.....724
4-35 MgO-Ni variation in sodic granitoid suite rocks from the English River Subprovince.....725
4-36 MgO-Cr variation in sodic granitoid suite rocks from the English River Subprovince.....725
6-1 Location of the mafic intrusive suite in the English River Subprovince.....726
6-2 Modal analyses of various members of the mafic intrusive suite. Pillowed mafic metavolcanic rocks of the English River Subprovince are given for comparison (diagram #4).....727
6-3 Major, minor and trace element variation of the Lake St. Joseph layered mafic sill (Smith 1977) based upon 23 analyses. Dashed line divide undifferentiated metagabbro (Unit 3) from differentiated metagabbro (Unit 2).....728
6-4 TiO_2 vs FeO_{total}/MgO plot (Miyashiro and Shido 1975) for English River Subprovince amphibolites.....729
6-5 Zr-Ti/100-Sr/2 plot (Pearce and Cann 1973) for English River Subprovince amphibolites of varying origin. OFB = ocean basalts, CAB = calc-alkaline basalts and LKT = low K tholeiites.....730
6-6 Chemical variation of amphibolites in gneissic suite at Kenora. **missing figure**
6-7 Zr-Ti/100-Y.3 and Ti-Cr plots (Pearce and Cann 1973; Pearce 1975) for amphibolites of the English River and Wabigoon Subprovinces. OFB = ocean floor basalt, CAB = calc-alkaline basalts, LKT = low K-tholeiite, WPB = within plate basalts, IAB = island arc basalts.....731
6-8 K_2O-TiO_2-P_2O_5 plot (Pearce et al. 1975) for amphibolites hosted in the gneissic granitoid suite at Kenora and Cedar Lake.....732
6-9 K_2O-TiO_2-P_2O_5 plot (Pearce et al. 1975) for amphibolites in the Chamberlain Narrows (Lac Seul) area.....733
6-10 TiO_2-MnO-P_2O_5x10 plot (pearce et al. 1975) for English River Subprovince amphibolites of intrusive and extrusive origin.....734
6-11 AFM plots (weight %) of various amphibolitic rocks from the English River Subprovince.....735
6-12 Chemical variation of mafic intrusive suite rocks hosted in the gneissic granitoid suite.....736
7-1 Distribution of the gneissic granitoid suite in the English River Subprovince.....737

7-2 Classification of gneissic granitoid suite rocks in the Kenora area (Gower 1978, p.84)....738
7-3 Modal variation of the gneissic granitoid suite (Sioux Lookout gneiss, Lac Seul gneiss, Melick gneiss, Cedar Lake gneiss and Twilight gneiss....739
7-4 Sedimentary/igneous discrimination function analyses (Shaw 1972) for the gneissic granitoid suite (A and C: Melick gneiss; B: Kenora and Deception Bay gneiss)....740
7-5 TiO_2 - SiO_2 igneous/sedimentary discrimination diagram (Tarney et al. 1976) for the gneissic granitoid suite....741
7-6 Spatial relation between the gneissic granitoid suite and granulite grade zones....742
7-7 AFM-CNK (weight %) variation of Deception Bay (Lac Seul) gneissic granitoid suite. Unit number (see Table 7-6) indicates relative age of intrusion....743
8-1 Distribution of sodic and potassic granitoid suite stocks and batholiths in the northern supracrustal domain....744
8-2 Distribution of the sodic granitoid suite in the southern plutonic domain....745
8-3 Modal variation of specific sodic suite plutons in the northern supracrustal domain....746
8-4 Modal variation of the Separation-Indian Lakes Complex (sodic granitoid suite)....746
8-5 Modal variation of the Armit Lake Complex, Dalles batholith (Gower 1978) and miscellaneous plutons....747
8-6 Geological setting of the Sen Bay stock....748
8-7 Quartz-total feldspar-mafics modal variation of the Sen Bay stock....749
8-8 Quartz-plagioclase-K-feldspar) modal variation of the Sen Bay stock....750
8-9 AFM and Mg-Li variation of the Sen Bay stock....751
9-1 Distribution of potassic granitoid suite in the southern plutonic domain....752
9-2 Modal analyses of the potassic granitoid suite....753
9-3 Location of occurrences of clotty quartz monzonite....754
9-4 CNK plot (weight %) of the matrix of clotty quartz monzonite....755
9-5 FeO vs Fe_2O_3 variation for homogeneous diatexite and the matrix of the clotty quartz monzonite....756
9-6 AFM plot (weight %) for clots from clotty quartz monzonite....757
9-7 Geology of the Lount Lake batholith....758
9-8 Modal variation of early and late units of the Lount Lake batholith....759
9-9 CNK plot (weight %) of the early and late units of the Lount Lake batholith....759
9-10 Harker variation diagrams for Lount Lake batholith....760
10-1 AFM (weight %) variation of gneissic granitoid suite....761
10-2 CNK (weight %) variation of gneissic granitoid suite....762
10-3 AFM (weight %) variation of specific sodic granitoid suite plutons....763
10-4 CNK (weight %) variation of specific sodic granitoid suite plutons....764
10-5 AFM (weight %) variation of the sodic granitoid suite....765

10-6 CNK (weight %) variation of the sodic granitoid suite....766
10-7 CNK and AFM (weight %) variation of the heterogeneous complexes of the sodic granitoid suite....767
10-8 AFM and CNK (weight %) variation of the potassic granitoid suite. Numbers 1-15 are miscellaneous samples in Table 10-17....768
10-9 AFM (weight %) variation of the major granitic suites....769
10-10 CNK (weight %) variation of major granitic suites....769
10-11 AFM-CNK (weight %) plots of average chemical analyses of other gneissic terrains compared to the average gneissic granitoid suite from the English River Subprovince (point 19). Points 9, 12, 13, 14, 15, 20 and 21 are averages of various metasedimentary rocks....770
10-12 Chemical composition of various Archean complexes (Lambert et al. 1975, pp. 379, 381)....771
11-1 AFM - CNK (weight %) variation of the Wabigoon Subprovince intrusive rocks....772
11-2 AFM and CNK (weight %) variation of Lewis Lake and Yett Lake stocks....773
14-1 General distribution of metamorphic zones within the English River, Uchi and parts of the Berens River and Sachigo Subprovinces of northwestern Ontario (after Thurston and Breaks 1978)....774
14-2 Distribution of metamorphic zones, isograds, and migmatization stages at the Uchi-English River subprovincial boundary in the Lake St. Joseph area....775
14-3 Inferred path of regional metamorphism across the Uchi-English River subprovincial boundary....776
15-1 Geology of the Clay-Cedar Lakes area....777
15-2 Vertical section of the important domal structures in the Cedar-Clay Lakes area....Back pocket
15-3 Distribution of important fault systems in the English River Subprovince and adjoining parts of the Uchi and Wabigoon Subprovinces....779
15-4 Geology of the Chase Lake area near the Sydney Lake Fault (after Stone 1981)....780
15-5 Contoured equal area stereoplot of slickensides from the Sydney Lake Fault between Sydney and Chase Lakes (after Stone 1981)....781
16-1 General geology near the Sandy Creek beryl occurrence....782
16-2 Detailed geology of the Sandy Creek beryl dyke....783
16-3 Distribution of rare-element pegmatites and isograds in the Dryden Pegmatite Field in relation to regional geology....784
16-4 Detailed geology of the Roadhouse River spodumene pegmatite dykes....785
16-5 Location of the Tot Lake Li- Cs-Rb-Ta Pegmatite, Webb Township....786
16-6 Detailed geology of the Tot Lake Pegmatite....787
16-7 K/Ba, K/Cs, K/Rb and Ba/Rb petrochemical relations and fractionation trends of spodumene pegmatites from the study area. Crustal abundance data for Ba, Cs, K and Rb from Table 16-1....788

16-8 Profiles of Ba, Be, Cs, Li, Rb, Sr, Th and U variation in Trench 2 of the Tot Lake Pegmatite....789
16-9 Profiles of K/Ba, Rb/Sr, K/Cs, K/Rb, Mg/Li, and Ba/Rb variation in Trench 2 of the Tot Lake Pegmatite....790
16-10 Li vs. Mg variation in the Tto Lake Pegmatite....791
16-11 Comparison of Mg-Li variation in uranium pegmatites and spodumene-bearing, rare-element pegmatites from the study area....792
16-12 Th vs. U variation in spodumene-bearing rare-element pegmatites compared to that in a uranium-rich pegmatite....793
16-13 Geological setting of spodumene pegmatite dykes of the North and South Zones of the Mavis Lake (Fairservice) property....794
16-14 Profiles showing petrochemical variation of Ba, Cs, K, Li, Na, Rb, Sn, Sr and U and ratios K/Ba, K/Cs, K/Rb, K/Th, K/U, Th/U, Ba/Rb and Rb/Sr across Dyke #5 of the Mavis Lake spodumene pegmatite dyke swarm....795
16-15 Uranium mineralization associated with metasedimentary migmatite....796
16-16 Geology of the Sydney Lake uranium occurrence....797
16-17 Radiometric ground survey of the Umfreville Lake uranium occurrence. Contours represent total counts per second taken by an Exploranium scintillometer (model GRS-101) by Noranda Mines Limited in 1976....798
16-18 General geology and uranium mineralization in the Umfreville-Tourist Lakes areas....799
16-19 Detailed geology, location of trenches and assay samples at the Umfreville Lake uranium occurence....800
16-20 Petrochemical variation of K/Ba, K/Cs, K/Rb, and Ba/Rb at the Umfreville Lake uranium occurrence....801
16-21 Th vs. U relations in Type I uranium mineralization at the Umfreville Lake occurrence. Average Canadian shield Th/U ratios of 4 and 6.2 from Shaw et al. (1976) and Fahrig and Eade (1968), respectively....802
16-22 Mg vs. Li relations at Celyn Lake, Davidson, Drope Township, Tourist Lake and Umfreville Lake uranium occurrences....803
16-23 Distribution of Type II uranium mineralization and associated plutons of the potassic granitoid suite in the English River and Wabigoon Subprovinces....804
16-24 Geology, trench locations and assay sites at the Celyn Lake uranium occurrence....805
16-25 Petrochemical variation of K/Ba, K/Cs, K/Rb and Ba/Rb in potassic granitoid suite rocks from the Celyn Lake uranium occurrence....806
16-26 Th vs U relations at the Celyn Lake uranium occurrence....807
16-27 General geology of area around the Drope Township uranium occurrence....808
16-28 Location of "high grade" and "low grade" zones of Conwest Exploration Company Limited and other radioactive granitoid pegmatites, Drope Township uranium occurrence....809

16-29 Detailed geology, location of diamond drill holes of Conwest Exploration Company Limited and sample location from the "high grade" zone, Drope Township uranium occurrence....810
16-30 Geology and location of drill hole 3 and Pit #1 at the "low grade" zone of the Drope Township uranium occurrence....811
16-31 Petrochemical variation of K/Ba, K/Cs, K/Rb and Ba/Rb in uranium pegmatites of the potassic granitoid suite at the Drope Township uranium occurrence....812
16-32 Th vs. U relations in uranium pegmatites at the Drope Township uranium occurrence....813
16-33 Geology, location of trenches and assay samples from the Main Zone of the Davidson uranium occurrence....814
16-34 Petrochemical variation of K, U and Th in Trenches 1, 2, 3 and 4 at the Davidson uranium occurrence. Arrows indicate analyses with Th values below the 10 ppm detection limit....815
16-35 Petrochemical variation of K, U and Th in Trench 6 of the Davidson uranium occurrence. Arrows indicate analyses with Th values below the 10 ppm detection limit....816
16-36 Profiles showing petrochemical variation of K/Ba, K/Rb, K/U, Th/U, Ba/Rb, and Mg/Li along Trenches 1, 2, 3 and 4 at the Davidson uranium occurrence....817
16-37 Profiles showing petrochemical variation of K/Ba, K/Rb, K/U, Th/U, Ba/Rb and Mg/Li at Trench 6 of the Davidson uranium occurrence....818
16-38 K/Ba, K/Cs, K/Rb and Ba/Rb petrochemical variation at the Davidson uranium occurrence....819
16-39 Th vs. U petrochemical relations at the Davidson uranium occurrence....820
16-40 Li vs. SiO_2 relations in S-Type uranium-bearing granitic pegmatite rocks from the Umfreville Lake uranium occurrence....821
16-41 General geology, location of trenches and assay samples at the Tourist Lake uranium occurrence. Geological map after Can-Fer Exploration Syndicate (Fiale 2.307, AFRO, Toronto)....822
16-42 K/Ba, K/Cs, K/Rb, and Ba/Rb relations in metawacke, porphyritic quartz monzonite, porphyritic syenite and mafic-rich, biotite granodiorite at the Tourist Lake uranium occurrence....823
16-43 Th vs. U relations in rocks from the Tourist Lake uranium occurrence....824
16-44 Mineral occurrences in the Ena-Vermilion Lakes area....825

MAP

P.3091 Compilation map - English River Subprovince....Back pocket

PHOTOGRAPHS

3-1 Diffuse, magnetite-diopside-hypersthene-bearing felsic segregations (photo centre) contained within a magnetite-diopside-hypersthene-hornblende-plagioclase-bearing, possible mafic metavolcanic host from Chamberlain Narrows, Lac Seul....826

3-2 Mafic tuff breccia from Troutfly Lake area in the Sioux Lookout greenstone belt....826

3-3 Gneissic mafic metavolcanic rocks from the Papaonga Lake-Lake St. Joseph greenstone belt. The banding is likely secondary but could also represent deformed tuffaceous bedding or pillow selvedges. Pencil = 22 cm....827

3-4 Intermediate tuff breccia containing fragments that are more mafic than the matrix. Outcrop located on the Ghost Lake road in southwest Webb Township....827

3-5 Contact between intermediate to felsic tuff (top of photo) and intermediate tuff breccia in the Lake St. Joseph greenstone belt....828

3-6 Felsic airfall tuff with mafic bomb (on left), situated about 3 km north of the eastern end of Gullwing Lake....828

3-7 Pillowed mafic metavolcanic rocks cut by quartz monzonite dyke in the Separation Lake greenstone belt near the Separation rapids....829

3-8 Complexely-deformed, thin dark bands in mafic metavolcanic rocks just south of Chamberlain Narrows. These bands possibly represent relict pillow selvedges....829

3-9 Diopside-hypersthene-bearing, mafic metavolcanic rock with possible partial melt of trondjemite composition from the Chamberlain Narrows area....830

3-10 Intermediate tuff breccia located just west of Fredhart Lake. The subtle fragments are slightly more felsic than the matrix....830

3-11 Porphyroblastic knots of andalusite in intermediate metavolcanic rocks southwest of Fredart Lake....831

3-12 Subvolcanic rock with brecciation possibly due to fumerolic degassing on the south shore of Fredhart Lake....831

3-13 Reworked tuffs and tuffaceous metasedimentary rocks from Upper Slate Lake....832

3-14 Cross-bedding in wacke metasedimentary rocks near Lower Slate Lake....832

3-15 Lit-par-lit injection of mafic metavolcanic rocks northeast of Papaonga Lake. The white bands consist of quartz monzonite....833

4-1 Multi-unit granitic rock exposure from the southern plutonic domain near Hudson....833

4-2 Inhomogeneous, meta-tonalite from the Sydney Lake area. Note the discrete to diffuse, mafic to ultramafic enclaves in varying states of reaction with the host and attendant, irregular zones of hybrid biotite-hornblende quartz diorite. Coin diameter = 2.3 cm....834

4-3 Multi-unit granitic exposure, west shore of Sydney Lake.....834
4-4 Protometatexite near Aerofoil Lake. Note the confinement of leucosome patches to the metamorphically coarsened pelitic paleosome layers. Metawacke layers have apparently resisted leucosome development and sporadically exhibit relict sedimentary laminae, as marked by hammer.....835
4-5 Detail of metapelitic layer in protometatexite, from the Wegg Lake area, which illustrates the abundance of cordierite and garnet porphyroblasts and intermingled patches of leucosome.....835
4-6 Combination of protometatexite and metatexite in metasedimentary migmatite at the Ear Falls damsite.....836
4-7 Metatexite metasedimentary migmatite, Ontario Hydro damsite at Ear Falls. Note the greater abundance of leucosome in the metapelitic paleosome (P) along the right. Metawacke paleosome (W) contains relatively sparse leucosome.....836
4-8 Inhomogeneous diatexite near Root Bay of Lake St. Joseph, illustrating the schollen structure. Bar = one metre.....837
4-9 Melanosome clot in the process of separation from a larger mass of restite to left of coin) contained within inhomogeneous diatexite of garnet-cordierite-biotite quartz monzonite composition. Treelined Lake. Coin diameter = 1.8 cm.....837
4-10 Transition from metatexite on right to inhomogeneous diatexite which contains twisted rafts of metawacke in cordierite-garnet-biotite leucosome at Treelined Lake.....838
4-11 Syenite leucosome from the Bear Narrows area of Lac Seul, exhibiting the large grain size range and hypidiomorphic-granular texture that is typical for the leucosome constituent.....838
4-12 Metatexite metasedimentary migmatite with exceptionally thick melanosome selvedges distributed only along one side of the leucosome. Ministry of Natural Resources warehouse site at Ear Falls. Coin Diameter = 1.8 cm.....839
4-13 Granite leucosome pod in protometatexite from the Wegg Lake area. The leucosome was apparently in the process of engulfing a large garnet porphyroblast (G) which lies adjacent to large cordierite poikiloblasts (C). Bar = 2 cm.....839
4-14 Dyke of "intrusive mobilizate" which sharpely truncates ptygmatically-folded leucosome in metawacke at Rao Lake. Coin diameter = 2.3 cm.....840
4-15 Apatite-biotite syenite leucosome in metatexite at the Ear Falls damsite. Note the symmetrical disposition of biotite-rich melansome selvedges along both leucosome contacts.....840
4-16 Biotite-cordierite-quartz clots in diatexite at Treelined Lake. Coin diameter = 1.8 cm.....841
4-17 Boudinage structure in metatexite metasedimentary migmatite, Wapesi Bay of Lac Seul.....841
4-18 Fibrous mat of sillimanite (S) associated with muscovite in

sillimanite-biotite-muscovite quartz monzonite in the Ghost Lake batholith. Highway 17 roadcut at Oxdrift. Coin diameter = 1.8 cm.....842
4-19 Cordierite-biotite quartz monzonite from Churchill Lake batholith near Sleen Lake. Euhedral cordierite indicated by arrow. Coin diameter = cm.....842
4-20 Hypidiomorphic-granular texture in homogeneous diatexite of biotite quartz monzonite composition at Jackson Lake. Bar = 2 cm.....843
4-21 Mafic diatexite of biotite tonalite composition near Conifer Lake. Bar = 1 cm.....843
4-22 Leucosome with abundant, euhedral cordierite, Ear Falls damsite. Coin diameter = 1.8 cm.....844
5-1 Medium-grained trondjemite, on right, intruded into quartz porphyry on Rexdale Property just southwest of Snakeweed Lake.....844
5-2 Irregular fracture pattern in subvolcanic intrusive (quartz porphyry) on the Rexdale Property.....845
6-1 Massive, medium-grained diorite at Muriel Lake, Kenora area.....845
6-2 Cataclastic quartz diorite of the Bruce Lake pluton situated about 8 km northwest of Bluffy Lake. Note the small, cross-cutting mass of pseudotachylite with well developed flow lines (centre).....846
6-3 Magmatic layering in unit 1D-i of the Lake St. Joseph mafic sill due to concentration of clots.....846
6-4 Clotty metagabbro of unit 1D-i of the Lake St. Joseph layered mafic sill. Note mafic-felsic mineral segregation suggesting top direction towards the photo top.....847
6-5 Mafic metagabbro dykes in the Bear Narrows area of Lac Seul.....847
6-6 Dykes of trondhjemite (T) and later quartz monzonite (Q) intruded into massive, coarse-grained, equigranular amphibolite (mafic intrusive suite). On the Minaki-Umfreville Lake road near Pistol Lake.....848
7-1 Gneissic granitoid suite with finely banded mafic aggregates, biotite tonalite, biotite trondhjemite and metasomatic K-feldspar (on left). Location is near the Wabigoon-English River subprovincial boundary at Kenora.....848
7-2 Intermediate gneiss from the Deception Bay area exhibiting diffuse, patchy hornblende diorite and small enclave of metaultramafic rock (on left).....849
7-3 Leucocratic trondhjemite gneiss, south of Bear Narrows, containing thin, continuous trains of biotite.....849
7-4 Gneissic granitoid suite at Deception Bay of Lac Seul. Rock contains foliated to gneissic biotite-hornblende diorite to quartz diorite and concordant trondjemite (T) which is discordantly intruded by fine-grained biotite trondhjemite.....850
7-5 Minor folds in gneissic granitoid suite from Pelican Lake near Sioux Lookout. Pen = 15 cm.....850
7-6 Rootless, intrafolial isoclinal folds in holo-leucocratic trondjemite constituent of a gneissic granitoid exposure on

Highway 105, just north of Vermilion Bay.....851
7-7 Rootless, intrafolial, isoclinal refolded fold defined by holo-leucocratic trondjemite and biotite-rich laminae in the Cedar Lake gneisses. Highway 105 roadcut near Cedar Lake. Ruler = 15cm.....851
7-8 Enclave of mafic metavolcanic or metagabbro rock in the gneissic granitoid suite, Deception Bay.....852
7-9 Highly disrputed, former dyke of mafic rock in intermediate gneiss from gneissic granitoid suite, Deception Bay area.....852
7-10 Interbanding in gneissic granitoid suite north of Tile Lake in the Deception Bay area. The main units comprise at least 3 units of trondjemite, 2 units of quartz monzonite and a mafic dyke. Arrows point to thin, biotite-rich selvedges along the margins of some concordant quartz monzonite units. Ruler = 15 cm.....853
7-11 Gneissic granitoid suite from the Deception Bay area, revealing interleaved biotite trondjemite, more leucocratic trondjemite (T) and quartz monzonite, marked by 15 cm-long ruler, with biotite-rich selvedges.....853
7-12 Gneissic granitoid suite near Wabigoon-English River subprovincial boundary, north shore of Pelican Lake.Outcrop contains several units of foliated biotite trondjemite interleaved with a more leucocratic trondjemite which are cut by a thin, discordant dyke of quartz monzonite. The mafic-rich enclaves may represent attenuated former dyke material. Pen = 15 cm.....854
7-13 An example of metamorphically-reworked mafic/felsic constituents in gneissic granitoid suite at Deception Bay.....854
7-14 Mafic to ultramafic enclaves (on right) from the gneissic granitoid suite, Deception Bay. The trondjemite unit (T) exhibits a wide colour index range.....855
7-15 Medium-grained, biotite-hornblende trondhjemite to quartz diorite unit of the sodic granitoid suite which contain a mafic band (on left) which is intruded by fine-grained, biotite trondjemite (right side) and by a discordant mass of inequigranular, quartz monzonite pegmatite. Outcrop is near the Wabigoon - English River subprovincial boundary just west of Highway 105. Ruler = 15 length.....855
7-16 Typical gneissose structure produced by interleaved, medium- to coarse-grained biotite-hornblende trondhjemite to quartz diorite, fine-grained biotite trondjemite, hornblende-rich mafic bands and minor, medium- to coarse-grained quartz monzonite. Photo located about 3 m from Photo 7-11.....856
7-17 Cataclastic quartz monzonite veins in gneissic granitoid suite north of Wabigoon - English River subprovincial boundary just west of Highway 105. Photo from same outcrop as Photos 7-15 and 7-16.....856
8-1 Foliated to gneissic, magnetite-diopside-hypersthene-biotite trondjemite near Chamberlain Narrows of Lac Seul. Coin diameter = 2.3 cm.....857

8-2 Stictolithic or fleck-textured hypersthene-biotite trondhjemite from just north of Chamberlain Narrows and marked by mafic segregations rich in magnetite enveloped by quartz-plagioclase leucocratic halos....857
8-3 Foliated to gneissose biotite trondhjemite (sodic granitoid suite) with diffuse, leucocratic, concordant, quartz monzonite vein of possible metasomatic origin. Bear Narrows area of Lac Seul....858
8-4 Kink bands in well foliated, hornblende-biotite trondhjemite to quartz diorite located on the Grassy Narrows-Oak Lake logging road, just north of Marshalok Lake....858
8-5 Porphyroblastic, medium- to coarse-grained, hornblende-biotite granodiorite on the Gordon Lake road north of the Grassy Narrows Reserve and south of Oak Lake. Coin diameter = 1.8 cm....859
8-6 Sodic granitoid suite near Chamberlain Narrows (Lac Seul), revealing a complex medley of units: Fine- to medium-grained biotite trondhjemite (unit A); medium- to coarse-grained hornblende-biotite trondhjemite to quartz diorite (unit B) intruded in order of decreasing relative agae by:....860
1) leucocratic trondhjemite (parallel to foliation of major units)
2) metagabbro dyke (parallel to widely-spaced, weak cleavage)
3) thin veins of leucocratic trondhjemite (parallel to cleavage)
4) late quartz monzonite (cross-cuts all units and structures).
8-7 Stictolithic quartz diorite of the Sen Bay stock intruded by trondhjemite (sodic suite) and quartz monzonite dykes....861
8-8 Medium- to coarse-grained magnetite-hornblende-biotite trondhjemite to quartz diorite from the Sen Bay stock with enclave of fine-to medium-grained biotite trondjemite (left corner) which is intruded by inequigranular, quartz monzonite (potassic suite)....861
9-1 Massive, medium-grained, equigranular, unmetamorphosed biotite quartz monzonite from the Nelson granite quarry near Vermilion Bay....862
9-2 Clotty quartz monzonite from Highway 105 roadcut at Perrault Falls....862
9-3 Clotty, garnet-bearing quartz monzonite northwest of Gymame Bay of Lac Seul....863
9-4 Equigranular, medium-grained quartz monzonite to granite (sensu stricto) with clots of garnet, quartz and biotite. Outcrop on the southern shore of Oak Lake....863
9-5 Inequigranular biotite quartz monzonite with clots of magnetite, cordierite and quartz located near Gymame Bay of Lac Seul. Note the concentration of clots adjacent to an enclave of trondjemite in the centre....864
9-6 Weakly cataclastic, porphyritic granodiorite sill at the Wabigoon-English River subprovincial boundary at Kenora Coin diameter = 1.8 cm....864
9-7 Possible rapakivi texture in porphyritic granodiorite of the Lount Lake batholith. Coin diameter = 1.8 cm....865
9-8 Porphyritic quartz monzonite from Lount Lake batholith in exposure

on the Kenora-Grassy Narrows road between Havik and Keys Lakes. Note the alignment of K-feldspar megacrysts which may relate to magmatic flowage....865
9-9 Dyke of magnetite-biotite syenite (potassic suite) intruded into foliated, biotite trondhjemite to quartz diorite, Chamberlain Narrows area of Lac Seul....866
9-10 Gneissic, leucocratic trondhjemite with amphibolite bands cut by zoned pegmatite-aplite dyke (marked by hammer), Anenimus Bay area of Lac Seul....866
9-11 Border unit of pegmatitic granite in batholith north of Papaonga Lake. Blade-like aggregates consist of magnetite, tourmaline and biotite....867
9-12 Medium-grained, equigranular, unmetamorphosed, biotite quartz monzonite to granite (sensu stricto) of the Tetu Lake Batholith containing consanguineous, quartz monzonite pegmatite pocket. Outcrop on the Minaki-Umfreville Lake road near Sashawa Lake....867
9-13 Pegmatite dyke in foliated hornblende-biotite trondhjemite. Note the perpendicular orientation of feldspar to the contacts and restriction of quartz masses to the dyke centre....868
10-1 Massive, fine-grained biotite trondhjemite (sodic granitoid suite) intruded in cataclastic, homogeneous diatexite. Outcrop on South Bay Mine road, northwest of Wenasaga Lake....868
10-2 Contact between the English River and Wabigoon Subprovinces at Kenora. The mafic metavolcanic rocks on left are intruded by a cataclastic, porphyritic granodiorite sill....869
10-3 Amphibolitic enclave of possible volcanic origin embedded in deformed inhomogeneous diatexite. Outcrop on island in Helder Lake about 100m north of boundary between northern and southern domains....869
14-1 Intense Fa_1 fold of originally discordant leucosome vein within garnet-sillimanite-cordierite-K-feldspar-biotite metapelite. Ministry of Natural Resources warehouse site at Ear Falls. Coin diameter = 2.3 cm....870
14-2 Fa_2 fold in metatexite metasedimentary migmatite on Wabaskang Lake....870
14-3 Leucosome distributed along the axial surface of Fa_2 open fold in metatexite metasedimentary migmatite on Wapesi Bay of Lac Seul....871
14-4 Interbedded fine-grained metawacke and highly porphyroblastic, andalusite metapelite near Temple Bay of Eagle Lake. Note the secondary planar fabric oriented at low angle to bedding, especially in metapelite layer to the left of the 4 cm long scale....871
14-5 Asymmetric Fa_1 folds in intrusive mobilizate vein which was initially discordant to metawacke (W)-metapelite (P) bedding in the sillimanite-K-feldspar-cordierite-garnet zone on Highway 17,

21 km west of Oxdrift. The left limbs of the two lowermost folds are almost detached along the strong axial planar fabric....872
14-6 Metatexite metasedimentary migmatite on the west shore of Pakwash Lake revealing arteritic leucosomes deformed by Fa_1 boudinage followed by Fa_3 open fold. Coin diameter = 2.3 cm....872
14-7 Fb_2 isoclinal folds in leucotrondhjemite layers in gneissic granitoid suite rocks in the Deception Bay area of Lac Seul. Coin diameter = 1.8 cm....873
14-8 Rootless, intrafolial Fb_1 fold of severely disrupted more mafic unit (possible former pillow selvedges) in granulite grade amphibolite of the Bear Narrows area of Lac Seul. Coin diameter = 2.3 cm....873
14-9 Isoclinal Fb_2 folds in holo-leucocratic trondjemite layers in amphibolite with superposed open fold (Fb_5?) from Deception Bay area. Coin diameter = 1.8 cm....874
14-10 Mylonite derived from homogeneous diatexite on the Sydney Lake Fault, south shore of Sydney Lake. Note the well developed fluxion structure composed of dark, quartz-rich bands and light, finely comminuted feldspar-rich bands. Porphyroclasts consist of K-feldspar, garnet and cordierite. Bar = 2 cm....874
14-11 Protomylonite derived from homogeneous diatexite at the Sydney Lake uranium occurrence, revealing the abundance of coarse porphyroclasts of quartz-feldspar and lack of a fluxion structure. Coin diameter = 2.3 cm....875
14-12 Pseudotachylite from the Sydney Lake Fault, south shore of Sydney Lake. Coin diameter = 1.8 cm....875
16-1 Sodic aplite from the Sandy Creek beryl pegmatite, revealing typical texture with megacrysts of euhedral beryl (near coin), quartz and books of muscovite. Coin diameter = 1.7 cm....876
16-2 Gradation between sodic aplite (A) and apatite-muscovite-rich pegmatite. Bar = 2 cm....876
16-3 Blocky K-feldspar in aplite unit of Dyke #2 at McCombe property. Coin diameter = 2.3 cm....877
16-4 Spodumene pegmatite unit of Dyke #1 at McCombe property. Note primary lineation defined by the near vertically-plunging K-feldspar megacrysts. Coin diameter = 2.3 cm....877
16-5 Spodumene-rich zone from Dyke #1 at the McCombe property. The relatively finer-grained spodumene exhibits a well defined linear fabric. Coin diameter = 2 cm....878
16-6 Longitudinal layering at the Tot Lake pegmatite, marked by the transition from pegmatite layers containing subhorizontally-aligned spodumene into finer-grained, equigranular, spodumene-poor layer (A). Quartz-rich core zone (Q) is situated along the upper left....878
16-7 Megacryst blades of spodumene near the northwestern end of the Tot Lake pegmatite....879

16-8 Partial replacement of pink spodumene megacryst (S) by lepidolite (L). Note the anhedral mass of pollucite (P) in contact with the spodumene. Coin diameter = 2.3 cm....879
16-9 Tantalite mineralization associated with quartz-rich (Q), albitized spodumene (S) - K-feldspar zone near the northwestern end of the Tot Lake pegmatite. The tantalite normally displays a marginal relationship to the albitized K-feldspar (A) megacrysts. Coin diameter = 2.3 cm....880
16-10 Blocky K-feldspar and local spodumene (S) in quartz-rich core zone (Q) at Pegmatite #1, Mavis Lake property. K-feldspar is partially enveloped by fine-grained green muscovite-albite aggregate (M). Coin diameter = 1.8 cm....880
16-11 Spodumene (S) rimmed by albite (A) in the quartz-rich zone of Pegmatite #1, Mavis Lake property. Coin diameter = 1.8 cm....881
16-12 Partially albitized K-feldspar in quartz-rich core zone of Pegmatite #1, Mavis Lake property. Albitization (A) tends to occur along the margins of the K-feldspar-rich (K) aggregate and commonly contains tantalite (T) as pointed by the arrows. Coin diameter = 1.8 cm....881
16-13 Porphyritic biotite quartz monzonite unit at the Tourist Lake uranium occurrence. Bar = 2 cm....882

ABSTRACT

This report describes a 1974-77 reconnaissance investigation of the English River Subprovince. The area is bounded by the Manitoba/Ontario boundary in the west, longitude 90°30'W in the east and north Latitudes 49°45' and 51°00'. All bedrock is Archean in age. The English River Subprovince consists of two major subdivisions: the **Southern Plutonic Domain,** a tract comprising plutonic rocks up to 3.02 Ga and derived orthogneisses, which forms a basement to the **Northern Supracrustal Domain**, dominated by high grade, migmatized clastic metasedimentary rocks younger than 2.74 Ga. Four classes of intrusive rocks are dispersed through the subprovince, i.e. the **gneissic granitoid suite**, metamorphosed plutonic rocks up to 3170 Ma and restricted to the Southern Plutonic Domain; a **mafic intrusive suite** comprising diorites, gabbros and ultramafic units which cut all supracrustal rocks; the syn- to post-tectonic, 2665 to 3002 Ma **sodic granitoid suite** (trondhjemite, tonalite and granodiorite) and the 2560 to 2702 Ma, dominantly post-tectonic, **potassic granitoid suite** (granite and granodiorite) which represents the majority of the youngest Archean rocks.

The Southern Plutonic Domain, forming the southern one-third of the subprovince, approximately consists of equal proportions of the sodic and potassic granitoid suites. The subordinate gneissic granitoid suite encompasses a broad compositional range, i.e. tonalite-trondhjemite-quartz diorite-diorite-ultramafic-anorthositic. These intensely deformed rocks display a banded or gneissic fabric and contain tectonically interleaved enclaves of metasedimentary and metavolcanic rocks and **lit-par-lit** injections of sodic and potassic suite rocks.

The Northern Metasedimentary Domain, which forms the northern two-thirds of the English River Subprovince, is dominated by a belt of wacke-pelite units of turbidite origin which is continuous for 700 km in Ontario. These rockshave been metamorphosed and partially melted at 2.68 Ga forming migmatites and S-type granites. Part of the southern boundary of the domain is marked by the Separation Lake metavolcanic belt, the eastern extension of the >2715 Ma Bird River greenstone belt of Manitoba. Scattered remnants of this belt, as enclave trains, occur over a distance of 250 km to the Lac Seul area to the east. It is inferred from stratigraphic relations near Uchi Lake that clastic metasedimentary rocks of the Northern Metasedimentary Domain are correlative with Uchi Subprovince metavolcanic rocks ranging from 2.9 to 2.7 Ga. Stratigraphic-structural relations of proximal facies metaconglomerates at Separation Lake suggest the Northern Domain and the Separation Lake volcanic belt are in part correlative.The division of the metasedimentary migmatite rocks was based on the concept of progressive migmatization with the following successive stages: protometatexite (incipient partial melting) -> metatexite -> inhomogeneous diatexite -> homogeneous diatexite (complete melting).

The sodic granitoid suite is widespread in the English River Subprovince. Two types of intrusive bodies were recognized: relatively early, heterolithic complexes and later, relatively simple, compositionally more uniform plutons. The early heterogeneous intrusive complexes comprise large, discrete batholiths or ill-defined masses which generally lie elongated subparallel to subprovince boundaries and are deformed by later intrusive rocks. Representative plutons such as the >3.02 Ga Sen

Bay stock comprise numerous units of gabbro-diorite-quartz-diorite-trondhjemite. Petrochemistry of this intrusive type is marked by depletion of Fe+Mg and enrichment of K with decreasing relative age of internal units. The simple pluton type, as exemplified by the Dalles batholith, is marked by relatively uniform compositions, generally 1-2 units of trondhjemite and granodiorite, which form discrete, commonly subcircular intrusions. These intrusions occur as diapirs which deflected host-rock structural fabrics.

The potassic suite culminated granitic igneous activity in the English River Subprovince and is mainly restricted to western part of the Southern Plutonic Domain. It forms large batholiths, up to 2200 km_2, marked by uniform compositions over a narrow range, i.e. granodiorite-quartz monzonite-granite.

The structural history of the area is protracted and involved three periods of folding (D_1, D_2 and $D_{3)}$ and ensuing phases of kink-style folding, shearing, fracturing and faulting (D_4, D_5 and D_6) which partially form the north and south subprovince boundaries. Abukuma-type regional metamorphism followed D_2 and reached granulite facies conditions of >750°C and >2.5 kbar.

The English River Subprovince has a low mineral potential which is mainly relegated to various lithophile elements. From detailed mapping and geochemistry, methods are described for evaluation of the economic potential of rare-element pegmatites and U-Th deposits.

THE ENGLISH RIVER SUBPROVINCE - AN ARCHEAN GNEISSIC BELT: GEOLOGY, GEOCHEMISTRY AND ASSOCIATED MINERALIZATION

Frederick W.Breaks[1] and William D. Bond[2]

1. Geologist, Ontario Geological Survey, Mines and Mineral Research Centre, 933 Ramsey Lake Road, Sudbury, Ontario.
2. Geologist, Goldfields Canadian Exploration Limited, 100 Front Street West, Toronto

Table 1-1: Classification of granulite rocks of the Regional Hypersthene Zone from Winkler.

Terminology of this report	Winkler (1974, p.258)
i) hypersthene bearing quartz monzonite to granite	charnokitic granolite
2) hypersthene-bearing granodiorite	charno-enderbitic granolite
3) hypersthene-bearing trondhjemite	enderbitic granolite
4) hypersthene-bearing quartz diorite or diorite	hypersthene-pyroclase granolite

Table 1-2: Classification of plutonic rocks used by the Ontario Division of Mines (prepared by S.B. Lumbers, L.D. Ayres, and E.G. Pye).

	RATIO $\frac{\text{POTASSIC FELDSPAR}}{\text{TOTAL FELDSPAR}}$	COMPOSITION OF PLAGIOCLASE			
		An_{0-10}	An_{10-30}	An_{30-50}	An_{50-100}
QUARTZ > 10%	> $\frac{2}{3}$	GRANITE			?
	$\frac{1}{3}$ – $\frac{2}{3}$	ALBITE QUARTZ MONZONITE	(OLIGOCLASE) QUARTZ MONZONITE	ANDESINE QUARTZ MONZONITE	?
	$\frac{1}{8}$ – $\frac{1}{3}$	ALBITE GRANODIORITE	(OLIGOCLASE) GRANODIORITE	QUARTZ DIORITE	QUARTZ GABBRO
	< $\frac{1}{8}$	ALBITE TRONDHJEMITE	(OLIGOCLASE) TRONDHJEMITE		
QUARTZ < 10%	> $\frac{2}{3}$	SYENITE			?
	$\frac{1}{3}$ – $\frac{2}{3}$	ALBITE MONZONITE	(OLIGOCLASE) MONZONITE	ANDESINE MONZONITE	CALCIC MONZONITE
	$\frac{1}{8}$ – $\frac{1}{3}$	ALBITE SYENODIORITE	(OLIGOCLASE) SYENODIORITE	DIORITE	GABBRO
	< $\frac{1}{8}$				

Table 2: Lithologic Units

PHANEROZOIC

CENOZOIC

QUATERNARY

RECENT

Lake, stream and swamp deposits

PLEISTOCENE

Sand, gravel, glacial till, ground moraine, varved clays

UNCONFORMITY

PRECAMBRIAN

MIDDLE TO LATE PRECAMBRIAN

DIABASE

INTRUSIVE CONTACT

EARLY PRECAMBRIAN

LATE TO POST TECTONIC PLUTONIC ROCKS

FELSIC TO INTERMEDIATE INTRUSIVE ROCKS (POTASSIC SUITE)

Equigranular phases (biotite quartz monzonite to granite; leucocratic biotite quartz monzonite to granite; biotite-muscovite quartz monzonite; hornblende-biotite, biotite-hornblende quartz monzonite; clotty quartz monzonite; biotite granodiorite, hornblende-biotite granodiorite; biotite, hornblende-biotite granodiorite to trondhjemite; syenite; aplite; biotite,

muscovite; muscovite-biotite pegmatite); Porphyritic (potassium feldspar) phases (porphyritic biotite trondhjemite, granodiorite, quartz monzonite; porphyritic hornblende-biotite granodiorite); cataclastic rocks; hybrid phases.

INTRUSIVE CONTACT

INTERMEDIATE TO MAFIC INTRUSIVE ROCKS (MAFIC SUITE)

Diorite; hornblende, biotite-hornblende quartz diorite; biotite, hornblende-biotite quartz diorite to trondhjemite; quartz diorite, diorite to syenodiorite, rare (andesine) monzonite.

EARLY TO SYNTECTONIC PLUTONIC ROCKS

FELSIC TO INTERMEDIATE INTRUSIVE ROCKS (SODIC SUITE)

Equigranular foliated and massive biotitic phases (Biotite trondhjemite (foliated), biotite-trondhjemite (massive); leucocratic biotite trondhjemite; magnetite-biotite trondhjemite; chlorite-biotite trondhjemite; very fine-grained massive biotite trondhjemite; leucocratic quartz-poor trondhjemite).

Equigranular foliated and massive hornblende phases (hornblende-biotite trondhjemite, granodiorite; epidote-hornblende trondhjemite; biotite-hornblende, hornblende

trondhjemite); foliated to gneissic phases (biotite trondhjemite to granodiorite; hornblende-biotite, biotite-hornblende trondhjemite to granodiorite, locally quartz diorite; magnetite-biotite trondhjemite); Porphyritic and/or porphyroblastic (potassium feldspar) phases (biotite granodiorite to trondhjemite; biotite granodiorite to trondhjemite (equigranular to subtlely porphyritic/porphyroblastic; hornblende-biotite granodiorite to quartz monzonite); Potassic phases (leucocratic quartz monzonite; biotite quartz monzonite to granodiorite); aplite; hybrid rocks; cataclastic rocks; stictolithic texture.

INTRUSIVE CONTACT

FELSIC TO INTERMEDIATE SUBVOLCANIC ROCKS

Quartz porphyry & quartz-feldspar porphyry; feldspar porphyry, equigranular trondhjemite; hololeucocratic chlorite-biotite equigranular trondhjemite.

MAFIC TO ULTRAMAFIC INTRUSIVE ROCKS (MAFIC SUITE)[2,3]

Gabbro; diorite, quartz diorite; porphyritic-/porphyroblastic gabbro, diorite; anorthositic gabbro, gabbroic anorthosite; amphibolite, hornblendite; mafic to ultramafic rocks; dikes; garnet-bearing mafic

dikes, stictolithic texture.

INTRUSIVE CONTACT

FELSIC TO MAFIC GNEISSIC ROCKS

Ultramafic association (hornblendite); Supracrustal Association (metagabbro, fine-to medium-grained, medium- to coarse-grained, locally metasedimentary wacke). Tonalite association (hornblende-biotite to biotite-hornblende trondhjemite to quartz diorite; biotite trondhjemite to quartz diorite, biotite trondhjemite). Leucogranitoid association (biotite to leucocratic biotite trondhjemite; hololeucocratic quartz monzonite to granite; hololeucocratic trondhjemite); Mafic dike association (amphibolite, mafic/mafelsic dikes; diorite; gabbro; porphyritic (plagioclase) gabbro; Potassic association (leucocratic fine- to medium-grained quartz monzonite to granite; medium- to coarse-grained quartz monzonite to granite; syenite; pegmatite; potassium metasomatism, conformable, sharp or gradational contact.

METASEDIMENTS AND DERIVED MIGMATITES

Greywacke; siliceous siltstone, chert; mudstone, siltstone, slate, argillite, pelite, iron formation; conglomerate;

volcanic conglomerate; sandstone with up to 10 percent granitoid mobilizate; metatexite[5]; protometatexite; inhomogeneous diatexite[5]; homogeneous diatexite[5]; mafic diatexite; fine- to medium-grained equigranular homogeneous diatexite; wacke with magnetite with complimentary leucocratic haloes.

METAVOLCANICS

FELSIC TO INTERMEDIATE METAVOLCANICS

Andesitic to dacitic metavolcanics; dacitic to rhyolitic metavolcanics[8]; tuff, lapilli-tuff, lapilli-stone; agglomerate, tuff breccia; crystal tuff; reworked pyroclastic rocks, bedded tuffs; fine- to medium-grained flows, porphyritic (plagioclase) flows; flow breccia; quartz-feldspar porphyry flow.

MAFIC TO INTERMEDIATE METAVOLCANICS[9]

Fine to medium flows; medium- to coarse-grained flows; pillowed flows; porphyritic (plagioclase) flows; porphyritic/porphyroblastic (amphibole) flows; vesicular flow; aquagene breccia, pillow breccia; flow top breccia; garnetiferous metavolcanics; amphibolite; tuff, lapilli tuff, tuff breccia; reworked pyroclastics, bedded pyroclastics, gneissic mafic metavolcanics; migmatitic

metavolcanics, up to 5% leucocratic trondhjemite in situ mobilizate[5].

NOTES

1) This is the youngest intrusive suite.

2) Age relationship between these two is unknown.

3) The age relationship of this suite varies widely; it is both older and younger than the sodic suite.

4) Age relationship of these rocks is unknown; they may in part be both time and genetically equivalent to the Sodic Suite. These rocks are believed to be plutonic in origin.

5) For definition see Mehnert (1971).

6) For definition see Breaks, Bond and Stone (1978).

7) Corresponds to intermediate composition.

8) Corresponds to felsic composition.

9) Corresponds to dominantly mafic composition.

Table 3-1: Chemical analyses of extrusive/intrusive rocks from Separation Lake.

	EXTRUSIVE ROCKS				SEPARATION LAKE					EXTRUSIVE ROCKS			SEPARATION LAKE				INTRUSIVE GABBROIC RX			SEPARATION LAKE	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	8-14-8	9-9-16	9-9-18	9-9-21A	9-9-21b	9-9-25	9-9-26	9-9-27	9-9-29	9-9-44	9-9-55	9-10-1	9-10-4	1028-1	9-936A	9-9-38	9-9-20	9-9-23	9-9-24	9-9.30	9-9-52
SiO_2	48.90	47.80	47.70	47.70	48.80	47.80	49.60	48.10	49.50	48.20	48.20	48.70	47.70	51.30	72.00	76.3	48.00	48.30	49.30	50.10	46.90
Al_2O_3	15.10	16.00	16.70	15.90	15.60	16.20	15.70	15.30	15.80	15.00	14.40	15.70	15.70	14.60	13.10	11.9	16.70	19.00	18.20	14.20	16.30
Fe_2O_e	1.70	1.70	1.90	1.50	0.80	1.60	1.90	1.90	1.38	1.40	2.00	1.40	1.70	2.20	0.68	0.38	1.95	1.95	2.18	0.97	0.90
FeO	10.20	10.40	9.41	9.71	9.71	9.56	8.37	10.20	8.75	9.81	11.00	9.26	10.20	12.70	2.89	1.71	8.60	6.37	6.45	7.92	8.55
MgO	7.90	8.44	8.94	8.53	8.53	9.21	7.82	8.43	8.02	9.42	7.03	7.29	7.98	2.63	1.27	0.14	9.94	7.12	6.79	9.77	9.94
CaO	11.7	11.10	11.00	12.80	12.80	11.70	11.20	11.20	11.70	11.50	11.50	12.60	11.40	8.49	1.70	0.28	11.10	12.20	12.20	13.50	13.20
Na_2O	1.41	1.78	1.56	1.27	1.38	1.28	2.91	1.89	2.54	1.56	2.51	2.33	2.56	3.27	2.85	2.26	1.52	2.75	2.67	1.34	1.18
K_2O	0.42	0.13	0.07	0.06	0.07	0.05	0.07	0.11	0.08	0.05	0.11	0.13	0.15	0.31	3.69	5.95	0.07	0.15	0.15	0.11	0.13
TiO_2	0.84	0.91	0.82	0.72	0.70	0.76	1.02	0.93	0.75	0.80	1.09	0.74	0.97	2.20	0.31	0.13	0.65	0.59	0.61	0.56	0.59
P_2O_5	0.04	0.04	0.03	0.03	0.02	0.04	0.06	0.05	0.03	0.03	0.06	0.03	0.05	0.28	0.04	0.0	0.02	0.01	0.02	0.01	0.01
S	0.01	0.03	0.22	0.07	0.02	0.07	0.02	0.06	0.05	0.12	0.01	0.08	0.06	0.01	0.12	0.01	0.08	0.01	0.03	0.02	0.02
MnO	0.26	0.20	0.18	0.20	0.19	0.19	0.21	0.20	0.20	0.19	0.25	0.19	0.21	0.45	0.04	0.05	0.18	0.14	0.15	0.19	0.20
CO_2	0.14	0.12	0.18	0.16	0.16	0.16	0.08	0.12	0.10	0.10	0.08	0.08	0.10	0.23	0.15	0.12	0.14	0.08	0.10	0.07	0.18
H_2O+	0.26	0.50	0.23	0.22	0.28	0.22	0.44	0.25	0.46	0.28	0.42	0.16	0.17	0.27	0.21	0.0	0.29	0.31	0.29	0.62	0.36
H_2O-	0.43	0.40	0.45	0.40	0.33	0.35	0.29	0.34	0.31	0.43	0.36	0.34	0.44	0.49	0.37	0.37	0.47	0.33	0.39	0.33	0.36
Total	99.3	99.5	99.4	99.3	99.4	99.2	99.7	99.1	99.7	98.9	99.0	99.0	99.4	99.4	99.4	99.6	99.7	99.3	99.5	99.7	98.8
Ag	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba	80	80	70	40	40	50	50	40	60	60	60	60	50	200	880	620	50	40	60	50	150
Be	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3	4	<1	<1	<1	<1	<1
Co	50	45	50	50	50	45	40	45	45	50	45	45	40	45	10	5	50	35	35	45	45
Cr	300	340	335	210	210	320	210	325	390	335	175	370	320	20	20	7	230	580	540	1320	420
Cs																					
Cu	10	105	220	90	100	100	105	120	120	115	25	80	100	5	20	5	140	80	155	85	60
Ga	15	15	15	15	15	15	15	15	10	15	15	15	15	20	15	15	10	15	15	15	15
Li	10	65	40	9	6	10	10	15	15	130	10	10	10	25	45	25	105	20	10	20	45
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	80	75	105	70	70	175	100	140	140	220	75	150	120	25	6	<5	120	45	75	60	180
Pb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	20	20	35	20	<10	<10	<10	<10
Rb	<10	<10	<10	<10	<10	<10	<10	10	10	10	10	10	10	10	90	140	<10	<10	<10	<10	<10
Sr	30	50	50	50	50	50	50	50	100	30	100	100	100		100	30	35	40	35	50	35
Th																	50	100	50	100	100
U														10							
V	250	250	300	250	250	250	350	300	250	250	350	350	300	350	35	10	250	250	200	300	200
Y	20	15	20	20	15	15	30	25	20	15	30	20	25	60	35	50	15	15	15	15	10
Zn	110	100	85	90	90	85	75	95	60	90	100	80	100	165	75	75	80	55	65	85	75
Zr	80	70	70	35	35	45	80	70	45	200	90	70	80	200	200	200	50	40	30	30	30
Sn	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<4	<3	<3	<3	<3	<3	<3

Nos. 1-5 inclusive, 10, 13 and 14 are fine- to medium-grained mafic volcanic flows.
Nos. 6-9 inclusive, 11, 12, are fine- to medium-grained mafic pillowed flows.
No. 15 - fine- to medium grained intermediate porphyritic (plagioclase) flow on crystal tuff.
No. 16 - very fine-grained felsic tuff or flow.
Nos. 17-21 - medium-grained metagabbro.

Table 3-2: List of Localities Representing the Extension of Separation Lake Belt.

Location	At Contact of Northern and Southern Domains (Distance from Contact)	Lithologies
Helder Lake	nil	fine-to medium-grained mafic volcanic flows
6 km south of Oak Lake	(6.4 km south)	coarse-grained, locally gneissose mafic volcanic flows
East End of Oak Lake	(6.4 km south)	fine- to medium-grained gneissic mafic volcanics
Northwest Anishinabi Lake	(1.6 km south)	gneissic, locally garnetiferous mafic volcanics
Southeast of Anishinabi Lake	(4.8 km south)	gneissic, locally garnetiferous mafic volcanics
Aerobus Lake	(0.8 km south)	gneissic mafic volcanics with iron-formation (gneissic banding at scale of 1-25 cm)
Wino Lake	nil	strongly banded amphibole with epidote pods + thin bedded siliceous biotite + quartz + plag. + garnet formation; only as inclusions
McLeod Bay (Wabaskang Lake)	nil	pillowed mafic volcanics (10?? thick) plus massive mafic flows (100 m thick); pillows stretched 10:1
Perrault Lake	nil	massive to gneissose mafic volcanic with associated conglomerate
Florence Lake	(4.8 km north)	mafic metavolcanic flows hornblende + plagioclase + biotite + clinopyroxene ± rare epidote with intermediate tuff and tuffaceous metasediments (5-10 m thick); biotite + quartz + plagioclase
Cliff Lake	(17.6 km south)	massive and possible pillowed mafic volcanic flows, banded mafic volcanics (banding due to differences in conce??? of hornblende + clinopyroxene
Trail Lake (at northeast edge of the Mystery Dome)	(22.4 km south)	mafic volcanics (180 +??? with 3 to 5 m thick iron formation (magnetite plus quartz)
South Inlet (Lac Seul)	(5.6 km south)	gneissose mafic volcanics
Lac Seul (north shore)	(2.0 km south)	gneissose mafic volcanics
Turteeweik Bay (Lac Seul)	2 lenses, one at contact one at 0.8 km south	mafic volcanics with hypersthene + diopside
Chamberlain Narrows (Lac Seul)	(6.4 km south)	mafic volcanics (with hypersthene + diopside) with interlayered iron formation (Photo 3-5)

Table 3-3: Chemical analyses of Chamberlain Narrows Extrusives

	MT-10	17-A	MT-24	MT-29	1202-20	41-2-47	23-21-5c	30-3-1	12-A	MT-8b
SiO_2	47.90	47.20	49.90	53.50	50.60	46.90	49.4	48.90	47.90	50.30
Al_2O_3	15.60	16.50	13.80	9.60	13.70	16.20	15.3	14.40	14.60	16.80
Fe_2O_3	2.36	2.49	3.48	2.76	3.32	2.81	4.89	3.60	3.19	4.08
FeO	8.69	8.29	11.90	7.25	9.18	8.46	7.21	9.18	13.60	7.41
MgO	8.42	7.34	5.32	11.30	6.78	8.34	7.32	6.73	3.76	5.55
CaO	11.70	12.70	9.79	9.84	10.60	12.20	10.2	9.85	9.18	11.20
Na_2O	2.23	2.25	2.25	1.42	2.46	1.88	2.80	3.03	3.20	2.36
K_2O	0.67	0.53	0.48	1.35	0.66	0.48	0.81	1.05	0.37	0.42
TiO_2	0.79	0.69	1.56	1.04	1.14	0.81	0.89	1.13	2.06	1.05
P_2O_5	0.09	0.04	0.14	0.18	0.12	0.06	0.09	0.10	0.17	0.11
S	0.03	0.36	0.02	0.14	0.03	0.04	0.09	0.02	0.16	0.05
MnO	0.20	0.18	0.23	0.16	0.20	0.19	0.20	0.25	0.42	0.17
CO_2	0.20	0.71	0.08	0.44	0.08	0.05	0.16	0.08	0.73	0.18
H_2O+	0.52	0.79	0.21	0.43	0.58	0.23	0.57	0.32	0.42	0.56
H_2O-	0.38	0.19	0.32	0.36	0.31	0.34	0.27	0.27	0.35	0.23
TOTAL	99.3	100.4	99.5	99.3	99.7	99.0	100.2	98.81	100.1	100.4
Ag	1		1	2	1		1			1
Ba	60	60	130	490	80	80	200	100	120	110
Be	1	1	1	1	1		1		1	1
Co	43	45	39	42	42	45	50	50	39	39
Cr	420	356	92	860	295	375	330	260	112	240
Cs	3	2	2	5	3			3	7	4
Cu	42	68	73	52	52	55	65	15	69	58
Ga	9		15	15	10		10			15
Li	5	13	7	14	6	6	9	15	20	6
Mo	1		1	1	1		1			1
Ni	137	163	51	198	67	170	140	85	50	91
Pb	10	10	10	10	10	15	15	25	10	10
Rb	10	10	10	40	10		10	10	10	10
Sc	40		45	30	45		30			45
Sn	3	3	3	3	3		1		3	3
Sr	80	120	90	310	90		100		120	140
Th	10	10	10	10	10			10	10	10
U	1	1	1	1	1			1	3	1
V	250	300	400	200	250		200		600	300
Y	25		40	40	30		20			30
Zn	90	80	126	141	98	85	110	135	133	98
Zr	80	60	150	100	100		45		150	100

Table 3-4: Chemical analyses of Sioux Lookout Amphibolites

	E 57-13-1	E 59-8-1	E 46-7-23	E 59-25-2	E 510-30-1	E SG-1	E SG-2	E 47-5-5
SiO_2	49.60	46.70	49.40	52.80	50.20	48.40	50.80	53.6
Al_2O_3	14.40	15.10	15.0	15.10	14.70	14.40	13.90	16.6
Fe_2O_3	2.51	2.37	2.68	2.35	2.13	2.79	6.39	8.76
FeO	10.90	9.58	8.13	7.08	12.50	9.74	7.49	
MgO	6.42	9.06	7.71	4.70	6.41	6.63	4.93	6.64
CaO	10.40	6.75	11.2	10.70	7.39	12.10	13.60	7.47
Na_2O	2.03	3.96	1.62	2.35	3.20	1.50	0.53	2.09
K_2O	0.22	0.09	0.64	0.08	0.08	0.04	0.06	1.50
TiO_2	1.14	1.69	0.74	0.96	1.48	0.59	0.54	0.70
P_2O_5	0.12	0.37	0.10	0.10	0.15	0.09	0.09	0.16
S	0.06	0.01	0.18	0.25	0.10	0.17	<0.01	0.0
MnO	0.25	0.16	0.20	0.19	0.22	0.22	0.30	0.13
CO_2	0.12	0.37	0.13	0.68	0.08	0.46	0.09	0.0
H_2O+	0.70	3.69	1.96	1.53	0.57	1.41	1.28	2.50
H_2O-	0.43	0.47	0.31	0.29	0.29	0.30	0.30	0.0
Total	99.3	100.4	100.0	99.2	99.5	98.8	100.3	100.2

	57-13-1	59-8-1	46-7-23	59-25-2	510-30-1	SG-1	SG-2
Ag	<1	<1	<1	<1	<1	<1	<1
Ba	80	110	100	50	60	30	50
Be	<1	<1	<1	<1	<1	<1	<1
Co	41	48	45	44	47	47	46
Cr	221	740	285	285	88	42	25
Cs	5	4	1	4	5	2	<1
Cu	142	76	140	189	122	123	14
Ga	15	15	15	15	15	10	15
Li	9	16	40	6	6	7	4
Mo	<1	<1	<1	<1	<1	<1	20
Ni	58	296	115	98	55	38	24
Pb	<10	<10	<10	<10	<10	<10	<10
Rb	<10	<10	<10	<10	<10	<10	<10
Sc	45	30	45	50	35	60	60
Sn	<3	<3	<3	<3	<3	<3	<3
Sr	110	150	110	110	90	50	90
Th	<10	<10	<10	<10	<10	<10	<10
U	<1	<1	<1	<1	<1	<1	<1
V	250	200	200	250	300	250	250
Y	25	30	20	25	30	30	30
Zn	166	123	85	91	134	98	114
Zr	90	150	60	60	150	70	70

I = Intrusive
E = Extrusive

Table 3-4: Chemical analyses of Sioux Lookout Amphibolites

	I 57-16-1	I 57-19-2	I 57-20-1	I 57-24-4	I 46-8-27	I 58-24-1	I 58-22-3
SiO_2	50.10	51.00	67.90	64.00	55.5	48.8	55.5
Al_2O_3	20.20	16.20	16.20	16.00	16.7	16.7	16.1
Fe_2O_e	1.90	4.81	1.01	2.36	2.37	3.45	4.69
FeO	7.57	8.37	2.25	2.58	6.20	7.89	5.15
MgO	3.17	3.75	1.60	3.70	4.13	7.03	3.21
CaO	7.94	7;82	3.77	7.08	7.62	9.87	6.82
Na_2O	4.28	4.19	4.76	3.56	3.91	3.36	4.35
K_2O	0.78	0.35	0.75	0.35	0.73	0.21	0.96
TiO_2	1.72	1.77	0.36	0.26	0.97	1.14	1.58
P_2O_5	0.48	0.61	0.11	0.07	0.25	0.30	0.43
S	0.02	0.04	0.01	0.01	0.03	0.06	0.08
MnO	0.13	0.19	0.06	0.10	0.14	0.20	0.15
CO_2	0.08	0.16	0.10	0.09	0.10	0.09	0.14
H_2O+	1.28	0.54	0.24	0.38	0.92	0.53	0.36
H_2O-	0.43	0.44	0.39	0.28	0.36	0.34	0.30
Total	100.1	100.2	99.5	100.8	99.9	100.0	99.8

	57-16-1	57-19-2	57-20-1	57-24-4	46-8-27	58-24-1	58-22-3
Ag	<1	<1	<1	<1	<1	<1	<1
Ba	190	150	270	100	190	100	300
Be	<1	<1	<1	<1	<1	<1	<1
Co	24	24	10	15	30	35	20
Cr	15	6	33	149	50	245	20
Cs	6	7	2	3	4	2	6
Cu	48	54	5	16	40	50	50
Ga	15	15	15	15	15	15	15
Li	15	10	27	6	15	40	15
Mo	<1	<1	<1	<1	<1	<1	<1
Ni	36	<5	30	91	60	90	20
Pb	<10	11	<10	<10	<10	<10	<10
Rb	20	<10	<10	<10	20	<10	20
Sc	10	25	5	15	35	30	20
Sn	<3	<3	<3	<3	<3	<3	<3
Sr	290	400	360	230	290	360	280
Th	<10	<10	<10	<10	<10	<10	35
U	<1	<1	<1	<1	<1	<1	<1
V	200	200	50	80	150	200	150
Y	20	60	<10	20	30	10	35
Zn	108	182	66	56	90	110	120
Zr	150	200	100	25	90	35	80

Table 4-1: Lithological Composition of the English River Subprovince

Lithology	Northern Supracrustal Domain A	Northern Supracrustal Domain B	Southern Plutonic Domain A	Southern Plutonic Domain B
Amphibolitic, foliated to gneissic mafic metavolcanic rocks		1.0		1
Felsic to Intermediate Metavolcanic rocks		1		-
Metasedimentary rocks and derived Migmatite		67		1
Metatexite	57			
Diatexite	10			
Metamorphosed mafic plutonic rocks		<1		3
Felsic to intermediate granitoid gneisses		-		19
Metamorphosed felsic to intermediate massive and foliated granitoid plutonic rocks		29		38
Strongly foliated to gneissic trondhjemite and granodiorite	1		4	
Moderately to weakly foliated trondhjemite and granodiorite	23		24	
Porphyritic granodiorite	4		4	
Foliated quartz monzonite	2		5	
Unmetamorphosed felsic to intermediate Massive to weakly foliated granitoid plutonic rocks		1		39
Equigranular trondhjemite and granodiorite	<1		3	
Porphyritic granodiorite and quartz monzonite	-		17	
Equigranular quartz monzonite and granite	1		19	
Unmetamorphosed mafic plutonic rocks	2		-	

Column A where applicable gives subdivision of total percentage as expressed in column B.

Table 4-2

Classification and descriptive features of migmatitic metasedimentary and related granitic rocks in the English River Subprovince (migmatite terminology *modified from* Brown 1973; Mehnert 1973; Breaks et al. 1978; Ashworth 1985).

Migmatitic Type	Leucosome Content of Migmatite or Granite	Field Relations, Petrography and Migmatite Structure	Possible Genetic Processes
Protometatexite	<10%	Characterized by low quantities of podiform and lensoid granite, leucosome mainly confined to high-grade, porphyroblastic pelite mesosome. Intercalated metawacke typically absent of leucosome.	Incipient anatexis selectively developed in low calcium, potassium feldspar + albite + quartz pelitic protoliths. Solid-state segregation in chemically or tectonically induced gradients (Ramberg 1949, 1952; Barth 1952; Reitan 1956; Kretz 1967; Sawyer and Robin 1986) and metasomatism (Misch 1968; Olsen 1985) could also be important.
Metatexite	10 to 60%	Migmatites of stromatic and/or phlebitic structure produced by striped leucosomes controlled by foliation and relict bedding in mesosome host; white leucosomes generally hololeucocratic, coarse grained, mainly granite (s.s.) and less commonly granodiorite, trondhjemite and quartz syenite. Melanosomes commonly present, 1 to 5 mm thick, rich in biotite with lesser cordierite, sillimanite and plagioclase.	Leucosomes may be derived by *in situ* anatexis (Holmquist 1921; Winkler and von Platen 1958) or by subsolidus mechanisms (*see* references in protometatexite category). Injection of mobile granitic magma along a planar fabric also important (Sederholm 1907).
Inhomogeneous Diatexite	60 to 90%	Granitic rocks featured by a conspicuous abundance of inclusions of metatexite and unmigmatized metawacke, and schlieren rich in biotite (possible melanosome). Nonmetasedimentary inclusions such as metaultramafic rock are rare. Schollen structure is especially characteristic. Leucosome typically coarse grained, white, hypidiomorphic granular, massive to moderately foliated. Colour index commonly 10 to 30.	Anatexis is dominant; increase in granitic melt component *vis-a-vis* mesosome component led to mechanical disruption of the stromatic leucosome–melanosome–mesosome framework of metatexite.
Homogeneous Diatexite	>90%	Granitic rock which is typically massive, homogeneous, and seriate, hypidiomorphic to granular, coarse grained to pegmatitic and colour index typically less than 10. Wide range in modal composition; granite (s.s.) is most common. Rare inclusions of metatexite and unmigmatized metawacke mesosome.	Extensive anatexis and probable amalgamation of granitic melt into magmatic masses which were capable of ascent into the crust above the zone of fusion of the metasedimentary protolith.

Table 4-3 : Modal Analyses of Mafic Diatexite From the English River Subprovince Metasedimentary Migmatite

	FC10-21	FC12-3	FF1-7	FF1-14	FG6-2	FG8-3	5-7-3	36-4-4	36-7-1	38-11-8	39-8-2
Quartz	23.6	24.6	25.6	18.4	20.0	27.2	25.8	25.2	28.2	29.8	21.0
K-feldspar	10.0	7.2	28.2	8.0	10.4	2.2	1.8	3.3	8.4	13.4	26.6
Plagioclase	38.8	39.0	34.8	40.0	39.8	50.4	49.6	39.1	43.6	35.2	30.4
Biotite	26.4	29.2	11.4	33.6	22.2	18.8	13.0	31.9	19.2	21.2	13.8
Hornblende											
Almandine	1.2			x	5.4	1.4		0.5		x	8.2
Cordierite							x				
Sillimanite											
Muscovite	x			x	2.2		9.8		0.6		
Andalusite											
Chlorite											
Apatite											
Epidote											
Fe-oxides											
Pyrite	x		x	x		x	x				
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.2	100.0	100.0	99.6	100.0
Colour Index	27.6	29.2	11.4	33.6	27.6	20.2	13.0	32.4	19.2	21.2	22.0
K-feldspar / Total Feldspar	0.20	0.16	0.45	0.17	0.21	0.04	0.04	0.04	0.16	0.28	0.47

x = Present in trace amounts

Table 4-4 : Modal Analyses of Leucosome from English River Subprovince Metasedimentary Migmatites

	FC12-4	FC12-14	FC14-44	FF8-25	FG2-6	FG8-2
Quartz	32.4	31.8	27.9	38.3	33.1	20.2
K-feldspar	17.6	18.7	54.3	41.9	27.5	27.2
Plagioclase	48.2	45.7	13.6	17.9	34.8	50.0
Biotite	1.8	3.8	1.7	1.9	4.6	2.0
Almandine						
Cordierite			2.5			0.7
Muscovite						
Orthopyroxene						
Fe-oxides						
Pyrite						
Total	100.0	100.0	100.0	100.0	100.0	100.1
Colour Index	1.8	3.8	4.2	1.9	4.6	2.7
$\frac{\text{K-feldspar}}{\text{Total Feldspar}}$	0.27	0.34	0.80	0.70	0.44	0.35

(Cont. Table 4-4)

	FG8-7	FG12-2	5-2-3	5-18-6	8-11-2A	8-12-3	19-11-5B	20-2-2	20-5-7	20-5-9A
Quartz	24.6	32.2	28.2	26.4	29.6	31.4	31.8	21.6	35.6	33.0
K-feldspar	27.0	35.8	28.2	3.0	39.4	43.8	8.0	0.4	35.4	47.3
Plagioclase	43.4	30.2	39.8	68.8	25.8	21.2	56.0	69.4	21.2	15.3
Biotite	3.4	0.4	3.2	1.8	5.2	1.4	4.2	8.4	0.6	4.4
Almandine	0.2		0.6			0.8				
Cordierite		1.4				0.4				
Muscovite	1.4					1.0	x		7.2	
Fe-oxides				x						
Pyrite						x				
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	100.0	100.0
Colour Index	3.6	1.8	3.8	1.8	5.2	2.6	4.2	8.4	0.6	4.4
$\frac{\text{K-feldspar}}{\text{Total Feldspar}}$	0.38	0.54	0.41	0.04	0.60	0.67	0.13	0.06	0.63	0.76

(Cont. Table 4-4.)

	20-5-14	20-6-18	20-6-26	20-8-1	20-16-3A	21-12-11	21-26-16
Quartz	29.8	25.4	34.2	26.7	24.1	41.1	30.0
K-feldspar	20.8	41.8	30.8	38.2	34.1	40.6	35.4
Plagioclase	44.2	30.6	31.2	33.9	40.6	13.8	28.0
Biotite	4.0	0.8	1.4	1.1	1.3	4.5	5.6
Almandine		0.2					
Cordierite							
Muscovite	1.2	1.2	2.4				1.0
Fe-oxides							
Pyrite		x					x
Total	100.0	100.0	100.0	99.9	100.1	100.0	100.0
Colour Index	4.0	1.0	1.4	1.1	1.3	4.5	5.6
K-feldspar / Total Feldspar	0.32	0.58	0.50	0.53	0.47	0.75	0.56

(Cont. Table 4-4)

	22-9-44	22-11-7	22-17-4	23-6-1	23-11-39	23-13-6B	23-14-13	24-9-17	24-22-20	24-22-29	25-9-19A
Quartz	27.6	30.2	27.4	26.4	24.0	29.6	30.0	29.8	38.8	5.6	28.6
K-feldspar	45.0	35.0	27.6	44.6	38.4	34.8	43.0	43.8	29.4	57.6	37.6
Plagioclase	27.4	30.2	43.0	27.4	29.4	30.8	22.0	18.4	28.2	29.8	26.0
Biotite		3.4	2.0	x	7.0	4.8	5.0	5.6	2.2	5.8	7.2
Almandine							x		1.4		
Cordierite											
Muscovite		1.2	x	x	1.2	x		2.4		1.2	
Fe-oxides											
Pyrite											
Total	100.0	100.0	100.0	98.4	100.0	100.0	100.0	100.0	100.0	100.0	99.4
Colour Index	-	3.4	2.0	-	7.0	4.8	5.0	5.6	3.6	5.8	7.2
K-feldspar / Total Feldspar	0.62	0.54	0.39		0.57	0.53	0.66	0.70	0.51	0.66	0.59

(Cont. Table 4-4)

	31-8-10	31-9-1	34-10-35	35-12-1	36-1-2	36-7-17	36-14-48
Quartz	25.8	33.6	27.8	26.2	31.6	32.4	36.2
K-feldspar	58.5	37.8	14.2	23.2	33.6	36.6	10.0
Plagioclase	9.0	26.4	49.5	48.6	29.6	25.4	53.6
Biotite	5.5	0.6	8.5	0.6	1.8	5.0	x
Almandine							0.2
Cordierite						x	
Muscovite	1.3	1.6		1.4	3.4	0.6	
Fe-oxides							
Pyrite							
Total	100.1	100.0	100.0	100.0	100.0	100.0	100.0
Colour Index	5.5	0.6	8.5	0.6	1.8	5.0	0.2
K-feldspar / Total Feldspar	0.87	0.59	0.22	0.32	0.53	0.59	0.16

(Cont. Table 4-4)

	37-9-2A	37-10-13	37-10-14	37-10-19	37-10-22	37-10-31	37-10-32	37-10-38	37-13-28	37-13-37	38-5-39	38-9-3
Quartz	21.2	32.8	33.0	25.4	31.2	36.0	27.8	22.8	22.1	26.0	28.6	26.2
K-feldspar	36.0	28.4	46.0	38.8	35.6	36.8	39.2	54.8	48.7	43.4	46.2	34.8
Plagioclase	32.2	34.2	20.2	32.8	29.4	27.0	25.0	20.0	23.8	19.6	22.2	36.4
Biotite	1.8	4.6	0.8	3.0	3.8	x	6.2		5.4	4.5	1.2	2.6
Almandine	5.0				x		1.8	1.4		6.5		
Cordierite	3.8		x			0.2	x	0.8			1.0	
Muscovite					x			0.2			0.8	
Fe-oxides												
Pyrite	x											
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Colour Index	10.6	4.6	0.8	3.0	3.8	0.2	8.0	2.2	5.4	11.0	2.2	2.6
K-feldspar / Total Feldspar	0.53	0.45	0.69	0.54	0.55	0.58	0.61	0.73	0.67	0.69	0.68	0.49

(Cont. Table 4-4)

	38-11-4	38-11-5	38-14-41	39-1-2	39-2-4	39-2-35	39-3-2	39-3-19	39-5-18	39-6-15	39-6-18A
Quartz	23.6	29.8	35.2	24.9	30.2	28.8	24.4	27.2	22.4	32.8	26.8
K-feldspar	30.4	37.4	42.0	27.9	31.4	14.8	31.6	41.6	40.2	34.2	38.2
Plagioclase	37.6	29.2	18.8	40.3	36.8	50.6	42.6	22.8	28.0	29.8	28.2
Biotite	8.4	3.6	4.0	6.9	1.4	4.6	0.8	8.4	3.0	2.8	2.0
Almandine	x	x							5.4	0.2	4.8
Cordierite		x	x						1.0		
Muscovite		x	x		0.2	x	0.6	x		0.2	
Fe-oxides						0.8					
Pyrite		x			x	x	x	x		x	
Total	100.0	100.0	100.0	100.0	100.0	99.6	100.0	100.0	100.0	100.0	100.0
Colour Index	8.4	3.6	4.0	6.9	1.4	5.4	0.8	8.4	9.4	3.0	6.8
$\frac{\text{K-feldspar}}{\text{Total Feldspar}}$	0.45	0.56	0.69	0.41	0.46	0.23	0.43	0.65	0.59	0.53	0.57

(Cont. Table 4-4)

	39-6-20	39-7-6	39-7-8	39-8-5	39-9-20	41-2-21	41-6-6A	41-7-42	42-2-1	43-4-1	P6-1-36	Umfreville Lake Uranium Occurrence
Quartz	31.0	27.0	24.6	25.4	27.4	3.0	35.7	25.8	26.4	11.2	27.9	35.8
K-feldspar	45.2	38.6	34.4	45.2	45.2	3.8	30.5	42.8	38.0	53.4	38.9	43.2
Plagioclase	20.2	27.2	39.2	19.3	24.6	80.6	30.2	27.4	32.6	24.8	25.2	19.4
Biotite	x	6.8	0.6	10.1	2.8	12.6	3.7	4.0	2.6	10.6	8.0	1.6
Almandine	0.8	0.4	1.2									
Cordierite	2.8	x										
Muscovite			x									
Fe-oxides									0.4			
Pyrite		x	x									
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.0	100.0	100.0
Colour Index	3.6	7.2	1.8	10.1	2.8	12.6	3.7	4.0	2.6	10.6	8.0	1.6
K-feldspar / Total Feldspar	0.69	0.59	0.47	0.70	0.65	0.05	0.50	0.61	0.54	0.68	0.61	0.69

x Present in Trace Amounts

Cont. Table 4-4)

	39-6-20	39-7-6	39-7-8	39-8-5	39-9-20	41-2-21	41-6-6A	41-7-42	42-2-1	43-4-1	P6-1-36	Umfreville Lake Uranium Occurrenc
uartz	31.0	27.0	24.6	25.4	27.4	3.0	35.7	25.8	26.4	11.2	27.9	35.8
-feldspar	45.2	38.6	34.4	45.2	45.2	3.8	30.5	42.8	38.0	53.4	38.9	43.2
lagioclase	20.2	27.2	39.2	19.3	24.6	80.6	30.2	27.4	32.6	24.8	25.2	19.4
iotite	x	6.8	0.6	10.1	2.8	12.6	3.7	4.0	2.6	10.6	8.0	1.6
lmandine	0.8	0.4	1.2									
ordierite	2.8	x										
uscovite			x						0.4			
e-oxides												
yrite		x	x									
otal	100.0	100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.0	100.0	100.0
olour Index	3.6	7.2	1.8	10.1	2.8	12.6	3.7	4.0	2.6	10.6	8.0	1.6
-feldspar												
otal Feldspar	0.69	0.59	0.47	0.70	0.65	0.05	0.50	0.61	0.54	0.68	0.61	0.69

Present in Trace Amounts

Table 4-5: Mean Bulk Chemical Composition of Wacke Metasediments from English River Subprovince in Comparison to Various Lithic Groups Selected from the Literature.

	1 $\bar{X}$	s.d.	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	66.73	2.80	66.75	64.67	64.43	63.66	63.91	65.67	66.1	77.1	67.30	61.74	68.52	63.40	65.1
Al_2O_3	15.53	1.06	13.45	13.41	15.48	14.85	15.34	12.73	8.1	8.7	14.80	15.17	15.92	16.39	16.0
FeO	3.83	1.14	3.54	4.53	ND	4.67	4.60	ND	1.4	0.7	3.44	5.74	1.23	2.18	1.5
Fe_2O_3	0.87	0.87	1.60	1.24	6.54	1.01	1.03	5.09	3.8	1.5	1.17	1.87	1.65	3.02	3.0
MgO	2.49	0.82	2.15	3.23	3.12	2.99	3.88	2.40	2.4	0.5	1.55	2.30	1.02	2.14	2.3
CaO	2.67	0.82	2.54	3.04	2.22	2.63	2.61	4.20	6.2	2.7	3.13	4.80	3.35	4.68	3.4
Na_2O	3.35	0.58	2.93	2.99	3.74	3.14	3.09	3.04	0.9	1.5	3.07	3.57	4.80	4.56	4.1
K_2O	1.94	0.41	1.99	2.02	2.44	2.30	1.96	1.87	1.3	2.8	1.40	0.54	1.45	1.70	2.7
TiO_2	0.57	0.12	0.63	0.57	0.62	0.63	0.78	ND	0.3	0.3	0.51	1.22	0.41	0.56	0.50
P_2O_5	0.12	0.06	0.16	0.14	ND	0.16	0.08	Nd	0.1	0.1	0.07	0.32	0.11	0.16	0.15
S	0.08	0.10	0.07	ND	ND	ND	ND	ND	Nd	ND	ND	ND	ND	ND	ND
MnO	0.07	0.02	0.12	0.13	ND	0.12	0.09	ND	0.1	0.2	0.08	0.14	0.04	0.08	0.20
CO_2	0.12	0.12	1.24	2.15	ND	1.24	ND	ND	5.0	3.0	0.98	0.47	0.15	0.16	0.08
H_2O+	0.53	0.30	2.42	1.94	ND	2.17	2.42	Nd	3.6	0.9	1.56	1.87	0.28	0.40	0.7
H_2O-	0.40	0.12	0.55	0.20	ND	ND	0.18	ND	0.7	ND	ND	ND	0.15	0.42	
Total	99.83		100.23	100.26	98.59	99.99	99.97	95.00	100.00	100.0	99.06	99.73	99.08	99.85	99.73

ND = Not Determined

1 = Average wacke metasedimentary rock from English River Subprovince (77 analyses from this study and 21 unpublished analyses from Operation Ignace-Armstrong)

2 = Average of 61 greywackes of various ages, Pettijohn (1963, p.515).

3 = Average of 12 greywackes of Precambrian age, Pettijohn (1963, p.57).

4 = Average of 25 Early Precambrian greywackes from Wyoming, Condie (1967, p.2139).

5 = Average of 20 Archean greywackes from Burwash Formation, Yellowknife Supergroup, Slave Province, Henderson (1972, p.890).

6 = Average of 19 greywackes from Vosges Mountains, Rivalenti and Sigbinolfi (1969, p.176-177).

7 = Average eugeosynclinal greywacke, Middleton (1960, p.1015).

8 = Average of 20 lithic arenites (subgreywacke), Pettijohn (1963, 57).

9 = Average of 32 arkoses, Pettijohn (1963, p.515).

10 = Average Superior Province rhyodacite, Goodwin (1968, p.75).

11 = Average of 3 Archean dacites, Wilson et al. (1965, p.167).

12 = Average of 47 biotite trondhjemites from English River Subprovince (this study and unpublished analyses from Operation Ignace-Armstrong.

13 = Average of 15 hornblende-bearing trondhjemites from English River Subprovince (this study and unpublished analyses from Operation Ignace-Armstrong).

14 = Average composition of Canadian Shield of Archean age, Fahrig and Eade (1968, p.1249).

Table 4-6: Mean Bulk Chemical Composition of Pelitic metasediments from English River Subprovince in comparison to various Lithic groups selected from the Literature.

	1		2		3		4	5
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S		
SiO_2	57.42	3.76	61.54	4.68	60.26	4.03	53.26	56.30
Al_2O_3	19.88	2.11	16.95	4.21	20.64	2.57	20.64	17.24
FeO	6.46	1.30	3.90	2.25	5.49	1.39	7.13	5.09
Fe_2O_3	1.59	0.48	2.56	1.97	1.41	0.90	1.26	3.83
MgO	3.94	1.17	2.52	1.91	1.93	0.34	4.81	2.54
CaO	1.40	0.96	1.76	2.03	0.52	0.29	1.24	1.00
Na_2O	1.96	0.82	1.84	1.18	1.38	0.58	2.20	1.23
K_2O	3.57	0.91	3.45	1.32	3.72	0.51	3.53	3.79
TiO_2	0.78	0.17	0.82	0.61	1.05	0.14	0.93	0.77
P_2O_5	0.12	0.06	ND		ND		0.16	ND
S	0.10	0.11	ND		ND		ND	ND
MnO	0.09	0.02	ND		ND		0.09	ND
CO_2	0.28	0.40	1.67	2.37	0.03	0.02	0.10	0.84
H_2O+	1.38	0.68	3.47	2.25	2.80	0.75	4.62	3.31
H_2O-	0.51	0.16	ND		ND		0.11	ND
SO_3	ND		ND		ND		ND	0.28
FeS_2	ND		ND		ND		ND	1.98
C	ND		ND		ND		ND	1.18
Total	99.48		100.48		99.23		99.98	100.00

ND = Not Determined

1 = Average metapelite from English River Subprovince (51 analyses in this study).
2 = Average of 155 metapelitic rocks, Shaw (1954, p.928).
3 = Average medium to high grade metapelitic rock, Littleton Formation, New Hampshire, Shaw (1954, p.929).
4 = Average of 3 mudstones, Burwash Formation of Yellowknife Supergroup, Slave Province, N.W.T. Henderson (1972, p.890).
5 = Average of 33 Precambrian lutites, Nanz (1953, p.57).

Table 4- 7 Chemical Analyses and Selected Element Ratios of Leucosome From Metasedimentary Migmatites of the English River Subprovince.

	7-14-17	20-6-26	21-12-11C	21-24-8	21-27-13B	22-14-22A	22-14-33	22-17-4A	31-8-10	35-16-4	36-7-1	36-16-7	37-10-19	38-5-51
SiO_2	66.6	72.3	73.8	75.0	73.1	75.2	73.8	74.0	71.5	66.8	67.8	70.8	73.1	70.9
Al_2O_3	18.6	15.8	15.7	14.1	16.2	14.1	14.3	15.4	16.5	17.8	15.6	17.1	14.2	16.2
Fe_2O_3	0.57	0.26	0.00	0.55	0.36	0.38	0.78	0.44	0.03	0.15	1.15	0.0	0.15	0.07
FeO	1.02	0.48	0.72	0.80	0.58	0.58	1.09	0.87	0.72	1.38	3.67	1.22	0.78	1.30
MgO	0.84	0.23	0.28	0.55	0.75	0.30	0.45	0.48	0.25	0.78	2.21	0.55	0.49	0.52
CaO	3.67	0.99	1.44	0.82	1.38	0.67	0.72	1.27	0.95	1.71	1.70	2.83	1.15	1.45
Na_2O	5.49	3.31	2.70	3.50	3.5	3.42	3.40	3.61	2.82	4.02	3.15	5.67	3.17	4.01
K_2O	1.50	4.82	4.13	5.30	5.47	5.32	5.34	4.86	6.27	5.73	3.68	1.37	5.24	4.93
TiO_2	0.30	0.08	0.10	0.15	0.07	0.09	0.20	0.03	0.09	0.18	0.53	0.18	0.15	0.13
P_2O_5	0.03	0.11	0.12	0.17	0.14	0.13	0.12	0.07	0.10	0.10	0.10	0.01	0.08	0.10
S	0.03	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.02	<0.01	0.01	<0.01	0.01	0.01
MnO	0.01	0.02	0.01	0.03	0.02	0.02	0.03	0.04	0.02	0.01	0.05	0.04	0.01	0.02
CO_2	0.30	0.47	0.34	0.13	0.10	0.14	0.12	0.13	0.42	0.06	0.08	0.06	0.06	0.06
H_2O+	0.57	0.29	0.21	0.47	0.23	0.15	0.15	0.06	0.02	0.25	1.09	0.35	0.05	0.20
H_2O-	0.08	0.4	0.20	0.20	0.22	0.31	0.57	0.16	0.44	0.37	0.26	0.24	0.66	0.38
Total	99.6	99.6	99.8	101.8	101.7	100.8	101.1	101.4	100.2	99.3	101.1	100.4	99.3	100.3
S.G.	2.67	-	-	2.62	2.61	2.62	2.63	2.62	-	2.64	2.72	2.64	2.62	2.64
Normative Corundum	1.36	-	-	1.50	3.05	1.80	1.90	2.03	-	2.14	3.59	1.17	1.43	1.87

(Cont. Table 4-7)

	38-7-17A	38-12-15	38-18-4	39-3-3	39-4-13A	39-8-2	40-3-3	FF1-7	FG8-7	41-2-21	43-4-1
SiO_2	72.2	67.6	75.3	70.7	74.0	67.5	72.5	68.8	70.9	57.8	64.3
Al_2O_3	15.3	17.4	13.8	16.5	14.7	16.4	14.7	14.9	15.1	22.7	18.1
Fe_2O_3	0.0	0.27	0.0	0.0	0.0	1.20	0.0	1.26	0.16	0.53	0.52
FeO	1.46	2.11	0.98	0.57	0.65	2.80	0.98	2.11	1.22	2.09	1.37
MgO	0.35	1.22	0.25	0.24	0.23	1.32	0.49	1.70	0.81	1.50	0.97
CaO	1.06	2.12	0.93	1.81	1.04	1.55	1.16	1.90	1.51	4.17	1.06
Na_2O	3.55	4.27	3.25	4.89	3.13	2.99	3.26	2.97	3.56	6.60	3.36
K_2O	5.19	3.94	4.92	4.14	5.30	4.94	5.42	4.72	4.42	2.49	8.24
TiO_2	0.02	0.34	0.08	0.10	0.03	0.49	0.13	0.10	0.27	0.60	0.25
P_2O_5	0.11	0.08	0.04	0.06	0.07	0.13	0.05	0.09	0.08	0.11	0.11
S	<0.01	0.02	<0.01	<0.01	<0.01	0.00	<0.01	0.03	0.01	0.01	0.01
MnO	0.04	0.02	0.03	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01
CO_2	0.06	0.06	0.10	0.33	0.06	0.08	0.07	0.15	0.10	0.23	0.13
H_2O+	0.31	0.43	0.28	0.16	0.15	0.82	0.38	0.61	0.30	0.53	0.14
H_2O-	0.30	0.38	0.18	0.45	0.37	0.27	0.35	0.49	0.44	0.32	0.34
Total	100.0	100.3	100.1	100.0	99.7	100.5	99.5	99.8	98.9	99.68	98.90
S.G.	2.63	2.66	2.62	2.63	2.61	2.67	2.62	2.68	2.83		
Normative Corundum	2.19	2.46	1.54	0.83	2.10	3.65	1.50	1.69	1.94		

TABLE 4-7

TRACE ELEMENTS (PPM)

Sample #	7-14-17	20-6-26	21-12-11c	21-24-8	21-27-13b	22-14-20a	22-14-33
Ag	<1	ND	<1	<1	<1	<1	<1
Ba	140	590	1700	320	630	200	360
Be	<1	<1	<1	2	3	6	2
Co	5	<5	<5	<5	<5	5	<5
Cr	20	5	27	10	15	<5	8
Cs	<5	6	5	ND	ND	ND	ND
Cu	20	<5	<5	10	6	<5	<5
Ga	15	ND	ND	9	9	10	15
Li	10	20	7	40	10	30	45
Mo	<1	ND	ND	<1	<1	<1	<1
Ni	10	<5	9	<5	5	<5	<5
Pb	20	70	36	40	60	50	40
Rb	30	130	70	180	90	180	230
Sc	<5	ND	ND	<5	<5	<5	<5
Sn	<1	<3	<3	<1	<1	<1	<1
Sr	400	210	340	100	300	50	100
Th	ND	20	<10	ND	ND	ND	ND
U	0.4	28	<1	4.1	2.4	5.3	5.1
V	20	ND	20	15	15	15	20
Y	<10	15	ND	<10	<10	<10	<10
Zn	40	21	16	45	20	30	60
Zr	<10	200	30	15	15	25	60

4-7

Sample #	22-17-4a	31-8-10	35-16-4	36-7-1	36-16-7	37-10-19	38-5-51
	<1	ND	ND	<1	ND	ND	ND
Ba	80	960	1680	400	330	610	1000
Be	<1	<1	ND	2	ND	ND	ND
Co	8	<5	6	15	7	5	7
Cr	<5	9	35	125	<5	5	25
Cs	ND	7	3	5	3	<1	5
Cu	5	<5	10	20	6	7	6
Ga	7	ND	ND	35	ND	ND	ND
Li	9	20	15	15	25	15	10
Mo	<1	ND	ND	4	ND	ND	ND
Ni	<5	<5	10	40	<5	7	7
Pb	25	47	65	20	25	60	40
Rb	60	170	90	60	30	100	110
Sc	<5	ND	ND	15	ND	ND	ND
Sn	<1	<3	ND	<3	ND	ND	ND
Sr	400	240	ND	400	ND	630	ND
Th	ND	10	ND	ND	ND	ND	ND
U	0.4	3	2.3	3.6	0.2	2.7	2.5
V	15	300	ND	100	ND	ND	ND
Y	<10	ND	ND	20	ND	ND	ND
Zn	15	186	30	85	30	30	20
Zr	<10	250	ND	250	ND	ND	ND

4-7

Sample #	38-7-17a	38-12-15	38-18-4	39-3-3	39-4-13a	39-8-2	40-3-3
Ag	ND	ND	ND	ND	ND	<1	ND
Ba	1200	190	320	1260	1520	800	1800
Be	ND	ND	ND	ND	ND	<1	ND
Co	<5	10	5	5	5	10	5
Cr	10	75	8	10	8	95	10
Cs	4	5	8	2	5	<5	4
Cu	<5	20	7	6	6	25	<5
Ga	ND	ND	ND	ND	ND	35	ND
Li	10	10	10	15	7	5	6
Mo	ND	ND	ND	ND	ND	1	ND
Ni	<5	25	5	<5	<5	35	6
Pb	50	45	60	30	45	30	45
Rb	80	40	50	70	120	70	80
Sc	ND	ND	ND	ND	ND	10	ND
Sn	ND	ND	ND	ND	ND	<3	ND
Sr	ND	ND	ND	ND	ND	600	ND
Th	ND	ND	ND	ND	ND	ND	ND
U	1.6	2.9	1.9	0.3	1.3	1.6	1.3
V	ND	ND	ND	ND	ND	100	ND
Y	ND	ND	ND	ND	ND	10	ND
Zn	10	40	10	15	15	55	70
Zr	ND	ND	ND	ND	ND	150	ND

4-7

Sample #	FF1-7	FG8-7	41-2-21	43-4-1			
	<1	ND					
	1090	780					
	<1	ND					
	10	9					
	85	25					
	ND	3					
	15	8					
	15	ND					
	10	15					
	<1	ND					
	25	9					
	35	50					
	80	100					
	<5	ND					
	<1	ND					
	400	ND					
	50	ND					
	2.0	1.0					
	70	ND					
	<10	ND					
	55	35					
	150	ND					

4-1

SELECTED ELEMENT RATIOS

Sample #	7-14-17	20-6-26	21-12-11c	21-24-8	21-27-13	22-14-20	22-14-33
K/Rb	416	308	490	244	504	245	192
K/Ba	89	68	20	137	72	221	123
K/Cs	<2490	6668	6856				
Na/K	2.63	0.5	0.47	0.48	0.40	0.46	0.46
Ba/Rb	4.7	4.5	24.3	1.8	7.0	1.1	1.6
Mg/Li	504	69	240	330	150	90	60
K/U	31,125	1429	34,280	10,730	18,920	8330	8690
A/CNK (mol)	1.075	1.270	1.363	1.087	1.206	1.120	1.129

~~SELECTED ELEMENT RATIOS~~

Sample #	22-17-4	31-8-10	35-16-4	36-7-1	36-16-7	37-10-19	38-5-51
K/Rb	672	306	528	509	379	435	372
K/Ba	504	54	28	76	127	71	41
K/Cs		7437	15,855	<6110	3790	>43490	8184
Na/K	0.54	0.33	0.51	0.82	2.98	0.44	0.59
Ba/Rb	1.3	5.6	18.7	6.7	11.0	6.1	9.1
Mg/Li	320	75	312	884	205	196	312
K/U	10,085	17,345	20,680		56,855	16,110	16368
A/CNK (mol)	1.140	1.256	1.119	1.274	1.073	1.096	1.113

4-7

38-7-17a	38-12-15	38-18-4	39-3-3	39-4-13a	39-8-2	40-3-3	FF1-7
538	818	817	491	367	586	562	489
22	166	75	29	15	27	13	20
6570	6320	3005	18,095	4630	>4425	6030	
0.49	0.78	0.48	0.85	0.43	0.58	0.44	0.45
15.0	4.8	6.4	18.0	12.7	11.4	22.5	13.6
210	732	150	96	197	1584	490	1020
16,420	10,895	12,660	$12X10^2$	17,820	13,830	18,560	10990
1.158	1.151	1.118	1.079	1.152	1.103	1.103	1.109

FG8-7	41-2-21	43-4-1					
367							
34							
12,230							
0.58	1.9	0.30					
7.8							
488							
1.295	1.075	1.107					

4·7

CIPW NORMATIVE MINERALS

~~MODES NO~~

Sample #	7-14-17	21-24-8	21-27-13b	22-14-20a	22-14-33	22-17-4a	35-16-4
Quartz	19.9	31.6	30.1	33.1	31.1	30.3	16.2
Orth.	9.0	31.1	32.0	31.4	31.5	28.4	34.6
Albite	47.1	29.3	25.5	28.9	28.7	30.2	34.5
Anor	18.3	2.9	5.9	2.5	2.8	5.8	7.9
Cor	1.4	1.5	3.1	1.8	1.9	2.0	2.1
En	2.1	1.4	1.9	0.8	1.1	1.2	2.0
Fs	0.8	0.8	0.7	0.6	1.1	1.3	2.1
Ap	0.1	0.4	0.3	0.3	0.3	0.3	0.2
Po	0.08						0.03
Ilm	0.6	0.3	0.1	0.2	0.4	0.1	0.4
Mt	0.8	0.8	0.5	0.6	1.1	0.6	0.2

36-7-1	36-16-7	37-10-19	38-5-51	38-7-17a	38-12-15	38-18-4	39-3-3
26.6	24.9	31.6	24.2	28.2	20.3	34.7	22.2
21.9	8.1	31.5	29.3	30.9	23.5	29.2	24.7
26.8	48.1	27.2	34.1	30.5	36.4	27.6	41.8
7.8	14.1	5.3	6.6	4.6	10.1	4.4	8.7
3.6	1.2	1.4	1.9	2.2	2.5	1.5	0.9
5.5	1.4	1.2	1.3	0.9	3.1	0.6	0.6
5.0	2.0	1.1	2.1	2.7	3.1	1.7	0.9
0.2	0.02	0.2	0.2	0.3	0.2	0.1	0.4
0.03	0.03	0.03	0.03	0.03	0.06	0.03	0.03
1.0	0.3	0.3	0.3	0.05	0.7	0.2	0.2
1.7		0.2	0.1		0.4		

4·7

39-4-13a	39-8-2	40-3-3	FF1-7	FG8-7			
32.9	24.9	29.4	26.3	28.9			
31.6	29.4	32.5	28.3	26.7			
26.7	25.5	27.9	25.5	30.7			
4.7	6.9	5.5	9.0	7.1			
2.1	3.7	1.5	1.7	1.9			
0.6	3.3	1.2	4.3	2.1			
1.1	3.4	1.6	2.6	1.7			
0.2	0.3	0.1	0.2	0.2			
0.03		0.03	0.1	0.03			
0.1	0.9	0.3	0.2	0.5			
	1.8		1.9	0.2			

4-7

39-4-13a	39-8-2	40-3-3	FF1-7	FG8-7			
32.9	24.9	29.4	26.3	28.9			
31.6	29.4	32.5	28.3	26.7			
26.7	25.5	27.9	25.5	30.7			
4.7	6.9	5.5	9.0	7.1			
2.1	3.7	1.5	1.7	1.9			
0.6	3.3	1.2	4.3	2.1			
1.1	3.4	1.6	2.6	1.7			
0.2	0.3	0.1	0.2	0.2			
0.03		0.03	0.1	0.03			
0.1	0.9	0.3	0.2	0.5			
	1.8		1.9	0.2			

Table 4-8: Chemical Analyses and Selected Element Ratios of Mafic Diatexites from English River Subprovince.

	36-7-7A	36-14-54	38-7-36	39-6-3	39-3-21	FF1-14	4-23-4
SiO_2	63.1	64.2	60.9	61.7	64.1	65.5	66.6
Al_2O_3	17.2	17.7	16.0	17.3	16.6	15.6	15.4
Fe_2O_3	2.01	1.27	1.06	1.36	0.96	2.04	0.96
FeO	5.71	3.01	4.39	5.28	4.96	4.29	3.35
MgO	2.38	2.02	4.42	3.12	2.73	2.80	2.09
CaO	1.54	3.25	4.52	2.24	2.17	2.20	1.59
Na_2O	2.73	3.94	3.46	3.99	3.78	3.13	2.71
K_2O	4.02	2.64	2.80	3.09	2.85	3.40	3.58
TiO_2	0.47	0.60	0.75	0.79	0.79	0.60	0.49
P_2O_5	0.12	0.27	0.32	0.05	0.04	0.07	0.12
S	0.02	0.03	0.01	0.03	0.02	0.04	0.01
MnO	0.16	0.03	0.08	0.09	0.08	0.03	0.06
CO_2	0.06	0.06	0.06	0.07	0.06	0.13	0.06
H_2O+	1.02	0.77	0.82	0.88	0.66	0.88	1.23
H_2O-	0.27	0.30	0.18	0.22	0.29	0.46	0.68
Total	100.1	100.1	99.8	100.2	100.1	101.2	98.9
S.G.	2.76	2.70	2.77	2.76	2.73	2.73	2.69

(Cont. Table 4-8)

	36-7-7A	36-14-54	38-7-36	39-6-3	39-3-21	FF1-14	4-23-4
Ag	<1	<1				<1	
Ba	530	420	1200	410	280	580	880
Be	<1	2				<1	
Co	15	15	20	20	15	20	15
Cr	115	125	175	205	195	200	105
Cs	<5	<5	10	2	7	<5	6
Cu	20	15	25	30	25	50	30
Ga	40	45				10	
Li	10	5	15	10	8	15	45
Mo	6	10				<1	
Ni	25	25	55	40	45	60	40
Pb	30	10	30	30	25	30	45
Rb	60	50	50	70	40	60	90
Sc	35	8				20	
Sn	<3	<3				<1	
Sr	300	500				300	310
Th	30	20				20	20
U	4.1	1.5	0.8	1.9	1.6	1.3	5.5
V	90	150				100	
Y	45	10				30	
Zn	75	75	80	90	60	80	70
Zr	300	250				150	

(Cont. Table 4-8)

CIPW Normative Minerals

	36-7-7A	36-14-54	38-7-36	39-6-3	39-3-21	FF1-14	4-23-4
Quartz	21.67	20.62	12.18	14.15	19.55	23.33	29.74
Orthoclase	23.91	15.78	16.78	18.46	17.02	20.18	21.84
Albite	23.23	33.69	29.66	34.09	32.28	26.57	23.65
Anorthite	6.89	14.51	20.11	10.89	10.6	10.50	7.33
Corundum	5.87	3.13	0.0	3.47	3.48	2.95	4.6
Diopside	0.0		0.27		0.27	0.0	0.0
Hedenbergite			0.13				
Enstatite	5.96	5.08	11.03	7.85	6.86	7.00	5.37
Ferrosilite	8.31	3.46	6.07	7.38	7.14	5.11	4.77
Forsterite	0.0						0.0
Fayalite	0.0						0.0
Apatite		0.63	0.75	0.12	0.09	0.16	0.29
Pyrrhotite			0.03	0.08	0.06		0.0
Ilmenite			1.44	1.52	1.51		0.0
Magnetite	2.93	1.86	1.56	1.99	1.41	2.98	1.44

(Cont. Table 4-8)

	36-7-7A	36-14-54	38-7-36	39-6-3	39-3-21	FF1-14	4-23-4
K/Rb	498	438	465	366	591	470	330
K/Ba	63	52	19	63	85	49	34
K/Cs	6673	>4382	2324	12823	3379	>5644	4952
K/U	8138	14608	29050	13498	14784	21708	5403
Na/K	0.64	1.42	0.90	1.15	1.18	0.67	0.72
Ba/Rb	8.8	8.4	24.0	5.9	7.0	9.7	9.8
Mg/Li	1428	2424	1768	1872	2048	1120	279
Th/U	7.31	13.33	-	-	-	15.39	3.64
K/Th	1112	1096	-	-	-	1411	1486
A/CNK$_{mol}$	1.479	1.496	1.662	1.371	1.300	1.217	1.379
K	33,366	21,912	23,240	25,647	23,655	28,220	29714
Rb	00	50	50	70	40	60	90
Li	10	5	15	10	8	15	45
Mg	14,280	12,120	26,520	18,720	16,380	16,800	12,540
Ca	10,934	23,075	32,092	15,904	15,407	15,620	11,289
Na	20,202	29,156	25,604	29,526	27,972	23,162	20,054

A/CNK$_{mol}$

Table 4-9 Modal Composition of Residual Fraction Resulting from Experimental Partial Melting of Harz Mountain Greywackes, 770'C, pH_2O=2000 bars

Sample #	Quartz	Plagioclase	Cordierite	Biotite	Sillimanite	Opaques	Amount of Melt	Ab/An of protolith
IV125	11.1	-	40.7	14.8	18.5	14.8	73%	5.8
IV/29	71.9	-	12.5	-	6.3	9.4	68%	5.7
IV/16	81.1	-	13.5	-	-	5.4	63%	2.0
1d	24.2	33.3	18.2	15.2	-	12.2	67%	1.5

Modes in weight percent recalculated to 100 percent

Table 4-10 Chemical analyses of melanosome component from metasedimentary migmatite of the Northern Supracrustal Domain

	21-12-11	21-16-7	25-6-1	B6-11
SiO_2	45.5	74.0	69.9	72.5
Al_2O_3	22.8	15.6	17.2	16.4
Fe_2O_3	1.40	3.66	1.10	1.29
FeO	9.90	0.36	3.46	3.49
MgO	5.09	3.88	2.15	3.28
CaO	1.37	0.06	0.16	0.04
Na_2O	2.36	0.19	0.00	0.25
K_2O	5.42	0.25	1.11	0.94
TiO_2	1.33	0.03	0.03	0.02
P_2O_5	0.04	0.00	0.00	0.02
S	0.10	0.01	0.02	<.01
MnO	0.11	0.06	0.11	0.04
CO_2	1.38	0.12	1.26	0.13
H_2O+	1.90	0.81	2.17	1.34
H_2O-	0.73	0.30	1.06	0.26
Total	99.4	99.30	99.4	100.0
A/CNK_{molar}	1.866	26.0	11.58	28.3

	21-12-11	21-16-7	25-6-1	B6-11
Ag	ND	<1	ND	<1
Ba	520	30	70	60
Be	3	35	15	20
Co	36	5	5	10
Cr	352	<5	<5	8
Cs	19	ND	2	ND
Cu	2	<5	5	7
Ga	ND	15	ND	25
Li	51	270	310	180
Mo	ND	<1	ND	<1
Ni	105	<5	<5	<5
Pb	14	<10	13	<10
Rb	190	<10	60	20
Sc	ND	<5	ND	<5
Sn	<3	<1	<3	<1
Sr	160	50	90	10
Th	<10	ND	<10	ND
U	3	ND	11	ND
V	300	<5	<10	<5
Zr	250	<10	80	20
Zn	186	80	106	65

Modes

	21-12-11
Quartz	1.2
K-feldspar	1.0
Plagioclase	35.0
Biotite	51.9
Hornblende	0.5
Almandine	
Cordierite	
Sillimanite	5.9
Muscovite	1.2
Andalusite	
Chlorite	1.4
Apatite	
Epidote	0.5
Fe-oxides	0.8
Tourmaline	0.2
Zircon	0.2
Total	99.8
Colour Index	54.8

21-12-11: Biotite-rich melanosome selvedge from metatexite, Ontario Hydro damsite, Ear Falls.

21-16-7: Quartz-cordierite-biotite-muscovite restite from clotty quartz monzonite, Wapesi Lake area.

25-6-1: Quartz-cordierite-biotite-sillimanite-almandine restite from clotty quartz monzonite, Perrault Falls.

B6-11: Quartz-cordierite-biotite-muscovite restite from clotty quartz monzonite, Greenbush Lake area.

Table 4-11 Modal analyses of metawackes from English River Subprovince.

	19-9-1	19-10-2	19-10-6	19-10-11	19-10-28	19-10-33	19-10-44	19-11-2	19-11-4	19-16-1	19-16-13
Quartz	31.1	33.3	34.3	32.7	37.0	37.3	33.0	32.0	35.0	34.7	31.
K-feldspar											
Plagioclase	41.5	40.3	36.5	42.2	33.0	36.1	38.9	43.4	41.0	44.5	41.3
Biotite	25.8	24.2	29.2	22.7	25.5	15.7	22.2	22.8	21.5	20.0	24.1
Orthopyroxene											
Garnet	10			2.3				0.2			
Cordierite											
Chlorite											
Sillimanite											
Muscovite					4.5	10.4	5.2	1.7	2.5	0.3	2.2
Epidote											
Apatite	0.6	x		x		0.2	0.5			0.5	
Fe-Oxide	x	1.2			x	0.2	0.2	x	x	x	0.5
Sericite[1]											
Zircon					x			x	x	x	x
Tourmaline											
Total	100.0		100.0	99.9	100.0	99.9	100.0	100.1	100.0	100.0	99.0
Colour Index	26.8		29.2	25.0	25.5	15.9	22.4	23.0	21.5	20.0	24.6

x = present in trace amounts
1 = Retrograde phase, usually after plagioclase

(Cont. Table 4-II)

	19-16-14	19-18-2	19-20-6A	19-20-7B	20-5-1	20-5-9A	20-7-4	20-16-3B	20-18-5	20-18-11A	20-20-3	20-20-3A	20-20-7	21-21-3
Quartz	27.4	26.9	36.8	31.0	30.	37.3	15.1	27.0	29.3	25.6	31.2	33.2	37.4	35.5
K-feldspar							0.8							0.8
Plagioclase	32.4	48.1	38.2	43.7	45.2	32.7	55.0	45.7	45.8	43.5	43.5	43.5	41.3	41.7
Biotite	40.2	21.4	22.2	25.3	23.5	25.5	26.8	25.5	24.4	29.4	24.7	22.2	18.8	21.0
Orthopyroxene														
Garnet							2.0	1.8			0.3			1.0
Cordierite							0.2							
Chlorite														
Sillimanite							x							
Muscovite		2.5	2.8			4.5				1.0			1.5	
Epidote														
Apatite		0.8	x	x								x		
Fe-Oxide		0.3	x		1.2	x	0.2	x	0.5	0.5	0.3	1.0	1.0	x
Sericite[1]														
Zircon				x		x		x		x	x	x	x	x
Tourmaline														
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.0	100.0	99.9	100.0	100.0
Colour Index	40.2	21.7	22.2	25.3	24.7	25.5	29.4	27.3	24.9	29.9	25.3	23.2	19.8	22.0

(Cont. Table 4-11)

	21-12-11A	21-21-4A	21-21-7	22-18-2A	22-21-5A	23-20-2A	32-5-7A	32-8-9A	34-4-7A	34-10-9A	34-10-9B	34-10-17A	34-10-19A
Quartz	38.9	39.1	27.7	28.0	33.8	30.8	15.9	28.2	26.8	33.4	38.8	26.8	27.2
K-feldspar			5.9								10.6		
Plagioclase	39.9	42.0	37.5	48.0	40.8	41.1	53.3	42.0	44.8	46.6	32.8	46.2	43.8
Biotite	18.4	17.9	19.4	20.0	21.0	22.7	28.6	29.4	24.2	20.0	13.0	27.0	29.1
Orthopyroxene													
Garnet		0.6	8.3	3.7	4.4	4.4	0.3		1.6				
Cordierite		0.4	1.2						2.4				
Chlorite								0.2		x			x
Sillimanite													
Muscovite										x	4.4		x
Epidote													
Apatite	0.3						x					x	
Fe-Oxide	2.5	x	x	0.3	x	1.0	1.9		0.2		0.4		
Sericite[1]								0.2					
Zircon					x								
Tourmaline							x					x	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.1
Colour Index	20.9	18.9	28.9	24.0	25.4	28.1	30.8	29.6	28.4	20.0	13.4	27.0	29.1

(Cont. Table 4-II)

	38-8-2A	35-8-4A	35-8-4B	35-8-6A	35-8-7A	35-8-7D	35-9-1	35-9-6	35-10-11A	35-10-11B	35-15-5B	35-15-15	36-4-6
Quartz	43.4	30.4	33.2	37.6	36.2	31.8	34.6	38.2	28.7	33.0	21.4	26.2	28.8
K-feldspar													
Plagioclase	33.2	45.0	32.8	39.8	40.4	32.8	41.6	37.2	42.9	41.0	44.0	40.4	45.6
Biotite	21.0	24.2	26.0	21.8	23.0	29.6	22.2	17.7	20.9	22.4	27.6	32.6	24.6
Orthopyroxene							0.4						
Garnet	1.6			0.6	0.4	0.2	0.2			x			0.8
Cordierite								0.6		2.8			
Chlorite						0.2		0.6					
Sillimanite	0.8		x			4.4					x		
Muscovite		0.2	8.0			1.0	0.8	5.6	7.6				
Epidote													
Apatite									x	0.2	7.0		
Fe-Oxide	x			0.1		x	x	0.2		0.6		0.8	0.2
Sericite[1]													
Zircon		x											
Tourmaline						x	x						
											x		
Total	100.0	99.8	100.0	99.9	100.0	100.0	99.8	100.1	100.1	100.0	100.0	100.0	100.0
Colour Index	22.6	24.2	26.0	22.5	23.7	30.0	22.8	19.1	20.9	25.8	34.6	33.4	25.6

(Cont. Table 4-11)

	36-10-7A	36-11-2	36-13-8	36-14-3	36-14-5	36-14-13	36-14-15	36-14-22	36-14-23	36-14-26	36-14-29B
Quartz	33.8	28.6	26.2	34.6	39.2	38.6	37.2	35.8	33.2	33.8	32.0
K-feldspar											
Plagioclase	42.0	52.0	44.7	37.0	40.4	38.4	40.2	48.8	55.6	40.8	44.8
Biotite	23.8	17.6	29.0	25.2	17.4	20.6	19.0	12.8	10.0	23.0	19.0
Orthopyroxene											
Garnet	0.4	0.6			2.8	2.4	3.2	2.6	1.2	2.4	3.8
Cordierite											
Chlorite											
Sillimanite		1.2									
Muscovite											
Epidote											
Apatite											
Fe-Oxide	x			0.6	0.2		0.4				
Sericite				3.2							0.4
Zircon											
Tourmaline											
Total	100.0	100.0	99.9	100.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Colour Index	24.2	18.2	29.0	25.8	20.4	23.0	22.6	15.4	11.2	25.4	23.2

(Cont. Table 4-11)

	36-14-33	36-14-34A	37-4-6	37-4-7	37-6-2	37-6-4	37-6-5	37-10-27	38-9-1	39-6-18B	39-8-7A	P1-6-2A	P1-6-2D
Quartz	37.4	33.8	29.4	45.4	25.2	31.4	21.2	37.2	43.2	40.0	33.4	37.8	28.2
K-feldspar					3.8	4.0							
Plagioclase	40.8	46.8	49.4	33.6	37.2	36.4	45.2	42.2	44.0	43.8	45.8	34.6	50.8
Biotite	19.0	14.8	21.0	19.2	28.6	20.0	33.6	18.2	11.8	10.4	15.8	19.6	17.2
Orthopyroxene													
Garnet	2.8	4.6		1.0	0.2	0.2		0.2	0.8	2.6	5.0		3.6
Cordierite					0.8								
Chlorite					0.6	1.0				2.8		1.0	
Sillimanite								1.4					
Muscovite				0.4	2.2	3.2		0.2				0.8	
Epidote													
Apatite													
Fe-Oxide		x	0.2	0.4	1.0	0.8		0.6	0.2	0.4	x	1.0	
Sericite[1]					0.4	3.0							
Zircon													
Tourmaline													
Others												5.0 (Calcite)	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8
Colour Index	21.8	19.4	21.2	20.6	31.2	22.0	33.6	19.2	12.6	16.2	20.8	21.6	20.8

(Cont. Table 4-11)

	P1-6-8	P1-6-9A	P1-6-11A	P1-6-13A	P3-12-9	P3-12-70	P6-1-15	P8-11-4
Quartz	36.4	35.6	38.8	33.3	33.8	27.6	29.0	39.2
K-feldspar								
Plagioclase	36.8	37.2	41.8	44.6	35.6	48.4	23.9	43.8
Biotite	24.0	27.2	19.4	21.7	26.8	23.6	4.4	13.2
Orthopyroxene							24.6	
Garnet	2.5			x	3.8			3.6
Cordierite								
Chlorite	x		x	0.4				
Sillimanite								
Muscovite				x			1.4	
Epidote							15.3	
Apatite			x		0.2			
Fe-Oxide	0.4						0.8	0.2
Sericite[1]								
Zircon								
Tourmaline	x							
Others						0.4 (Kyanite?)	0.6 (diopside)	
Total	100.1	100.0	100.0	100.0	100.2	100.0	100.0	100.0
Colour Index	26.9	27.2	19.4	22.1	30.6	23.6	30.4	17.0

Table 4-12 Modal analyses of metapelites from English River Subprovince.

	20-7-4	20-8-2A	20-8-4	20-16-21	21-12-11B	21-13-13A	21-19-19	21-19-23A	23-18-1	27X-5-58	31-5-3	31-10-15A	31-10-15B
Quartz	15.1	22.8	19.2	7.4	23.9	17.2	13.6	12.3	14.6	22.0	28.9	2.0	23.8
K-feldspar	0.8	2.0	7.0	x	3.1	11.2		11.1	13.7	20.5	3.2	0.3	
Plagioclase	55.0	35.4	19.8	34.4	26.5	20.0	30.6	27.5	24.6	23.3	31.4	56.3	24.0
Biotite	26.8	20.2	18.0	43.9	39.8	22.2	44.2	19.5	31.9	18.2	29.4	27.5	22.8
Hornblende												4.5	
Garnet	2.0	3.0	4.6	3.0		6.0	0.6	8.8	4.4	5.4		3.5	
Cordierite	0.2	13.8	24.6	3.4	1.4	13.0	5.4	14.0	10.7	8.9	2.1		
Chlorite													8.6
Sillimanite	x	2.8	6.6	0.8	1.9	10.4	5.2	6.8			2.6		
Andalusite					1.7								0.4
Muscovite		x		7.0						0.3	0.6		15.8
Epidote													
Apatite											0.1	5.8	0.2
Fe-oxide	0.2	x	x		1.7		0.4	x	x	1.3	1.8		3.8
Sericite[1]			0.2										
Zircon													
Tourmaline													0.4
Total	100.1	100.0	100.0	99.9	100.0	100.0	100.0	100.0	99.9	99.9	100.1	99.9	99.8
Colour Index	29.2	37.0	47.2	50.3	42.9	41.2	50.6	42.3	47.0	33.8	33.3	41.3	35.6

1. Retrograde phase usually after plagioclase

x. Present in trace amounts

(Cont. Table 4-12)

	32-5-3B	32-5-7B1	32-5-7C	34-10-3A	35-8-3	35-13-2	35-17-8	35-18-6	36-4-3B	36-4-7B
Quartz	11.9	24.5	21.5	14.2	2.2	-	20.2	14.8	12.6	23.6
K-feldspar		0.2	0.2				1.0	6.0		
Plagioclase	22.2	16.5	21.8	47.2	57.8	42.2	28.6	35.0	35.4	34.8
Biotite	39.0	39.5	29.7	37.6	39.4	40.4	32.8	30.5	29.0	37.2
Garnet										
Cordierite						1.6	2.0		3.0	
Chlorite			2.6	x		9.8	13.6	14.0	19.6	4.4
Sillimanite					0.4	0.4				
Andalusite	18.8	10.5	4.9			5.0	x		0.2	x
Muscovite	7.7	6.5	16.0							
Epidote										
Apatite			0.5		0.2					
Fe-Oxide	0.4	1.8	2.1	1.0	x	0.4	0.2	x	0.2	x
Sericite							1.2		x	
Zircon					x					
Tourmaline		0.6	0.7							
Total	100.0	100.1	100.0	100.0	100.0	100.0	99.6	99.8	100.0	100.0
Colour Index	39.4	41.9	35.1	38.6	39.4	52.6	48.6	44.0	52.0	41.6

1. Average of two modal analyses of different sections

(Cont. Table 4-12)

	36-7-2	36-7-6A	36-7-10B	36-10-2A	36-10-7B	36-14-18A	36-14-20B	36-14-29A	36-14-30B	36-14-34B	37-2-2	37-2-68
Quartz	24.2	2.6	21.2	11.8	18.8	15.8	x	16.2	19.4	23.4	15.8	2.0
K-feldspar	0.6	13.0		2.6	1.6	31.4	5.4	5.8			15.2	16.4
Plagioclase	23.8	32.8	33.2	21.2	31.4	19.4	45.8	42.6	16.1	27.2	20.0	20.2
Biotite	29.4	33.2	32.2	37.0	36.8	20.2	19.6	19.4	42.5	20.6	29.6	35.8
Hornblende												
Garnet	0.2	7.2	x	0.2	x	6.4	1.6	0.2		3.8	0.2	5.0
Cordierite	19.0	9.4	10.2	24.6	7.4	6.6	26.4	15.0	7.1	18.6	18.0	18.8
Chlorite												
Sillimanite	1.6	2.2		1.8	3.6	0.4	1.0	0.4	11.8	2.0	1.2	1.4
Andalusite												
Muscovite		x	3.2	0.6					0.4	0.2		0.4
Epidote												
Apatite												
Fe-Oxide	0.8			0.2	0.4	x	0.2	0.2	1.8	1.2	x	x
Sericite	0.4				x	0.2		0.2	0.9	3.8		x
Zircon			x									
Tourmaline												
Total	100.0	100.4	100.0	100.0	100.0	100.4	100.0	100.0	100.0	100.8	100.0	100.0
Colour Index	49.4	49.8	42.4	62.0	44.6	33.4	47.8	34.8	51.4	44.2	47.8	59.6

(Cont. Table 4-12)

	37-13-31	39-8-8	39-8-7B	P2-8-17	P2-9-36	P4-11-8	P4-11-13	P4-11-15	FG14-10	39-6-23
Quartz	6.6	23.0	0.8	0.4	13.1	1.6	14.6	0.6	15.6	27.0
K-feldspar	19.2	5.2	31.0	6.0	15.6	x	0.8			
Plagioclase	12.2	43.2	20.8	53.4	25.5	27.2	35.8	61.6	36.0	24.4
Biotite	20.2	12.6	23.6	19.2	24.8	43.6	32.6	29.2	48.2	11.2
Garnet										37.0
Cordierite	15.2	3.4	8.0	0.2	4.0			1.6	0.2	
Chlorite	26.0	11.4	15.8	11.4	12.3	27.6	16.2	7.0		
Sillimanite				0.2						0.2
Andalusite				9.2	0.6					
Muscovite										
Epidote										
Apatite										
Fe-Oxide	0.6	1.2	0.2		0.4				x	0.2
Sericite		x			3.8					
Zircon										
Tourmaline										
Total	100.0	100.0	100.2	100.0	100.1	100.0	100.0	100.0	100.0	100.0
Colour Index	62.0	28.6	47.6	31.0	41.5	71.2	48.8	37.8	48.4	48.6

Table 4-13 Chemical Analyses and Selected Element Ratios of Metawackes from the English River Subprovince

	FC14-42	FC15-2A	FC15-12	FF4-1	105-1	4-17-37	5-165-38	5-165-5	1028-25E	21-12-11A	4-17-35	21-27-13A	22-14-27
SiO_2	70.0	68.5	70.9	68.6	68.1	57.7	68.5	69.7	67.2	68.9	67.4	67.4	67.4
Al_2O_3	15.3	16.2	14.0	14.0	15.1	18.0	17.2	16.7	15.2	14.8	14.7	15.1	14.5
Fe_2O_3	1.50	1.86	0.89	1.38	1.09	2.00	1.31	1.18	1.39	1.09	0.73	1.63	1.49
FeO	2.53	3.24	3.54	3.78	3.38	4.30	2.47	2.98	3.41	2.98	3.86	4.22	3.86
MgO	1.62	2.28	2.02	2.43	2.71	2.95	1.43	2.19	3.18	1.73	2.23	2.49	3.55
CaO	2.24	2.19	2.50	2.25	1.26	5.15	3.84	1.82	3.06	2.44	3.51	2.40	2.13
Na_2O	3.37	3.72	3.37	2.86	3.59	3.26	3.21	2.89	3.31	2.85	2.51	3.21	2.91
K_2O	1.57	2.19	1.82	1.97	1.14	2.25	1.35	1.66	1.90	1.79	1.92	2.17	2.86
TiO_2	0.45	0.48	0.48	0.56	0.54	1.00	0.50	0.43	0.57	0.48	0.51	0.58	0.54
P_2O_5	<0.05	<0.05	0.11	0.12	0.13	0.53	0.17	0.11	0.15	0.08	0.15	0.07	0.13
S	0.11	0.05	0.26	0.23	0.15	0.24	<0.01	<0.01	0.03	0.28	0.25	0.09	0.01
MnO	0.05	0.06	0.09	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.07	0.08	0.07
CO_2	0.16	0.15	0.33	0.07	0.08	0.19	0.06	0.10	0.08	0.41	0.05	0.11	0.10
H_2O^+	1.02	0.87	0.41	0.28	1.44	0.55	0.19	0.31	0.25	0.31	0.41	0.39	1.08
H_2O^-	0.34	0.26	0.50	0.40	0.42	0.56	0.48	0.53	0.59	0.50	0.38	0.41	0.26
Total	100.3	102.1	101.2	99.00	99.20	98.7	100.8	100.7	100.4	98.7	98.7	100.4	100.9
S.G.	2.69	2.73	2.74	-	-	2.78	2.70	2.70	2.71	-	-	2.74	2.73
Normative Corundum	4.04	3.70	2.21	-	-	2.17	3.88	7.12	2.51	-	-	3.29	3.07
Metamorphic Grade1	H	M	H	G	G	H	H	H	G	H	H	H	H

(Cont. Table 4-13

	31-10-15A	32-9-1A	32-5-7A	34-10-10	35-6-1	35-6-2	35-8-2A	35-8-4A	35-8-7A	35-8-17	35-9-1
SiO_2	60.1	65.7	67.7	66.5	69.2	66.2	69.4	66.1	67.0	60.9	65.9
Al_2O_3	16.0	16.2	16.2	14.6	14.8	14.7	14.2	14.8	15.1	12.0	15.7
Fe_2O_3	4.67	1.26	1.38	1.27	0.84	1.17	0.93	0.99	0.89	1.37	1.35
FeO	6.60	4.03	2.98	4.44	3.17	3.50	3.77	4.33	4.02	6.71	3.57
MgO	1.89	2.22	2.13	2.77	2.03	2.90	2.05	2.47	2.37	7.35	2.85
CaO	3.06	2.28	3.40	1.91	2.37	3.11	2.91	1.88	2.39	3.26	2.32
Na_2O	3.38	2.87	2.58	3.15	3.97	3.49	2.88	3.82	3.73	2.07	3.77
K_2O	2.03	2.22	1.87	2.58	1.75	2.66	1.88	2.50	2.14	3.00	2.16
TiO_2	0.93	0.54	0.48	0.61	0.46	0.50	0.48	0.55	0.54	0.53	0.56
P_2O_5	0.12	0.11	0.01	0.16	0.08	0.12	0.12	0.13	0.13	0.16	0.19
S	0.19	0.09	0.34	0.18	0.05	0.10	0.25	0.09	0.01	<0.01	0.02
MnO	0.17	0.09	0.12	0.08	0.05	0.07	0.11	0.09	0.08	0.07	0.06
CO_2	0.53	0.94	0.37	0.06	0.08	0.10	0.09	0.06	0.06	0.35	0.09
H_2O+	0.60	1.10	0.46	0.49	0.17	0.29	0.33	0.60	0.22	0.82	0.78
H_2O-	0.61	0.48	0.41	0.67	0.62	0.50	0.50	0.74	0.52	0.45	0.38
Total	100.4	100.1	100.5	99.5	99.6	99.4	99.9	99.1	99.2	99.0	99.7
S.G	-	-	-	2.74	2.76	2.74	2.83	2.75	2.82	2.77	2.75
Normative											
Corundum	-	-	-	3.60	2.29	0.72	2.45	2.77	2.65	0.00	3.45
Metamorphic Grade	M	M	M	M	M	M	M	M	M	M	M

(Cont. Table 4-13

	35-9-6	35-10-11	35-11-1	36-14-20A	35-15-15	36-1-4B	36-4-6	36-6-4	36-10-7A	36-11-2	36-13-8
SiO_2	67.9	65.5	69.1	68.5	63.3	66.6	65.2	67.7	67.6	68.5	69.2
Al_2O_3	15.4	15.7	16.2	14.8	15.2	16.0	16.2	15.5	15.2	14.8	15.0
Fe_2O_3	1.05	1.27	0.71	0.97	1.61	3.00	1.42	1.19	1.21	1.03	1.13
FeO	3.57	4.13	2.17	3.15	4.39	1.75	3.99	3.99	4.02	3.25	3.22
MgO	2.14	2.86	1.14	2.00	2.77	2.15	2.74	2.90	2.45	2.00	1.88
CaO	1.09	1.70	3.21	3.04	2.81	1.82	2.30	1.68	2.51	1.61	3.13
Na_2O	3.78	4.22	4.47	3.46	4.05	4.37	3.64	2.62	3.02	4.51	2.74
K_2O	2.46	2.08	1.38	1.64	2.39	2.26	2.44	2.05	2.44	1.75	1.61
TiO_2	0.52	0.58	0.44	0.52	0.53	0.58	0.61	0.55	0.59	0.45	0.54
P_2O_5	0.13	0.15	0.16	0.12	0.17	0.14	0.12	0.09	0.15	0.12	0.15
S	0.02	0.23	0.02	0.05	0.49	0.04	0.04	0.02	0.02	0.02	0.03
MnO	0.05	0.07	0.05	0.05	0.12	0.06	0.07	0.03	0.09	0.07	0.08
CO_2	0.08	0.06	0.28	0.17	0.10	0.08	0.08	0.08	0.06	0.09	0.06
H_2O+	1.07	0.42	0.45	0.08	0.81	0.77	0.88	1.19	0.63	0.72	0.62
H_2O-	0.48	0.42	0.38	0.50	0.70	0.50	0.46	0.36	0.42	0.67	0.38
Total	99.7	99.4	100.2	99.0	99.4	100.1	100.2	100.0	100.4	99.6	99.8
S.G	2.68	2.73	2.70	2.74	2.76	2.71	2.75	2.69	2.73	2.71	2.73
Normative Corundum	4.94	3.84	1.92	2.13	1.28	3.43	3.72	6.24	3.41	2.90	3.46
Metamorphic Grade	M	M	M	H	L	H	H	H	H	H	H

(Cont. Table 4-13

	36-14-2	36-14-5	36-14-15	36-14-22	36-14-25	36-14-26	36-14-29B	36-14-33	36-14-34A	36-16-1	36-16-3
SiO_2	69.0	68.6	67.6	69.3	67.9	69.0	67.9	69.7	68.7	68.9	66.1
Al_2O_3	15.0	14.6	15.2	15.6	15.9	14.8	15.8	14.7	15.5	16.8	15.4
Fe_2O_3	1.46	1.77	1.19	1.18	1.26	1.16	1.31	1.06	1.20	0.39	1.19
FeO	3.39	3.78	4.02	3.01	3.92	4.02	3.46	3.15	3.39	2.20	4.88
MgO	2.20	2.27	2.91	1.71	2.11	2.47	2.14	1.79	1.91	1.40	3.00
CaO	2.20	2.42	2.62	3.46	2.47	2.04	3.41	2.61	2.92	2.80	1.89
Na_2O	3.45	2.88	3.02	3.11	3.42	3.39	3.03	3.46	3.27	4.80	3.27
K_2O	2.10	1.86	2.20	1.42	1.91	2.03	1.70	1.63	1.63	1.71	2.46
TiO_2	0.53	0.59	0.60	0.54	0.58	0.54	0.58	0.53	0.59	0.48	0.64
P_2O_5	0.15	0.15	0.17	0.15	0.13	0.15	0.19	0.15	0.15	0.10	0.09
S	0.02	0.04	0.18	0.01	0.10	0.01	0.01	0.01	0.04	<0.01	<0.01
MnO	0.07	0.10	0.08	0.11	0.07	0.08	0.10	0.07	0.08	0.03	0.08
CO_2	0.08	0.08	0.07	0.07	0.08	0.08	0.08	0.07	0.08	0.05	0.08
H_2O+	0.70	0.77	0.48	0.56	0.80	0.17	0.26	0.39	0.58	0.16	0.76
H_2O-	0.32	0.23	0.21	0.21	0.20	0.46	0.47	0.42	0.45	0.28	0.30
Total	100.7	100.1	100.6	100.4	100.8	100.4	100.4	99.7	100.5	100.1	100.1
S.G	2.73	2.74	2.76	2.74	2.73	2.75	2.76	2.72	2.73	2.69	2.75
Normative											
Corundum	3.43	3.85	3.50	3.03	4.04	3.69	3.24	2.89	3.43	2.21	4.18
Metamorphic Grade	H	H	H	H	H	H	H	H	H	H	H

(Cont. Table 4-13

	37-2-6B	37-4-6	37-10-5	37-12-49	37-13-27	37-14-7B	37-14-9	38-5-11	38-7-9	38-7-12	38-9-1
SiO_2	68.9	63.8	71.1	67.9	67.3	69.8	69.9	65.9	71.7	68.0	71.7
Al_2O_3	14.8	18.3	14.5	14.8	15.5	13.7	14.0	16.2	13.6	16.1	14.0
Fe_2O_3	1.06	1.07	0.97	1.30	1.36	0.72	0.84	1.15	0.49	0.3	1.81
FeO	3.67	2.40	3.09	4.03	4.15	3.50	3.41	4.39	4.55	3.66	2.34
MgO	2.34	3.24	1.75	2.24	2.29	2.40	1.89	2.28	1.70	1.43	2.09
CaO	2.61	3.73	3.16	2.05	2.42	2.93	1.86	2.58	2.04	2.89	2.81
Na_2O	3.06	3.75	3.04	3.54	3.62	3.02	2.88	3.91	3.14	4.30	2.98
K_2O	2.15	2.27	1.45	1.74	1.70	1.72	2.96	1.96	1.39	1.39	1.61
TiO_2	0.51	0.27	0.49	0.53	0.50	0.50	0.51	0.70	0.49	0.58	0.47
P_2O_5	0.15	0.15	0.10	0.09	0.12	0.09	0.09	0.05	0.08	0.14	0.16
S	0.00	0.07	0.03	0.03	<0.01	0.47	0.02	0.02	0.19	0.07	0.03
MnO	0.07	0.04	0.08	0.08	0.09	0.06	0.06	0.07	0.04	0.03	0.05
CO_2	0.08	0.15	0.10	0.22	0.13	0.22	0.12	0.08	0.05	0.06	0.06
H_2O+	0.65	0.80	0.29	0.49	0.07	0.11	0.09	0.45	0.20	0.35	0.65
H_2O-	0.42	0.38	0.51	0.57	0.46	0.42	0.55	0.33	0.38	0.19	0.16
Total	100.5	100.4	100.7	99.6	99.7	99.7	99.2	100.1	100.0	99.5	100.9
S.G	2.78	2.71	2.72	2.73	2.77	2.72	2.88	2.74	2.75	2.74	2.72
Normative											
Corundum	3.07	3.28	2.43	3.64	3.63	1.78	2.94	3.10	3.44	2.63	2.63
Metamorphic Grade	H	H	H	H	H	H	H	G	G	G	G

(Cont. Table 4-β)

	38-15-11B	38-18-7	39-3-12	39-4-13	39-8-7A	39-10-10A	41-3-13	41-3-13A
SiO_2	68.1	67.4	67.1	64.2	65.6	64.3	68.1	60.3
Al_2O_3	14.9	15.5	15.9	16.2	16.1	16.4	14.1	16.1
Fe_2O_3	1.82	0.80	0.91	1.24	2.05	1.98	0.70	4.00
FeO	2.73	3.98	4.31	5.61	3.64	4.08	7.48	9.27
MgO	1.89	2.28	2.37	3.17	2.56	2.60	2.22	3.13
CaO	2.96	2.46	2.69	2.30	2.64	2.94	1.92	2.06
Na_2O	3.59	3.95	3.94	3.70	3.60	3.70	2.85	2.69
K_2O	1.68	2.14	1.52	2.21	1.82	1.63	1.44	1.47
TiO_2	0.52	0.55	0.60	0.70	0.62	0.63	0.53	0.66
P_2O_5	0.11	0.11	0.11	0.07	0.15	0.12	0.08	0.12
S	0.18	0.09	0.14	0.02	0.17	0.31	0.04	0.02
MnO	0.07	0.05	0.09	0.09	0.08	0.11	0.06	0.09
CO_2	0.25	0.06	0.12	0.06	0.08	0.06	0.06	0.07
H_2O+	0.31	0.53	0.46	0.46	0.52	0.06	0.13	0.11
H_2O-	0.63	0.21	0.32	0.23	0.24	0.45	0.32	0.34
Total	99.7	100.1	100.6	100.3	99.9	99.4	100.0	100.4
S.G	2.72	2.73	2.76	2.81	2.77	2.77	2.80	3.05
Normative Corundum	2.09	2.49	3.16	3.73	3.81	3.54	4.58	6.63
Metamorphic Grade	H	H	G	G	G	G	G	G

(Cont. Table 4-13)

	FC14-42	FC15-2A	FC15-12	FF4-1	105-1	4-17-37	5-165-3B	5-165-5	1028-25E	21-12-11A	4-17-35	21-27-13A	22-14-27
Ag	<1	<1					<1	<1	<1			<1	<1
Ba	140	280	270	610	130	190	340	520	650	420	420	190	220
Be	<1	<1					2	3	2	<1		3	2
Co	10	15	15	23	20	20	10	10	15	15	18	15	15
Cr	140	160	145	200	147	40	90	75	195	152	174	210	270
Cs	5	5	5	6	4	4	10	<5	8	7	7	4	
Cu	50	25	60	60	40	80	30	<5	35	62	66	40	20
Ga	9	9					9	10	15			10	10
Li	20	20	15	15	11	15	20	45	25	14	16	20	25
Mo	<1	<1					<1	<1	<1			<1	<1
Ni	45	45	45	60	61	30	25	35	40	40	61	35	45
Pb	20	25	25	41	31	20	20	25	20	20	46	50	20
Rb	45	50	60	60	30	50	70	90	80	60	50	70	80
Sc	9	10					10	10	15			10	10
Sn	<1	<1					<1	<1	<3	<3		<1	<1
Sr	300	300	200			890	300	300		280		200	300
Th	20	20	<10	<10	<10	<10	<10	<10	20	10	17	10	
U			3.5	<1	<1	1.2	8	20	<2	2	<1	2.2	3.0
V	40	50					50	30	100	80		70	70
Y	10	<10					<10	20	20			<10	<10
Zn	60	65	75	83	55	110	55	70	75	60	78	85	90
Zr	100	80					80	150	150	200		80	60

(Cont. Table 4-13)

	31-10-15A	32-9-1A	32-5-7A	34-10-10	35-6-1	35-6-2	35-8-2A	35-8-4A	35-8-7A	35-8-17	35-9-1
Ag											<1
Ba	560	470	320	410	210	480	520	180	350	210	480
Be	<1	<1	4								2
Co	14	11	17	15	15	20	30	20	30	20	20
Cr	160	173	150	250	140	180	980	160	180	260	140
Cs	10	<10	6	15	3	8	30	30	20	4	8
Cu	44	24	87	45	30	35	7	35	65	40	30
Ga											35
Li	44	34	16	185	15	25	55	70	60	15	15
Mo											1
Ni	18	23	56	20	35	55	270	65	115	60	55
Pb	23	32	22	30	30	20	25	40	20	20	10
Rb	90	90	60	100	50	60	90	160	80	60	40
Sc											15
Sn	<3	<3	<3								>3
Sr	190	260	290	250			460	140	120	320	600
Th	<10	10	20	<10	<10	20	<10	20	20	<10	10
U	<1	4	6	6.6	2.6	1.9	3.0	4.4	3.2	1.2	2.4
V	250	100	90								90
Y											15
Zn	210	66	108	80	70	70	65	105	90	100	75
Zr	200	200	200								200

(Cont. Table 4-B)

	35-9-6	35-10-11	35-11-1	36-14-20A	35-15-15	36-1-4B	36-4-6	36-6-4	36-10-7A	36-11-2	36-13-8
Ag	<1		<1			<1	<1	<1	<1		<1
Ba	340	210	270	250	430	220	280	160	200	180	220
Be	3		2			<1	2	15	2		3
Co	10	10	5	20	20	10	15	15	10	15	10
Cr	150	160	5	155	230	130	180	145	185	110	165
Cs	5	10	7	7	8	7	6	<5	5	5	5
Cu	15	15	5	55	60	15	25	45	15	2	25
Ga	35		40			35	40	45	40		40
Li	10	45	10	10	20	15	10	20	5	10	5
Mo	<1		<1			1	2	4	3		2
Ni	25	25	<5	50	40	15	30	55	25	50	25
Pb	20	20	10	30	180	<10	70	10	10	35	10
Rb	40	70	20	50	80	40	50	50	50	60	40
Sc	15		9			15	15	10	20		15
Sn	<3		<3			<3	15	<3	<3		<3
Sr	300	320	500		370	400	400	300	400	140	500
Th	10	60	<10	20	<10	10	<10	<10	20	10	
U	2.9	3.2	1.6	3.4	2.1	2.6	2.8	2.7	2.8	2.6	
V	100		70			100	150	100	150		100
Y	10		10			20	15	<10	20		20
Zn	60	70	55	75	85	65	80	85	70	60	60
Zr	150		150			150	250	200	400		500

(Cont. Table 4-13)

	36-14-2	36-14-5	36-14-15	36-14-22	36-14-25	36-14-26	36-14-29B	36-14-33	36-14-34A	36-16-1	36-16-3
Ag	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Ba	140	180	310	120	180	300	120	190	200	450	450
Be	2	2	3	4	<1	<1	3	<1	<1		
Co	10	10	20	10	15	10	15	10	15		25
Cr	160	205	165	150	130	185	185	150	165	9	175
Cs	<5	<5	6	<5	4	5	<5	<5	6	25	6
Cu	10	40	50	20	50	10	15	30	20	4	55
Ga	35	30	35	35	30	35	30	30	30	6	
Li	5	5	5	5	5	1	5	5	5		20
Mo	<1	1	1	3	3	3	3	2	3		
Ni	25	25	55	20	25	25	35	20	20	15	60
Pb	10	10	10	<10	10	10	10	10	10		30
Rb	50	40	40	30	40	50	40	30	40	8	70
Sc	15	15	15	20	20	15	20	20	15	30	
Sn	<3	<3	<3	<3	<3	<3	<3	<3	>3	60	
Sr	400	300	400	300	500	300	300	400	400		
Th	<10	20	10	20	20	<10	<10	10	10		
U	3.0	4.0	2.9	2.9	2.4	3.2	2.4	3.2	3.2	4	4
V	100	100	100	100	100	100	100	90	100		
Y	15	20	20	30	15	20	25	20	20		
Zn	70	80	80	60	70	80	60	65	65	60	90
Zr	250	200	200	200	250	200	150	200	250		

(Cont. Table 4-13)

	37-2-6B	37-4-6	37-10-5	37-12-49	37-13-27	37-14-7B	37-14-9	38-5-11	38-7-9	38-7-12	38-9-1
Ag	<1	<1									<1
Ba	280	320	190	260	180	420	560	220	190	320	170
Be	3	3									2
Co	10	15	15	15	20	20	10	15	15	10	10
Cr	180	95	155	195	165	170	155	175	110	125	140
Cs	6	4	3	4	4	8	2	5	5	4	<5
Cu	20	35	30	40	30	90	9	15	50	15	15
Ga	35	35									35
Li	10	10	10		15	8	10	10	10	10	5
Mo	4	<1									4
Ni	30	50	35	60	50	70	15	20	30	10	25
Pb	10	10	15	25	20	20	20	25	20	30	10
Rb	70	50	60	70	60	60	70	60	40	50	50
Sc	15	10									15
Sn	<3	<3									<3
Sr	400	400									600
Th	<10	<10	20	20	10	<10	10				30
U	2.8	0.5	2.5	2.5	3.2	1.7	2.1	4	3	3	3.5
V	100	50									100
Y	15	<10									15
Zn	80	70	50	70	70	60	70	80	55	60	55
Zr	200	70									200

(Cont. Table 4-13

	38-15-11B	38-18-7	39-3-12	39-4-13	39-8-7A	39-10-10A	41-3-13	41-3-13A
Ag					<1			
Ba	330	780	310	240	220	780	400	510
Be					<1			
Co	20	20	25	20	25	20	15	20
Cr	160	165	185	210	170	190	115	145
Cs	1	8	5	4	<5	4	6	5
Cu	50	50	50	35	50	20	10	7
Ga					40			
Li	10	20	10	7	5	10	6	8
Mo					1			
Ni	45	35	65	65	85	60	20	30
Pb	25	25	20	20	40	25	20	20
Rb	50	80	40	40	40	60	30	40
Sc					20			
Sn					8			
Sr					500	230		
Th	<10				<10	20		
U		6	3	4	2.3	2.3	1.9	2.1
V					150			
Y					20			
Zn	75	70	80	90	75	90	55	75
Zr					200			

(Cont. Table 4-13)

	P2-9-47	P2-10-73	P3-9-52	P3-9-57	P3-9-59	P3-9-65	P3-9-68	P3-9-70	P3-10-3	P3-12-9	P3-10-20	P4-11-7
SiO_2	66.4	67.6	69.2	68.7	66.3	61.7	68.4	66.6	66.4	63.8	62.1	66.7
Al_2O_3	15.1	14.4	14.9	16.7	15.7	17.1	15.2	15.9	16.5	16.3	16.6	16.0
Fe_2O_3	0.90	1.08	1.11	0.21	0.59	0.82	0.89	0.96	2.69	3.09	6.48	1.53
FeO	4.72	4.31	3.74	2.68	5.77	7.40	3.90	4.55	2.03	3.01	3.90	3.25
MgO	2.49	2.12	2.13	1.37	2.34	2.83	2.31	2.62	2.42	3.28	3.16	2.34
CaO	2.34	3.01	2.33	2.65	2.37	2.58	2.12	2.13	2.45	3.03	2.16	2.75
Na_2O	3.20	2.67	3.31	4.67	3.43	3.49	3.81	3.82	4.29	3.12	2.55	3.01
K_2O	1.96	1.73	2.01	1.55	1.57	2.01	1.88	1.95	1.94	2.57	2.46	2.17
TiO_2	0.55	0.56	0.55	0.39	0.57	0.66	0.50	0.55	0.59	0.62	0.61	0.56
P_2O_5	0.12	0.13	0.11	0.12	0.10	0.12	0.11	0.08	0.09	0.16	0.13	0.12
S	0.01	0.17	<0.01	<0.01	<0.01	<0.01	0.03	0.03	<0.01	0.06	0.02	0.05
MnO	0.09	0.09	0.06	0.02	0.06	0.09	0.07	0.09	0.05	0.09	0.10	0.04
CO_2	0.06	0.07	0.06	0.06	0.07	0.06	0.09	0.10	0.06	0.06	0.06	0.06
H_2O+	0.60	0.19	0.31	0.26	0.24	0.47	0.29	0.47	0.17	0.70	0.46	0.41
H_2O-	0.40	0.32	0.24	0.35	0.18	0.33	0.39	0.39	0.33	0.38	0.31	0.39
Total	98.9	98.4	100.1	99.7	99.3	99.7	100.0	100.2	100.0	100.3	101.1	99.4
S.G	2.77	2.76	2.75	2.70	2.80	2.84	2.73	2.77	2.75	2.75	2.87	2.73
Normative Corundum	3.83	3.04	3.32	2.84	4.34	4.84	3.33	3.85	3.12	3.29	6.11	4.05
Metamorphic Grade	H	H	H	H	H	H	H	H	H	G	H	H

(Cont. Table 4-13

	P2-9-47	P2-10-73	P3-9-52	P3-9-57	P3-9-59	P3-9-65	P3-9-68	P3-9-70	P3-10-3	P3-12-9	P3-10-20	P4-11-7
Ag												
Ba	220	340	270	210	250	220	430	220	250	420	710	210
Be												
Co	15	25	15	9	15	20	15	15	20	20	25	15
Cr	185	185	120	40	125	150	160	180	160	215	170	155
Cs	8	7	7	5	4	9	7	5	9	9	8	8
Cu	25	130	8	10	20	15	20	55	20	20	10	30
Ga												
Li	10	10	10	15	10	10	10	10	9	10	20	30
Mo												
Ni	60	65	50	8	30	55	40	65	45	45	40	20
Pb	25	30	20	20	30	20	30	20	25	25	20	20
Rb	60	50	50	50	10	60	50	50	50	70	80	110
Sc												
Sn												
Sr												
Th												
U	3.1	3.7	1.6	2.9	2.3	1.7	2.6	2.6	2.7	4	2.0	3
V												
Y												
Zn	80	80	75	70	70	85	70	75	80	85	80	75
Zr												

(Cont. Table 4-13)

	FC14-42	FC15-2A	FC15-12	FF4-1	105-1	4-17-37	5-165-3B	5-165-5	1028-25E	21-12-11A	21-27-13A	22-14-27
K/Rb	290	363	252	273	315	374	160	153	197	248	257	296
K/Ba	93	65	56	27	73	98	33	27	24	35	94	108
K/Cs	26	36	15	27	24	47	11	>28	20	21	45	-
K/U	-	-	43	>163	>95	156	14	69	>70	74	82	79
Na/K	2.05	1.62	1.76	1.38	2.99	1.50	2.13	1.55	1.65	1.51	1.41	0.97*
Ca/Sr												
Ba/Rb	3.1	5.6	4.5	10.2	4.3	3.8	4.9	5.8	8.1	7.0	2.7	2.8
U/Th	-	-	>0.35	-	-	>0.12	>0.8	>2	<0.1	0.2	0.2	-
K/Th												
Al_2O_3/Na_2O	4.54	4.35	4.15	4.90	4.21	5.52	5.36	5.78	4.59	5.19	4.70	4.98

(Cont. Table 4-13)

SELECTED ELEMENT RATIOS

	35-10-15A	32-9-1A	32-5-7A	34-10-10	35-6-1	35-6-2	35-8-2A	35-8-4A	35-8-7A	35-8-17	35-9-1
K/Rb	187	205	259	214	290	368	173	130	223	415	448
K/Ba	30	39	49	52	69	46	30	115	51	119	37
K/Cs	17	>18	26	14	48	28	5	7	9	62	22
K/U	>169	4692	26	32	56	12	52	47	56	21	75
Na/K	1.58	1.23	1.32	1.16	2.28	1.31	1.53	1.45	1.65	0.66*	1.67
Ca/Sr											
Ba/Rb	6.2	5.2	5.3	4.1	4.2	8.0	5.8	1.1	4.4	3.5	12.0
U/Th		0.4	0.3	>0.7	>0.3	0.1	>0.3	0.2	0.2	0.1	0.2
K/Th											
Al_2O_3/Na_2O	4.73	5.64	6.28	4.63	3.73	4.21	4.93	3.87	4.05	5.80	4.16

(Cont. Table 4-13)

SELECTED ELEMENT RATIOS

	35-9-6	35-10-11	35-11-1	36-14-20A	35-15-15	36-1-4B	36-4-6	36-10-7A	36-11-2	36-13-8	
K/Rb	510	247	575	272	248	470	406	340	406	237	335
K/Ba	60	82	42	54	46	85	72	106	101	81	61
K/Cs	41	17	16	19	25	27	34	17	41	29	27
K/U	70	54	72	40	94	78	72	63	72	56	-
Na/K	1.47	1.92	3.07	2.01	1.62	1.84	1.41	1.21	1.18	2.51	1.61
Ca/Sr											
Ba/Rb	8.5	3.0	13.5	5.0	5.4	5.5	5.6	3.2	4.0	3.0	5.5
U/Th	0.29	0.05	0.16	0.17	0.21	0.26	>0.28	>0.27	0.14	0.26	-
K/Th											
Al_2O_3/Na_2O	4.07	3.72	3.62	4.28	3.75	3.66	4.45	5.92	5.03	3.28	4.79

(Cont. Table 4-13)

SELECTED ELEMENT RATIOS

	36-14-2	36-14-5	36-14-15	36-14-22	36-14-25	36-14-26	36-14-29B	36-14-33	36-14-34A	36-16-1	36-16-3
K/Rb	348	385	458	393	396	336	353	450	338	237	292
K/Ba	125	86	59	98	88	56	118	71	68	32	45
K/Cs	>17	>15	30	>12	40	34	>14	>14	23	35	34
K/U	58	39	63	41	60	53	59	42	42	35	51
Na/K	1.57	1.48	1.31	2.09	1.70	1.60	1.70	2.02	1.91	2.68	1.26
Ca/Sr											
Ba/Rb	2.8	4.5	7.8	4.0	4.5	6.0	3.0	6.3	5.0	7.5	6.4
U/Th	>0.30	0.20	0.29	0.15	0.12	>0.32	>0.24	0.32	0.32	-	-
K/Th											
Al_2O_3/Na_2O	4.35	5.07	5.03	5.02	4.65	4.37	5.21	4.25	4.74	3.50	4.71

(Cont. Table 4-13)

SELECTED ELEMENT RATIOS

	36-2-6B	37-4-6	37-10-5	37-12-49	37-13-27	37-14-7B	37-14-9	38-5-11	38-7-9	38-7-12	38-9-1
K/Rb	254	376	200	206	235	238	352	271	288	231	268
K/Ba	64	59	63	56	78	34	44	74	61	36	79
K/Cs	30	47	40	36	35	18	12	33	23	29	>13
K/U	64	377	43	58	44	84	117	41	39	39	38
Na/K	1.36	1.57	2.00	1.94	1.84	1.67	0.93	1.90	2.16	2.96	1.75
Ca/Sr											
Ba/Rb	4.0	6.4	3.2	3.7	3.0	7.0	8.0	3.7	4.8	6.4	3.4
U/Th	>0.28	>0.05	0.14	0.13	0.32	>0.02	0.21	-	-	-	0.12
K/Th											
Al_2O_3/Na_2O	4.84	4.88	4.77	4.18	4.28	4.54	4.86	4.14	4.33	3.74	4.70

(Cont. Table 4-13)

	SELECTED ELEMENT RATIOS							
	38-15-11B	38-18-7	39-3-12	39-4-13	39-8-13	39-87A	39-10-10A	41-3-13	41-3-13A
K/Rb	278	222	315	459	378	225	398	305	
K/Ba	42	23	41	76	69	17	30	24	
K/Cs	139	22	25	46	>30	34	20	24	
K/U	-	30	42	46	66	19	16	58	
Na/K	2.04	1.75	2.47	1.60	1.88	2.16	1.88	1.75	
Ca/Sr									
Ba/Rb	6.6	9.8	7.8	6.0	5.5	13.0	13.3	12.8	
U/Th	-	-	-	-	>0.23	0.12	-	-	
K/Th									
Al_2O_3/Na_2O	4.15	3.92	4.03	4.38	4.47	4.43	4.95	7.82	

(Cont. Table 4-13)

SELECTED ELEMENT RATIOS

	P2-9-47	P2-10-73	P3-9-52	P3-9-57	P3-9-59	P3-9-65	P3-9-68	P3-9-70	P3-10-3	P3-12-9	P3-1020	P4-11-7
K/Rb	271	287	337	257	1303	278	312	278	161	305	255	164
K/Ba	74	42	62	61	52	76	36	74	64	51	29	86
K/Cs	20	21	24	26	33	19	22	32	18	24	26	23
K/U	52	39	104	44	57	98	60	62	60	53	102	60
Na/K												
Ca/Sr												
Ba/Rb	3.7	6.8	5.4	4.2	25.0	3.7	8.6	4.4	5.0	6.0	8.9	1.9
U/Th	-	-	-	-	-	-	-	-	-	-	-	-
K/Th												
Al_2O_3/Na_2O	4.72	5.39	4.50	3.58	4.58	4.90	3.99	5.32	4.16	3.85	5.22	6.51

1 Division of metamorphic grade based upon Winkler (1979) L = Low Grade, M = Medium Grade, H = High Grade
G = Low-Pressure Granulite

Table 4-14: Chemical Analyses and Selected Element Ratios of Metapelites from the English River Subprovince

	5-165-3A	8-12-7A	19-1-2A	21-12-11B	27X-5-58A	31-5-3	31-15-16	31-10-15B	32-5-2	32-5-3A	32-5-3B
SiO_2	57.0	55.9	55.7	61.1	54.2	61.5	57.2	60.8	57.4	63.8	51.1
Al_2O_3	25.3	14.8	22.8	18.7	22.4	18.2	19.7	17.0	19.2	19.6	23.3
Fe_2O_3	1.93	1.21	1.09	1.01	3.05	1.06	1.81	1.99	1.75	1.13	2.77
FeO	5.46	6.90	5.20	5.55	6.12	6.28	6.16	5.64	6.52	2.90	6.60
MgO	3.17	10.2	3.13	3.19	4.21	3.16	3.71	3.31	3.62	2.56	4.54
CaO	1.16	7.21	0.50	1.44	0.82	1.33	0.63	1.07	0.79	1.18	0.84
Na_2O	1.81	0.83	1.30	2.36	1.89	1.69	1.08	1.75	0.98	1.84	1.13
K_2O	2.22	1.30	4.96	3.25	4.00	3.24	4.97	2.90	3.83	3.45	4.28
TiO_2	0.81	0.8	0.80	0.71	0.89	0.71	0.75	0.64	0.82	0.49	0.82
P_2O_5	0.09	0.42	0.05	0.06	0.06	0.12	0.11	0.11	0.16	0.12	0.16
S	0.07	0.10	0.14	0.16	0.19	0.11	0.20	0.03	0.10	0.02	0.30
MnO	0.05	0.14	0.09	0.08	0.10	0.08	0.08	0.08	0.09	0.06	0.10
CO_2	0.07	0.15	0.12	0.71	0.75	0.78	0.09	1.18	1.11	1.12	1.36
H_2O+	0.88	0.07	2.71	1.79	0.90	0.90	2.20	1.96	1.22	1.82	2.03
H_2O-	0.62	0.39	0.34	0.27	0.32	0.32	0.87	0.62	0.42	0.43	0.57
Total	100.6	100.4	98.9	100.4	99.8	99.5	99.6	99.1	98.0	100.5	99.9
S.G	2.78	2.95	2.81	-	-	-	2.82	-	-	-	-
Normative Corundum	18.20	0.00	15.15	-	-	-	12.11	-	-	-	-
Metamorphic Grade1	H	H	M	H	G	H	M	M	M	M	M

(Cont. Table 4-14)

	32-9-1B	32-5-7B	32-5-7C	33-15-14B	34-10-3C	34-10-14A	34-11-6	34-11-11	34-11-36	34-14-19	35-4-3B
SiO_2	56.6	58.7	59.0	58.6	58.9	58.1	62.6	60.9	58.3	67.5	55.1
Al_2O_3	19.8	20.3	19.2	20.1	18.4	17.9	17.5	17.6	19.7	16.5	20.4
Fe_2O_3	2.03	1.40	1.61	1.60	1.12	1.50	1.66	1.33	1.50	1.14	2.63
FeO	5.64	6.44	5.72	4.06	4.94	7.84	4.47	6.24	5.12	4.83	7.09
MgO	3.25	3.80	3.41	3.53	3.33	3.38	2.78	3.83	3.43	2.51	4.56
CaO	0.84	1.03	0.89	1.00	1.80	1.44	1.04	0.32	0.89	1.06	1.93
Na_2O	1.01	0.79	1.37	1.99	2.95	2.85	2.49	2.13	1.80	1.59	2.64
K_2O	4.99	3.79	3.32	4.63	3.08	2.82	3.03	2.77	3.57	3.36	2.33
TiO_2	0.74	0.75	0.74	0.70	0.64	0.62	0.59	0.68	0.67	0.71	0.82
P_2O_5	0.11	0.12	0.12	0.16	0.18	0.19	0.14	0.14	0.13	0.11	0.07
S	0.15	0.03	0.05	0.24	0.09	0.01	0.01	0.01	0.13	0.04	0.05
MnO	0.07	0.08	0.09	0.08	0.07	0.06	0.06	0.06	0.08	0.05	0.14
CO_2	1.88	0.98	1.15	0.07	0.06	0.08	0.07	0.13	0.34	0.08	0.30
H_2O^+	2.19	0.83	1.55	1.60	2.81	2.43	2.14	2.90	2.85	1.07	1.07
H_2O^-											
Total											
S.G	-	-	-	2.78	2.75	2.78	2.74	2.75	2.76	2.72	2.81
Normative											
Corundum	-	-	-	10.74	7.72	8.27	8.89	11.30	12.14	-	10.43
Metamorphic Grade	M	M	M	M	M	M	M	M	M	M	M

(Cont. Table 4-14)

	35-8-2B	35-8-6B	35-13-2	35-15-8	36-6-2B	36-7-2	36-7-10	36-10-1	36-10-2A	36-10-7B	36-13-4B
SiO_2	54.7	60.9	58.0	63.2	60.0	59.7	57.6	60.8	51.0	57.5	54.4
Al_2O_3	20.5	18.6	20.5	17.2	18.6	18.6	18.2	17.1	23.1	19.9	20.8
Fe_2O_3	1.30	1.11	1.43	0.81	1.61	1.30	1.86	1.97	1.73	1.51	2.06
FeO	6.59	5.74	6.90	4.80	5.60	6.82	6.01	5.95	7.98	6.89	7.00
MgO	3.76	3.28	3.67	2.73	3.34	3.73	3.56	3.33	4.79	4.02	4.30
CaO	2.28	1.28	1.08	1.69	1.73	1.43	1.16	2.14	1.35	1.24	1.51
Na_2O	4.34	2.05	1.85	2.64	3.04	2.28	2.38	2.67	2.23	2.00	2.24
K_2O	3.56	2.99	3.61	2.95	3.40	3.10	4.03	3.12	4.11	3.92	4.05
TiO_2	0.78	0.68	0.75	0.56	0.75	0.76	0.70	0.78	1.00	0.90	0.99
P_2O_5	0.13	0.14	0.15	0.14	0.11	0.14	0.10	0.11	0.12	0.15	0.12
S	0.05	0.24	0.06	0.03	0.04	0.17	0.04	0.02	0.02	0.15	0.05
MnO	0.06	0.08	0.08	0.06	0.08	0.11	0.10	0.09	0.12	0.10	0.10
CO_2	0.06	0.08	0.08	0.06	0.06	0.08	0.06	0.06	0.06	0.07	0.07
H_2O+	1.04	1.01	1.21	1.46	1.27	1.23	1.58	0.99	1.76	1.13	1.44
H_2O-	0.58	0.64	0.56	0.41	0.33	0.32	0.70	0.24	0.62	0.49	0.54
Total	99.7	98.8	99.9	98.7	100.0	99.8	98.1	99.4	100.0	100.0	99.7
S.G	2.74	2.79	2.81	2.69	2.74	2.76	2.74	2.78	2.75	2.78	2.78
Normative Corundum	5.79	10.31	12.18	7.15	7.16	9.41	8.41	5.81	13.14	10.66	10.52
Metamorphic Grade	M	M	M	M	H	H	H	H	H	H	H

(Cont. Table 4-14)

	36-14-20B	36-14-29A	36-14-30A	36-14-34	37-2-2	37-6-5	38-5-11A	38-5-51A	38-7-9A	38-7-12A	39-2-39	39-3-25
SiO_2	58.1	63.5	56.0	61.0	61.3	56.6	60.5	57.4	54.9	56.6	48.4	57.3
Al_2O_3	20.3	17.3	20.5	17.6	19.1	19.9	18.2	20.1	21.3	19.7	23.4	21.1
Fe_2O_3	1.64	1.40	1.63	1.54	1.45	1.63	0.95	1.14	1.32	1.39	1.51	1.33
FeO	7.35	5.40	7.98	7.07	5.60	7.98	6.26	6.83	7.80	9.02	9.35	6.91
MgO	3.89	3.25	4.06	3.46	3.51	3.75	3.38	4.22	3.87	3.81	6.04	4.69
CaO	1.20	1.53	0.84	1.60	1.15	0.63	2.01	1.40	2.10	1.56	1.90	1.08
Na_2O	1.98	2.17	1.58	1.84	2.02	1.25	3.35	2.61	4.17	2.60	2.72	2.12
K_2O	3.55	2.82	4.10	2.14	4.08	5.49	3.62	4.36	2.37	3.00	3.82	3.53
TiO_2	0.94	0.73	1.03	0.77	0.75	0.84	0.74	0.81	0.09	0.87	1.09	0.84
P_2O_5	0.12	0.15	0.10	0.10	0.13	0.10	0.08	0.08	0.07	0.07	0.05	0.08
S	0.04	0.01	0.01	0.63	0.10	0.07	0.02	0.04	0.16	0.05	0.19	0.02
MnO	0.09	0.06	0.09	0.07	0.07	0.08	0.06	0.09	0.11	0.12	0.16	0.10
CO_2	0.06	0.07	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05
H_2O+	1.32	0.89	1.38	1.07	1.04	1.15	0 37	0.59	0.86	0.75	0.63	1.01
H_2O-	0.37	0.60	0.63	0.40	0.28	0.53	0.30	0.62	0.47	0.23	0.42	0.39
Total	101.0	99.5	100.0	99.4	100.7	100.1	99.9	100.3	99.6	99.8	99.7	100.5
S.G	2.74	2.72	2.83	2.79	2.73	2.71	2.77	2.79	2.80	2.87	2.86	2.77
Normative Corundum	11.40	8.43	12.43	9.83	9.65	11.18	5.35	8.81	8.38	9.62	11.62	12.13
Metamorphic Grade	H	H	H	H	H	H	G	G	G	G	G	G

(Cont. Table 4-14)

	39-8-7B	39-10-10B	41-3-14	P4-11-8	P4-11-13	41-2-51
SiO_2	51.9	55.8	54.6	45.7	53.5	66.9
Al_2O_3	21.1	20.1	23.0	24.3	22.0	17.3
Fe_2O_3	1.90	2.30	0.55	2.15	1.95	0.48
FeO	8.19	6.36	6.59	9.51	7.89	3.50
MgO	4.69	4.19	4.54	5.89	5.45	5.85
CaO	0.98	2.09	1.35	1.31	0.85	0.40
Na_2O	2.13	2.85	2.81	2.42	1.83	1.59
K_2O	6.45	2.75	3.72	4.32	3.30	2.53
TiO_2	0.90	0.88	0.91	1.26	0.92	0.58
P_2O_5	0.10	0.10	0.08	0.05	0.05	0.03
S	0.10	0.02	0.15	0.08	0.12	<0.01
MnO	0.12	0.12	0.06	0.09	0.06	0.04
CO_2	0.06	0.08	0.06	0.06	0.07	0.06
H_2O+	0.96	0.66	0.77	1.83	1.37	0.54
H_2O-	0.49	0.70	0.46	0.73	0.60	0.31
Total	100.1	99.0	99.6	99.7	100.0	100.1
S.G	2.81	2.80	2.75	2.79	2.76	2.67
Normative						
Corundum	9.20	9.10	12.30	13.79	14.30	12.30
Metamorphic Grade	G	G	G	H	M	G

(Cont. Table 4-14)

	5-165-3A	8-12-7A	19-1-2A	21-12-11B	27X-5-58A	31-5-3	31-15-16	31-10-15B	32-5-2	32-5-3A	32-5-3B
Ag	<1	<1	<1								
Ba	480	690	690	630	470	660	380	520	1400	890	700
Be	3	4	<1	<1	<1	<1		<1	<1	6	8
Co	30	40	30	25	33	27	30	20	21	14	34
Cr	170	600	180	194	277	214	215	151	217	102	245
Cs	8	20	4	7	12	14	20	10	31	6	31
Cu	45	35	35	50	64	46	70	24	46	<5	83
Ga	15	15	20								
Li	60	9	50	38	21	27	55	74	94	25	61
Mo	<1	<1	<1								
Ni	110	230	75	89	105	84	95	44	62	38	122
Pb	20	20	15	15	17	20	20	46	18	29	18
Rb	80	110	80	90	90	90	170	70	120	90	90
Sc	20	30	30								
Sn	<1	<3	<3	<3	<3	3		<3	7	<3	3
Sr	400			180	90	150	110	110	110	210	100
Th	<10	20	35	<10	<10	<10	<10	<10	<10	10	<10
U	6			<1	<1	<1	3.7	<1	<1	4	4
V	100	200	250	150	250	150		250	200	70	200
Y	20	25	15								
Zn	95	105	100	94	116	87	90	69	137	62	96
Zr	90	250	150	200	200	200		200	100	200	100

(Cont. Table 4-14)

	32-9-1B	32-5-7B	32-5-7C	33-15-14B	34-10-3C	34-10-14A	34-11-6	34-11-11	34-11-36	35-4-3B
Ag										
Ba	320	760	660	620	400	350	410	800	500	210
Be	4	4	4							
Co	17	23	24	25	15	20	20	10	30	20
Cr	150	206	192	185	135	165	150	170	210	260
Cs	13	12	11	10	15	15	9	8	8	9
Cu	87	22	23	55	110	10	70	30	60	55
Ga										
Li	16	38	46	40	35	165	110	60	50	35
Mo										
Ni	56	64	66	55	40	65	60	55	105	50
Pb	17	23	22	25	45	25	25	50	25	20
Rb	120	130	100	120	80	100	70	120	90	70
Sc										
Sn	3	<3	<3							
Sr	110	150	150	140	250	200	370	190		
Th	<10	<10	<10	<10	20		10	20		30
U	3	<1	5	3.9	2.6	2.3	2.7	3.3	2.5	3.0
V	250	250	200			<10		<10		
Y										
Zn	81	100	96	95	65	50	75	85	90	100
Zr	150	200	200							

(Cont. Table 4-14)

	35-8-2B	35-8-6B	35-13-2	35-15-8	36-6-2B	36-7-2	36-7-10	36-10-1	36-10-2A	36-10-7B	36-13-4B
Ag			<1		<1	<1		<1	<1	<1	<1
Ba	220	300	240	470	280	280	460	360	320	350	450
Be			3		<1	2		2	2	3	3
Co	20	25	25	15	25	25	15	15	25	30	20
Cr	150	235	190	135	220	215	130	210	310	260	305
Cs	6	9	21	10	9	12	10	4	13	6	10
Cu	65	25	40	15	25	55	15	30	65	50	60
Ga			40		40	45			50	50	50
Li	15	30	45	45	10	25	50	10	20	20	20
Mo			4		7	3		4	15	4	7
Ni	50	65	65	55	70	100	40	45	105	115	75
Pb	20	25	10	25	20	20	25	10	20	10	10
Rb	70	110	80	90	50	50	90	70	60	40	50
Sc			25		25	30		25	35	30	30
Sn			5		<3	<3		<3	3	<3	<3
Sr	130	160	200	150	400	300	230	400	300	300	300
Th	30	10	<10	30	10	<10	<10	<10	10	<10	10
U	4.4	3.4	2.6	2.4	3.2	3.0	2.8	2.1	2.9	3.1	3.0
V			150		200	200		150	300	200	250
Y			20		20	30		25	25	20	30
Zn	60	100	90	65	100	100	65	95	120	110	110
Zr			150		200	150		400	300	300	300

(Cont. Table 4-14)

	36-14-20B	36-14-29A	36-14-30	A36-14-34B	37-2-2	37-6-5	38-5-11A	38-5-51A	38-7-9A	38-7-12A	39-2-39	39-3-25
				<1	<1	<1						
	260	330	390	370	330	330	460	720	220	780	1200	370
Be	4	4	<1	3	3	4						
Co	25	15	30	25	25	25	15	25	30	30	40	30
Cr	265	205	245	160	205	220	150	250	245	225	350	280
Cs	7	<5	10	4	8	7	7	5	7	7	<2	5
Cu	50	55	40	110	45	40	25	30	40	25	70	50
Ga	40	40	45	45	40	45						
Li	15	10	30	15	10	35	15	15	20	20	15	10
Mo	10	4	10	5	1	4						
Ni	60	65	100	70	80	85	50	65	95	60	130	90
Pb	10	10	<10	<10	10	20	25	30	30	25	35	25
Rb	40	40	70	40	40	60	60	80	50	80	50	40
Sc	35	15	35	25	25	25						
Sn	<3	<3	<3	<3	<3	<3						
Sr	300	300	100	400	300	200						
Th	20	10	-	<10	10	<10						
U	2.7	2.5	1.9	1.6	2.7	1.6	1.2	2.2	1.7	1.5	2.0	1.8
V	200	150	250	200	200	200						
Y	30	20	35	25	20	20						
Zn	105	100	125	105	90	90	85	110	120	120	140	100
Zr	200	200	250	200	105	200						

(Cont. Table 4-14)

	39-8-7B	39-10-10B	41-3-14P	4-11-8	P4-11-13	41-2-51
Ag	<1					
Ba	380	430	460	280	400	410
Be	4					
Co	30	30	30	40	30	9
Cr	290	250	265	370	310	15
Cs	6	6	6	9	12	4
Cu	60	30	50	80	70	<5
Ga	40					
Li	5	15	15	40	60	25
Mo	5					
Ni	75	65	105	145	80	10
Pb	20	35	25	25	20	15
Rb	80	70	40	100	110	20
Sc	40					
Sn	<3					
Sr	300	230				
Th	10	<10				
U	1.8	2.3	2.0	3.2	4.3	0.9
V	300					
Y	45					
Zn	110	105	120	180	135	70
Zr	200					

(Cont. Table 4-14)

	5-165-3A	8-12-7A	19-1-2A	21-12-11B	27X-5-58A	31-5-3	31-15-16	31-10-15B	32-5-2	32-5-3A	32-5-3B
K/Rb	230	98	515	300	369	298	243	344	265	318	395
K/Ba	38	16	60	43	71	41	109	46	23	32	51
K/Cs	23	5	10	39	28	19	21	24	10	48	11
K/U	31			>270	>332	>269	111	>241	>318	72	89
Na/K	0.73	0.60	0.25	0.69	0.45	0.50	0.21	0.57	0.24	0.51	0.25
Ba/Rb	6.0	6.3	8.6	7.0	5.2	7.3	2.2	7.4	11.7	9.9	7.8
Mg/Li											
U/Th	>0.6	-	-	0.01	0.1	0.1	>0.37	0.1	0.1	0.4	>0.4
K/Th											
Al_2O_3/Na_2O	13.98	17.8	17.5	7.92	11.8	10.80	18.24	9.71	19.59	10.65	20.62

(Cont. Table 4-14)

	32-9-1B	32-5-7B	32-5-7C	33-15-14B	34-10-3C	34-10-14A	34-11-6	34-11-11	34-11-36	35-4-3B
K/Rb	345	242	276	320	320	234	359	192	329	276
K/Ba	129	83	42	62	64	67	61	29	59	92
K/Cs	32	26	25	38	17	16	28	29	37	22
K/U	138	>315	55	98	98	102	93	70	119	65
Na/K	0.19	0.20	0.39	0.41	0.91	0.96	0.78	0.73	0.48	1.08
Ba/Rb	2.7	5.8	6.6	5.2	5.0	3.5	5.9	6.7	5.6	3.0
Mg/Li										
U/Th	>0.3	0.1	>0.5	>0.39	0.13	-	0.27	0.17	-	0.10
Al_2O_3/Na_2O	19.60	25.69	14.01	10.10	6.24	6.28	7.03	8.26	10.94	7.73

(Cont. Table 4-14)

	35-8-2B	35-8-6B	35-13-2	35-15-8	36-6-2B	36-7-2	36-7-10	36-10-1	36-10-2A	36-10-7B	36-13-4B
K/Rb	422	226	375	272	564	286	372	370	569	813	672
K/Ba	134	83	125	52	101	92	73	72	107	93	75
K/Cs	49	28	14	25	31	21	33	65	26	54	34
K/U	67	73	115	102	88	86	119	123	118	105	112
Na/K	1.16	0.65	0.49	0.85	0.85	0.70	0.56	0.81	0.52	0.49	0.53
Ba/Rb	3.1	2.7	3.0	5.2	5.6	5.6	5.1	5.1	5.3	8.8	9.0
Mg/Li											
U/Th	0.15	0.34	>0.26	0.08	0.32	>0.30	>0.28	>0.21	0.29	>0.31	0.30
Al_2O_3/Na_2O	4.72	9.07	11.08	6.52	6.12	8.16	7.65	6.40	10.36	9.95	9.29

(Cont. Table 4-14)

	36-14-20B	36-14-29A	36-14-30A	36-14-34B	37-2-2	37-6-5	38-5-11A	38-5-51A	38-7-9A	38-7-12A	39-2-39	39-3-25
K/Rb	737	585	486	444	847	759	501	452	393	311	634	732
K/Ba	113	71	87	48	103	207	65	50	89	32	26	79
K/Cs	42	>47	34	44	42	65	43	72	28	36	>158	59
K/U	109	94	179	111	125	285	250	165	116	166	156	163
Na/K	0.53	0.73	0.37	0.81	0.47	0.22	0.88	0.57	1.67	0.82	0.68	0.57
Ba/Rb	6.5	8.3	5.6	9.3	8.3	5.5	7.7	9.0	4.4	9.8	24.0	9.3
U/Th	0.14	0.25	-	>0.16	0.27	>0.16	-	-	-	-	-	-
Al_2O_3/Na_2O	10.25	7.97	12.97	9.56	9.46	15.92	5.43	7.70	8.99	7.58	8.60	9.95

(Cont. Table 4-14)

	39-8-7B	39-10-10B	41-3-14	P4-11-8	P4-11-13	41-2-51	
K/Rb	669	326	772	359	249	1050	
K/Ba	141	53	67	128	68	51	
K/Cs	89	38	51	40	23	53	x102
K/U	297	99	154	112	64		$x10^2$
Na/K	0.31	0.99	0.72	0.53	0.53	0.60	
Ba/Rb	4.8	6.1	11.5	2.8	3.6	20.5	
U/Th	0.18	>0.23	-	-	-	-	
Al_2O_3/Na_2O	9.91	7.05	8.19	10.04	12.02		

1. Division of metamorphic grade based upon Winkler (1979): M = Medium Grade; H = High Grade; G = Low Pressure Granulite

Table 4-15 : Range and Mean Abundance of Selected Trace Elements from English River Subprovince Metawacke, Metapelite, and Various Archean Lithic Groups.

	1		2		3		4		5		6	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Ba	297	60-780	489	210-1400	222	80-520	54	30-160	420	250-610	305	70-520
Co	16	5-25	25	10-40	<7	<5-10	66	30-100	15	7-20	<11	<5-35
Cr	169	5-980	225	120-600	12	5-30	279	40-620	56	10-100	19	5-65
Cu	33	5-130	48	10-110	6	5-15	123	5-240	44	10-160	56	5-350
Ni	42	5-270	79	40-230	<8	<5-25	124	45-270	49	10-100	<11	<5-35
Rb	58	10-160	79	40-170	26	10-40	6.1		ND		ND	
V	88	30-250	189	10-300	29	10-60	237	100-400	54	35-70	33	10-70
Zr	154	60-500	200	90-500	68	10-150	43	10-140	130	80-200	133	20-400

1) Metawacke paleosome from English River Subprovince (49 Analyses).
2) Metapelitic paleosome from English River Subprovince (97 Analyses).
3) Metamorphosed trondhjemite situated within and proximal to English River Subprovince (11 Analyses)
4) Tholeiitic metabasalts, Sturgeon Lake metavolcanic belt, Wabigoon Subprovince (70 unpublished analyses from Trowell). Average Rb value for metabasalts from (Hart et al. 1970, p.24).
5) Dacite, Uchi Subprovince (7 Analyses) in Sage and Breaks (1982).
6) Dacite, Wabigoon Subprovince, Sage and Breaks (15 unpublished analyses from Operation Ignace-Armstrong).

Table 4-16: Average Abundance of Selected Trace Elements from English River Subprovince Metawacke in Comparison to Metawackes from the Literature.

	1		2	3	4	5	6	7		8		9	10	11	12	13
	$\bar{x}$	range						$\bar{x}$	range	$\bar{x}$	range					
Ba	297	60-780	380	743	399	431	1600	336	80-960	337	160-800	383	54	790	1070	380
Co	16	5-25	20	21	39		10	<8	<5-15	14	9-27	4	66		12	12
Cr	169	5-980	50	64	208	235	50	<19	<-250	52	10-220	38	279	80	35	70
Cs	7	1-30	ND	ND												2.7
Cu	33	5-130	45	31	37	51	30			15	8-55	44	123		14	30
Ga	21	6-40	14	ND			20					32			14	17
Li	18	5-185	51	22				19	7-40	20	10-40				22	30
Ni	42	5-270	40	49	85	130	30	<10	<5-100	21	6-73	24	124	23	19	44
Pb	27	8-180	ND	ND			30	<17	<10-54	21	10-55	7.6			17	15
Rb	58	10-160	80	41				39	10-70	52	20-80		6.1*		110	120
Sc	-	-	-	-			20								7	14
Sr	313	120-890	200	383	232		450					201			316	290
Th			6.3	ND										9.7	10	11
U	2.6	0.9-7.1	1.8	ND										1.2	2.5	3.5
V	88	30-250	67	119	120	210	80	28	10-70	50	25-70	82	237		53	95
Zn	76	55-210	60	83			<200	63	12-360	78	65-120	72			52	60
Zr	154	60-500	450	ND	182		170	79	25-200	161	15-300	217	43		300	160
Mn						870										

1) Average wacke metasediment, English River Subprovince (77 analyses in this study, other 21 unpublished analyses from Operation Ignace-Armstrong.
2) Average greywacke from composite sample of 17 Devonian and Carboniferous greywackes from Germany, Wedepohl (1968, p.1011-1013).
3) Average of 35 Proterozoic volcanic greywackes from Hoggar area, Algeria. Caby et al. (1977, p.292).
4) Average of 35 greywackes from Vosges Mountains, France. Rivalenti and Sighinolfi (1969, p.176-179).
5) Average of 13 Proterozoic volcanic greywackes from Canadian Shield. Macpherson (1958, p.78).
6) Recent greywacke sediment, Columbia River basin. Whetten (1966, p.1058).
7) Average biotite trondhjemite, English River Subprovince, this study.
8) Average hornblende-bearing trondhjemite, English River Subprovince, this study.
9) Average salic volcanic fraction in Canadian Shield. Baragar and Goodwin (1969, p.139).
10) Average tholeiitic basalt from Sturgeon Lake metavolcanic belt, northwestern Ontario (70 analyses) from Trowell, personal communication). Average value for Rb from tholeiitic basalts of Abitibi metavolcanic belt (Hart et al., 1970, p.24).
11) Average composition of Canadian Shield of Archean age, Fahrig and Eade (1968, p.1249).
12) Average composition of Canadian Shield of Archean and Proterozoic ages, Shaw et al. (1967 and 1976).
13) Average composition of earth's upper crust, Wedepohl (1968, p.1011-1013).

Table 4-17: Average Abundance and Range of Selected Trace Elements from English River Subprovince Metapelite In Comparison to Similar Rocks from the Literature.

	1		2	3	4
	$\bar{x}$	range			
Ba	489	210-1400	444	580	570
Co	25	10-40	ND	19	18
Cr	225	120-600	231	90	110
Cs	10	2-31	ND	5.5	ND
Cu	48	10-110	65	45	18
Ga	39	15-50	ND	19	19
Li	36	5-165	ND	60	55
Ni	79	40-230	112	68	64
Pb	22	10-50	ND	20	16
Rb	79	40-170	ND	140	ND
Sc	ND	ND	ND	13	14
Sr	196	110-370	ND	300	710
Th	ND	ND	ND	12	ND
U	2.6	1.2-4.4	ND	3.7	ND
V	189	10-300	177	130	120
Zn	99	50-180	ND	95	ND
Zr	200	90-500	ND	160	200

1) Average metapelitic rock from English River Subprovince (51 analyses in this study).
2) Average of 62 low-grade pelitic schists, from Canadian Shield, Macpherson (1958, p.78).
3) Average shale, Wedepohl (1968, p.1011-1013).
4) Average pelitic rock from Littleton Formation, New Hampshire, Shaw (1954, p.932).
ND = Not Determined

Table 4-18: Average Composition of Metawacke and Metapelite from the English River Subprovince Compared to that of Upp

	A Average Upper Crust	B Average Metawacke, ERS	C Average Metapelite, ERS	Enrichment or Depletion Factors B/A	 C/A
Li	12	42	61	3.5	5.1
Na	24,500	24,800	14,500	1.01	0.59
Mg	13,900	14,900	23,800	1.07	1.71
Al	78,300	82,150	105,200	1.05	1.34
Si	305,400	312,300	268,700	1.02	0.88
P	810	430	432	0.53	0.53
S	310	800	1000	2.67	3.23
K	28,200	16,100	29,600	0.57	1.05
Ca	28,700	19,100	10,000	0.67	0.35
Ti	4,700	3,400	4,670	0.72	0.99
V	95	88	189	0.92	1.99
Cr	70	169	225	2.41	3.21
Mn	690	420	543	0.61	0.71
Fe	35,400	37,700	57,600	1.06	1.63
Co	12	16	25	1.33	2.08
Ni	44	42	79	0.95	1.08
Cu	30	33	48	1.10	1.60
Zn	60	76	99	1.27	1.65
Ga	17	21	39	1.24	2.30
Rb	91	69	94	0.64	1.03
Sr	450	313	196	0.69	0.43
Zr	160	154	200	0.96	1.25
Sn	2				
Cs	3	10.5	13	3.5	4.3
Ba	400	346	599	0.87	1.50
Pb	15	27	22	1.80	1.47
U	3.5	2.9	3.0	0.83	0.86

Average crustal values in parts per million from Mason (1966) and Table 14-1A.

TABLE 6-1: Modal analyses of Broadcast Lake Pluton from Desnoyers (1977, p.22).

Specimen No.	25-9-27	24-11-10a	24-13-5	25-11-1a	25-9-21	24-13-7
plagioclase	55.7	45.5	44.7	47.3	51.6	52.4
biotite	31.5	18.8	14.5	8.0	31.6	24.2
quartz	12.8	14.7	11.3	8.0	17.2	14.4
hornblende	-	8.5	15.5	19.7	-	-
potassium feldspar	-	12.5	14.0	17.0	-	9.0
sphene	x	x	x	x	-	-
Fe-Ti oxides	x	x	x	x	x	-
clinozoisite	x	x	x	x	-	-
Color index	31.5	27.3	30.3	27.7	31.0	24.2

Table 6-2: Petrologic subdivision of layered mafic sill at Lake St. Joseph summarized from Smith (1977, p.1-39).

Sub-stage	LITHOLOGY	SUBUNIT LITHOLOGIES	MINERALOGY	NATURE OF UPPER CONTACT	UNIT THICKNESS (metres)	DESCRIPTION	LAYERING	FACING DIRECTION	CLOTTING DIKES	FACING DIRECTION	DESCRIPTION OF LAYERING AND CLOTTING
I	Metagabbro to Anorthositic Gabbro					continuous across the complex but broken up locally by later intrusions (2 and 3 below)					
1A	Clotty, glomero-porphyritic (locally layered) metagabbro		- medium-grained with 70% clots plagioclase (saussuritized) + hornblende - hornblende locally forms radiating crystal clots	basal contact: discordant, intrusive, 0.3-0.6 m chilled contact, in contact with metagabbro and in part with banded tuffs upper contact: marked at beginning of rhythmic layering, is gradational to 1B-I)	457				i) lenticular clots 0.3 to 1.5 cm up to 8 cm in length ii) coarse-grained pegmatite patches - 2 types A) small equant to tabular B) large dentritic forms	 NE NE	ii) grain size 0.5-2 cm up to 8 cm A) concordant to trend of sill B) discordant to trend of sill
1B	Diffuse clotty (locally layered) metagabbro	possibly 3 subunits that may form continuous layers: i) massive medium-grained gabbro		lower contact marked by highest occurrence of glomeroporphyritic clots of 1A and absence of layering	91.4 1.8 to 2.4	Colour Index (C.I.) 55-60 - local extremes 45-75					
		ii) rhythmically layered metagabbro	hornblende, actinolite rimmed by hornblende 50-70% plagioclase 15-35% quartz 5% leucoxene 0-10% ilmenite 1-10% epidote 4% calcite, apatite	upper contact - gradational with 1B-ii-marked by highest occurrence of diffuse clots gradational to 1B-iii	3.1 to 7.6	medium-grained (1-2 mm)	Three types of layering A) completely gradational mafic/felsic components B) abrupt layering (thin-1-2 cm) interspaced with (12 cm) massive metagabbro C) abrupt unconformable layering interspaced with (12-15 cm) massive metagabbro	SW Reverse layering	i) coarse-grained pegmatite patches locally present ii) well differentiated doles 5-10 cm wide up to 4.5 m long	 NE	Layering - due to diffuse mafic/felsic segregation A & B type layering parallel to trend of sill C type layering discordant to trend of sill Pegmatite patches 15 to 20 cm across - both concordant and discordant to layering
		iii) diffuse clotty metagabbro		Base contact - equal proportions of mafic and felsic clots elongation of clots becomes more prominant towards top plus clots become less concentrated towards top. gradational up to unit 1c	12.2 to 15.2	C.I. 40-45	layering 46-50 cm thick - - segregation occurs only over 3-4 cm	NE	clots comprise 40 percent of rock i) irregular-shaped clots are mafic with or without felsic segregations - no facing direction possible ii) rare small diffuse gradationally segregated products 91 x 18 cm. Fine to medium grained iii) Pegmatite Patches locally altered leucocratic clots 0.5 to 1.5 cm	 NE NE	-Clots are dominantly mafic with diffuse borders situated in dominantly felsic matrix; clots are elongate (1-3 cm) parallel to trend of sill Clots are glomeroporphyritic accumulation of mafic minerals - layering is subparallel to trend of sill-locally unconformable - elongate clots parallel to trend of sill

Table 6-2:

Sub-stage	LITHOLOGY	SUBUNIT LITHOLOGIES	MINERALOGY	NATURE OF UPPER CONTACT	UNIT THICKNESS (metres)	DESCRIPTION	LAYERING	FACING DIRECTION	CLOTTING DIKES	FACING DIRECTION	DESCRIPTION OF LAYERING AND CLOTTING
1C	Massive Metagabbro		hornblende 65% opaque 10% plagioclase 20% chlorite 4% quartz 1% apatite, calcite accessories	gradational to 1d-i)	4.6-7.6	CI 60, grain size less than 1 mm					
1D	Distinct clotty, layered meta-gabbro	i) mafic clotty phase	hornblende + saussuritized plagioclase (30%) + epidote group minerals (10%) + quartz (4%) + calcite, apatite	gradational to 1d-ii)	12.2-15.2 7.6-10.7		weak layering due to clot concentration 7.5 to 28 cm (Photo 6-3)	NE	-1-15 cm clots, most have almost no felsic counterpart (Photo 6-3)		irregular shaped clots, elongate parallel to trend of sill, locally unconformably
		ii) metagabbro	slightly saussuritized plagioclase (45%) + poikiloblastic hornblende (35%) + quartz (10%) + opaque (8%) + apatite, biotite, epidote	gradational to 1d-iii)	3.0 to 4.6	fine- to medium-grained, C.I. 35-50	local weak layering due to clot concentration		- large clots have segregated felsic component (Photo 6-4) - locally small segregated clots 0.5-4.0 cm	NE NE	conformable to trend of sill, clots have sharp boundaries
		iii) layered anorthositic gabbro	plagioclase (60%) + hornblende (30%) + quartz (10%)	gradational to 1E	0.6 to 3		layering 5 to 25 cm defined by slight changes in C.I.	NE			
1E	Anorthositic Gabbro		plagioclase (55%) + hornblende (25%) + opaques (5%) + quartz (8%) + apatite epidote, calcite	gradational to 1f	3 to 6.0 (metres)	similar to 1D-iii but no layering, medium to coarse grained (1-10 mm)					
1F	Diffuse glomero-porphyritic gabbro				unknown as unit passes into lakes	saussuritized plagioclase-rich areas (10-15%) + melanocratic areas (10%) in metagabbro matrix (75%), medium-grained			irregular blotchy plagioclase and locally melanocratic complimentary areas	NE	
II	Gabbroic Anorthosite		plagioclase (50%) + hornblende (20%) + quartz (20%) + calcite (5%) + epidote (29%) + opaques (2%)	diffuse boundary but not gradational	7.62	intrudes between units 1e and 1f, no chilled contact					contains inclusions of unit 1e
III	Metagabbro		hornblende (65%) + plagioclase (15%) + opaque (10%) + quartz (5%) + epidote (49%) + biotite, calcite, apatite		61-91	intrudes unit 1B and between 1A and 1B, CI 50-65, chilled contact			-locally blotchy accumulations of minerals -pegmatite patches with a lot of mafic component, some with no complimentary felsic component	NE	parallel to locally discordant to trend of sill

TABLE 6-3: Chemical analyses of fine-grained Amphibolites (from Gower 1978, p.558, 559)

	G177	G229A	G410	G431	G577	G579D	G589C	G635	G835A	G842A	G850C
SiO_2	50.29	50.07	50.06	48.53	49.51	51.02	51.37	50.42	51.02	51.78	46.50
Al_2O_3	13.49	14.97	14.44	14.21	14.00	14.96	14.44	14.03	14.34	14.17	14.00
Fe_2O_3	7.34	3.43	2.85	4.21	2.88	3.08	3.38	3.99	3.11	3.13	4.51
FeO	7.16	9.29	8.96	8.62	9.67	8.50	8.20	8.43	10.38	8.54	9.57
MgO	5.24	5.78	7.83	7.54	7.82	6.77	6.46	7.52	5.80	7.61	8.45
CaO	12.08	10.72	10.95	13.05	10.97	11.86	12.23	10.42	11.18	11.17	12.33
Na_2O	2.29	3.30	2.97	2.07	3.18	2.23	2.09	3.29	2.31	1.94	2.34
K_2O	0.49	0.60	0.78	0.46	0.71	0.34	0.58	0.72	0.15	0.45	0.75
TiO_2	1.28	1.50	0.80	1.03	0.99	0.96	0.97	0.92	1.41	0.95	1.25
P_2O_5	0.10	0.14	0.07	0.08	0.07	0.07	0.08	0.07	0.10	0.08	0.08
S											
MnO	0.24	0.20	0.19	0.21	0.20	0.20	0.20	0.20	0.20	0.19	0.22
CO_2											
H_2O+											
H_2O-											
Ag											
Ba	91	113	107	38	76	67	72	62	30	72	91
Be											
Co											
Cr											
Cs	6	4	5	7	6	3	6	12	13	0	2
Cu											
Ga											
Li											
Mo											
Ni											
Pb	9	4	6	2	4	4	7	4	3	3	7
Rb	4	10	6	5	4	3	15	7	2	4	4
Sc											
Sn											
Sr	329	152	123	110	99	115	176	105	145	82	88
Th	2	1	0	0	2	1	3	0	2	1	1
U											
V											
Y	25	30	17	22	20	18	18	21	31	19	18
Zn											
Zr	61	77	38	43	40	44	48	43	71	40	26

and mafic dikes

TABLE 6.4: Chemical analyses of medium-grained amphibolites (Kenora) - from Gower 1978, p.561, 562.

	G107B	G166	G174	G252	G263	G350C	G6542	G788B	G876	G885C	G1033	G5960	G1902	G1903
SiO_2	48.51	52.15	52.13	49.49	48.72	50.12	50.98	50.01	50.07	51.11	48.82	51.52.	51.10	52.24
Al_2O_3	15.15	14.25	15.02	11.28	15.93	14.18	12.52	13.33	16.45	16.97	12.70	13.46	13.68	13.38
TiO_2	1.01	.93	.71	.69	.71	1.15	1.51	1.10	.62	1.67	2.04	.86	.89	.87
Fe_2O_3	3.40	3.48	2.86	4.15	3.63	3.39	4.83	4.13	2.80	3.72	3.91	3.48	3.62	3.42
FeO	9.07	7.66	6.62	6.77	6.43	9.20	10.19	8.97	7.42	8.71	8.30	5.97	5.89	6.26
MnO	.19	.16	.17	.24	.20	.21	.23	.20	.16	.19	.21	.15	.17	.17
MgO	8.69	6.82	8.02	12.58	10.18	7.08	5.90	7.72	7.05	2.84	8.30	9.82	9.99	9.37
CaO	8.77	9;75	10.56	10.79	8.82	9.84	9.82	10.33	11.74	8.06	10.59	9.40	9.28	9.75
Na_2O	3.05	3.67	3.25	2.38	2.71	3.71	2.94	3.25	2.84	4.91	3.05	3.61	3.25	2.90
K_2O	2.08	1.04	.68	1.39	2.63	1.04	.97	.89	.58	1.18	1.28	1.40	1.71	1.24
P_2O_5	.08	.07	.06	.25	.02	.08	.10	.08	.08	.64	.80	.34	.43	.40
RB	65.	17.	8.	45.	140.	14.	5.	4.	4.	16.	22.	55.	101.	85.
SR	160.	170.	107.	244.	372.	94.	103.	81.	130.	211.	261.	847.	636.	437.
BA	181.	163.	84.	211.	617.	103.	75.	75.	103.	152.	272.	488.	395.	311.
CS	5.	5.	3.	112.	0.	11.	0.	10.	0.	67.	100.	152.	147.	125.
NB	4.	0.	0.	0.	0.	0.	0.	0.	0.	20.	20.	0.	0.	11.
ZR	37.	50.	37.	48.	28.	60.	68.	50.	38.	225.	144.	103.	98.	92.
Y	17.	21.	15.	19.	12.	26.	30.	22.	18.	39.	25.	16.	22.	21.
TH	0.	2.	0.	11.	0.	0.	0.	0.	0.	0.	3.	10.	8.	8.
PB	7.	8.	10.	5.	0.	11.	4.	6.	4.	10.	5.	6.	7.	10.

TABLE 6-5: Chemical analyses of Lac Seul mafic dikes.

	1	2	3	4	5	6	7	8
	MT-1	MT-2b	45-6-3c	43-2-1	40-10-19	42-1-6b	42-1-11c	P2-9-45
SiO_2	48.50	51.40	57.10	52.10	48.9	48.2	47.4	48.20
Al_2O_3	15.20	13.20	15.30	19.70	15.3	13.4	13.5	15.40
Fe_2O_3	3.33	1.69	3.02	0.74	2.78	11.6	13.5	1.94
FeO	8.45	7.25	6.04	4.99	9.74	6.28	4.43	8.62
MgO	7.70	10.80	4.65	7.72	8.01	3.81	5.33	7.46
CaO	10.60	9.86	6.21	10.50	11.2	8.59	10.20	12.40
Na_2O	3.23	1.18	3.94	0.97	2.42	3.85	2.58	1.60
K_2O	0.89	0.97	1.78	1.21	0.61	0.67	0.58	0.62
TiO_2	0.98	0.88	0.90	0.47	0.87	2.50	1.61	0.82
P_2O_5	0.11	0.40	0.26	0.24	0.05	0.30	0.11	0.05
S	0.01	0.03	0.01	0.01	0.06	0.02	0.19	0.01
MnO	0.21	0.16	0.15	0.09	0.20	0.28	0.27	0.20
CO_2	0.08	0.11	0.09	0.11	0.11	0.07	0.23	0.80
H_2O+	0.47	0.42	0.38	0.18	0.13	0.41	0.21	0.33
H_2O-	0.33	0.43	0.37	0.41	0.43	0.39	0.37	0.39
Total	100.1	98.8	100.2	99.43	100.8	100.4	100.5	98.8
Ag	<1	<1	<1					
Ba	60	1100	260	750	100	100	50	120
Be	<1	4	4					
Co	44	37	25	30	51	30	53	50
Cr	295	880	170	600	301	6	64	330
Cs	<1	8	5	5				
Cu	80	32	16	6	80	15	146	85
Ga	9	15	15					
Li	4	8	16	6	6	6	6	10
Mo	<1	<1	<1					
Ni	112	188	74	250	149	<5	43	150
Pb	<10	12	15	15	14	<10	<10	30
Rb	<10	50	80	70				10
Sc	40	25	25					
Sn	<3	<3	<3					
Sr	90	960	250					
Th	<10	21	28	<10				
U	<1	<1	<1	<1				
Y	20	30	60					
Zn	114	110	120	65	98	138	156	110
Zr	100	200	200					
V	300	200	150					

1) Diorite to metagabbro sill in Sen Bay Batholith.
2) Metagabbro sill in Sen Bay Batholith.
3) Diorite to metagabbro dike
4) Mafic metagabbro dike.
5) Metagabbro dike
6) Diorite (amphibolite) dike.
7) Metagabbro (amphibolite) dike.
8) Metagabbro dike

TABLE 6-6: Chemical analyses of anorthositic, mafic and ultramafic enclaves , Lac Seul.

	1	2	3	4	5
Sample No.	45-5-23A	45-5-23c	42-2-18	46-3-2	38-17-4
SiO_2	51.20	48.40	44.70	53.20	54.00
Al_2O_3	5.44	15.40	9.24	4.15	14.90
Fe_2O_3	3.03	2.76	4.79	2.38	2.49
FeO	8.61	8.77	10.90	6.04	6.50
MgO	15.40	8.01	14.70	23.80	7.11
CaO	11.90	11.00	9.97	4.93	7.97
Na_2O	0.71	2.22	0.25	0.01	3.71
K_2O	0.42	0.69	0.68	2.78	1.22
TiO_2	0.21	0.84	1.06	0.06	0.94
P_2O_5	0.03	0.08	0.07	0.01	0.24
S	0.01	0.03	0.03	0.02	0.03
MnO	0.36	0.20	0.35	0.36	0.16
CO_2	0.09	0.11	0.25	0.22	0.35
H_2O+	0.55	0.41	2.73	0.84	0.72
H_2O-	0.28	0.43	0.47	0.34	0.19
Total	98.23	99.35	100.2	99.1	100.5
Ag					
Ba	40	100	60	70	220
Be					
Co	50	50	76	70	35
Cr	1460	335	1740	2350	285
Cs	2	4	6	9	<2
Cu	8	30	5	<5	25
Ga					
Li	7	9	52	49	20
Mo					
Ni	880	135	790	1130	135
Pb	<10	<10	46	11	30
Rb	<10	<10	30	150	50
Sc					
Sn					
Sr			20	10	
Th	23	<10	<10	<10	
U	1	<1	<1	<1	3
Y					
Zn	190	95	194	136	110
Zr					
V					

1,2) Anorthositic Suite enclave in Deception Bay (Lac Seul).
3) Ultramafic enclave in Deception Bay (Lac Seul).
4) amphibolite enclave in Deception Bay (Lac Seul) Gneissic suite.
5) Mafic (amphibolite) enclave in sodic intrusive north of the Armit Lake complex.

TABLE 6-7: Chemical analyses of mafic enclaves, Lac Seul

	1	2	3	4	5	6	7	8	9	10	11	12
	MT-29	MT-50b	MT-79	24-23-15	42-6-5	45-5-23b	30-3-1	43-4-7	27-20-21	15-A	105-255-24	27-20-31
SiO_2	53.50	49.00	55.70	49.50	50.00	49.60	48.9	47.1	49.5	54.10	49.30	53.8
Al_2O_3	9.60	15.40	14.30	14.40	13.60	14.90	14.4	16.6	14.8	22.40	16.10	12.9
Fe_2O_3	2.76	3.36	1.39	3.86	5.63	3.67	3.60	4.57	4.43	3.05	2.81	3.91
FeO	7.25	8.69	6.44	9.50	9.26	8.13	9.18	8.94	8.52	6.12	7.73	5.75
MgO	11.30	7.47	9.15	6.72	5.37	7.09	6.73	7.27	6.53	4.21	7.75	7.46
CaO	9.84	11.00	7.68	10.10	8.89	8.12	9.85	9.80	10.2	0.82	11.70	10.6
Na_2O	1.42	2.84	0.73	2.92	2.49	3.09	3.03	2.82	2.70	1.89	2.45	3.13
K_2O	1.35	0.70	2.10	0.86	1.07	1.85	1.05	0.34	1.01	4.00	0.51	0.82
TiO_2	1.04	0.86	0.89	1.14	1.41	1.22	1.13	1.42	1.03	0.89	0.65	0.70
P_2O_5	0.18	0.10	0.42	0.12	0.15	0.28	0.10	0.13	0.09	0.06	0.05	0.06
S	0.14	0.01	0.04	0.01	0.01	0.13	0.02	0.02	0.02	0.19	0.01	0.05
MnO	0.16	0.20	0.12	0.24	0.26	0.18	0.25	0.23	0.24	0.10	0.18	0.10
CO_2	0.44	0.09	0.07	0.06	0.10	0.18	0.08	0.13	0.11	0.75	0.19	0.38
H_2O+	0.43	0.24	0.37	0.34	0.54	0.62	0.32	0.26	1.14	0.90	0.56	0.28
H_2O-	0.36	0.31	0.44	0.34	0.38	0.38	0.27	0.44	1.31	0.32	0.23	0.42
Total	99.8	100.3	99.8	100.1	99.2	99.44	98.81	100.1	100.6	99.8	100.2	100.5
Ag	<1	<1	<1	<1	<1							<1
Ba	490	80	910	90	120	300	100	50	120	470	60	160
Be	<1	<1	3	<1	<1				<1	<1		<1
Co	42	38	37	43	43	45	48	46	45	33	43	40
Cr	860	319	680	288	121	270	259	89	210	277	279	25
Cs	5	3	6	3	2	6	3			12	<1	
Cu	52	58	36	14	42	115	13	34	45	64	124	90
Ga	15	15	15	15	15				9			9
Li	14	4	8	12	4	2	14	3	15	21	10	10
Mo	<1	<1	<1	<1	<1				<1			<1
Ni	198	97	258	82	49	120	84	64	95	105	100	120
Pb	<10	<10	17	<10	<10	15	23	<10	15	17	<10	15
Rb	40	10	100	10	20	60	10		20	90	<10	20
Sc	30	45	20	40	45				25			25
Sn	<3	<3	<3	<3	<3				<1	3		<1
Sr	310	100	680	130	130				50	90	90	100
Th	<10	<10	<10	<10	<10	17	<10			<10	14	
U	<1	<1	<1	<1	<1	<1	<1			<1	<1	
V	200	300	150	300	350				150	250		100
Y	40	30	15	30	35				<10			<10
Zn	141	94	111	138	135	160	135	36	140	116	82	85
Zr	100	100	250	100	150				25	200		20

1) Medium-grained amphibolite
2) Medium-grained hypersthene ± diopside volcanic inclusion (tholeiitic basalt according to Irvine and Baragar (1971) from 11 km north of Chamberlain Narrows)
3) Fine- to medium-grained hypersthene metagabbro
4) Fine- to medium-grained diopside ± hypersthene amphibolite
5) Massive medium- to coarse-grained amphibolite
6) Amphibolite
7) Amphibolite enclave
8) Amphibolite enclave

TABLE 6-8 RANGE AND MEAN VALUES

	N	BA Mean	BA Range	RB MEAN	RB RANGE	SR MEAN	SR RANGE	K MEAN	K RANGE
Gower (1978) Kenora Area									
Fine-grained amphibolites	14	69	30-113	6	2-15	128	74-329	4482	1245-6474
Medium-grained amphibolites	11	191	75-617	31	4-140	176	81-372	10382	4814-21829
Westerman (1977) Cedar Lake Area									
Group I amphibolites	8	119	34-210	17	4-35	169	66-288	8549	6142-11371
Group II amphibolites	9	64	37-136	19	4-77	111	33-162	5210	3071-10707
Lac Seul Area									
Sills, Dikes	3	346	60-1100	53	<10-80	433	90-960	7956'	4814-14774
Inclusions (amphibolite)	7	298	80-910	36	<10-100	270	100-680	8912	7138-11703
(ultramafic)	4	68	40-100	50	<10-150	25	10-20	4952	3486-5727
Extrusive Amphibolites	8	179	60-490	23	<10-90	124	80-310	5252[a]	3486-11205
								Does not include anomalous value 33299	
Separation Lake Belt									
Extrusive Amphibolites	13	57	40-80	$<10^3$	<10	52	30-100	1073	415-3486
Intrusive amphibolites	5	70	40-150	$<10^3$	<10	80	50-100	1012	581-1245
Sioux Lookout Belt									
Extrusive amphibolites	7	69	30-110	$<10^3$	<10	101	50-150	1434	332-5312
Intrusive (gabbroic)	6	167	100-270	+3	<10-20	322	230-400	4385	1743-6474
Jutten Volcanics									
(N. Trowell per. comm.)	79	47	20-280	ND		122	60-350	591	0-12,201
Sturgeon Lake Volcanics (Hart et al.)	70	54	30-160	ND					

Table 6-8 continued ...

	K/Rb	K/Sr	K/Ba	Rb/Sr	Ba/Sr
Gower (1978) Kenora Area					
Fine-grained amphibolites	747	35	65	.0463	0.54
Medium-grained amphibolites	335	59	54	.176	1.08
Westerman (1977) Cedar Lake Area					
Group I amphibolites	503	51	72	.1005	0.704
Group II amphibolites	274	47	81	.171	.577
Lac Seul Area					
Sills, Dikes	150	18	23	.122	.799
Inclusions (amphibolite)	248	33	30	.133	1.10
(ultramafic)	99	198	73	2	272
Extrusive Amphibolites	228	42	29	.185	1.44
Separation Lake Belt					
Extrusive Amphibolites	107	21	19	.192	1.10
Intrusive amphibolites	101	13	14	.125	.975
Sioux Lookout Belt					
Extrusive amphibolites	143	14	21	.10	.68
Intrusive (gabbroic)	337	14	26	.0403	519
Jutten Volcanics					
(N. Trowell per. comm.)	-	5	13	-	385
Sturgeon Lake Volcanics (Hart et al.)	-	-	-	-	-

TABLE 6-9: Range and mean for Cr, Cu, Ni, Zn for various mafic suites.

METAGABBRO SILLS/DIKES, LAC SEUL

LAC SEUL - ENCLAVE

Trace Elements	Range	Mean	Number
Cr	25-860	306	12
Cu	13-124	57	12
Ni	49-258	114	12
Zn	36-160	114	12

LAC SEUL - DIKES

Trace Elements	Range	Mean	Number
Cr	6-880	331	8
Cu	6-146	58	8
Ni	5-250	121	8
Zn	65-156	114	8

LAC SEUL - ULTRAMAFIC ENCLAVE

Trace Elements	Range	Mean	Number
Cr	285-2350	1234	5
Cu	5-30	15	5
Ni	135-1130	614	5
Zn	95-194	145	5

LAC SEUL - EXTRUSIVES

Trace Elements	Range	Mean	Number
Cr	92-860	322	13
	15-124	61	13
Ni	50-198	109	13
Zn	80-141	107	13

SIOUX LOOKOUT AMPHIBOLITES

EXTRUSIVE

Trace Elements	Range	Mean	Number
Cr	25-740	241	7
Cu	14-189	115	7
Ni	24-296	98	7
Zn	85-166	116	7

INTRUSIVE

Trace Elements	Range	Mean	Number
Cr	6-245	74	7
Cu	5-54	38	7
Ni	<5-91	47	7
Zn	56-182	105	7

SEPARATION LAKE - EXTRUSIVE

Trace Elements	Range	Mean	Number
Cr	195-390	293	12
Cu	10-220	99	12
Ni	70-220	117	12
Zn	60-110	88	12

SEPARATION LAKE - INTRUSIVE

Trace Elements	Range	Mean	Number
Cr	230-1320	618	5
Cu	60-155	104	5
Ni	45-180	96	5
Zn	55-85	72	5

TABLE 7-1: Mappable rock associations within the gneissic suite from Westerman (1976).

Map Code	Map Association	Components*
4a	Leucocratic, biotite trondhjemite, biotite granodiorite gneiss (C.I.<5), very few mafic schlieren present (may be remobilized equivalent of 4b adjacent to late potassic intrusions.	(v) ± (i)
4b	Biotite trondhjemite, biotite granodiorite gneiss (C.I.5-15) containing amphibolite xenoliths (locally with mafic hornblende quartz diorite rims) and mafic hornblende quartz diorite xenoliths, all intruded by metamorphosed trondhjemite and unmetamorphosed quartz monzonite.	(iv) + (i) ± (iii) ± (ii)
4c	Mafic, fine- to medium-grained, strongly banded hornblende-biotite gneiss, trondhjemite in composition (C.I.>15), possibly paragneiss.	(ii) ± (i)
4d	Fine- to medium-grained biotite trondhjemite gneiss (C.I.<15) with gneissic banding on a millimeter scale.	(viii)
4e	Strongly foliated to gneissic, coarse-grained biotite trondhjemite, quartz diorite (usually contains minor amphibolite xenoliths).	(v) + (iii) ± minor (i)
4f	Interbanded, foliated to gneissic amphibolite (1) and mafic fine-grained hornblende-biotite gneiss (4c) intruded by or included in a medium-grained gneissic trondhjemite.	(i) + (ii) + (v)
4g	Interbanded gneissic biotite trondhjemite to granodiorite with minor amphibolite and biotite gneiss inclusions, locally garnetiferous and locally metamorphosed to the granulite facies.	(v) ± (i), affected by granulite metamorphism
4h	Interbanded massive, leucocratic trondhjemite, foliated biotite trondhjemite and massive leucocratic hornblende trondhjemite with late quartz monzonite injections and mafic inclusions.	Trondhjemite equivalent of (iv) + (vi) + minor (vii)
4k	Interbanded foliated to gneissic mafic amphibolite and quartzofeldspathic gneisses, locally metamorphosed to the granulite facies.	(i) + (ii) ± (v), affected by granulite metamorphism

Abbreviation: C.I. - Colour Index

- * Refer to units i) to viii) intrusive in text.

TABLE 7-2: Differences between fine-grained and coarse-grained amphibolites at Kenora from Gower (1978, p.206).

Fine-grained amphibolites	Medium-grained amphibolites
1. Mappable units up to 1 km wide and several km long	Only a few metres wide and a small proportion of the total outcrop
2. Fine-grained	Medium-grained
3. Leucogranitoid veins generally concordant to banding	Leucogranitoid veins as an agmatitic network
4. Usually good banding	Banding generally not present
5. Common calcic pods mineralogy	No pods
6. Common mafic veneers	No veneers

TABLE 7-3: Comparison of Rock Associations for Cedar Lake, Melick and Deception Bay (Sioux Lookout) Gneissic Suites.

CEDAR LAKE GNEISS	MELICK GNEISS (GOWER, 1978)	DECEPTION BAY-LAC SEUL GNEISS (for location see Figure (8-5, this study
		ULTRAMAFIC ASSOCIATION Ultramafic-Anorthositic gabbro association
SUPRACRUSTAL ASSOCIATION 1) Amphibolite a) weakly banded b) strongly banded 2) Ultramafic	SUPRACRUSTAL ASSOC. 1) Amphibolite a) fine-grained b) medium-grained 2) Ultramafic 3) Sediments	SUPRACRUSTAL ASSOCIATION 1) amphibolite
TONALITE ASSOCIATION 1) Tonalite gneiss 2) Granodiorite gneiss 3) Mafic biotite tonalite gneiss	TONALITE ASSOCIATION 1) Hornblende-biotite tonalite gneiss 2) Biotite tonalite gneiss 3) Melick tonalite	TONALITE ASSOCIATION 1) Quartz diorite (locally diorite to trondhjemite 2) Biotite-hornblende trondhjemite (locally quartz diorite) 3) Biotite trondhjemite
LEUCO GRANITOID* ASSOCIATION 1) Leucotonalite	LEUCOGRANITOID ASSOCIATION 1) Leucotonalite	LEUCO GRANITOID ASSOCIATION 1) leucocratic biotite trondhjemite 2) Hololeucocratic quartz monzonite to granite 3) Hololeucocratic trondhjemite
MAFIC ASSOCIATION 1) Unbanded Amphibolite	MAFIC ASSOCIATION 1) Mafic/Mafelsic Dikes 2) Miscellaneous Dioritic Rocks	MAFIC ASSOCIATION (DIKES) 1) Equigranular gabbro 2) Porphyritic gabbro
LEUCOGRANITOID** ASSOCIATION 1) Concordant (Early) 2) Discordant (Late)	LEUCOGRANITOID ASSOCIATION 1) Leuco granite 2) Granite pegmatite gneiss 3) Mixed biotite tonalite-granite pegmatite gneiss	POTASSIC ASSOCIATION 1) Quartz monzonite a) Concordant b) Discordant 2) Syenite 3) Pegmatite

* dominantly sodic in composition
** dominantly potassic in composition

TABLE 7-4: Major Lithologic Associations and Genesis of Cedar Lake Gneiss Summarized from Westerman (1977).

Lithology	Abundance	Association/Remarks	Mineralogy/Texture/Grain Size	Fabric	C.I.	Approx. numerical order of genesis	Origin
1) Amphibolite 1A) weakly banded	minor	- small lenses of plagioclase + quartz flattened in plane of gneissosity - as small inclusions in gneissic	- plagioclase (An_{33-38}) + hornblende ± diopside	- weak compositional banding due to plagioclase + quartz lenticles; banding augmented by concentrations of biotite		1	- are tholeiitic basalts, locally marginally calc-alkaline - originally extrusive volcanics included in Cedar Lake gneiss protolith
1B) strongly banded	average	- concordant to gneissic layering - contains leucocratic tonalite veins - occurs as inclusions or units 50-150 m wide and up to 1.5 km length - structurally concordant - siliceous-magnetite iron formation associated at 1 locality - mostly found in Cedar-Clay Lakes area	- banding on scale of 0.5 to 2.0 m - frequently contains lensoid pods of coarse-grained clinopyroxene ± epidote	- banding defined by ratio of hornblende to clinopyroxene + minor biotite			
2) Ultramafic	rare	- as inclusions - also as thin hornblende-rich rims associated with leucotonalite veins	- granoblastic intergrowth of diopside + hornblende + minor plagioclase				
3) Tonalite gneiss	common		- grey - plagioclase (An_{22-30}) + quartz + biotite + hornblende	- banded gneiss, strongly foliated - banding accentuated by injection of compositionally variable granitic phases - banding is discontinuous; contacts are both sharp and gradational		2	
4) Granodiorite gneiss	common	dominant granodiorite composition is a function of interbanding of tonalitic and later granitic (sensu stricto) component	- similar to above but with Kspar	- banding mostly defined by percentage of mafic minerals			
5) Mafic biotite tonalite	less common	- as thin (50-100 m wide) units, concordant, traceable for up to 2 km - gradational boundaries with gneiss units 3, 4 - frequently associated with massive amphibolite units	- fine-grained, equigranular, granoblastic - plagioclase (An_{30}) + quartz + biotite + hornblende	- strongly foliated, weakly banded - banding defined by variation in grain size and mafic mineral content and further augmented by leucotonalite veins (6A)			
6) Leucotonalite	common	A) associated as sharply defined veins or bands in gneiss - concordant but may have been originally discordant	- grey to white - plagioclase (oligoclase) + quartz + biotite - medium to coarse-grained (1-2 mm) - locally with biotite-rich selvages	- weak foliation defined by biotite - are deformed into isoclinal, rootless folds		3	early intrusives into Tonalite Association
	common	B) associated as thin veins within amphibolite - sharp contacts					
7) Pink leucogranite	common	A) concordant - locally have mafic (biotite-rich) schlieren - sharp and gradational boundaries - discontinuous veins or bands rarely exceeding 3 cm	- medium to very coarse-grained (1-4 mm) - Kspar + plagioclase + quartz	- less deformed than leuco tonalite bands - massive to weakly foliated		4	
	less common	B) Discordant - up to 5 to 10° discordance between dikes and gneissic banding - on structural grounds these are not equivalent to later intrusive POTASSIC SUITE MEMBERS	as above (7A)				
8) Amphibolite (unbanded)	common	A) Small inclusions - boudins and semi-continuous trains of boudins elongated in plane of gneissosity - commonly associated with mafic biotite tonalite gneiss	- granoblastic, equigranular	foliated, locally lineated		4	possibly injected originally as dikes
		B) Continuous bands - up to 50 m wide, traceable for up to 1 km	- granoblastic - hornblende + plagioclase (An_{30}) - locally porphyritic plagioclase (An_{55-60}) rimmed by plagioclase (An_{30})	- lineated - hornblende aligned parallel to alignment of megacrysts of plagioclase			

TABLE 7-5: Lithological and Genetic Characteristics of the Gneissic Suite at Kenora summarized from Gower (1978).

LITHOLOGY	ABUNDANCE	ASSOCIATION/REMARKS	DOMINANT MINERALOGY	DOMINANT FABRIC	APPROX. C.I.	AGE Rb/Sr	RELATIVE AGE BASED ON FIELD OBSERVATION	ORIGIN
1) Amphibolite	major component							
1a) Fine-grained			- hornblende + plagioclase + calcic pods ± quartz - grey-black	-massive, foliated, locally strongly banded (due to mineralogical and grain-size changes + addition of component 6a			1	-tholeiitic chemistry similar to ocean floor or island arc environments fine-grained are extrusive;
1b) Medium-grained			- hornblende + plagioclase ± quartz				1	medium-grained are probably cogenetic intrusives
1) Ultramafic	rare	- lenses, blocks, irregular boudins and sills within gneissic rocks including metasediments	- amphibole + plagioclase ± clinopyroxene ± biotite; biotite + clinoamphibole + quartz + opaque + feldspar + carbonatite + sphene + opatite	- massive to schistose			1	-metasomatically modified basaltic komatiites
2) Metasediments	rare	- Associated with fine-grained amphibolites; possibly as thin discontinuous layer in gneissic suite	- banded chert - iron-formation, arkose, greywacke, argillite, stratified tuff are quartz rich and all chemically distinct from all other gneissic rocks	- bedding			1a	-chemical and clastic sedimentation
3) Hornblende-biotite tonalite gneiss	most common phase		- composition ranges from quartz diorite to granodiorite - plagioclase (An_{28-36}) + quartz + hornblende + biotite - grey	- banded gneiss - banding defined by layers of components of 6b, 7, biotite Schlieren, amphibolite			2	
4) Biotite tonalite gneiss	also very common phase	- Gradational to hornblende-biotite tonalite gneiss and mixed biotite tonalite-granite pegmatite gneiss - gradation occurs both across and along strike	- medium-grained - plagioclase (An_{27-43} average An_{28}) + quartz + biotite - excluding inhomogeneities arising from banding this phase is compositionally uniform - pale grey	- foliated, foliated to gneissic, gneissic, banded gneiss - banding due to mineralogical inhomogeneities including layers of components 6, 7, plus hornblende and biotite schlieren		2760±50	2	- are plutonic, believed intrusive into supracrustal assemblage - banding is tectonic in origin
5) Melick tonalite	common		- medium-grained - plagioclase (An_{23-35}) + quartz + biotite	- foliated, lineated, rarely gneissic		2630±70	3	
6) Leucotonalite (Low K-type)	common	A) Associated as pods as patches within amphibolite	- plagioclase (An_{30-38}) + quartz form 90-97% of rock - coarse-grained, white	- massive			4	- possibly end stage residual liquid from partial melting of mafic magma
		B) Interlayered with biotite tonalite gneiss and hornblende-biotite gneiss	- plagioclase (An_{22-29}) + quartz - white				4	
7) Leuco granite (high K-type)	common	Interlayered with biotite tonalite gneiss and hornblende-biotite tonalite gneiss	- Kspar + plagioclase (An_{22-29}) + quartz + biotite - white				4	- intrusive into tonalite gneisses, possibly part of later potassic suite
8) Granite pegmatoid gneiss	less common	- marginal phase of Dalles Granadiorite plus locally throughout gneissic tonalites as small isolated layers	- Kspar + plagioclase (An_{15-21}) + quartz + biotite	- gneissic to banded gneiss, fabric is discontinuous			4	- Deformed pegmatite injected discordantly and concordantly into tonalitic gneisses
9) Mixed biotite tonalite-granite pegmatite gneiss	less common	- peripheral to Dalles granodiorite; other occurrences show no obvious spatial correlation	- Kspar + plagioclase (An_{14-32}) + quartz + biotite	- gneissic, discontinuous banding due to interlayering of two end-member components; locally foliated			4	- mixing of two end members (unacceptable based on REE patterns) - fractional crystallization followed by mixing
10) Miscellaneous Dioritic Rocks	rare	A) Diorite, Quartz diorite, hornblende-tonalite i) gradational with components 6a, 3 (concordant) ii) discordant intruding components 3, 4	A + B) plagioclase (An_{26-46}) + hornblende + quartz + biotite				?	- Origin uncertain field evidence suggests assimilation process but is probably more complex
		B) Leuco diorite, quartz diorite as dikes					?	
		C) Quartz leucodiorite dikes	C) -plagioclase (An_{33-37}) + biotite + quartz -coarse-grained				?	
11) Mafic/mafelsic dikes	less common	A) Mafic dikes - severely deformed	A) mafic composition Plagioclase (An_{23-36}) + hornblende+biotite + less abundant: quartz + Kspar + epidote	-Folded, boudined -severity of deformation variable			5	A) Intrusive early dikes genetically related to batholiths
		B) Mafelsic dikes - weakly deformed	B) intermediate composition	- weak internal foliation			5	B) Intrusive younger dikes

TABLE 7-6: Lithologic Associations and Characteristics of the Deception Bay - Lac Seul (Sioux Lookout) Gneissic Suite.

Lithology	Sample No. from Table 10-2	Abundance	Association	Colour/Texture/Mineralogy/Remarks	Approximate C.I.	Dominant Fabric	Reworking	Apparent Relative age
1) Ultramafic		rare	- occurs as pods and lenses in phase 4 - does not occur in sodic suite members to north of Sioux Lookout-Deception Bay Gneisses	- hornblende + minor phlogopite + minor plagioclase		massive, locally lineated	- little reworking, gen. has sharp contacts with host	1A
2) Ultramafic-anorthositic gabbro	20 21 22 23 24	extremely rare	- as discontinuous lense or concordant layer in phase 6 and 7 - does not occur in sodic suite members	- plagioclase + hornblende in variable amounts - ranges from gabbro to anorthositic gabbro to gabbroic anorthosite - locally weak cumulate texture - plagioclase (oligoclase-andesine) + hornblende + sphene + opaque + retrograde chlorite, biotite, epidote, clinozoisite		massive to lineated		1A
3) Metagabbro		common	- concordant, discontinuous lenses; commonly hybridized - locally appear as concordant broken linear bands that may have originally been dikes	- dark grey black	>40	massive	- diffuse diorite to quartz-diorite margins due to assimilation	1
4) Quartz diorite (locally diorite) to trondhjemite	7, 1, 9, 12, 19, 17	less common	- occurs mainly as inclusions in phase 5; commonly as hybrid diffuse, linear, concordant lenses	- dark grey, medium-grained - magnetite + hornblende + biotite - plagioclase (oligoclase) + quartz + hornblende + biotite	8-20	foliated to gneissic, inequigranular, locally massive gneissic	- hybrid border zones	2
5) Trondhjemite (locally to quartz diorite)	6, 2 13, 18	most common phase	- commonly interleaved concordantly with phases 1 to 7 inclusive;	- grey to light grey; fine- to medium-grained, dominantly medium-grained to coarse-grained - biotite ± hornblende - mafics in lenticular clots - plagioclase + quartz + biotite + hornblende ± K-feldspar ± epidote	5-14	foliated, locally gneissic, locally lineated, inequi-granular	- exhibits evidence of reworking in the form of assimilation of phases 2-4 inclusive	3
6) Trondhjemite	16	less common to rare	- rare discordancy, intrudes phase 5	- grey to light grey, fine to medium-grained	>5	weakly foliated, equigranular		4
7) Leucocratic biotite trondhjemite	10	common	- commonly interleaved with phase 5 - occurs as fairly wide concordant bands and thin veins, locally with biotite schlieren associated along margin adjacent to phase 5	- light to grey to white, very fine-grained	4-8	massive, equigranular, locally gneissose (marked by diffuse linear concentration bands of biotite)	- locally diffuse contacts due to assimilation - exhibit isoclinal folds	5
8) Hololeucocratic quartz monzonite to granite		less common to rare	- as thin concordant veins	- white, very fine-grained, locally fine-grained to medium-grained - K-feldspar + quartz + plagioclase + biotite + muscovite	<5	massive, equigranular	- similar to phase 7	6
9) Hololeucocratic trondhjemite		common	A) as thin veins, concordant, locally have thin biotite-rich veneer along margin; veins characterized by mainly sharp contacts, locally diffuse contacts	- fine to medium-grained, locally medium-grained, white	<5	massive to weakly foliated, equigranular		6
		less common	B) as massless pods, less commonly as veins associated with phase 4; sharp contacts	- medium-grained, white	<1	massive, equigranular		?

10) Trondhjemite	14	common	- very distinctive phase, as dikes discordant to all of the above	- battleship grey, aphanitic to very fine-grained - plagioclase + quartz + biotite ± hornblende ± K-feldspar	5-10	- massive, equigranular	- no reworking	7
11) Metagabbro A) Equigranular		common	- as thin to medium wide dikes cutting all the above - sharp contacts - also intrude Sen Bay Batholith (sodic suite) - locally dioritic in composition	- medium-grained, hornblende + plagioclase + biotite ± quartz ± Kspar	>50	A) Equigranular, massive	- are contorted as fairly open flexures and are also boudined	8
B) Porphyritic					>50	B) Porphyritic, massive		8
12) Leucocratic Quartz monzonite and other Potassic Phases A) Fine-to medium-grained and medium-grained to coarse-grained		common	I) Concordant to gneissic fabric - as thin to medium-thick veins commonly metasomatically injected along or adjacent to phases 7 and 9 - diffuse and sharp contacts equally abundant - localy biotite schlieren along margins	- fine to coarse-grained, locally very coarse-grained, almost always pinkish but locally white to grey tones are indicated - K-feldspar + quartz + plagioclase + musc. ± hornblende	<5	- massive, commonly inequigranular	- contorted mainly open folds, locally rare isoclinal folds - locally hybrid with inclusions of mafic biotitic schlieren	9
	3	common but less abundant than concordant	II) Discordant - as thin to medium-thick cross-cutting dikes - at least 3 successive ages of intrusion are indicated - characterized by sharp contacts but locally may be diffuse - composition varies from granite to dominantly quartz monzonite to locally granodiorite	- fine to medium-grained and medium to coarse-grained, commonly dikes are zoned as follows: I) coarse-grained border phase grading abruptly to fine- to medium grained central zone II) medium-grained border phase grading abruptly to coarse-grained central zone. This is less common than relation I) - compositional zoning also occurs frequently whereby plagioclase or Kspar is selectively concentrated along the border phase; quartz is dominantly in the central zone - nearly always pink to pinkish grey (granodiorite varieties).	<5	- massive, commonly equigranular	- relatively undeformed and unreworked	10
B) Syenite		rare	- dominantly concordant, discontinuous lenses gradational to phase 12-I	- inequigranular, dominantly pink	about 5	massive inequigranular	relatively undeformed and unreworked	9
C) Pegmatite		less common common	- gradational to phases 12 - I and II, most commonly associated with phase 12-I - commonly as consanguineous pods associated with phases 12 - I and II - tends to be older than phase 12-II but locally is youngest phase	- pegmatitic grain size, pink	<5	massive, inequigranular		both pre 9 to pre 10

TABLE 7-7 : Petrographic differences between fine-grained and coarse-grained amphibolites at Kenora from Gower (1978, p.206).

Fine-grained amphibolites	Medium-grained amphibolites
1. Mappable units up to 1 km wide and several km long	Only a few metres wide and a small proportion of the total outcrop
2. Fine-grained	Medium-grained
3. Leucogranitoid veins generally concordant to banding	Leucogranitoid veins as an agmatitic network
4. Usually good banding	Banding generally not present
5. Common calcic pods*	No pods
6. Common mafic veneers	No veneers

* comprised of epidote + quartz + clinopyroxene + garnet ± plag ± amphibole (Gower, 1978, p.560).

TABLE 8-1: Petrologic description of phases of the Sen Bay Stock.

Lithology	Grain Size	Fabric	Equigranularity	Mineralogy (major minerals are underlined)	Plagioclase Description	Sequence of Intrusion	No. on Figure 8-8 Table 8-2	Remarks
A) Diorite to Locally Quartz Diorite	f-mg, mostly m-cg	weakly foliated	inequigranular	plagioclase + hornblende + biotite + quartz ± diopside + opaque ± K-feldspar + allanite + apatite (C.I. >20)	inequigranular, anhedral, untwinned	1	1	- occurs locally as inclusions in phases C, and D - locally shows evidence of remobilization of mafic/felsic components due to hybridization or metamorphic differentiation - dated by Krogh et al. (1976) - date modified by Hinton and Long (1979).
B) Diorite to Quartz Diorite	mg, mg-vcg	weakly foliated, with stictolithic clots	inequigranular	plagioclase (oligoclase) + hornblende + quartz + biotite + K-feldspr + chlorite + opaque (magnetite) + sphene + allanite (C.I. >20)	inequigranular, anhedral, twinned	1 possibly pre 1	1A	Stictolithic of fleck texture see Mehnert (1971, p.37) Relationship to phase A unknown but may be older based on extensive degree of reworking
C) Hornblende-biotite Trondhjemite to Quartz Diorite	mg-cg	foliated to gneissic mafics locally in clots, locally lineated	inequigranular	plagioclase + quartz + biotite + hornblende (C.I. 12-18)		2	2	- may or may not be discordant to phase A, is discordant to phase B
D) Biotite trondhjemite	mg-cg	foliated, locally foliated to gneissic, mafics locally in clots locally foliated to lineated	inequigranular	plagioclase + quartz + biotite + hornblende + K-feldspar + opaque + diopside + chlorite + apatite + epidote + sphene (C.I. 10-12) (hornblende is porphyroblastic)	inequigranular	3	3	exhibits slight discordance to phase C
E) Biotite granodiorite	m-cg	foliated to lineated		plagioclase + quartz + K-feldspar + biotite		4	4	minor phase, may in part be consanguineous with phase D
F) Metagabbro	f-mg and m-cg	massive		plagioclase + hornblende ± quartz ± diopside (C.I.>40)	anhedral, equigranular locally porphyritic megacrysts	5	5	occurs mostly as isolated concordant rafts of questionable origin, locally as slightly discordant dikes
G) Magnetite biotite Trondhjemite	vfg-fg	massive	equigranular	plagioclase + quartz + biotite + K-feldspar + magnetite + hornblende (minor) ± muscovite + chlorite + apatite	inequigranular, to equigranular, locally minor, sericitic alter twinned and/or untwinn	6	6	- occurs as thin highly discordant dikes cutting phases C, D, and F
H) Hololeucocratic biotite trondhjemite	fg, locally m-cg	massive	equigranular and/or inequigranular	plagioclase + quartz + biotite + rare K-feldspar (C.I. <5)	anhedral, inequigranul twinned and untwinned	7	7	occurs as thin dikes and veins cutting all of the above
I) Leucocratic biotite quartz monzonite	i) f-mg	massive	equigranular or inequigranular	plagioclae + K-feldspar + quartz + biotite		8	8	dikes cut all the above phases, locally consanguinous with pegmatite
	ii) m-cg	massive	inequigranular	plagioclae + K-feldspar + quartz + biotite		9		thin and thick dikes commonly cuts f-mg quartz monzonite dikes
	iii) pegmatitic	massive	inequigranular	plagioclae + K-feldspar + quartz + biotite		10		dikes cut m-cg quartz monzonite locally consanguineous with f-mg quartz monzonite

* vfg - very fine-grained
fg - fine-grained
mg - medium-grained
cg - coarse-grained

TABLE 8-2: Chemical analyses of the Sen Bay stock

**	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
***		5			1	1	1			1A	2	6	3	4		8	7
Sample No.	42-2-18	24-23-15	42-1-11C	26-20-11	24-23-10	42-2-26A	24-23-14	25-21-12	42-1-11A	24-23-20	42-2-26C	42-2-26b	24-23-18	24-23-13	26-20-13A	42-2-26C	42-2-26d
SiO_2	44.7	49.5	47.4	52.9	56.3	54.8	57.8	62.0	64.9	59.5	65.8	66.0	71.3	70.5	67.8	72.9	74.4
Al_2O_3	9.24	14.4	13.5	17.8	18.6	19.0	17.1	17.4	16.7	18.2	17.0	17.1	15.3	16.5	16.6	15.4	15.9
Fe_2O_e	4.79	3.86	13.5	2.77	2.23	4.89	2.74	1.98	2.27	1.95		1.32	1.15	1.03	1.51	0.55	0.00
FeO	10.9	9.50	4.43	5.47	4.83	2.33	4.59	2.91	2.77	3.78	4.43	2.42	1.69	1.37	1.23	0.38	0.23
MgO	14.7	6.72	5.33	4.82	3.62	3.58	3.42	2.94	1.90	2.70	1.49	1.23	1.11	0.87	1.46	0.14	0.00
CaO	9.97	10.1	10.2	7.55	7.42	7.30	6.33	5.34	3.67	6.30	3.53	3.95	2.97	2.99	2.23	0.47	3.39
Na_2O	0.25	2.92	2.58	4.24	4.42	4.79	4.59	4.50	4.57	4.61	4.59	4.76	4.40	4.76	3.74	2.15	4.88
K_2O	0.68	0.86	0.58	1.59	1.19	1.02	1.47	1.52	1.73	1.28	1.73	1.44	1.86	1.67	3.96	7.26	0.46
TiO_2	1.06	1.14	1.61	0.96	0.91	0.76	0.94	0.54	0.69	0.69	0.55	0.54	0.38	0.33	0.36	0.08	0.04
P_2O_5	0.07	0.12	0.11	0.26	0.24	0.23	0.28	0.17	0.20	0.22	0.20	0.14	0.13	0.12	0.18	0.02	0.00
S	0.03	0.01	0.19	0.06	0.01	0.03	0.01	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.00	0.02	0.02
MnO	0.35	0.24	0.27	0.13	0.11	0.12	0.11	0.08	0.08	0.08	0.06	0.06	0.05	0.03	0.05	0.01	0.01
CO_2	0.25	0.06	0.23	0.15	0.09	0.51	0.09	0.12	0.08	0.09	0.58	0.40	0.09	0.10	0.13	0.51	0.40
H_2O+	2.73	0.34	0.21	0.81	0.44	0.69	0.53	0.64	0.31	0.29	0.32	0.22	0.10	0.15	0.75	0.16	ND
H_2O-	0.47	0.34	0.37	0.48	0.36	0.37	0.39	0.32	0.39	0.37	0.32	0.26	0.29	0.42	0.52	0.27	0.17
Total	100.2	100.1	100.5	100.0	100.8	100.4	100.4	100.5	100.3	100.1	100.6	99.9	100.8	100.8	100.6	100.3	99.9
Sp. Gravity		3.04			2.84		2.82	2.75		2.79			2.69	2.68			
ppm																	
Ba	60	90	50	400	310	210	330	180	280	330	190	443	450	410	1100	800	190
Be		<1		3	3	4	4	5	.4	3	3	<1	3	2	3		3
Co	76	45	53	31	25	22	20	15	13	20	12	10	8	7	10	<1	<5
Cr	1740	290	64	162	45	79	65	50	28	35	30	8	15	8	53	<5	<5
Cs	6	3			3		2			4			5	2			
Cu	5	15	146	48	10	55	55	10	20	20	10	20	5	<5	<5	<5	24
Ga		15		15	15	15	15	15	15	15	15	15	15	15	15	10	15
Li	52	10	6	10	20	17	10	20	22	30	40	26	25	18	12	11	9
Mo		<1		<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	790	80	43	81	45	44	40	50	19	25	15	5	10	8	19	<5	<5
Pb	46	<10	<10	62	15	55	20	20	21	15	20	16	15	20	23	35	33
Rb	30	10			50		40	80		50			80	50			
Sc	30	40		20	15	15	15	9	10	20	6	6	<5	<5	6	<5	<5
Sn	3	<3		<3	6	<3	<3	<1	<3	<3	<3	<3	<3	<3	<3	<3	<3
Sr	20	130		300	350	300	390	200	250	370	250	400	250	380	800	200	300
Th		<10			<10		<10	20		<10							
U	<1	.3		1	.6		.7	1.2		1.2			.8	.3			
V	200	300		100	150	100	150	70	60	100	45	50	40	30	40	<10	<10
Y	30	30		45	40	40	40	20	30	45	15	10	<10	<10	10	<10	<10
Zn	194	140	156	102	90	88	100	80	92	80	360	67	60	50	49	22	32
Zr	100	100		300	150	200	250	70	150	250	150	150	90	150	150	20	15

Table 8-2:

* 1 - Mafic to ultramafic dike
* 2 - Mafic inclusion or dike
* 3 - Amphibolite dike
4 to 9 - Medium-grained meta diorite, foliated to lineated
*10 - Medium to coarse-grained, in equigranular diorite with stictolithic texture, foliated
11 - Medium to coarse-grained quartz diorite to trond.
*12 - Very fine-grained biotite trondhjemite dike, massive
13 - Medium-grained biotite trondhjemite, foliated
14, 15 - Fine- to medium-grained magnetite biotite trondhjemite to granodiorite, foliated
*16 - Medium-grained quartz monzonite, massive, leucocratic (potassic suite)
*17 - Fine- to medium-grained, equigranular, hoisleucocratic biotite trondhjemite (commonly occurs as dikes).

* Denotes phase is found outside the batholith.
** Nos. (refers to AFM diagram [illegible]

TABLE 9-1: Chemical analyses of the matrix and clots of the clotty quartz monzonite.

~~CLOTTY QUARTZ MONZONITE~~ OK

	1	2	3	4	5	6	7	8	9	10	11
				*	*	*					
	7-18-10	9-9-34f	19-A	1-1M	2-1M	3-2M	5-165-2	21-16-7	B6-11	19-B	9-9-34M
SiO_2	73.7	73.5	73.5	74.15	74.70	75.40	69.7	74.0	72.5	69.6	62.1
Al_2O_3	14.8	14.4	15.6	14.38	13.71	13.11	17.3	15.6	16.4	17.2	18.2
Fe_2O_e	0.27	0.37	0.00	0.39	0.10	0.04	0.49	0.36	1.29	1.10	2.87
FeO	0.87	1.34	0.32	0.60	0.24	0.14	0.73	3.66	3.49	3.46	4.60
MgO	0.23	0.37	0.00	0.12	0.08	0.22	0.20	3.88	3.28	2.15	2.79
CaO	0.79	1.00	0.80	0.84	1.72	2.27	1.20	0.06	0.04	0.16	0.0
Na_2O	2.80	3.69	3.83	4.35	4.02	4.05	4.69	0.19	0.25	0.00	0.22
K_2O	5.92	4.36	4.98	4.92	4.84	4.17	4.03	0.25	0.94	1.11	5.86
TiO_2	0.01	0.30	0.07	0.00	0.00	0.00	0.15	0.03	0.02	0.03	0.09
P_2O_5	0.05	0.10	0.13	0.22	0.20	0.18	0.04	0.00	0.02	0.00	0.0
S	0.00	0.01	0.01				0.06	0.01	0.01	0.02	0.0
MnO	0.07	0.01	0.02	0.02	0.00	0.01	0.02	0.06	0.04	0.11	0.08
CO_2	0.22	0.14	0.24	0.00	0.03	0.03	0.10	0.12	0.13	1.26	0.11
H_2O+	0.34	0.05	0.06	(0.23	(0.12	0.03	0.07	0.81	1.34	2.17	1.45
H_2O-	0.09	0.28	0.20	(	(		0.27	0.30	1.26	1.06	0.44
Total	100.2	99.9	99.8	100.22	99.76	99.65	99.0	99.3	100.0	99.4	98.8

<1 <1 <1 <1 <1 <1 Ba 360
270 300 650 30 60 70 50 Be <1 <1
<1 2 35 20 15 50 Co <5 <5 <5
<5 5 10 5 5 Cr <5 15 <5
6 <5 8 <5 8 Cs <5 <1
<5 2 Cu <5 <5 <5
15 <5 7 5 <5 Ga 8 15 10
15 25 30 Li 20 30 5 30 270
180 310 130 Mo <1 <1 <1 <1 <1
<1 <5 <5 <5 7 <5 <5 <5
<5 b 50 35 32 100 <10 <10 13 95
Rb 140 160 110 130 <10 20 60 70 Sc
<5 <5 <5 <5 <5 <5 Sn <1
<3 <3 <1 <1 <1 <3 <3 Sr 10 100
90 300 50 <10 90 30 Th <10
<10 U <6 4
9 11 <2 V <5 15 <10
15 <5 <5 <10 <10 Y <10 <10
<10 <10 <10 <10 Zn 15 75 9 45
80 65 106 240 Zr 50 150 90 45 <10
20 80 50

Nos. 1-7 inclusive on samples of the matrix
8-11 inclusive on samples of the clots
*From Morin (1970)

Table 9-2: Lithophile trace Element Chemistry of samples from the pegmatite border phase mantling the potassic batholith north of Papaonga Lake (Uchi Subprovince).

Field Sample No.	Sample No.	Tantalum	Lithium	Beryl-lium	Cesium	Radio-activity (U_3O_8 Equiv.)	U_3O_8	ThO_2	Ra
18-16-1	1	(0.01%)	(0.01%)	2 ppm	55 ppm	0.005%	-	-	0.070
18-16-27	2	"	"	6 ppm	10 ppm	0.001	-	-	0.025
18-16-35	3	"	"	4 ppm	5 ppm	0.003	-	-	0.035
18-16-36	4	"	"	6 ppm	15 ppm	0.002	-	-	0.020
18-16-36A	5	"	"	4 ppm	20 ppm	0.004	-	-	0.068
18-18-15	6	"	"	6 ppm	15 ppm	0.003	-	-	0.065

1) Pegmatite, biotite + muscovite, quartz monzonite
2) Pegmatite, dominantly albite with minor muscovite + quartz + Kspar.
3) Pegmatite, biotite + minor muscovite + minor tourmaline.
4 & 5) Tourmaline-bearing muscovite-biotite pegmatite, minor apatite.
6) Fine-grained aplitic quartz-feldspar intergrowth.

TABLE 10-1 Chemical Analyses of the Gneissic Suite, Deception Bay Area

	1	2	3	4	5	6	7	8	9	10	11	12
	45-5-13A	45-5-19B	45-5-19C	45-6-3	45-6-5A	45-6-6A	45-6-6C	45-6-12A	45-6-12B	45-6-13B	45-6-14A	45-6-16
SiO_2	68.1	70.9	66.8	72.3	67.6	65.1	67.7	63.4	64.1	76.3	67.7	62.9
Al_2O_3	15.2	15.8	17.3	15.4	15.9	15.5	16.0	19.8	13.7	14.9	17.9	14.9
Fe_2O_3	1.84	0.51	1.25	0.62	1.88	2.39	1.66	0.98	2.06	0.12	0.72	3.00
FeO	2.82	0.97	1.53	1.45	2.90	3.22	2.50	1.37	4.11	0.40	1.37	2.94
MgO	1.06	0.63	0.97	1.03	1.60	2.18	1.84	1.05	4.32	0.26	0.87	3.60
CaO	2.89	2.54	2.79	1.32	3.42	4.55	4.15	4.10	4.25	2.97	3.10	4.99
Na_2O	4.73	5.58	4.98	3.04	4.03	4.23	4.22	5.91	2.97	4.15	5.42	4.04
K_2O	1.51	1.38	3.38	4.45	1.86	1.33	1.68	1.60	3.18	0.61	1.96	1.49
TiO_2	0.63	0.22	0.50	0.32	0.56	0.71	0.47	0.15	0.51	0.08	0.33	0.61
P_2O_5	0.18	0.11	0.20	0.13	0.18	0.18	0.15	0.15	0.11	0.07	0.14	0.18
S	0.12	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
MnO	0.05	0.03	0.03	0.02	0.07	0.11	0.06	0.03	0.14	0.01	0.04	0.10
CO_2	0.10	0.11	0.08	0.13	0.10	0.06	0.07	0.10	0.09	0.08	0.06	0.07
H_2O+	0.11	0.11	0.11	0.25	0.12	0.35	0.14	0.52	0.27	0.22	0.45	0.39
H_2O-	0.35	0.31	0.37	0.37	0.35	0.33	0.31	0.37	0.37	0.34	0.32	0.41
Total	99.7	99.2	100.3	100.9	100.5	100.3	101.0	99.5	100.2	100.5	100.4	99.6
Ag	1	1	1	1	1	1	1	1	1	1	1	1
Ba	310	340	1650	1750	530	250	410	270	830	200	230	37
Be	4	4	4	1	3	3	3	4	3	35	3	4
Co	10	5	7	8	10	15	10	6	20	6	6	20
Cr	8	5	15	25	25	40	30	15	300	5	7	105
Cs	9	1	4	5	5	6	4	1	4	3	3	4
Cu	80	15	40	9	5	35	15	15	20	5	5	10
Ga	15	15	15	15	15	15	15	15	15	9	15	15
Li	20	10	15	10	25	25	20	20	25	6	25	15
Mo	4	1	1	1	1	1	1	1	1	1	1	1
Ni	10	8	6	20	7	20	20	8	80	7	5	80
Pb	20	25	35	45	15	20	15	25	20	10	25	15
Rb	90	40	90	110	90	60	60	60	100	20	80	50
Sc	10	5	·5	5	15	15	10	5	35	5	5	20
Sn	3	3	3	3	3	3	3	3	3	3	3	3
Sr	290	340	570	360	260	310	340	390	240	270	320	330
Th	20	15	60	70	10	10	15	10	20	10	10	15
U	1	1	1	1	1	1	1	1	1	1	1	1
V	40	15	50	50	80	90	80	25	100	10	25	150
Y	20	15	15	20	15	30	20	10	60	10	10	25
Zn	80	35	55	40	115	90	60	45	105	10	60	75
Zr	300	100	150	300	150	200	100	80	150	45	100	150

TABLE 10-1

	13	14	15	16	17	18	19	20	21	22	23	24	25
	45-6-17	45-6-18	26-17-18	45-4-20d	45-4-31b	45-4-31c	45-4-3b	45-5-23A	45-5-23b	45-5-23c	45-5-23d	45-523E	45-5-2
SiO_2	70.4	66.3	61.6	66.7	55.1	67.7	56.5	51.2	49.6	48.4	50.3	49.1	65.7
Al_2O_3	16.6	18.4	16.0	16.5	20.1	15.8	15.9	5.44	14.9	15.4	26.3	26.9	16.3
Fe_2O_3	1.29	1.69	3.45	1.18	2.08	1.62	1.44	3.03	3.67	2.76	1.26	1.52	2.19
FeO	0.97	1.69	3.57	2.17	4.03	2.25	4.99	8.61	8.13	8.77	2.33	2.17	2.66
MgO	0.68	1.33	3.08	1.15	2.44	0.92	5.66	15.4	7.09	8.01	2.39	2.31	1.37
CaO	2.87	4.08	4.16	3.66	6.91	3.98	6.12	11.9	8.12	11.0	11.8	12.4	3.79
Na_2O	5.57	4.77	4.61	4.54	5.72	4.53	4.15	0.71	3.09	2.22	3.55	3.52	4.38
K_2O	1.66	1.35	2.02	1.44	1.10	1.02	2.00	0.42	1.85	0.69	0.58	0.62	1.66
TiO_2	0.27	0.44	0.73	0.45	0.46	0.44	0.46	0.21	1.22	0.84	0.22	0.11	0.79
P_2O_5	0.11	0.14	0.32	0.13	0.20	0.14	0.14	0.03	0.28	0.08	0.05	0.03	0.27
S	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.13	0.03	0.01	0.01	0.08
MnO	0.03	0.04	0.13	0.04	0.12	0.04	0.12	0.36	0.18	0.20	0.07	0.06	0.05
CO_2	0.08	0.08	0.13	0.07	0.14	0.06	0.08	0.09	0.18	0.11	0.15	0.28	0.08
H_2O+	0.12	0.16	0.48	0.29	0.47	0.04	0.68	0.55	0.62	0.41	0.38	0.34	ND
H_2O-	0.22	0.32	0.59	0.28	0.27	0.33	0.35	0.28	0.38	0.43	0.37	0.49	0.47
Total	100.9	100.8	100.9	98.6	99.16	98.87	98.59	98.23	99.44	99.35	99.75	99.85	99.79
Ag	1	1	1										
Ba	470	430	200	330	220	480	800	40	300	100	100	120	960
Be	3	1	3										
Co	5	7	15	10	15	10	25	50	45	50	15	15	10
Cr	5	6	75	5	40	5	220	1460	270	335	15	6	20
Cs	3	2		1	2	3	3	2	6	4	1	2	4
Cu	5	5	20	6	10	8	8	8	115	30	6	6	30
Ga	15	15	15										
Li	20	30	25	20	10	15	20	7	2	9	6	8	20
Mo	1	1	1										
Ni	5	5	55	6	25	5	175	880	120	135	35	30	9
Pb	20	10	20	20	20	15	20	10	15	10	20	15	20
Rb	50	40	70	60	30	40	60	10	60	10	10	10	60
Sc	5	5	20										
Sn	3	3	1										
Sr	480	460	200										
Th	10	10		10	10	10	10	23	17	10	10	10	47
U	1	1		1	1	1	1	1	1	1	1	1	1
V	20	40	70										
Y	10	10	20										
Zn	45	55	150	65	80	65	120	190	160	95	45	40	80
Zr	150	150	100										

Table 10-2:

1 - Medium-grained foliated to gneissic magnetite-biotite trondhjemite

2 - Massive, medium-grained biotite trondhjemite to granodiorite

3 - Fine-grained biotite granodiorite dike

4 - Medium-grained biotite granodiorite to quartz monzonite

5 - Very fine-grained biotite trondhjemite to quartz diorite

6 - Fine- to medium-grained massive to gneissose biotite trondhjemite to quartz diorite

7 - Foliated to gneissic hornblende-biotite trondhjemite to quartz diorite

8 - Fine-grained biotite trondhjemite

9 - Medium- to coarse-grained biotite-hornblende quartz diorite

10- Medium- to coarse-grained inequigranular, massive to gneissose leucocratic, biotite trondhjemite

11- Fine-grained, massive to weakly-foliated biotite trondhjemite

12- Medium-grained massive to weakly gneissose quartz diorite

13- Fine-grained massive to weakly foliated biotite trondhjemite

14- Very fine-grained massive biotite trondhjemite to quartz diorite

15- Biotite trondhjemite

16- Biotite trondhjemite

17- Biotite hornblende trondhjemite to quartz diorite

18- Biotite trondhjemite to quartz diorite

19- Biotite hornblende quartz diorite to diorite

20- Mafic to ultramafic

21- Gabbro

22- Amphibolite

23- Anorthositic Gabbro

TABLE 10-2 Chemical Analyses of the Melick Gneiss (Kenora)

	14-14-11	14-14-43A	14-14-54	14-14-54	16-11-16	16-13-35A	17-12-31	15-15-12	17-12-1	15-13-35b	14-11-27	16-15-13
SiO_2	65.3	66.0	66.0	67.2	68.4	68.3	64.1	65.0	64.1	57.4	65.1	67.2
Al_2O_3	18.4	19.4	17.3	16.1	16.4	17.7	18.6	16.4	17.3	18.0	16.2	17.4
Fe_2O_3	0.87	0.79	1.45	3.68	1.32	0.73	1.29	1.35	1.84	2.57	5.19	1.41
FeO	2.18	1.89	2.11		2.91	1.97	2.62	3.28	3.50	5.10		2.26
MgO	1.62	1.38	1.18	1.08	1.23	0.89	2.37	1.77	2.23	3.45	2.05	1.14
CaO	3.83	3.57	3.66	3.72	3.32	3.39	4.49	4.09	4.37	6.84	4.38	3.35
Na_2O	4.21	4.69	4.34	4.29	3.88	4.56	4.42	3.75	3.56	4.04	4.24	4.77
K_2O	2.43	1.98	1.83	1.77	2.02	1.62	1.88	1.83	2.27	1.21	1.57	1.64
TiO_2	0.43	0.40	0.41	0.41	0.45	0.32	0.25	0.51	0.54	0.66	0.57	0.51
P_2O_5	0.19	0.18	0.15	0.14	0.11	0.13	0.06	0.15	0.15	0.10	0.19	0.12
S			0.00	0.0				0.00			0.01	
MnO	0.04	0.04	0.04	0.05	0.06	0.03	0.08	0.06	0.07	0.12	0.09	0.04
CO_2				0.44							0.52	
H_2O+	0.66	0.61	0.58	1.0	0.79	0.52	0.79	1.11	0.85	1.12		0.73
H_2O-				L.O.I.								
Total	100.2	100.9	99.1	99.4	100.9	100.2	101.0	99.3	100.8	100.6	100.3	100.6
Ag												
Ba	930	430	580		390	510	330	430	620	150	170	340
Be												
Co												
Cr												
Sc	5	5	5		5	5	5	5	5	5	5	5
Cu												
Ga												
Li	15	25	25		45	35	20	25	10	25	25	30
Mo												
Ni												
Pb												
Rb	60	60	60		80	40	30	50	50	20	60	40
Sc												
Sn												
Sr	700	400	500		200	500	300	400	200	300	400	500
Th												
U												
V												
Y												
Zn												

Table 10-3: Chemical Analyses of the Gneissic Suite north of the Tustin-Bridges Area. Samples M-40, T-26 and T-26A from Morin (1979).

	Gneissic Suite, Tustin-Bridges Area			
	15-22-61	M-40*	T-26*	T-26A*
SiO_2	65.7	64.95	72.45	68.35
Al_2O_3	16.4	15.52	14.04	14.98
Fe_2O_3	1.88	1.84	0.95	1.43
FeO	2.04	3.04	0.92	2.12
MgO	1.66	1.80	0.46	1.52
CaO	3.97	5.25	1.75	4.15
Na_2O	4.50	4.40	3.64	4.88
K_2O	1.83	1.38	4.71	1.30
TiO_2	0.53	0.60	0.22	0.50
P_2O_5	0.15	0.20	0.11	0.21
S	0.0			
MnO	0.05	0.09	0.03	0.08
CO_2	0.11	0.11	0.09	0.19
H_2O+	(0.29	(0.69	(0.34	(0.53
H_2O-	(0.11	(	(	(
Total	99.2	99.87	99.74	100.24

* From Morin (1979)

	15-22-61
Ag	
Ba	400
Be	2
Co	15
Cr	35
Cs	5
Cu	15
Ga	10
Li	20
Mo	1
Ni	15
Pb	10
Rb	60
Sc	9
Sn	1
Sr	400
Th	50
U	1
V	45
Y	10
Zn	60
ZR	90

Table 10-4: Chemical Analyses of the Sioux Lookout Gneissic Suite.

	27-18-39	27-20-3A	27-20-12	27-20-17	27-20-47
SiO_2	71.7	64.6	67.2	55.1	55.6
Al_2O_3	15.1	14.8	15.1	15.5	18.7
Fe_2O_3	1.58	4.71	2.91	3.69	2.00
FeO	1.09	3.13	2.91	5.68	3.86
MgO	0.89	1.54	1.39	5.20	4.37
CaO	2.79	3.77	3.82	7.96	8.11
Na_2O	4.69	4.07	4.02	3.61	4.56
K_2O	1.26	1.90	2.32	1.37	1.02
TiO_2	0.28	0.96	0.73	0.89	0.73
P_2O_5	0.08	0.23	0.19	0.21	0.15
S	0.00	0.31	0.00	0.02	0.01
MnO	0.06	0.09	0.09	0.17	0.08
CO_2	0.11	0.11	0.10	0.10	0.11
H_2O+	0.13	0.36	0.28	1.21	0.39
H_2O-	0.59	0.54	0.52	0.32	0.35
Total	100.4	101.1	101.64	101.0	100.0
Ag	1	1	1	1	1
Ba	220	230	530	280	190
Be	3	3	2	2	1
Co	5	20	10	30	30
Cr	10	8	10	140	140
Cs					
Cu	8	160	20	50	85
Ga	10	15	10	10	10
Li	20	35	15	10	25
Mo	1	1	1	1	1
Ni	8	10	10	85	80
Pb	25	20	20	20	20
Rb	50	50	60	40	30
Sc	5	15	5	20	15
Sn	1	1	1	1	1
Sr	200	200	200	200	300
Th					
U					
V	30	70	30	100	90
Y	10	20	20	20	10
Zn	60	100	90	110	75
R	90	400	300	100	10

Table 10-5: Chemical analyses of Cedar Lake Gneiss from Westerman (1977) see Appendix 2, p.274, 275.

Cedar Lake Gneiss

Sample	21	22	24	62	78	322	331	349	350	432	504	560
SiO_2	69.46	69.13	72.23	74.17	71.62	71.89	72.76	62.28	69.26	71.34	72.95	74.77
Al_2O_3	14.80	14.20	14.70	14.15	15.18	14.33	14.11	16.04	14.52	14.57	15.01	13.70
TiO_2	.54	.26	.18	.13	.31	.28	.26	.54	.43	.35	.20	.12
Fe_2O_3 (TOT)	3.84	4.31	1.51	1.04	2.34	2.40	2.09	4.15	4.20	2.86	1.49	.92
MnO	.05	.09	.03	.02	.03	.03	.04	.05	.07	.04	.03	.01
MgO	.95	1.38	.62	.44	.80	.75	.62	1.07	1.12	.93	.63	.51
CaO	3.38	4.65	1.46	2.25	3.00	2.61	2.16	3.45	3.61	2.68	2.48	1.82
Na_2O	3.69	4.06	3.67	3.52	4.80	3.82	3.52	4.35	4.10	3.59	4.51	3.69
K_2O	2.23	.83	4.98	3.68	1.24	3.06	3.72	2.05	1.80	2.91	2.16	3.96
P_2O_5	.15	.06	.05	.05	.09	.09	.07	.20	.18	.13	.08	.04
Total	99.11	98.97	99.44	99.46	99.40	99.29	99.35	99.28	99.29	99.39	99.53	99.55
Rb	47	16	113	80	48	79	110	68	57	96	115	74
Sr	197	235	245	239	357	196	175	324	253	205	197	292
Ba	1135	347	1497	1313	427	983	1178	687	641	1084	658	1246
Ce	112	44	27	34	66	62	96	184	96	62	27	63
K/Rb	399	453	367	383	221	324	283	251	266	253	158	448
K/Ba	17	21	28	24	25	26	26	25	23	22	28	27
Ca/Sr	125	145	43	68	61	96	89	77	104	95	91	45
Rb/Sr	.240	.069	.458	.334	.134	.402	.624	.209	.221	.466	.575	.251
K_2O/Na_2O	.60	.20	1.36	1.05	.26	.80	1.06	.47	.44	.81	.48	1.07
MLI	9.8	7.4	14.0	12.8	9.6	11.5	12.6	9.1	9.1	11.1	11.0	13.4
DF	+2.13	+2.09	+3.01	+2.45	+3.18	+2.46	+2.17	+3.28	+2.38	+1.88	+3.12	+2.44

Table 10-6: Chemical Analyses of Biotite tonalite gneiss at Kenora from Gower (1978, p.567, 568, 567).

	BIOTITE TONALITE GNEISS						
	G1317A	G1366C	G1396B	G1389	G1474C	G1566	G16226B
SiO_2	71.53	74.41	73.99	75.55	67.84	70.99	64.90
Al_2O_3	15.56	14.45	14.24	13.46	15.54	16.62	16.10
TiO_2	.44	.21	.22	.26	.77	.19	.59
Fe_2O_3	.98	.33	.55	.42	1.16	.51	2.11
FeO	1.64	1.12	1.80	1.11	3.88	1.02	3.74
MnO	.08	.05	.05	.07	.05	.05	.13
MgO	.76	.60	.54	.35	1.33	.57	1.97
CaO	4.62	3.50	2.68	1.94	3.40	3.27	4.91
Na_2O	3.81	4.11	3.84	3.26	3.55	5.50	3.90
K_2O	.51	1.22	2.04	3.59	2.22	1.23	1.42
P_2O_5	.08	.01	.06	.06	.26	.05	.23
Rb	4.	64.	68.	90.	86.	30.	25.
Sr	474.	480.	170.	152.	221.	558.	384.
Ba	167.	1619.	601.	864.	596.	332.	591.
Ce	9.	12.	40.	15.	81.	10.	33.
Nb	0.	0.	8.	9.	22.	0.	9.
Zr	272.	82.	151.	85.	267.	63.	195.
Y	10.	0.	13.	16.	30.	0.	22.
Th	0.	0.	8.	5.	16.	0.	0.
Pb	0.	8.	10.	13.	12.	9.	9.
K_2O/Na_2O	.13	.30	.53	1.10	.62	.22	.36
Fe_2O_3/FeO	.60	.30	.30	.38	.30	.50	.56
Rb/Sr	.608	.132	.399	.594	.391	.054	.084
K/Rb	1139.79	159.50	249.66	329.40	213.11	336.71	464.76
Ba/Rb	45.14	25.49	8.85	9.55	6.90	16.93	23.26
Ba/Sr	.35	3.37	3.53	5.67	2.70	.66	1.94
Ca/Sr	69.69	52.17	112.47	91.05	110.07	41.91	115.32
Ca/Y	3239.97	R	1508.19	877.09	807.78	R	1608.73

	G1317A	G1366C	G1396B	G1389	G1474C	G1566	G16226B
Qz	35.50	36.00	36.04	36.66	30.74	25.38	25.59
Co	1.20	.33	1.39	1.20	3.01	.71	.58
Or	0.00	4.55	8.85	19.40	5.73	4.84	.08
Ab	34.66	37.23	34.90	29.70	32.33	49.08	35.36
An	21.14	16.72	12.29	8.66	12.67	15.14	21.01
Ho	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bi	4.88	4.36	5.36	3.39	12.11	3.81	13.42
Hy	.47	0.00	0.00	0.00	0.00	0.00	0.00
Wo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mt	1.04	.35	.58	.45	1.23	.53	2.23
Tn	.93	.44	.47	.42	1.63	.39	1.24
Ap	.17	.02	.13	.13	.55	.10	.49
Qtz	35.1	35.8	31.9	31.5	28.9	27.5	22.7
Plag	53.2	49.7	50.0	39.2	43.4	60.3	50.7
K-Spar	0.0	6.5	8.1	21.7	.5	5.3	0.0
Husc	4.0	.1	1.7	0.0	2.2	.9	0.0
Biot	5.0	7.7	6.5	6.9	21.4	5.0	12.0
Amph	0.0	0.0	0.0	0.0	0.0	0.0	10.8
Epio	2.3	.1	1.2	.5	2.0	.8	2.7
Opaq	.1	0.0	.1	0.0	.1	0.0	.1
Rest	.1	.1	.4	.1	1.5 S 1.2	.2	1.8 S 0.6
Cpx	.1	0.0	0.0	0.0	0.0	0.0	0.0
Gnt	.1	0.0	.1	.1	0.0	0.0	0.0

Table 10- 6

609 BIOTITE TONALITE GNEISS

	G100	G106B	G120	G160A	G207	G256	G305
SiO_2	72.41	71.71	71.30	69.51	70.78	65.35	71.74
Al_2O_3	14.74	14.45	14.17	15.65	15.75	17.70	14.94
TiO_2	.28	.38	.63	.46	.37	.54	.41
Fe_2O_3	.88	.98	1.26	1.19	.76	1.52	.77
FeO	1.61	2.07	2.48	1.92	1.34	1.69	1.73
MnO	.07	.06	.04	.05	.05	.08	.05
MgO	.61	.78	.95	1.14	.78	1.18	.73
CaO	3.38	3.54	3.69	3.79	3.31	5.41	3.21
Na_2O	4.94	4.88	4.10	4.91	5.65	5.40	4.96
K_2O	.98	1.05	1.18	1.27	1.12	.97	1.38
P_2O_5	.11	.10	.19	.11	.09	.15	.08
Rb	48.	49.	54.	43.	36.	33.	45.
Sr	333.	221.	217.	477.	629.	355.	306.
Ba	486.	361.	409.	478.	333.	263.	342.
Ce	25.	27.	28.	36.	33.	16.	27.
Nb	3.	6.	8.	0.	0.	4.	9.
Zr	285.	160.	782.	132.	150.	175.	138.
Y	13.	9.	21.	0.	0.	12.	6.
Th	0.	0.	2.	0.	4.	0.	7.
Pb	8.	7.	9.	5.	8.	9.	12.
K_2O/Na_2O	.20	.22	.29	.26	.20	.18	.28
Fe_2O_3/FeO	.55	.47	.51	.62	.56	.90	.45
Rb/Sr	.143	.222	.250	.091	.057	.094	.148
K/Rb	171.62	178.42	181.01	243.09	260.44	241.82	253.26
Ba/Rb	10.24	7.39	7.54	11.07	9.31	7.89	7.54
Ba/Sr	1.46	1.64	1.89	1.00	.53	.74	1.12
Ca/Sr	72.67	114.87	121.57	56.82	37.58	108.81	75.00
Ca/Y	1803.82	2694.57	1287.51	R	R	3333.83	3701.45

	G100	G 106B	G120	160A	G207	G256	G305
Qz	30.89	30.37	33.90	26.59	24.99	18.48	29.03
Co	.03	0.00	.79	.18	0.00	0.00	.18
Or	2.76	2.24	2.29	2.97	3.45	1.60	4.63
Ab	44.55	43.97	37.23	44.14	50.47	48.19	44.64
An	15.14	14.52	15.08	16.51	14.23	21.07	14.01
Ho	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bi	4.88	6.40	7.64	7.17	5.01	6.55	5.66
Hy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wo	0.00	.46	0.00	0.00	.09	1.11	0.00
Mt	.92	1.03	1.34	1.25	.79	1.58	.81
Tn	.59	.80	1.33	.96	.77	1.12	.86
Ap	.23	.21	.40	.23	.19	.31	.17
Qtz	35.9	31.4	37.8	29.7	26.4	23.8	36.9
Plag	53.0	49.1	42.6	52.3	58.0	61.6	46.2
K-Spar	.3	0.0	0.0	.3	.8	.5	1.4
Husc	4.3	0.0	.2	.1	2.2	.3	.7
Biot	4.5	13.6	12.6	13.7	10.5	8.0	12.0
Amph	0.0	0.0	.2	0.0	0.0	.5	0.0
Epio	1.3	5.8	5.4	1.7	1.7	4.5	2.4
Opaq	.2	.1	.1	.5	0.0	.1	0.0
Rest	.5	.1	1.3 CA 0.5	2.0 S 0.9	.5	.8	.5
Cpx	0.0	0.0.	0.0	0.0	0.0	0.0	0.0
Gnt	0.0	0.0	0.0	0.0	0.0	0.0	0.0
An P/C	29	32	30	28	27	30	36

Table 10-6

610 BIOTITE TONALITE GNEISS

	G350A	G378A	G801	G839B	G843A	G875A	G1237
SiO_2	69.15	69.46	65.72	62.01	72.66	71.42	72.34
Al_2O_3	15.25	15.46	17.01	17.38	15.11	15.02	14.65
TiO_2	.46	.31	.49	.72	.35	.41	.33
Fe_2O_3	1.19	1.09	1.78	.77	.74	.80	1.19
FeO	2.43	2.21	2.31	5. 6	1.48	2.00	1.74
MnO	.06	.04	.09	.12	.04	.06	.06
MgO	1.15	1.32	1.42	1.98	.81	.68	.87
CaO	4.23	3.78	4.26	5.40	3.23	3.36	3.41
Na_2O	4.88	4.98	5.28	4.75	4.42	4.78	4.
K_2O	1.11	1.29	1.51	1.66	1.09	1.39	1.33
P_2O_5	.10	.08	.14	.17	.08	.09	.09
Rb	44.	45.	64.	57.	42.	58.	57.
Sr	204.	414.	620.	448.	457.	175.	274.
Ba	364.	427.	510.	380.	440.	387.	347.
Ce	65.	30.	51.	23.	38.	38.	51.
Nb	6.	6.	5.	0.	4.	9.	7.
Zr	215.	127.	184.	81.	130.	159.	200.
Y	15.	11.	5.	11.	0.	11.	6.
Th	10.	4.	8.	3.	5.	5.	13.
Pb	11.	7.	7.	9.	6.	11.	12.
K_2O/Na_2O	.23	.26	.29	.35	.25	.29	.33
Fe_2O_3/FeO	.49	.49	.77	.15	.58	.40	.69
Rb/Sr	.217	.109	.104	.127	.092	.330	.208
K/Rb	208.29	236.53	194.00	242.04	216.75	199.90	192.78
Ba/Rb	8.19	9.48	7.92	6.67	10.51	6.71	6.08
Ba/Sr	1.78	1.03	.82	.55	.96	2.21	1.27
Ca/Sr	147.80	65.25	49.14	86.18	50.50	137.38	88.95
Ca/Y	2026.58	2431.27	6624.96	3538.09	R	2203.11	3929.70

	G350A	G376A	G801	G839B	G843A	G875A	G1237
Qz	26.56	26.08	19.30	15.85	33.90	29.45	34.84
Co	0.00	0.00	0.00	0.00	1.55	.30	1.18
Or	1.39	2.31	3.59	0.00	3.06	4.47	4.28
Ab	43.95	44.70	47.20	42.57	39.95	43.11	36.33
An	16.45	16.02	18.18	21.16	14.38	14.76	15.36
Ho	0.00	0.00	0.00	1.78	0.00	0.00	0.00
Bi	8.31	8.49	8.46	15.66	5.47	6.04	5.86
Hy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wo	.93	.45	.10	.31	0.00	0.00	0.00
Mt	1.24	1.14	1.85	.80	.78	.84	1.26
Tn	.96	.65	1.02	1.50	.74	.84	.70
Ap	.21	.17	.29	.35	.17	.19	.19
Qtz	30.0	29.0	23.1	18.4	26.4	36.4	30.4
Plag	53.3	51.0	53.3	45.6	45.4	47.8	45.9
K-Spar	0.0	.6	1.2	0.0	.2	2.9	1.0
M ~~Musc~~	0.0	0.0	.1	0.0	0.0	.1	3.5
Biot	10.0	11.4	17.0	22.9	18.2	10.8	13.9
Amph	2.3	6.3	0.0	5.1	5.8	0.0	0.0
Epi~~dot~~	3.9	1.5	3.9	6.3	3.6	1.5	5.1
Opaque oxides	0.0	.1	.6	.1	.1	.3	.1
Rest	.5	.3	.9	1.7 S 1.3	.5	.2	.1
Cpx	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gnt	0.0	0.0	0.0	0.0	0.0	0.0	0.0
An P/C	32	28	33	43	31	33	29

Table 10-7: Chemical analyses of amphibol gneiss from the Kenora Area from Gower (1978, p.566).

	HORNBLENDE BIOTITE TONALITE GNEISS				
	G118A	G173	G248A	G529	G1554
SiO_2	63.20	66.61	62.50	67.92	59.21
Al_2O_3	15.89	15.21	16.70	15.36	14.70
TiO_2	.79	.47	.74	.54	1.39
Fe_2O_3	1.87	1.42	1.65	1.33	3.31
FeO	4.79	3.23	4.06	2.76	5.38
MnO	.13	.11	.11	.08	.16
MgO	1.93	2.72	2.49	1.64	3.97
CaO	4.71	4.40	4.61	3.99	5.46
Na_2O	4.20	4.18	4.40	4.86	3.49
K_2O	2.16	1.56	2.30	1.4	2.38
P_2O_5	.33	.11	.43	.12	.55
Rb	84.	77.	89.	48.	59.
Sr	293.	180.	281.	261.	371.
Ba	725.	464.	646.	462.	553.
Ce	41.	62.	172.	36.	100.
Nb	11.	8.	12.	6.	19.
Zr	202.	148.	186.	200.	215.
Y	26.	13.	39.	15.	33.
Th	0.	15.	53.	5.	9.
Pb	11.	15.	18.	14.	8.
K_2O/Na_2O	.51	.37	.52	.29	.68
Fe_2O_3/FeO	.39	.44	.41	.48	.62
Rb/Sr	.287	.429	.315	.183	.239
K/Rb	212.86	167.10	215.79	243.14	222.78
Ba/Rb	8.61	5.22	7.29	9.66	6.23
Ba/Sr	2.47	2.24	2.30	1.77	1.49
Ca/Sr	114.12	174.12	117.11	1 9.32	105.11
Ca/Y	1285.37	2344.11	835.51	1875.62	1195.92
Qz	20.54	25.54	18.59	24.80	19.44
Co	0.00	0.00	.63	0.00	0.00
Or	3.08	0.00	3.43	1.60	0.00
Ab	38.00	37.54	39.43	43.69	31.70
An	18.27	18.23	17.49	15.98	17.62
Ho	0.00	.96	0.00	0.00	.52
Bi	15.65	14.78	16.25	10.69	22.76
Hy	0.00	0.00	0.00	0.00	0.00
Wo	.13	.24	0.00	.47	.36
Mt	1.97	1.49	1.73	1.38	3.50
Tn	1.66	.98	1.55	1.13	2.94
Ap	.70	.23	.90	.25	1.16
Qtz	28.8	29.7	25.6	26.0	20.5
Plag	40.5	51.6	46.9	51.3	39.6
K-Spar	.1	.1	.4	.5	0.0
Husc	0.0	0.0	0.0	0.0	0.0
Biot	20.4	5.4	25.1	17.5	24.8
Amph	2.0	6.8	.2	.1	9.1
Epio	6.7	.1	1.1	3.6	3.8
Opaq	.2	0.0	.2	.1	.1
Rest	1.3 A 0.6	6.4 C 5.7	.6	.8	2.1
Cpx	0.0	0.0	0.0	0.0	0.0
Gnt	0.0	0.0	0.0	0.0	0.0
An P/C	30	33	32	36	

Table 10-8: Chemical analyses of the Campfire Lake Pluton (Sodic Suite)

	1 6-13-10	2 6-13-12*	3 6-13-13*	4 6-13-29	5 6-13-31	6 OL-10	7 OL-15	8 OL-16	9 OL-17
SiO_2	68.9	69.0	66.6	68.5	66.6	70.4	71.1	70.3	65.2
Al_2O_3	18.3	17.5	17.2	16.3	19.0	15.4	15.3	14.5	18.2
Fe_2O_3	0.15	0.78	1.45	1.74	0.38	1.94	1.40	1.37	1.24
FeO	1.02	1.38	1.60	1.33	0.67	0.81	2.01	1.37	2.58
MgO	0.69	0.70	1.23	0.27	0.85	0.45	0.73	1.08	1.27
CaO	4.22	4.00	7.33	4.93	4.33	5.52	3.91	4.96	4.56
Na_2O	4.68	4.91	3.06	4.13	5.86	3.37	4.13	3.69	4.53
K_2O	1.16	0.95	0.39	0.74	1.12	0.50	0.77	0.65	1.17
TiO_2	0.34	0.52	0.43	0.36	0.17	0.40	0.31	0.36	0.48
P_2O_5	0.06	0.25	0.14	0.10	0.02	0.16	0.11	0.13	0.13
S	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.02	0.11
MnO	0.01	0.04	0.13	0.05	0.01	0.05	0.05	0.04	0.07
CO_2	0.32	0.44	1.08	0.76	0.16	0.73	0.42	0.83	0.24
H_2O+	0.60	0.65	0.91	0.05	0.16	0.29	0.30	0.15	0.42
H_2O-	0.05	0.03	0.28	0.41	0.42	0.49	0.42	0.43	0.42
Total	100.5	101.2	101.8	99.7	99.8	100.5	101.0	99.9	100.6
Sp. Gr.	2.67	2.68	2.71	2.69	2.64	2.69	2.69	2.70	2.70
Ag									
Ba	200	140	160	160	200	170	290	200	260
Be	<1	<1	<1	3	<1	2	<1	<1	3
Co	5	<5	<5	7	7	6	7	7	10
Cr	15	25	25	20	7	15	10	15	15
Cs	<5	<5	<5			2	2	2	2
Cu	10	5	5	10	7	<5	<5	10	25
Ga	15	10	15	20	15	15	15	15	15
Li	20	15	15	6	15	15	15	25	20
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	<5	<5	<5	6	7	<5	<5	7	10
	20	<10	20	15	<10	<10	<10	<10	<10
Rb	20	<10	<10	<10	<10	<10	<10	<10	20
Sc	<5	5	7	5	<5	6	6	8	7
	<1	<1	<1	<3	<3	<3	<3	<3	<3
	300	200	200	300	300	280	240	280	330
Th	<50	<50	<50			15	<10	15	<10
U	<0.2	<0.2	0.4	0.4	<0.2	1.7	0.4	0.2	0.2
V	20	20	20	25	10	30	30	40	50
Y	<10	<10	<10	<10	<10	10	<10	10	<10
Zn	55	50	80	35	25	20	75	55	75
Zr	40	60	100	100	10	150	150	100	150

1) Fine-grained leucocratic biotite trondhjemite.
*2) Fine-grained leucocratic clinopyroxene-biotite trondhjemite.
*3) Fine-grained leucocratic clinopyroxene-actinolite-biotite trondhjemite.
4) Fine-grained leucocratic biotite trondhjemite.
*5) Fine-grained leucocratic biotite trondhjemite with pyroxene?
*6) Fine-grained leucocratic clinopyroxene + amphibole trondhjemite.
*7) Fine-grained leucocratic pyroxene-biotite.
8) Fine-grained leucocratic hornblende-biotite.
*9) Fine-grained leucocratic hypersthene-diopside-biotite.
* Denotes enderbitic affinity

Table 10-9: Chemical analyses of and Daniels Lake plutons

	1 13-35-5	2 13-35-11	3 13-35-8A	4 15-22-14	5 15-22-28	6 15-23-29
SiO_2	64.9	70.4	70.6	72.9	70.7	71.4
Al_2O_3	16.5	15.3	16.2	16.2	16.5	16.5
Fe_2O_3	1.79	1.15	0.80	0.64	1.01	0.63
FeO	1.97	1.93	1.61	0.66	0.80	0.58
MgO	2.08	0.93	0.95	0.33	0.60	0.45
CaO	3.50	2.81	2.59	2.66	2.53	2.68
Na_2O	3.95	3.94	3.67	5.19	4.87	5.70
K_2O	3.36	2.53	3.04	1.47	2.29	1.30
TiO_2	0.42	0.41	0.36	0.17	0.25	0.17
P_2O_5	0.14	0.14	0.14	0.03	0.05	0.03
S	0.00	0.01	0.01	0.00	0.00	0.00
MnO	0.05	0.04	0.03	0.02	0.02	0.01
CO_2	0.23	0.08	0.10	0.10	0.10	0.15
H_2O+	0.46	0.15	0.44	0.16	0.33	0.39
H_2O-	0.18	0.36	0.41	0.14	0.10	0.11
Total	99.5	100.2	100.9	100.7	100.2	100.1
Sp. Gr.	2.72	2.67	2.65	2.65	2.66	2.65
Ba	1020	970	1060	440	510	220
Be	2	3	3	2	2	2
Co	5	8	7	<5	5	<5
Cr	80	15	15	5	5	10
Cs	<5	4	2	<5	<5	<5
Cu	5	<5	15	<5	5	10
Ga	10	15	15	9	10	10
Li	10	10	10	10	10	10
Mo	<1	<1	<1	<1	<1	<1
Ni	20	9	15	<5	<5	<5
Pb	20	25	25	10	10	10
Rb	60	70	90	30	50	30
Sc	9	7	5	<5	<5	<5
Sn	<1	<3	<3	<1	<1	<1
Sr	600	160	190	400	300	400
Th		15	<10			
U	0.3	1.6	0.5	0.3	0.4	<0.2
V	40	35	30	15	15	15
Y	20	15	10	<10	<10	<10
Zn	65	70	55	35	45	40
Zr	150	300	200	25	25	35

1 - 3 Bowder L. Intrusive; 4 - 6 Daniels L. Intrusive

Bowden Lake Intrusive

1) Hornblende-biotite trondhjemite to quartz diorite
2) Biotite charnokite (granodiorite to quartz monzonite)
3) Biotite granodiorite

Daniels Lake Pluton

4) Biotite trondhjemite
5) Biotite granodiorite
6) Leucocratic biotite trondhjemite

Table 10- . Chemical analyses of Sodic Suite miscellaneous intrusions into sediments.

	1	2	3	4	6	7	8	9	10	11	12*	13*	24	15	16	17	18
	MT-93A	MT-36	36-16-6	46-2-20	?	40-1-4	MT-106	1200-3C	24-22-32	25-19-23	21-27-15	21-27-23A	24-20-2	25-19-14	25-21-1A	42-2-27A	39-8-26
SiO_2	64.6	47.2	69.9	67.1	63.7	64.1	71.6	77.4	65.5	64.5	61.8	60.5	64.6	63.4	70.8	66.0	64.9
Al_2O_3	16.0	10.1	16.3	17.3	18.4	17.0	15.9	13.4	17.0	17.4	19.9	19.3	16.1	15.3	16.3	16.9	17.1
Fe_2O_3	1.19	2.32	0.33	0.98	1.31	2.23	0.57	0.53	1.46	1.67	1.75	1.77	1.81	1.94	1.25	4.05	1.63
FeO	3.70	14.4	1.95	1.69	2.33	2.33	1.69	0.81	2.33	1.61	2.33	2.33	2.55	2.48	0.87	0.40	1.69
MgO	3.36	5.34	1.20	1.13	1.80	2.29	1.27	0.38	1.44	1.88	1.37	2.49	3.58	3.85	0.76	1.68	1.70
CaO	3.92	16.5	2.75	3.47	4.48	4.33	5.85	2.06	3.92	3.19	5.41	5.07	3.93	4.01	2.76	4.05	3.60
Na_2O	3.32	0.29	5.20	5.61	4.75	4.56	1.49	3.44	4.19	4.52	4.50	4.85	3.96	4.02	5.31	5.01	4.58
K_2O	1.92	0.06	1.44	1.36	1.97	1.86	1.05	2.44	2.06	3.12	1.61	2.54	1.88	3.58	1.93	1.33	2.49
TiO_2	0.66	0.21	0.36	0.41	0.54	0.65	0.27	0.15	0.47	0.25	0.33	0.38	0.49	0.46	0.27	0.54	0.44
P_2O_5	0.28	0.20	0.06	0.14	0.15	0.32	0.14	0.06	0.17	0.24	0.21	0.24	0.28	0.27	0.09	0.16	0.14
S	0.02	0.64	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.02	0.00	0.01
MnO	0.08	0.24	0.02	0.04	0.06	0.07	0.04	0.01	0.05	0.08	0.09	0.07	0.08	0.07	0.03	0.08	0.06
CO_2	0.24	0.93	0.06	0.08	0.43	0.08	0.08	0.08	0.22	0.07	0.13	0.15	0.15	0.15	0.12	0.08	0.17
H_2O+	0.69	0.36	1.24	0.19	0.32	0.18	0.25	0.0	0.31	0.17	0.30	0.46	0.58	0.38	0.20	0.13	0.03
H_2O-	0.39	0.37	0.28	0.28	0.34	0.36	0.28	0.28	0.38	0.44	0.26	0.24	0.39	0.39	0.27	0.41	0.37
Total	100.4	99.2	101.1	99.8	100.6	100.4	100.5	101.0	99.51	99.1	100.0	100.4	100.4	100.3	101.0	100.8	98.9
~~Ba~~																	
Ba	1000	80	160	300	380	830	260	1340	440	1200	230	160	340	140	300	300	1100
Be	4	<1		3	<1	4	5	2	4	4	4	3	4	3	2		
Co	20	20	10	7	11	15	7	<5	12	9	10	10	15	15	6	12	11
Cr	170	25	20	<5	33	40	45	<5	14	67	55	60	250	270	5	24	32
Cs	6	1	4	4	6	4	4	2	2	4							
Cu	30	65	8	6	20	<5	7	<5	26	20	8	15	5	8	15	14	<5
Ga	15	10		15		15	15	9	15	15	10	10	15	10	15		
Li	20	10	25	6	42	15	8	10	18	12	15	10	10	15	10	24	20
Mo	<1	<1		<1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Ni	50	35	8	<5	16	20	20	<5	13	29	25	30	100	110	5	16	13
Pb	30	<10	30	20	20	15	40	20	16	19	15	20	25	20	20	16	34
Rb	100	<10	40	60	80	50	70	40	70	90	50	60	60	60	40		
Sc	10	7		<5		7	<5	<5	9	20	<5	<5	6	7	<5		
Sn	<3	<3		<3	<3	<3	<3	<3	<3	<3	<1	<1	<1	<1	<1		
Sr	720	130		540	370	800	500	390	300	1100	800	800	600	700	500		
Th	10	<10		20	<10	10	25	15	<10	10	<10	10	<10	40	20		
U	<1	1.2		0.5	2	0.4	<1	<1	<1	0.4	1.1	0.4	3.6	0.5	<0.2		
V	100	60		40	60	90	30	10	50	60	50	50	60	6			
Y	15	25		<10		15	15	<10	45	10	<10	<10	<10	<10	<10		
Zn	80	360	50	70	62	85	40	20	50	70	55	60	80	80	50	74	65
Zr	200	150		100	200	150	100	70	250	70	25	15	200	150	90		

*SiO_2 & Al_2O_3 anomalous each off by 3 with reciprocal 12-16 in Book C under Sodic (Bear Narrows)

Table 10-10

Individual Sodic Suite Members

1) Massive, medium to coarse-grained biotite quartz diorite (Adamhay Lake Pluton).
2) Very fine-grained leucocratic trondhjemite dike cutting metasediments (north of Chamberlain Narrows (Lac Seul)).
3) Fine-grained to medium-grained garnet-biotite trondhjemite (small stock in Quaint Lake area) may be rare diatexitic phase of metasediments.
4) Massive, medium to coarse-grained, weakly lineated biotite trondhjemite.
5) Massive, medium to coarse-grained biotite trondhjemite from sodic suite on Red Lake Road 1/2 mile north of English River/Wabigoon Subprovince Boundary.
6) Fine-grained magnetite-biotite trondhjemite to quartz diorite from Wapesi Bay Intrusive (eastern Lac Seul).
7) Very fine-grained hypersthene-biotite enderbite Wapesi Bay Intrusive.
8) Fine-grained leucocratic, massive biotite, trondhjemite Wapesi Bay Intrusive.
9) Trondhjemite, pluton in eastern Lac Seul.
10) Granodiorite, pluton in eastern Lac Seul.
11) Biotite Trondhjemite (Maskara Lake).
12) Hornblende-biotite trondhjemite to quartz diorite (Maskara Lake)
13) Biotite trondhjemite (eastern Lac Seul).
14) Hornblende-biotite granodiorite (Eastern Lac Seul north of Sioux Lookout).
15) Biotite trondhjemite (eastern Lac Seul north of Sioux Lookout).
16) Porphyritic/Porphyroblastic trondhjemite to granodiorite (Japan Lake).
17) Biotite granodiorite (Carling Lake Intrusive).

Table 10-11 Chemical analyses of the Sen Bay stock

	A 44-3-4A	B 44-3-13	C 44-3-6	D 44-3-7	E 44-3-12	F 42-6-8	G 45-4-17	H 45-5-13A	I 45-5-19b	J 42-7-23	K 45-5-19C	L 45-4-18A
SiO_2	69.2	67.7	73.9	73.5	71.0	68.4	66.8	68.1	70.9	72.5	66.8	72.5
Al_2O_3	16.0	16.9	16.0	15.2	14.9	17.5	17.9	15.2	15.8	15.1	17.3	15.5
Fe_2O_3	1.22	1.33	0.00	0.98	1.22	1.17	1.48	1.84	0.51	1.07	1.25	0.34
FeO	1.85	2.17	0.32	0.89	1.05	1.85	1.69	2.82	0.97	1.21	1.53	0.56
MgO	1.24	1.39	0.16	0.58	0.49	1.26	1.23	1.06	0.63	0.85	0.97	0.26
CaO	3.46	3.57	2.16	1.71	0.71	3.31	3.35	2.89	2.54	2.82	2.79	1.69
Na_2O	4.08	4.42	4.49	3.28	2.82	4.57	5.33	4.73	5.58	4.67	4.98	4.19
K_2O	1.43	1.50	3.07	3.99	6.46	1.50	1.51	1.51	1.38	1.33	3.38	3.89
TiO_2	0.45	0.47	0.04	0.25	0.43	0.46	0.38	0.63	0.22	0.30	0.50	0.13
P_2O_5	0.15	0.18	0.07	0.10	0.19	0.16	0.14	0.18	0.11	0.11	0.20	0.07
S	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.12	0.01	0.01	0.01	0.01
MnO	0.05	0.05	0.01	0.04	0.03	0.05	0.04	0.05	0.03	0.03	0.03	0.01
CO_2	0.11	0.08	0.10	0.06	0.10	0.08	0.08	0.10	0.11	0.10	0.08	0.06
H_2O+	0.29	0.66	0.15	0.38	0.44	0.72	0.46	0.11	0.11	0.06	0.11	0.33
H_2O-	0.36	0.35	0.31	0.37	0.42	0.30	0.38	0.35	0.31	0.42	0.37	0.31
Total	99.9	100.8	100.8	101.3	100.3	101.3	100.8	99.7	99.2	100.6	100.3	99.9
Sp. Gr.	2.69	2.70	2.63	2.64	2.62	2.69	2.69	2.73	2.65	2.67	2.68	2.62
Ag												
Ba	510	440	770	840	850	320	260	310	340	170	1650	1400
Be	<1	3	3	3	<1	3	3	4	4	3	4	2
Co	10	9	<5	6	<5	9	8	10	<5	6	7	5
Cr	10	10	<5	6	5	9	5	8	<5	7	15	<5
Cs	6	8	3	2	2	4	6	9	1	1	4	3
Cu	<5	15	<5	8	5	<5	6	80	15	<5	40	<5
Ga	15	15	10	10	15	15	15	15	15	15	15	15
Li	15	20	8	13	9	20	30	20	10	15	15	10
Mo	<1	<1	<1	<1	<1	<1	<1	4	<1	<1	<1	<1
Ni	10	10	<5	<5	<5	10	<5	10	8	<5	6	<5
Pb	15	20	25	35	40	15	20	20	25	20	35	25
Rb	60	60	70	120	170	50	50	90	40	60	90	80
Sc	5	7	<5	<5	5	6	<5	10	5	5	<5	<5
Sn	<3	<3	<3	<3	<3	<3	<3	<3	3	<3	<3	<3
Sr	350	360	380	220	160	350	440	290	340	300	570	540
Th	<10	<10	<10	45	75	10	15	20	15	20	60	15
U	0.5	2.7	1.0	0.6	2.3	<1	1.2	0.3	1.4	<0.2	0.7	0.8
V	45	60	<10	20	20	45	25	40	15	30	50	<10
Zn	50	65	10	30	40	65	70	80	35	45	55	20
Zr	150	200	20	55	200	100	150	300	100	100	150	35
Y	10	10	<10	20	20	10	<10	20	15	<10	15	<10

SEN BAY COMPLEX
ARCHER LAKE DOME

1) A Medium-grained clotty magnetite-biotite trondhjemite to quartz diorite.
1A Foliated biotite trondhjemite
3C Fine-grained foliated leucocratic biotite metagranodiorite
2D Medium-grained foliated biotite granodiorite to quartz monzonite
4E Very fine-grained massive leucocratic biotite quartz monzonite (potassic suite)

SEN BAY COMPLEX

F Biotite trondhjemite near Holger Lake fine-grained, weakly foliated
G Fine-grained biotite trondhjemite
H Medium-grained foliated to gneissic magnetite-biotite trondhjemite
I Biotite trondhjemite, massive, medium-grained, biotite
J Biotite trondhjemite
K Fine-grained weakly metamorphosed biotite granodiorite dike (cutting phase sample No. I above)
L Massive medium-grained leucocratic biotite quartz monzonite (potassic suite)

Table 10-12 Chemical analyses of the Chamberlain Narrows Intrusive Comple

	1 41-2-1	2 MT - 45A	3 41-2-30	4 Mt - 11A
SiO_2	48.5	62.9	65.4	62.8
Al_2O_3	15.8	16.8	17.9	16.9
Fe_2O_3	6.28	1.77	1.12	2.57
FeO	8.94	3.06	2.25	2.66
MgO	4.45	3.34	2.06	1.87
CaO	9.67	5.64	3.77	4.97
Na_2O	3.03	3.85	4.83	3.73
K_2O	0.55	1.14	1.51	1.25
TiO_2	1.65	0.57	0.55	0.68
P_2O_5	0.10	0.20	0.18	0.21
S	0.05	0.02	0.01	0.01
MnO	0.22	0.08	0.05	0.08
CO_2	0.07	0.24	0.09	0.10
H_2O+	0.22	0.52	0.29	0.21
H_2O-	0.34	0.38	0.38	0.42
Total	99.9	100.5	100.4	98.5
Ba	90	590	370	480
Be		<1	3	<1
Co	45	15	10	15
Cr	20	100	<5	25
Cs	7	2	2	5
Cu	140	15	6	20
Ga		15	15	15
Li	6	15	20	10
Mo		<1	<1	<1
Ni	40	15	10	15
Pb	15	30	15	55
Rb	<10	30	60	30
Sc		15	7	15
Sn		<3	<3	<3
Sr		600	360	330
Th				
U	0.4	<1	2.1	0.9
V		100	60	100
Y		10	<10	30
Zn	125	75	60	70
Zr		150	150	250

1) Medium-to-coarse grained biotite trondhjemite
2) Medium-grained massive to weakly lineated magnetite-biotite trondhjemite
3) Clotty, medium-grained magnetite biotite trondhjemite, main phase of Chamberlain Narrows Intrusive (clotty structure refers to concentration of mafic minerals into aggregate lenticles).
4) Fine-to medium-grained hypersthene-magnetite-biotite trondhjemite.

Table 10- Chemical analyses of the Separation-Indian Lake Complex

SEPARATION - INDIAN LAKES COMPLEX

	1	2	3	4	5	6	7	9	9	10	10A	11	12	13	14	15	16	17
	9-13-28	8-14 9 9	22 C1	9-11 6	9-11-11 8	24-16	9-15-25 9	16-29	9-20-3	9-20 2 9	21-6	9-11-5	9-16-20	9-14-C2 8	21-6 7	16-18 8	22 10	8-17-28
SiO_2	65 2	63 0	63 7	67 0	66 3	71 1	68 9	69 9	70 5	69 0	72 6	69 6	72 1	71 4	69 3	66 0	67 9	70 8
Al_2O_3	16 3	15 0	17 6	14 3	14 9	15 0	16 4	15 8	16 7	16 8	15 5	15 4	15 4	14 9	16 1	17 6	15 6	14 4
Fe_2O_3	2 64	1 70	2 21	1 48	1 51	1 36	1 65	1 90	1 01	1 40	0 53	0 97	1 62	1 46	1 57	1 20	2 03	1 20
FeO	2 40	5 85	2 69	2 89	2 67	1 38	1 38	1 53	0 87	1 31	0 58	2 08	1 46	1 38	2 26	1 53	2 77	1 60
MgO	1 69	2 25	1 61	1 87	1 75	0 73	0 93	0 79	0 47	0 77	0 36	0 85	0 62	0 66	0 97	1 28	1 39	0 86
CaO	4 15	3 49	4 83	3 88	3 67	2 43	3 04	3 02	3 02	3 44	0 81	3 15	3 02	2 52	3 05	2 62	3 45	2 31
Na_2O	4 18	3 49	4 58	3 62	4 34	4 42	4 73	4 79	5 44	4 97	3 53	5 02	4 39	4 08	4 05	4 56	4 09	3 50
K_2O	1 39	2 58	1 31	2 35	3 01	1 94	1 60	1 23	1 03	1 13	5 61	1 15	1 07	2 17	2 72	3 38	2 53	3 59
TiO_2	0 55	1 08	0 63	0 51	0 51	0 37	0 35	0 42	0 19	0 31	0 15	0 32	0 34	0 33	0 48	0 42	0 53	0 28
P_2O_5	0 12	0 23	0 14	0 11	0 11	0 07	0 08	0 08	0 03	0 05	0 10	0 08	0 08	0 06	0 09	0 19	0 11	0 05
S	0 01	0 03	0 00	0 01	0 01	0 00	0 00	0 00	0 00	0 00	0 00	0 01	0 00	0 00	0 00	0 03	0 01	0 00
MnO	0 07	0 13	0 07	0 08	0 07	0 04	0 04	0 05	0 03	0 03	0 00	0 05	0 05	0 04	0 05	0 02	0 08	0 05
CO_2	0 11	0 20	0 10	0 13	0 20	0 09	0 10	0 09	0 08	0 10	0 10	0 12	0 10	0 12	0 10	0 20	0 10	0 16
H_2O+	0 33	0 67	0 63		0 14	0 31	0 44	0 41	0 20	0 41	0 36	0 19	0 49	0 12	0 24	0 51	0 18	0 37
H_2O-	0 21	0 43	0 15	0 44	0 47	0 20	0 18	0 16	0 10	0 12	0 11	0 50	0 17	0 20	0 15	0 05	0 06	0 13
Total	99 4	100 1	100 3	98 7	99 7	99 5	99 8	100 2	99 7	99 9	100 4	99 5	100 9	99 5	101 1	99 6	100 7	99 3
Sp Gr	2 73	2 77	2 72	2 72	2 70	2 68	2 68	2 68	2 66	2 68	2 60	2 69	2 69	2 67	2 70	2 65	2 72	2 63
Ba	330	440	340	400	400	340	360	140	260	500	390	160	110	600	500	880	340	340
Be	<1	4	<1	3	3	2	<1	2	<1	<1	<1	4	2	3	<1	<1	<1	2
Co	10	20	10	15	9	<5	<5	5	<5	<5	<5	8	5	<5	5	<5	10	<5
Cr	15	25	5	40	40	10	5	<5	5	15	10	10	<5	10	10	25	15	15
Cs	<5		<5			<5	<5	<5	<5	<5	<5		<5	<5	<5	<5	<5	<5
Cu	20	55	15	20	10	<5	<5	5	<5	<5	<5	<5	10	5	10	10	10	5
Ga	15	20	10	15	15	10	10	10	9	10	9	15	10	9	10	15	10	10
Li	20	30	40	30	40	25	30	25	10	10	30	30	25	25	10	10	20	20
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	10	8	<5	20	20	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	5	5	5
Pb	10	<10	<10	20	25	10	<10	<10	10	<10	50	15	<10	10	10	20	10	30
Rb	40	40	40	50	80	60	50	50	20	20	160	40	30	50	40	80	50	100
Sc	10	15	10	10	10	<5	<5	<5	<5	<5	<5	5	10	<5	10	<5	15	9
Sn	<1	3	<1	<3	3	<1	<1	<1	<1	<1	<1	<3	<1	<1	<1	<1	<1	<1
Sr	200	50	300	300	300	200	300	50	300	300	50	300	100	200	100	900	200	10
Th															<50	<50	<50	<50
U	1 0	4 0	0 5	3 6	4 7	1 5	1 1	1 8	0 2	0 3	2 6	2 3	0 6	0 9	0 8	1 4	1 1	1 9
V	35	100	40	60	60	15	20	20	10	15	<10	25	20	20	30	25	40	20
Y	<10	45	20	20	40	<10	<10	<10	<10	<10	<10	<10	<10	<10	20	<10	47	25
Zn	85	100	80	65	65	65	65	70	45	60	40	60	65	60	65	65	75	55
Zr	150	600	150	150	100	100	100	100	35	90	25	100	60	100	100	100	200	30

Table 10-14:

1) Massive hornblende-biotite trondhjemite to quartz diorite;
2, 3, 4, 5) Weakly foliated to foliated medium-grained biotite trondhjemite to quartz diorite,
6) Foliated biotite trondhjemite
7) Foliated biotite trondhjemite inclusion in potassic stock at Indian Lake,
8, 9, 10) Weakly foliated biotite trondhjemite (typical map code 7a) medium grained,
10A) Quartz monzonite (potassic suite),
11) Medium-grained, massive to weakly foliated biotite trondhjemite
12) Massive biotite trondhjemite
13) Massive leucocratic biotite trondhjemite
14 15, 17) Weakly foliated porphyroblastic biotite granodiorite
16) Weakly foliated porphyroblastic hornblende-biotite granodiorite,

4 Phases - Hornblende Biotite Tr
Bio Trond
- Leucocratic Bio Tr
- Porphyroblastic Gndi

Table 10- Chemical analyses of the Armit Lake Complex.

ARMIT LAKE COMPLEX

	1	2	3	4	5	6	7	8	9
	P2-9-45	38-17-4	40-16-2	43-11-11	43-11-10	39-6-26	P6-1-13	P3-12-26	P3-12-26
SiO_2	48.2	54.0	57.5	64.5	72.7	59.6	61.0	64.0	64.3
Al_2O_3	15.4	14.9	22.8	16.4	14.4	16.0	15.5	15.3	15.1
Fe_2O_3	1.94	2.49	0.63	1.81	0.99	1.85	2.08	1.04	0.98
FeO	8.62	6.50	1.14	2.74	1.21	3.77	3.87	3.53	3.57
MgO	7.46	7.11	1.59	1.98	0.60	4.31	4.66	3.78	3.78
CaO	12.4	7.97	3.90	4.30	1.41	4.80	3.81	3.96	3.93
Na_2O	1.60	3.71	8.46	4.22	3.17	3.49	4.76	3.90	3.72
K_2O	0.62	1.22	1.22	2.00	3.44	2.62	1.80	1.57	1.55
TiO_2	0.82	0.94	0.42	0.61	0.18	0.70	0.64	0.34	0.34
P_2O_5	0.05	0.24	0.10	0.24	0.09	0.38	0.25	0.23	0.23
S	0.01	0.03	0.01	0.02	0.01	0.02	0.03	0.02	0.01
MnO	0.20	0.16	0.04	0.08	0.05	0.10	0.11	0.16	0.16
CO_2	0.80	0.35	0.06	0.32	0.24	0.10	0.15	0.10	0.11
H_2O+	0.33	0.72	1.50	0.34	0.27	0.52	0.40	0.19	0.24
H_2O-	0.39	0.19	0.41	0.53	0.39	0.61	0.50	0.50	0.49
Total	99.8	100.5	99.8	100.1	99.1	98.9	99.6	98.6	98.5
Sp. Gr						2.73	2.75	2.79	2.75
Ba	120	220	140	370	670	660	560	360	560
Be				4	3				
Co	50	35	9	10	<5	25	15	25	15
Cr	350	285	10	20	5	205	175	175	185
Cs	4	<2	3	6	3	7	2	4	3
Cu	85	25	6	35	<5	60	15	65	15
Ga				15	15				
Li	10	20	15	50	20	35	7	8	6
Mo				<1	<1				
Ni	150	135	10	15	<5	80	50	85	50
Pb	30	30	15	15	20	30	25	30	20
Rb	10	50	30	90	100	110	50	60	50
Sc				10	<5				
Sn				<3	<3				
Sr				340	180	160	270	330	270
Th				25	15				
U	3	2.4	3.1	0.8	1.6V				80
Y				25	10				
Zn				80	50	110	85	80	85
Zr				200	100				

20

ARMIT LAKE COMPLEX

1) Volcanic (tholeiitic basalt) inclusion or horizon in migmatized metasediments Miniss Lake
2) Metadiorite inclusion west of Delessep's Lake
3) Fine to medium-grained (oligoclase) leucocratic syenodiorite (rare phase northwest of Savant Lake Greenstone Belt
4) Biotite trondhjemite) Schist
5) Biotite granodiorite to quartz monzonite) Lake
6) Coarse grained foliated enderbite
7) Biotite-hypersthene enderbite
8) Medium to coarse-grained enderbite
9) Medium to coarse-grained enderbite

Table 10- Chemical analyses of the Lount Lake Batholith.

LOUNT LAKE BATHOLITH (LATE QUARTZ MONZONITE PHASES)

	A	B	C	D	E	F	G	H	J	L	M	N	P	Q	R	S	T
	9-17-38	10-19-1	10-17-1	10-21-4	11-19-4	12-21-7	13-33-4	13-33-39	15-26-28	12-14-18	11-21-13	11-19-6	12-15-36	12-13-2	12-14-6	12-16-5	12-16-11
SiO_2	69.3	70.5	69.6	68.8	69.5	68.4	68.0	68.0	67.4	68.4	70.2	67.9	72.3	72.7	68.7	70.8	72.3
Al_2O_3	16.1	16.4	16.5	15.5	16.3	17.0	16.7	17.0	18.0	14.9	14.7	15.6	16.3	15.3	15.8	15.1	15.4
Fe_2O_3	1.25	1.35	1.32	1.55	1.37	1.11	1.07	1.21	1.03	2.10	2.21	1.83	0.69	0.81	1.48	1.52	0.68
FeO	1.09	1.02	0.87	1.17	1.02	0.87	1.24	1.02	1.31	2.55	1.09	1.82	0.51	0.44	1.60	1.24	0.73
MgO	0.93	0.74	0.82	1.10	0.98	0.84	1.08	0.99	1.06	0.98	0.66	0.84	0.37	0.25	0.69	0.49	0.63
CaO	2.62	2.64	2.80	2.39	2.66	2.68	3.14	3.26	2.65	1.82	1.57	1.75	1.19	1.32	1.45	1.32	1.91
Na_2O	4.68	4.79	4.76	4.30	4.58	4.87	4.54	4.98	4.83	3.44	3.12	3.34	4.15	3.85	2.93	3.36	4.77
K_2O	2.28	2.30	2.07	2.50	3.04	2.83	2.34	1.99	3.13	4.47	4.60	5.38	4.92	4.73	6.00	5.32	3.08
TiO_2	0.26	0.28	0.23	0.34	0.27	0.23	0.29	0.26	0.37	0.86	0.53	0.65	0.13	0.17	0.70	0.39	0.19
P_2O_5	0.06	0.07	0.05	0.09	0.09	0.05	0.07	0.07	0.13	0.29	0.17	0.26	0.05	0.04	0.26	0.17	0.04
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.03	0.04	0.04	0.04	0.05	0.03	0.03	0.02	0.03	0.06	0.03	0.05	0.01	0.01	0.03	0.03	0.03
CO_2	0.10	0.11	0.14	0.10	0.14	0.13	0.20	0.19	0.12	0.10	0.11	0.21	0.10	0.23	0.35	0.11	0.18
H_2O+	0.46	0.29	0.19	0.16	0.17	0.22	0.45	0.20	0.38	0.55	0.51	0.31	0.03	0.04	0.61	0.09	0.22
H_2O-	0.21	0.17	0.18	0.17	0.12	0.18	0.17	0.17	0.12	0.17	0.21	0.13	0.17	0.20	0.17	0.15	0.17
Total	99.4	100.7	99.6	98.2	100.3	99.5	99.3	99.4	100.6	100.7	99.7	100.1	100.9	100.1	100.8	100.1	100.3
Ag	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba	830	830	740	360	780	1220	860	840	890	650	620	860	720	740	620	480	620
Be	<1	3	2	3	4	2	2	2	3	3	2	2	2	<1	1	2	2
Co	<5	<5	<5	5	5	<5	<5	<5	5	5	<5	5	<5	<5	<5	<5	<5
Cr	25	25	25	35	25	25	25	25	30	15	10	10	<5	5	10	5	15
Cs																	
Cu	<5	<5	<5	<5	5	<5	<5	5	5	10	5	10	<5	<5	10	5	<5
Ga	9	10	9	10	10	7	8	9	10	10	10	10	9	8	15	9	8
Li	20	30	25	25	20	15	10	10	20	30	25	30	15	10	20	25	10
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	10	5	5	10	10	10	5	10	10	<5	<5	<5	<5	<5	<5	<5	<5
Pb	10	10	10	10	10	10	20	10	20	20	20	20	20	20	40	30	20
Rb	50	60	50	70	90	40	40	30	80	200	150	160	100	100	190	200	40
Sc	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	<5	7	<5	<5	<5	<5	<5
Sn	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sr	400	400	300	300	400	500	500	500	400	200	50	5	300	400	30	100	400
Th	<50	<50	<50	<50	<50	<50	<50	<50	<50		90	<50	<5	<50	90	<50	<50
U	0.8	1.2	1.5	0.8	1.8	0.4	0.5	0.3	0.8	1.9	3.9	2.1	1.8	2.9	4.5	4.1	0.3
V	15	15	15	20	20	20	20	20	15	30	15	25	8	15	15	20	15
Y	<10	<10	<10	<10	15	<10	<10	<10	<10	20	<10	25	<10	10	<10	30	<10
Zn	45	55	50	60	55	40	45	45	60	95	70	80	30	20	70	55	35
Zr	45	80	20	100	250	60	80	10	150	150	150	250	50	60	250	150	40

Samples A - B = Marginal porphyritic trondhjemite, north margin; Samples C - J = Main porphyritic granodiorite phase; Samples L - N = Flow aligned porphyritic quartz monzonite; Samples P - T = Massive, equigranular quartz monzonite

Table 10-16:

P - Massive, medium-grained equigranular, leucocratic biotite (<5%) quartz monzonite (map code 8A)

Q - Massive, medium- to coarse-grained equigranular, biotite (5-8%) quartz monzonite (map code 8b)

R - Massive, fine-grained equigranular, biotite quartz monzonite (map code 8b)

S - Massive, medium- to coarse-grained, equigranular biotite (5-8%) quartz monzonite (map code 8b)

T - Massive, equigranular diopside-hornblende biotite quartz monzonite.

Table 10- Chemical analyses of miscellaneous Potassic Suite

POTASSIC SUITE MISCELLANEOUS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	8-15-4	15-9-3	24-22-10	9-15-14	12-5-3A	9-15-23	15-22-56	16-9-14	7-20-21	7-21-6	40-18-2				24-22-1B
SiO_2	72.4	73.4	71.1	72.9	73.5	73.0	69.8	62.8	67.1	75.3	70.9	70.5	73.2	70.1	69.7
Al_2O_3	14.9	15.4	15.8	14.9	13.9	14.7	16.7	16.6	18.1	13.7	15.2	16.6	15.5	15.3	16.6
Fe_2O_3	0.74	0.64	1.48	0.59	0.64	1.21	1.35	2.30	0.86	0.58	0.88	0.88	0.07	0.86	0.86
FeO	1.31	0.49	0.51	0.44	0.42	0.80	1.02	2.11	0.43	0.51	0.73	0.72	0.56	1.30	1.29
MgO	0.51	0.25	0.39	0.15	0.23	0.49	0.68	2.57	0.44	0.29	0.60	0.39	0.00	0.45	1.03
CaO	0.74	1.30	1.21	0.87	0.88	1.93	2.68	5.12	1.95	0.70	1.88	1.74	0.66	1.25	3.24
Na_2O	3.21	3.48	3.45	3.55	2.94	3.53	4.28	4.48	5.19	3.46	5.85	3.52	3.09	2.75	4.93
K_2O	5.89	5.64	6.32	5.04	6.22	3.40	3.00	2.43	4.30	5.01	3.03	4.26	5.62	6.08	1.99
TiO_2	0.28	0.19	0.13	0.11	0.17	0.22	0.30	0.59	0.20	0.14	0.22	0.13	0.01	0.36	0.26
P_2O_5	0.04	0.01	0.08	0.02	0.01	0.03	0.08	0.12	0.06	0.00	0.09	0.07	0.02	0.10	0.08
S	0.00	0.01	0.00	0.00	0.01	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.0
MnO	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.08	0.02	0.01	0.03	0.0	0.15	0.03	0.04
CO_2	0.20	0.18	0.11	0.10	0.12	0.10	0.11	0.14	0.24	0.18	0.09	0.55	0.35	0.48	0.26
H_2O+	0.48	0.19	0.31	0.18	0.01	0.29	0.27	0.08	0.36	0.09	0.13	0.08	0.14	0.04	0.05
H_2O-	0.14	0.42	0.36	0.24	0.42	0.21	0.12	0.46	0.19	0.12	0.35	0.43	0.28	0.46	0.46
TOTAL	100.7	101.6	101.3	99.1	99.5	100.0	100.4	99.9	99.5	100.1	100.0	99.3	99.7	99.6	100.8
AG			<1												
Ba	200	180	320	400	520	1200	1020	200	2160	130	710	760	30	910	940
Be	<1	3	<1	3	<1	<1	2	2	3	<1		<1	<1	<1	3
Co	<5	<5	7	<5	<5	<5	<5	10	<5	<5	5	<5	<5	<5	7
Cr	<5	10	15	<5	5	<5	5	65	<5	<5	15	10	<5	7	28
Cs	<5	-		<5	-	<5	<5	-	<5	<5	5	3	2	2	
Cu	5	<5	10	5	<5	20	<5	20	5	<5	7	6	<5	32	<5
GA	9	10		10	6	8	9	15	15	9					10
Li	40	10		30	15	10	25	25	20	35	30	15	7	18	15
Mo	<1	<1	<1	<1	1	<1	<1	<1	<1	<1					<1
Ni	<5	<5	9	<5	<5	<5	<5	30	<5	<5	<5	<5	<5	<5	13
Pb	60	30	35	40	45	10	20	15	20	20	40	29	57	32	15
Rb	290	190	110	230	160	60	60	30	70	70	70	110	150	200	
Sc	<5	<10	<5	<5	<10	<5	"5	15	<5	<5					
Sn	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		<3	<3	<3	6
Sr	10	200	300	50	200	50	300	800	900	10		250	20	190	<3
Th	<50	40	40		60	<50		<10				40	30	70	500
U	10.9	7.5	1.4	4.7	5.4	1.3	1.2		2.5	3.4	4	2.1	12	<1	
V	10	15	25	<10	7	10	15	100	<5	<5		20	<10	30	30
Y	30	<10	10	<10	<10	<10	<10	15	<10	<10					<10
Zn	60	25	25	45	35	45	55	70	35	30	50	34	8	52	44
Zr	200	150	?	50	90	100	90	200	100	150		250	25	250	150

Table 10-[16] Chemical analyses of miscellaneous Potassic Suite

1) Massive medium-grained equigranular-quartz monzonite from just east of the Helder Lake Greenstone Belt (8A)
2) Massive medium- to coarse-grained equigranular quartz monzonite (8A) dikes in gneissic suite near Catatrophe Lake (8A)
3) Massive medium-grained equigranular quartz monzonite stock intrusive into metasediments, eastern Lac Seul (8A)
4) Massive medium-grained biotite, equigranular-quartz monzonite (8b) dikes in Separation - Indian Lake Complex
5) Massive medium-grained biotite equigranular quartz-monzonite Tetu Batholith (8b)
6) Massive, medium-grained, equigranular biotite granodiorite to quartz monzonite (8i)
7) Porphyritic granodiorite sill at contact of Wabigoon/English River Subprovinces, Linklater Lake.
8) Porphyritic granodiorite Muriel Lake Area.
9) Massive fine-grained equigranular leucocratic biotite quartz monzonite (eastern Oak Lake).
10) Weakly foliated biotite quartz monzonite (Anishinabi Lake)
11) Wiggle Creek Pluton, porphyritic granodiorite
12) Massive, medium-grained, equigranular, leucocratic biotite quartz monzonite, stone quarry, Docker Township (Tustin Bridges Area)
13) Massive, equigranular biotite quartz monzonite dike in mafic volcanics of Wabigoon Belt at margin of English River Subprovince.
14) Massive equigranular biotite quartz monzonite dike in gneissic suite, Red Lake Road north of Vermillion Bay.
15) Late syenite dike cutting sodic suite, eastern Lac Seul.

Table 10-17 Chemical analyses of the Fletcher Lake Batholith

FLETCHER LAKE BATHOLITH

	1	2	3	4	5	6	7	8	9	10	11	12	13
	HFE 6-4	FE 5-14	HFG 4-2	FG 4-2	FG 4-6	FG 4-3(72)	FG 4-8	FG 4-11	FG 2-7	FG 2-8	FG 2-9	FG 4-3(74)	FG 8-6
SiO_2	63.7	67.0	63.1	69.6	64.2	68.3	62.6	64.7	63.9	59.4	71.5	62.2	64.3
Al_2O_3	17.2	16.7	18.1	16.6	14.4	16.1	18.2	17.1	17.8	19.0	15.9	19.4	17.6
Fe_2O_3	3.40	0.43	1.93	0.36	1.52	1.33	2.00	1.32	1.65	2.17	0.40	0.45	0.74
FeO	0.56	2.25	2.25	1.53	3.62	1.53	1.69	1.69	1.85	1.93	0.03	0.97	2.74
MgO	2.50	1.59	2.05	0.92	5.22	1.65	2.30	1.95	2.28	1.69	0.32	0.66	2.28
CaO	3.77	2.52	3.57	2.02	5.43	2.43	3.20	2.69	3.34	2.59	1.07	1.52	3.04
Na_2O	4.63	3.85	4.47	4.45	2.65	3.87	4.69	3.90	4.20	3.70	2.98	2.84	4.33
K_2O	2.11	3.96	2.46	3.78	0.97	3.70	4.00	4.45	3.49	6.96	6.44	10.5	4.13
TiO_2	0.44	0.33	0.83	0.31	0.49	0.36	0.47	0.50	0.48	0.60	0.10	0.14	0.46
P_2O_5	0.26	0.18	0.27	0.13	0.17	0.18	0.28	0.26	0.26	0.77	0.08	0.87	0.26
S	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MnO	0.07	0.06	0.02	0.03	0.12	0.04	0.06	0.05	0.05	0.03	0.01	0.02	0.06
CO_2	0.34	0.35	0.24	0.18	0.26	0.12	0.12	0.47	0.16	0.18	0.16	0.18	0.14
H_2O+	0.34	0.29	0.54	0.02	0.20	0.02	0.05	0.26	0.14	0.12	0.15	0.03	0.18
H_2O-	0.48	0.41	0.45	0.39	0.52	0.40	0.50	0.49	0.40	0.60	0.35	0.39	0.38
TOTAL	100.8	99.9	100.3	100.3	99.8	100.0	100.2	99.8	100.0	99.7	99.5	100.2	100.6
~~AG~~													
Ba	1200	1200	750	1000	730	1100	1800	1500	1600	1700	1900	1000	1900
Be	5	4	3	4	5	5	4	3	4	<1	2	<1	
Co	14	12	15	9	24	10	15	12	13	14	6	9	13
Cr	123	56	83	24	400	61	90	80	79	48	7	9	90
Cs													
Cu	11	<5	23	10	6	<5	<5	6	10	6	<5	<5	5
Ga	15	15	20	15	15	15	15	20	15	15	15	15	
Li	22	16	20	16	10	12	14	21	14	20	10	9	24
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Ni	47	23	30	13	64	25	35	29	31	18	6	8	3
Pb	21	20	44	23	<10	24	27	18	23	33	25	62	30
Rb													
Sc	10	7	5	<5	20	6	8	6	8	<5	<5	<5	
Sn	3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	
Sr	900	800	700	700	600	700	1000	1000	1000	700	800	700	
Th													
U													
V	70	45	60	30	100	40	60	70	60	60	<10	20	
Y	20	10	10	<10	10	10	<10	<10	15	25	<10	45	
Zn	66	96	80	41	77	65	65	54	60	72	15	36	63
Zr	150	150	250	100	50	70	200	50	200	60	<10	10	

1, 2, 4, 6, 8, 12, 13 = Porphyritic Quartz Monzonite
11 = Equigranular Quartz Monzonite
10 = Syenite
3, 7, 9 = Porphyritic Granodiorite
5 = Enderbite

18

TABLE 10- Chemical analyses at Lateral Lake

LATERAL LAKE

	1	2	3	4
SiO_2	75.2	73.2	62.5	75.2
Al_2O_3	15.2	15.6	18.6	15.4
Fe_2O_3	0.00	0.00	2.29	0.00
FeO	0.24	0.16	0.16	0.24
MgO	0.00	0.00	0.00	0.00
CaO	0.65	0.11	0.07	0.80
Na_2O	4.77	2.31	1.03	6.16
K_2O	3.73	7.78	13.2	1.32
TiO_2	0.04	0.03	0.00	0.05
P_2O_5	0.00	0.00	0.00	0.01
S	0.04	0.02	0.07	0.02
MnO	0.01	0.01	0.01	0.01
CO_2	0.10	0.10	0.00	0.12
H_2O+	0.03	0.00	0.07	0.13
H_2O-	0.44	0.40	0.42	0.31
TOTAL	100.5	99.7	99.1	100.8
~~Ag~~				
Ba	170	820	290	110
Be	4	3	<1	5
Co	<5	<5	8	<5
Cr	<5	<5	<5	<5
~~Cs~~				
Cu	8	<5	44	<5
Ga	15	15	15	15
Li	<3	<3	<3	<3
Mo	50	150	2000	<1
Ni	<5	<5	<5	<5
Pb	10	35	114	11
Rb				
Sc	<5	<5	<5	<5
Sn	<3	<3	<3	<3
Sr	250	300	350	<100
~~Th~~				
~~U~~				
V	<10	<10	<10	<10
Y	<10	<10	<10	<10
Zn	8	6	10	7
Zr	15	40	<10	20

#1 - Aplite
#2 - Medium-grained equigranular quartz monzonite
#3 - Syenitic pegmatite
#4 - Aplite

TABLE 10-19: Range and mean values of selected trace element chemistry for the gneissic suite.

	GNEISSIC SUITE	
	TOTAL MEAN VALUE	TOTAL NUMBER
Ba	561	91
Cs	3	35
Li	19	41
Rb	58	93
Sr	329	83
Y	14	48
Zr	173	48

TABLE 10-19 :

GOWER GNEISS BIOTITE TONALITE GNEISSES

Trace Elements	Range	Mean	Number (A)	Trace Elements	Range	Mean	Number (B)
Ba	263-486	381	7	Ba	347-510	407	7
Cs	-	-	-	Cs	-	-	-
Li	-	-	-	Li	-	-	-
Rb	33-54	44	7	Rb	42-64	52	7
Sr	217-629	4362	7	Sr	175-620	370	7
Y	2-21	9	7	Y	1-15	8	7
Zr	132-782	260	7	Zr	81-215	156	7

Trace Elements	Range	Mean	Number (C)	Trace Elements	Range	Mean	Number (D)
Ba	167-1619	681	7	Ba	286-870	563	7
Cs	-	-	-	Cs	-	-	-
Li	-	-	-	Li	-	-	-
Rb	4-90	52	7	Rb	27-89	63	7
Sr	152-558	337	7	Sr	180-922	364	7
Y	1-30	13	7	Y	12-39	23	7
Zr	82-272	162	7	Zr	70-215	165	7

TABLE 10-19 :

MELICK GNEISS (KENORA)				CHEMICAL ANALYSES CEDAR-CLAY LAKES AREA			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	150-930	443	11	Ba	347-1497	912	9
Cs	<5	<5	11	Cs			
Li	10-45	25	11	Li			
Rb	20-80	50	11	Rb	16-113	68	9
Sr	200-700	400	11	Sr	175-357	246	9
Y	-	-	-	Y	-	-	-
Zr	-	-	-	Zr	-	-	-

CHEMICAL ANALYSIS CEDAR-CLAY LAKES AREA				CHEMICAL ANALYSIS ARCHEAN GNEISSES			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	465-2025	976	8	Ba	263-947	573	5
Cs	-	-	-	Cs	-	-	-
Li	-	-	-	Li	-	-	-
Rb	50-115	74	8	Rb	27-111	83	7
Sr	184-292	222	8	Sr	140-725	386	7
Y	-	-	-	Y	-	-	-
Zr	-	-	-	Zr	-	-	-

TABLE 10-19 : Range and mean values of selected trace element chemistry for the gneissic suite.

GNEISSIC SUITE

(DECEPTION BAY, LAC SEUL) GNEISS				GNEISSIC SIOUX LOOKOUT-DECEPTION BAY			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	200-1750	595	12	Ba	40-960	350	13
Cs	1-9	4	12	Cs	<1-6	2	12
Li	6-25	18	12	Li	2-30	14	13
Rb	20-110	70	12	Rb	<10-70	39	13
Sr	240-570	335	12	Sr	200-480	380	3
Y	<10-60	20	12	Y	<10-20	13	3
Zr	45-300	152	12	Zr	100-150	133	3

SIOUX LOOKOUT GNEISSES				GNEISSIC SUITE, TUSTIN-BRIDGES AREA			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	190-530	290	5	Ba			
Cs	-	-	-	Cs			
Li	10-35	21	5	Li			
Rb	30-60	46	5	Rb	Only one sample		
Sr	200-300	220	5	Sr			
Y	<10-20	16	5	Y			
Zr	10-400	183	5	Zr			

TABLE 10-29: Range and mean values of selected trace element chemistry for the sodic suite.

SODIC SUITE

Trace Element	Total Mean Value	Total Number
Ba	428	92
Cs	3	69
Li	29	92
Rb	51	81
Sr	357	75
Y	21	70
Zr	130	70

TABLE 10-20 : Range and mean values of selected trace element chemistry for the sodic suite.

SODIC SUITE MISCELLANEOUS INTRUSION INTO SEDIMENTS				CHAMBERLAIN NARROWS INTRUSIVE			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	140-1100	367	7	Ba	90-590	382	4
Cs	-	-	-	Cs	2-7	4	4
Li	10-24	14	7	Li	6-20	12	4
Rb	40-60	54	5	Rb	<10-60	32	4
Sr	500-800	680	5	Sr	330-600	430	3
Y	<10	<10	5	Y	<10-30	86	3
Zr	15-200	96	5	Zr	150-250	183	3

CAMPFIRE LAKE PLUTON			
Trace Elements	Range	Mean	Number
Ba	140-290	197	9
Cs	2->5	3	7
Li	6-25	16	9
Rb	<10-20	12	9
Sr	200-330	270	9
Y	<10-10	10	9
Zr	40-150	95	9

TABLE 10- : Range and mean values of selected trace element chemistry for the sodic suite.

INDIVIDUAL SODIC SUITE PLUTONS				SEN BAY BATHOLITH			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	220-1060	703	6	Ba	50-443	239	12
Cs	2->5	4	6	Cs	2-6	3	5
Li	10	10	6	Li	6-52	21	12
Rb	30-90	55	6	Rb	10-80	43	6
Sr	160-600	341	6	Sr	20-390	243	6
Y	<10-20	12	6	Y	20-45	34	6
Zr	25-300	122	6	Zr	70-250	159	6

SEN BAY BATHOLITH				SODIC SUITE MISCELLANEOUS INTRUSION INTO SEDIMENTS			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	190-1100	392	5	Ba	80-1340	599	10
Cs	2-5	3	2	Cs	1-6	3	10
Li	9-25	15	5	Li	6-42	160	10
Rb	50-80	65	2	Rb	<10-100	61	10
Sr	250-380	315	2	Sr	130-1100	568	8
Y	<10	<10	2	Y	<10-25	14	7
Zr	90-150	120	2	Zr	70-200	138	7

TABLE 10-20: Range and mean values of selected trace element chemistry for the sodic suite.

SODIC SUITE

SEPARATION-INDIAN LAKES COMPLEX				SEPARATION-INDIAN LAKES COMPLEX			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	140-440	354	11	Ba	110-880	418	7
Cs	<5	<5	8	Cs	<5	<5	6
Li	10-40	26	11	Li	10-30	20	7
Rb	20-160	55	11	Rb	30-100	55	7
Sr	50-300	213	11	Sr	10-900	258	7
Y	<10-45	17	11	Y	<10-47	18	7
Zr	35-600	150	11	Zr	30-200	98	7

SEN BAY COMPLEX				ARMIT LAKE COMPLEX			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	170-1650	655	12	Ba	120-670	406	9
Cs	1-9	4	12	Cs	<2-7	3	9
Li	8-30	15	12	Li	6-50	19	9
Rb	40-170	78	12	Rb	10-110	61	9
Sr	160-570	358	12	Sr	160-340	258	6
Y	<10-20	13	12	Y	10-25	17	2
Zr	20-300	129	12	Zr	100-200	150	2

Table 10-21: Range and mean values of selected trace element chemistry for the potassic suite.

FLETCHER LAKE BATHOLITH				POTASSIC SUITE MISCELLANEOUS			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	730-1900	1337	13	Ba	30-2160	669	14
Cs	-	-	-	Cs	2-5	4	10
Li	9-24	16	13	Li	7-40	21	14
Rb	-	-	-	Rb	30-290	138	13
Sr	-	-	-	Sr	10-900	248	12
Y	-	-	-	Y	10-30	13	9
Zr	-	-	-	Zr	25-250	138	12

	Trace Elements	Total Mean Value	Total Number
LATE QUARTZ MONZONITE	Ba	872	44
PHASES	Cs	4	10
EARLY PORPHYRITIC	Li	19	44
PHASES	Rb	113	30
FLETCHER LAKE	Sr	282	29
BATHOLITH	Y	13	26
POTASSIC SUITE	Zr	121	29
MISCELLANEOUS			

Table 10-21: Range and mean values of selected trace element chemistry for the potassic suite.

LOUNT LAKE BATHOLITH

LATE QUARTZ MONZONITE PHASES				EARLY PORPHYRITIC PHASES			
Trace Elements	Range	Mean	Number	Trace Elements	Range	Mean	Number
Ba	480-860	664	8	Ba	360-1220	817	9
Cs	-	-	-	Cs	-	-	-
Li	10-30	21	8	Li	10-30	19	9
Rb	40-200	143	8	Rb	30-90	57	9
Sr	5-400	186	8	Sr	300-500	411	9
Y	10-30	16	8	Y	10-15	11	9
Zr	40-250	138	8	Zr	10-250	88	9

Trace Elements	Total Mean Value	Total Number
Ba	741	17
Cs	-	-
Li	20	17
Rb	100	17
Sr	299	17
Y	14	17
Zr	113	17

TABLE 10-22 Summary of Nature of plutonism in the English River Subprovince.

		GNEISSIC	SODIC	POTASSIC
DISTRIBUTION	Spatial Distribution	Southern Domain only, dominantly adjacent to Wabigoon Subprovince	Widespread, throughout south and north domains	Mostly in the south domain mainly west of Highway 105
	Intrusive Style	linear beltiform discontinuous complexes, rare domes	conspicuous plutons (simple) in north and locally in south domains; coalescing, linear, beltiform (meterogeneous) complexes in south, plutons range from 2 to 64 km; diapiric style tend to be more equidimensional	conspicuous plutons, locally coalescing plutons, large batholiths (up to 64 km in length) dikes and sills common, emplacement structurally controlled, tendency for batholiths to show lobate advancement; tendency towards equidimensions but Lount L. Batholith is rectangular.
COMP. MAGMATIC ACTIVITY	Gross composition	mafic to sodic, locally ultramafic	sodic	potassic
	Compositional range	ultramafic (rare) - gabbro-diorite-quartz-diorite-trondhjemite-granodiorite	diorite (minor)-quartz-diorite-trondhjemite-granodiorite	granodiorite-quartz monzonite-granite (rare) - syenite (rare)
	Magmatic activity, degree of complexity	multiphase	simple uniform single phase batholiths; multiphase batholiths and complexes	compositionally uniform over wide areas
	Relationship of phases	conformable, haphazardly distributed	conformable and disconformable multi phase are haphazardly distributed	discordant
	Deformation, degree of reworking	highly deformed, extensively reworked by: i) folding ii) metamorphism iii) metasomatism iv) partial anatexis v) hybridization	weakly to moderately deformed, reworked locally by: i) kinking ii) metamorphism iii) metasomatism (minor) iv) partial anatexis (rare) v) hybridization less reworked than gneissic suite	undeformed, dominantly unreworked, minor recrystallization of quartz, deuteric alteration of plagioclase
PETROLOGY	Structural fabric	gneissose to gneissic heterolithic banding	foliated, locally foliated to gneissic, locally massive, lineated	massive, locally primary lineation
	Texture	equigranular, allotiomorphic-granular	equigranular, commonly inequigranular, locally seriate, allotriomorphic-to hypidiomorphic granular, rarely porphyritic (plagioclase)	equigranular common, porphyritic (K-feldspar) texture common, locally seriate.
	K-feldspar	rare, interstitial	rare, interstitial	common, idiomorphic and interstitial
	Hornblende	prominant	prominant	rare (granodiorite and syenite compositions only)
	Dominant petrology	plagioclase + quartz + hornblende + biotite	plagioclase + quartz + biotite ± hornblende	K-feldspar + plagioclase + quartz + biotite ± muscovite
AGE EMPLACEMENT	Emplacement	probably intrusive, style unknown	passive, stoping, diapiric, forcefull	diapiric, forcefull, structurally controlled
	Depth Zone	mesozonal -> catazonal	mesozonal	mesozonal - epizonal
	Age Relationship	mainly equivalent to the sodic suite but possibly oldest age may come from this suite		
	Time span of emplacement	unknown	3.3 to 2.68 b.y. ± 20 b.y. (620,000 m.y.)	2.65 ± 40 b.y. - 2.56 (900,000 m.y.)
	Chemical Range	large	large	narrow
	Magma/Pluton generation	similar to sodic suite	probably episodic cyclical pulses	dominantly 1 major pulse

TABLE 10- : Compilation of Age Data for the major plutonic suites of the English River Subprovince.*

Suite	Phase	Method	(my) (Date)	Initial Ratio ($^{87}Sr/^{86}Sr$)	Reference
Gneissic	Biotite Tonalite gneiss	Rb/Sr	2760±50	0.7009±.0003	Gower (1978, p.266)
	trondhjemite to granodiorite gneiss at Tannis Lake	Rb/Sr	2950±150	0.7028±.0014	Clark et al. (1981, p.94)
	Clay Lake Gneiss	U/Pb	2750?		Beakhouse (1983)
	Cedar Lake Gneiss	U/Pb	2722?		Beakhouse (1983)
	Kenora biotite tonalite Gneiss	Rb/Sr	2760±40	0.7009±3	Gower and Clifford (1981)
	Kenora tonalite Gneiss	Rb/Sr U/Pb	2875±211 2830	0.7014±15	Beakhouse (1983)
Sodic (Simple Style)	Melick tonalite	Rb/Sr	2630±50	0.7012±.0003	Gower and Clifford (1986)
(Simple Style)	Dalles Batholith	Rb/Sr U/Pb	2630±10 >2762	0.7014±.0001	Gower 1978, p.411 Beakhouse (1983)
(Complex Style)	Sen Bay Stock (Quartz diorite) (Figure 8-5)	U/Pb	3300±10		Krogh et al. (1976) revised by Hinton and Long (1979)
(Complex)	Sen Bay Complex	Rb/Sr	2865±115	0.7025±8	Wooden and Goodwin (1980)
(Complex)	Lac Seul trond-gndi gneiss	Rb/Sr	2780±90	0.7009±4	Wooden and Goodwin (1980)
Mafic	Muriel Lake	Rb/Sr	2660+25	0.7010±7	Gower and Clifford (1981)
Potassic	Granite phase in Dalles Batholith	Rb/Sr	2630±10	0.7014±.0001	Gower, 1978, p.411
	Massive grano-diorite sill south of Bear Narrows (Fig. 8-5)	U/Pb	2652±40		Krogh et al. 1978
	Pegmatite dike	U/Pb	2560±40		Krogh et al. 1976
	Lac du Bennet Pluton	Rb/Sr	2680±91		Farquharson (1975)

Rennie Batholith	Rb/Sr	2603±320		Farquharson & Clark (1971)
Whiteshell Porphyritic Granodiorite	Rb/Sr	2610±113		Farquharson & Clark (1971)
Caddy Lake Quartz Monzonite	Rb/Sr	2558±12		Farquharson & Clark (1971)
Microgranite and granite pegmatite	Rb/Sr	2625±61		Farquharson & Clark (1971)
Pink granodiorite	Rb/Sr	2664±50		Farquharson & Clark (1971)
Perrault Falls Clotty Gneiss	Rb/Sr	2611±94	0.7033±0.0042	Beakhouse 1983
Lount Lake Batholith	Rb/Sr U/Pb	2635±56 2701.9	0.7022±4	Beakhouse 1983
Granitic Dike in Sen Bay	Rb/Sr	2580±45	0.7027±13	Wooden and Goodwin (1980)

1 probably belongs to sodic suite
2 Beakhouse (1983, p.274) indicates this is from the sodic granitoid suite.
* Portions of this table are summarized from Beakhouse (1983)

II-1

Table Chemical Analyses of the Robinson Batholith.

ROBINSON BATHOLITH

	1	2	3	4	5	6	7	8	9	10	11	12	13
	46-9-1	46-9-15	45-10-3	45-10-24	45-10-41	45-13-17	45-13-23	45-13-58	45-13-59	45-13-60	45-13-67	45-14-7	53-9-2
SiO_2	71.7	72.8	65.3	72.3	74.4	73.3	72.6	71.3	72.4	71.8	72.6	60.9	72.0
Al_2O_3	16.2	15.9	16.3	15.7	16.3	15.6	15.8	16.9	16.5	16.5	16.1	20.2	16.2
Fe_2O_3	0.98	0.42	1.90	0.67	0.22	0.43	0.39	0.38	0.31	0.17	0.26	1.61	0.59
FeO	0.48	0.32	2.90	0.40	0.24	0.48	0.48	0.64	0.32	0.48	0.40	1.77	0.40
MgO	0.51	0.20	1.84	0.31	0.12	0.35	0.23	0.28	0.11	0.16	0.11	1.47	0.28
CaO	2.61	1.27	4.85	1.70	2.09	1.47	1.73	1.91	1.98	1.97	1.03	5.63	1.68
Na_2O	5.41	5.65	3.91	5.10	6.39	5.07	4.90	5.45	5.39	5.72	5.01	5.33	5.42
K_2O	0.99	2.52	1.13	2.39	0.70	2.56	2.63	2.04	1.80	1.67	3.21	1.28	2.02
TiO_2	0.16	0.09	0.60	0.13	0.04	0.01	0.09	0.11	0.07	0.08	0.06	0.47	0.10
P_2O_5	0.08	0.08	0.17	0.07	0.05	0.08	0.07	0.06	0.04	0.05	0.06	0.15	0.05
S	0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01
MnO	0.03	0.03	0.07	0.03	0.01	0.04	0.04	0.04	0.03	0.03	0.06	0.04	0.05
CO_2	0.09	0.08	0.09	0.08	0.10	0.08	0.08	0.08	0.07	0.06	0.08	0.10	0.09
H_2O+	0.13	0.45	0.67	0.17	0.0	0.09	0.47	N.D	N.D.	N.D.	0.18	0.39	0.24
H_2O-	0.31	0.36	0.31	0.35	0.34	0.38	0.34	0.50	0.44	0.52	0.46	0.40	0.40
TOTAL	99.7	100.2	100.0	99.4	101.0	99.9	99.9	99.7	99.5	99.2	99.6	99.8	99.5
Ag	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba	370	1240	280	800	130	810	1000	890	740	390	710	240	750
Be	<1	3	<1	2	2	2	3	<1	<1	3	3	<1	2
Co	5	<5	15	<5	<5	<5	<5	7	<5	<5	<5	15	7
Cr	<5	5	20	<5	<5	<5	<5	<5	<5	<5	<5	10	<5
Cs	4	1	1	2	3	3	1	5	1	3	2	4	<1
Cu	<5	<5	30	<5	<5	<5	<5	<5	6	<5	5	35	<5
Ga	15	15	15	15	15	15	15	15	15	15	20	20	15
Li	35	5	20	20	10	30	35	50	20	20	85	70	35
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	<5	<5	15	<5	<5	<5	<5	<5	<5	<5	<5	8	<5
Pb	<10	15	<10	10	<10	15	15	15	10	<10	10	10	10
Rb	20	50	30	30	<10	50	50	40	40	40	90	40	40
Sc	<5	<5	10	<5	<5	<5	<5	<5	<5	<5	<5	9	<5
Sn	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Sr	400	500	280	480	320	330	340	400	500	350	250	600	350
Th	<10	<10	<10	95	15	<10	<10	15	10	10	<10	<10	<10
U	<10	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
V	15	<10	80	<10	<10	10	<10	10	<10	<10	<10	60	<10
Y	<10	<10	15	<10	<10	<10	<10	<10	<10	10	<10	<10	<10
Zn	40	25	75	40	15	30	40	35	25	25	40	55	40
Zr	35	10	150	20	<10	25	25	15	20	10	10	20	30

Table 11-2 : Chemical Analyses of the Nagron Lake Stock.

	NAGRON LAKE STOCK				
	1	2	3	4	5
	46-8-23	46-7-24	46-8-25	46-8-29	57-14-1
SiO_2	62.9	65.1	67.6	69.3	69.4
Al_2O_3	16.8	14.6	15.4	16.8	16.2
Fe_2O_3	4.32	0.99	1.82	0.82	0.75
FeO	1.29	2.74	1.93	1.93	1.85
MgO	1.46	1.88	1.68	1.09	0.94
CaO	3.62	2.99	3.47	2.97	2.69
Na_2O	4.67	4.56	4.37	5.29	5.39
K_2O	1.59	1.61	1.46	1.52	1.50
TiO_2	0.71	0.41	0.40	0.31	0.31
P_2O_5	0.17	0.12	0.10	0.10	0.09
S	<0.01	0.13	<0.01	<0.01	<0.01
MnO	0.09	0.06	0.06	0.05	0.05
CO_2	0.13	1.74	0.10	0.07	0.14
H_2O+	0.16	1.31	0.43	0.05	0.12
H_2O-	0.46	0.29	0.27	0.31	0.34
Total	98.4	98.5	99.1	100.6	99.8
Ag	<1	<1	<1	<1	<1
Ba	410	280	330	430	320
Be	3	<1	<1	<1	<1
Co	10	10	10	8	8
Cr	<5	20	25	15	10
Cs					
Cu	20	40	15	6	6
Ga	15	15	15	15	15
Li	15	10	15	20	20
Mo	<1	<1	<1	<1	<1
Ni	5	20	25	15	10
Pb	<10	<10	<10	<10	10
Rb	30	50	40	40	50
Sc	15	6	8	6	5
Sn	<3	<3	<3	<3	<3
Sr	250	170	260	380	320
Th					
U					
V	50	60	50	30	25
Y	45	10	10	<10	<10
Zn	80	40	55	55	60
Zr	250	100	90	60	80

Table II-2 :

NAGRON LAKE STOCK

	46-8-23			46-7-24			46-8-25		
Na	2.80)		A 45.63	2.74)		A 50.75	2.62)		A 50.26
K	1.32)	4.12	F 44.63	1.34)	4.08	F 35.20	1.21)	3.83	F 36.48
Mg	.88)		M 9.75	1.13		M 14.05	1.01		M 13.25
Fe^{2+}	3.02)			.69)			1.27)		
Fe	1.01)	4.03		2.14)	2.83		1.51)	2.78	
		9.03			8.04			7.62	
Ca	2.61		C 38.78	2.15		C 34.51	2.50		C 39.49
	6.73		N 41.60	6.23		N 43.98	6.33		N 41.39
			K 19.61			K 21.51			K 19.12

	46-8-29			57-14-1		
Na	3.17)		A 62.40	3.23)		A 63.91
K	1.26)	4.53	F 28.65	1.25)	4.48	F 28.10
Mg	.65		M 8.95	.56		M 7.99
Fe^{2+}	.57)			.53)		
Fe	1.51)	2.08		1.44)	1.97	
		7.26	C 32.08		7.01	C 30.22
Ca	2.14		N 47.53	1.94		N 50.31
	6.67		K 18.89	6.42		K 19.47

Table Chemical Analyses of the Lake of Bays Batholith.

	LAKE OF BAYS BATHOLITH							
	1	2	3	4	5	6	7	8
	47-10-1	47-13-1	47-13-2	59-15-4	510-14-3	59-19-3	59-19-5	510-21-1
SiO_2	71.6	70.1	70.3	69.2	71.2	60.0	64.5	67.5
Al_2O_3	16.1	15.9	16.4	16.4	15.9	17.6	16.3	16.9
Fe_2O_3	0.73	1.17	0.65	0.75	0.76	1.79	2.05	1.64
FeO	0.64	0.81	0.72	0.64	0.24	2.42	1.69	1.05
MgO	0.57	0.80	0.51	0.57	0.28	2.97	1.62	1.26
CaO	1.98	2.07	1.99	2.01	1.52	4.72	3.06	3.02
Na_2O	5.60	5.15	5.65	5.26	4.86	5.63	5.33	5.25
K_2O	2.33	2.73	2.41	2.93	3.24	1.59	2.77	2.11
TiO_2	0.20	0.28	0.22	0.22	0.13	0.57	0.55	0.38
P_2O_5	0.10	0.12	0.10	0.10	0.08	0.26	0.21	0.16
S	<0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
MnO	0.03	0.03	0.02	0.03	0.02	0.07	0.05	0.04
CO_2	0.08	0.06	0.07	0.10	0.08	0.10	0.08	0.09
H_2O+	0.16	0.31	0.47	0.42	0.14	0.74	0.10	0.23
H_2O-	0.31	0.35	0.34	0.43	0.43	0.47	0.42	0.45
TOTAL	100.4	99.9	100.4	99.1	98.9	98.9	98.7	100.1
Ag	<1	<1	<1	<1	<1	<1	<1	<1
Ba	1030	1000	1220	1260	820	570	570	740
Be	3	3	2	3	3	3	5	4
Co	<5	<5	5	5	<5	15	10	8
Cr	<5	10	5	6	<5	75	30	25
Cs								
Cu	8	6	5	<5	6	7	25	6
Ga	15	15	15	15	15	15	20	15
Li	30	30	25	20	15	10	20	25
Mo	<1	<1	1	<1	<1	<1	<1	<1
Ni	<5	<5	5	<5	<5	35	20	15
Pb	20	10	15	20	20	<10	15	15
Rb	60	70	50	50	90	30	90	60
Sc	<5	<5	<5	<5	<5	8	5	<5
Sn	<3	<3	<3	<3	<3	<3	<3	<3
Sr	690	630	700	600	430	550	530	600
Th								
U								
V	20	25	15	15	<10	70	50	35
Y	<10	<10	<10	<10	<10	15	10	<10
Zn	45	55	45	45	30	70	80	60
Zr	80	100	40	50	10	150	200	90

Table Chemical analyses of the Sturgeon River Batholith.

STURGEON RIVER BATHOLITH

	54-1-8	55-1-5	55-7-2	56-17-2	56-18-1	56-22-2	26-23-3	57-25-4	58-26-2	46-9-27
SiO_2	69.5	66.8	69.8	66.1	61.7	67.9	67.1	64.7	69.1	65.1
Al_2O_3	16.3	16.6	16.5	16.5	16.6	15.8	16.0	16.7	16.1	17.1
Fe_2O_3	1.15	1.77	1.07	0.56	2.09	1.78	1.81	1.83	0.98	1.84
FeO	1.37	2.01	1.05	3.70	3.86	1.93	2.74	2.82	1.85	2.25
MgO	0.85	1.29	0.74	1.69	2.59	1.08	1.64	1.75	1.10	1.48
CaO	3.33	3.94	2.93	4.57	5.72	3.23	4.51	4.77	3.24	4.25
Na_2O	4.57	4.37	5.03	4.06	4.15	4.64	3.87	3.98	5.08	4.42
K_2O	1.13	1.46	1.61	1.27	1.10	1.50	1.23	1.56	1.23	1.49
TiO_2	0.35	0.45	0.28	0.54	0.72	0.40	0.59	0.57	0.32	0.51
P_2O_5	0.12	0.15	0.11	0.15	0.17	0.14	0.17	0.16	0.10	0.17
S	0.01	0.01	<0.01	0.01	0.01	<0.01	0.01	0.01	0.01	<0.01
MnO	0.13	0.05	0.04	0.07	0.09	0.06	0.07	0.07	0.06	0.08
CO_2	0.07	0.22	0.06	0.08	0.20	0.41	0.09	0.09	0.09	0.08
H_2O+	0.14	0.22	0.62	0.79	0.60	0.23	0.32	0.22	0.23	0.47
H_2O-	0.43	0.39	0.37	0.33	0.37	0.45	0.40	0.37	0.40	0.38
TOTAL	99.4	99.7	100.2	100.4	100.0	99.6	100.5	99.6	99.9	99.6
Ag	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ba	320	310	320	310	230	290	340	370	230	320
Be	<1	<1	<1	<1	<1	<1	<1	3	<1	<1
Co	7	8	7	10	20	8	15	10	8	10
Cr	<5	8	6	25	40	8	15	15	15	10
Cs										
Cu	15	100	6	20	35	8	25	195	10	20
Ga	15	15	15	15	15	15	15	15	15	15
Li	30	30	35	20	20	30	30	30	55	45
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	<5	8	<5	15	30	<5	15	15	10	9
Pb	<10	<10	10	<10	<10	10	<10	15	<10	<10
Rb	40	40	40	30	30	40	30	40	40	50
Sc	<5	10	<5	8	15	10	10	10	6	9
Sn	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Sr	360	330	400	250	230	200	250	270	340	290
Th										
U										
V	30	50	25	70	100	40	80	80	40	60
Y	<10	10	<10	10	25	20	15	20	10	15
Zn	60	70	55	75	75	60	75	75	55	75
Zr	80	200	80	150	80	150	150	100	90	150

Table Chemical Analyses of the Lewis Lake Batholith

	LEWIS LAKE BATHOLITH							
	1	2	3	4	5	6	7	8
	45-11-2	45-12-4	45-13-4	45-13-63	45-14-6	45-13-44	45-13-4	42-12-3
Ag	<1	<1		<1	<1	<1	<1	<1
Ba	270	360		340	350	270	350	560
Be	<1	<1		<1	<1	<1	<1	<1
Co	15	9		8	8	5	7	8
Cr	20	15		6	<5	6	9	<5
Cs	2	2		3	2	3	3	2
Cu	25	10		7	6	8	6	10
Ga	15	15		15	15	15	15	15
Li	25	25		20	20	20	20	10
Mo	<1	<1		<1	<1	<1	<1	<1
Ni	15	9		<5	<5	5	6	<5
Pb	<10	10		<10	10	10	<10	<10
Rb	30	30		30	30	30	30	50
Sc	10	<5		6	<5	<5	7	7
Sn	<3	<3		<3	<3	<3	<3	<3
Sr	300	300		350	300	290	300	150
Th	10	75		<10	20	15	15	<10
U	<1	<1		<1	<1	<1	<1	<1
V	70	30		35	25	25	50	20
Y	15	<10		<10	<10	<10	<10	35
Zn	70	60		0	60	50	70	40
Zr	150	100			150	90	200	150

Table 14-1: Metamorphic and Deformational Events in the Uchi and English River Subprovinces of Ontario (Modified after McRitchie and Weber, 1971).

		S_0	Original Sedimentary and volcanic fabric.
D_1			Isoclinal folds in volcanic sequences and nappes in the Red L.-Bee areas.
	M_1	S_1	Development of planar fabric preserved as inclusion trains in staurolite, biotite, and almandine, and andalusite.
	M_1A		Main regional metamorphic event-development chlorite, biotite, hornblende, muscovite, cordierite, almandine, sillimanite. Migmatization of metasediments in English River Subprovince probably commenced during this event.
D_2			Regional Folding, roration of M_1 porphyroblasts associated with emplacement of granitic intrusions in Uchi volcanic sequence.
	M_2	S_2	Matrix coarsening and development of main axial plane schistosity of biotite and muscovite parallel to D_2 folds. Further migmatization of metasediment in English River Subprovince; minor volumes of mobilizate controlled by axial surfaces of mesoscopic D_2 folds.
D_3			Large scale S folds.
	M_3	S_3	Muscovite parallel to D_3 axial planes, pinitization of cordierite and andalusite.
D_4		S_4	Late stage development of mylonite on strike slip faults.
	M_4		Regrograde muscovite and chlorite in shear zones of D_4.
D_5		S_5	Late transcurrent faulting, Bear Lake fault.
	M_5		Minor recrystallization assoc. with D_5

Table 14-2: Metamorphic Mineral Assemblages from Lake St. Joseph and Eastern Lac Seul Areas.[1]

Zone	Assemblage	Rock Type
	LOW GRADE	
Chlorite-Biotite	Chl + Mu + Bio + Ep ± Gr	W
	Mu + Chl + Gf + Tour	W
	Bio + Chl + Ep + Act	W
	Bio + Mu + Chl + Gf	P
	Bio + Ep + Mu	W
	Chl + Act + Ep	M
	Act + Hb + Bio	M
	MEDIUM GRADE	
Staurolite-Chlorite-Biotite	Mu + Chl + Bio	W
	Bio + Mu	W
	St + Bio + Chl + Mu (Chl, Mu)	P
	Mu + Bio + St + Alm (Alm)	P
	Bio + St + Mu (Chl, Mu)	P
	Bio + Chl + Mu (St, And)	P
	Bio + Sill + Alm ± Gf (Alm)	P
	Sill + Bio + Mu (Chl)	P
	Bio + Alm + Sill ± Tour ± Gf (St)	P
	Bio + Cord + Sill + Alm ± Mu	P
	Bio + Mu + Sill ± Alm ± Tour (St)	P
	Trem + Bio	UM
	Bio + Cord + Alm (St)	P
Sillimanite-Muscovite	Bio + Mu	W
	Bio + Mu + Alm	W
	Bio + Sill + Mu + Alm	P
	Bio + Mu + Sill	P
	Bio + Sill + Mu ± Tour (St)	P
	Bio + Sill + Alm + Mu ± Gf	P
	Bio + Cord + Sill ± Alm ± Tour	W
	Bio + Sill (Mu)	P
	Bio + Cord + Alm + Mu	W
	Bio + Cord	W
	HIGH GRADE	
Sillimanite-K-Feldspar	Bio-Alm	W
	Bio-Alm-Cord	P
	Bio-Kspar-Cord-Sill	P
	Bio-Cord-Sill-Alm ± Kspar	P
	Bio-Sill-Cord-Alm	P
Almandine-Cordierite-K-feldspar	Bio-Alm	W
	Bio-Alm ± Mu	W
	Bio-Cord-Alm (Sill)	P
	Bio-Cord ± Alm ± Kspar (Sill)	P
	Kspar-Bio-Cord	P
Low Pressure Granulite Zone	Bio-Opx-Cpx-Hbl ± Alm ± Qtz	M
	Opx-Cpx-Hbl ± Alm	M
	Bio-Cord-Alm-Kspar (Sill)	P
	Opx-Cord-Bio-Hbl	I

Abbreviations: Act = actinolite; Alm = almandine garnet; And = andalusite; Bio = biotite; Chl = chlorite; Cord = cordierite; Ep = epidote/clinozoisite; Gf = graphite; Hbl = hornblende; Kspar = K-feldspar; Mu = Muscovite; Sill = Sillimanite; St = Staurolite; Tour = Tourmaline; Trem = Tremolite; I = Intermediate Granitoid Rocks; M = Mafic Metavolcanics, Mafic Dikes; P = Pelitic Metasediments; UM = Ultramafic Rocks; W = Wacke Metasediments. Minerals enclosed by rounded brackets () represent porphyroblastic M_1 relict phases exhibiting preserved internal foliation. Those enclosed by squared brackets [] represent M_3 diaphoritic mineral phases.

[1] quartz and plagioclase common to all assemblages except those of UM bulk composition.

Table 14-3: Metamorphic Mineral Assemblages in Metasediments from Dryden-Eagle Lake Area[1]

Zone	LOW GRADE Assemblage	Rock Type
Chlorite-Biotite	Bio + Chl ± Mus ± Tour ± Ep ± Fe-oxide	W
	Bio + Chl ± Mus ± Tour ± Fe-oxide	P
	MEDIUM GRADE	
Andalusite	Bio + And + Mus [Chl, Ser, Fib]	P
	Bio + And + Cord + Mus (Bio)	P
	Bio + Gar + Hbl + Fe-oxide	W
	Bio ± Mus ± Gar	W
Staurolite	Bio + St + Mu	P
Sillimanite-Muscovite	Mus-Cord-Sill-Bio	P
	Tour-Mus-Sill-Bio	P
	HIGH GRADE	
Sillimanite-K-feldspar	Bio + Cord + Sill + Kspar + Gar	P

Abbreviations: And = andalusite; Bio = biotite; Chl = chlorite; Cord = cordierite; Ep = epidote; Fib = fibrolitic sillimanite; Gar = garnet; Hbl = hornblende; Kspar = K-feldspar, Mus = muscovite; Sill = sillimanite; St = staurolite; Tour = tourmaline; M = Metawacke; P = Metapelite

Minerals enclosed by rounded brackets () represent M_1 relict phases containing preserved internal foliation. Those enclosed by squared brackets represent M_3 diaphoritic mineral phases.
1 Quartz and Plagioclase common to all assemblages.

Table 15-1: Summary of Structures and Metamorphism in the Northern Supracrustal Domain of English River Subprovince in Ontario and Manitoba

Manigotagan Gneissic Belt, Manitoba (McRitchie and Weber, 1971)				Clay Lake - Wabaskang Lake Area (Westerman 1977)		
Deformation Event	Metamorphism	Planar Fabric	Structure Types	Structure Group	Deformation	Structure Types
		S_0	Bedding in clastic sediments			Primary compositional banding as on Wabaskang Lake
D_1	M_1A	S_1	Intense isoclinal folding about subhorizontal axes and vertical axial surfaces which parallel trend of gneissic belt	Fa_1	D_3	Isoclinal folding of compositional banding and buckling of discordant leucosome veins in metasedimentary migmatite Development of E-W foliation in metasedimentary migmatite belt. Boudinage of concordant leucosomes in metasedimentary migmatite and thin amphibolite layers.
D_2	M_2	S_2	Intense, asymmetrical, similar Z-folding to SE or NW at with trending moderate plunges. Steep axial planes	Fa_2	D_4	Asymmetric, tight to close folds with west trending axes and sallow plunges. Frequently disharmonic with upright axial planes and foliation. Interlimb angles 25° to 70°.
D_3	M_3	S_3	Open asymmetric concentric folds with axes plunging steeply to NW	Fa_3	D_5	Concentric, close to open folds with steeply plunging axes and upright NW-SE axial planes Interlimb angles 60° to 110°.
D_4	M_4	S_4	Broad, curvilinear shear zones Development of subprovince boundary faults			Not observed in Cedar-Wabaskang Lakes area
D_5	M_5	S_5	Regional Z-warping, conjugate joints, minor Z and S-folds	?		May correlate with reverse kinks in Twilight metasedimentary gneiss
D_6		S_6	Linear mylonite and ultramylonite zones with significant dextral movement			Not observed in Cedar-Wabaskang Lakes area.

Table 15-2 Summary of Geological and Tectono-Metamorphic History of Cedar Lake - Clay Lake Area of English River Subprovince (mainly after Westerman, 1977)

Deformation Event	Structure Group	Metamorphism	Structural Features	Geochronological Age
pre-D1	Not observed	Not observed	Emplacement of tonalite plutonic precursors to Cedar Lake gneisses	
D1	Fb1	M1	Deformation of pre-D1 lithologies producing compositional banding and rootless, intrafolial, very tight to isoclinal F_{b1} folds in leucotonalite veins. Axial plane fabric coplanar with enclosing gneissosity.	
D2	Fb^2	M2	Deformation of pre-existing compositional banding producing tight folds with 5°-20° interlimb angles. Axial planar fabric coplanar with enclosing gneissosity. Intrusion of Clay Lake granitoid suite Structural Discordance or Disconformity	
			Deposition of supracrustals - clastic sedimentary precursors of Twilight gneisses, banded chert-magnetite iron formation, pillowed mafic volcanic flows, and Perrault Lake orthoconglomerate	Equivalent to 2.959 for Cycle I metavolcanics of Confederation Lake Belt of Uchi Subprovince (Nunes and Thurston 1980).
D3	Fb3	M3 (high grade to granulite)	Migmatization of clastic sedimentary precursors of Twilight gneisses Intense layer normal compression event produces tight to isoclinal flattened buckle folds in leucotonalite veins of Cedar Lake gneisses and in Twilight metatexitic metasedimentary migmatites (equivalent to fold generation F_{a1} of Westerman 1977, p.203). Subhorizontal tectonic deformation via thrusting or recumbent nappes results in interleaving of basement (Cedar Lake gneisses) and cover (Twilight gneiss) Boudinage of F_{b2} folds and normal kinking of Fb2 folds and foliation Development of highly penetrative foliation and lineation	Anatexis of metasediments dated at 2.6 by Krogh et al 1976

D_4	Fb4	M4 Retrogression of M3 Assemblage Replacement of biotite by chlorite, sericitization of feldspar, orthopyroxenes converted to pale brown, serpentine-like minerals	Development of major EW and NW-SE dome structures due to emplacement of the Lount Lake Batholith (Cliff Lake porphyritic granodiorite of Westerman 1977). Close folds with axial planes oblique to regional foliation /gneissosity, and disharmonic with interlimb angles 35-65°	Lount Lake Batholith dated at 2635 ± 56 Ma by Beakhouse (1980).
D5	Fb5, Fb6, F_{b7}		Minor folds that have deformed dikes associated with late granitic plutons. Variation in fold style possibly different expressions of one deformation period (Westerman 1977, p.89). F_b5 folds are open to close with 35° to 65° interlimb angles and upright axial planes oriented oblique to regional foliation/gneissosity. F_{b6} folds are conjugate and kink-like best developed in Cedar Lake gneisses and frequently axial surfaces of these folds control emplacement of granitic pegmatites F_b7 folds are open to gentle warps with 90° to 150° interlimb angles and upright axial surfaces markedly oblique to regional foliation/gneissosity Local deformation of pegmatitic granitic apophyses of Cliff Lake porphyritic granodiorite is notable.	

Table 15-3: Summary of Structural and Metamorphic History of Kenora Area (After Gower, 1978; Gower and Clifford, 1981, p.1079).

Deformation Event	Metamorphic Event	Structural and Lithologic Event	Geochronological Age
D_0		Remnant supracrustal sequence, mainly mafic metavolcanics	2770 ± 200 Ma
		Emplacement of tonalite gneiss precursors	2760 ± 40 Ma
D1	Regional high grade metamorphism coeval with D_1 and D2 deformations	Tight to isoclinal single layer folds, intrafolial, rootless, axial planes coplanar with gneissosity. Main development of regional gneissosity.	
		Emplacement of Melick Tonalite	2630 ± 50 Ma
		Marginal Granodiorite,	2735 ± 65 Ma
		and leucogranitoid injection	
D2		Tight to close (interlimb angle 10-60°) gradational into close to open (interlimb angle 60°-120°) multiple layer folds. Refolding of D_1 folds. Development of major F2 folds mainly in Black Sturgeon Lake area.	
		Emplacement of granitoid plutons and mafic dikes	
		Mafic dikes	2630 ± 50 Ma
		Lulu Granodiorite	2470 ± 140 Ma (K-Ar biotite, Peterman et al. 1972)
		Austin Granite (Lount Lake Batholith)	2635 ± Ma (Beakhouse and McNutt 1980).
D3	M2 Retrograde metamorphism associated with Dalles Pluton	Diapiric emplacement of Dalles Granodiorite. Refolding of macroscopic D_2 folds. Dextral movement on Rabbit Lake Fault (5.8 kilometers) and Kenora Fault, the latter forming the subprovince boundary	2630 ± 10 Ma
		Emplacement of post-tectonic Muriel Diorite-Granodiorite	2660 ± Ma
		Emplacement pegmatites, intermediate and grey granodiorite dikes, and diorite intrusion breccia	
D4		Open, NE - trending, upright folds Buckling of pegmatites Final movement on Kenora and Rabbitt Lake Faults	
D5		Pegmatite emplacement Faulting and shearing Diabase dikes Faulting	

Table 16-1 Average Crustal Abundances of Selected Elements and Computed Element Ratios Used in Chapter 16.

Element	Average Crustal Abundance	Reference
Ba	400 ppm	Mason (1966)
Be	2 ppm	Mason (1966)
Ca	3.63%	Mason (1966)
Cs	3 ppm	Cocco et al. (1972)
K	2.10%	Heier and Adams (1963)
Li	12 ppm	Heier and Billings (1972)
Mg	2.09%	Mason (1966)
Rb	91 ppm	Heier and Adams (1963)
Sr	450 ppm	Turekian and Kulp (1956)
Th	10 ppm	Mason (1966)
Average Canadian Shield	10.3 ppm	Shaw et al. (1976)
" " "	13.0 ppm	Eade and Fahrig (1971)
U	2 ppm	Mason (1966)
Average Canadian Shield	2.45 ppm	Shaw et al. (1976)
" " "	2.1 ppm	Eade and Fahrig (1971)

Average Crustal Element Ratios

Ba/Rb = 4.4	Mg/Li = 1742
K/Ba = 53	Rb/Sr = 0.20
K/Cs = 7000	K/Th = 2100
K/Rb = 231	K/U = 10,500
Ca/Sr = 81	Th/U = 5

Table 16-2 Partial Major and Trace Element Petrochemical Analyses, Sandy Creek Beryl Pegmatite[1].

	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	SC-7	SC-8	SC-9	SC-10	SC-11					X	n
SiO_2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	67.8	69.8	67.5	68.9		
Al_2O_3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17.9	17.5	18.5	18.1		
Fe_2O_3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.16	0.19	0.38	0.05		
MgO	0.00	0.00	0.00	0.11	0.00	0.12	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.00		
CaO	0.75	0.44	0.66	1.05	0.64	0.95	0.40	1.29	0.86	0.32	1.91	0.74	0.61	0.83	0.85		
Na_2O	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.23	9.71	9.09	9.74		
K_2O	0.47	1.11	0.30	4.49	0.75	3.55	0.43	1.32	0.31	0.24	1.62	0.72	0.35	0.95	0.33		
Ba	30	30	20	40	20	40	10	30	20	20	20	40	30	30	30	27	15
Be	200	20	150	15	300	300	20	200	20	6	300	ND	ND	ND	ND	139	9
Cs	9	14	1	75	22	61	4	16	1	1	34	10	8	2	7	18	15
Li	58	67	30	208	54	175	18	70	12	14	96	47	44	16	104	68	15
Nb	<1	8	65	55	4	40	<1	15	<1	<1	<1	3	<1	<1	10	?	
Rb	40	130	10	460	60	360	10	110	20	10	160	60	20	20	120	143	15
Sn	8	20	3	75	15	75	3	25	3	3	35	9	3	3	20	31	9
Ta	<5	<5	240	21	5	17	<5	7	<5	<5	8	<5	<5	<5	<5	?	
Th	15	11	3	32	12	5	18	19	18	11	20	10	20	10	11	15	12
U	22.8	6.4	15.1	8.3	6.9	29.7	5.4	14.5	2.4	6.2	18.7	2.5	5.0	2.2	5.0	10	15
Sr	70	60	100	50	100	80	60	70	40	60	120	35	60	35	75	68	15
Y	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	?	
Zr	40	30	30	30	30	100	30	50	30	<20	30	40	30	40	30	37	15
Facies	A	A	A	P	A	P	A	A	A	A	A	A	A	A	A		

(A = Aplite, P = Pegmatite)

K/Rb	97	71	250	81	104	82	357	100	129	199	84	100	145	394	23	136
K/Ba	130	307	124	932	311	737	357	365	129	100	672	149	97	263	91	318
K/Cs	433	658	2490	497	283	483	892	685	2573	1992	395	598	363	394	391	875
K/U	171	1439	165	4490	902	992	661	756	1072	321	719	2390	581	3584	548	1253
K/Th	260	837	830	1165	519	5893	198	577	143	181	672	598	291	789	249	960
Th/U	0.66	1.72	0.20	3.85	1.74	0.17	3.33	1.31	7.50	1.77	1.07	4.0	2.0	4.5	2.2	2.13
Rb/Sr	0.57	2.22	0.1	9.2	0.6	4.5	0.2	1.6	0.5	0.2	1.3	1.71	0.33	0.57	1.60	1.68
Ca/Sr	76	52	47	149	45	84	47	131	153	38	113	150	72	168	80	94
Ba/Rb	0.75	0.20	2.0	0.001	0.33	0.11	1.00	0.27	1.0	2.0	0.13	0.67	1.5	1.5	0.25	0.59
Mg/Li	-	-	-	3.19	-	4.1	3.3	0.86	-	4.29	0.63	1.3	2.7	3.7	-	9.60
Na/K												11.4	24.8	8.5	26.7	

[1] ND = Not Determined
n = number of analyses

Table 16-3: Analysis of a Composite Muscovite Samples from the

	1	2
SiO_2	43.6	46.9
Al_2O_3	38.8	34.5
Fe_2O_3	0.75	0.74
FeO	0.48	0.32
MgO	0.37	0.15
CaO	0.09	0.15
Na_2O	0.54	0.44
K_2O	9.88	9.41
CO_2	0.30	0.30
TiO_2	0.14	0.02
P_2O_5	0.06	0.02
S	0.02	0.02
MnO	0.02	0.29
H_2O+	4.06	3.75
H_2O-	ND	1.35
Ba	30	20
Be	20	20
Cs	128	1056
Li	530	560
Rb	1400	15,400
Sn	120	130
Th	38	181
U	1	1
Ga	ND	200
Zn	ND	503

Table 16-4 Selected Mean Inter-element Ratios from Beryllium, Lithium and Uranium Pegmatites of the Study Area.

	URANIUM PEGMATITES									RARE-METAL PEGMATITES				
	UMFREVILLE LAKE	CELYN LAKE	DAVIDSON		DROPE TOWNSHIP			TOURISTLAKE						
			Homogeneous Diatexite	Potassic Suite Granitoids	Low Grade Zone	High Grade Zone	Meta-wacke	Porphyritic Quartz Monzonite	Mafic Biotite Granodiorite	Tot Lake	Mavis Lake	McCombe Property	Sandy Creek Beryllium Pegmatite	Average Crustal Ra
K/Ba	73	93	162	111	205	317	126	154	66	591	377	190	136	53
K/Cs	6,751	3,019	12,334	14,475	6,017	3,201	3,861	9,359	2,337	45	214	79	875	7,000
K/Rb	279	141	170	231	151	160	90	154	66	7	14	11	136	231
K/Th	846	807	1,787	2,710	363	1,432	1,774	837	81	229	422	-	960	2,100
K/U	1811	418	501	2739	380	1,850	3,433	4,343	40	11,634	4,291	-	1,253	10,500
Th/U	2.88	0.27	0.14	0.20	0.89	1.24	3.00	6.44	0.50	22.8	9.0	-	2.13	5
Ba/Rb	4.62	2.26	1.08	2.17	1.12	0.51	0.95	1.95	0.25	0.04	0.23	0.05	0.59	4.4
Mg/Li	356	256	28	33	181	610	199	145	173	4.3	14	-	9.6	1,742
Ca/Sr	50	-	-	-	29	54	146	61	118	85	52	-	93	81

Table 16-5 Partial Analyses and Selected Element Ratios of Spodumene Pegmatite from the McCombe Property of Capital Lithium Mines Limited.

Sample No.	Li	Baa	Csx	Bes	Nbs	Tas	Rba	Sns	K/Rb	K/Cs	Ba/Rb	K/Ba
Roadhouse River No.1	0.7%	20	100	150	60	<1000	510	20	12	60	0.04	249
Roadhouse River No.2	0.86%	40	130	175	80	<1000	620	20	11	51	0.06	137
Roadhouse River No.3	1.0%	40	70	125	200	<1000	990	28	9	126	0.04	183

Whole Rock Analyses by Mineral Research Branch, Ontario Division of Mines. Results reported in ppm unless otherwise indicated.

a = Atomic Absorption Spectrophotometry
s = Emission Spectroscopy
x = X-ray Fluorescence

Table 16-6 Selected Major and Trace Elements, Tot Lake Li-Cs-Rb-Ta Pegmatite.

	P TR2-0'	A TR2-2'	P TR2-4'	SPOD RICH TR2-6'	P TR2-8'	P TR2-10'	SPOD RICH TR2-12'	P RT2-14'	A RT2-16'	POLLUCITE RICH TR-2-18'	P. QUARTZ RICH TR-20'
SiO_2	63.60	65.70	68.70	70.30	64.50	72.90	63.20	72.90	69.90	71.50	79.50
Al_2O_3	18.40	21.30	20.50	23.10	21.90	16.90	26.70	19.90	18.30	20.80	15.40
Fe_2O_3	2.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	1.57	0.09	0.07	0.20	0.10	0.04	0.08	0.13	0.05	0.27	0.19
CaO	3.09	0.51	0.40	0.30	0.30	0.20	0.24	0.34	0.52	0.30	0.35
Na_2O	4.77	10.3	5.02	2.12	4.60	2.33	1.92	3.95	9.42	2.55	3.26
K_2O	2.45	0.96	2.60	1.25	6.21	4.79	0.43	1.24	0.21	1.12	1.10
Ba	660	60	50	20	20	40	30	10	10	30	20
Be	50	35	7	35	45	6	27	45	50	35	20
Cs	4495	185	249	308	1148	808	160	347	130	21700	357
Li	835	82	1300	16000	5600	5200	24500	8400	85	5000	2400
Rb	3400	1240	2060	1650	6200	6250	640	1800	380	1900	1360
Sr	90	40	60	30	110	90	20	30	20	40	30
Th	7	30	50	40	90	80	20	40	20	30	30
U	3.1	2.4	ND	2.4	0.8	0.9	0.9	3.1	4.9	2.1	1.0
							120	70	160	65	32

Table 16-6

	A TR3-0'	A TR3-2'	A TR3-4'	A TR3-6'	P TR3-8'	P TR3-10'	P TR3-12'	P TR3-14'	A TR3-16'	A TR3-18'	TR4-5'	TR4-10'	TR4-15'
SiO_2	63.50	58.30	78.60	65.80	63.50	65.30	67.50	66.70	78.20	64.90	67.50	65.90	69.40
Al_2O_3	23.30	24.90	14.70	21.60	21.60	21.20	22.30	21.20	13.60	22.50	21.20	21.00	19.40
Fe_2O_3	0.28	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
MgO	0.14	0.22	0.07	0.05	0.07	0.06	0.11	0.05	0.05	0.16	0.14	0.05	0.07
CaO	1.15	3.31	0.32	0.37	0.30	0.30	0.37	0.25	0.22	0.42	0.78	0.08	0.44
Na_2O	10.00	8.28	4.37	10.70	5.45	5.17	5.89	5.36	5.22	8.26	8.28	11.60	10.90
K_2O	1.10	1.37	1.54	0.83	6.44	4.54	2.18	7.22	0.70	1.97	1.42	0.27	0.12
TiO_2	0.02	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01
P_2O_5	0.25	0.20	0.09	0.10	0.14	0.12	0.10	0.10	0.04	0.11	0.13	0.07	0.12
MnO	0.23	0.05	0.08	0.04	0.06	0.07	0.15	0.05	0.04	0.05	0.19	0.04	0.04
Ba	40	120	40	20	40	30	40	30	20	40	90	40	20
Be	4	35	15	50	40	15	15	15	4	9	50	7	30
Cs	207	115	142	328	1332	922	390	1166	94	287	195	24	34
Li	215	425	51	315	3800	5400	5500	2000	28	125	74	22	20
Rb	1510	1090	1330	1050	9000	6300	2080	9500	530	1800	1290	230	160
Sr	100	150	40	30	110	90	40	112	20	50	80	40	10
Th	50	30	40	30	110	90	50	100	20	50	40	10	10
U	0.4	0.5	0.4	3.4	4.2	4.2	3.0	3.3	0.9	3.8	3.6	3.5	2.6
Ta	190	23	110	230	410	ND	400	ND	30	350	ND	150	170
	8280	23832	2232	2664	2160		2664	1800	1584	7024	5616	576	3168

Table 16-6

SELECTED ELEMENT RATIOS

	TR2-0'	TR2-2'	TR2-4'	TR2-6'	TR2-8'	TR2-10'	TR2-12'	TR2-14'	TR2-16'	TR2-18'	TR2-20'	TR4-5'	TR4-10'	TR4-15'	[illegible]
K/Rb	6	6	10.5	6	8	6	6	6	5	5	7	9	10	6	7
K/Ba	31	133	432	519	2577	994	119	1029	174	310	456	131	56	50	5[illegible]
K/Cs	4.5	43	87	34	34	49	22	30	13	0.43	26	60	93	29	4[illegible]
K/U	6560	3320	-	4323	64429	44174	1151	2100	830	9296	22825	3274	640	38	1[illegible]
Na/K	1.74	9.53	1.72	1.51	0.66	0.43	3.94	2.83	41.0	2.03	2.65	5.19	39.0	80.7	9
Ca/Sr	247	92	48	72	20	16	86	82	187	54	85	70	14	317	8[illegible]
Ba/Rb	0.19	0.05	0.02	0.01	0.003	0.006	0.05	0.006	0.03	0.02	0.015	0.07	0.17	0.125	0
Mg/Li	11.3	6.6	0.32	0.08	0.11	0.05	0.02	0.09	3.6	0.33	0.48	11.4	13.7	21.1	4
Th/U	22.6	12.5	-	16.7	112.5	88.9	6.5	8.2	9.5	30.0	75.0	11.1	2.8	3.8	2[illegible]
K/Th	291	266	432	259	573	497	178	257	87	310	304	295	224	100	2[illegible]
Rb/Sr	37.8	31.0	34.3	55.0	56.4	69.4	32.0	60.0	19.0	47.5	45.3	16.1	5.8	16.0	2[illegible]

Table 16-7 : Chemical Analyses of Columbite - Tantalite Minerals from the Tot Lake Pegmatite (Ucakuwun 1981, 113).

	1	2	3	4
Ta_2O_5	36.20	61.51	74.61	76.26
Nb_2O_6	45.51	21.59	11.50	10.33
MnO	16.73	12.86	11.19	11.40
FeO	1.65	2.02	2.70	2.01
Total	100.09	97.98	100.00	100.00
Nb/Ta	1.26	0.35	0.15	0.14

Table 16-8 Petrochemical Analyses across Pegmatite No.5, Main Zone, Mavis Lake Li-Be-Ta Property

	0 m							
SiO_2	69.0	70.4	71.9	68.8	63.8	65.9	70.8	64.9
Al_2O_3	17.4	21.8	17.7	19.3	17.5	20.7	17.2	18.9
Fe_2O_3[1]	0.21	0.18	0.13	0.14	2.89	0.19	0.11	1.02
MgO	0.00	0.01	0.04	0.00	1.56	0.04	0.00	0.57
CaO	0.56	0.08	0.15	0.06	3.73	0.05	0.04	1.81
Na_2O	10.1	1.93	4.69	6.12	4.28	8.24	5.65	8.68
K_2O	0.11	1.93	4.69	6.12	4.28	8.24	5.65	8.68
TiO_2	0.01	0.02	0.17	0.01	0.40	0.02	0.01	0.19
P_2O_5	0.82	0.09	0.16	0.12	1.36	0.11	0.14	1.00
MnO	0.28	0.08	0.07	0.02	0.09	0.02	0.01	0.08
H_2O+	0.40	1.00	0.70	1.50	1.20	1.30	0.90	0.80
Total	98.9	96.8	96.8	98.7	97.5	98.8	98.2	98.1

[1] Total Fe as Fe_2O_3

Ba	50	40	40	20	80	20	20	20
Be	50	30	60	50	60	25	20	60
Cs	6	37	53	86	94	51	70	22
Li	126	14,000	6,600	90	370	70	140	84
Rb	40	730	1200	1700	480	1300	1700	70
Sn	70	150	150	200	200	300	250	80
Sr	35	25	30	45	375	40	45	90
Th	<10	24	24	69	17	40	46	<10
U	11.1	4.5	10.3	5.5	4.1	4.5	1.6	3.5
Ta	200	54	110	140	68	120	33	160
	4032	576	1080	432	26,856	360	288	13,032
K/Rb	23	14	7	13	13	14	16	12
K/Ba	18	257	218	110	77	921	1374	42
K/Cs	152	278	164	257	67	361	392	38
K/U	82	2287	846	4014	1498	4095	17,171	392
K/Th	>91	428	363	320	361	461	597	>83
Th/U	<0.9	5.3	2.33	12.5	4.15	8.9	28.8	2.9
Rb/Sr	1.14	29.2	40.0	37.8	1.28	32.5	37.8	0.78
Ca/Sr	115	23	36	10	72	9	6	145
Ba/Rb	1.25	0.06	0.03	0.01	0.17	0.02	0.01	0.29
Mg/Li	-	0.004	0.037	-	25.4	3.4	-	40.9
Na/K	82	1.4	4.0	2.1	5.2	3.3	1.5	78

Table 16-9 Average Li, Rb, Cs, Ba, and U Contents (in ppm) of Metawackes and Metapelites. From Lake St. Joseph area, English River Subprovince, as a Function of Metamorphic Grade.

Zone	N	Li	Rb	Cs	Ba	U
Medium Grade						
Metapolites	7	66	91	11	394	2.9
Metawackes	9	45	68	11	326	3.0
High Grade						
Metapelites	17	25	62	9	332	2.8
Metawackes	39	11	53	6	287	2.7
Granulite						
Metapelites	9	14	61	6	558	1.8
Metawackes	9	10	42	5	379	1.0

n = number of samples

Table 16-10 Average Lithium Contents in Muscovite and Biotite from the Study Area and the Literature.

Rock Type	Location	Lithium Content of Muscovite	Lithium Content of Biotite	Reference
Lacorne Batholith	Quebec	3050	3010	Siroonian et al. (1959)
Lamotte Batholith	Quebec	2260	2640	Siroonian et al. (1959)
Preissae Batholith	Quebec	1110	1530	Siroonian et al. (1959)
Sandy Creek Beryl Pegmatite	N.W. Ontario	530	Not Present	This study
Tot Lake Li-Rb-Cs Pegmatite	N.W. Ontario	560	Not Present	This study
Pegmatites	Northern Portugal	1863	-	Neiva (1975)
Li-Cs-Ta Pegmatite	Russia	1370	-	Gordiyenko (1971)
Uranium Pegmatite	N.W. Ontario	Not Present	610	This study

Table 16-11 Classification of Unzoned Uraniferous Granitoid Pegmatites in Western English River Subprovince.

I Metasedimentary Migmatite Association (White Pegmatites)

1. Umfreville Lake Occurrence
2. Sydney Lake Fault System Occurrences
3. Anderson Occurrence
4. Holunga Occurrence
5. Davidson Occurrence (in part)

II Potassic Granitoid Intrusive Suite Association (Pink to Red Pegmatites)

A. Porphyritic Biotite-Hornblende Syenite, accompanied by coarse-grained to pegmatitic biotite quartz monzonite to granite

1. Celyn Lake Occurrence
2. Bee Lake Occurrence (Pryslak, 1972)

B. Porphyritic Coarse-Grained Biotite Quartz Monzonite

1. Tourist Lake Occurrence

C. Inequigranular Coarse-Grained to Pegmatitic Quartz Monzonite and Granite

1. Davidson Occurrence (in part)
2. Ena Lake Occurrence
3. Drope Township Occurrence
4. Aerobus Lake Occurrence
5. New Campbell Island Mines Occurrence
6. Perch Lake Occurrence
7. Gilbeault Occurrence

Table 16-12 Partial Major and Trace Element Petrochemical Analyses, Umfreville Lake Uranium Occurrence1.

	Trench 1 Grab Max.RA	Trench 1 #1	Trench 1 #2	Trench 1 #3	Trench 1 Grab Max. RA	Trench 1 0'	Trench 1 5'	Trench 1 10'	Trench 1 15'	Trench 1 Grab Max.RA	Trench 1 0'	Trench 1 5'
						8712	3528	21,312	15,408		3456	4896
CaO	ND	ND	ND	ND	ND	1.21	0.49	2.96	2.14	ND	0.48	0.68
K_2O	6.57	2.49	1.06	4.73	5.35	8.89	8.43	3.82	0.95	4.73	6.49	7.91
Na_2O	ND	ND	ND	ND	ND	2.48	3.01	4.27	3.64	ND	1.60	1.78
MgO	1.14	2.06	1.65	1.48	5.30	3.53	0.37	0.68	0.04	3.98	0.62	0.51
Ba	900	340	280	820	470	860	1100	460	130	500	900	1400
Be	1	1	1	1	1	1	1	1	3	1	1	1
Cs	7	8	5	5	40	20	4	3	1	27	3	5
Li	24	22	12	18	22	45	8	15	3	47	10	10
Rb	200	130	60	160	360	220	210	100	20	230	180	190
Sn	3	3	3	3	3	4	3	3	3	ND	3	3
Th	171	12	10	74	1175	10	120	20	90	780	310	95
U	428	6.6	5.7	80.5	1492	65.0	50.0	10.0	71.8	584	229	18.5
K/Rb	273	130	147	245	73	335	333	317	394	171	299	345
K/Ba	61	61	31	48	95	86	64	69	61	79	60	47
K/Cs	7790	2583	1760	7852	1110	3689	17492	10568	7885	1454	17955	13130
K/U	127	2952	1466	485	30	1135	1399	3171	110	60	235	3549
K/Th	319	1722	880	531	38	7379	583	1584	88	50	41	202
Th/U	0.40	1.80	1.75	0.92	0.79	0.15	2.40	2.00	1.25	1.34	1.35	5.14
Rb/Sr	-	-	-	-	-	1.1	0.5	0.3	0.1	-	0.7	0.6
Ca/Sr	-	-	-	-	-	44	9	71	55	-	13	15
Ba/Rb	4.50	2.62	4.68	5.13	1.31	3.91	5.24	4.60	6.50	2.17	5.00	7.37
Mg/Li	286	565	829	496	551	473	279	237	80	511	374	308

Table 16-12

	Trench 3 10'	Trench 3 15'	Trench 4 Grab Max. RA	Trench 4 0'	Trench 4 5'	Trench 4 10'	Trench 4 15'	Trench 4 20'	Trench 4 25'	Trench 4 30'	Trench 4 35'	Trench 4 40'
	7416	54,216		15,192	3,816	21,528	7,128	16,128	,312 40,032	,408 5,400	18,720	14,976
CaO	1.03	7.53	ND	2.11	0.53	2.99	0.99	2.24	5.56	0.75	2.60	2.08
K_2O	1.67	0.17	4.82	2.55	9.37	1.78	6.25	2.88	2.14	5.56	3.95	4.17
Na_2O	1.20	0.49	ND	3.30	2.83	4.91	4.37	3.94	4.00	2.32	4.89	3.49
MgO	1.77	1.25	2.68	2.17	1.01	0.88	0.35	1.97	3.11	0.42	2.21	2.89
Ba	100	110	820	250	1600	300	1200	390	840	1000	440	540
Be	1	1	3	1	1	4	1	ND	3	1	3	1
Cs	20	2	29	10	10	5	1	10	17	4	18	20
Li	30	4	47	20	20	20	8	30	25	10	20	40
Rb	120	10	230	150	270	80	10	170	80	140	170	230
Sn	3	5	ND	3	3	3	3	ND	5	3	3	3
Sr	130	350	ND	240	350	400	390	320	960	300	290	300
Th	1405	10	1214	40	25	305	40	90	20	65	155	360
U	336	5.6	360	35.7	13.0	22.9	11.5	179	1.6	124.0	29.8	32.2
K/Rb	115	141	174	141	288	184	324	140	222	329	192	150
K/Ba	139	13	49	85	49	49	43	61	21	46	75	64
K/Cs	693	705	1379	2116	778	2955	51875	2390	1044	11537	1821	1730
K/U	41	252	111	593	5982	645	4511	1335	11101	372	1100	1075
K/Th	10	141	33	529	778	5	130	266	888	710	212	96
Th/U	4.18	1.79	3.37	1.12	1.92	13.30	3.48	5.02	12.50	0.52	5.20	11.20
Rb/Sr	0.9	0.03	-	0.6	0.8	0.2	0.4	0.5	0.08	0.5	0.6	0.8
Ca/Sr	57	155	-	63	11	54	18	50	42	18	65	50
Ba/Rb	0.83	11.00	3.57	1.67	5.93	3.75	7.50	2.29	10.50	7.14	2.59	2.35
Mg/Li	356	1884	344	654	304	265	264	396	750	253	666	436

Table 16-12

	Trench 4 45'	Trench 5 Grab Max. RA	Trench 5 0'	Trench 5 3'	Trench 5 8'	Trench 5 13'	Trench 5 18'	Trench 5 23'	Trench 5 28'	Trench 5 33'
	13896		13320	3384	8568	18360	15120	1512	10224	14976
CaO	1.93	ND	1.85	0.47	1.19	2.55	2.10	0.21	1.42	2.08
K_2O	ND	2.55	2.49	7.71	2.90	0.92	2.34	8.89	8.46	4.56
Na_2O	3.62	ND	4.25	2.32	2.88	4.66	3.60	2.08	2.28	3.96
MgO	2.45	0.53	0.92	0.25	0.15	0.46	2.21	0.14	1.63	3.27
Ba	970	230	200	800	330	100	110	910	720	500
Be	1	1	1	1	1	ND	1	1	1	1
Cs	15	5	6	2	1	2	9	10	20	15
Li	30	14	20	10	6	20	40	10	45	30
Rb	190	80	90	170	70	40	110	170	170	110
Sn	3	ND	3	3	3	ND	4	3	6	3
Sr	300	ND	240	300	240	270	160	260	240	180
Th	185	128	25	25	40	80	15	15	30	30
U	25.2	506	25.9	19.5	76.6	41.4	5.6	27.6	83.4	4.4
K/Rb	226	265	229	376	344	191	177	434	413	344
K/Ba	44	92	103	80	73	73	177	81	98	76
K/Cs	2871	4233	3444	31996	24070	3818	2158	7379	3510	2523
K/U	171	42	798	3282	314	184	3468	2673	842	8602
K/Th	233	165	827	2560	602	95	1295	4919	2341	1262
Th/U	7.34	0.25	0.96	1.28	0.52	1.93	2.68	0.54	0.36	6.82
Rb/Sr	0.6	-	0.4	0.6	0.3	0.15	0.7	0.7	0.7	0.6
Ca/Sr	46	-	56	11	36	68	95	6	43	83
Ba/Rb	5.11	2.88	2.22	4.71	4.71	2.50	1.00	5.35	4.24	4.55
Mg/Li	510	228	277	151	151	139	333	84	218	627

Table 16-12

	Trench 6 Grab	Trench 6 0'	Trench 6 5'	Trench 6 10'	Trench 6 15'	Trench 6 20'	Trench 6 25'	Trench 6 28'	Trench 7 Grab	Trench 7 0'	Trench 7 5'	Trench 7 10'
		7992	10008	7056	8424	19650	15480	17784		10656	2160	9576
CaO	ND	1.11	1.39	0.98	1.17	2.73	2.15	2.47	ND	1.48	0.30	1.33
K_2O	2.43	3.79	3.76	5.55	4.07	1.67	2.71	2.61	6.05	1.26	6.53	5.17
Na_2O	ND	2.75	3.32	2.70	2.90	5.21	3.20	3.31	ND	2.76	1.44	3.67
MgO	2.23	0.17	0.04	0.14	0.21	0.43	2.74	2.73	1.21	1.12	0.02	0.13
Ba	250	340	340	500	410	190	280	220	740	50	620	430
Be	1	1	1	1	1	1	1	1	1	1	1	1
Cs	13	1	1	50	15	5	15	10	19	5	3	6
Li	44	10	5	6	10	20	30	20	55	20	4	9
Rb	160	80	70	110	90	50	120	90	180	60	120	90
Sn	ND	3	3	3	3	3	3	3	ND	3	3	3
Sr	ND	190	210	210	200	290	230	240	ND	110	190	190
Th	44	30	25	25	40	105	10	10	346	30	55	25
U	77.0	150	29.8	24.5	28.0	334	4.2	5.2	47.8	22.2	67.7	25.6
K/Rb	126	393	446	419	375	277	187	241	279	174	452	477
K/Ba	81	93	92	92	82	73	80	98	68	209	87	100
K/Cs	1551	31457	31208	921	2252	2772	1499	2166	2643	2091	18066	7151
K/U	262	210	1047	1880	1206	42	5355	4166	1046	471	801	1676
K/Th	458	1049	1248	1843	845	132	2249	2166	145	349	985	1716
Th/U	0.57	0.20	0.84	1.02	1.43	0.31	2.38	1.92	7.2	1.35	0.81	0.98
Rb/Sr	-	0.4	0.3	0.5	0.45	0.2	0.5	0.4	-	0.5	0.6	0.5
Ca/Sr	-	42	48	34	42	68	67	74	-	98	11	50
Ba/Rb	1.56	4.25	4.86	4.55	4.56	3.800	2.33	2.44	4.11	0.83	5.17	4.78
Mg/Li	306	103	48	141	127	130	551	823	133	338	30	87

Table 16-12

	Trench 7 15'	Trench 7 20'	Trench 7 25'	Trench 7 30'	Trench 7 35'	Trench 7 38'	$\bar{X}$
	5256	13104	16272	8856	7560	26856	
CaO	0.73	1.82	2.26	1.23	1.05	3.73	
K_2O	6.15	2.76	6.75	7.24	6.23	1.68	
Na_2O	2.14	4.00	1.49	3.54	3.09	3.16	
MgO	0.38	0.09	1.29	0.57	0.12	1.84	
Ba	670	300	760	1100	1000	1000	572
Be	1	1	1	1	1	1	1.2
Cs	6	4	7	10	5	7	11
Li	15	6	50	25	8	15	21
Rb	130	60	150	120	110	70	133
Sn	3	3	4	3	3	3	4.2
Sr	220	240	180	320	330	200	274
Th	20	15	260	270	40	20	108*
U	16.3	12.0	37.2	29.0	27.5	4.2	52*
K/Rb	393	382	374	501	470	199	279
K/Ba	76	76	74	55	52	14	73
K/Cs	8507	5727	8003	6009	10341	697	6751
K/U	3132	1909	1506	2072	1880	3320	1811
K/Th	2552	1527	215	223	1293	697	846
Th/U	1.23	1.25	6.99	9.31	1.45	4.76	2.88
Rb/Sr	0.6	0.3	0.8	0.4	0.3	0.4	0.5
Ca/Sr	24	55	90	28	23	134	50
Ba/Rb	5.15	5.00	5.07	9.17	9.09	14.29	4.62
Mg/Li	153	91	156	137	91	740	356

* Average values for U and Th exclude grab samples selected for maximum radioactivity.
1 ND = Not Determined

Table 16-13: Chemical Analyses of Metasediments with Anomalous Trace Levels of Uranium and Thorium in Umfreville Lake Area.

	1	2	3
SiO_2	46.7	60.0	65.4
Al_2O_3	19.5	17.8	15.6
Fe_2O_3	3.06	6.53*	6.89*
FeO	9.58	ND	ND
MgO	5.38	2.54	2.61
CaO	1.99	1.93	1.99
Na_2O	3.96	3.62	3.43
K_2O	5.46	5.19	2.77
TiO_2	1.05	0.84	0.63
P_2O_5	0.10	0.05	0.12
S	0.23	ND	ND
MnO	0.16	0.06	0.07
CO_2	0.11	ND	ND
H_2O+	0.97	1.10	0.90
H_2O-	0.35	ND	ND
Total	98.6	99.7	100.4

* Total Fe as Fe_2O_3

Ag	<1	ND	ND
Ba	730	970	260
Be	<1	ND	ND
Co	50	ND	ND
Cr	340	ND	ND
Cs	35	ND	ND
Cu	55	ND	ND
Ga	20	ND	ND
Li	75	30	45
Mo	3	ND	ND
Ni	145	ND	ND
Pb	30	ND	ND
Rb	340	190	120
Sc	30	ND	ND
Sn	7	ND	ND
Sr	250	300	190
V	200	ND	ND
Y	25	ND	ND
Zn	240	ND	ND
Zr	250	ND	ND
Th	25	185	10
U	30	25.2	57.2

Table 16-14: Partial Major and Trace Element Petrochemical Analyses, Celyn Lake Uranium Occurrence

	Trench 1 #1	Trench 1 #2	Trench 1 #3	Trench 2 #1	Trench 2 #2	Trench 2 #3	Trench 3 #1	Trench 3 #2	Trench 4 #1	Trench 6 #1	Trench 6 #2	$\bar{X}$
K_2O	0.89	5.90	7.10	2.07	5.18	8.56	0.78	0.29	0.96	2.06	2.97	
MgO	0.27	0.90	1.54	2.98	1.10	0.53	0.83	5.04	0.60	1.58	0.22	
Ba	60	820	1240	250	650	1320	70	80	60	110	130	435
Be	6	4	10	9	5	4	10	1	4	6	3	6
Cs	5	9	16	19	7	8	28	3	8	27	26	13
Li	25	24	22	65	37	33	58	24	77	69	70	46
Rb	60	260	280	110	180	300	120	20	120	260	260	179
Sn	3	6	30	45	3	3	3	3	3	3	3	-
Th	92	217	96	368	77	16	112	10	32	10	284	130
U	228	1166	189	3510	196	27	776	2.3	1098	151	1107	768
	123	188	211	156	239	237	54	120	66	95	95	141
	123	60	48	69	66	54	93	30	133	190	190	93
	1477	5441	3683	904	6142	8881	231	802	1996	1541	1541	2885
	32	42	312	5	219	2631	8	1203	7	22	22	418
	80	226	614	47	558	4440	58	241	249	87	87	807
	0.40	0.19	0.51	0.10	0.39	0.59	0.14	4.30	0.03	0.26	0.26	0.27
	1.00	3.15	4.43	2.27	3.61	4.40	0.58	4.00	0.50	0.50	0.50	2.26
	65	226	422	276	179	97	86	1266	47	19	19	256

Table 16-15 Partial Major and Trace Element Petrochemical Analyses, Drope Township Uranium Occurrence

	PIT 3 GRAB SPECI-MEN: MAX.RA	PIT 3	PIT 3	PIT 3	PIT 3	PIT 3	PIT 2	PIT 2	PIT 2	PIT 2	PIT 2 GRAB SPECI-MEN: MAX.RA
	5544	49248	5616	2232	4536	5472	6768	864	7128	7560	2957
CaO	0.77	6.84	0.78	0.31	0.63	0.76	0.94	0.12	0.99	1.05	0.41
K_2O	3.56	0.97	4.47	7.65	4.34	0.26	0.32	0.27	1.97	0.74	5.96
Na_2O	4.44	4.73	3.95	2.69	4.27	7.58	4.23	0.00	6.13	5.77	2.41
MgO	0.31	2.88	0.17	0.22	0.12	0.25	0.19	0.09	0.13	0.12	0.18
Ba	110	150	160	250	110	50	40	30	70	60	110
Be	3	1	4	1	4	6	5	1	6	7	3
Cs	8	1	3	4	6	2	2	1	3	1	8
Li	10	9	4	6	4	6	9	3	4	3	7
Rb	200	50	240	240	240	20	20	20	110	40	350
Sn	3	3	3	3	3	3	3	3	3	3	4
Sr	100	100	120	70	100	120	100	10	110	120	50
Th	120	20	30	70	50	70	125	10	305	225	3500
U	209	1.4	38.1	161	97.6	42.2	130	1.3	168	263	3161
K/Rb	148	161	155	261	150	108	133	112	149	154	141
K/Ba	269	54	232	251	327	43	66	75	234	102	450
K/Cs	3693	8051	12367	15687	6003	1076	1328	2241	5450	6142	6183
K/U	141	5751	974	390	369	51	20	1724	97	23	16
K/Th	246	403	1237	896	720	31	21	224	54	27	37
Th/U	0.57	14.3	0.79	0.43	0.51	1.66	0.96	7.69	1.81	0.86	0.42
Rb/Sr	2.0	0.5	2.0	3.4	2.4	0.2	0.2	2.0	1.0	0.3	7.0
Ca/Sr	55	492	47	32	45	46	68	86	65	63	59
Ba/Rb	0.55	3.00	0.67	1.04	0.46	2.50	2.00	1.50	0.64	1.50	0.31
Mg/Li	186	1920	255	220	180	250	127	180	195	240	154
Na/K	1.12	4.32	0.79	0.31	0.88	2.60	11.59	-	2.77	7.00	0.36

Table 16-15

	PIT 1 GRAB	PIT 2 GRAB	RADIOACTIVE GRANITE FROM PORTAGE NEAR CREST OF RIDGE	$\bar{X}$ HIGH GRADE ZONE	$\bar{X}$ LOW GRADE ZONE
K/Rb	166	154	133	151	160
K/Ba	297	336	205	317	223
K/Cs	5940	462	2171	6017	3201
K/U	2446	1071	8005	380*	1759
K/Th	1386	1477	2606	363*	1432
Th/U	1.76	0.72	3.38	0.89	1.24
Rb/Sr	1.3	1.4	2.7	1.6	1.3
Ca/Sr	26	34	10.0	54	29
Ba/Rb	0.56	0.46	0.69	1.12	0.51
Mg/Li	120	1100	300	181*	610
Na/K	0.61	0.85	0.28	2.74	0.73

Table 16-15

	PIT 1 GRAB	PIT 1 GRAB	RADIOACTIVE GRANITE FROM PORTAGE NEAR CREST OF RIDGE	$\bar{X}$ HIGH GRADE ZONE	$\bar{X}$ LOW GRADE ZONE
CaO	0.72	0.80	0.25	0.68	0.75
K_2O	5.01	4.45	7.85	2.95	4.73
Na_2O	3.41	4.26	2.47	4.15	3.84
MgO	0.12	0.11	0.10	0.18	0.11
Ba	140	110	340	103	125
Be	3	4	1	4	3.5
Cs	7	8	30	3.8	7.5
Li	6	6	20	6	6
Rb	250	240	490	148	245
Sn	3	3	3	-	-
Sr	200	170	180	90	185
Th	30	25	25	450	27.5
U	17.0	34.5	7.4	427	25.8

16-15

Pit 1 - Grab Specimen : Albite quartz monzonite
Pit 1 - Bulk Chip Sample : Albite quartz monzonite

Pit 2 - 0': Quartz-rich albite trondhjemite with hematite plagioclase
pit 2 - 2'" Quartz vein

Pit 2 - 4': Albite trondhjemite

Pit 2 - 6': Albite trondhjemite
Pit 2 - Maximum Radioactivity Grab Specimen: Biotite albite quartz monzonite
Pit 3 - 0':Amphibolitized mafic metavolcanic
Pit 3 - 2':Biotite albite quartz monzonite
Pit 3 - 4':Biotite albite quartz monzonite
Pit 3 - 6':Biotite albite quartz monzonite
Pit 3 - 8':Biotite albite trondhjemite
Pit 3 - Maximum Radioactivity Grab Specimen: Biotite albite quartz monzonite
Bluett Lake Portage Grab Specimen: Biotite granite

Table 16-16 Partial Major and Trace Element Petrochemical Analyses, Davidson Uranium Occurrence

	Trench 1 Bio-' tite	Trench 1 Grab Sample Max. RA	Trench 1 0'	Trench 1 2'	Trench 1 4'	Trench 1 6'	Trench 1 8'	Trench 1 10'	Trench 1 12'	Trench 1 14'	Trench 1 16'
K_2O	6.90	6.64	0.40	3.50	4.70	7.22	6.03	4.56	5.92	5.94	7.43
MgO	4.25	0.23	0.04	0.31	0.20	0.11	0.12	0.11	0.06	0.23	0.11
Ba	340	500	50	290	350	520	500	330	460	450	660
Be	1	1	4	4	1	1	1	2	1	1	1
Cs	39	2	1	7	9	3	2	1	2	3	2
Li	600	40	6	49	32	20	22	23	16	32	24
Rb	690	230	10	120	170	240	200	160	200	210	240
Sn	20	10	5	3	3	3	5	3	3	3	3
Th	62	22	10	14	43	10	11	15	29	26	10
U	221	3.04	12.3	42.8	186	27.2	86.9	59.2	49.3	214	47.0
K/Rb	83	240	332	242	230	250	250	236	246	235	267
K/Ba	168	110	66	100	111	115	100	115	107	110	97
K/Cs	1469	27556	3330	4150	4334	19975	25024	37848	24568	16434	32079
K/U	259	181	277	676	210	2220	575	642	1003	234	1365
K/Th	924	2505	332	2075	907	5993	4550	2532	1694	1896	6416
Th/U	0.28	0.07	0.81	0.33	0.23	0.37	0.13	0.25	0.59	0.12	0.20
Ba/Rb	0.49	2.17	5.0	2.42	2.06	2.17	2.00	2.06	2.30	2.14	2.75
Mg/Li	43	35	40	38	38	33	33	29	23	43	28

Table 16-16

	Trench 2 30'	Trench 2 35'	Trench 2 40'	Trench 2 45'	Trench 2 50'	Trench 2 55'	Trench 3 0'	Trench 3 5'	Trench 3 10'	Trench 3 15'	Trench 3 20
K_2O	0.49	6.42	7.03	6.83	6.10	6.02	5.65	3.49	10.4	5.32	5.23
MgO	0.02	0.05	1.05	0.03	0.24	0.20	0.19	0.07	0.00	0.30	0.01
Ba	40	460	440	470	460	460	480	310	320	420	290
Be	4	1	1	1	1	1	2	3	1	1	2
Cs	4	2	12	3	3	3	3	2	3	4	1
Li	14	12	115	13	42	40	56	26	7	70	14
Rb	20	230	370	240	240	230	220	140	380	210	170
Sn	3	3	5	3	3	3	3	3	3	3	3
Th	10	25	67	10	27	12	10	24	10	32	12
U	16.7	24.0	943	22.5	37.8	78.2	5.6	48.3	2.6	198	11.8
K/Rb	203	230	158	236	211	271	213	207	227	210	255
K/Ba	102	116	133	121	110	109	98	93	270	105	150
K/Cs	1017	26643	4862	19896	16877	16655	14531	14483	28773	11039	43409
K/U	239	2220	62	2465	1332	641	7816	604	33200	223	3617
K/Th	407	2131	871	5669	1875	4164	4690	1207	8632	1380	3617
Th/U	2.00	1.91	1.19	1.96	1.92	2.00	2.18	2.21	0.84	2.00	1.71
Ba/Rb	9	25	55	14	35	30	21	16	-	26	4
Mg/Li	0.60	1.04	0.07	0.40	0.71	0.15	1.79	0.50	3.85	0.16	1.02

Table 16-16

	Trench 3 25'	Trench 4 Grab	Trench 4 0'	Trench 4 5'	Trench 4 10'	Trench 4 15'	Pit 1 Grab	Pit 2 Grab	Pit 3 Grab	Pit 5 Grab	Trench 6 0
K_2O	7.28	2.08	7.98	5.46	6.96	5.73	8.43	0.62	2.34	3.56	3.23
MgO	0.15	0.92	0.11	0.05	0.11	0.19	0.21	0.24	0.64	0.01	0.26
Ba	610	410	640	420	570	470	560	50	150	160	160
Be	1	1	1	1	1	1	1	3	3	3	3
Cs	3	12	3	2	3	5	1	1	8	2	14
Li	33	156	14	11	23	40	30	38	78	8	70
Rb	270	320	320	200	260	240	360	50	170	140	180
Sn	3	5	3	3	3	3	3	3	3	3	3
Th	24	87	19	32	14	69	11	27	10	54	47
U	315	903	49.9	41.1	354	376	77.3	13.8	162	140	341
K/Rb	224	91	207	227	222	198	194	103	114	211	149
K/Ba	99	144	104	108	101	101	125	103	130	195	168
K/Cs	20141	1439	22078	22659	19256	9512	69969	5145	2427	14774	1915
K/U	192	19	1325	1105	163	126	909	368	120	211	77
K/Th	2518	198	3486	1416	4126	689	6361	191	1942	547	570
Ba/Rb	2.26	0.63	2.00	2.10	2.19	1.96	1.56	1.00	0.88	1.14	0.89
Mg/Li	27	32	47	27	29	29	42	38	50	8	22
Th/U	0.08	0.10	0.38	0.78	0.40	1.84	0.14	1.96	0.06	0.39	0.14

Table 16-16

	Trench 6 5'	Trench 6 10'	Trench 6 15'	Trench 6 20'	Trench 6 25'	Trench 6 30'	Trench 6 35'	Trench 6	Trench 6	X
K_2O	3 58	2 30	5 93	7 53	2 52	6 56	5 89	6 99	8 13	
MgO	0 09	0 00	0 64	0 08	0 52	0 00	0 09	0 17	1 16	
Ba	180	140	260	380	100	340	280	360	350	405
Be	3	3	3	1	4	1	5	1	1	1 7
Cs	3	1	14	3	14	5	5	6	22	7
Li	25	7	146	25	110	8	26	32	300	54
Rb	140	90	350	330	180	270	240	320	430	233
Sn	3	3	4	6	3	3	3	3	4	3 8
Th	14	26	38	19	27	28	19	27	129	34
U	103	580	502	827	792	225	52 6	212	25 0	184
K/Rb	212	212	141	189	116	202	204	181	157	
K/Ba	165	136	189	165	209	160	176	161	193	
K/Cs	9905	19090	3516	20833	1494	1090	9777	9669	3067	
K/U	288	33	98	753	26	242	922	274	2699	
K/Th	2122	734	1295	3289	775	1945	2573	2149	523	
Ba/Rb	1 29	1 56	0 74	1 15	0 56	1 26	1 17	1 13	0 81	
Mg/Li	22	-	26	19	29	-	21	32	23	
Th/U	0 14	0 04	0 08	0 23	0 03	0 12	0 36	0 13	5 2	

Table 16-16

	Trench 1 18'	Trench 1 20'	Trench 1 22'	Trench 1 24'	Trench 2 Grab Sample Max. RA	Trench 2 0'	Trench 2 5'	Trench 2 10'	Trench 2 15'	Trench 2 20'	Trench 2 25
K_2O	6.44	7.06	5.85	5.85	4.25	6.95	7.74	4.24	7.58	5.91	4.65
MgO	0.15	0.11	0.11	0.18	0.31	0.06	0.00	0.12	0.43	0.15	0.65
Ba	530	520	1290	1170	303	460	550	270	500	410	290
Be	1	1	1	1	1	1	1	1	1	1	1
Cs	2	4	1	2	5	3	2	2	6	3	13
Li	29	22	29	30	57	14	3	22	58	30	109
Rb	220	230	170	180	190	240	250	150	280	210	250
Sn	3	3	3	3	3	3	3	3	3	3	5
Th	34	41	24	25	64	44	10	73	36	24	15
U	99.7	178	5.9	6.1	879	141	17.0	455	174	25.1	99.7
K/Rb	243	256	286	270	186	240	257	235	225	234	154
K/Ba	101	113	38	42	116	125	117	130	126	120	133
K/Cs	26726	14649	48555	24277	7055	19228	32121	17596	10485	16851	2969
K/U	534	329	8092	8093	40	409	3779	77	362	1962	386
K/Th	1572	1429	2023	1942	551	1311	6424	482	1748	2044	2573
Th/U	2.41	2.26	0.76	6.5	1.60	1.92	2.20	1.80	1.79	1.95	1.16
Ba/Rb	31	30	23	36	33	26	-	33	45	30	36
Mg/Li	0.34	0.23	4.07	4.10	0.07	0.31	0.59	0.16	0.21	0.96	0.15

Table 16-17 Average* U, Th, K/Ba, K/Cs, K/Rb, K/Th, K/U, Ba/Rb, Mg/Li and Th/U in the No. 1 Zone, Davidson Uranium Occurrence.

	U	Th	Th/U	K/U	K/Th	K/Rb	K/Ba	K/Cs	Ba/Rb	Mg/Li
I. Pink Quartz Monzonite (Potassic Granitoid Suite)	127	25	0.20	2739	2710	231	111	14475	2.17	33
II. White Quartz Monzonite (Metasedimentary Migmatite Affiliation)	236	33	0.14	501	1787	170	162	1233	1.08	28

* Excludes grab samples selected from areas of highest radioactivity.

Table 16-18 Partial Major and Trace Element Petrochemical Analyses, Tourist Lake Uranium Occurrence

	Trench A #1	Trench A #2	Trench A #3	Trench B #1	Trench B #2	Trench B #3	Trench B #4	Trench B #5	Trench B #6	Trench C #1	Trench C #2
CaO	0.66	1.62	1.64	0.68	0.35	0.21	2.47	2.27	0.96	0.95	1.61
K_2O	6.22	1.38	2.51	5.49	9.22	8.80	1.81	2.82	5.29	5.16	1.89
Na_2O	2.35	3.13	3.16	2.24	2.06	1.52	4.16	3.35	2.66	2.60	3.13
MgO	0.30	0.92	1.92	0.37	1.29	1.54	1.15	1.27	0.51	0.60	1.39
Ba	660	110	190	490	860	880	380	290	490	500	120
Be	1	10	7	1	1	1	1	1	1	1	1
Cs	25	4	6	1	7	9	4	5	4	3	6
Li	15	35	35	15	55	75	40	40	25	25	50
Rb	290	160	210	270	520	590	200	220	290	290	220
Sn	3	3	4	4	3	3	3	3	3	3	3
Sr	110	90	80	100	100	100	140	150	110	100	70
Th	50	30	15	25	70	35	30	15	95	80	15
U	14.4	25.9	5.8	18.7	28.3	20.1	3.7	4.0	12.5	16.2	9.0
K/Rb	178	71	99	168	147	124	75	106	151	148	118
K/Ba	78	104	110	93	89	92	40	81	90	86	217
K/Ca	2065	2863	3472	45567	10932	8115	3756	4681	10976	14276	4330
K/U	3585	442	3592	2437	2704	3633	4060	5852	3513	2644	2887
K/Th	103	382	1389	1823	1093	2087	501	1560	462	535	1732
Th/U	3.47	1.16	2.59	1.34	2.47	1.74	8.10	3.75	7.60	4.94	1.67
Rb/Sr	2.6	1.8	2.6	2.7	5.2	5.9	1.4	1.5	2.6	2.9	3.1
Ca/Sr	43	130	148	49	25	15	127	109	63	68	166
Ba/Rb	2.28	0.69	0.90	1.81	1.65	1.36	1.90	1.32	1.69	1.72	0.55
Mg/Li	120	158	329	148	141	123	173	191	123	148	168
Na/K	5.16	1.15	2.08	4.56	7.65	7.3	1.50	2.34	4.39	4.28	1.57

Table 16-18

	Trench C #3	Trench C #4	Trench D #1	Trench D #2	Trench D #3	Trench D #4	Trench D #5	Trench E #1	Trench E #2	$\bar{X}$ Metawacke	$\bar{X}$ Porphyry ritic Qtz. Monz. (White)	$\bar{X}$ Syen-ite	$\bar{X}$ Mafic Biotite Grano-diorite
CaO	1.04	1.91	1.15	1.16	8.53	1.07	0.90	2.07	2.46	1.92	0.96	0.28	2.27
K_2O	5.53	2.45	6.45	6.78	0.72	5.39	5.67	2.79	3.77	2.14	5.79	9.01	3.28
Na_2O	2.70	3.03	2.72	3.42	0.69	2.74	2.83	1.44	1.55	3.32	2.68	1.79	1.50
MgO	0.52	1.85	0.66	0.90	5.89	0.73	0.25	1.57	2.19	1.42	0.57	1.42	1.88
Ba	550	100	720	870	40	750	340	90	120	198	668	830	105
Be	1	5	1	3	1	1	1	1	1	-	-	-	-
Cs	6	5	4	6	6	6	3	15	10	5	8	4	13
Li	25	65	20	30	15	30	15	60	70	44	31	35	65
Rb	330	300	320	320	40	320	270	380	440	185	344	395	410
Sn	3	4	3	3	5	3	3	3	3	-	-	-	-
Sr	100	70	120	140	80	120	80	30	40	100	112	100	35
Th	85	4	75	100	10	100	90	325	345	18	77.5	47.5	335
U	14.6	5.4	7.3	7.7	0.5	7.3	40.9	598	753	9.0	12.5	23.5	675
K/Rb	139	68	167	176	149	140	174	61	71	90	158	136	66
K/Ba	84	203	74	65	149	60	138	257	261	126	79	90	259
K/Ca	7650	4067	13383	9379	996	7456	15687	1544	3129	3861	13844	9524	2337
K/U	3144	3766	7334	7308	11952	6128	1151	39	42	3433	4512	3169	40
K/Th	540	5084	714	563	598	447	523	71	91	1774	650	1590	81
Th/U	5.82	0.74	10.30	13.0	20.0	13.7	2.20	0.54	0.46	3.00	7.52	2.10	0.50
Rb/Sr	3.3	4.3	2.7	2.3	0.5	2.7	3.4	12.7	11.0	2.45	2.7	5.6	1.45
Ca/Sr	75	196	69	60	768	64	81	497	443	146	61	20	118
Ba/Rb	1.67	0.33	2.25	2.72	1.00	2.34	1.26	0.24	0.27	0.95	2.06	1.50	0.25
Mg/Li	125	.72	199	181	2368	147	101	158	189	199	149	132	173
Na/K	4.59	2.03	5.35	5.63	5.98	4.47	2.35	1.19	1.29	1.78	4.80	7.48	1.92

Table 16-19 Chemical Analyses and Selected Element Ratios from Ena Lake and Perch Lake Uranium Occurrences

	Ena Lake Grab Sample 1	Ena Lake Grab Sample 2	Ena Lake Grab Sample 3	Perch Grab Sample 1	Perch Grab Sample 2
SiO_2	70.5	73.6	81.0	72.8	79.8
Al_2O_3	17.0	14.7	10.7	14.8	13.3
Fe_2O_3	0.34	0.40	0.12	1.53	0.25
MgO	0.16	0.09	0.03	0.53	0.00
CaO	1.68	0.59	0.10	0.81	1.51
Na_2O	5.16	3.90	1.34	1.93	2.69
K_2O	3.67	4.87	5.62	6.15	2.68
TiO_2	0.02	0.04	0.02	0.37	0.03
P_2O_5	0.03	0.01	0.01	0.04	0.02
MnO	0.01	0.02	0.01	0.04	0.01
H_2O+	0.40	0.70	0.50	0.70	0.50
Total	99.0	98.9	99.4	99.7	100.8
Ba	140	100	170	450	130
Be	7	3	<1	<1	3
Cs	2	9	3	5	2
Li	14	8	9	35	4
Rb	150	250	230	270	100
Sn	<3	<3	<3	ND	ND
Sr	80	155	50	100	100
Th	109	13	25	130	95
U	102	72.6	30.8	204	51.9
K/Rb	203	162	203	189	222
K/Ba	218	404	274	113	171
K/Cs	15,231	4,491	15,549	10,209	11,122
K/U	299	557	1,514	250	429
K/Th	279	3,109	1,866	393	234
Th/U	1.07	0.18	0.81	0.64	1.83
Rb/Sr	1.88	1.61	4.60	2.70	1.00
Ca/Sr	151	27	14	58	109
Ba/Rb	0.93	0.40	0.74	1.67	1.30
Mg/Li	69	68	20	91	-

This page left blank intentionally.

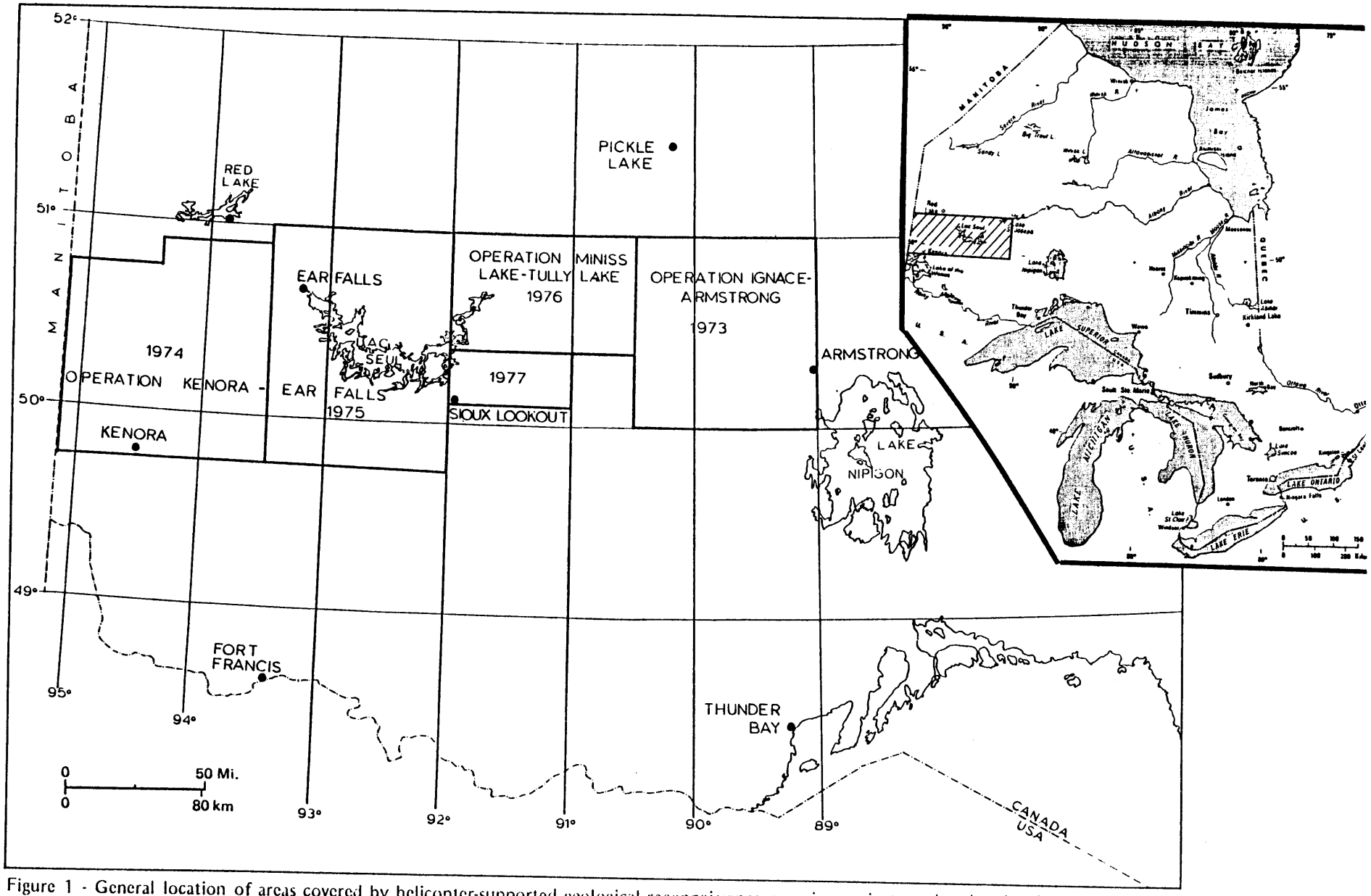


Figure 1 - General location of areas covered by helicopter-supported geological reconnaissance mapping projects undertaken by the Ontario Geological Survey in the English River Subprovince including that proposed for 1977.

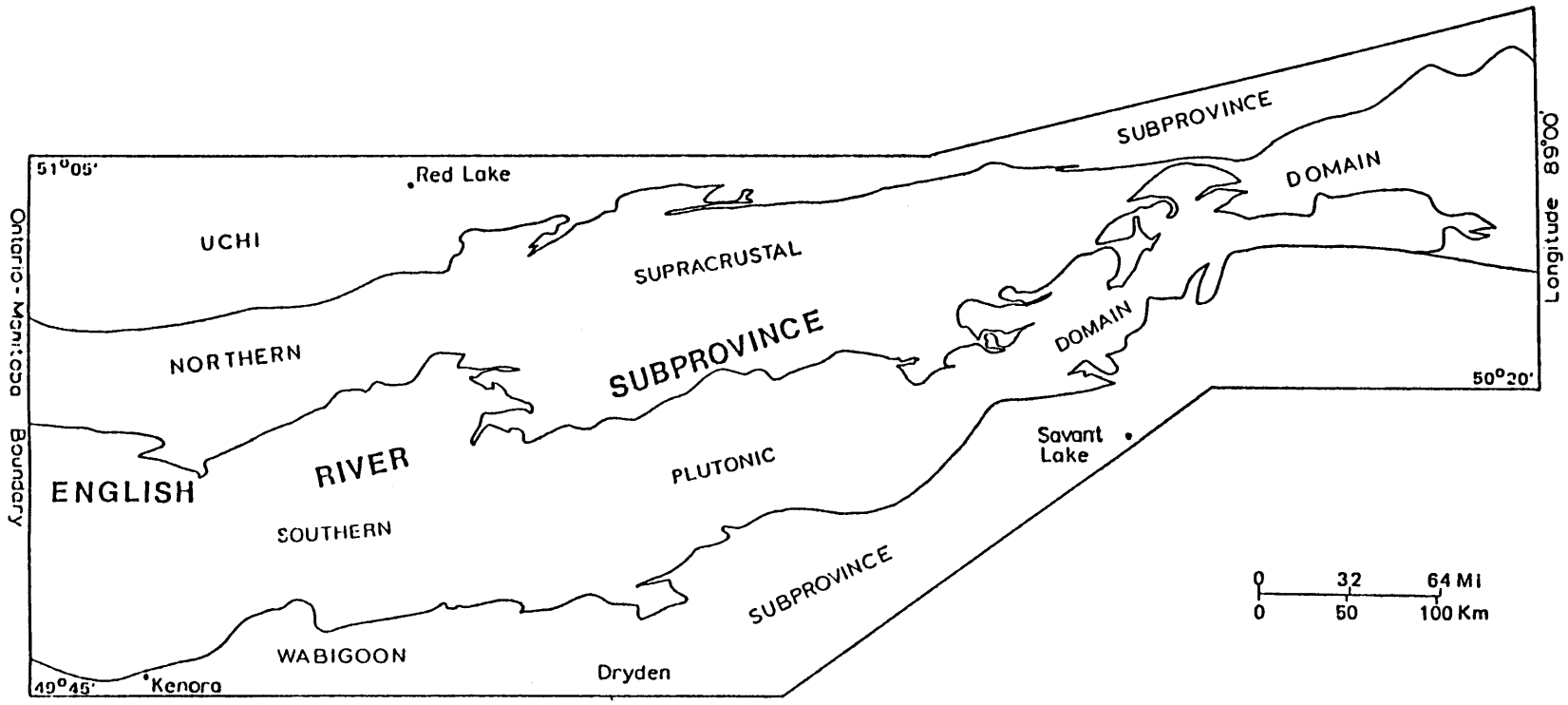


Figure 1-2 :Division of the English River Subprovince, Northwestern Ontario into the Southern Plutonic Domain and the Northern Supracrustal Domain

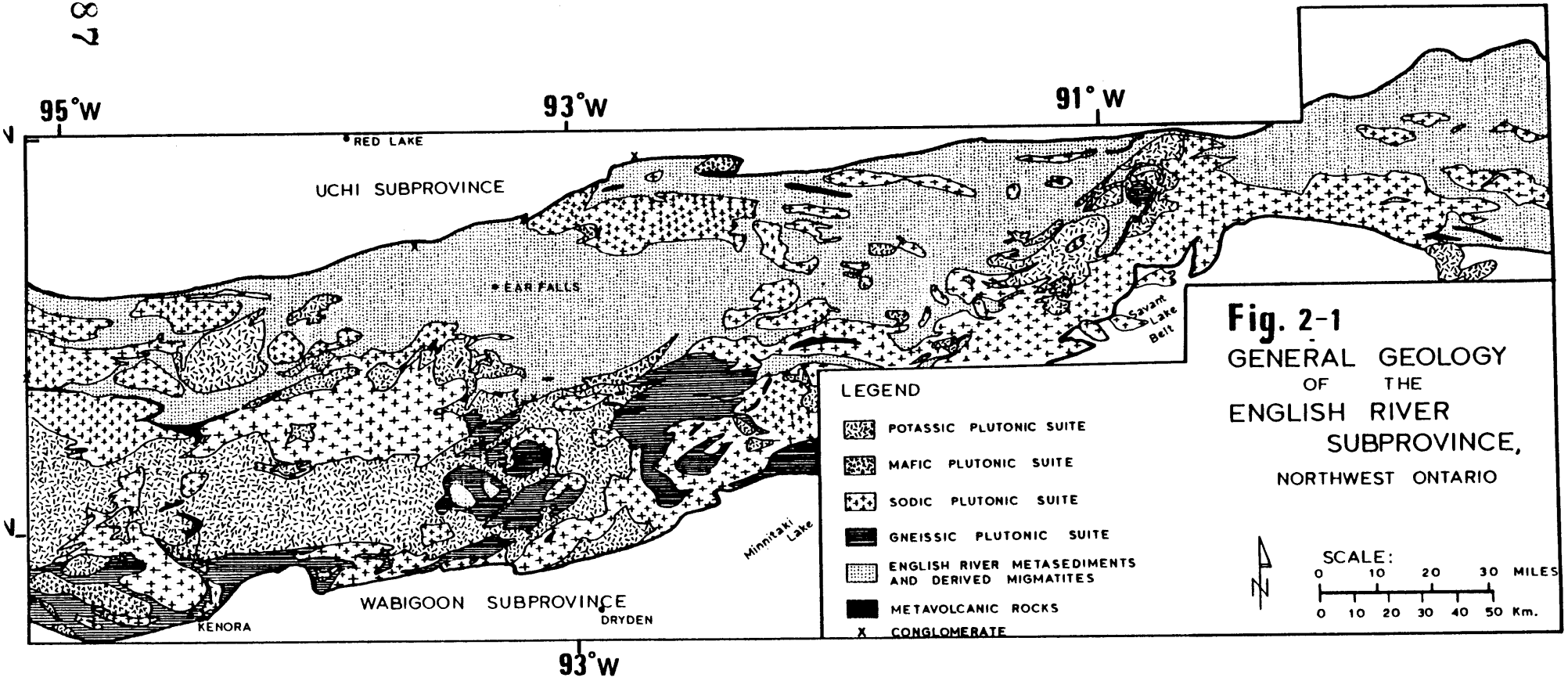


Fig. 2-1
GENERAL GEOLOGY OF THE ENGLISH RIVER SUBPROVINCE, NORTHWEST ONTARIO

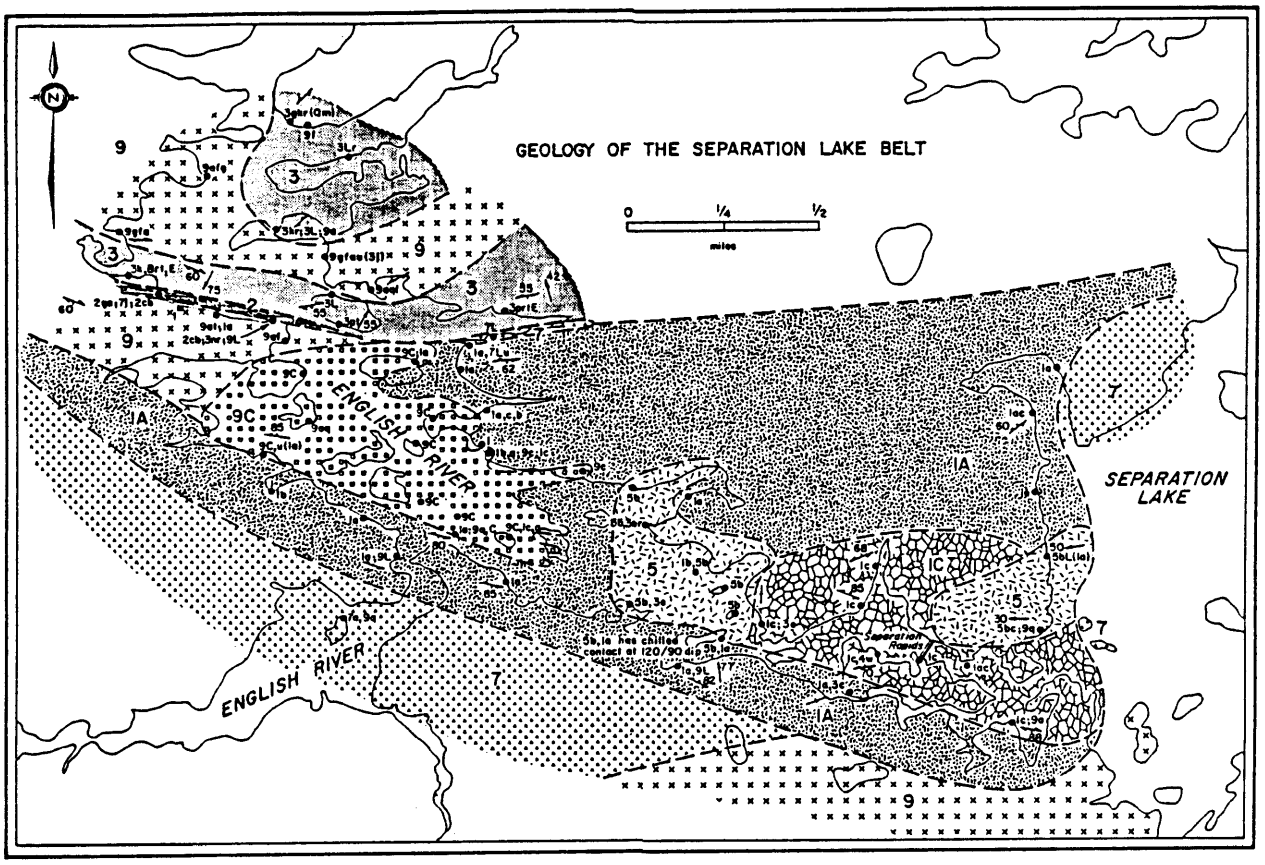


FIG. 3-0

SEPARATION LAKE BELT
LEGEND

- Potassic Suite
- White Zoned Pegmatite
- Sodic Suite
- Metagabbro
- Metasedimentary Migmatites
- Intermediate to Felsic Metavolcanics
- Massive Mafic Metavolcanics
- Pillowed Mafic Metavolcanics

- foliation and dip
- lineation and dip
- bedding with vertical dip
- geological contact

Codes correspond to legends for 1976 (Miniss - Tully Lakes Area) and 1977 (English River - Marchington Lake Area)

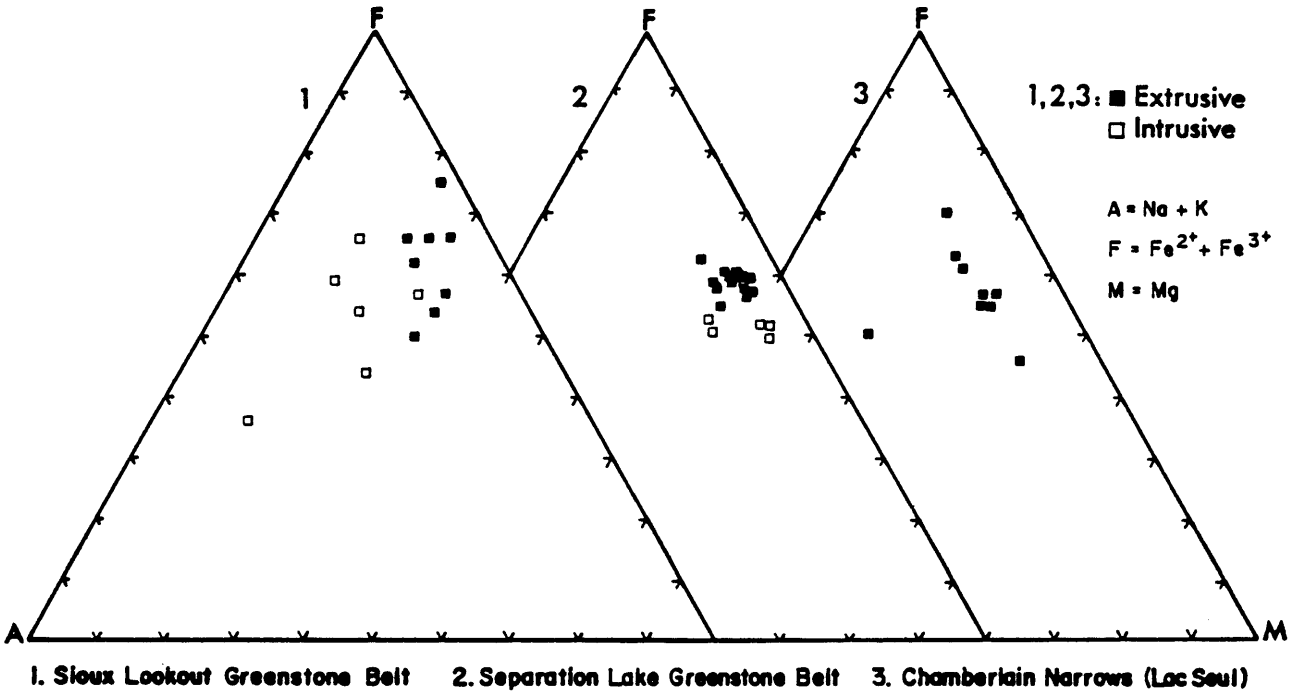


Figure 3-1: AFM (Element WT%) Diagrams of extrusive volcanic rocks. A = NA + K, F = Fe^{2+} + Fe^{3+}, M = Mg.

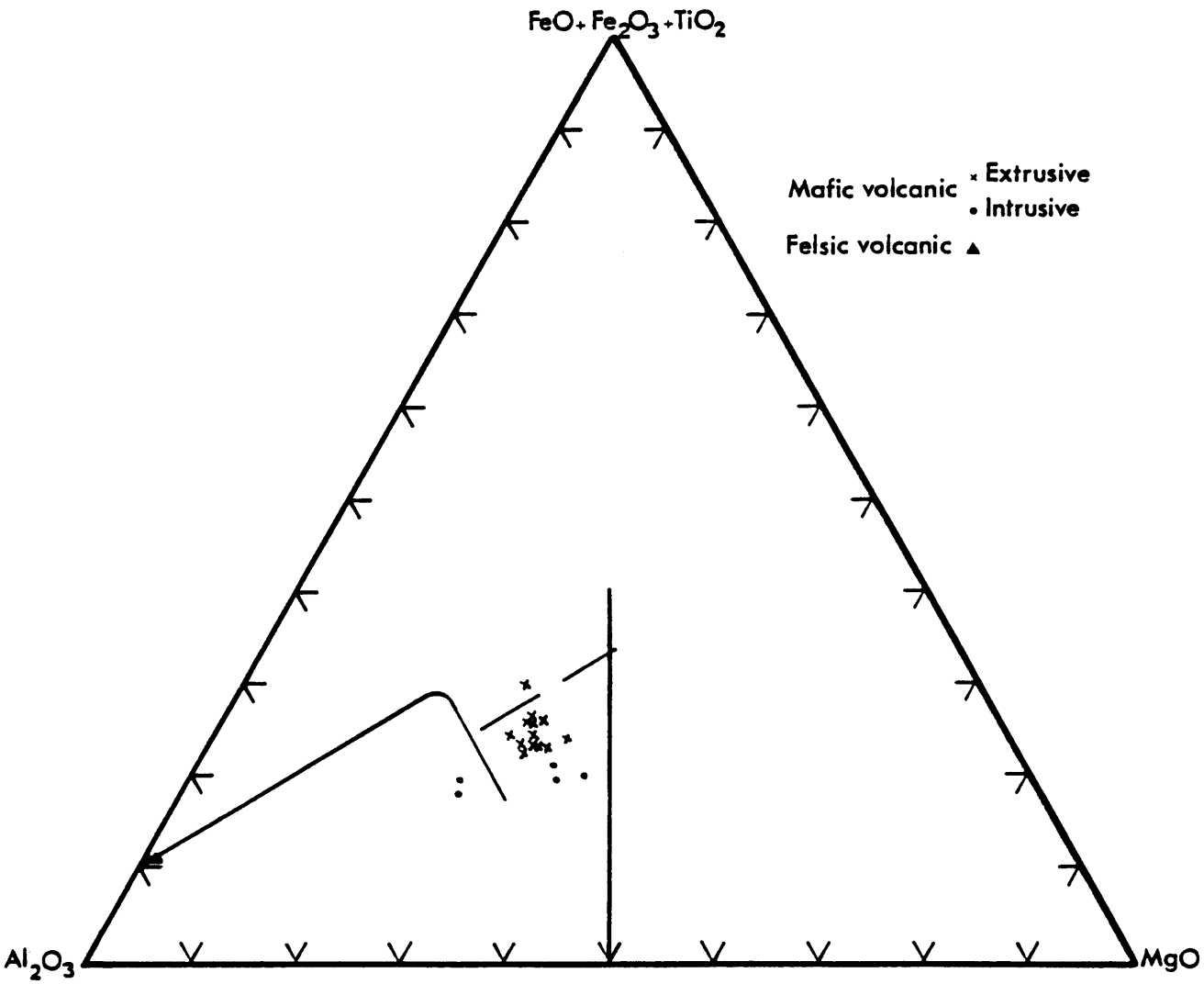


Figure : Jensen Cation Plot of Separation Lake mafic volcanics, felsic volcanics, and mafic intrusive rocks

Figure 3-2: Jensen Cation Plot of Separation Lake mafic volcanics, felsic volcanics, and mafic intrusive rocks (diagram after Jensen, 1976).

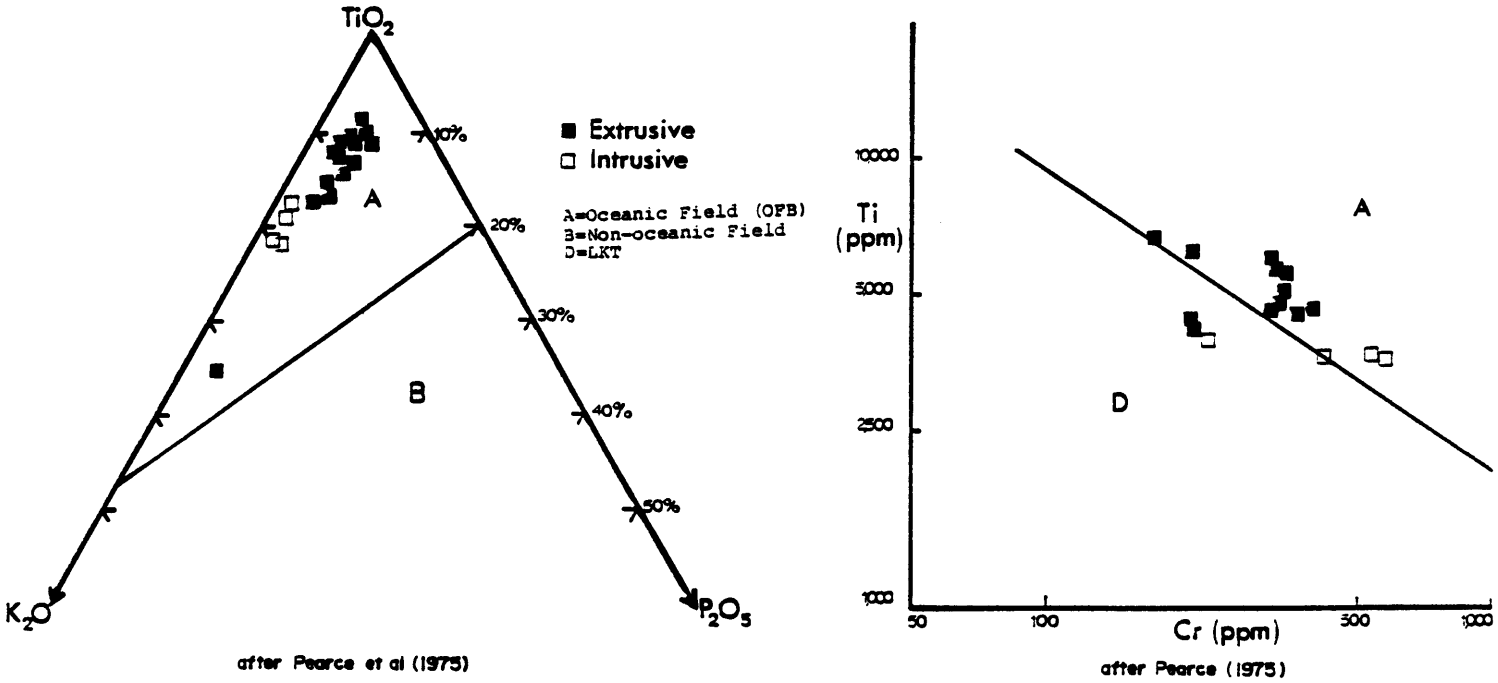


Figure Chemical variation of Separation Lake mafic volcanic extrusive and intrusive rocks

Figure 3-3: Chemical variation of Separation Lake mafic volcanic extrusive and intrusive rocks.

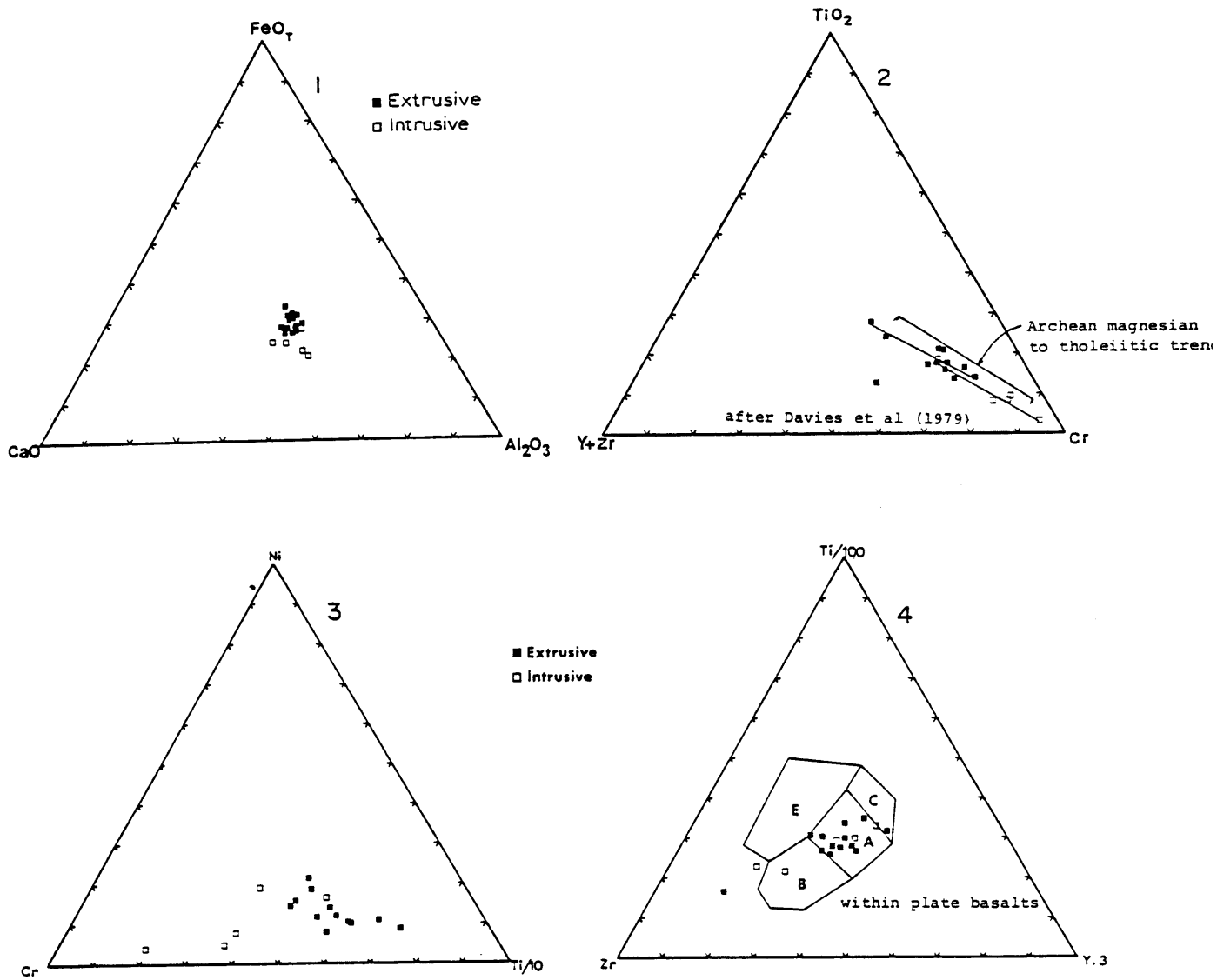


Figure 3-4: Chemical variation of Separation Lake mafic volcanic extrusive and intrusive rocks. OFB = ocean floor basalts; CAB = Calc-Alkaline basalt
LKT = Low K Tholeiites
WPB = Within Plate Basalts

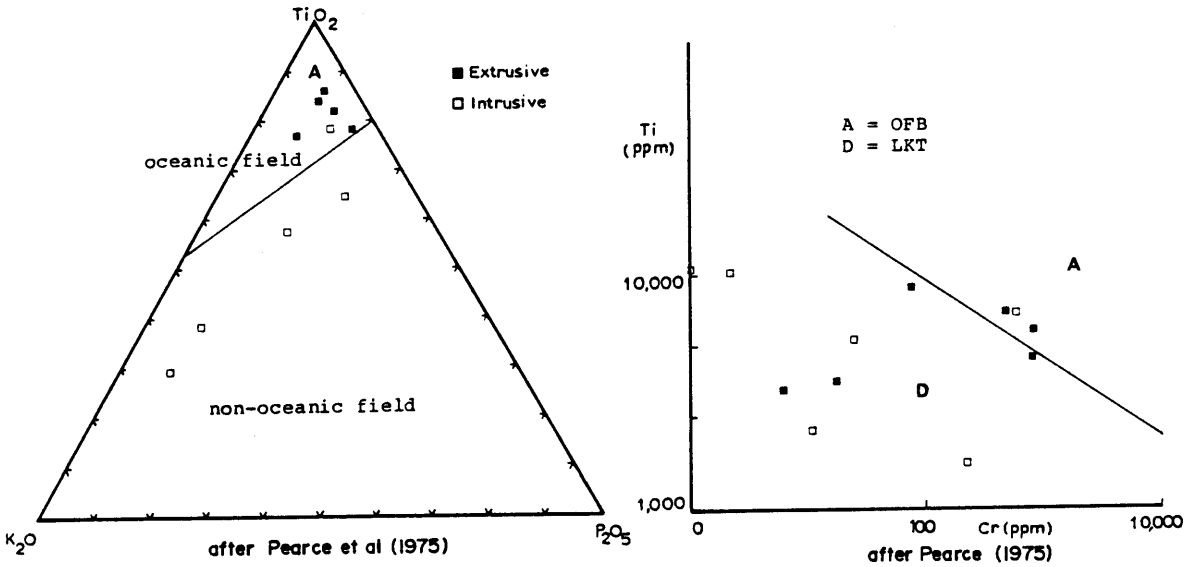


Figure 3-5 : Chemical variation of Sioux Lookout mafic volcanic and intrusive rocks

Figure 3-5: Chemical variation of Sioux Lookout mafic volcanic and intrusive rocks.

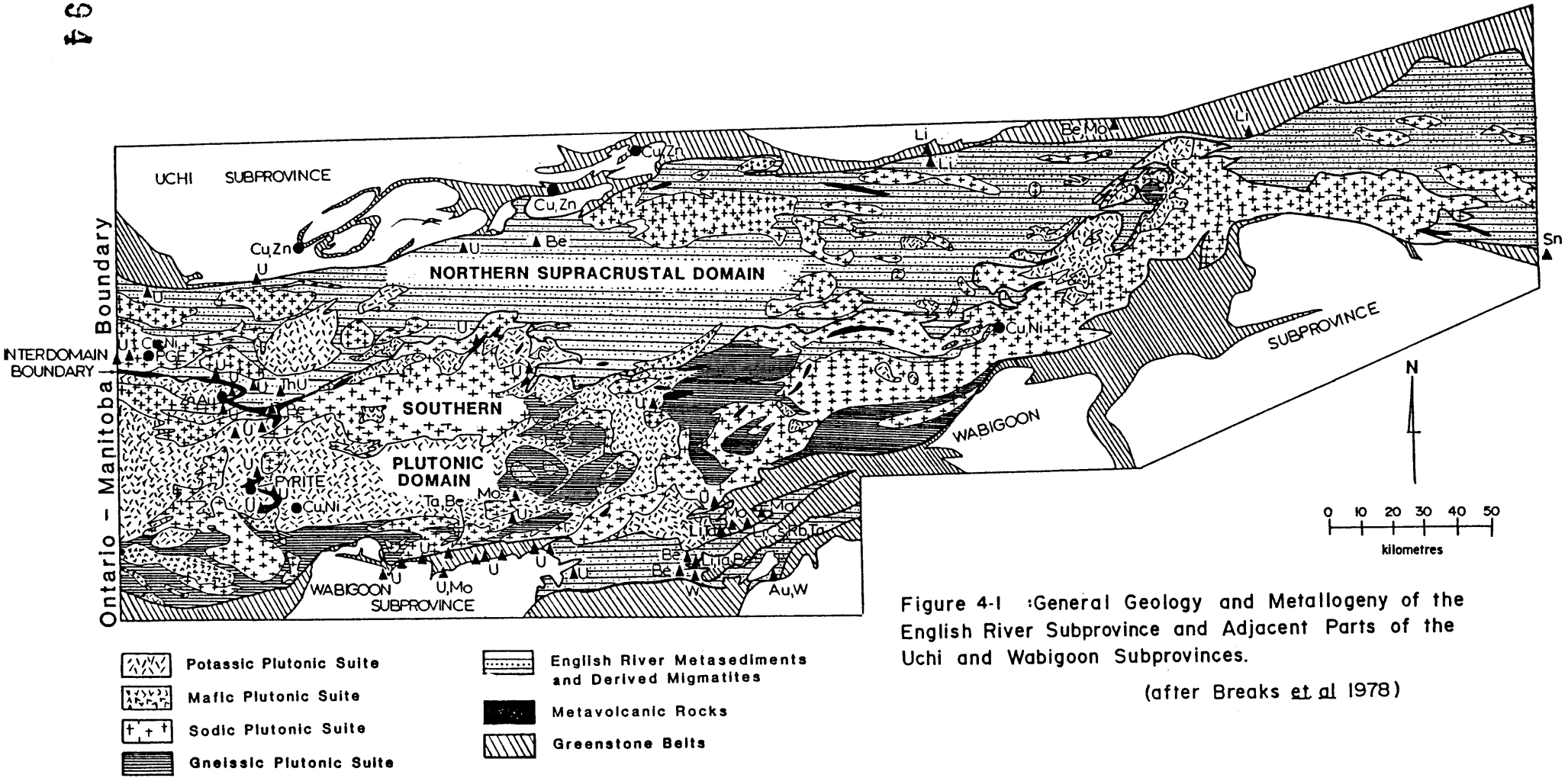


Figure 4-1 :General Geology and Metallogeny of the English River Subprovince and Adjacent Parts of the Uchi and Wabigoon Subprovinces.

(after Breaks et al 1978)

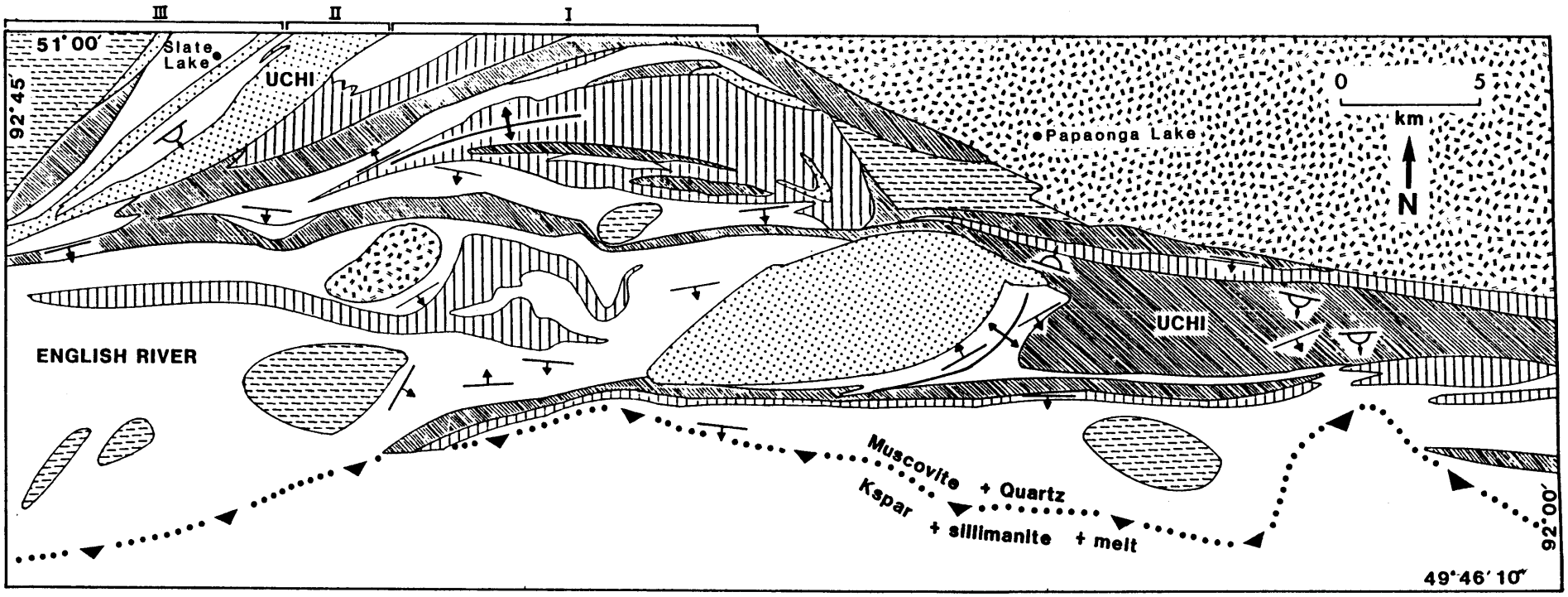
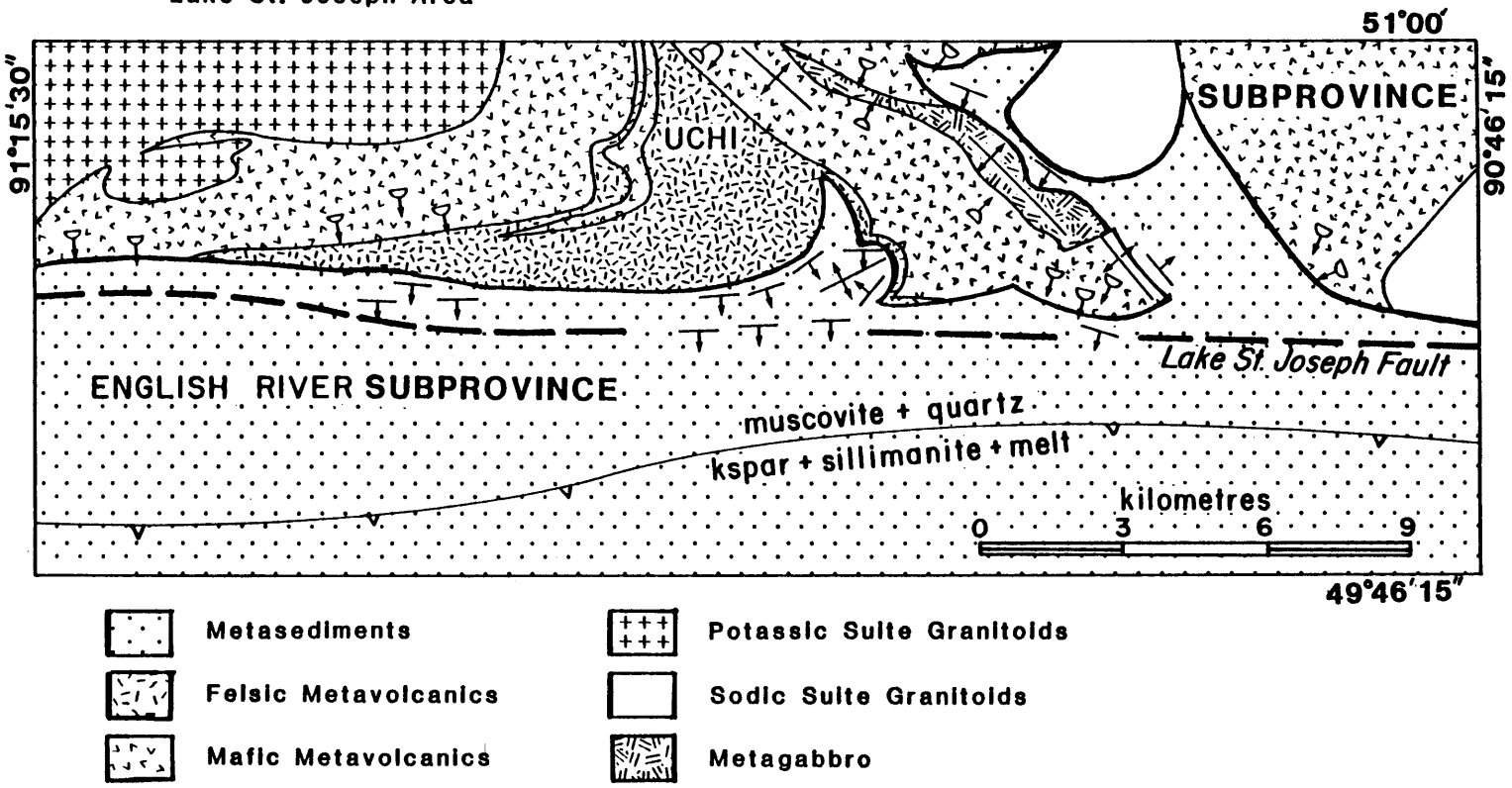
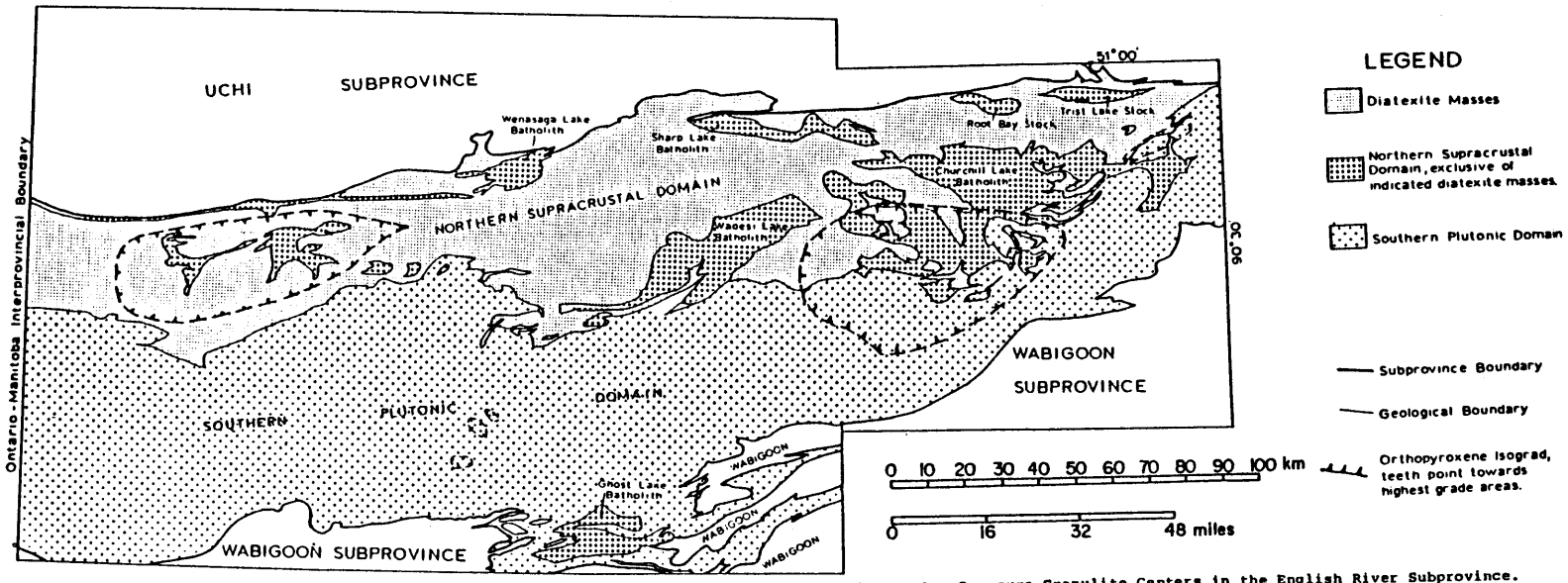


Figure 4-2 :General Geology of the English River-Uchi Subprovinces Interface in the Papaonga Lake area

- Potassic Granitoid Suite
- Sodic Granitoid Suite
- Mafic Granitoid Suite
- Felsic Metavolcanics
- Mafic Metavolcanics
- Metasediments and Derived Migmatites
- Facing Direction of Metasediments Based Upon Graded Bedding
- Facing Direction of Lava Flows Based Upon Pillow Shape and Packing
- Anticlinal Fold Axis
- Synclinal Fold Axis
- Isograd Separating Zones of Medium Grade and High Grade Metamorphism (teeth pointing to higher grades)

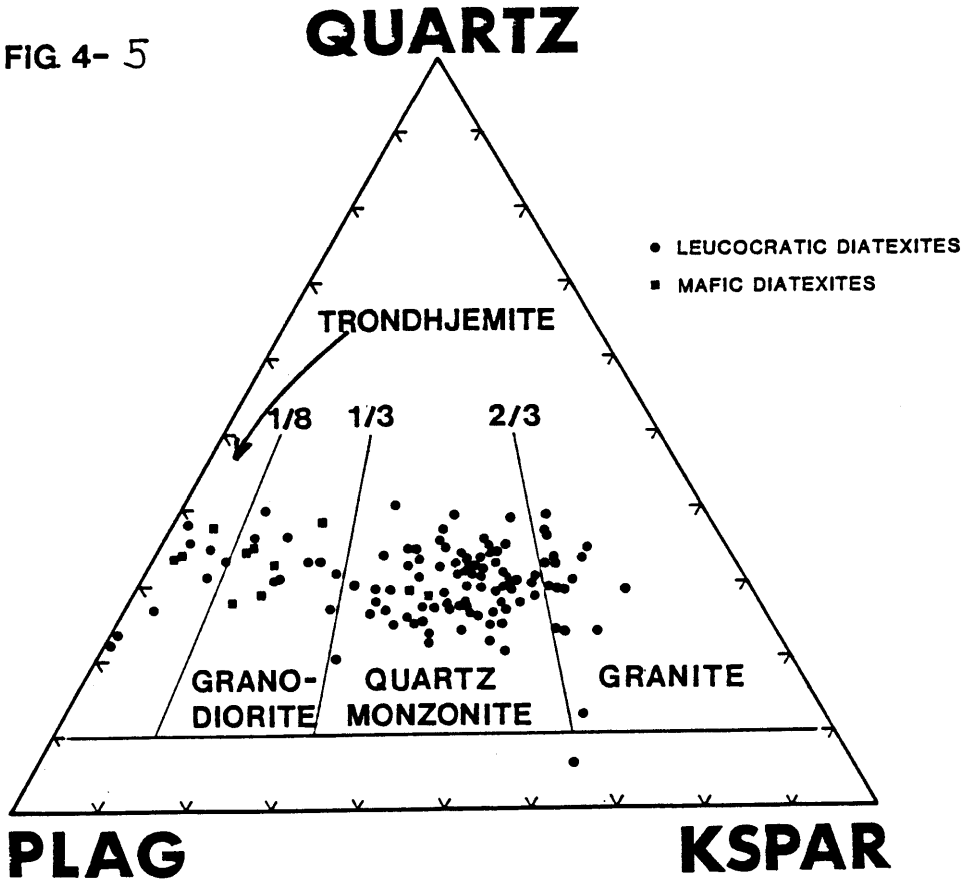
Fig. 4-3 :General Geology of the Interface Between Uchi Subprovince Metavolcanics and Northern Supracrustal Domain Metasediments (English River Subprovince) in the Western Lake St. Joseph Area



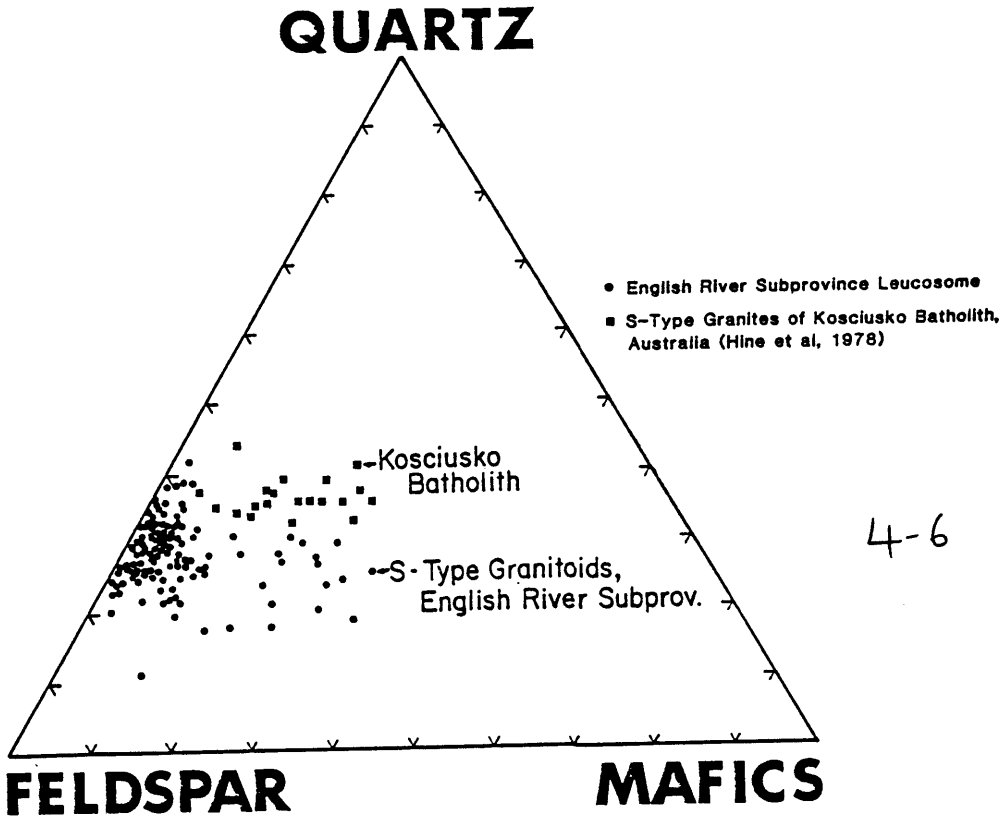


Distribution of Advanced Stage Metasedimentary Migmatites (Diatexites) in Relation to Low-Pressure Granulite Centers in the English River Subprovince.

FIG. 4- 5

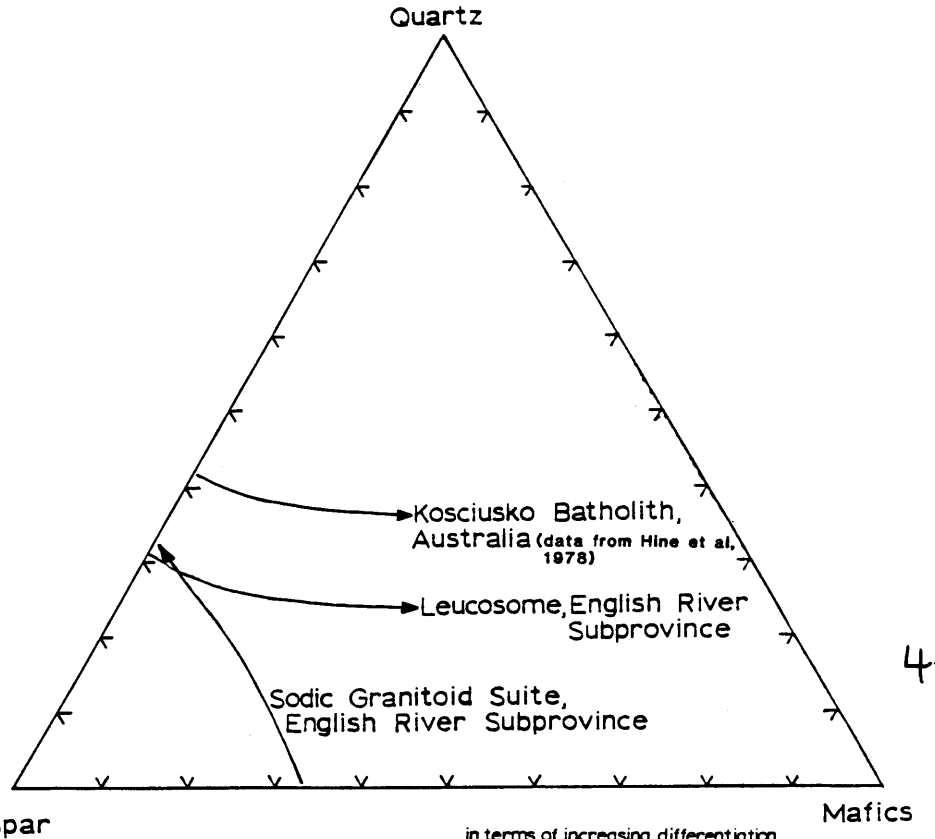


MODAL VARIATION OF QUARTZ: PLAGIOCLASE: K-FELDSPAR IN LEUCOSOME FROM NORTHERN DOMAIN METASEDIMENTARY MIGMATITE



4-6

FIGURE MODAL VARIATION OF QUARTZ-FELDSPAR-COLOUR INDEX IN LEUCOSOME FROM NORTHERN SUPRACRUSTAL DOMAIN METASEDIMENTARY MIGMATITE AS COMPARED TO S-TYPE GRANITOIDS FROM THE KOSCIUSKO BATHOLITH.



4-7

Figure :Generalized Modal Variation Trends in terms of increasing differentiation in S-type Granitoid Rocks (Northern Supracrustal Domain Leucosome and Kosciusko Batholith) in Comparison to I-type Granitoids From Southern Plutonic Domain.

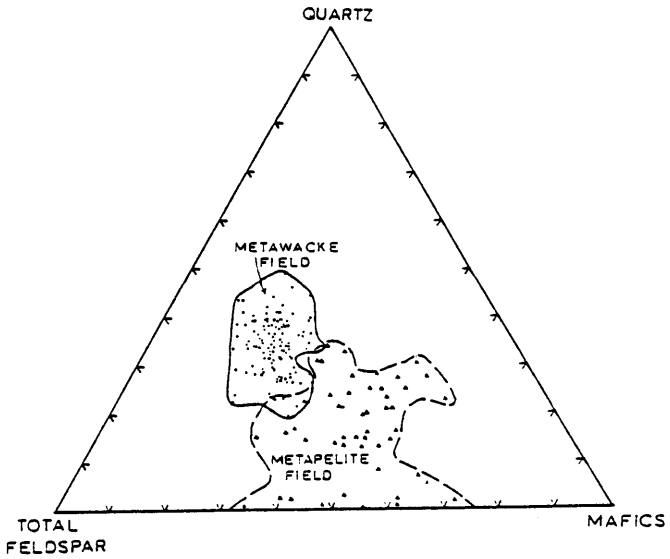


Fig. 4-8 QFM Variation in Metawackes and Metapelites from Northern Supracrustal Domain.

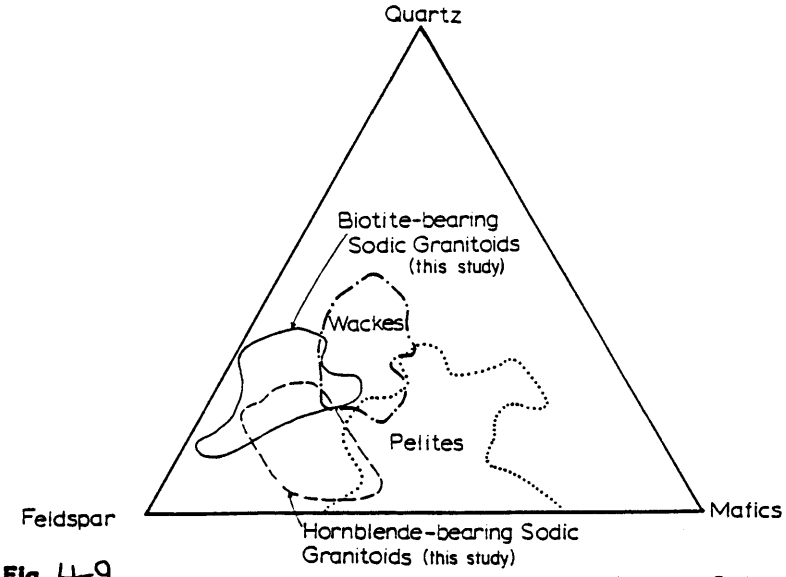


Fig. 4-9 Comparison of Metawacke and Metapelite QFM Modal Fields with Biotite- and Hornblende-Bearing Sodic Granitoid Suite Fields of the English River Subprovince.

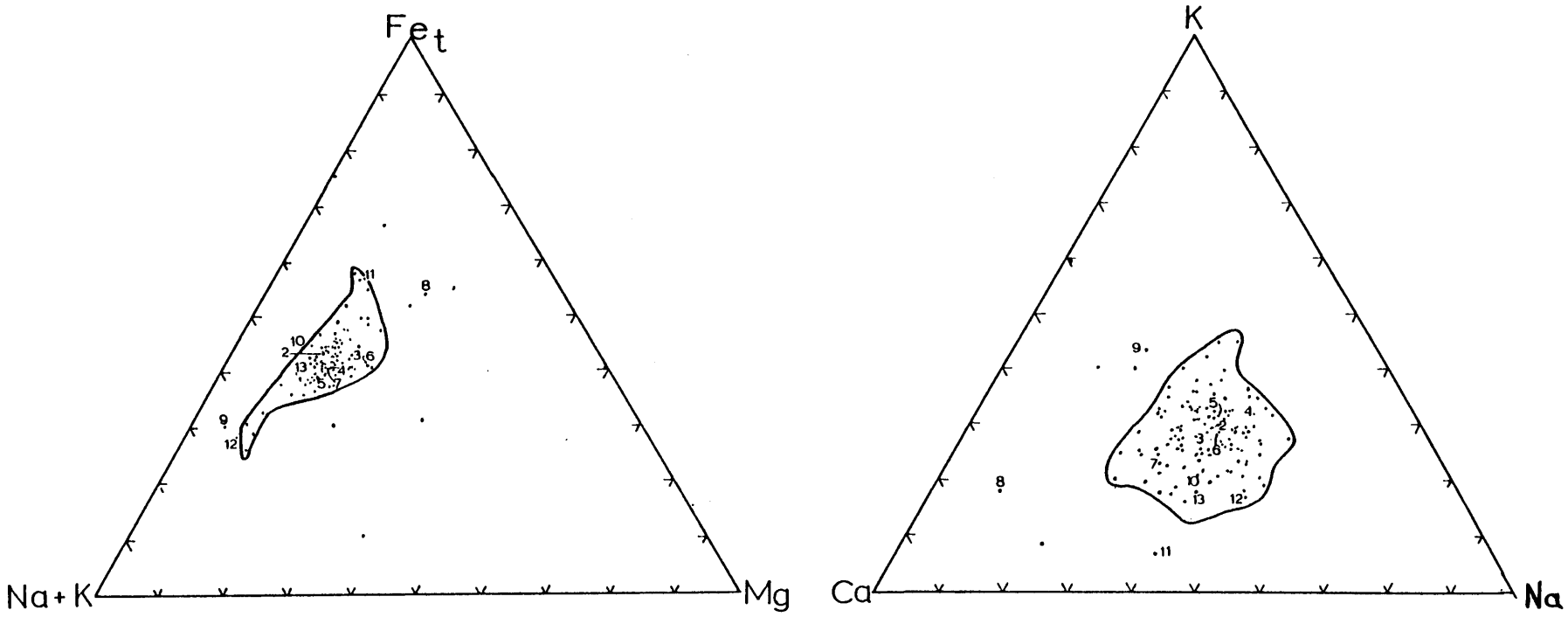


FIGURE 4-10 AFM AND CNK PLOTS (WEIGHT PERCENT) ILLUSTRATING COMPOSITIONAL VARIATION OF METAWACKE FROM THE NORTHERN SUPRACRUST DOMAIN. ENUMERATED ANALYSES CORRESPOND TO SELECTED MEAN LITHIC COMPOSITIONS FROM THE LITERATURE AS GIVEN IN TABLE 4-3

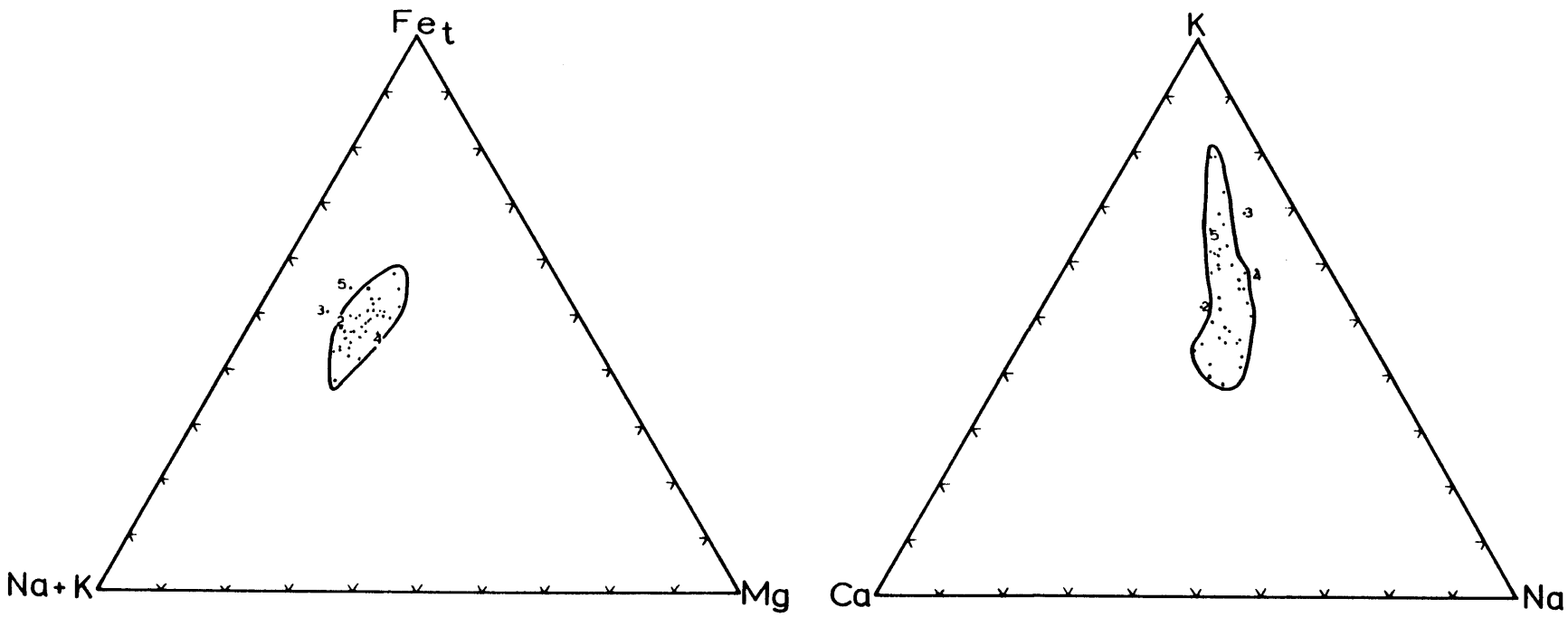
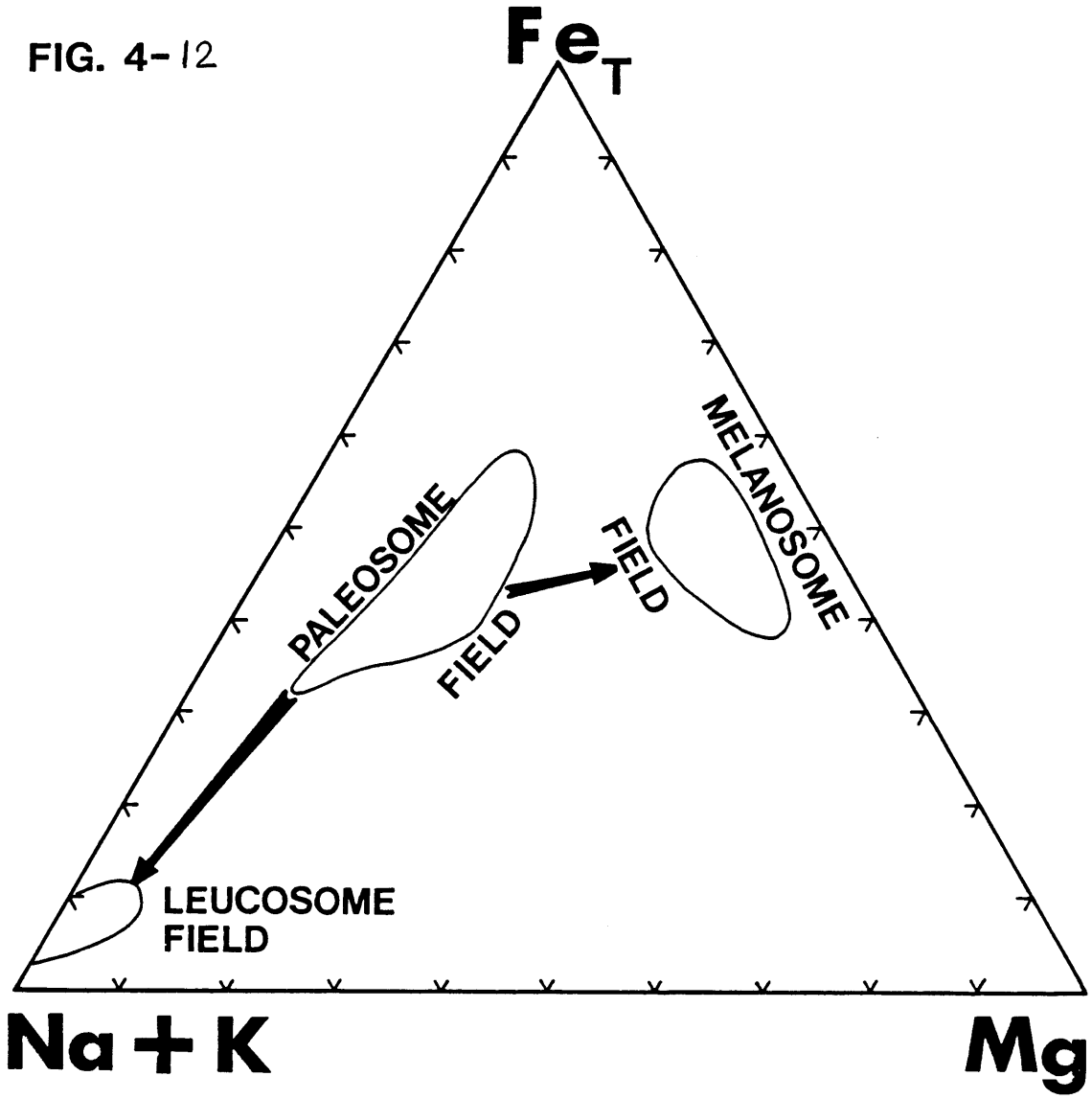


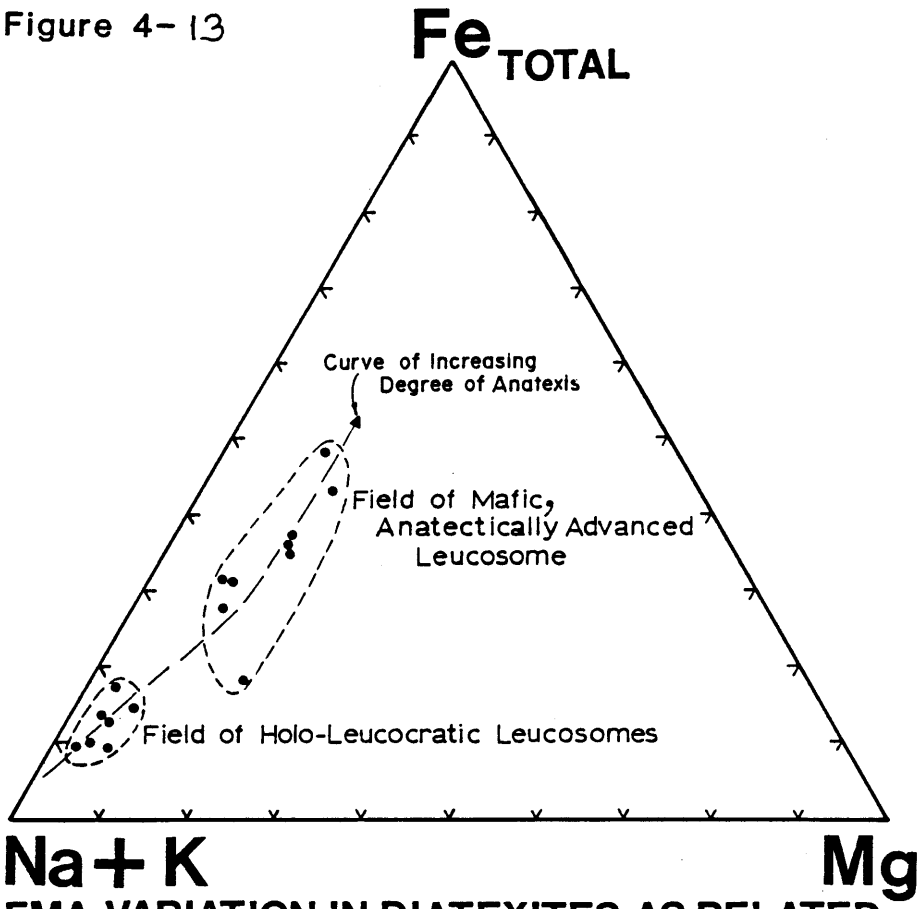
FIGURE 4-11 AFM AND CNK PLOTS (WEIGHT PERCENT) ILLUSTRATING COMPOSITIONAL VARIATION OF METAPELITES FROM THE NORTHERN SUPRACRUSTAL DOMAIN. ENUMERATED ANALYSES CORRESPOND TO SELECTED MEAN LITHIC COMPOSITIONS FROM THE LITERATURE AS GIVEN IN TABLE 4-3

FIG. 4-12



FMA EXPRESSION OF METATEXIS-ANATECTIC SPLITTING OF PALEOSOME FORMING MELANOSOME & LEUCOSOME COMPONENTS

Figure 4-13



FMA VARIATION IN DIATEXITES AS RELATED TO PROGRESSIVE FUSION OF METASEDIMENTARY PROTOLITH **Curve defining increased anatexis derived from this study supplemented with data of Winkler (1979).**

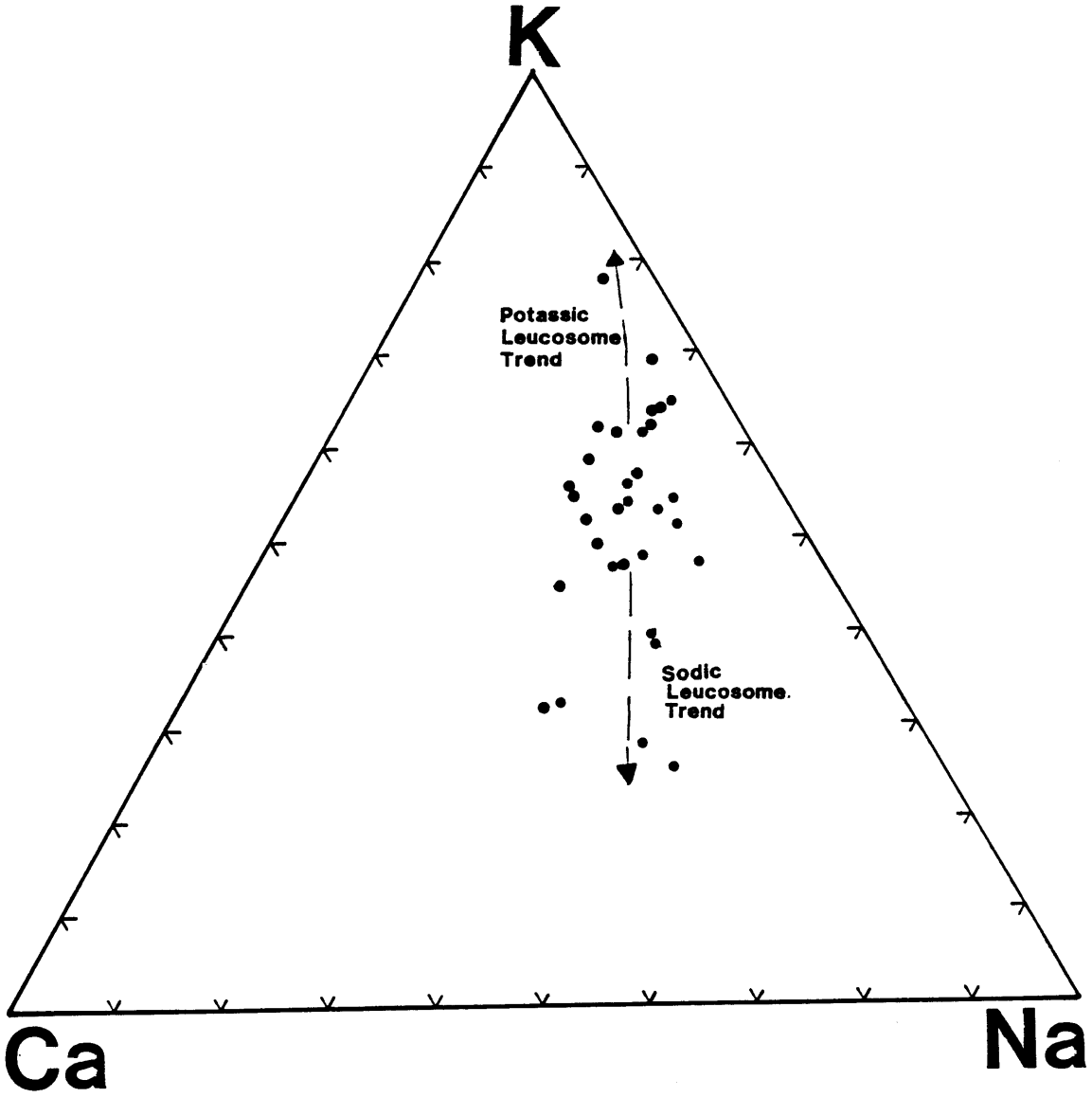


Figure 4-14:CNK Variation in Diatexites Showing Sodic and Potassic Leucosome Trends

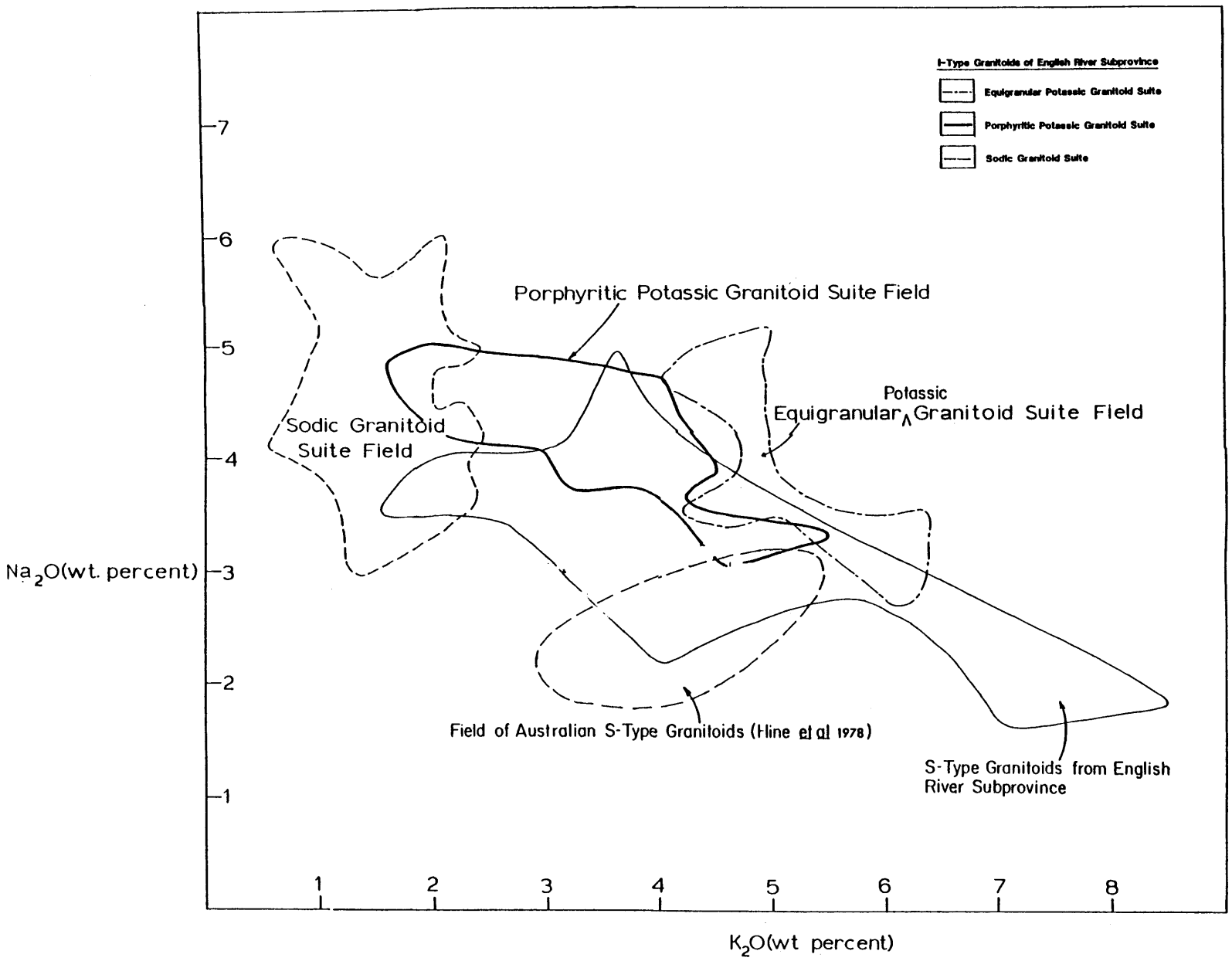


Figure 4-15: K_2O vs. Na_2O Variation in Leucosome Component from Metasedimentary Migmatite of Northern Supracrustal Domain in Comparison to Sodic and Potassic Granitoid Suite Plutonic Rocks and Australian S-Type Granitoids

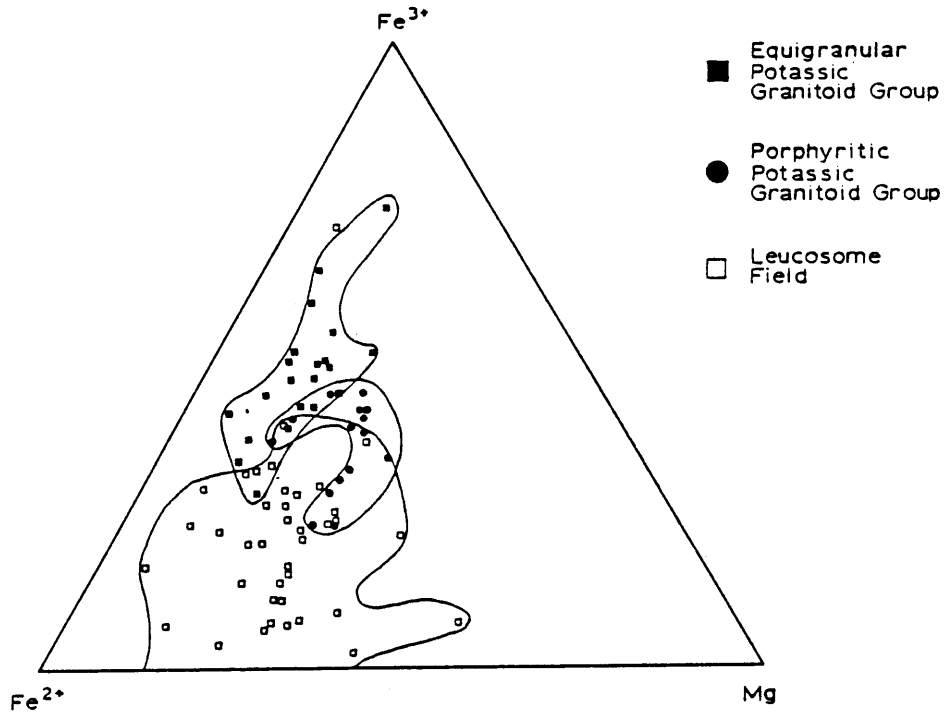


Fig. 4-16 Fe^{3+}-Fe^{2+}-Mg Variation in Leucosome From Northern Supracrustal Domain and Equigranular and Porphyritic Potassic Granitoid Groups From Southern Plutonic Domain.

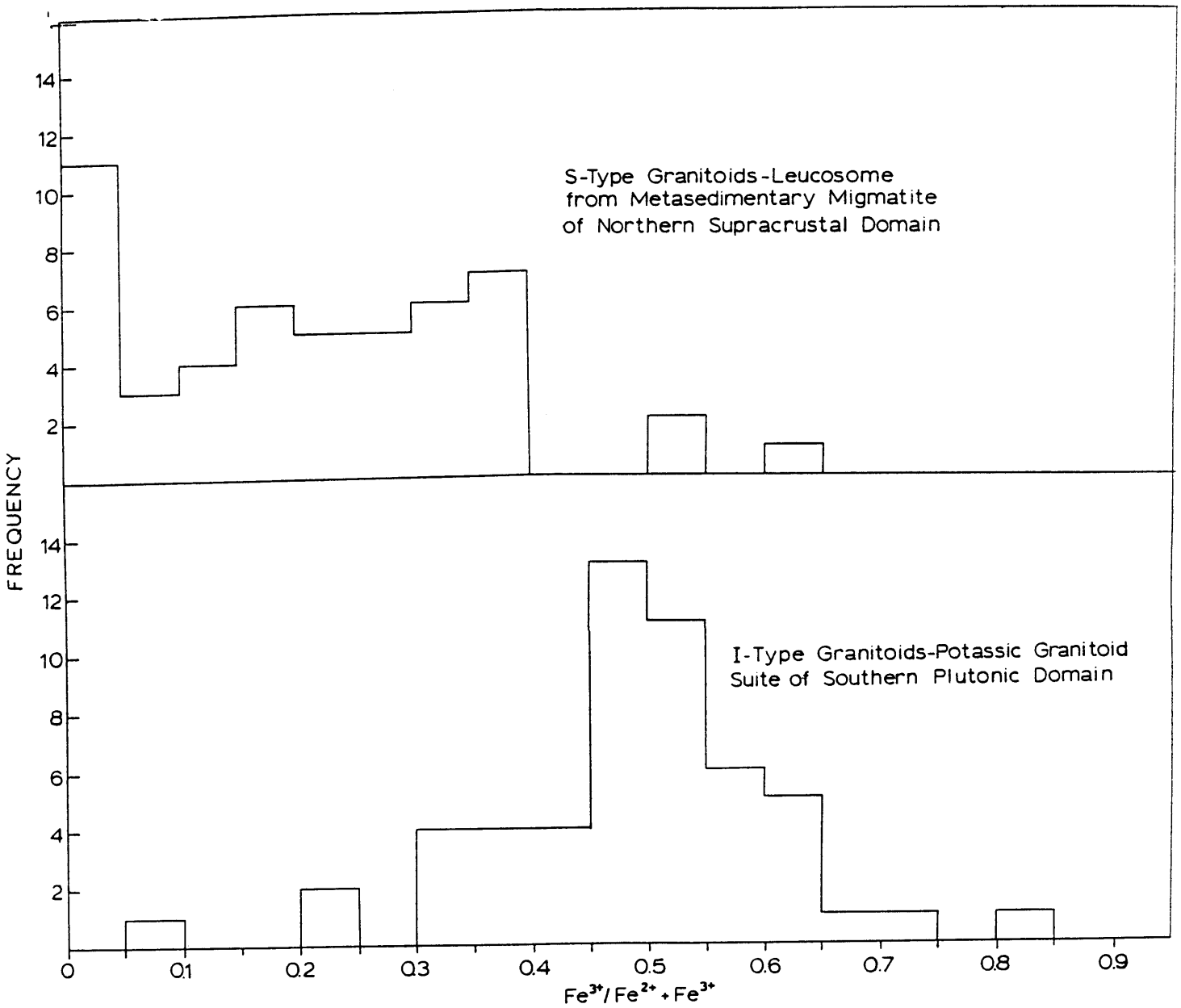


Fig. 4-17 Histograms Showing Frequency of $Fe^{3+}/Fe^{2+}+Fe^{3+}$ in Leucosome from Northern Supracrustal Domain vs. Potassic Granitoid Suite Rocks from Southern Plutonic Domain.

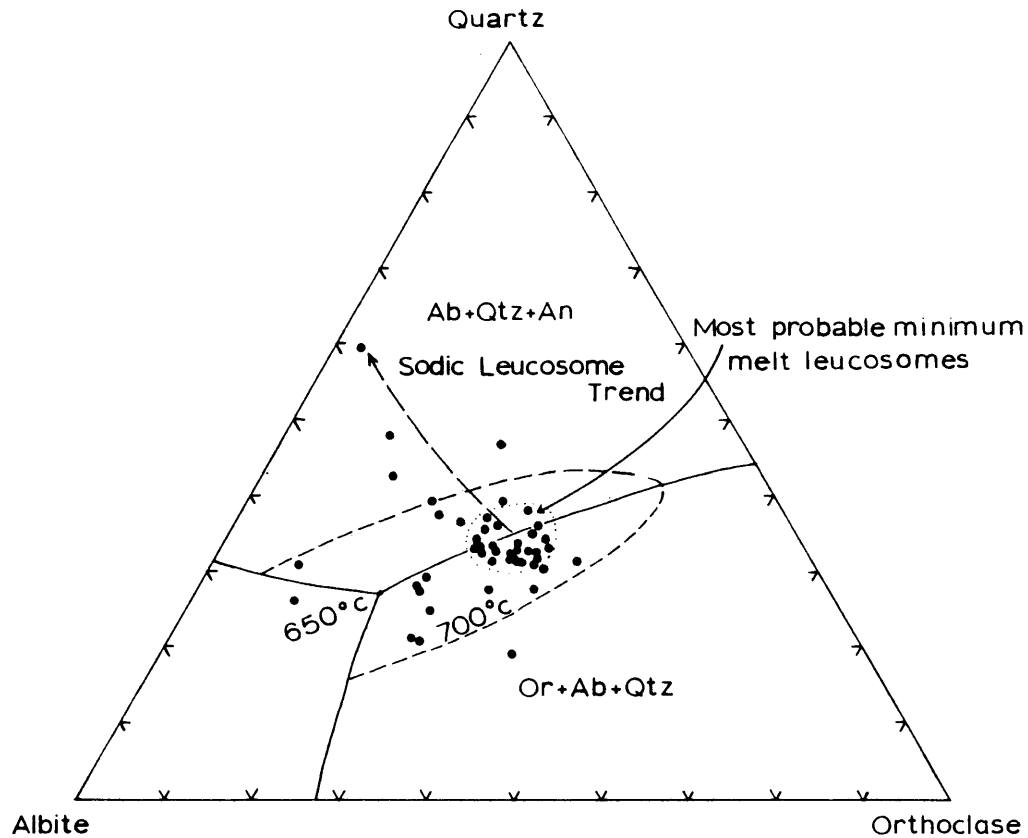


Figure 4-18 Normative Quartz - Albite - Orthoclase for Leucosome from Northern Supracrustal Domain Isotherms and Cotectic Projection Taken From Winkler et al, 1975 at P_{H_2O} = 5 Kbars

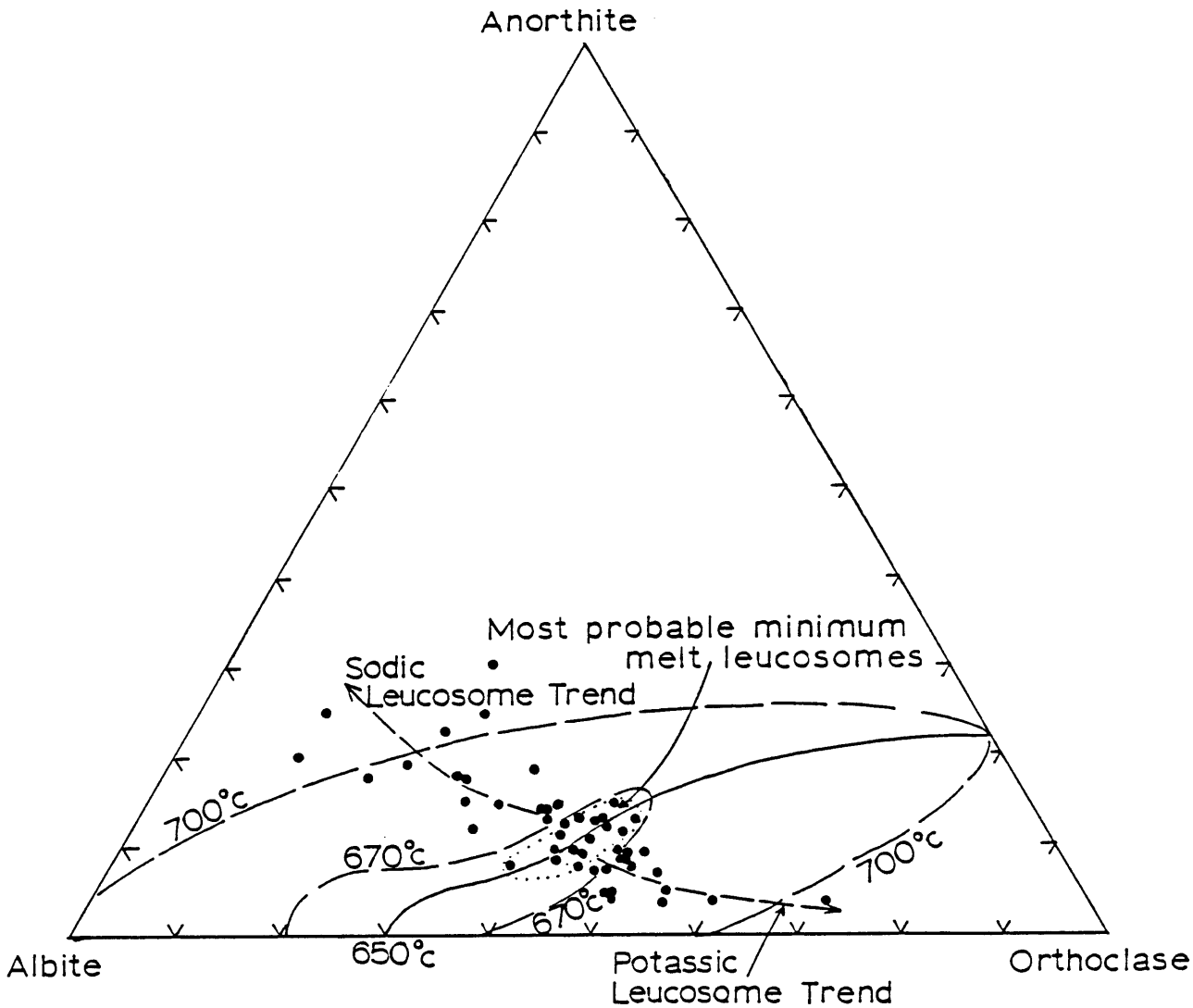


Figure 4-19: Normative Anorthite - Albite - Orthoclase for Leucosome From Northern Supracrustal Domain. Isotherms and Cotectic Projection Taken From Winkler et al, 1975.

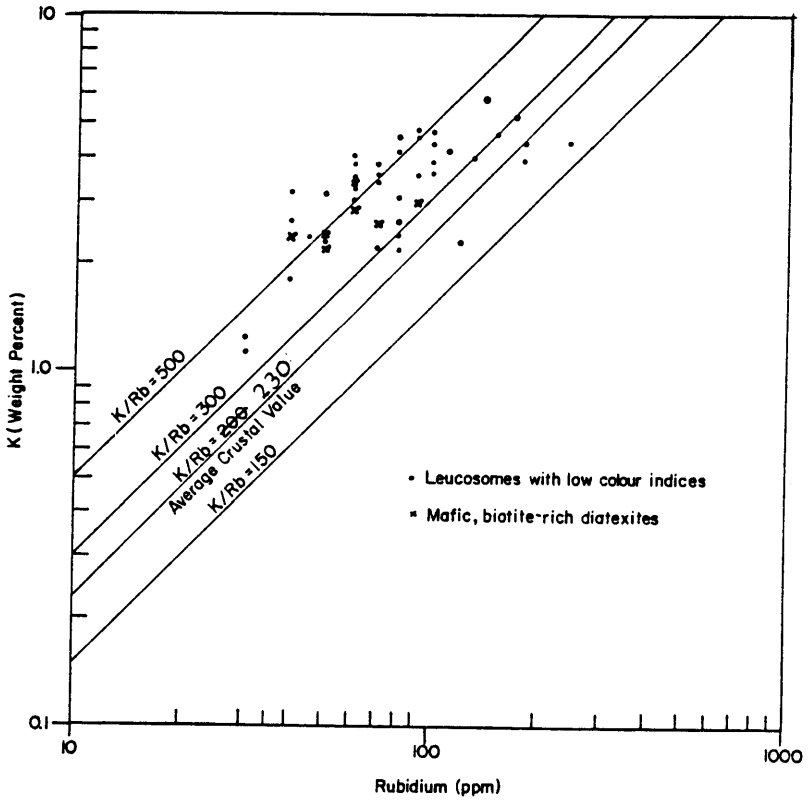


Figure 4-20 K vs. Rb Variation in Leucosome from Metasedimentary Migmatite of the English River Subprovince

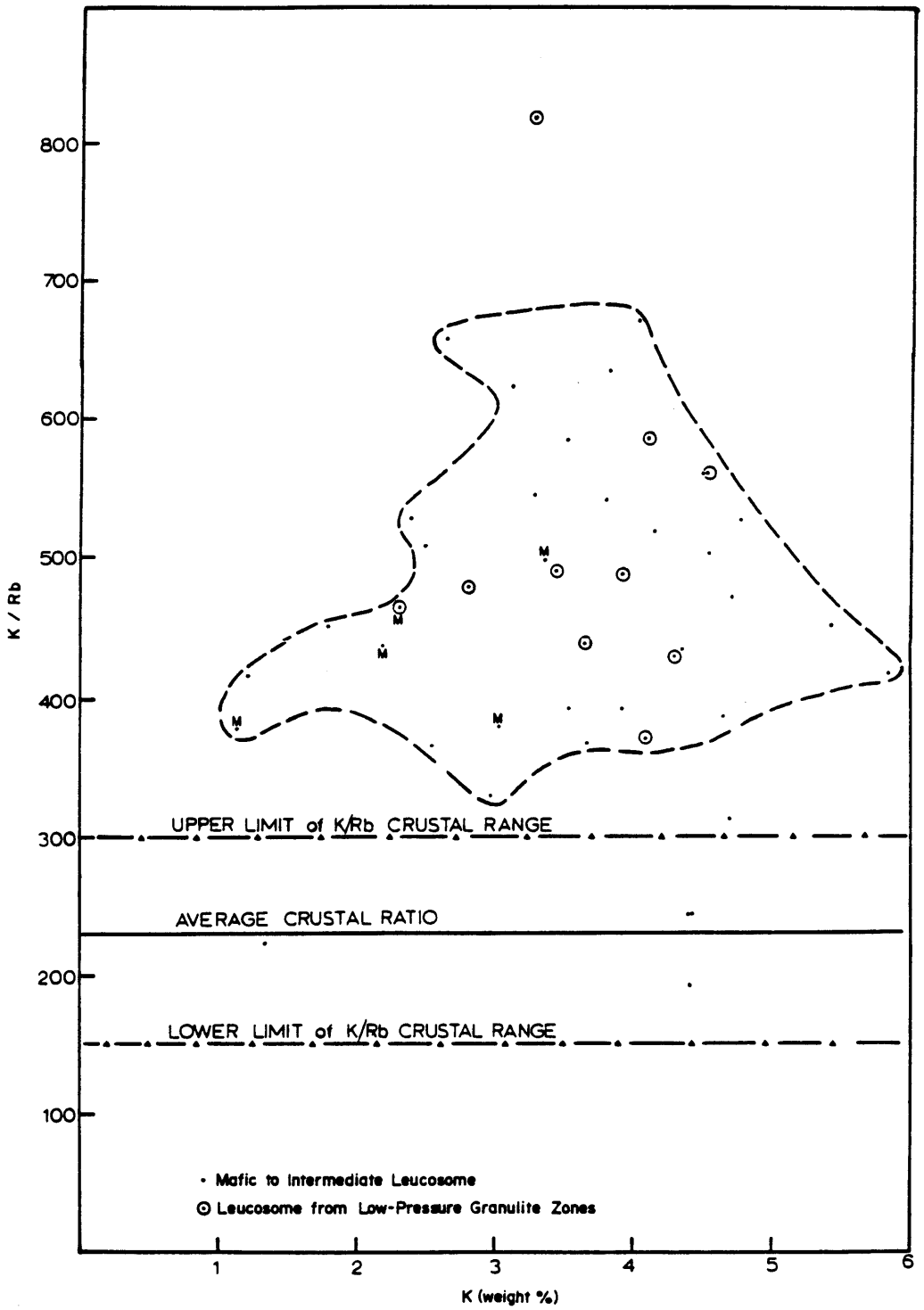


Figure 4-21 K vs. K/Rb Variation in Leucosome from Metasedimentary Migmatites, Northern Supracrustal Domain

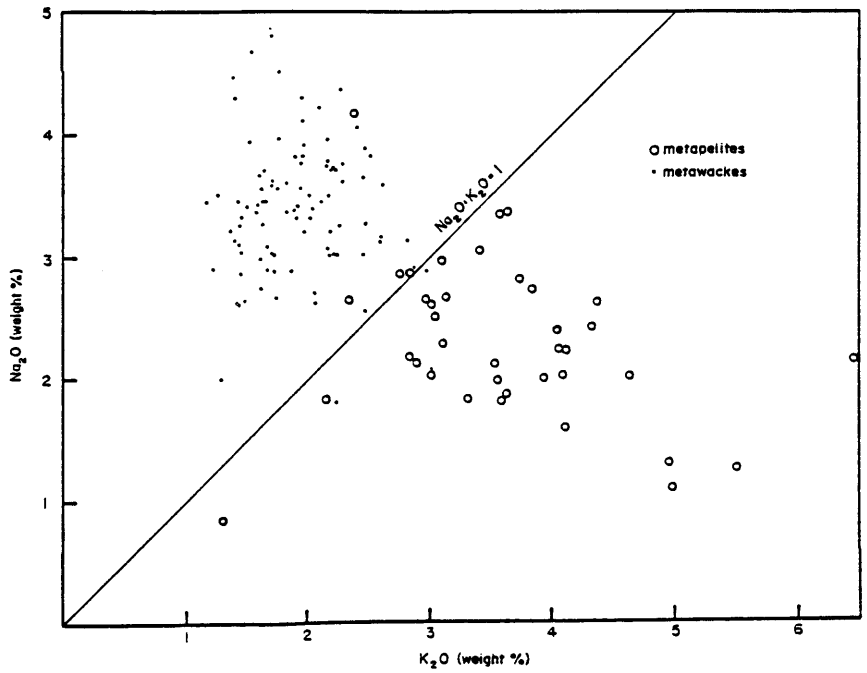


Fig. 4·22 Na_2O - K_2O Variation in Metasediments From English River Subprovince

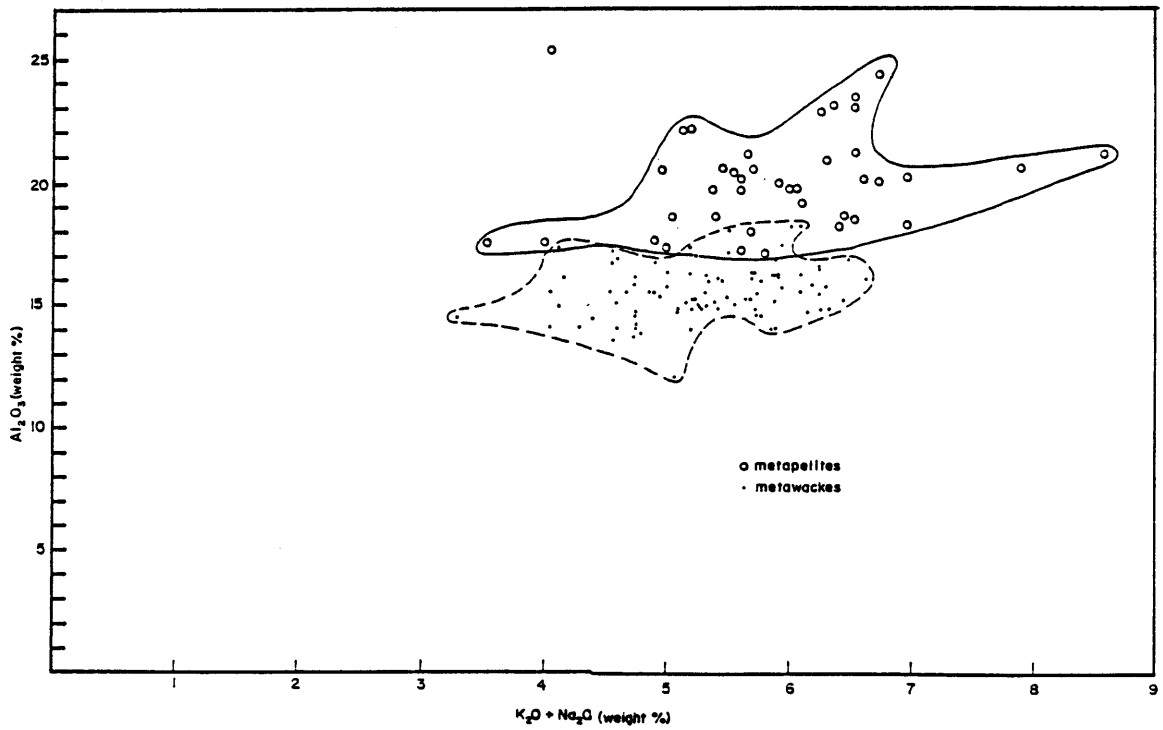
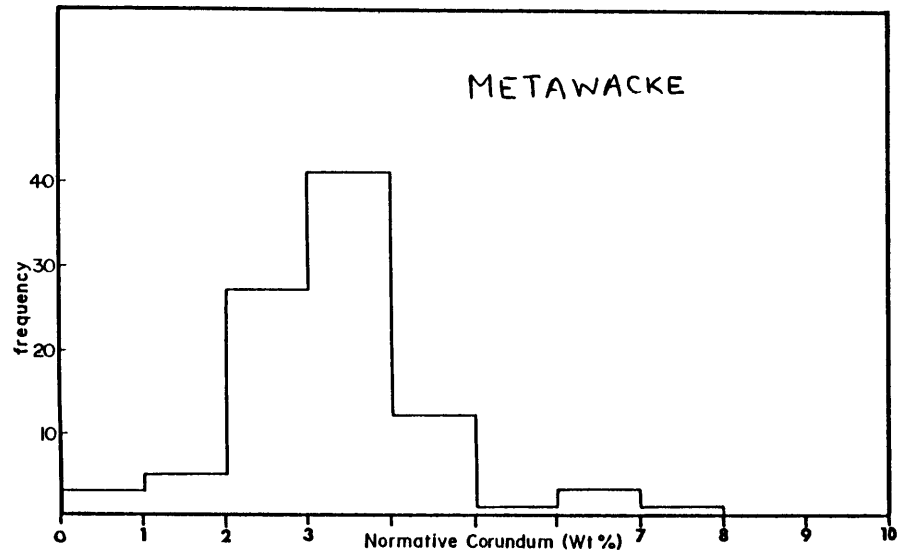


Fig. 4·23 Al_2O_3 vs. K_2O+Na_2O Variation in Metasediments of English River Subprovince



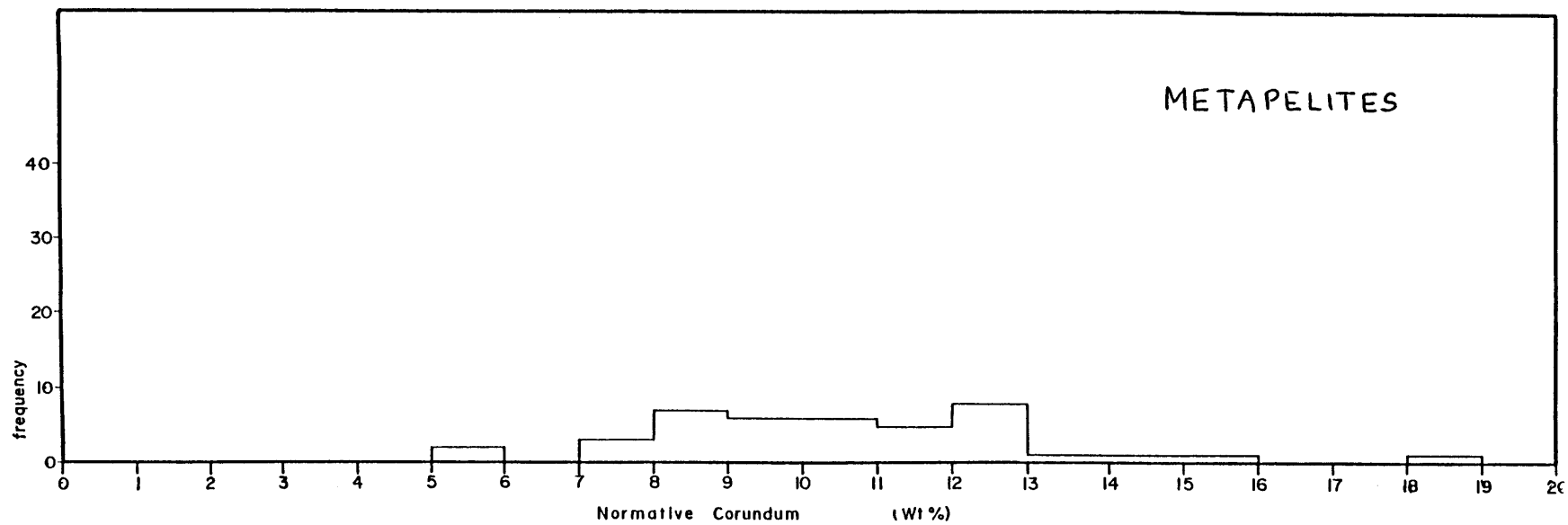


Fig 4·24 Histogram Showing Variation of Normative Corundum In Metapelitic Rocks of English River Subprovince

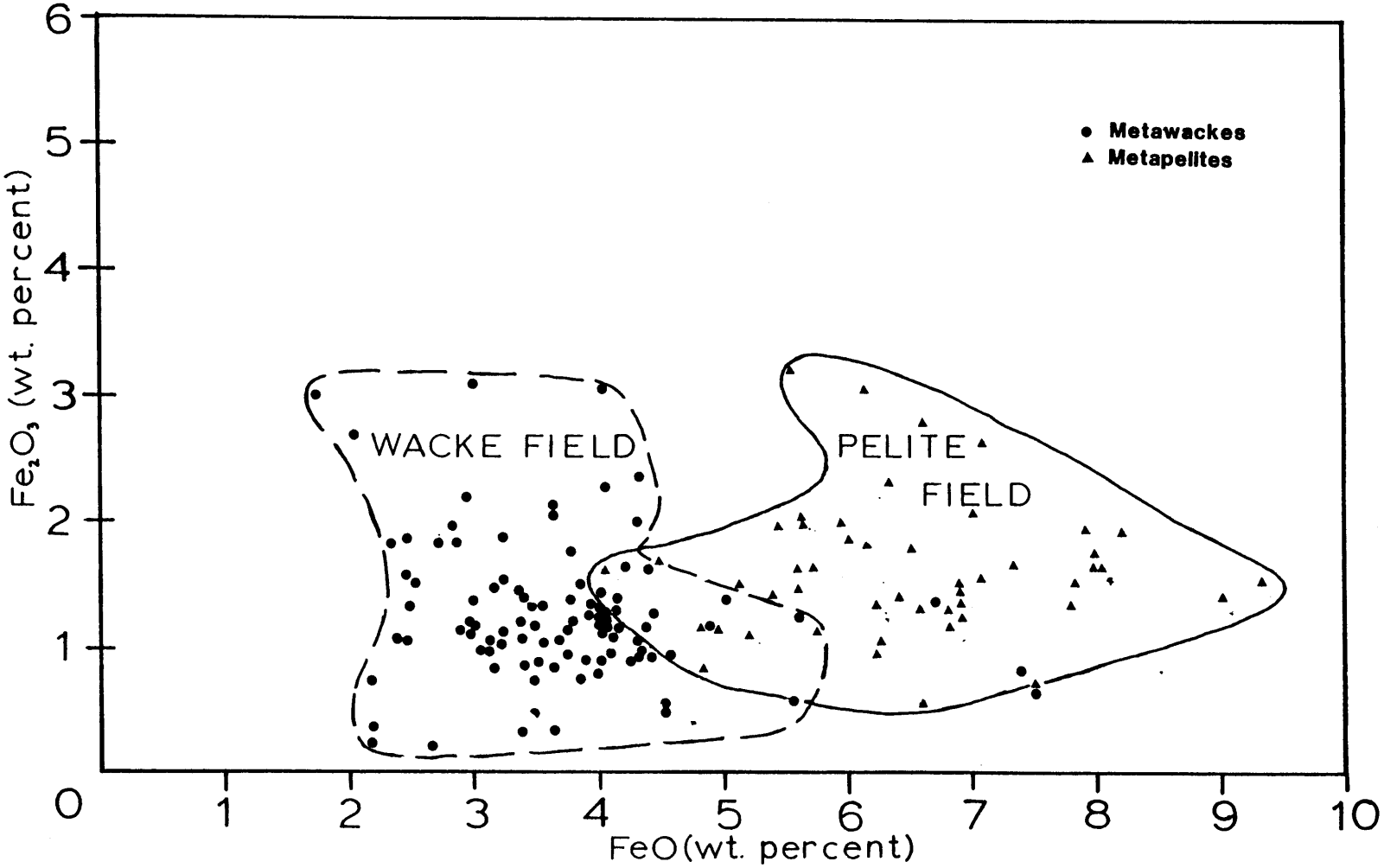
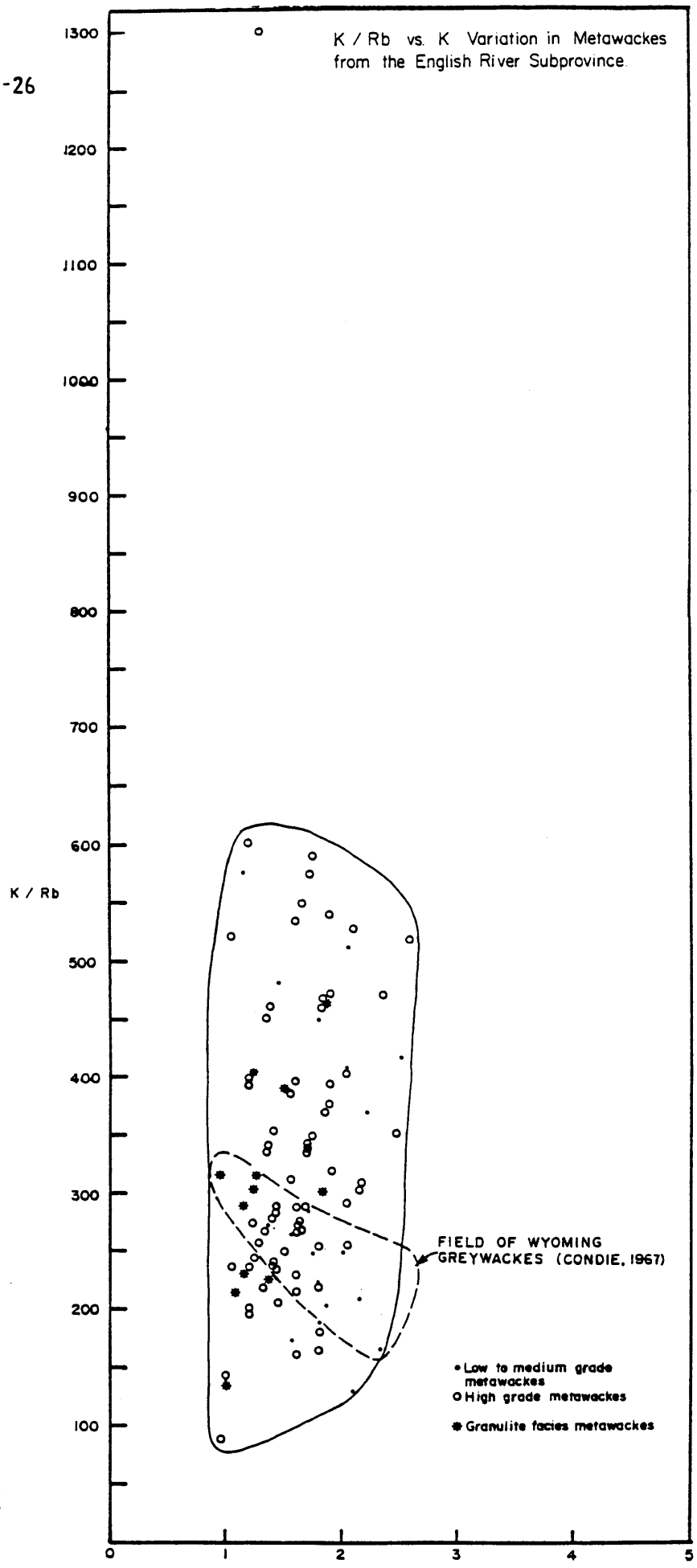


FIGURE 4-25 FeO vs Fe_2O_3 Variation in Metawacke and Metapelite Metasediments from English River Subprovince.

Fig. 4-26


K / Rb vs. K Variation in Metawackes from the English River Subprovince.
K / Rb
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1
2
3
4
5
FIELD OF WYOMING GREYWACKES (CONDIE, 1967)
• Low to medium grade metawackes
o High grade metawackes
* Granulite facies metawackes

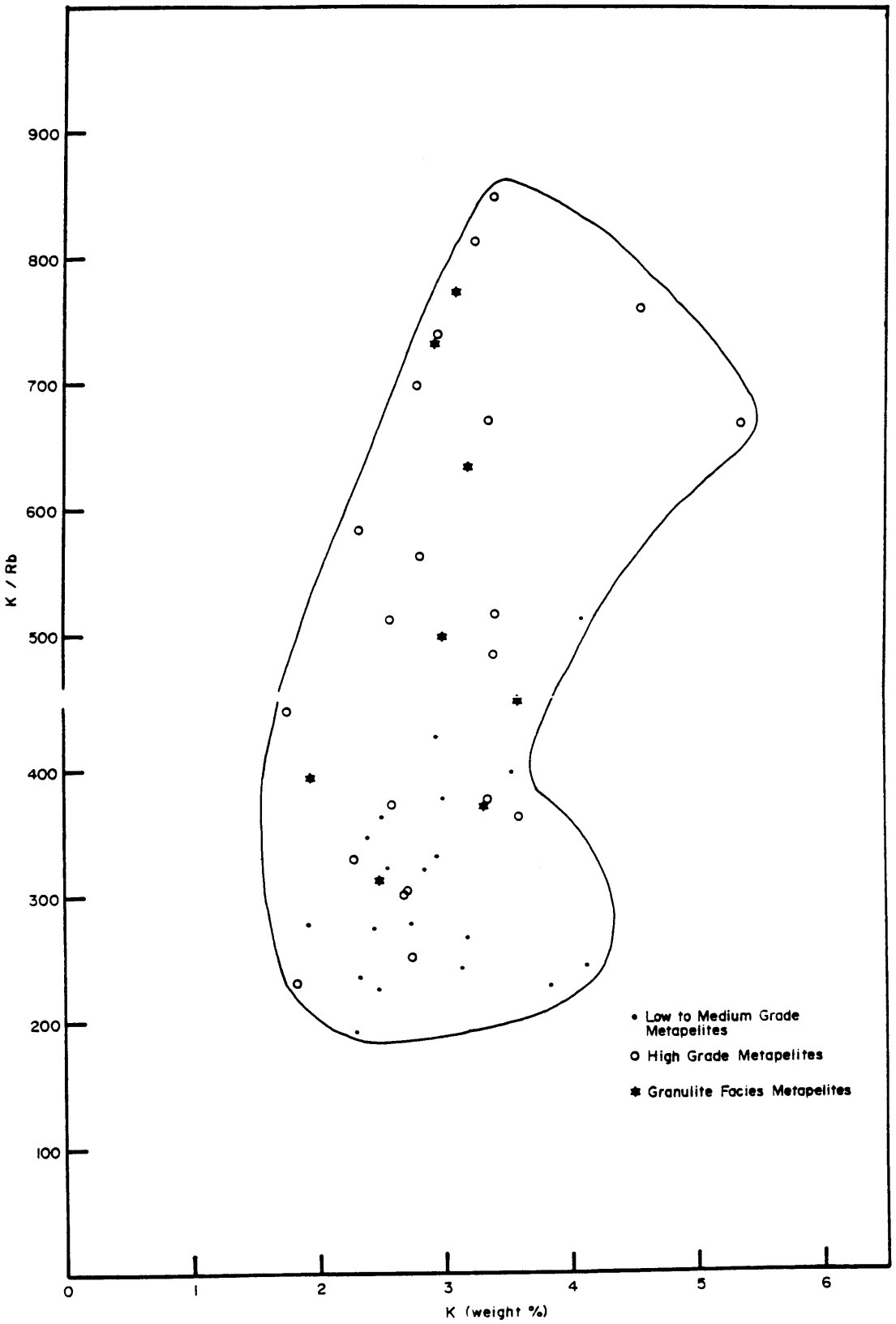


Figure 4-27 K / Rb vs. K Variation in Metapelites from English River Subprovince

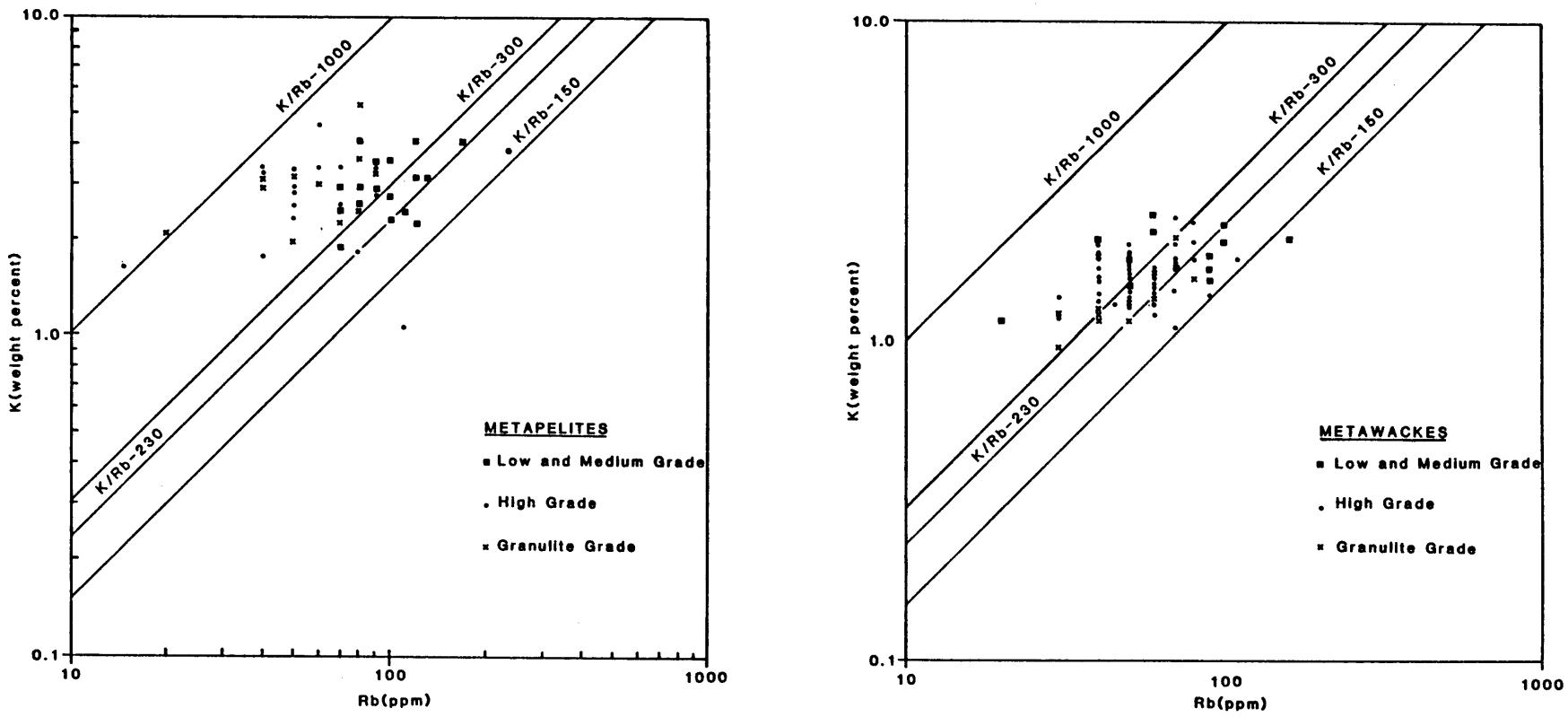


FIGURE 4-6 :K-Rb Relationships on Pelitic and Wacke Metasediments from the English River Subprovince as a Function of Regional Metamorphism

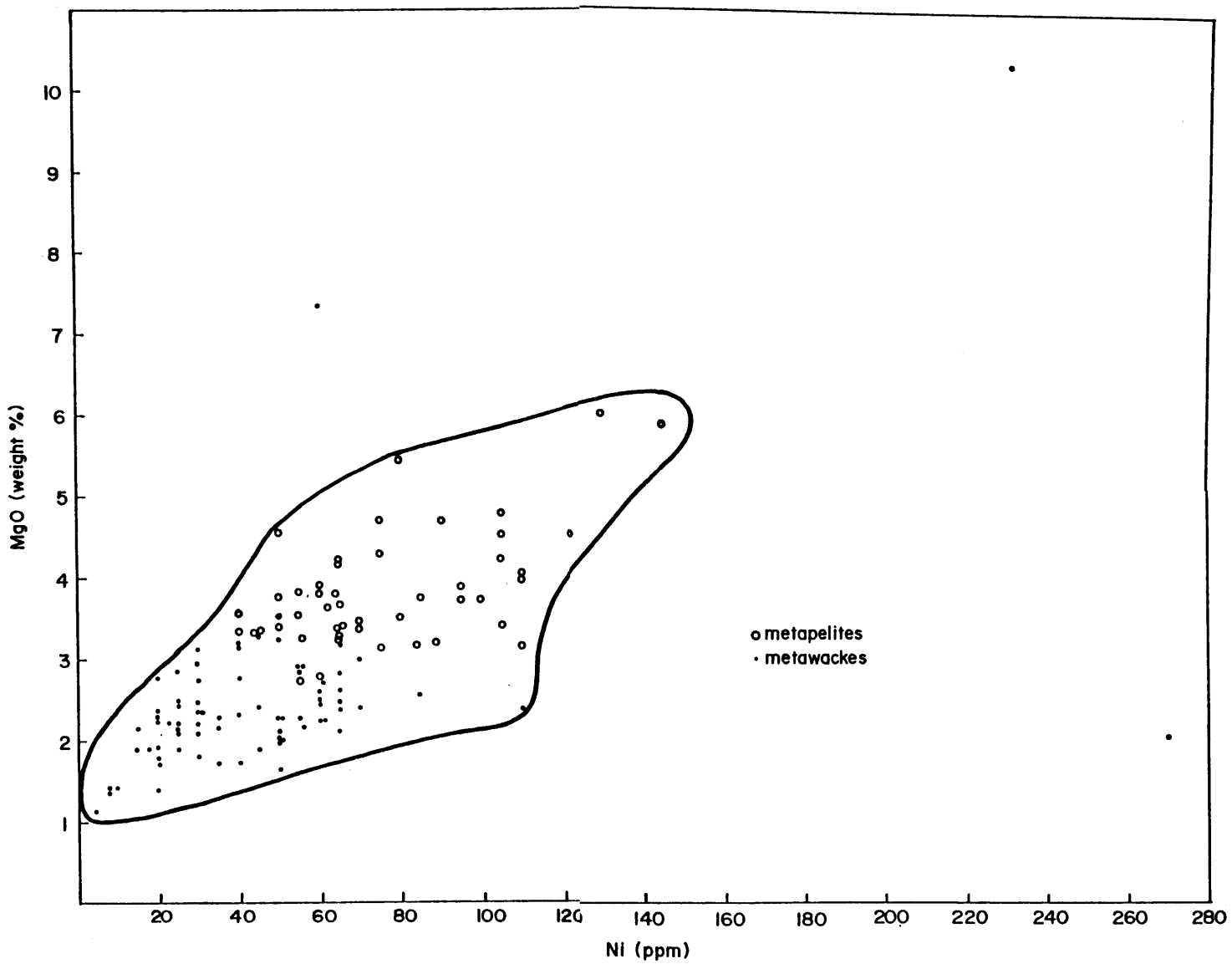


Figure 4-7: MgO vs. Ni Variation in Metasediments from English River Subprovince Based upon 123 analyses, this study

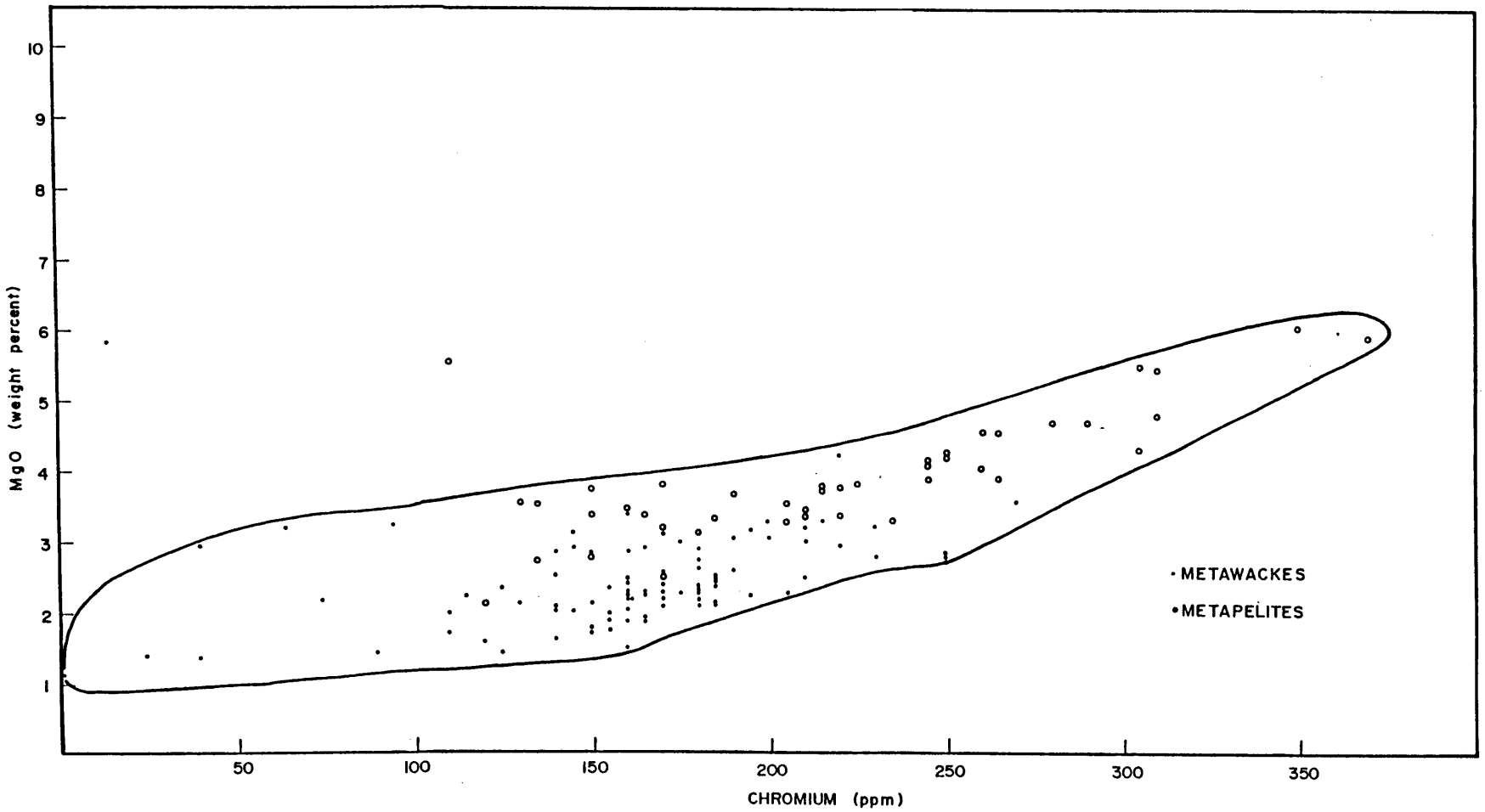


FIGURE 4-30 :MgO vs. Cr VARIATION IN METASEDIMENTS FROM ENGLISH RIVER SUBPROVINCE BASED UPON 132 ANALYSES IN THIS STUDY

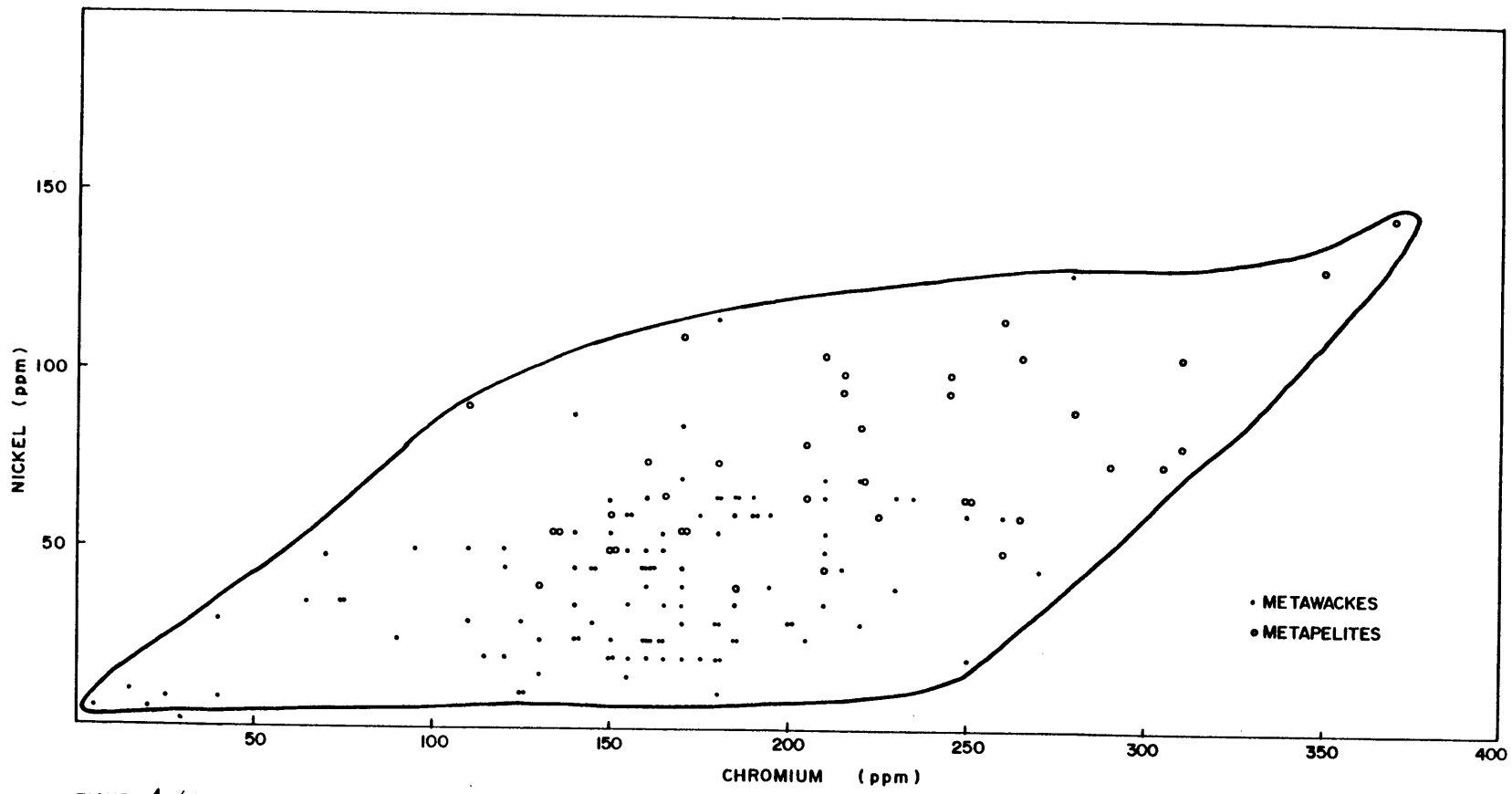


FIGURE 4-[illegible], Ni vs. Cr VARIATION IN METASEDIMENTS FROM ENGLISH RIVER SUBPROVINCE

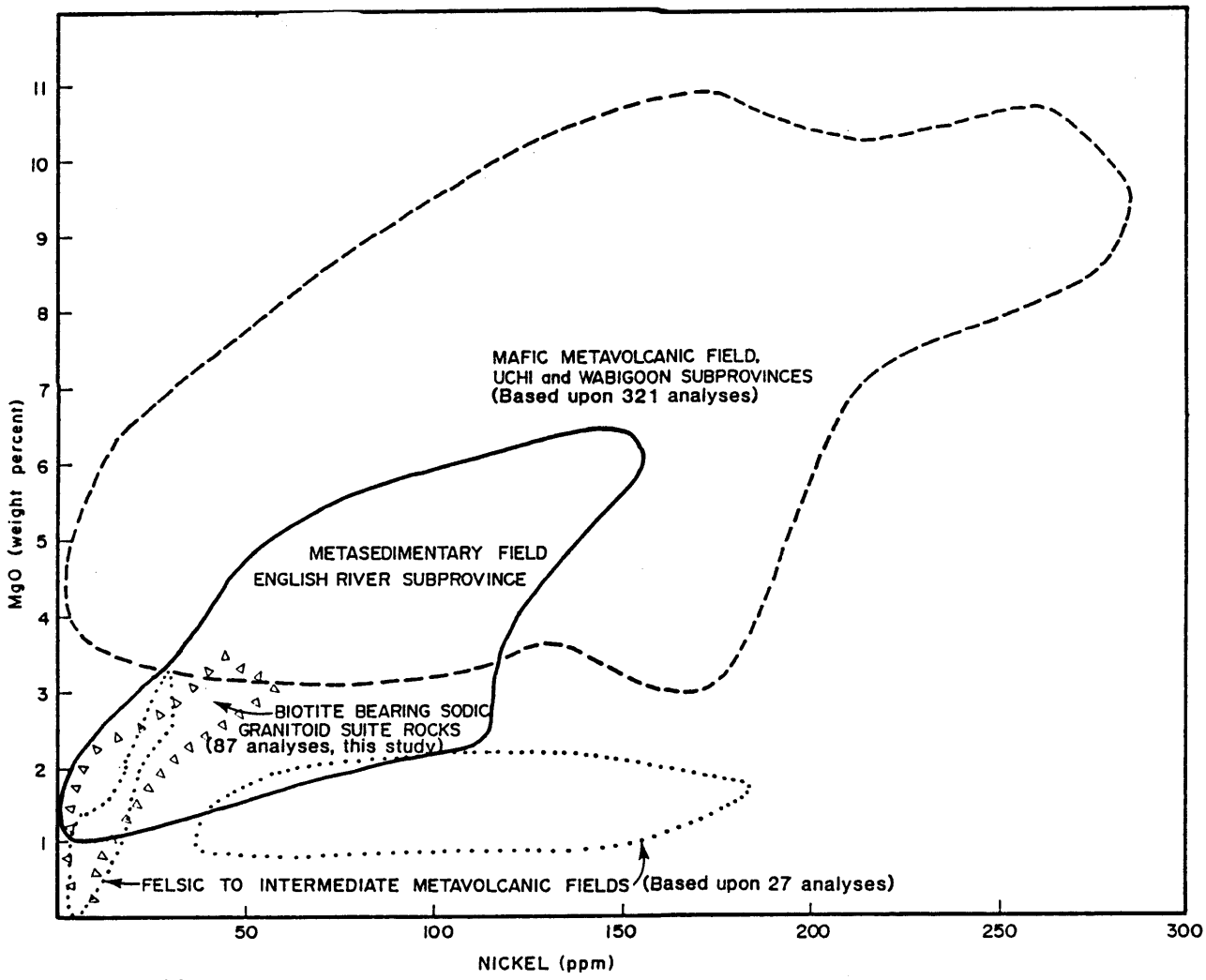


FIGURE 4·32: MgO-NI DIAGRAM DEPICTING RELATIONSHIP OF ENGLISH RIVER SUBPROVINCE METASEDIMENTARY FIELD WITH COMMON SPATIALLY ASSOCIATED LITHIC GROUPS

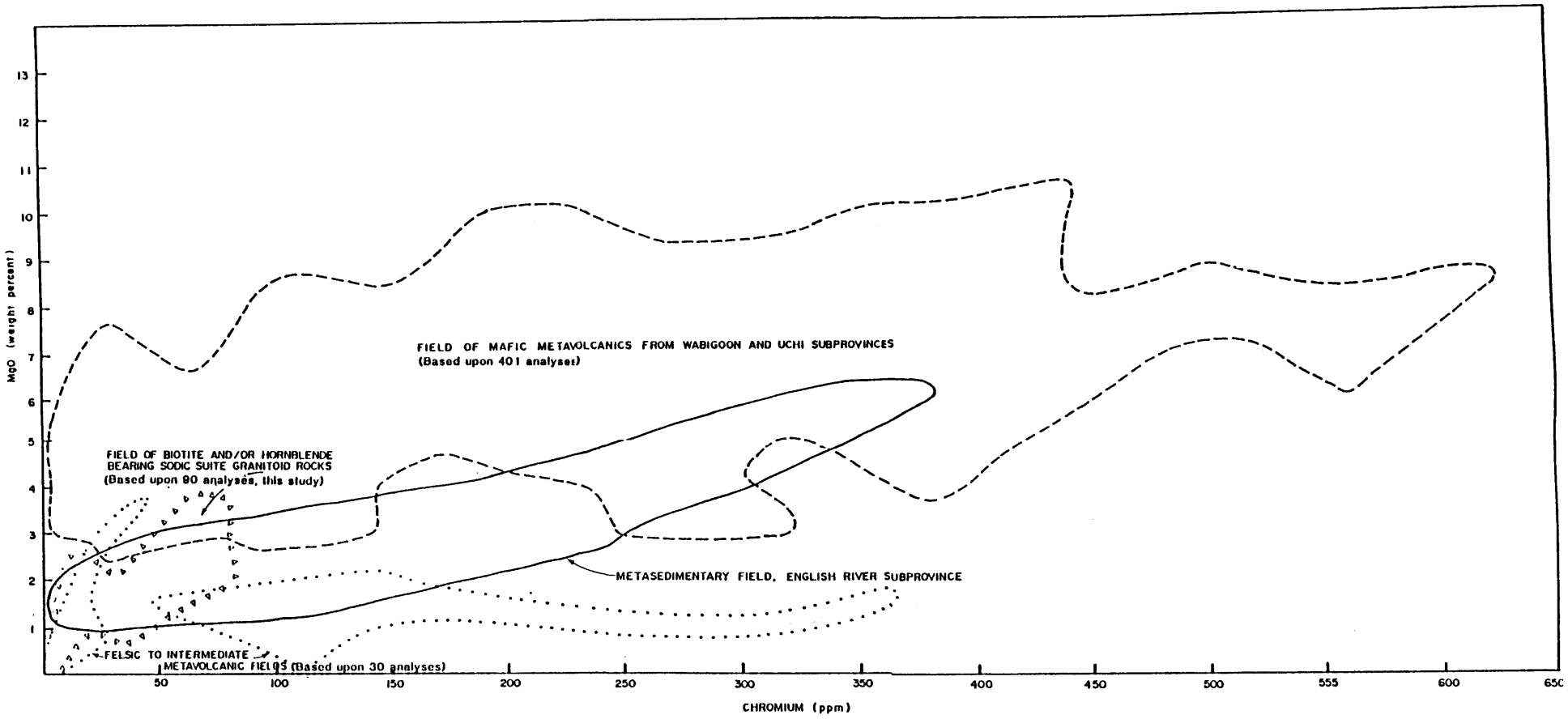


FIGURE MgO-Cr DIAGRAM DEPICTING RELATIONSHIP OF ENGLISH RIVER SUBPROVINCE METASEDIMENTARY FIELD WITH COMMON SPATIALLY ASSOCIATED LITHIC GROUPS

4-33

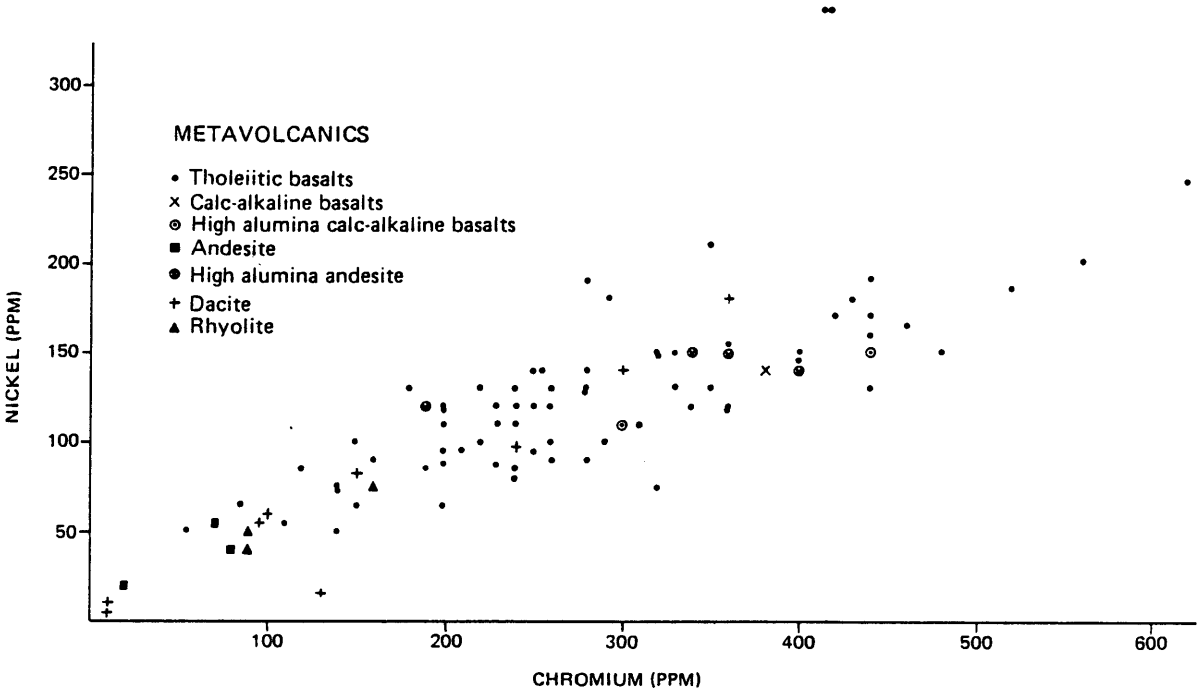


Fig. 4·34 Chromium-nickel variation in metavolcanics from Uchi and Wabigoon Subprovinces.

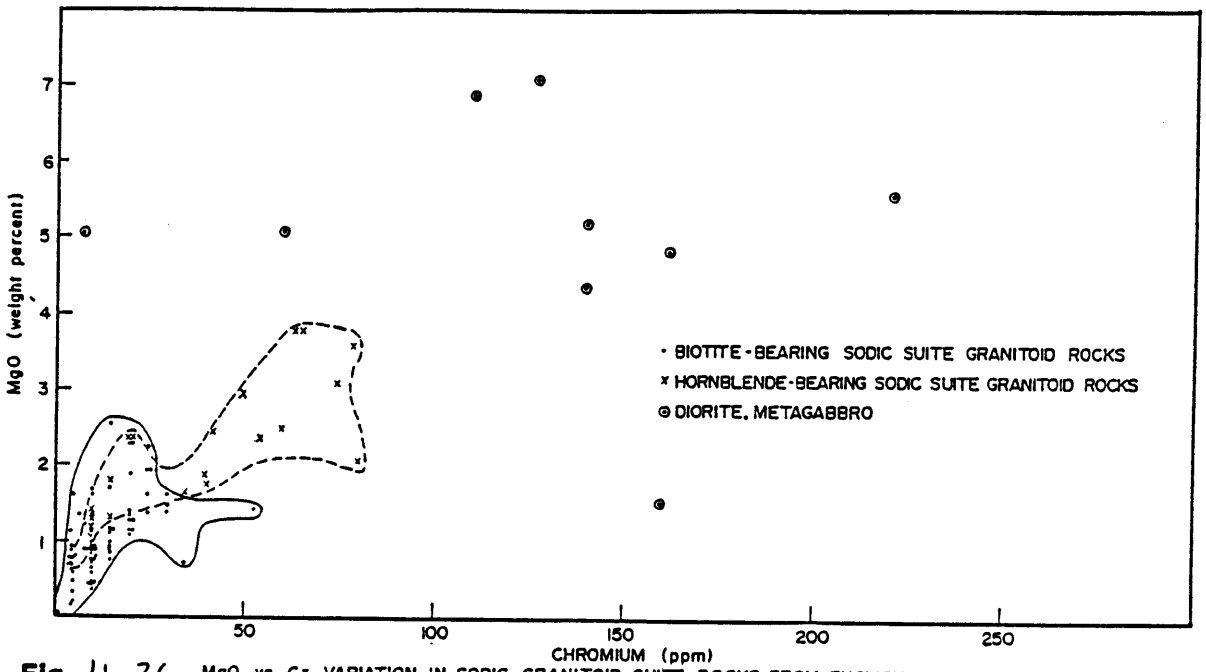


Fig. 4-36 MgO vs. Cr VARIATION IN SODIC GRANITOID SUITE ROCKS FROM ENGLISH RIVER SUBPROVINCE

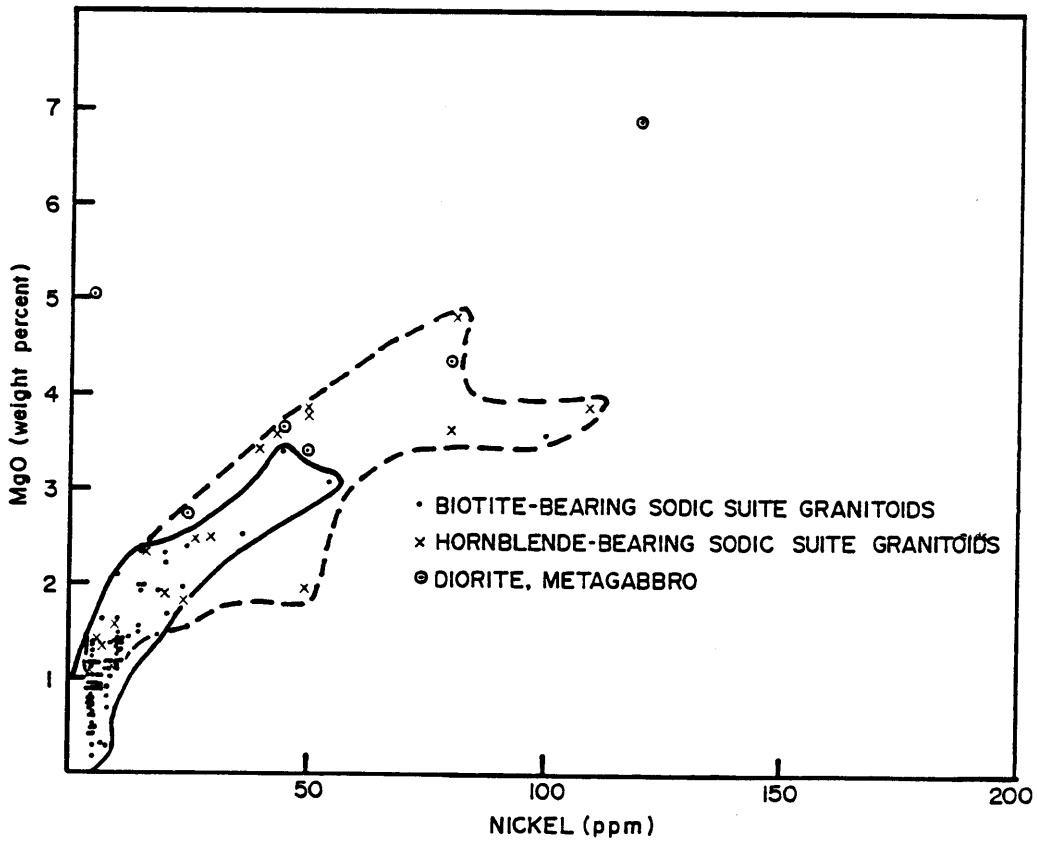


FIGURE 4-35 MgO vs. NI VARIATION IN SODIC SUITE GRANITOID ROCKS FROM ENGLISH RIVER SUBPROVINCE

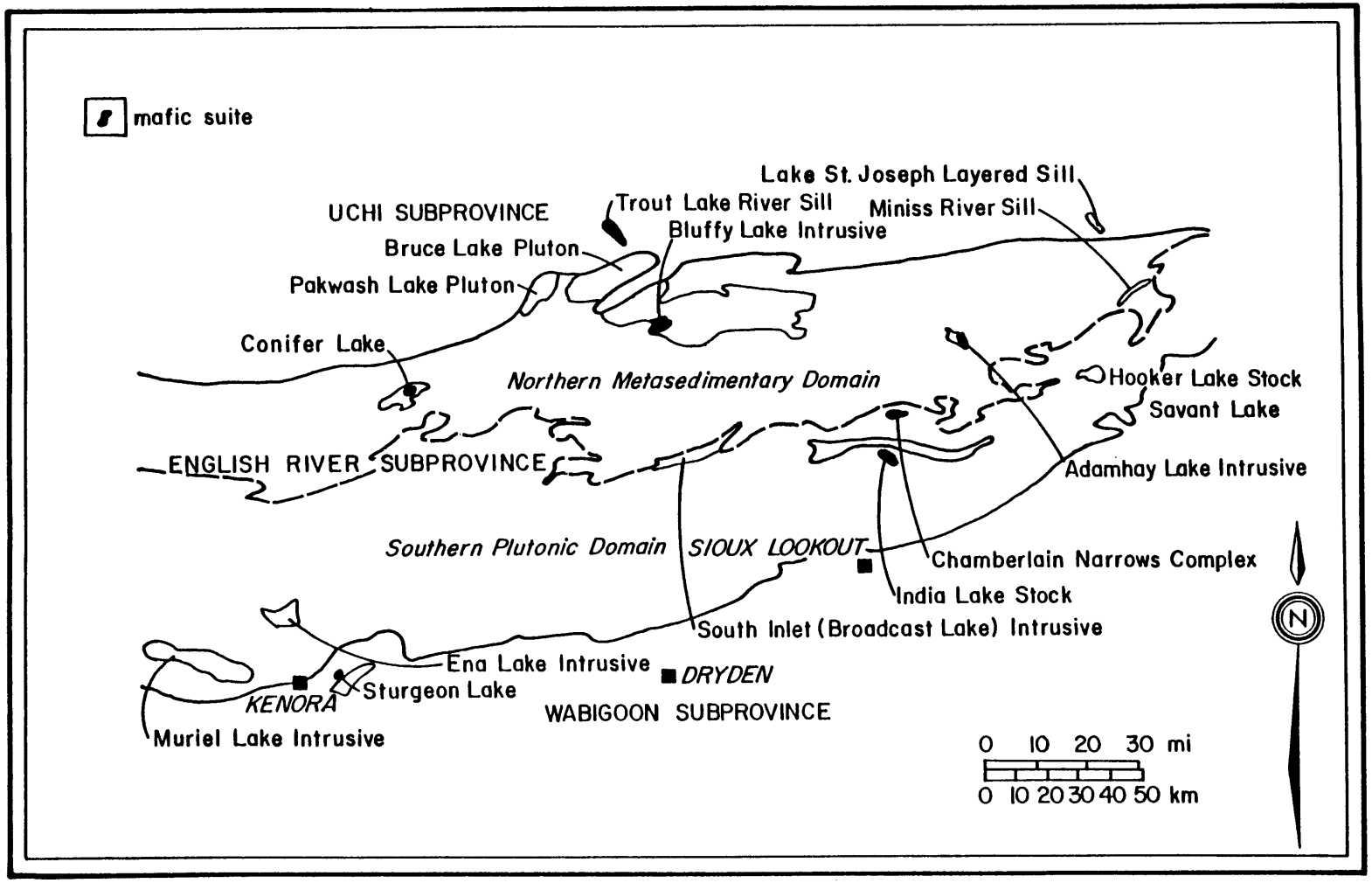


Figure 6-1 : English River Northern and Southern Domains showing the location of intrusives of the mafic suite.

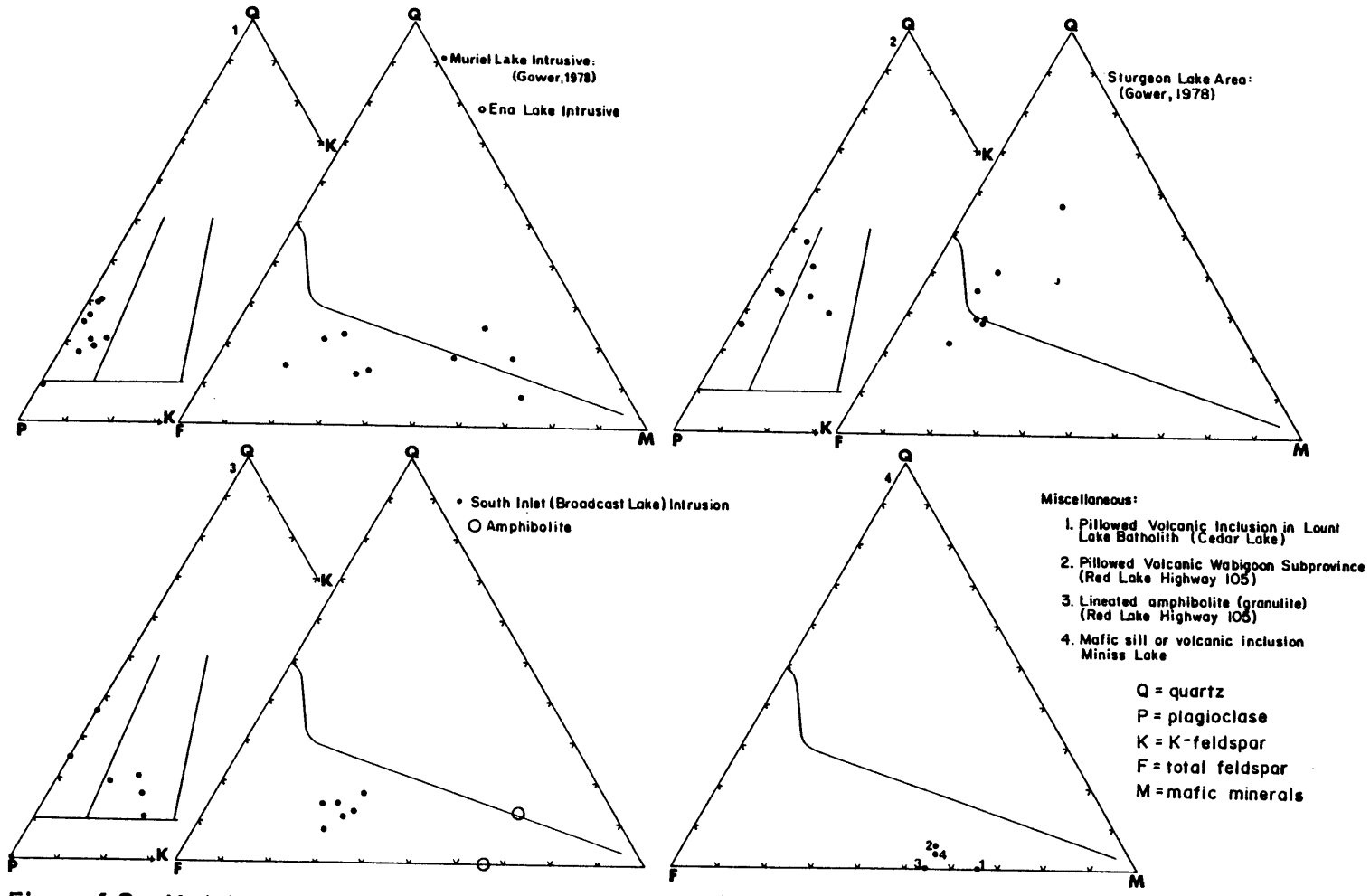
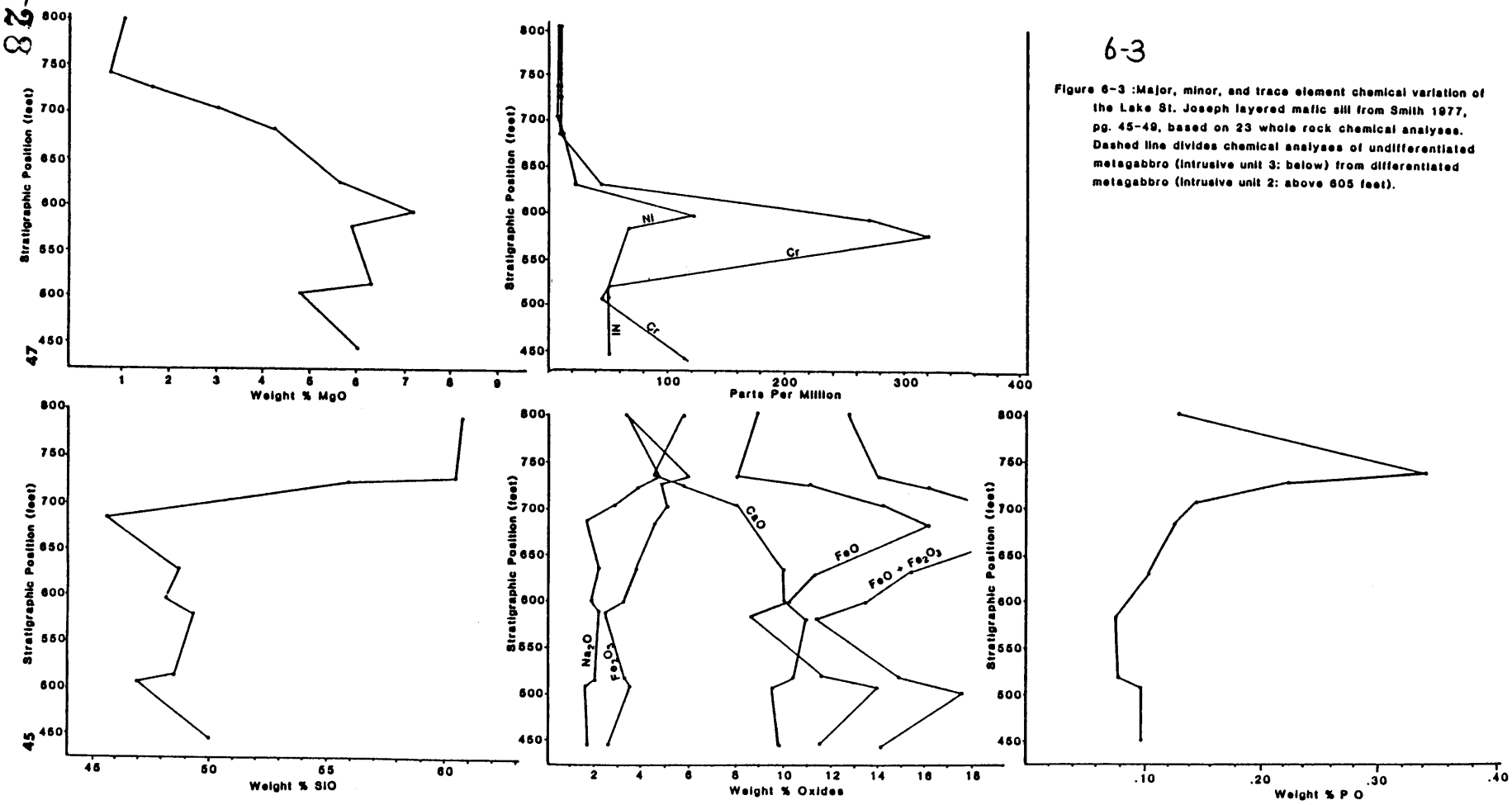


Figure 6-2 : Modal analyses of various members of the mafic suite. Plot of pillowed mafic volcanics (diagram 4, no's 1,2) given for comparison.



6-3

Figure 6-3 :Major, minor, and trace element chemical variation of the Lake St. Joseph layered mafic sill from Smith 1977, pg. 45-49, based on 23 whole rock chemical analyses. Dashed line divides chemical analyses of undifferentiated metagabbro (intrusive unit 3: below) from differentiated metagabbro (intrusive unit 2: above 605 feet).

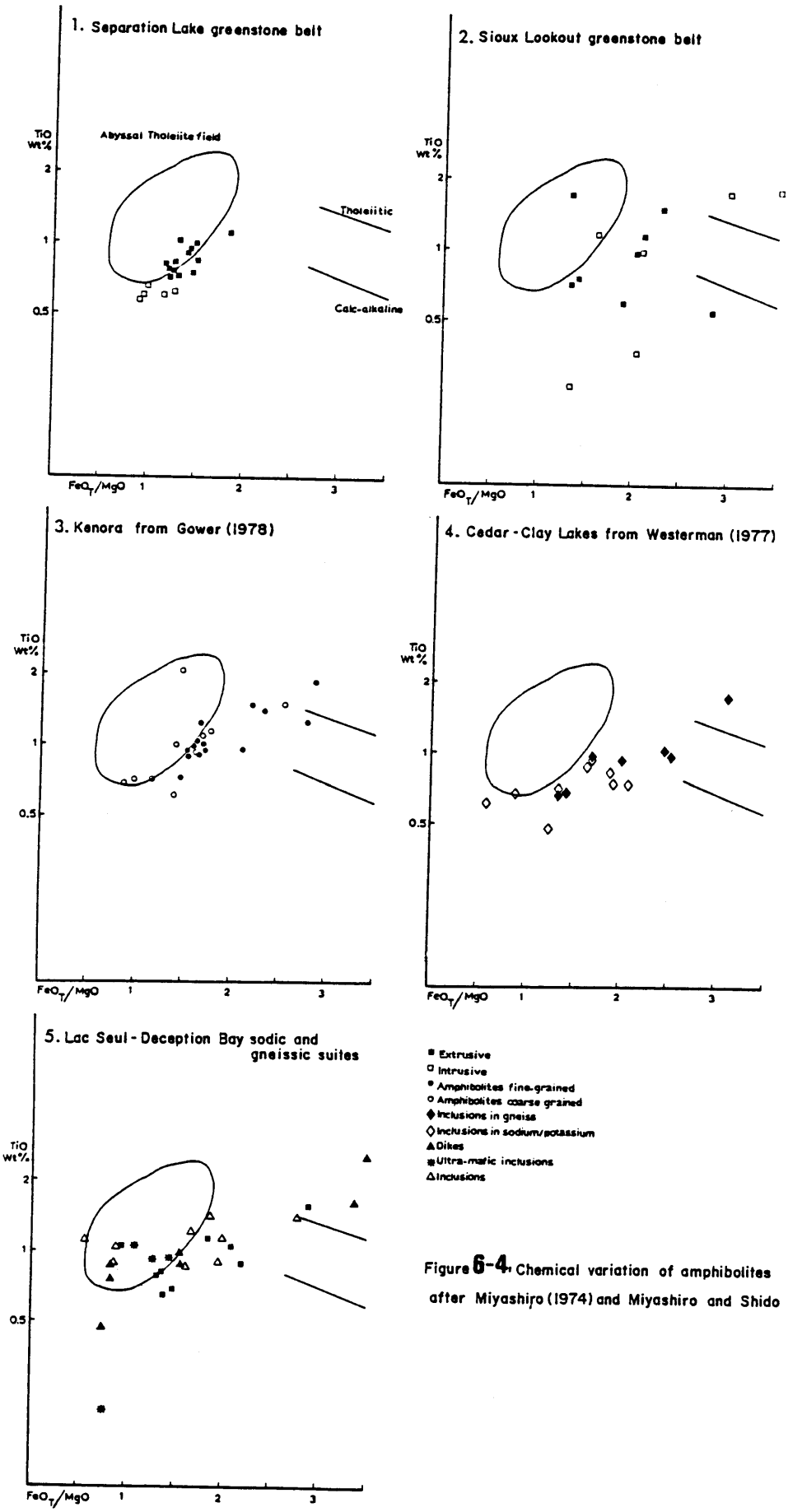


Figure 6-4. Chemical variation of amphibolites after Miyashiro (1974) and Miyashiro and Shido (1975

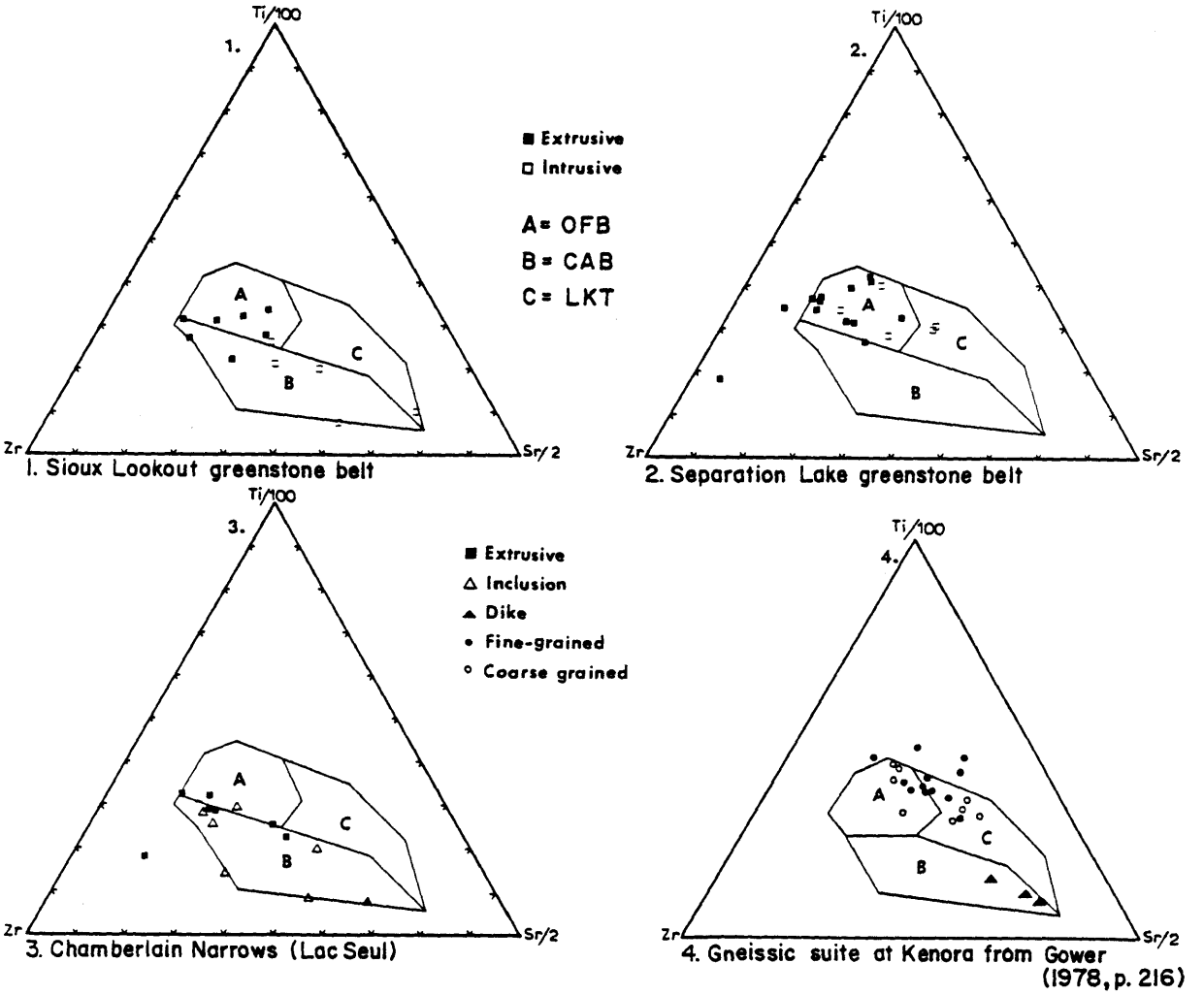


Figure 6-5: Chemical variation of extrusive and intrusive amphibolites (after Pearce and Cann, 1973). OFB = Ocean basalts; CAB = calc-alkaline basalts LKT = Low K-tholeiite

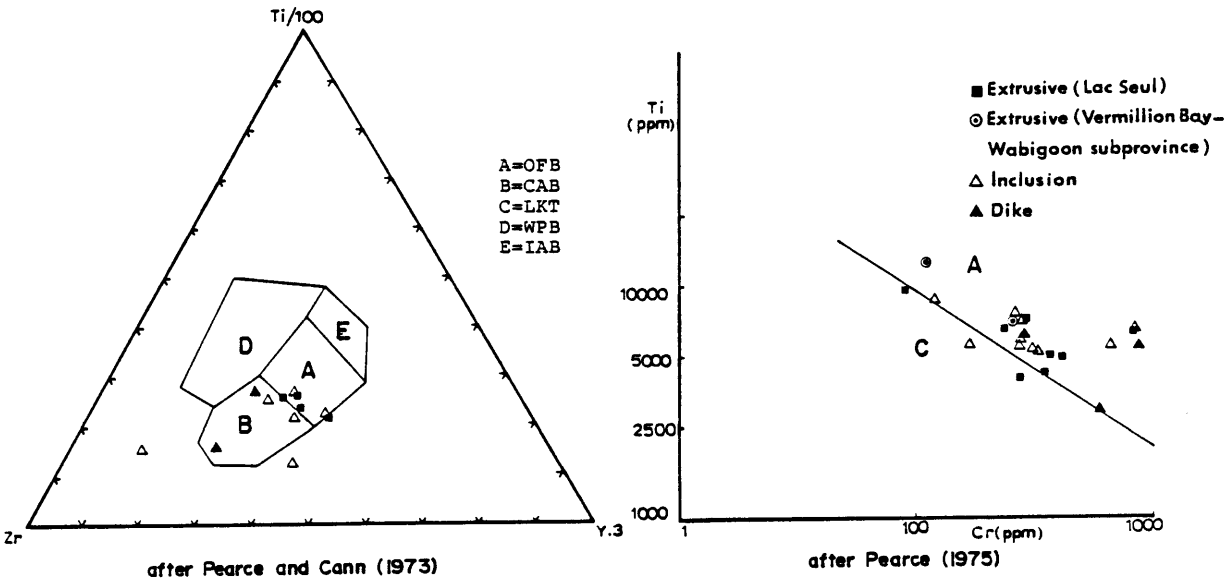


Figure 6-7: Chemical variation of amphibolites in English River Subprovince.

OFB = Ocean Floor Basalt; CAB = Calc-Alkaline Basalt;
LKT = Low K-tholeiite (Island Arc Environment);
WPB = Within Plate Basalts; IAB = Island Arc Basalts

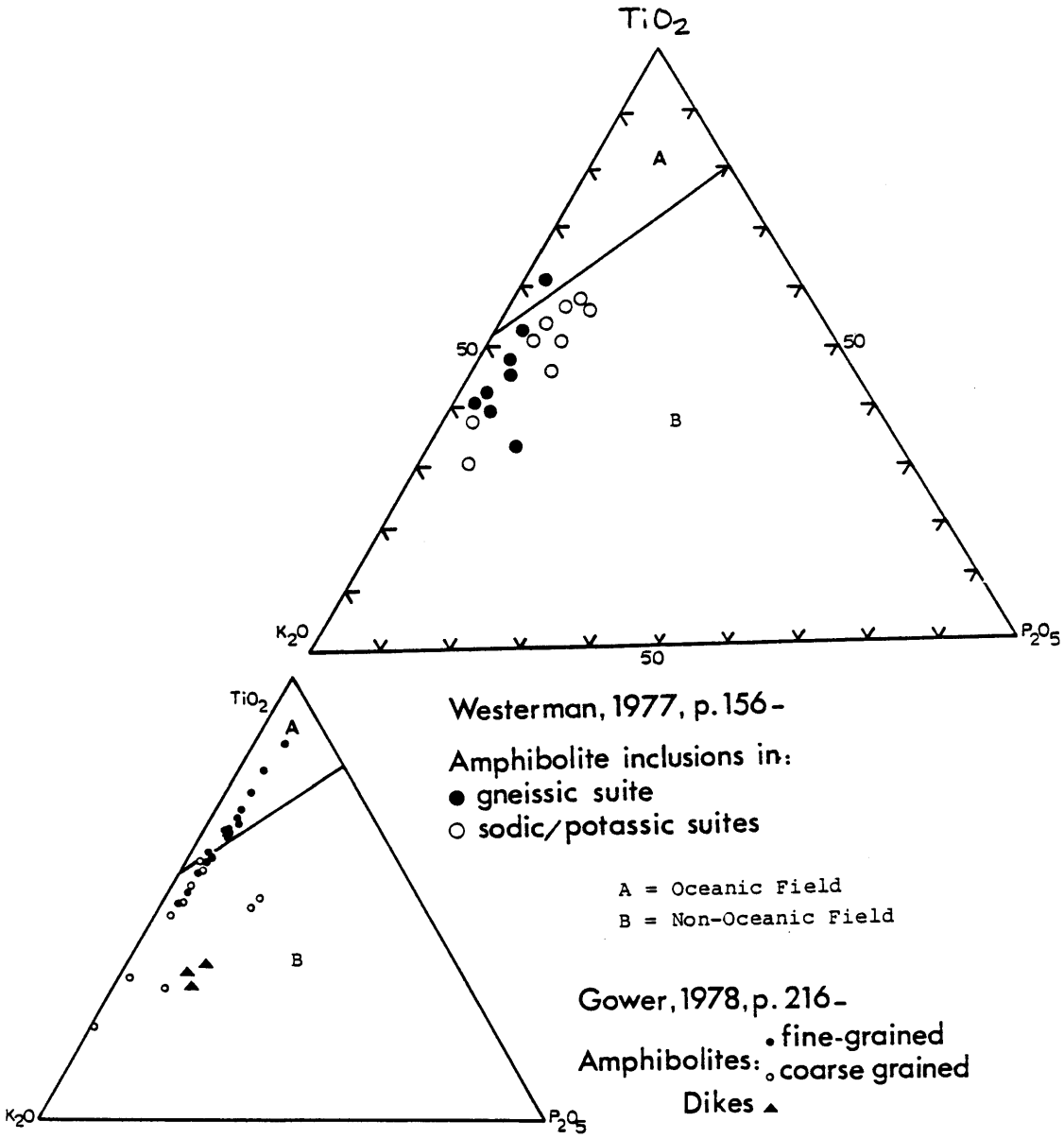


Figure 6-8 : Chemical variation of amphibolites in gneissic suite at Kenora and Cedar Lake (after Pearce et al, 1975)

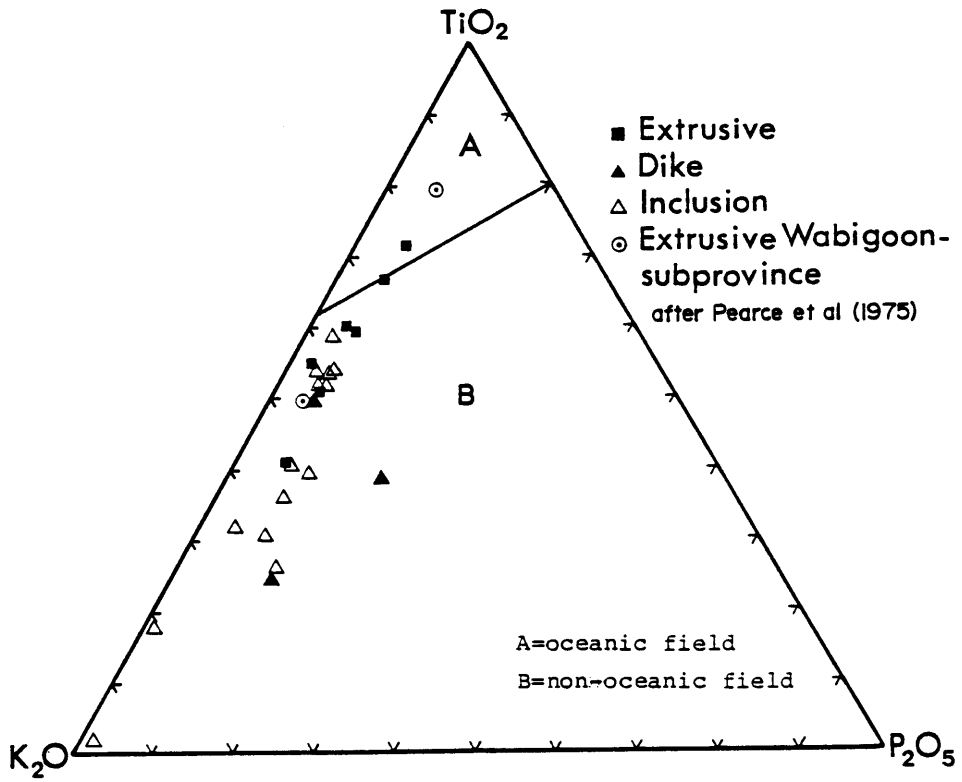


Figure 6-9 : Amphibolites in the Chamberlain Narrows (Lac Seul) area.

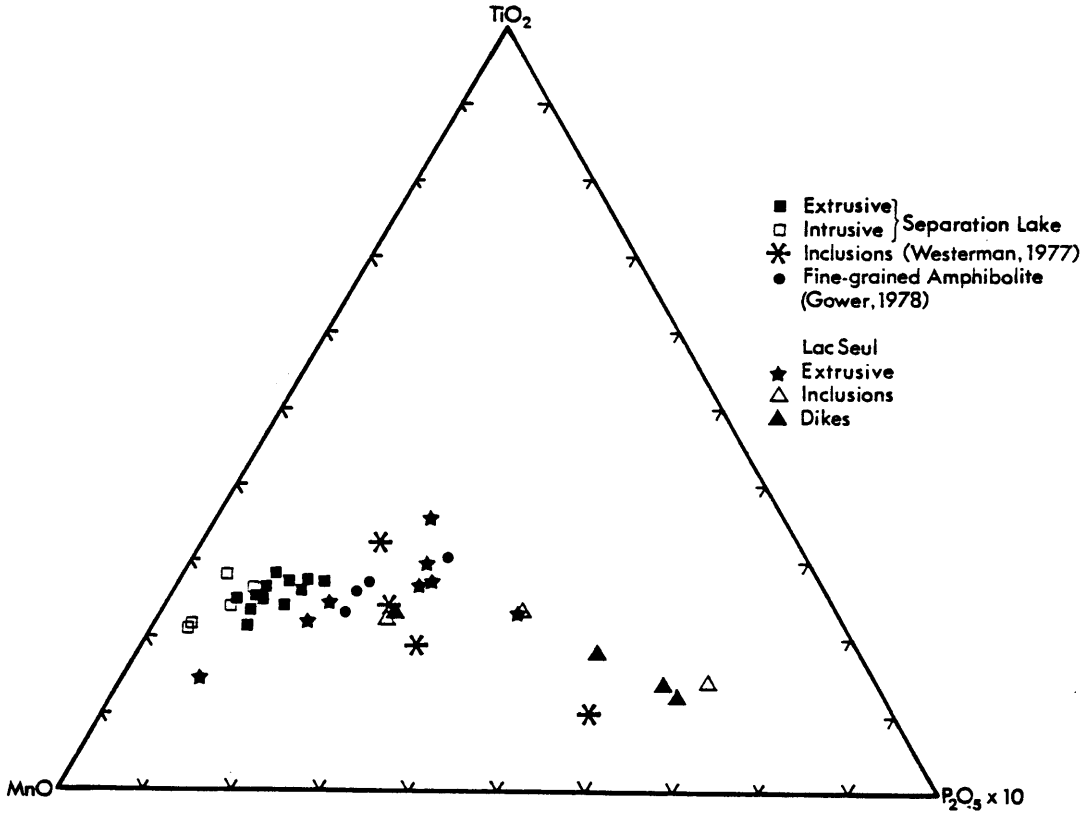


Figure 6-10: Chemical variation of intrusive and extrusive amphibolites.

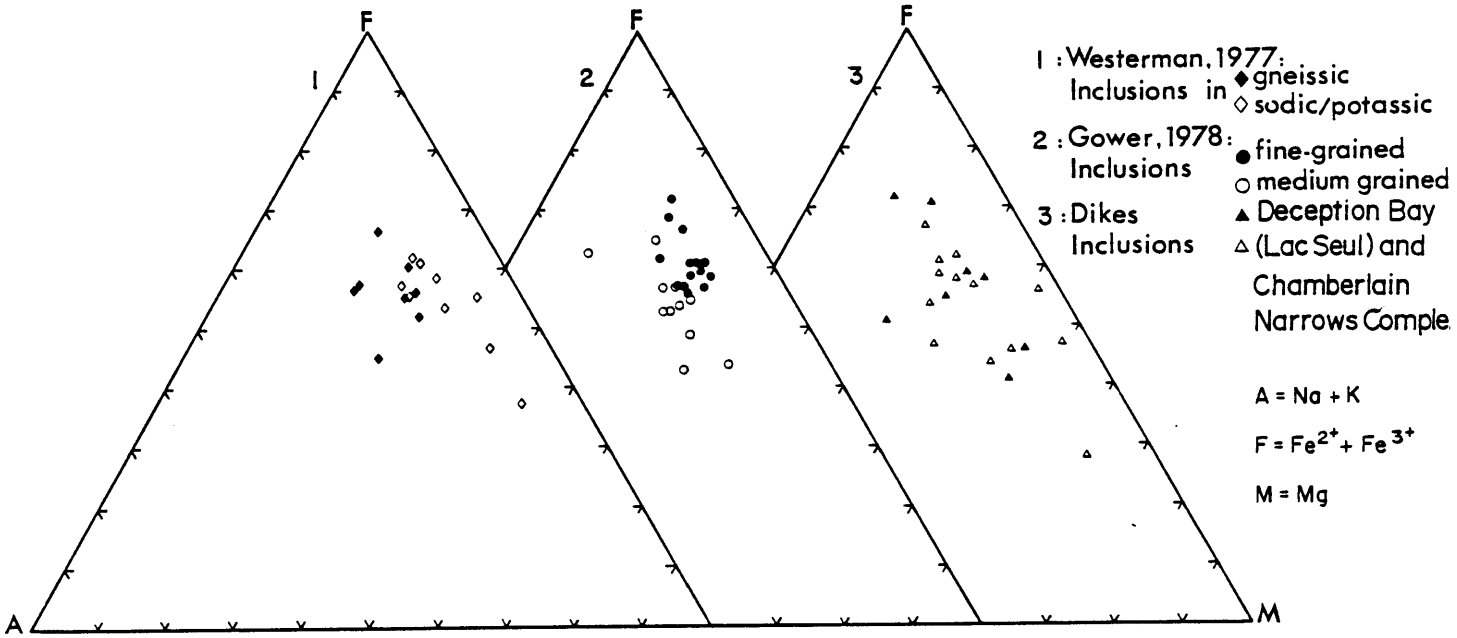


Figure 6-11: AFM (element wt%) plots) of amphibolites

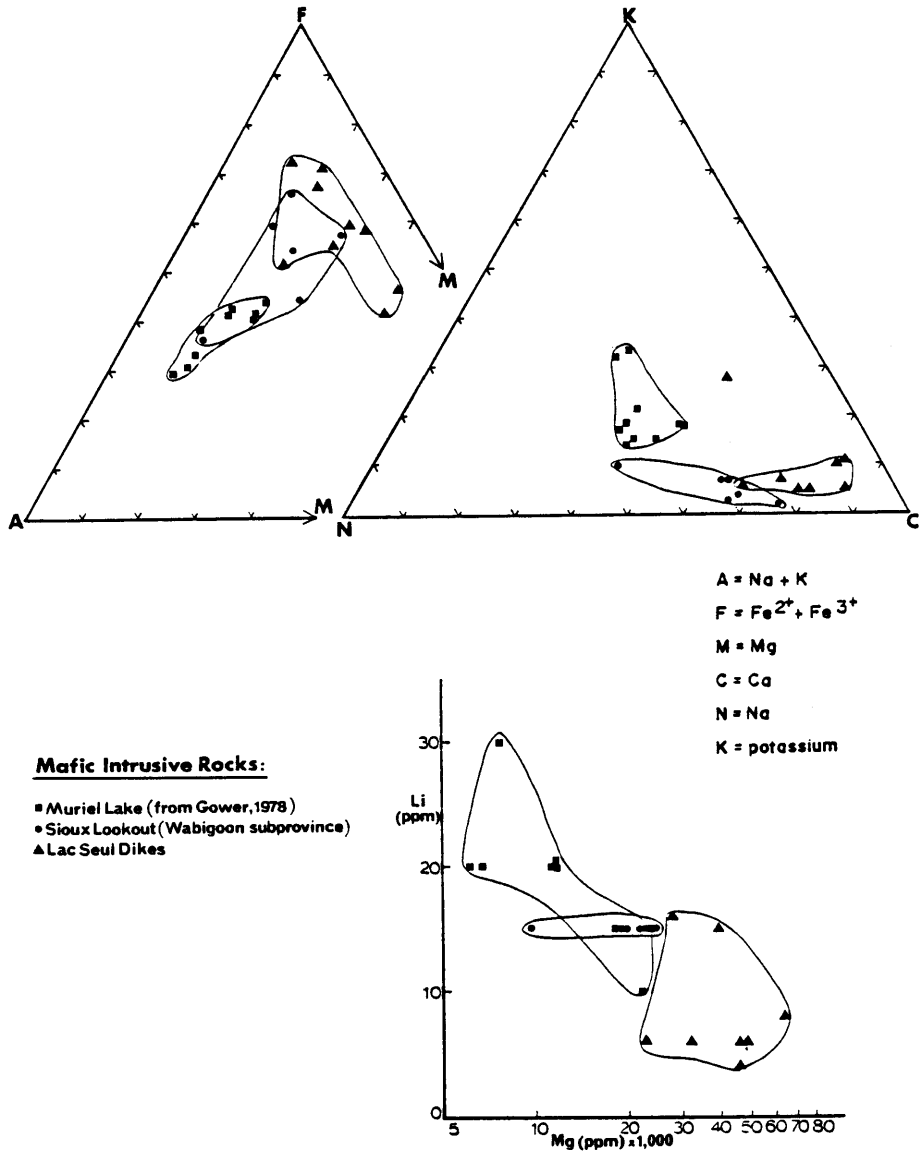


Figure 6-12: Chemical variation (AFM wt %; CNK-element wt %) of mafic intrusive plutons and mafic dikes in Gneissic Suite. AFM - A = Na_2O + K_2O; F = FeO + CNK - C = ca, N = Na, K = potassium.

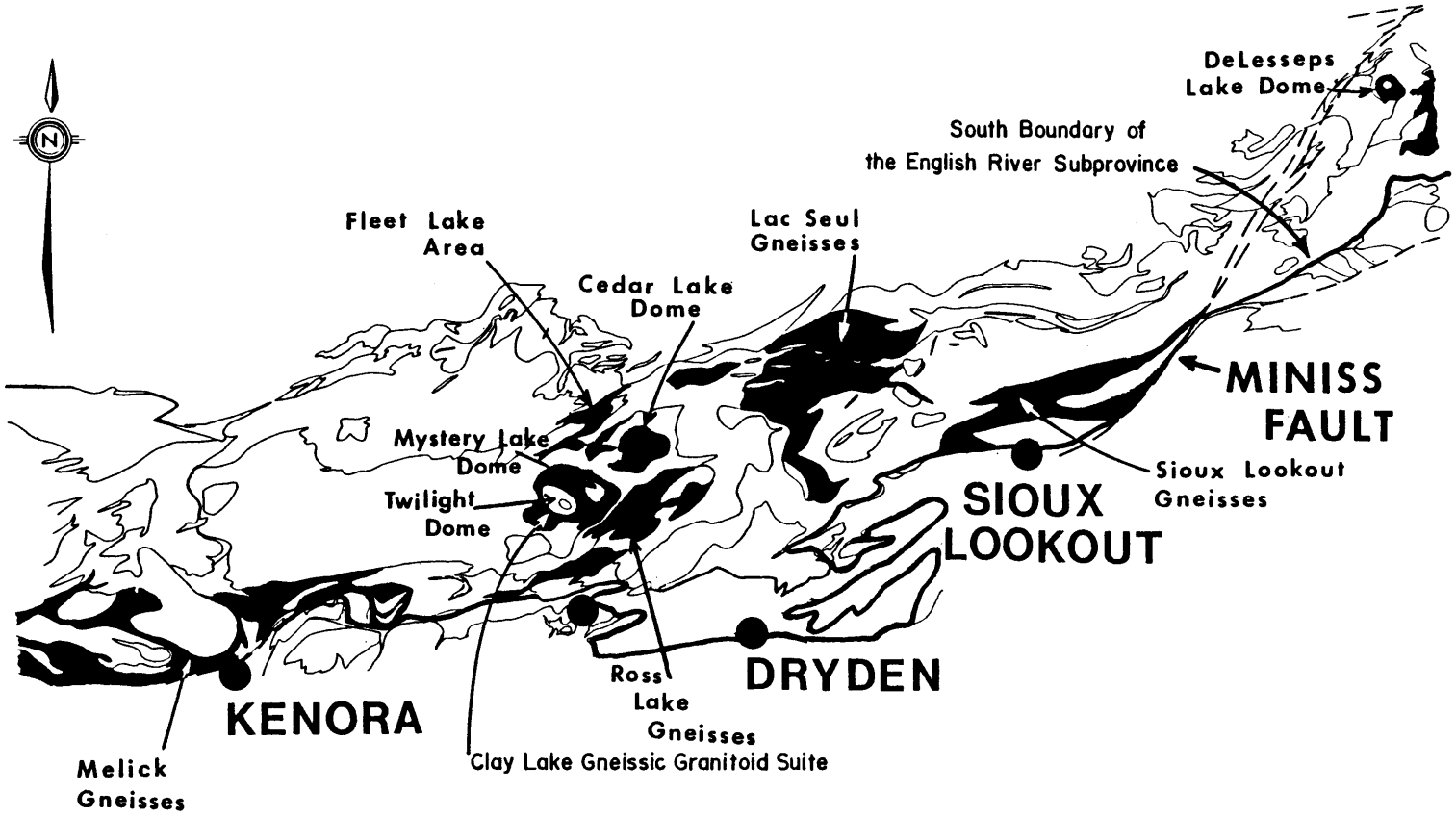


Figure 7-1: English River Southern Plutonic Domain showing distribution of Gneissic Suite. Heavy line marks the southern limit of the English River Subprovince.

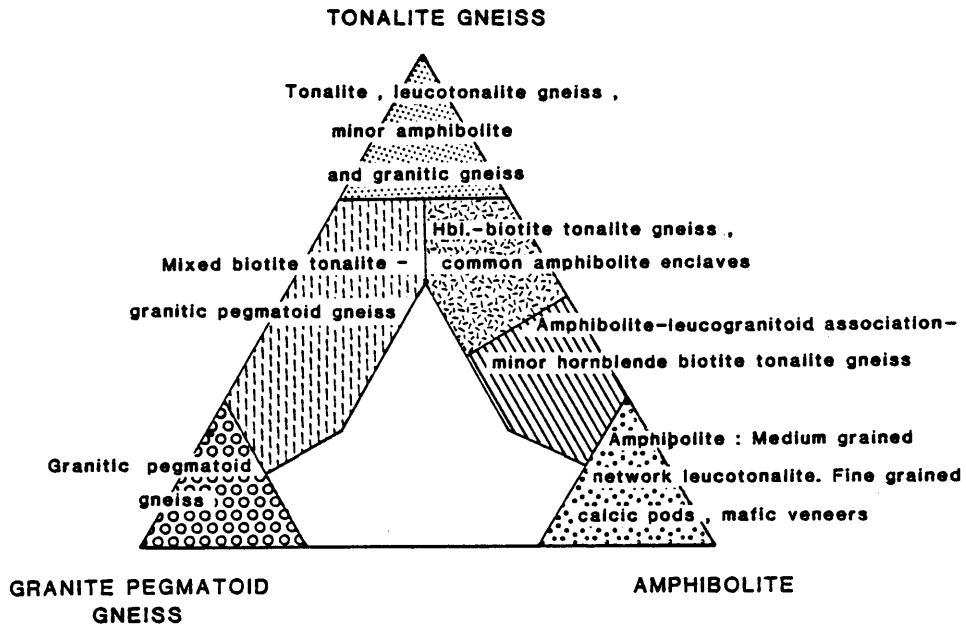


Figure 7-2: Classification of gneissic rocks in the Kenora Area from Gower (1978, p.84).

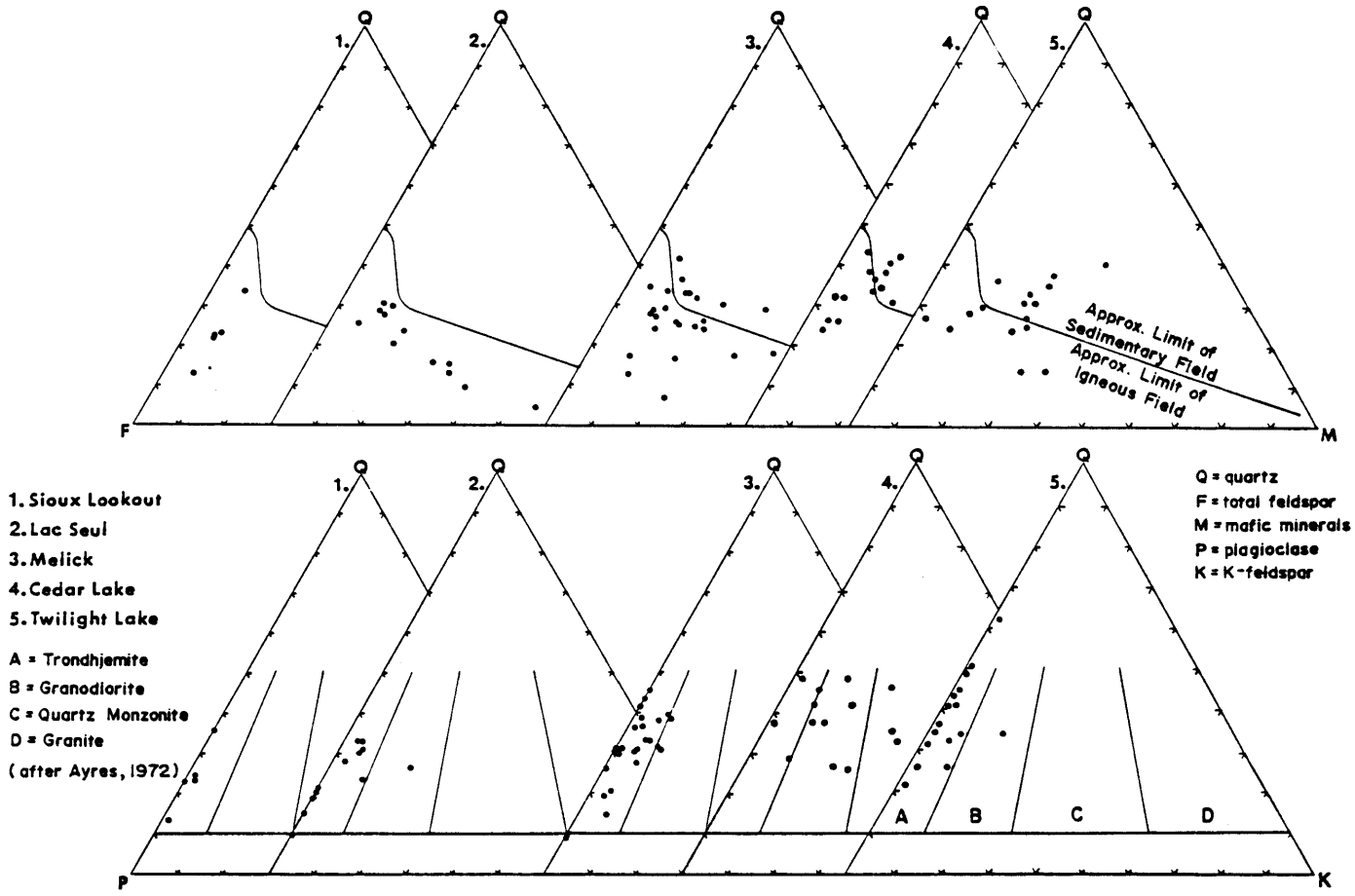


Figure 7-3: Modal analyses (QFM and QPK) of the gneissic suite from the Sioux Lookout, Lac Seul, Melick Gneiss (Gower, 1978), Cedar Lake Gneiss (Westerman, 1977) and Twilight Gneiss (Westerman, 1977).

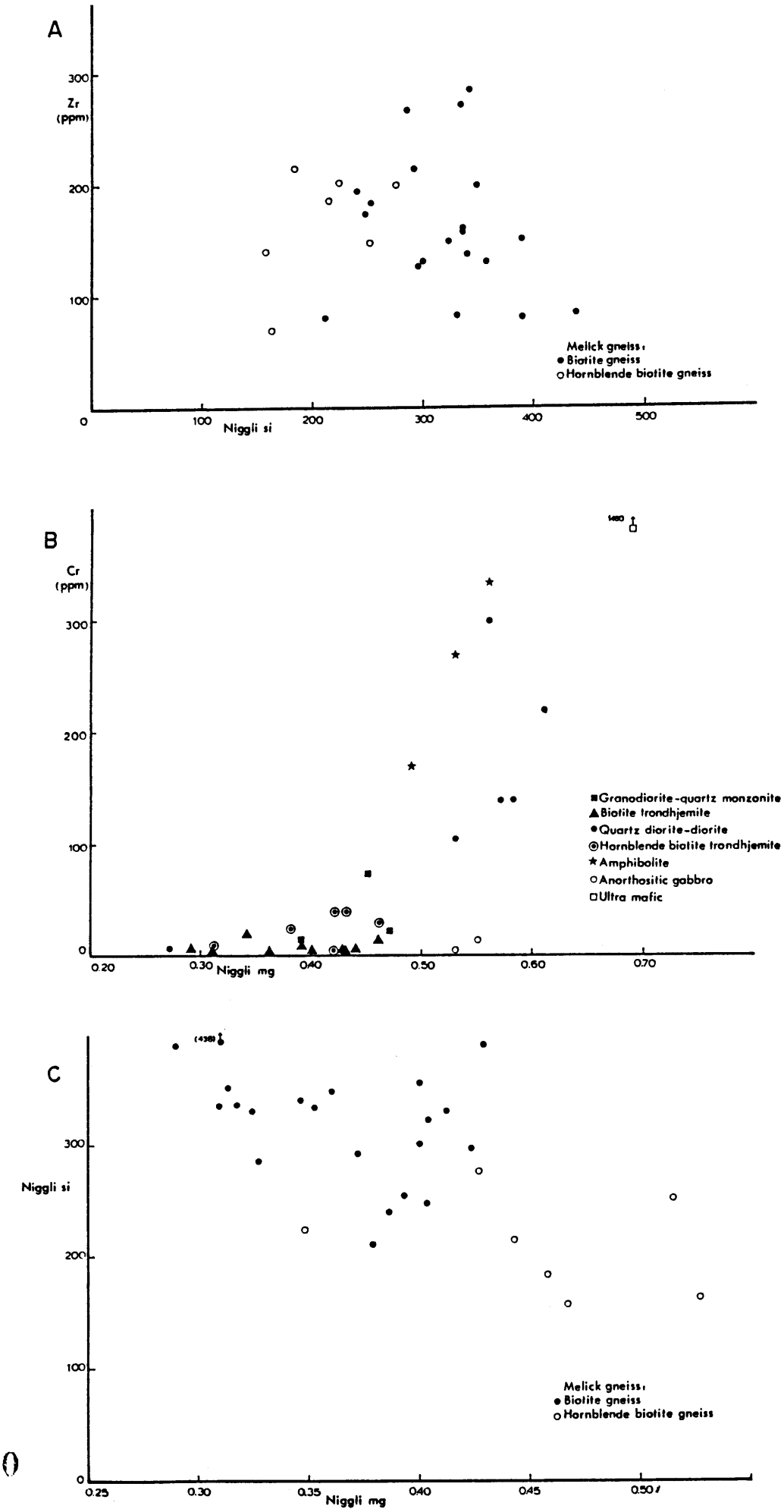


Figure 7-4 Sedimentary/Igneous discrimination function analyses (after Shaw, 1972) from the gneissic suite: A,C-Melick Gneiss at

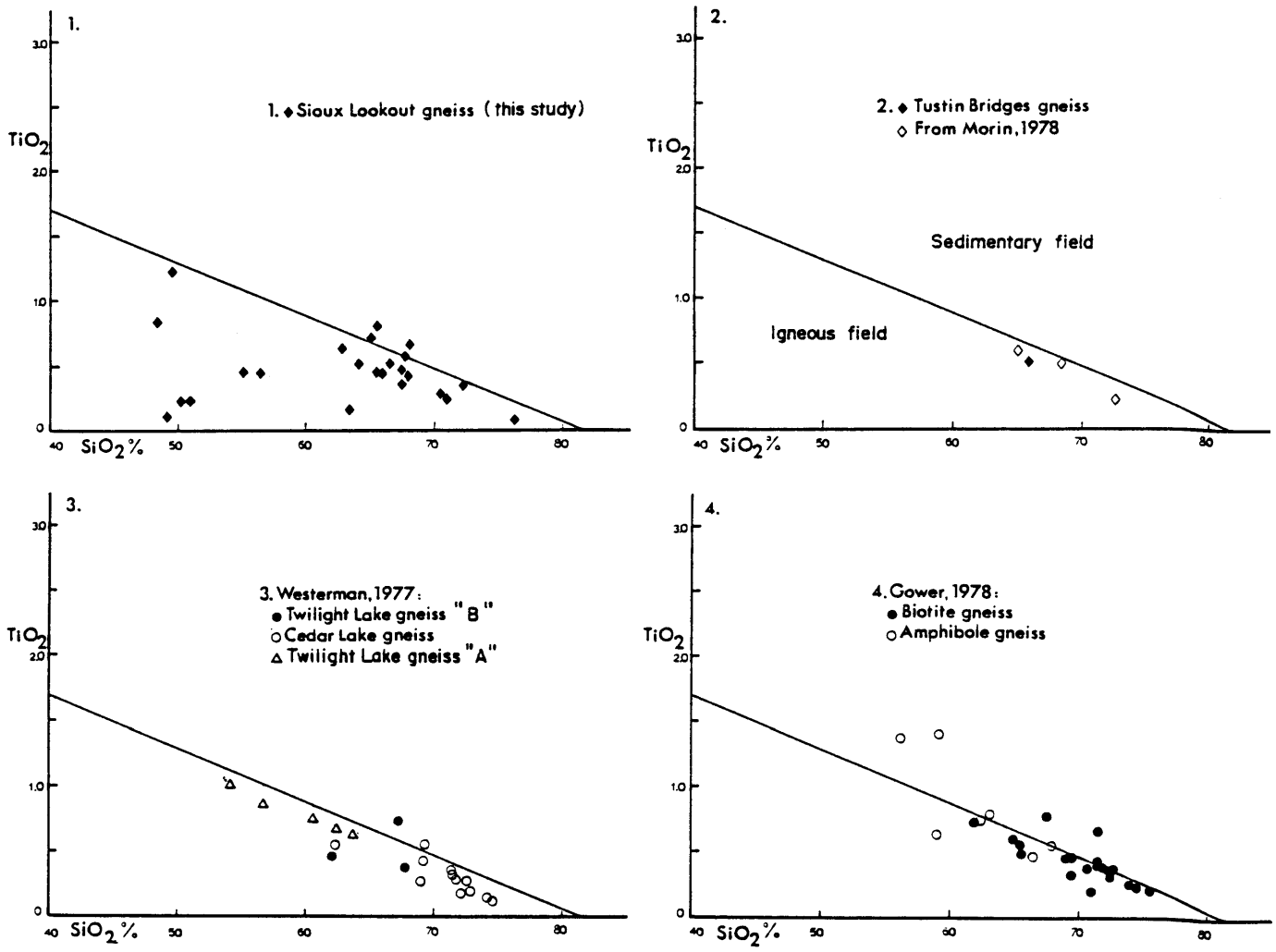


Figure 7-5: Igneous/Sedimentary Discrimination diagram TiO_2 vs SiO_2 after Tarney et al. (1976).

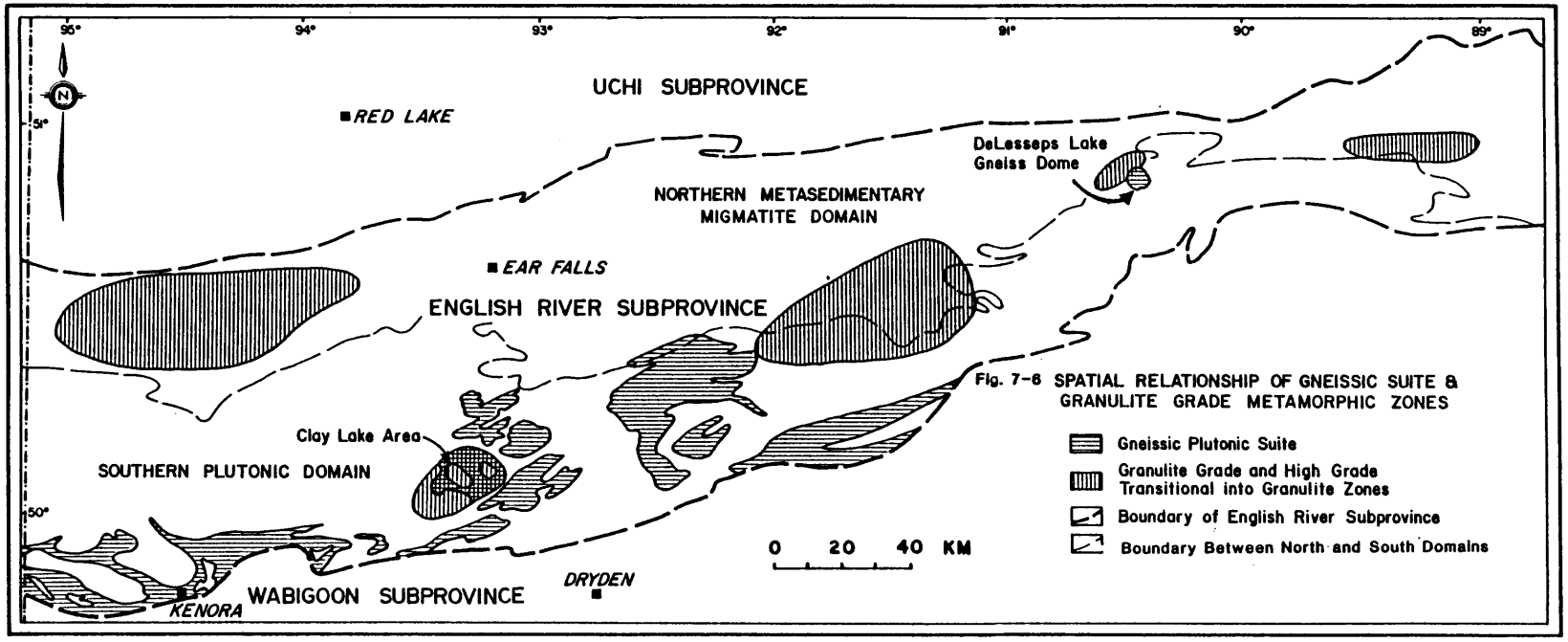


Fig. 7-6 SPATIAL RELATIONSHIP OF GNEISSIC SUITE & GRANULITE GRADE METAMORPHIC ZONES

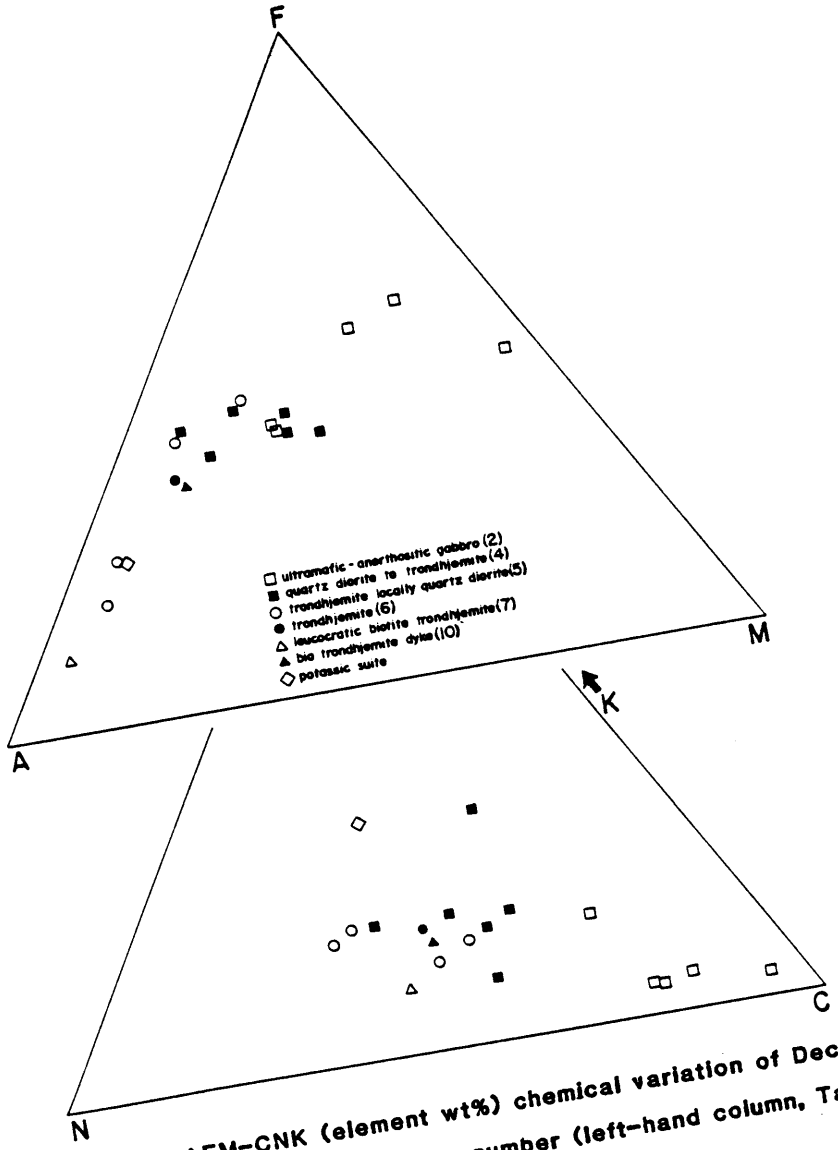
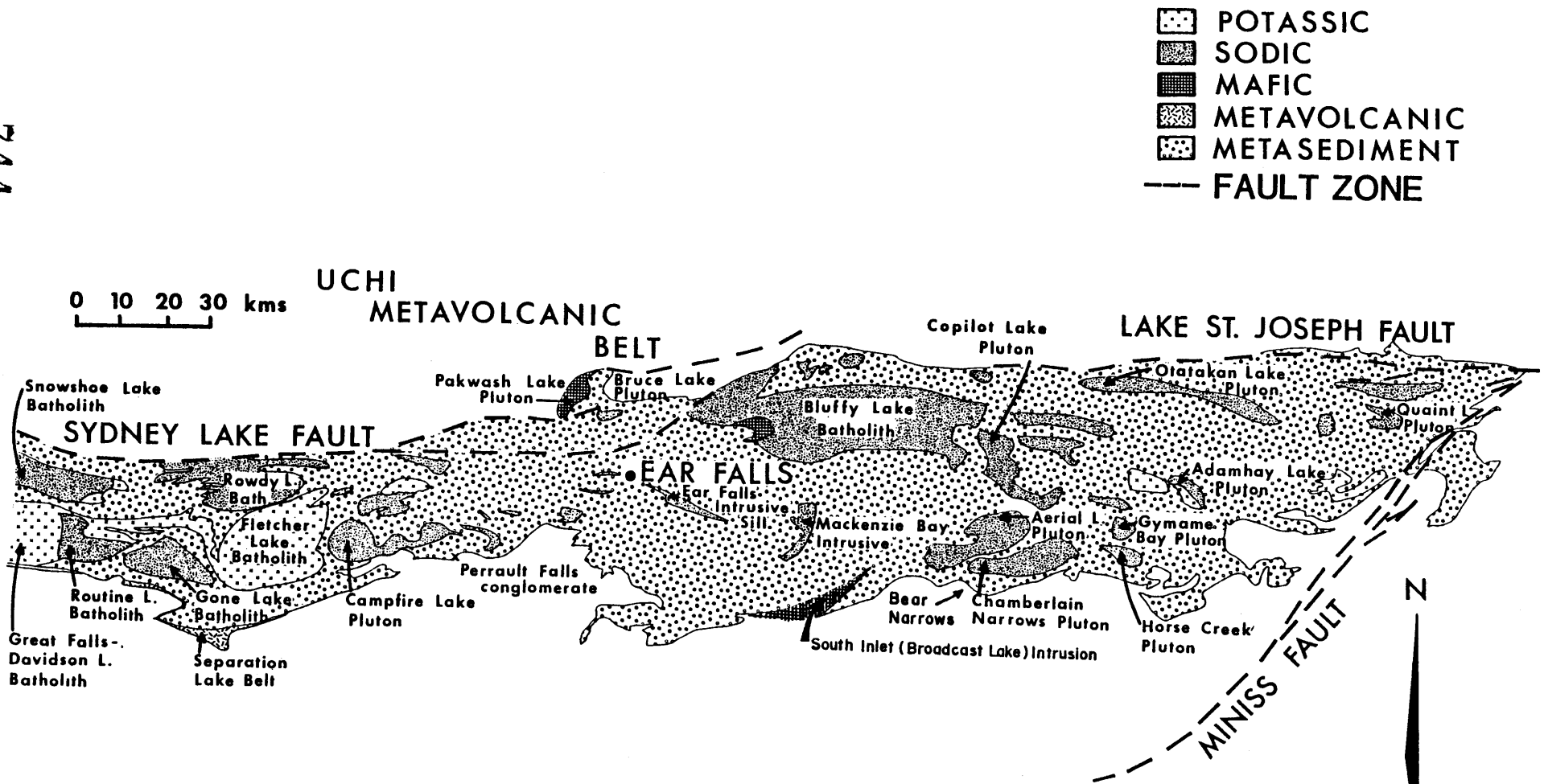


Figure 7-7 AFM-CNK (element wt%) chemical variation of Deception Bay (Lac Seul). Lithology number (left-hand column, Table 7-6) indicates relative age of intrusion.



ENGLISH RIVER NORTHERN DOMAIN

FIGURE 8-1A : NORTHERN METASEDIMENTARY DOMAIN SHOWING LOCATION OF INDIVIDUAL SODIC AND POTASSIC STOCKS / BATHOLITHS

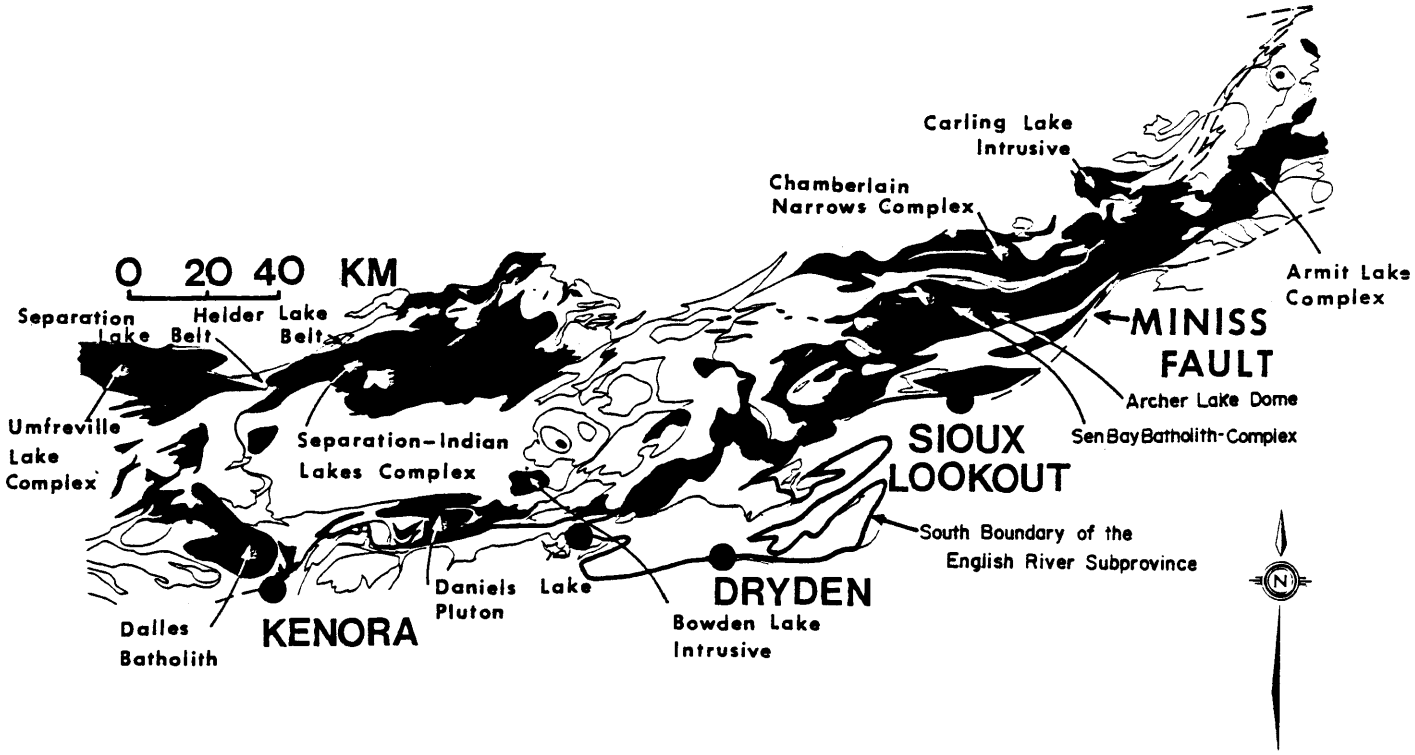


Figure 8-~~1~~2: English River Southern Plutonic Domain showing distribution of Sodic Suite.

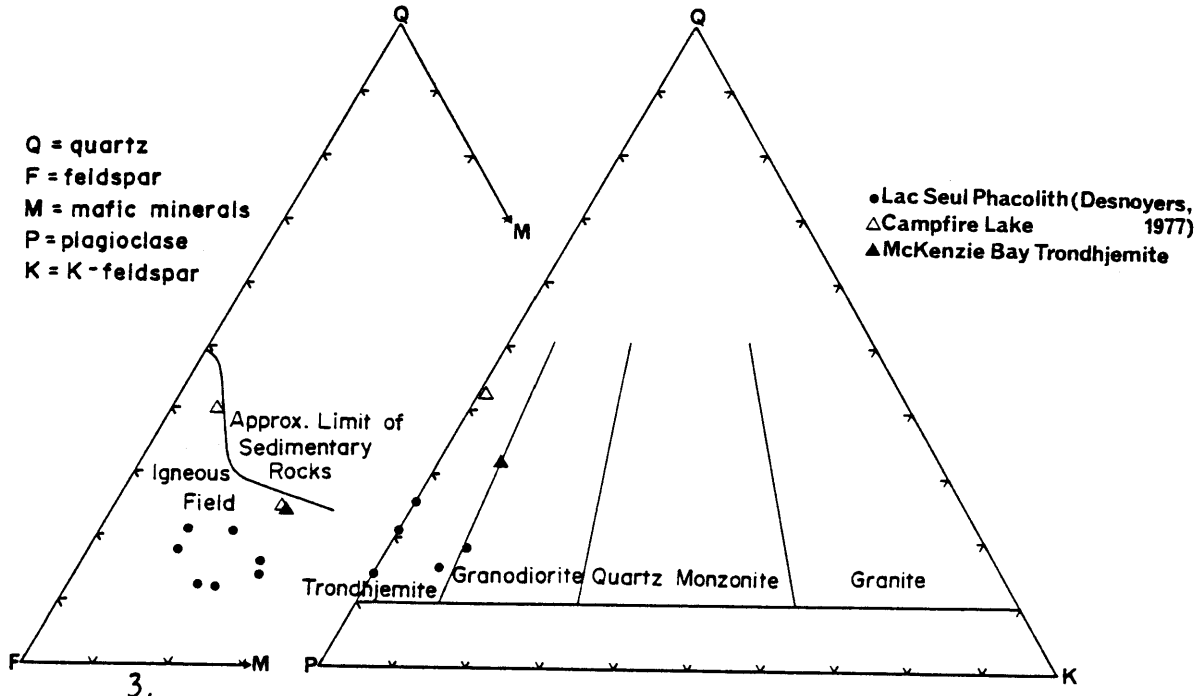


Figure 8-2 : Modal variation of specific sodic suite plutons in the Northern Metasedimentary Domain(after Ayres,1972).

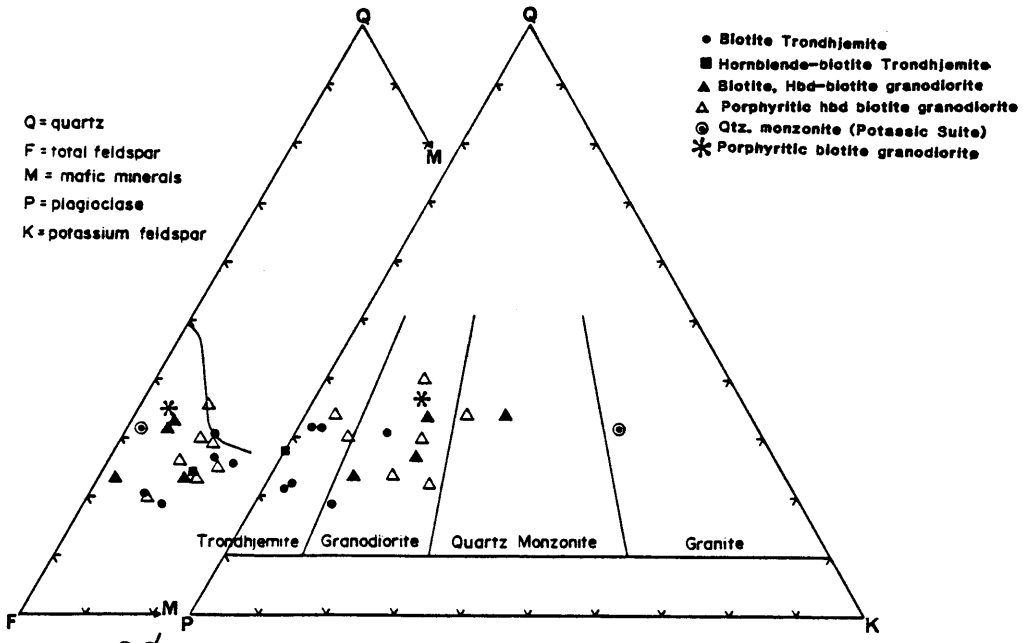


Figure 8-3: Modal variation of the Separation-Indian Lakes Complex (Sodic Suite) after Ayres (1972).

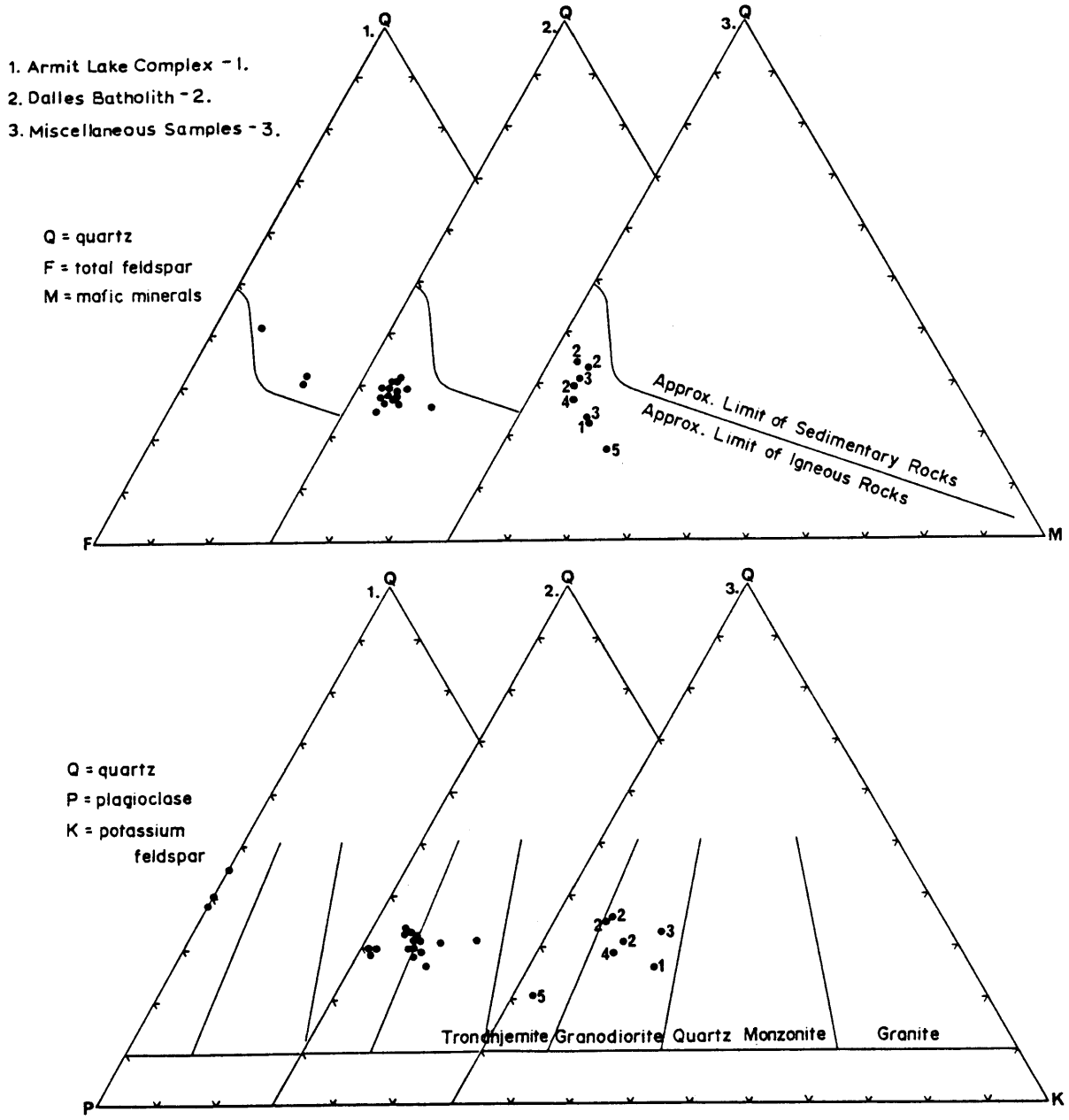


Figure 8-5 : Modal variation of the Armit Lake Complex (Diagram 1), Dalles Batholith (Diagram 2) from Gower (1978), and Miscellaneous (Diagram 3) as follows:

1. Bowden Lake pluton
2. Daniels Lake pluton
3. Tustin-Bridges porphyritic granodiorite
4. Tustin-Bridges leucocratic trondhjemite
5. Sodic Suite general from Red Lake road just north of English River-Wabigon subprovince boundary.

(Classification after Ayres (1972).

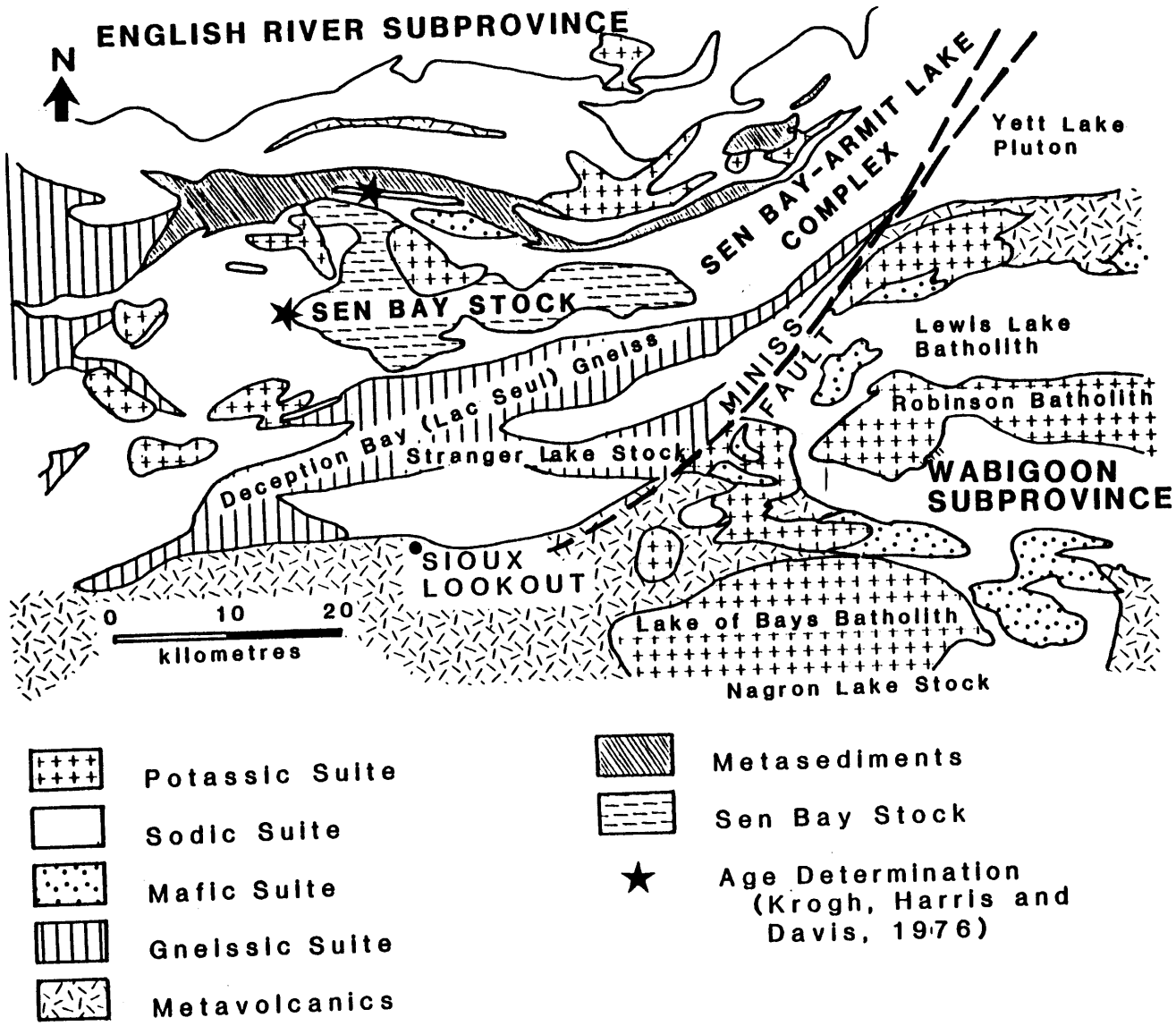


Figure 8-~~5~~ 6 :Location of the Sen Bay Batholith

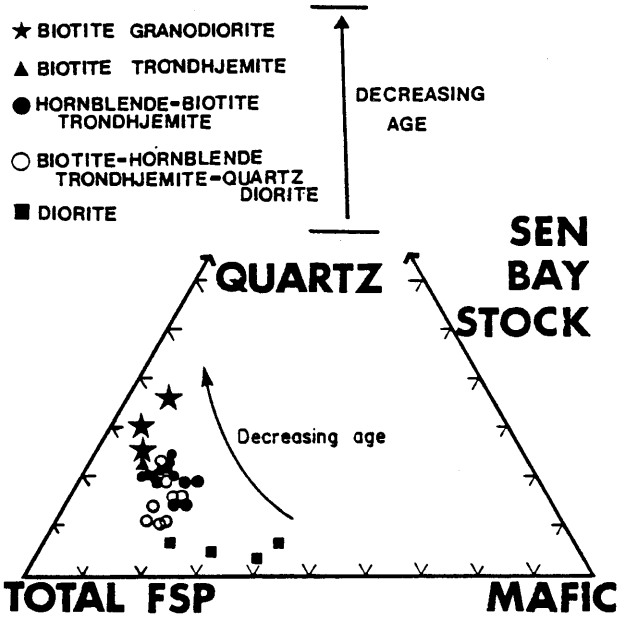


Figure 8-~~6~~7: Modal analyses (Quartz-total Feldspar-Mafics) of the Sen Bay Batholith.

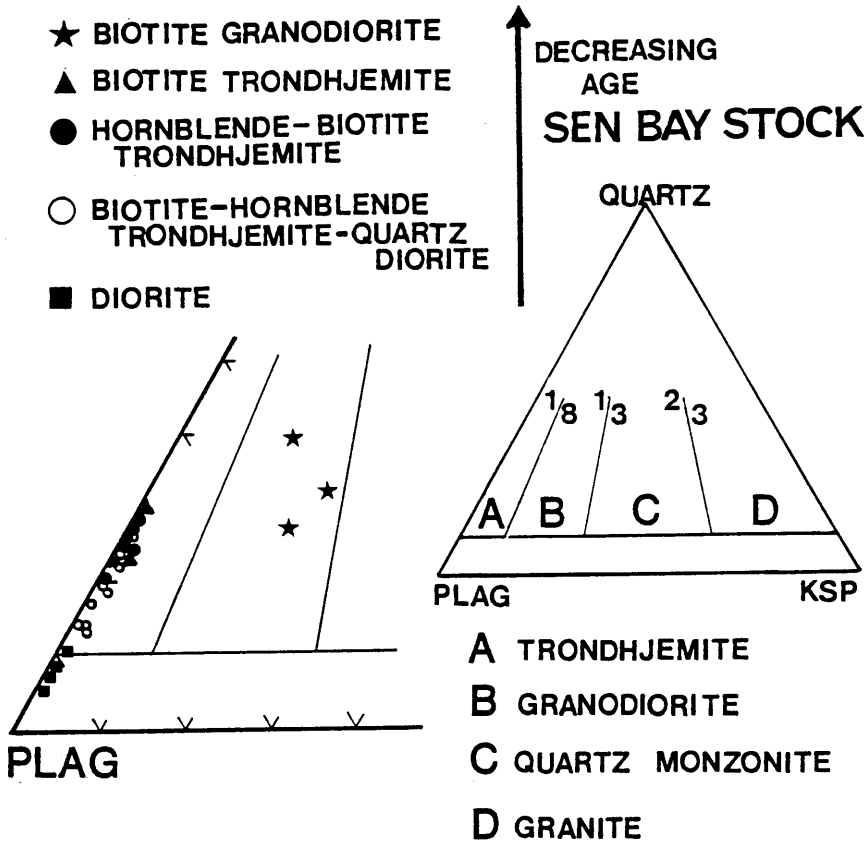


Figure 8-~~7~~8: Modal analyses (Quartz-Plagioclase-K-Feldspar) of the Sen Bay Batholith.

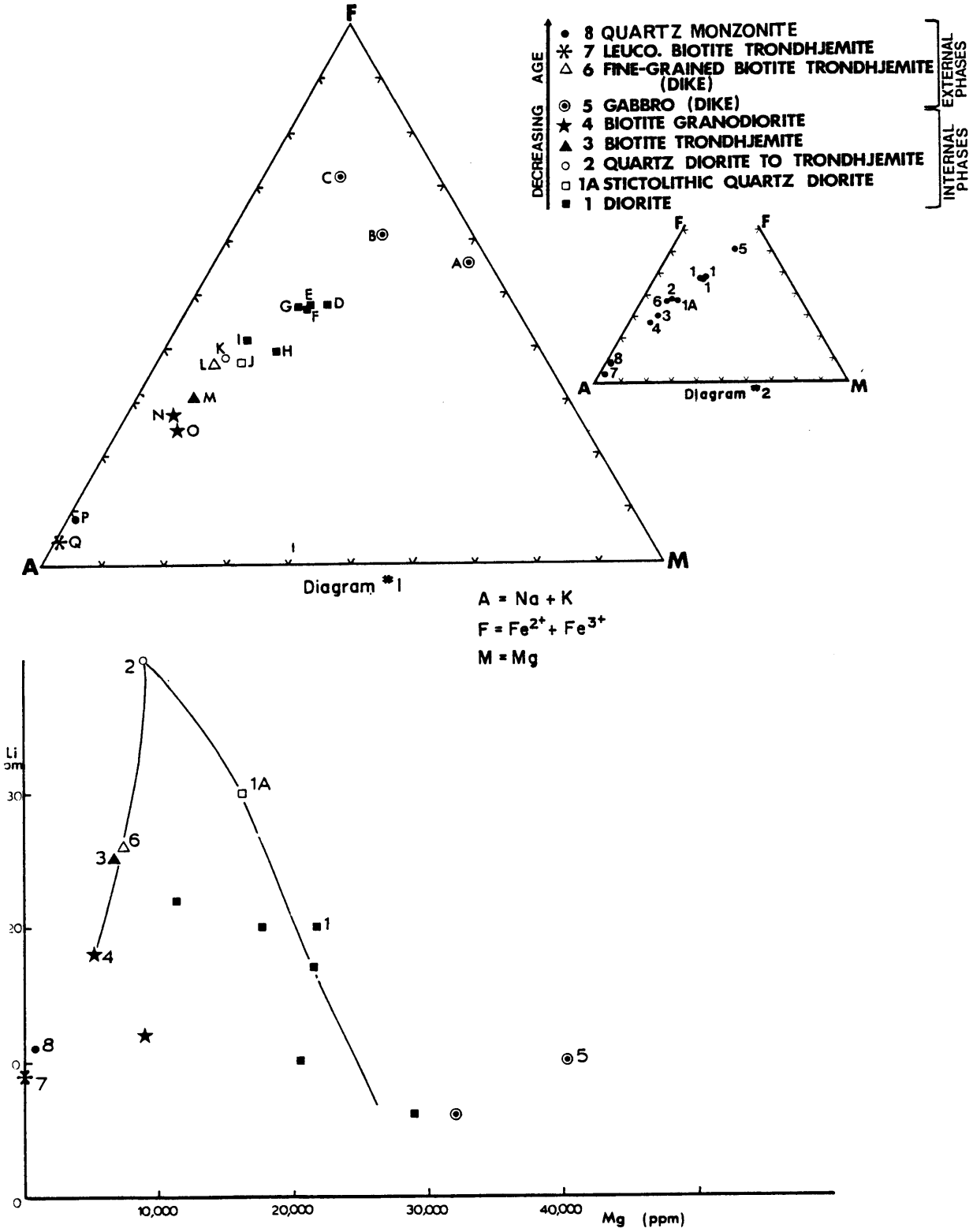


Figure 8-~~8~~9: Chemical variation of the Sen Bay Batholith. AFM (element wt%) A = Na + K, F = Fe^{2+} + Fe^{3+}, M = Mg, Li/Mg in ppm values.

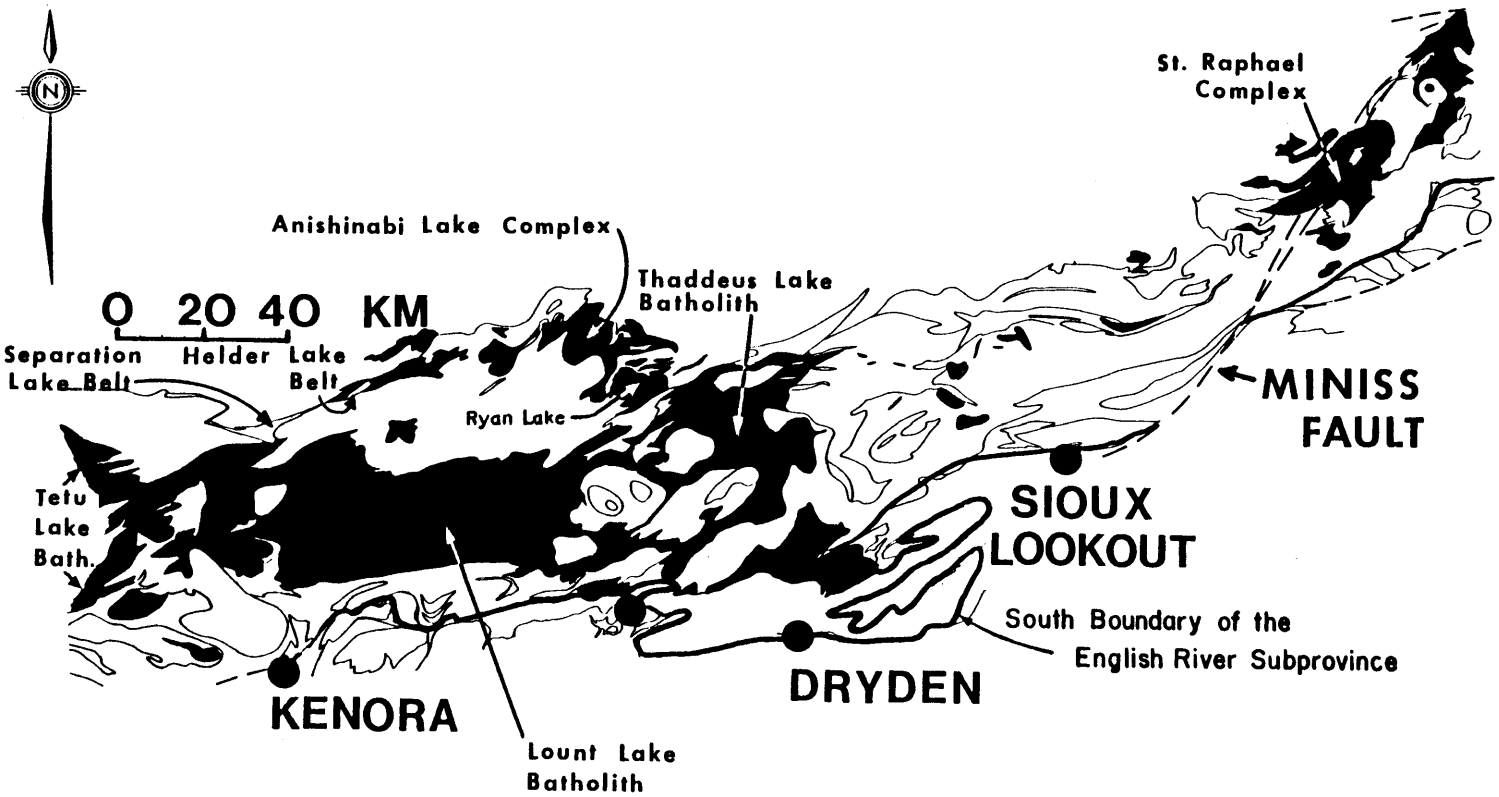


FIG. 9-1 : English River Southern Plutonic Domain showing distribution of Potassic Suite

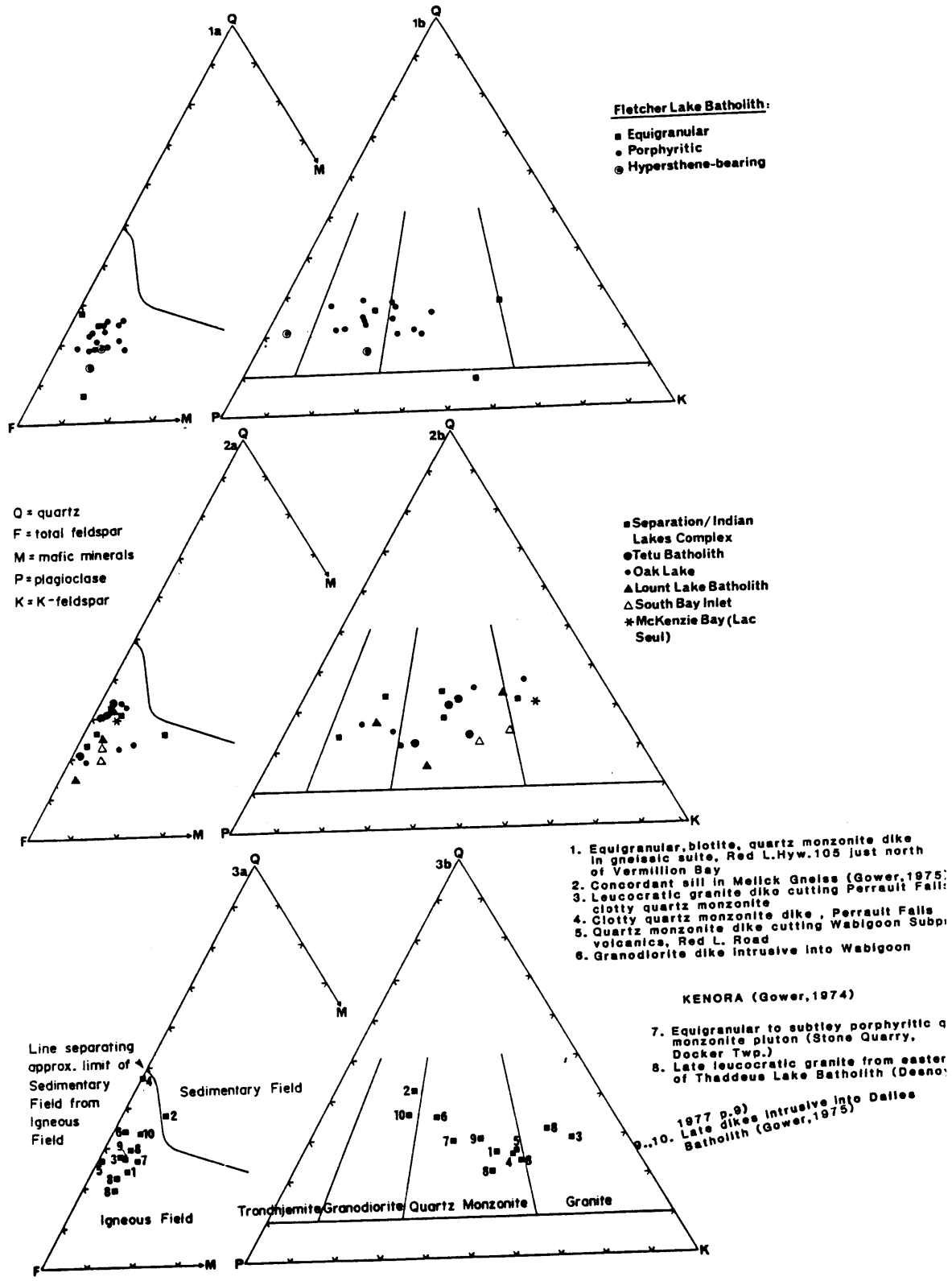


Figure 9-2: Potassic Suite Modal Analyses after Ayres (1972).

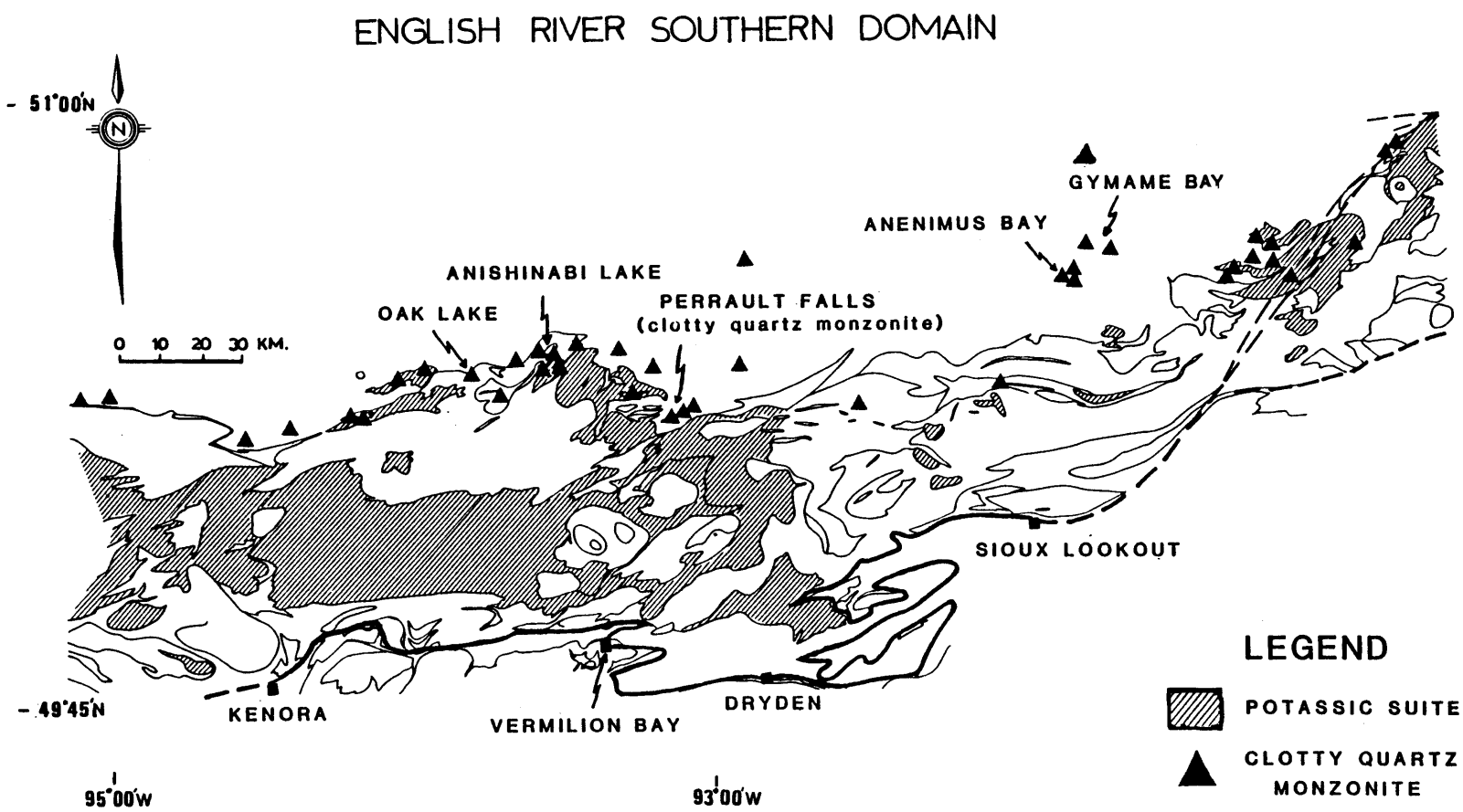


FIG. 9-[illegible] .: Location of Clotty quartz monzonite

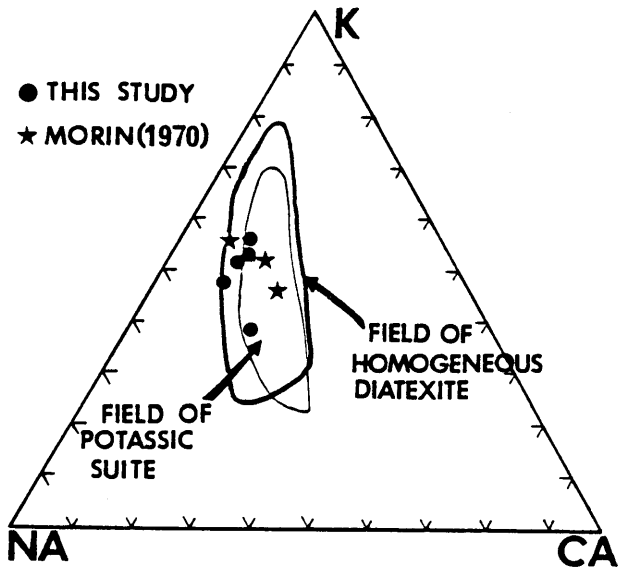


Figure 9-4: CNK (element WT %) plot of matrix of clotty quartz monzonite.

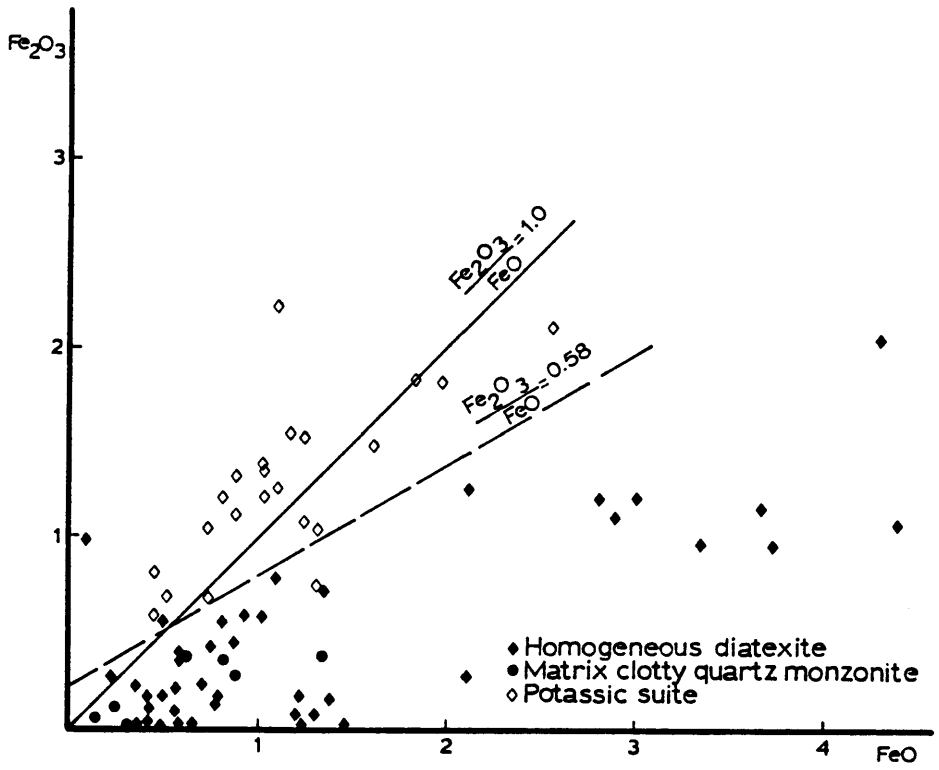
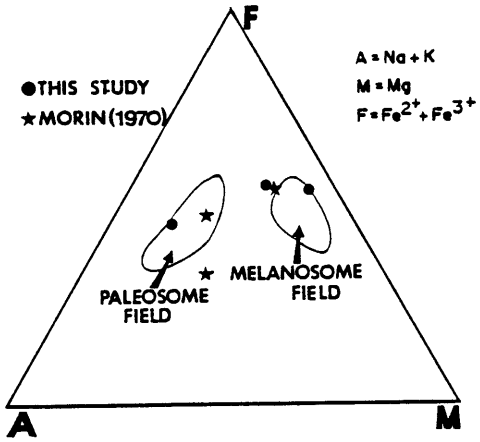


Figure 9-5 : Chemical Distinction between homogeneous diatexite and the matrix of the clotty quartz monzonite.



(element wt%)

Figure 9-6 : AFM plot of clots from clotty quartz monzonite.

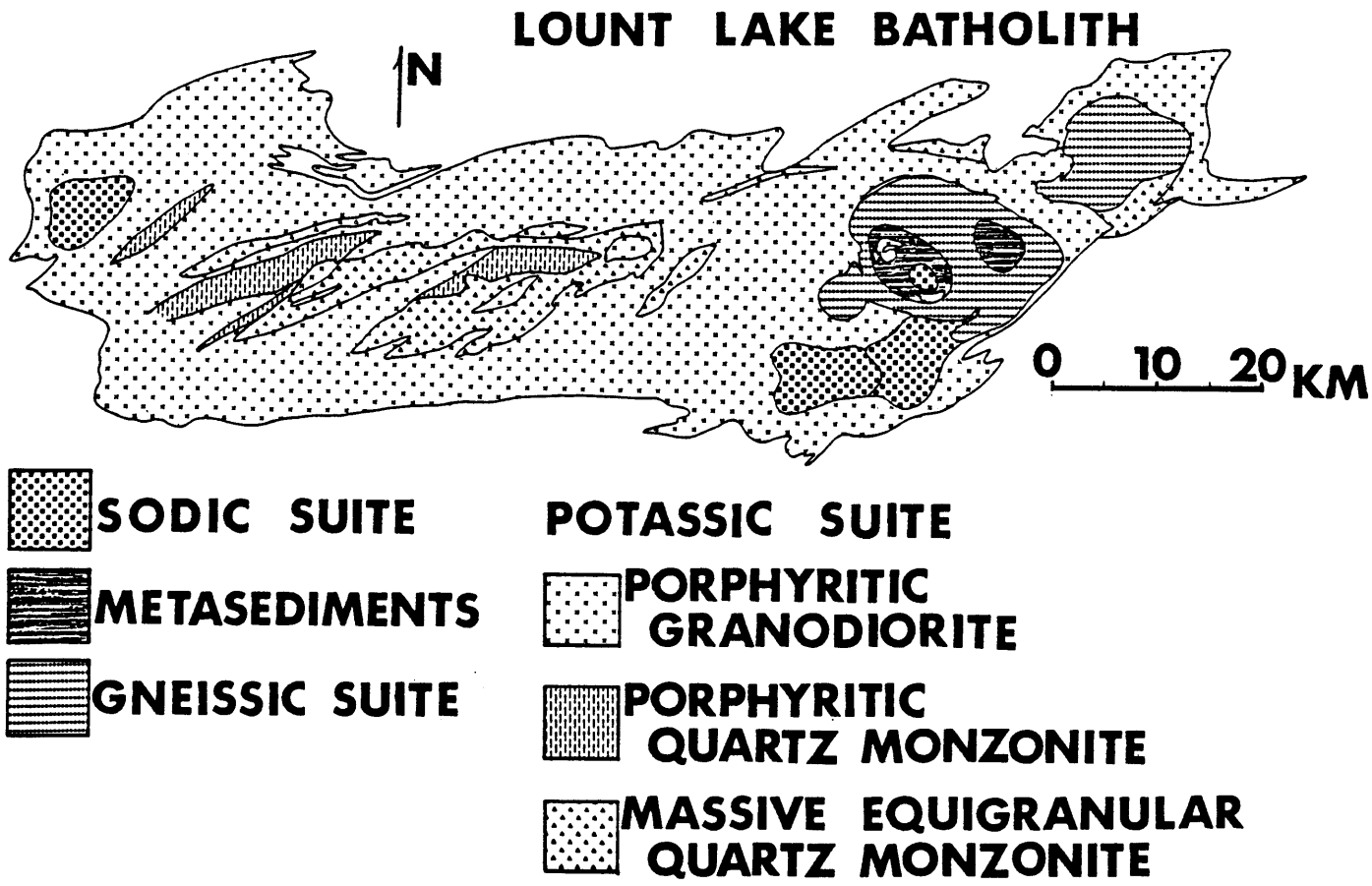


Figure 9-7 : Geology of the Lount Lake Batholith. See Figure 9-1 for location of batholith in the Southern Plutonic Domain.

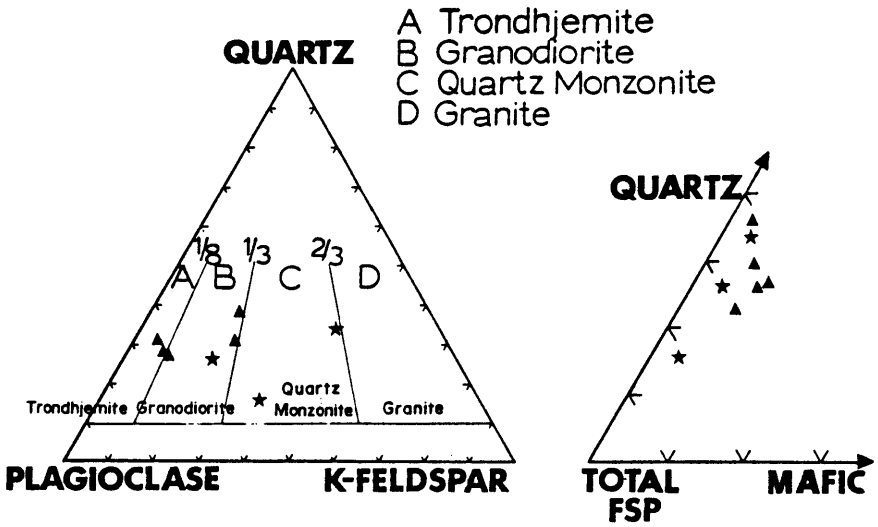


FIG. 9-8 : **MODAL VARIATION OF EARLY (▲) AND LATE (★) PHASES OF THE LOUNT LAKE BATHOLITH**
(after Ayres, 1972).

9-8

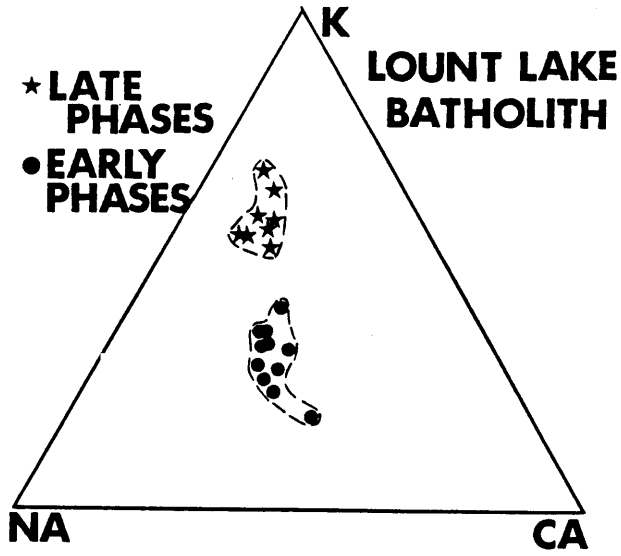


FIG. 9-9 CNK (element wt%) plot of the early and late phases of the Lount Lake Batholith

9-9

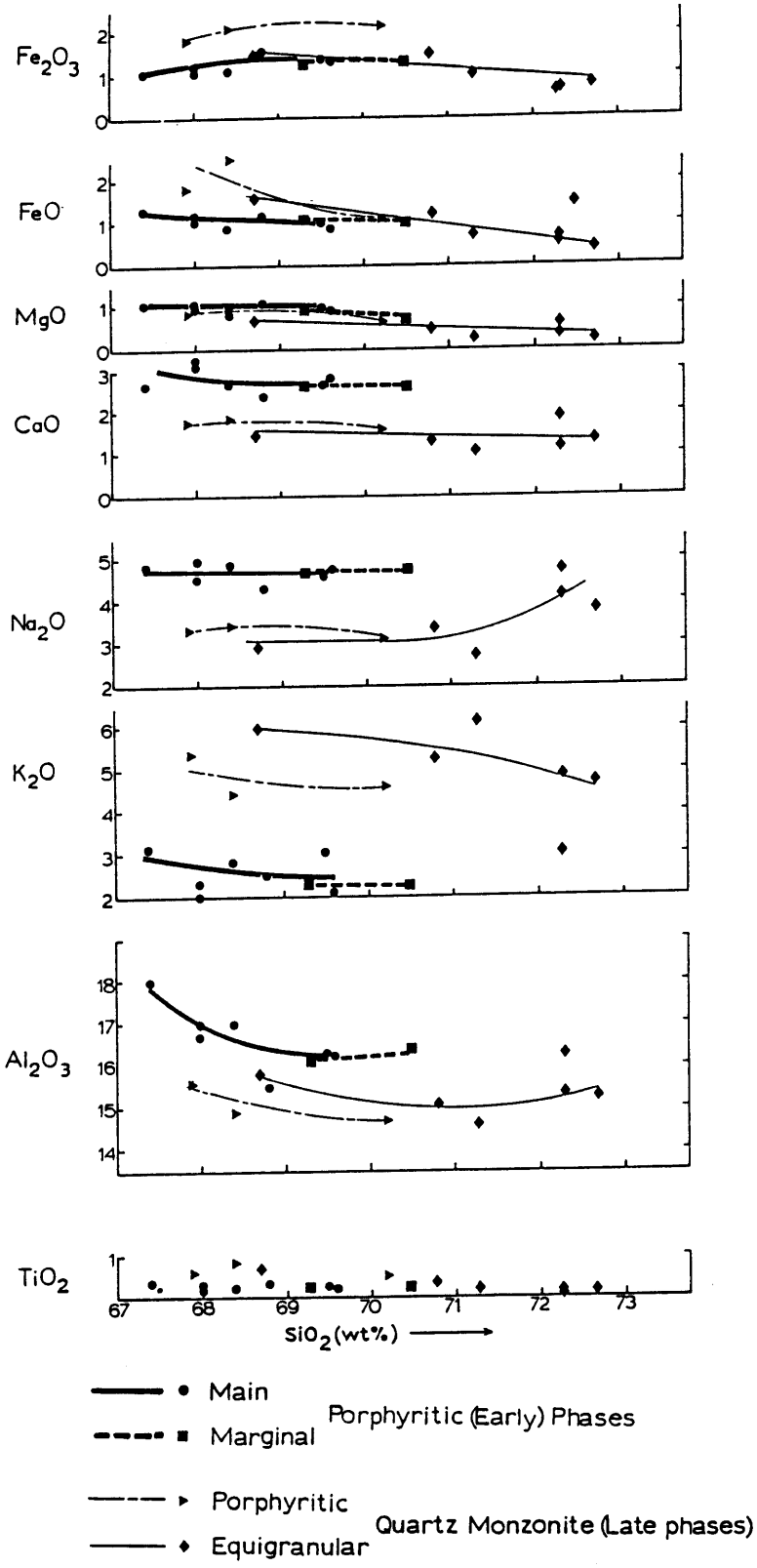


Figure 9-10: Harker variation diagram for Lount Lake Batholith.

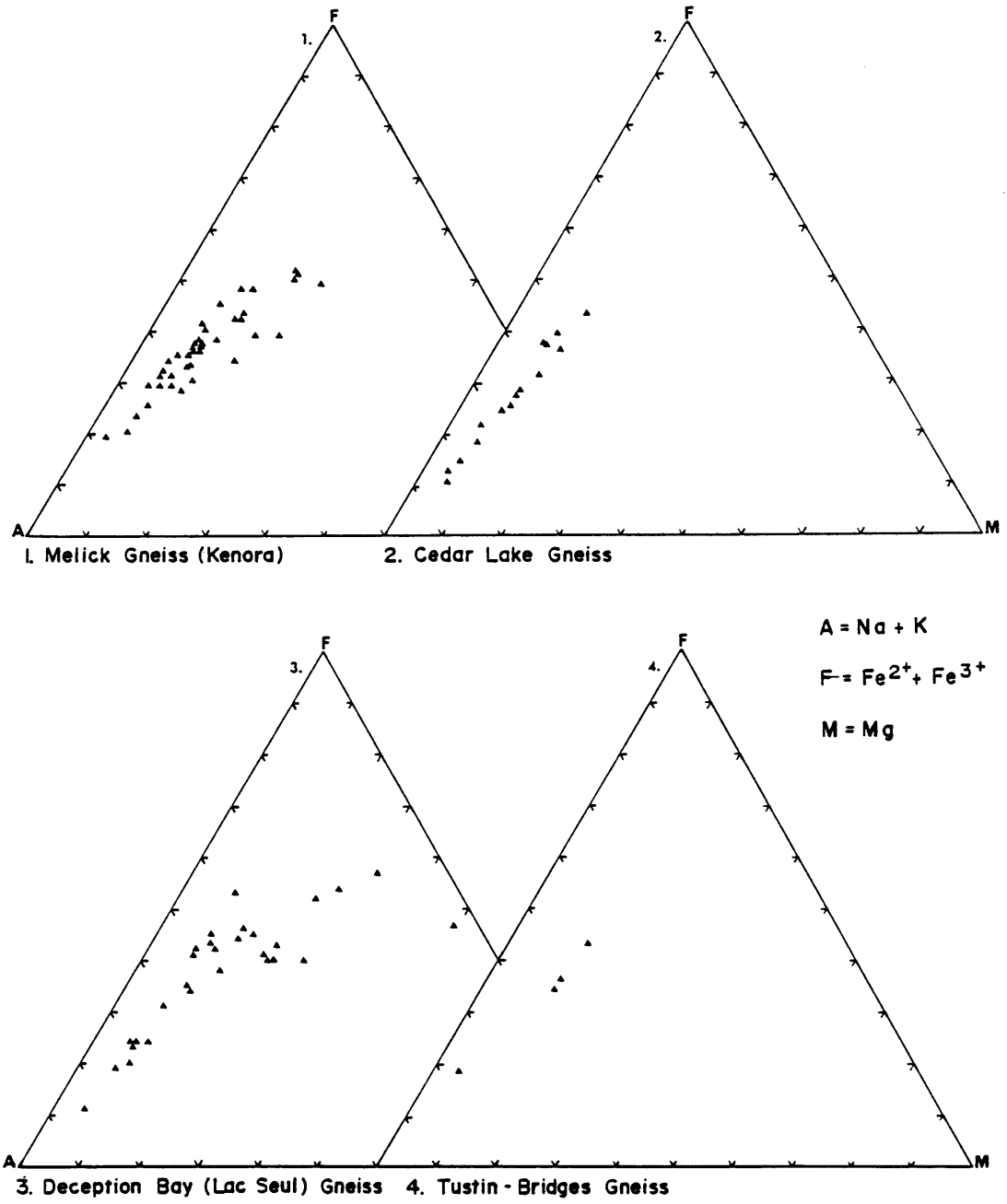


Figure 10-1: AFM (Element wt.%) plots showing chemical variation of gneissic suite. A = Na + K, F = Fe^{2+} + Fe^{3+}, M = Mg

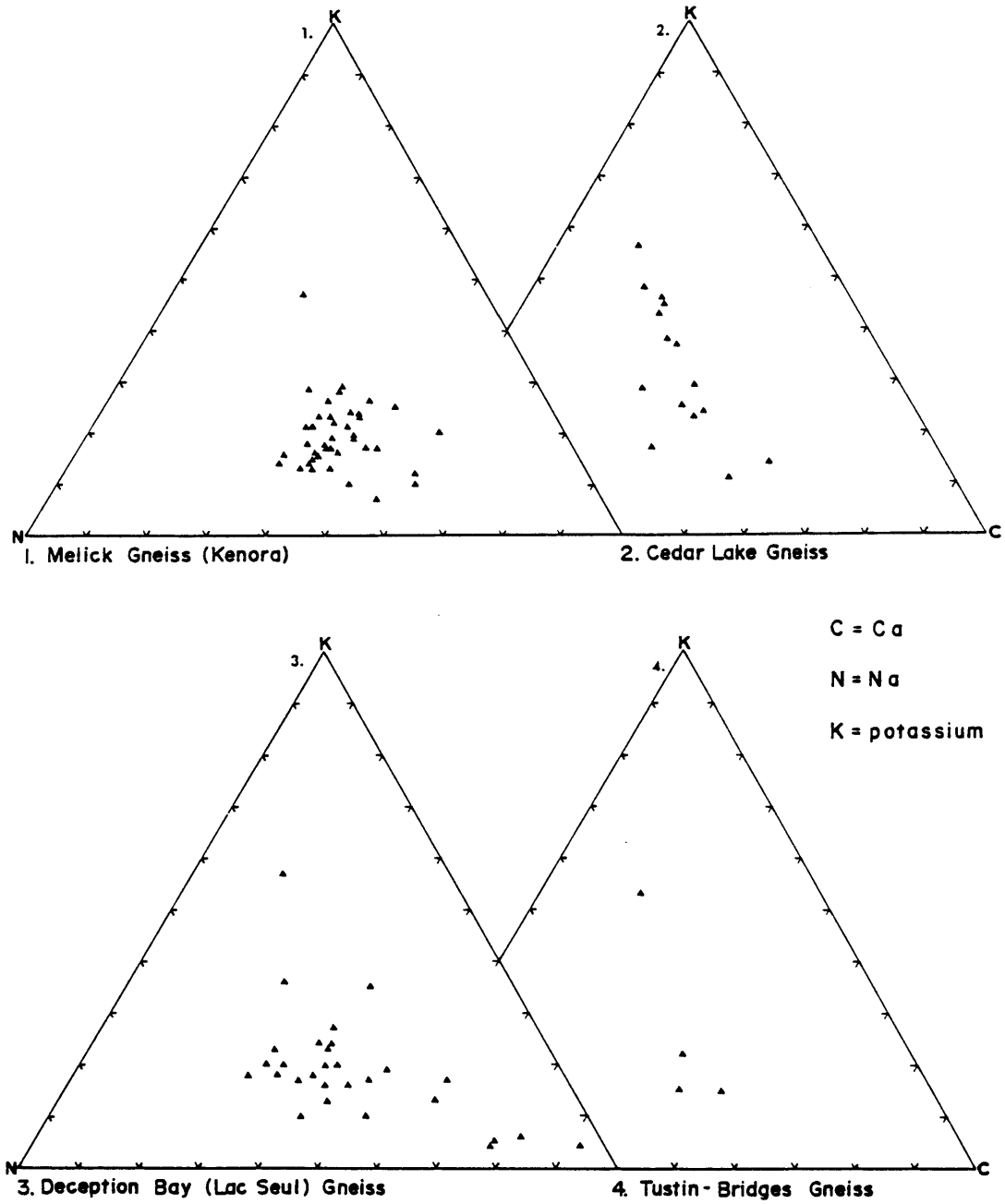


Figure 10-2: CNK (Element wt.%) chemical variation of gneissic suite. C = ca, N = Na, K = potassium.

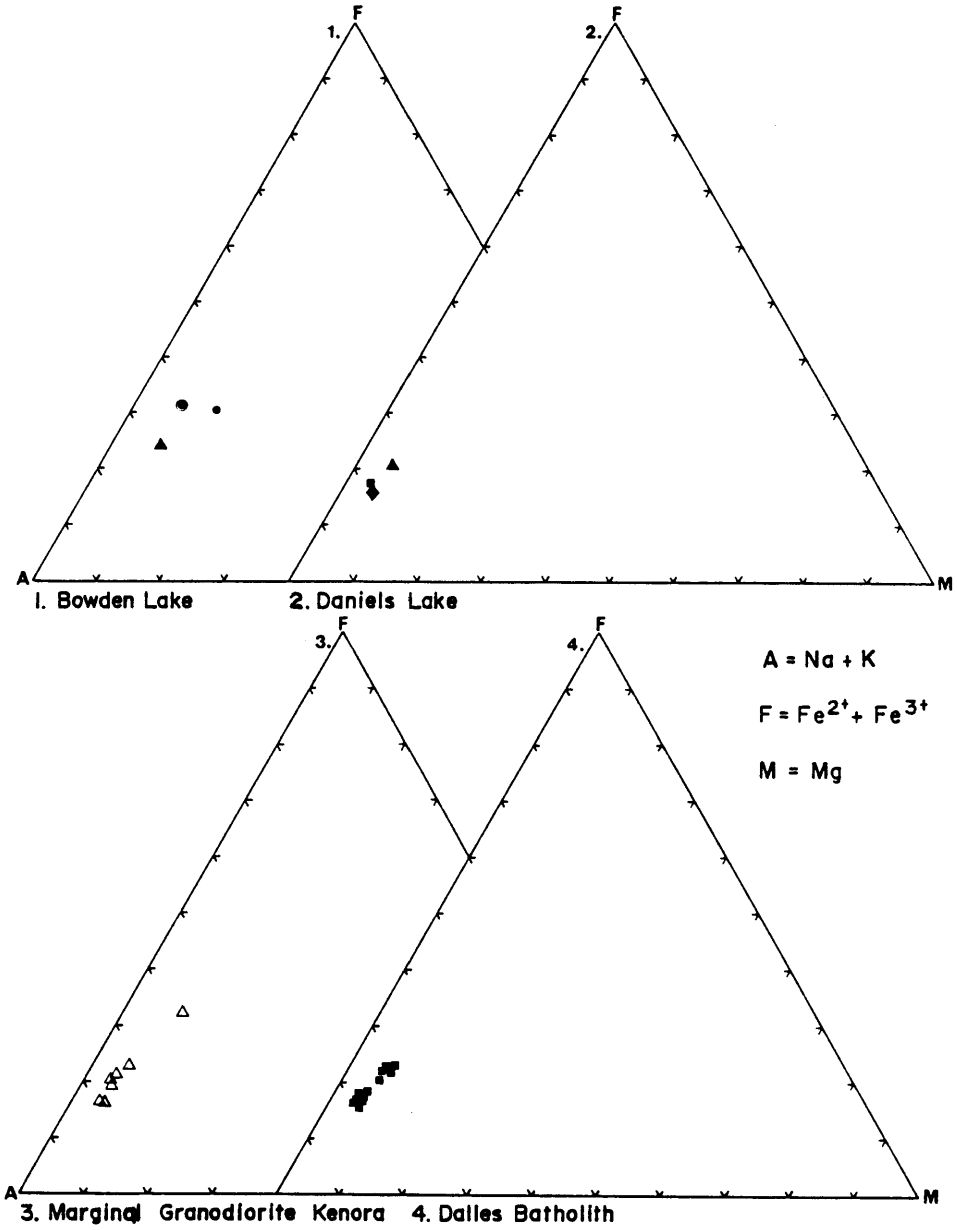


Figure 10-3 : AFM (Element wt.%) plots showing chemical variation of specific sodic intrusives. A = Na + K, F = Fe^{2+} + Fe^{3+}, M = Mg

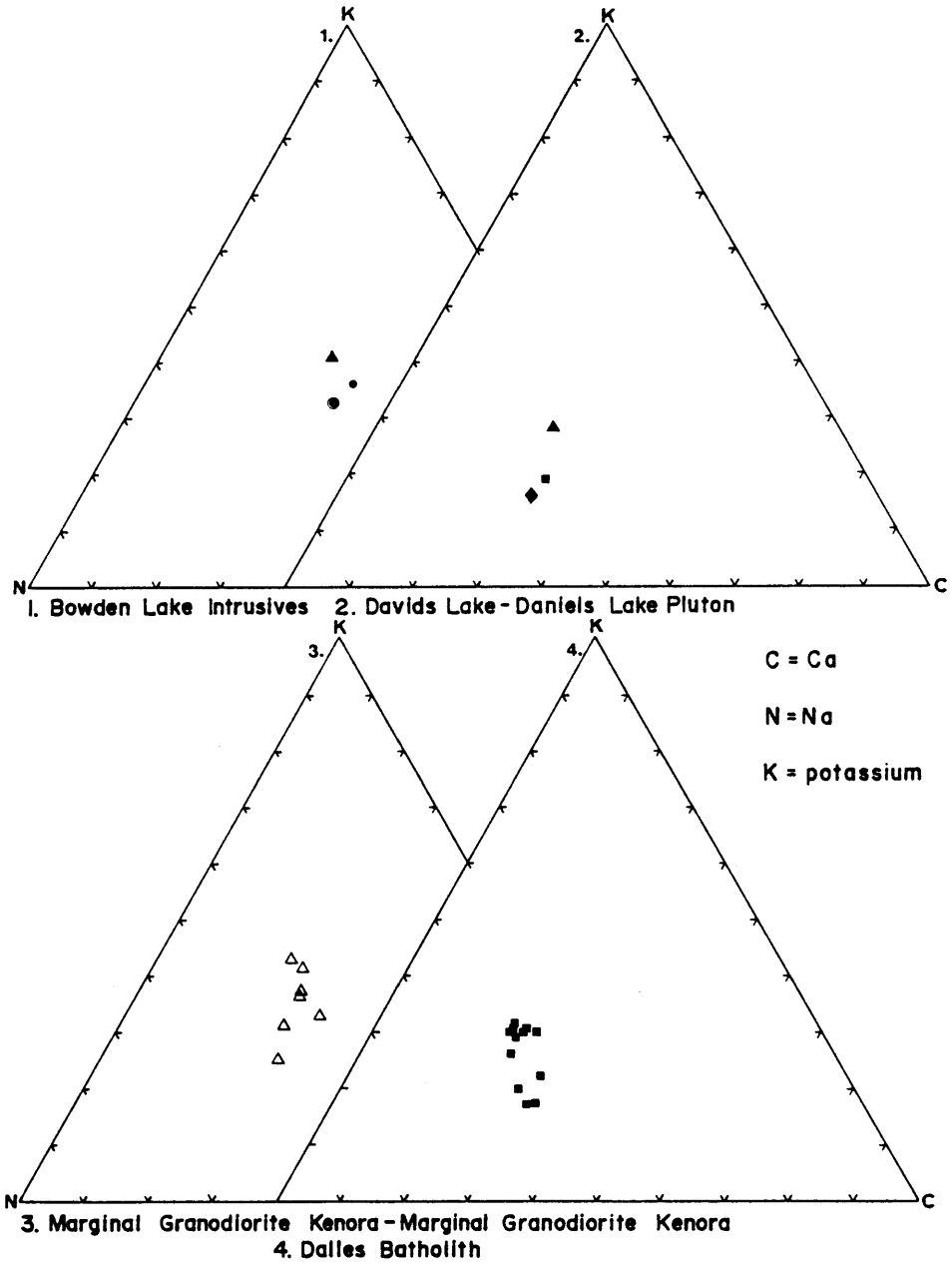


Figure 10-4: CNK (Element wt.%) plots showing chemical variation of specific sodic intrusives. C = Ca, N = Na, K = potassium.

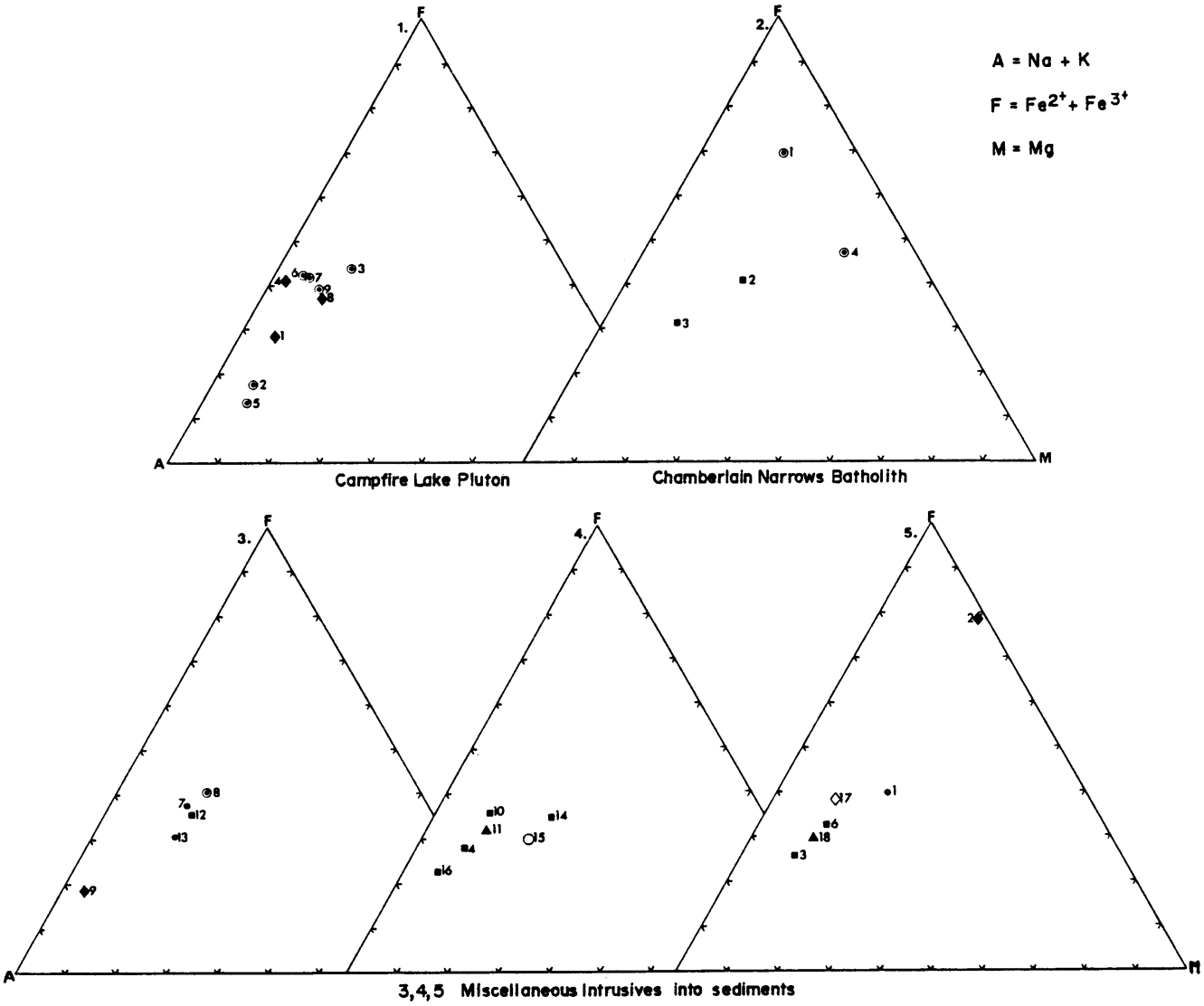


Figure 10-5 : AFM (Element wt.%) plot showing chemical variation of sodic suite (sample numbers correspond to numbered analyses in respective chemistry tables of sodic suite). A = Na + K, F = Fe^{2+} + Fe^{3+}, M = Mg.

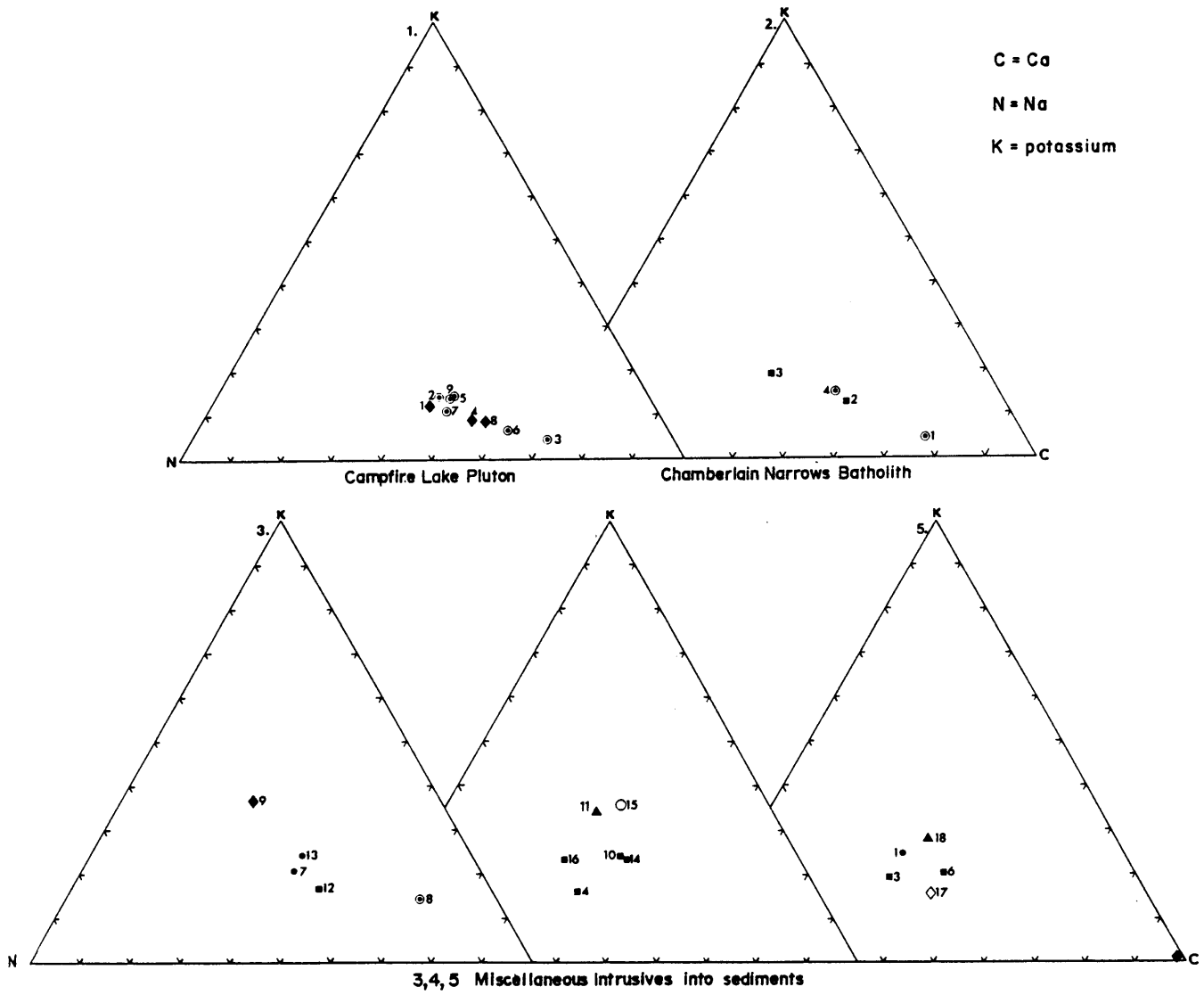


Figure 10-6 : CNK (Element wt.%) plot showing chemical variation of sodic suite (sample numbers correspond to numbered analyses in the respective tables of sodic suite). C = Ca, N = Na, K = potassium.

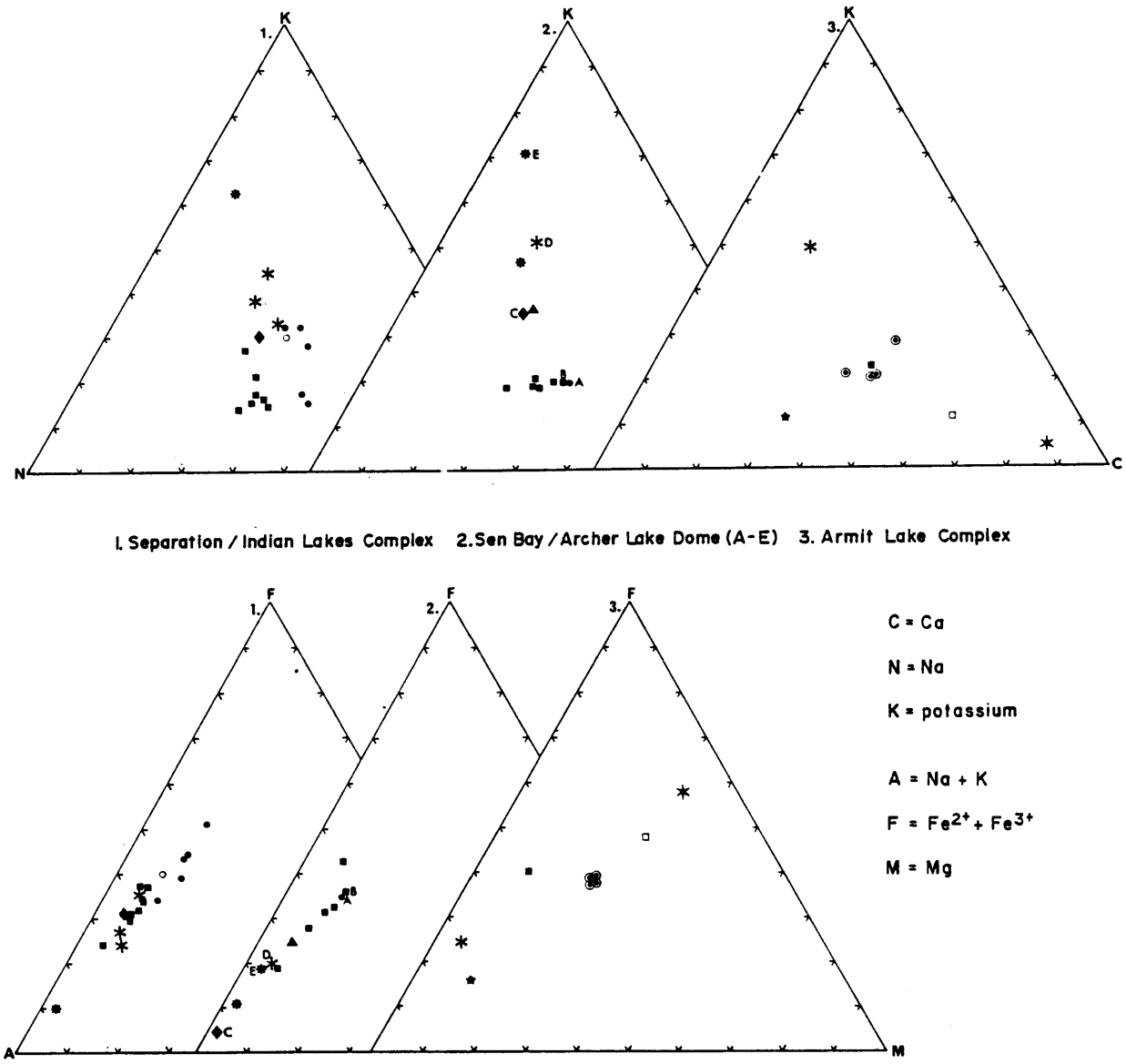
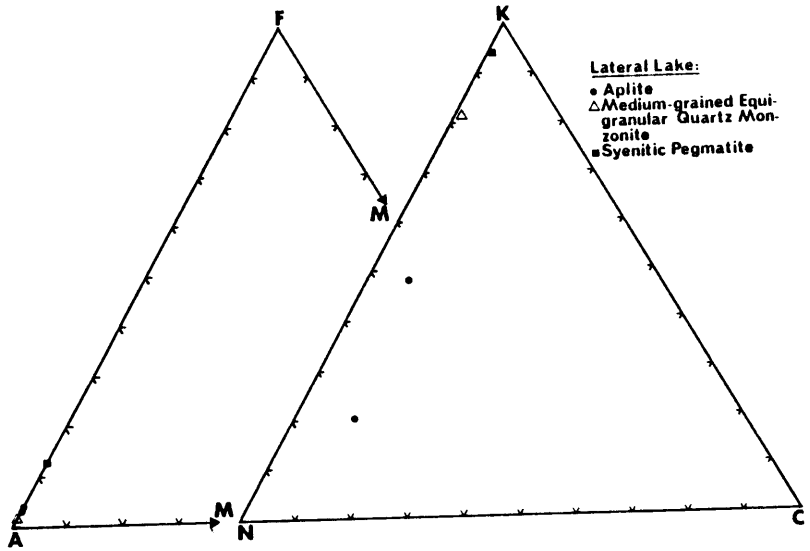
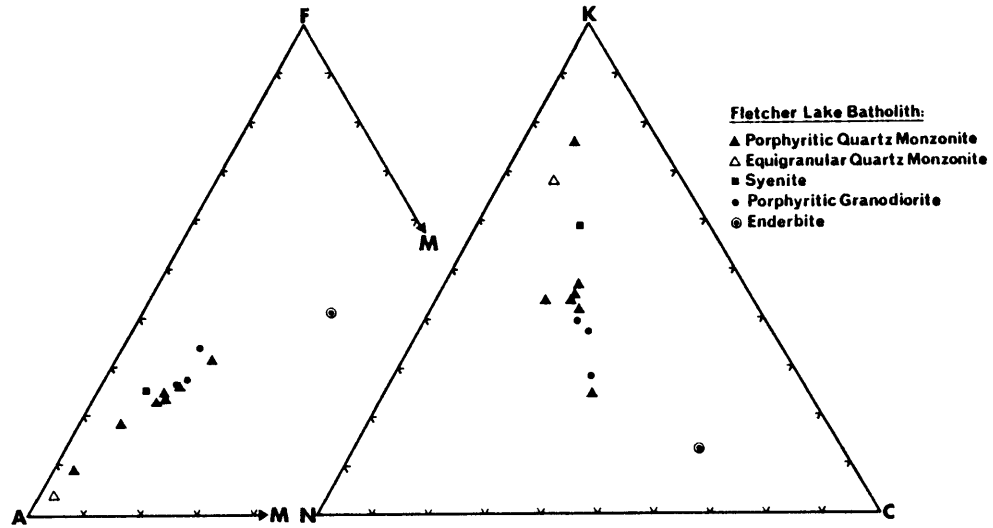


Figure 10-7: CNK - AFM (Element wt.%) plots showing chemical variation of Sodic Suite heterogeneous complexes.

A = Na + K, F = Fe^{2+} + Fe^{3+}, M = Mg

C = Ca, N = Na, K = potassium





A = Na + K

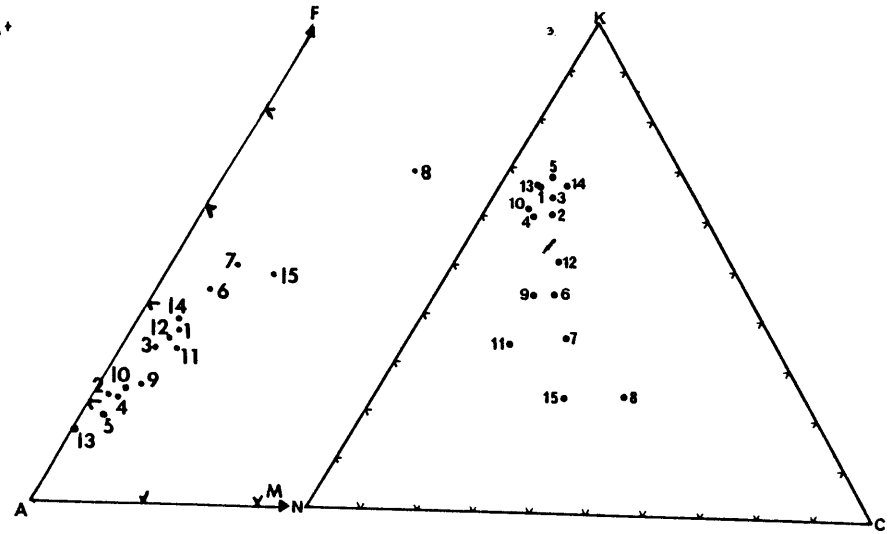
F = Fe^{2+} + Fe^{3+}

M = Mg

C = Ca

N = Na

K = potassium



Element wt%

Fig. AFM-CNK (^ Plots) chemical variation of potassic suite (Numbers 1-15 are miscellaneous samples, see table 10-17)

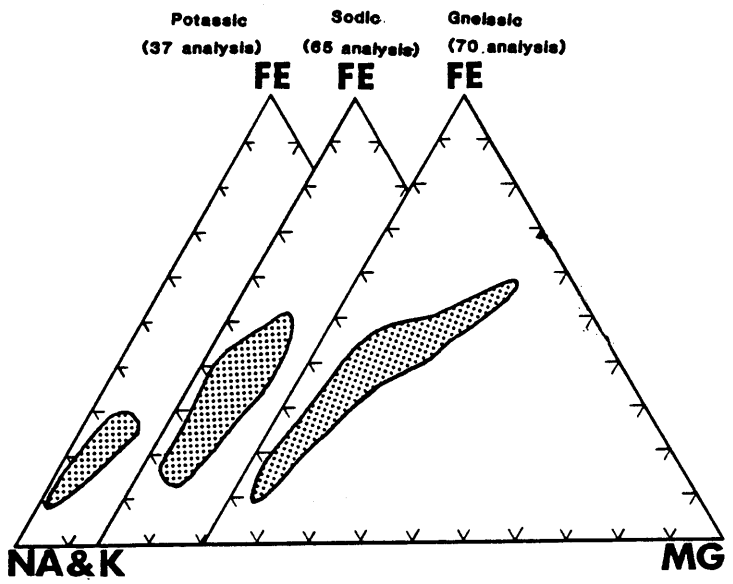


Figure 10-9: AFM (Element wt.%) plot showing chemical restrictions of major igneous suites.

10-9

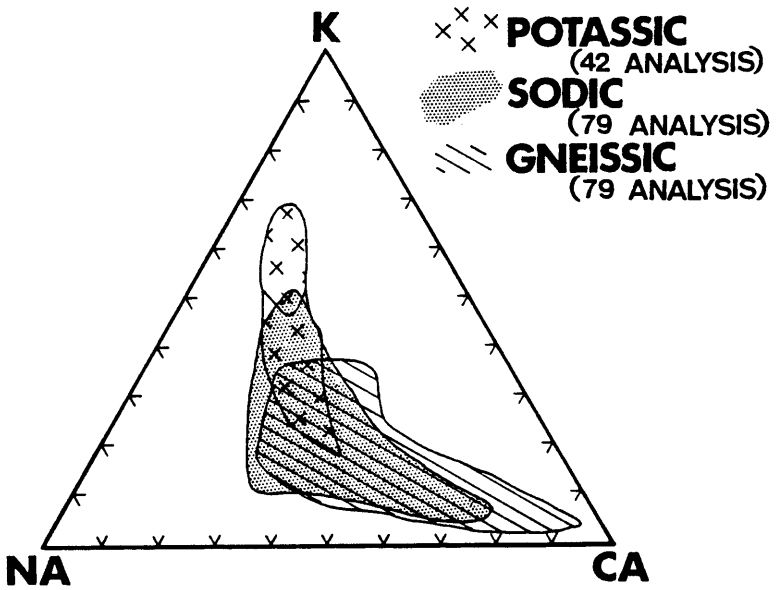


Figure 10-10: CNK (Element wt %) plot showing chemical variation of major granitoid suites.

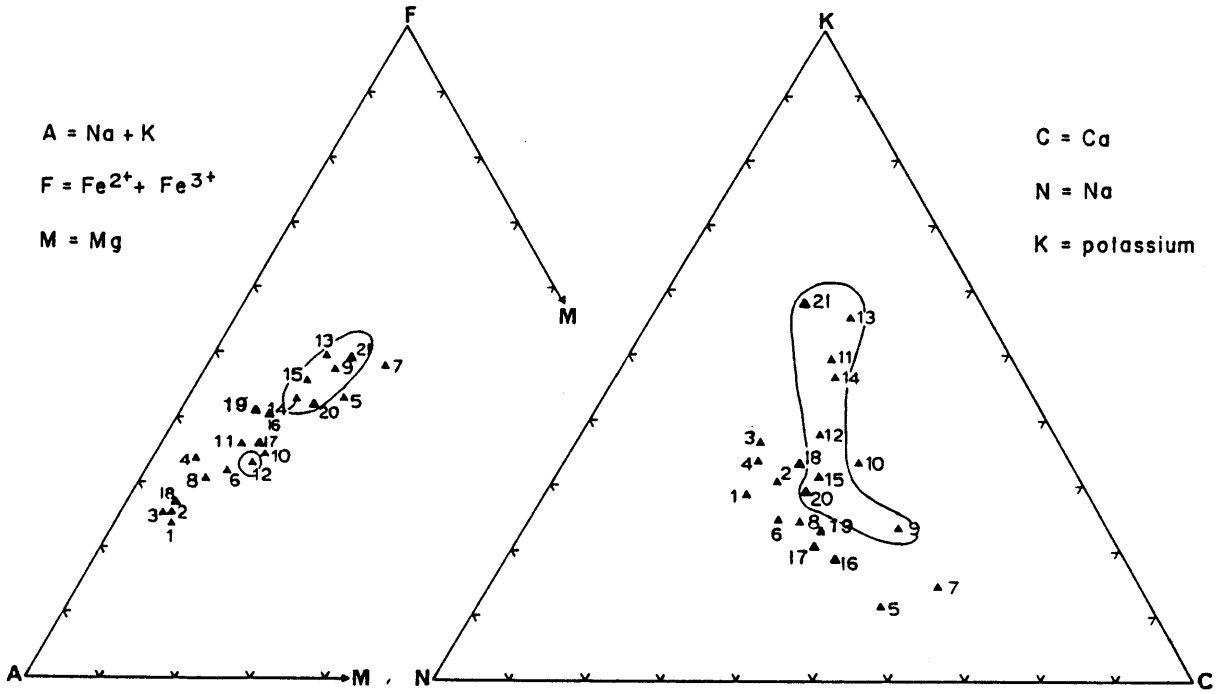


Figure 10-11: AFM-CNK (Element wt %) plots showing of average chemical analyses of other gneissic terrains including average composition of English River Gneissic Suite (19). Points 9, 12, 13, 14, 15, 20, 21 are averages of various metasedimentary series (circled). Explanation of coded numbers given on following page.

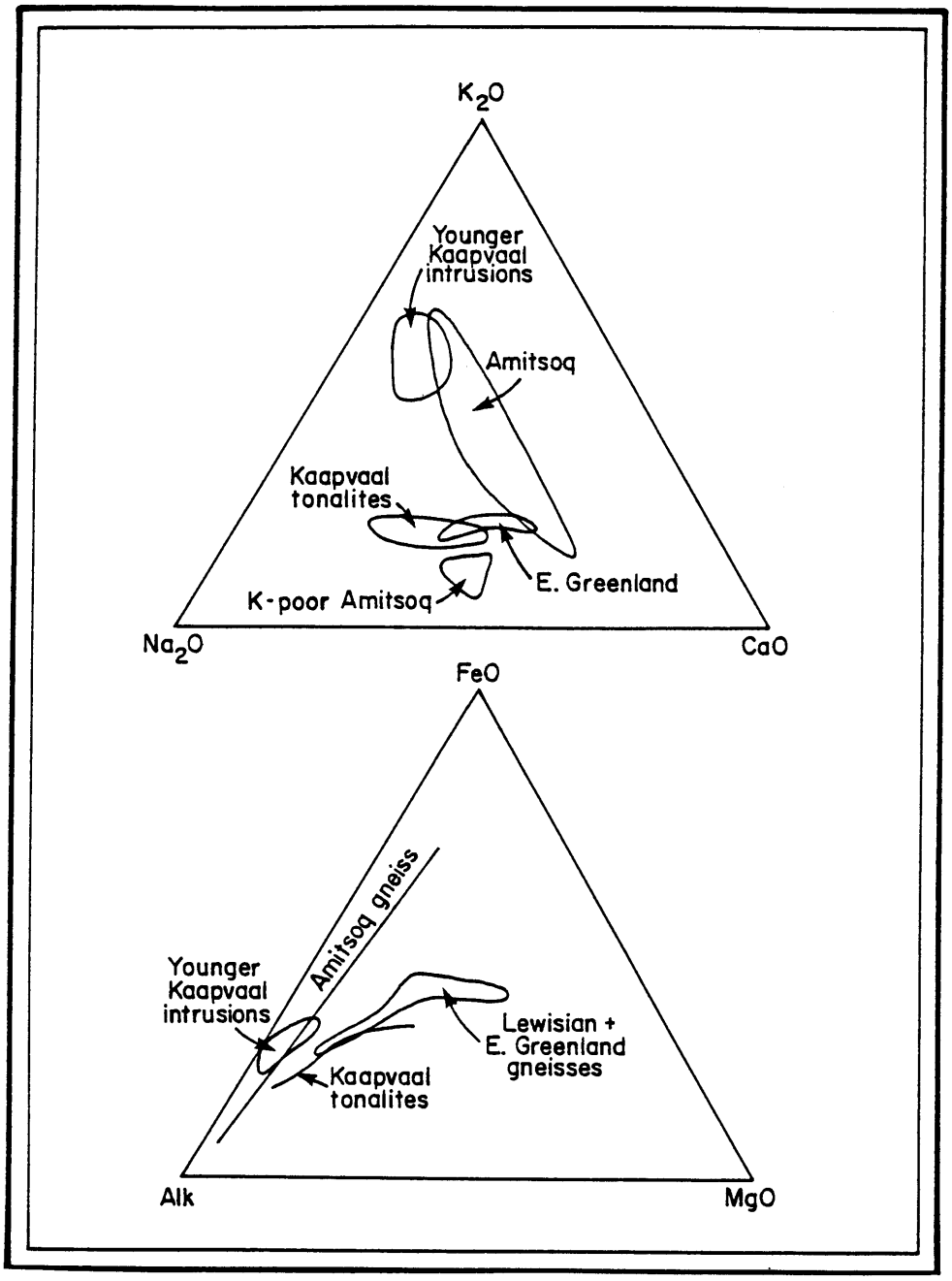
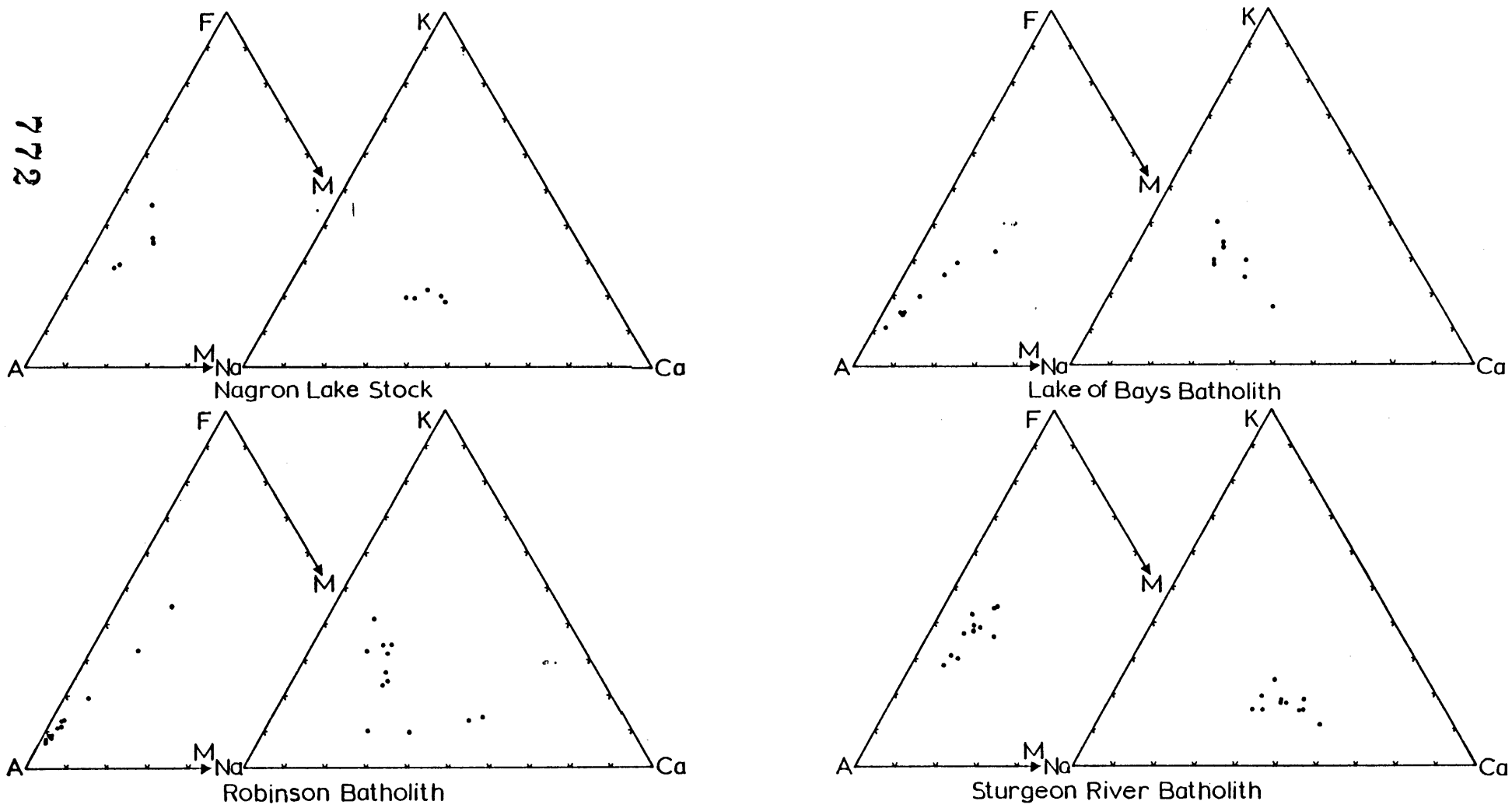


Figure 10-12 : Chemical composition of Archean complexes from Lambert et al. 1975, pgs. 379, 381.



(Element wt%)

Fig. 11-1 : AFM & CNK Diagrams of Intrusives of the Wabigoon Subprovince

772

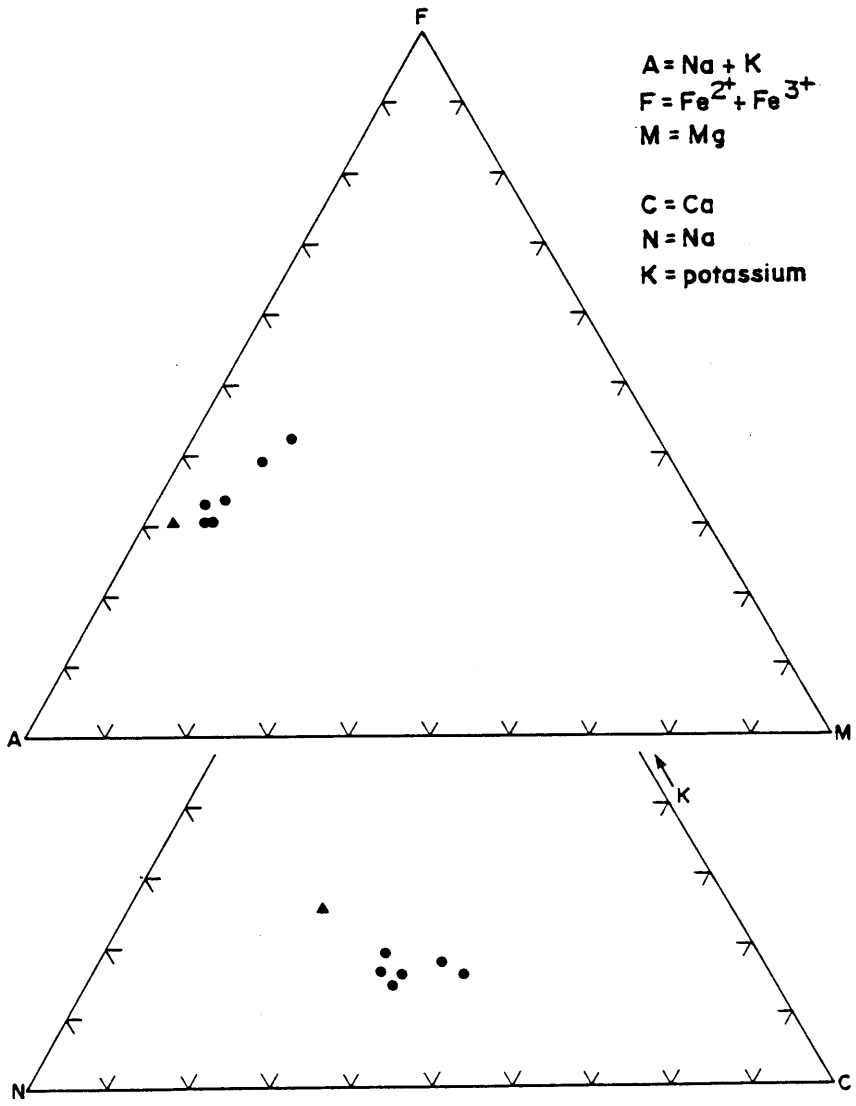


Fig. 11-2 :AFM-CNK (element wt%) chemical variation of Lewis Lake(●) and Yett Lake Stock(▲)

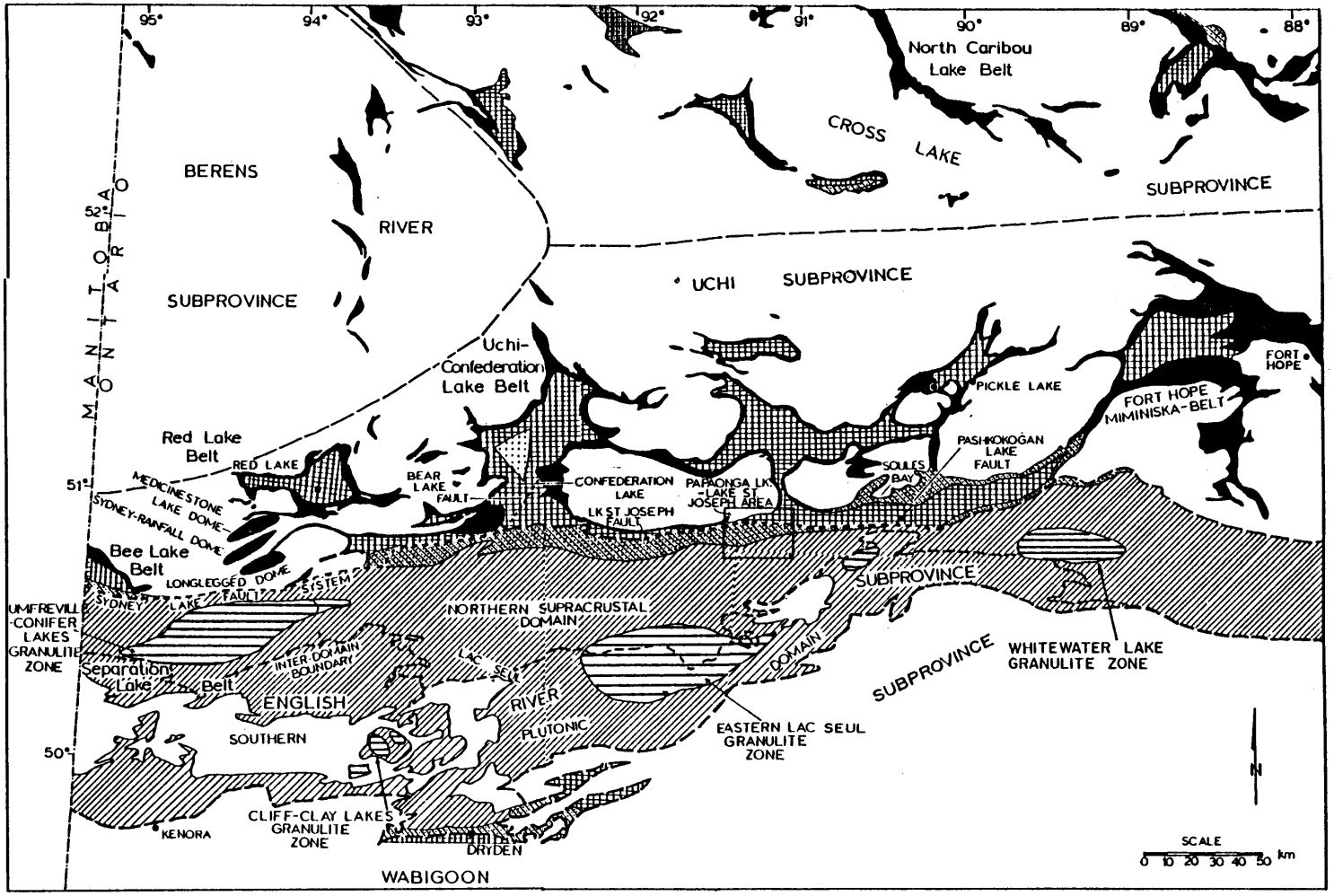


FIG. 1-1 - Generalized distribution of metamorphic zones within the English River, Uchi and parts of the Berens River and Cross Lake Subprovinces in Northwestern Ontario (from Thurston and Breaks **1978**).

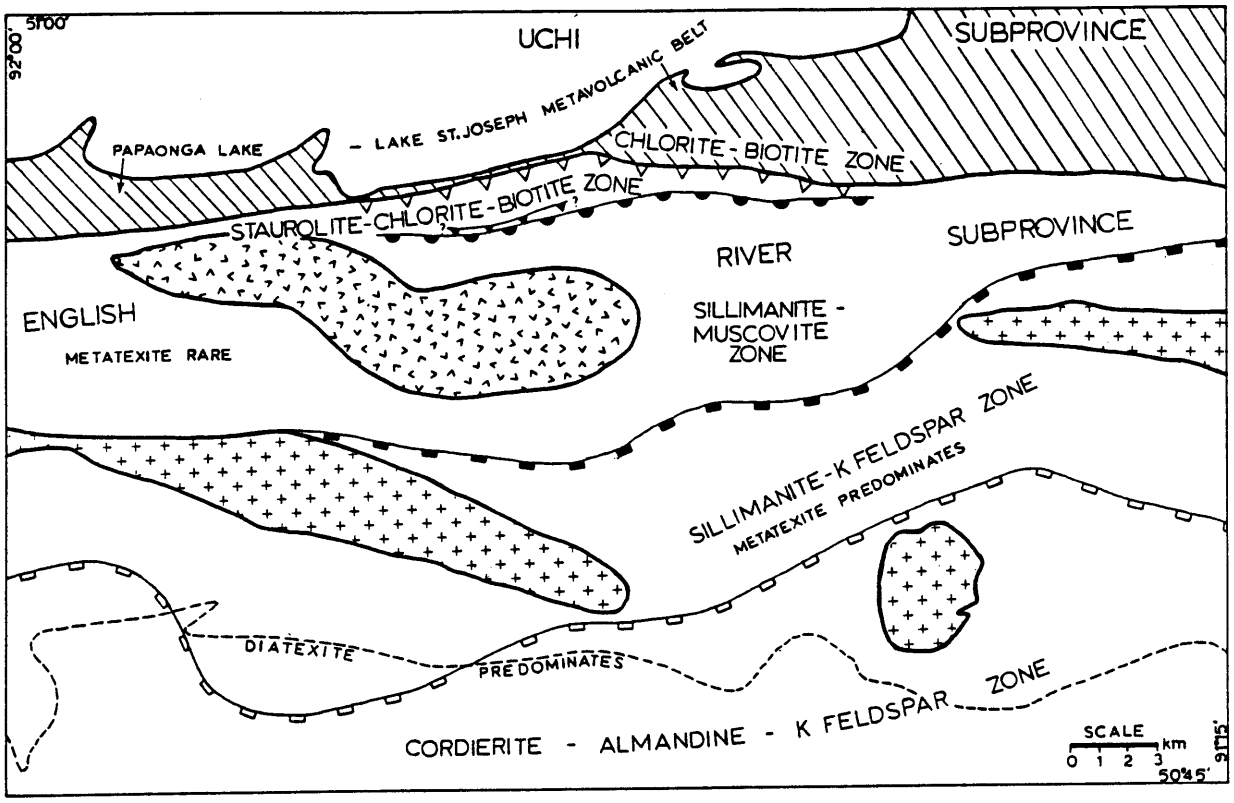


Figure 14-2 :Distribution of metamorphic zones, isograds, and metasedimentary migmatite stages at Uchi Subprovince–English River Subprovince interface, Lake St. Joseph area (after Thurston and Breaks, 1978).

LEGEND

CLASTIC METASEDIMENTS AND ANATECTIC EQUIVALENTS (ENGLISH RIVER SUBPROVINCE)

METAVOLCANICS AND METASEDIMENTS (UCHI SUBPROVINCE)

ALLOCHTHONOUS DIATEXITE

METAMORPHOSED TRONDHJEMITE

REACTION ISOGRADS (Teeth on high grade side)

Chlorite + muscovite = biotite + staurolite + quartz + H_2O .....

Chlorite + muscovite + quartz = biotite + sillimanite + cordierite + H_2O .....

Muscovite + staurolite + quartz = biotite + sillimanite + almandine + H_2O .....

Muscovite + quartz = sillimanite + K feldspar + melt .....

Biotite + sillimanite + quartz + H_2O = cordierite + almandine + melt .....

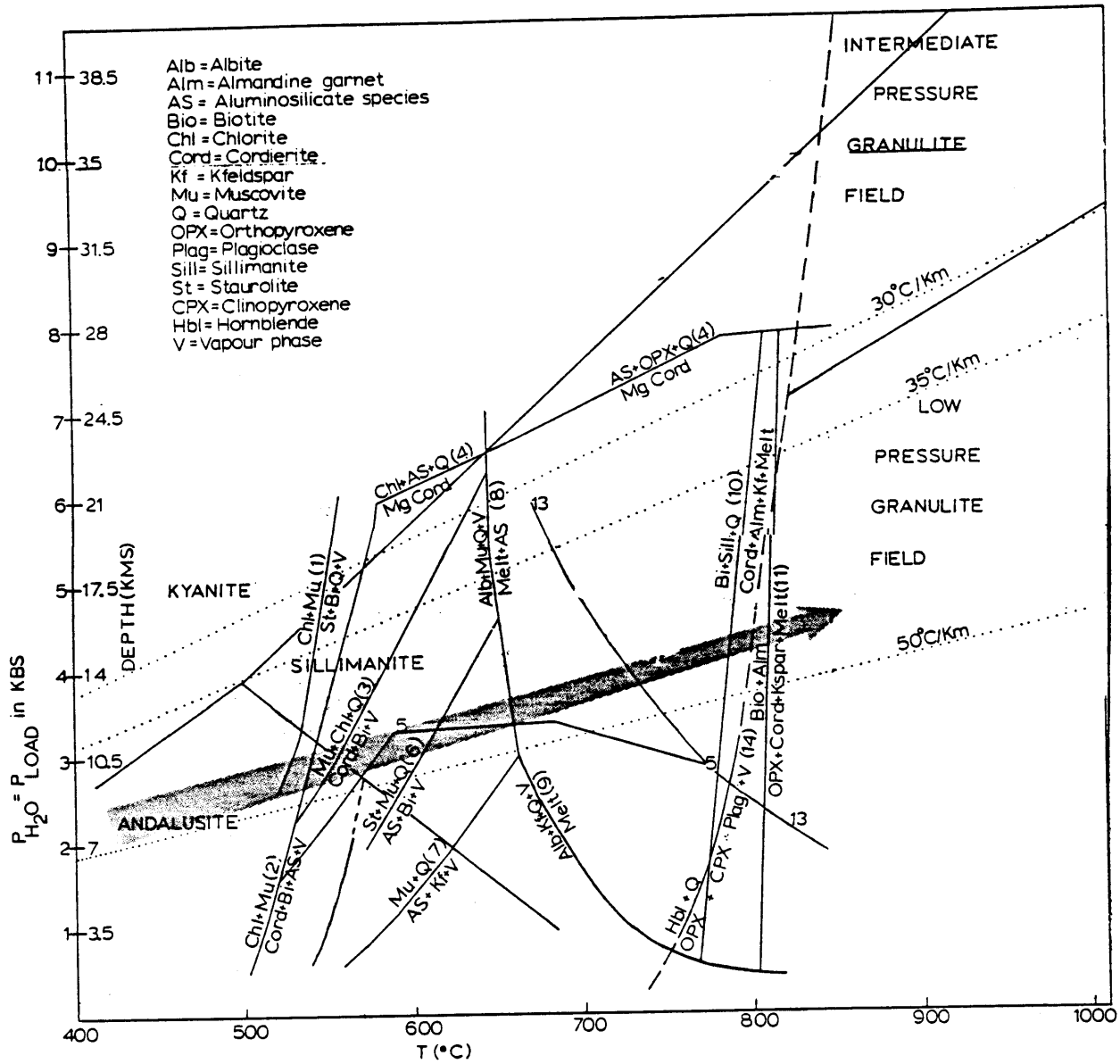


FIG. 14·3 Inferred path of regional metamorphism from Uchi Subprovince transitional into English River Subprovince. 1=Hoschek(1969), 2=Hirschberg and Winkler(1968), 3=Schreyer and Seifert(1969), 4=upper pressure stability of magnesian cordierite after Schreyer and Seifert(1969)and Newton et al (1974), 5=upper pressure stability of Fe cordierite Richardson (1968), 6=Hoschek (1969), 7=Althaus et al(1970) 8=Storre and Karotke (1971), 9 after Merrill et al(1970)and Tuttle and Bowen (1958), 10+11 = Grant (1973), Aluminosilicate system after Holdaway (1971), 12 = Binns (1969), 13 = beginning of melting curve for quartz bearing amphibolite and hornblende pyroxene gneiss after Binns (1969), 14 = boundary between high grade and granulite conditions based on breakdown for common hornblende in presence of quartz (Binns 1969) and extrapolated beyond 3 Kbars, 15 = boundary between low and intermediate pressure granulite fields as defined by upper pressure stability of olivine + plagioclase in basaltic compositions with 100 Mg/Mg+Fe^{2+} = 60, Green and Ringwood 1967.

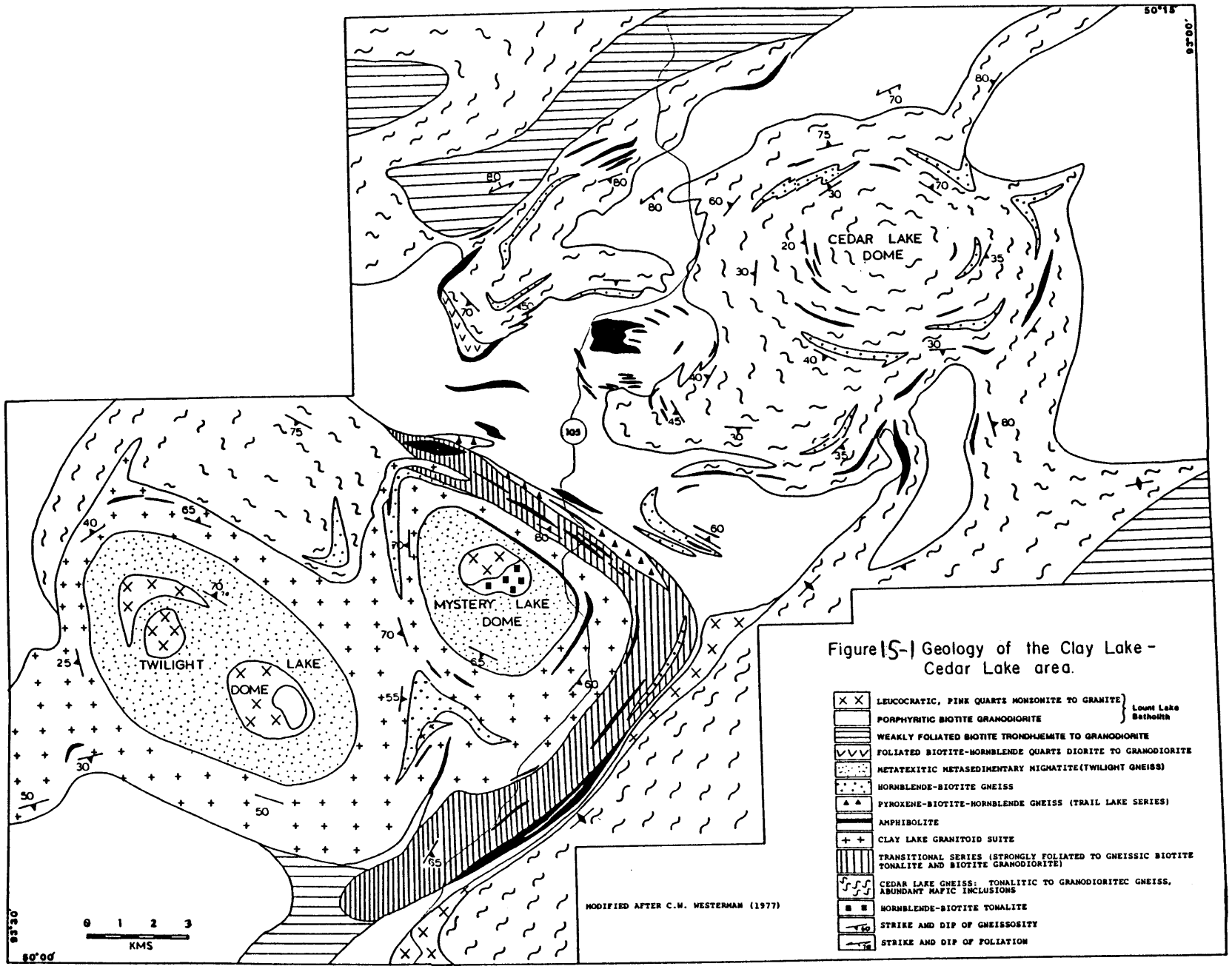


Figure 15-1 Geology of the Clay Lake - Cedar Lake area.

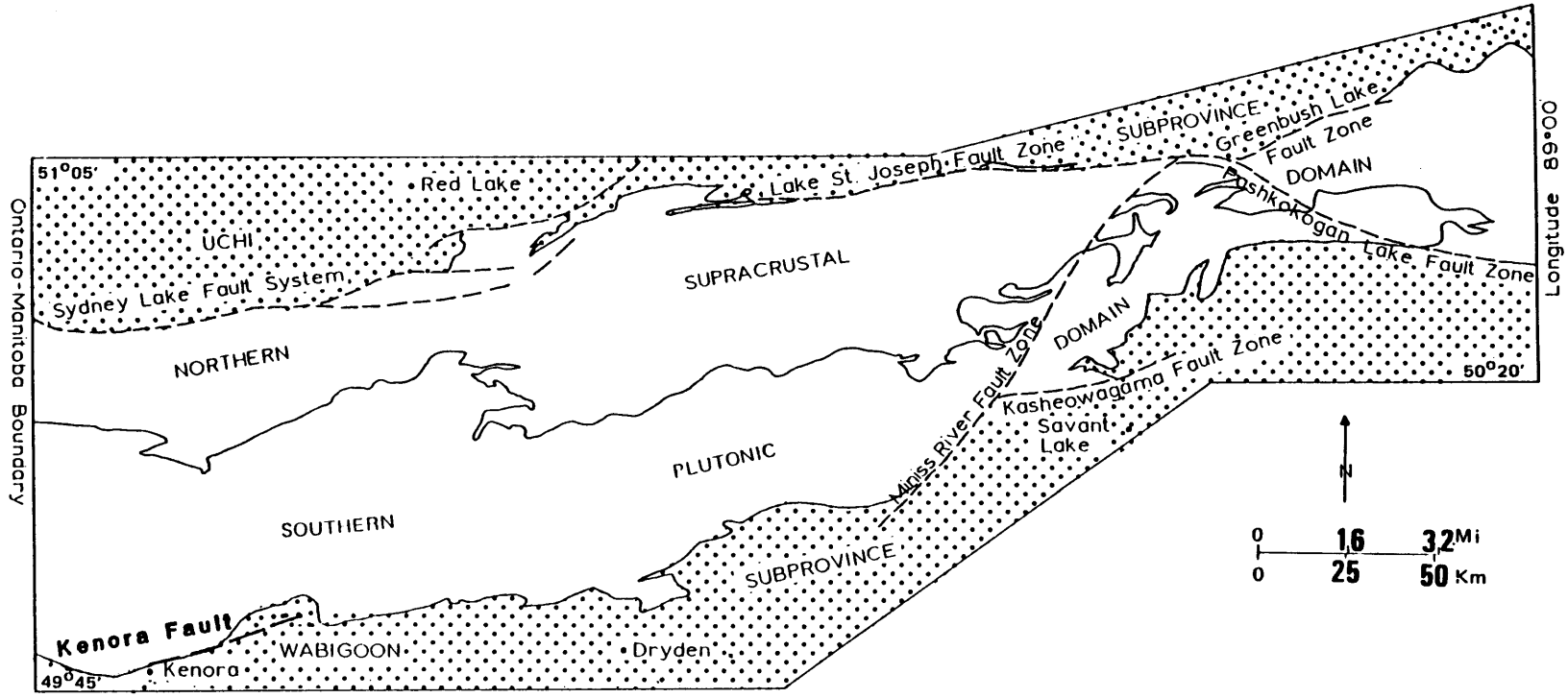


Fig. Distribution of major fault systems in the English River Subprovince and adjoining segments of Uchi and Wabigoon Subprovinces.

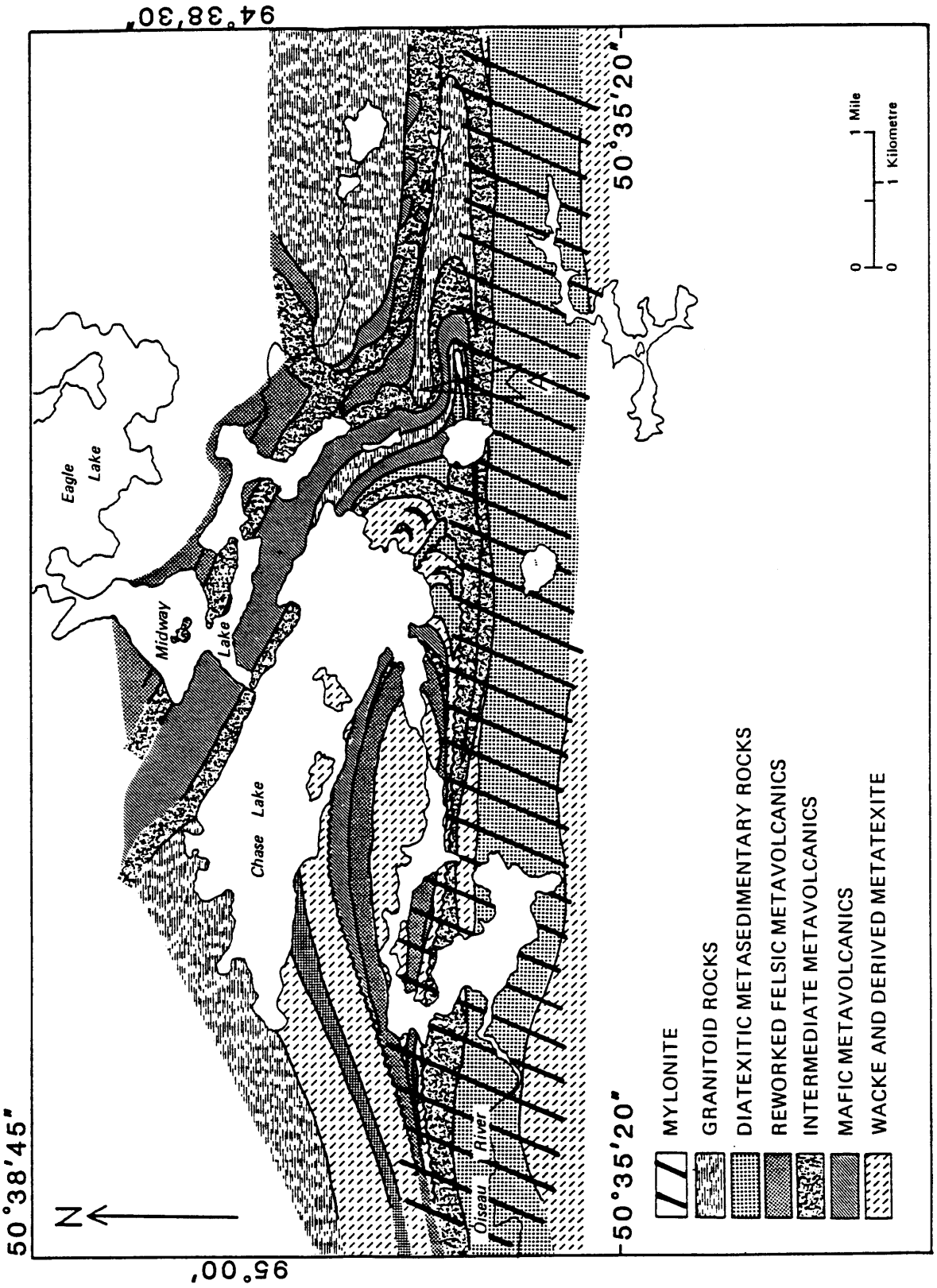


Fig. 15-4 : Geology of the Chase Lake in the vicinity of the Sydney Lake Fault. Mapping by Denver Stone 1976.

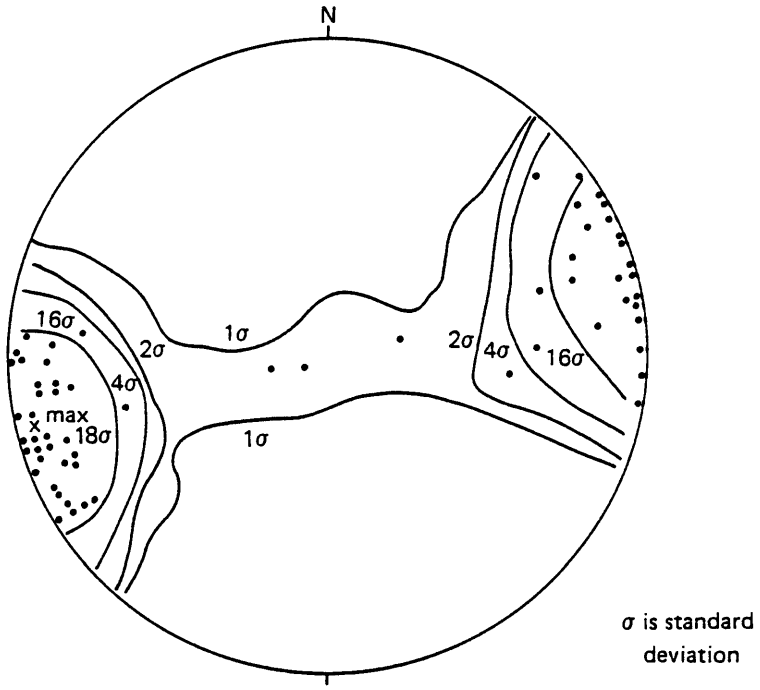


Fig. 15-5 : Contoured equal area plot of slickensides within the Sydney Lake Fault between Sydney Lake and Chase Lake.

This page left blank intentionally.

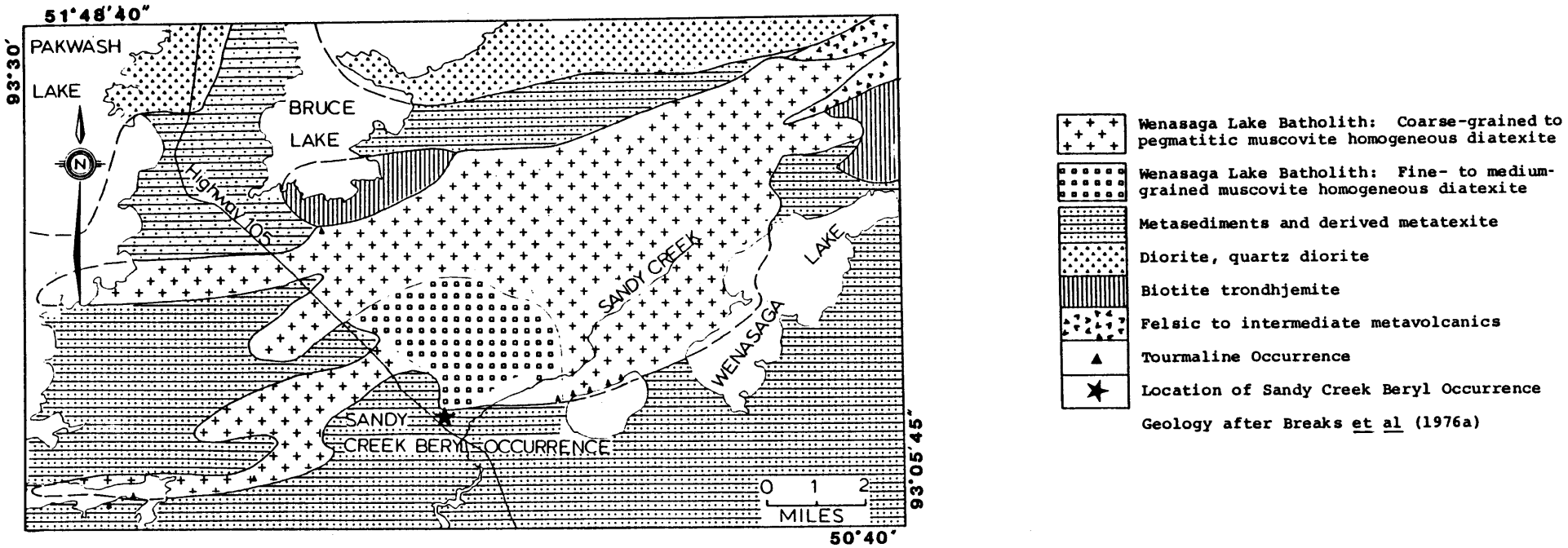


Figure 16-1 General Geology in Vicinity of the Sandy Creek Beryl Pegmatite Occurrence

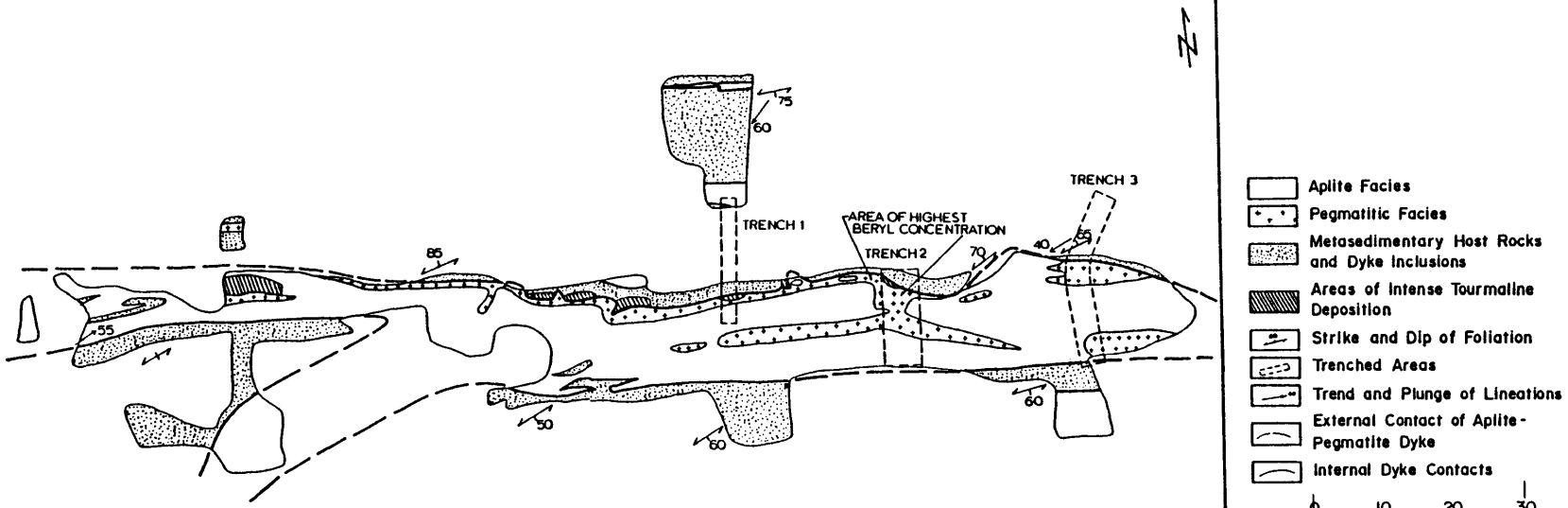


Fig 16-2 Detailed Geology of Beryliferous Pegmatite-Aplite Dyke, near Sandy Creek and Highway 105

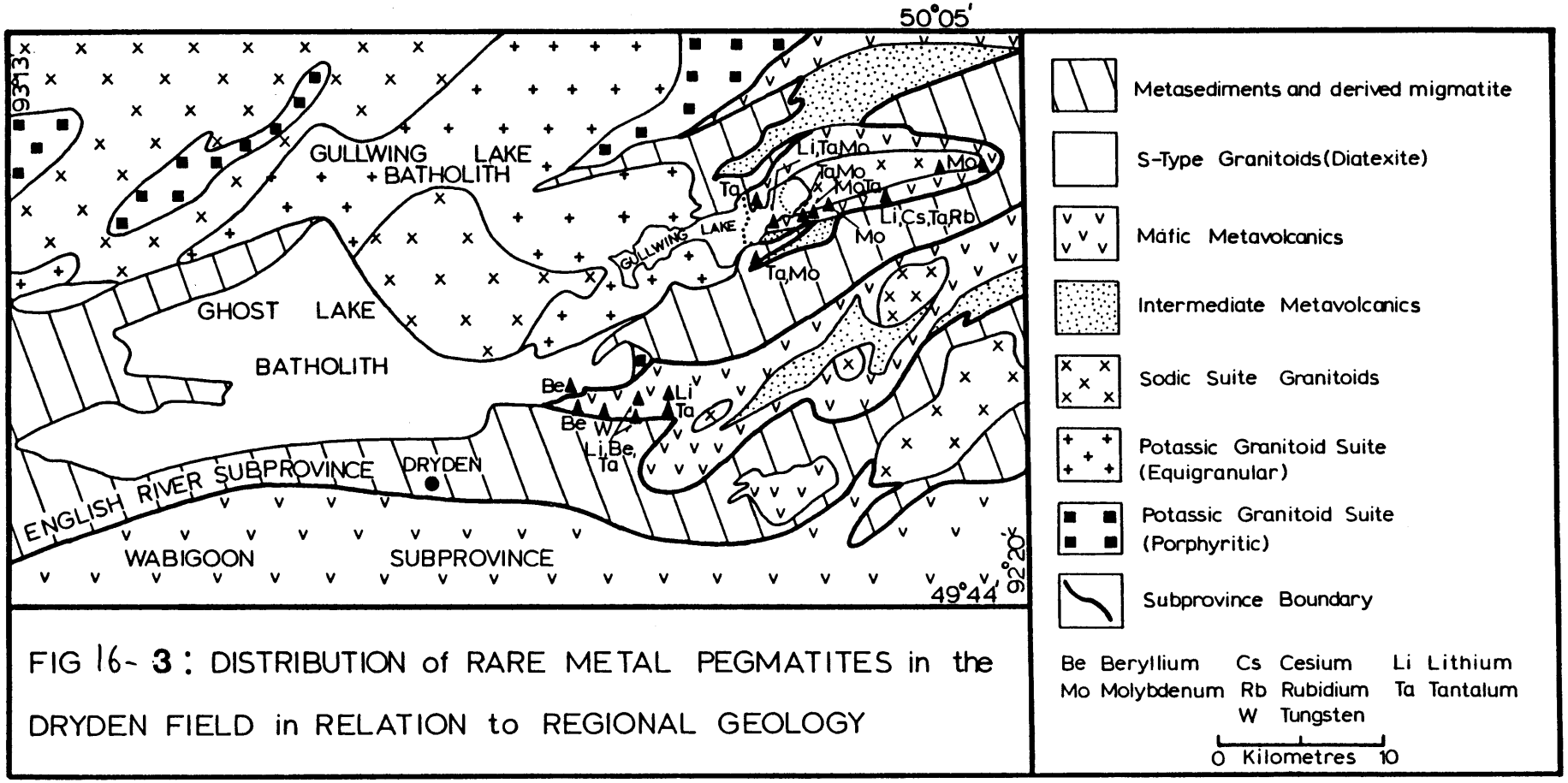
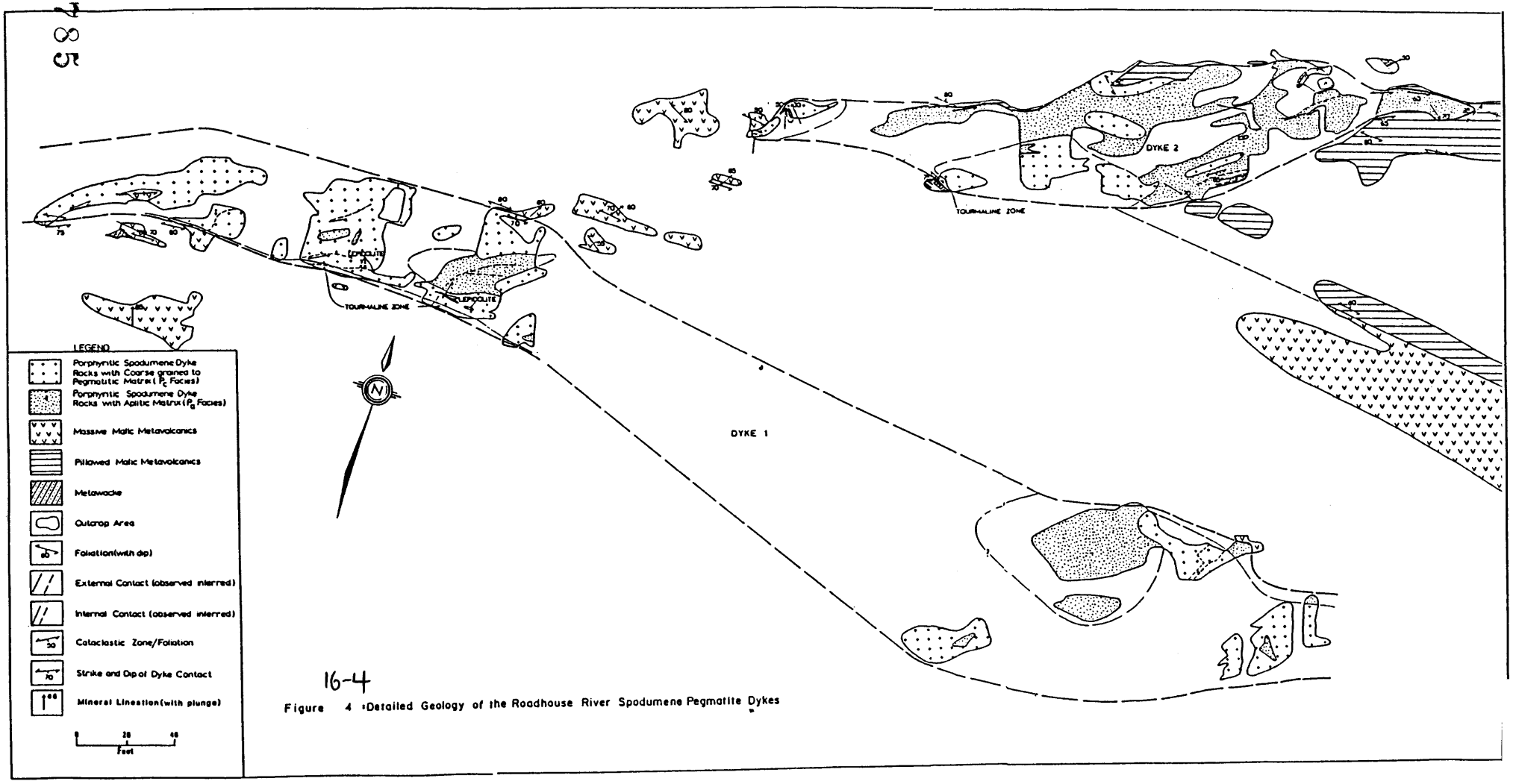
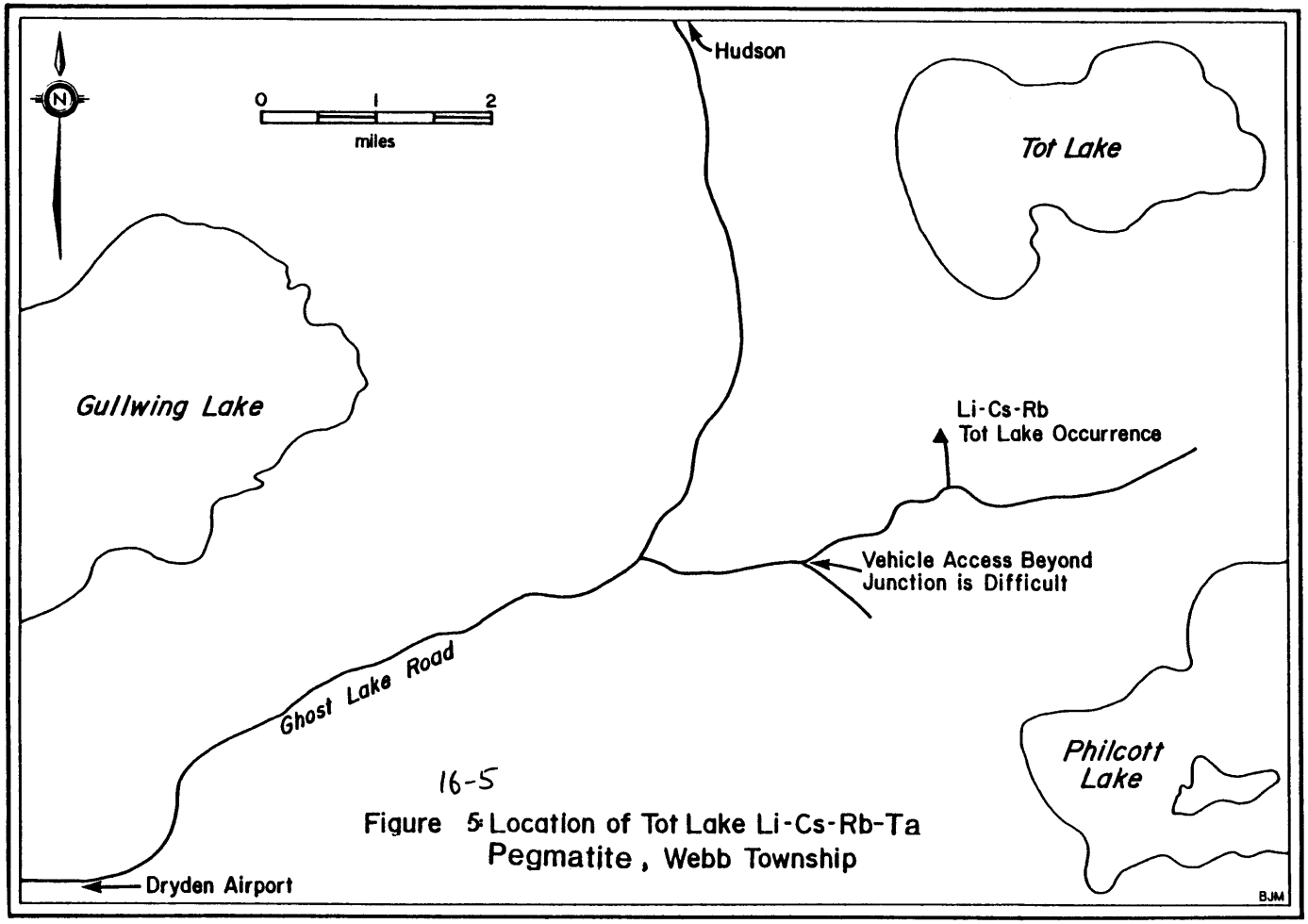


FIG 16- 3 : DISTRIBUTION of RARE METAL PEGMATITES in the DRYDEN FIELD in RELATION to REGIONAL GEOLOGY



16-4

Figure 4 :Detailed Geology of the Roadhouse River Spodumene Pegmatite Dykes



16-5

Figure 5 Location of Tot Lake Li-Cs-Rb-Ta Pegmatite, Webb Township

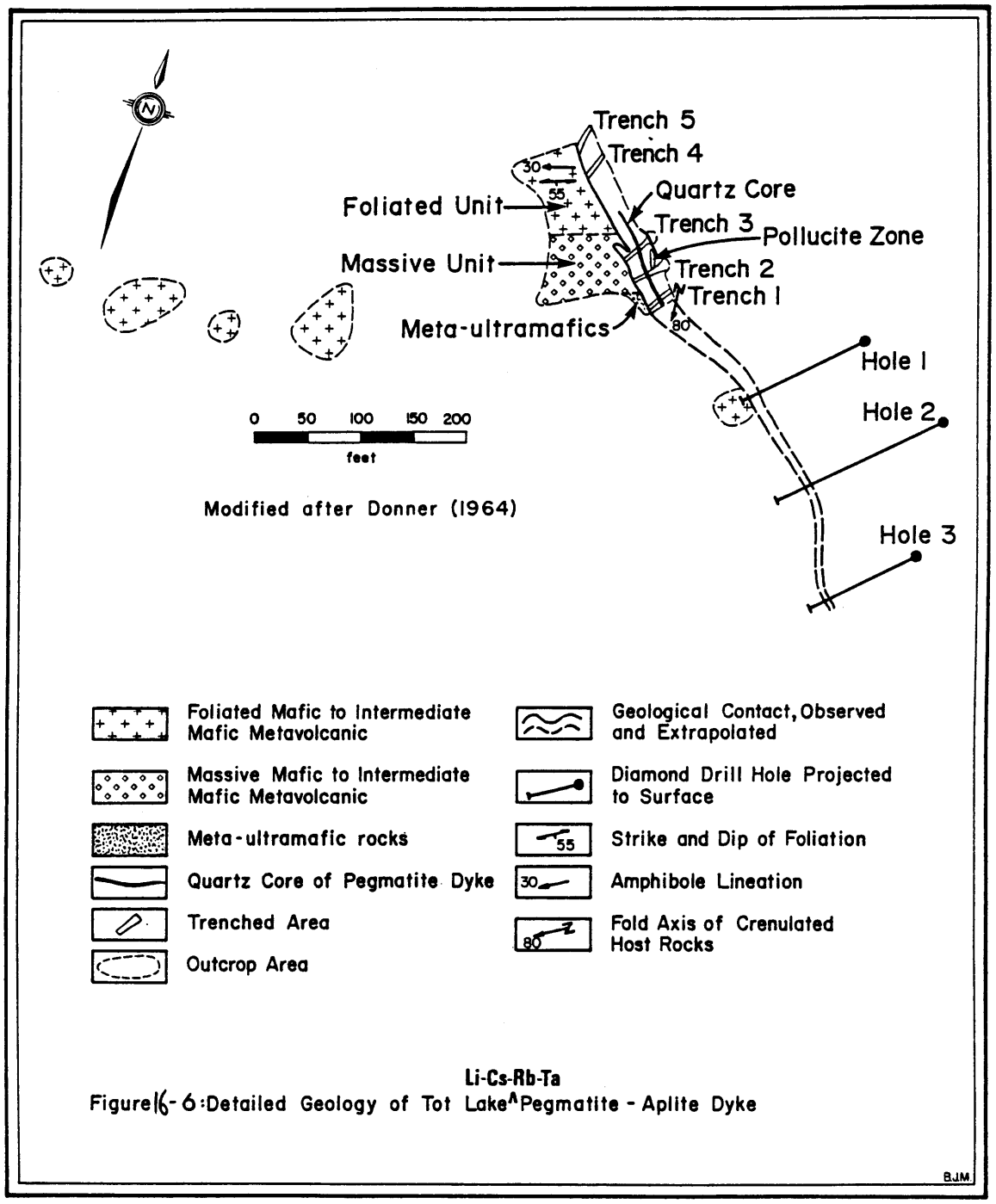


Figure 16-6: Detailed Geology of Tot Lake Li-Cs-Rb-Ta Pegmatite - Aplite Dyke

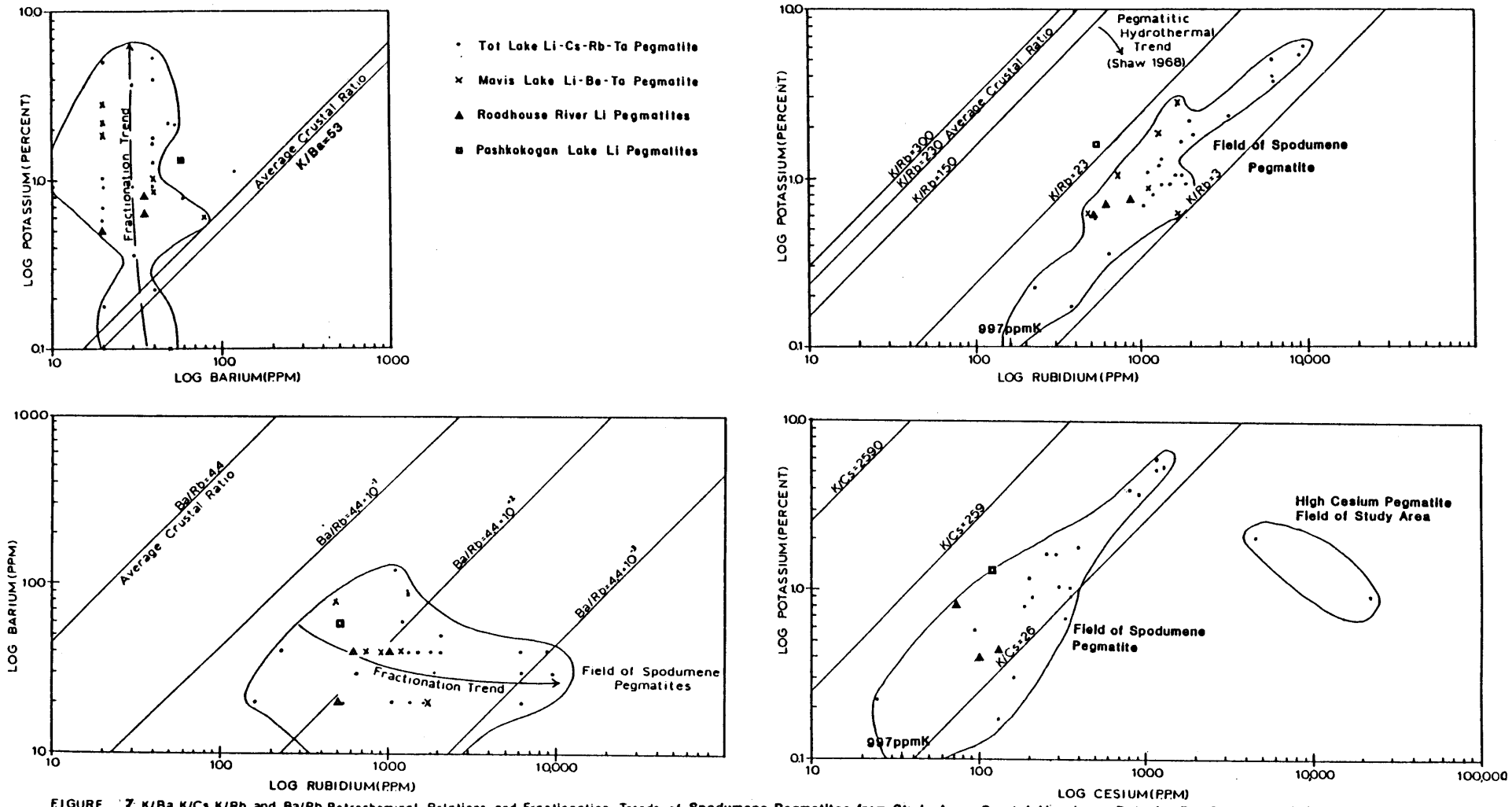


FIGURE 7: K/Ba, K/Cs, K/Rb, and Ba/Rb Petrochemical Relations and Fractionation Trends of Spodumene Pegmatites from Study Area. Crustal Abundance Data for Ba, Cs, K and Rb from Table 14-1A.

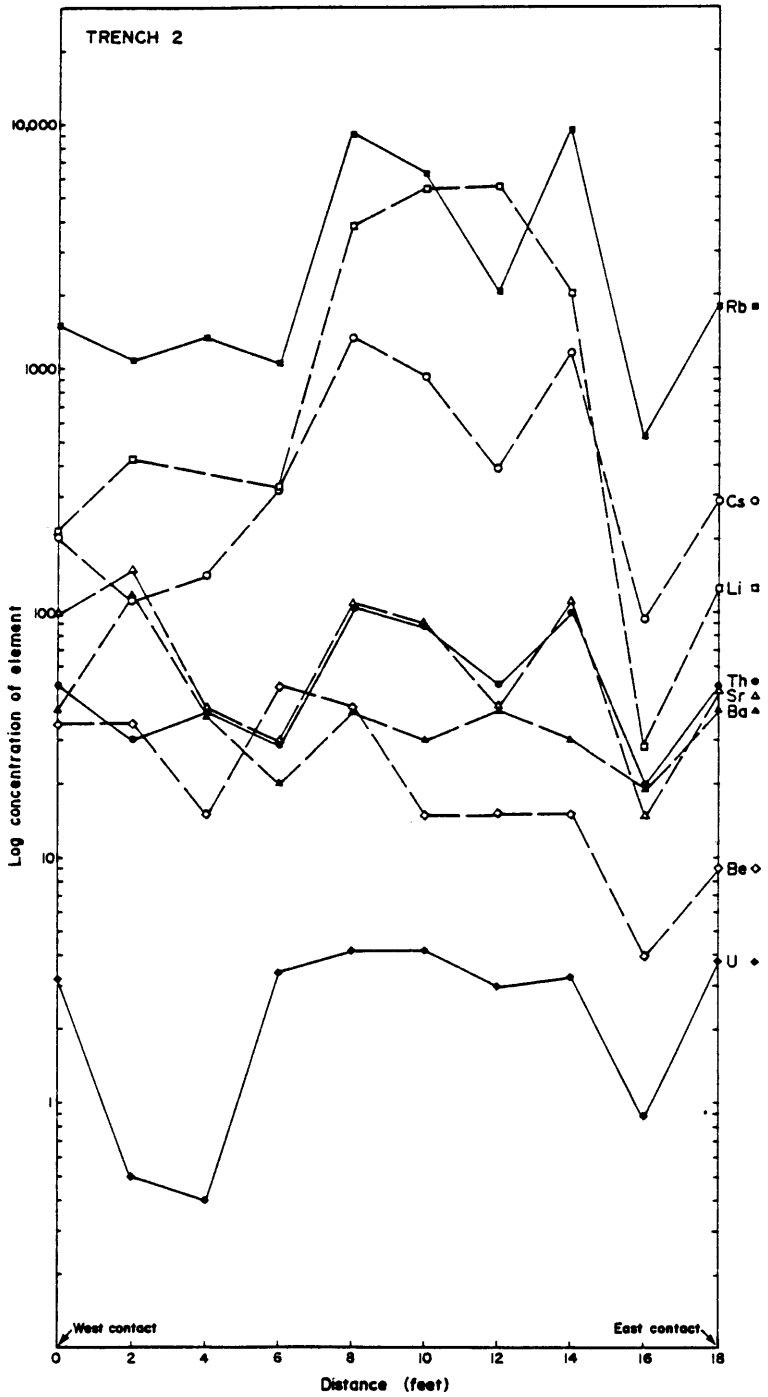


Figure 16- 8 :Profiles of Ba, Be, Cs, Li, Rb, Sr, Th, and U Variation in Trench 2 Tot Lake Li-Cs-Rb-Ta Occurrence

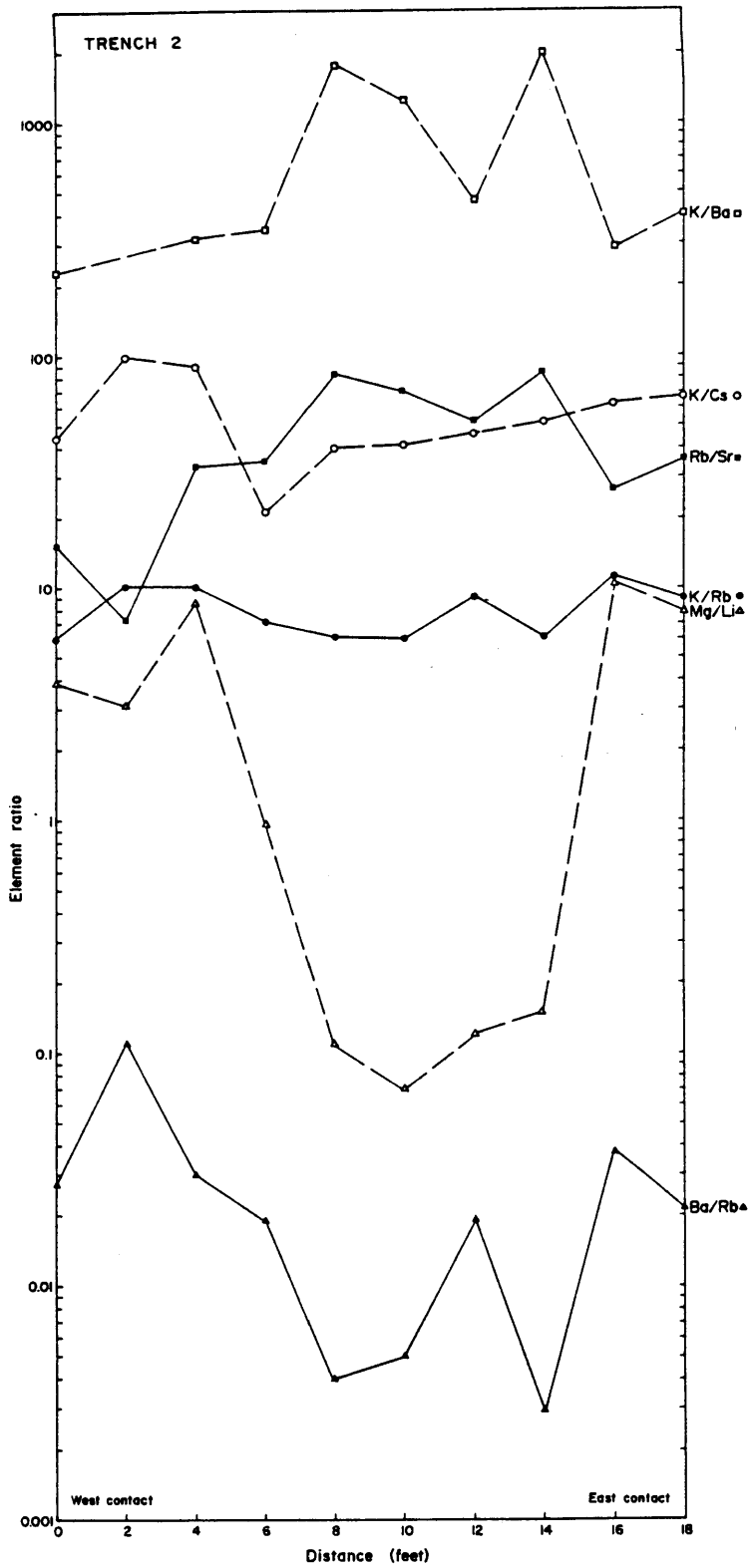


Figure 16-9 :Profiles of K/Ba, Rb/Sr, K/Cs, K/Rb, Mg/Li, and Ba/Rb Variations in Trench 2 Tot Lake Li-Cs-Rb-Ta Occurrence

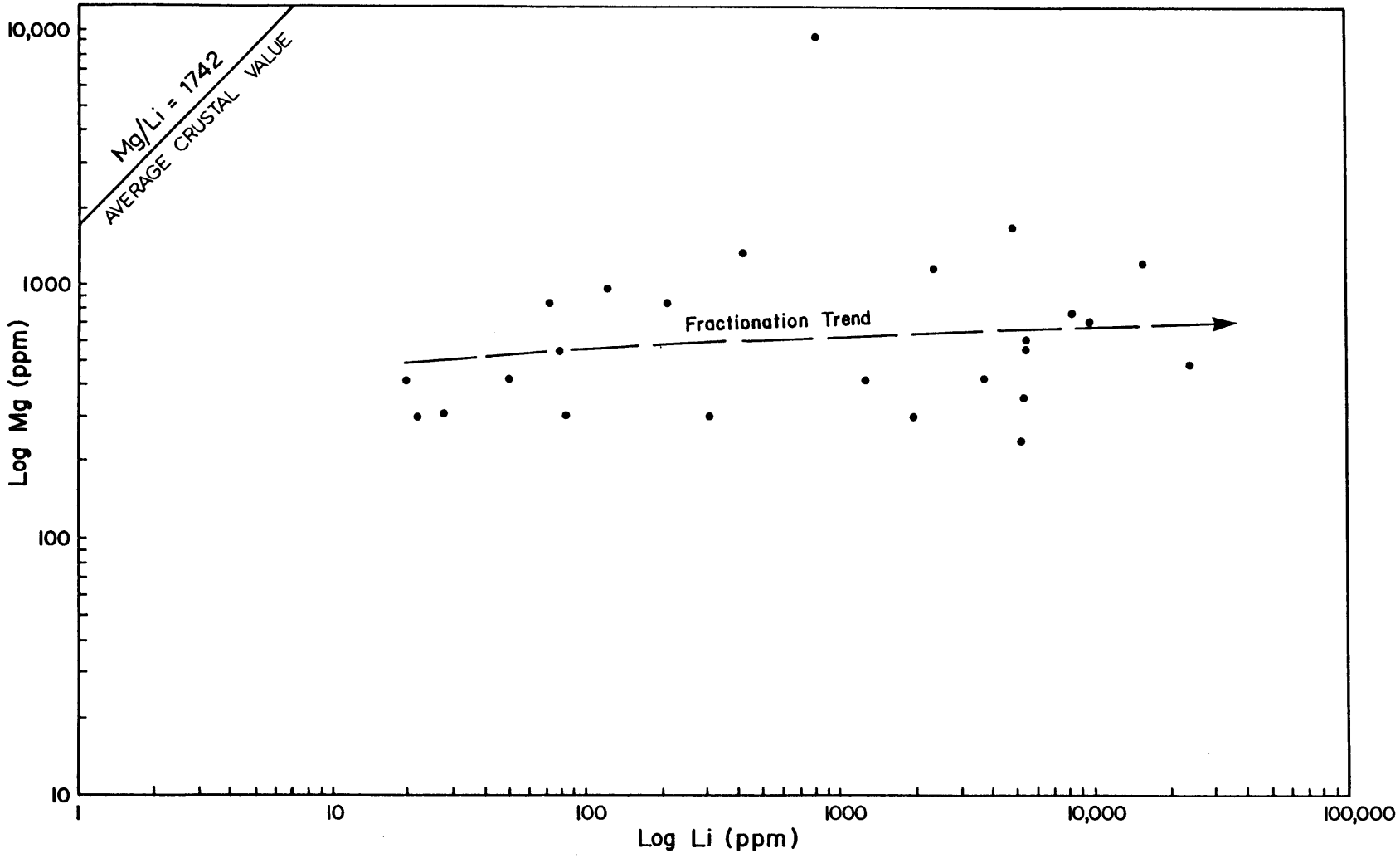


Fig. 16-10 : Li-Mg Relationships in Tot Lake Li-Cs-Rb Occurrence

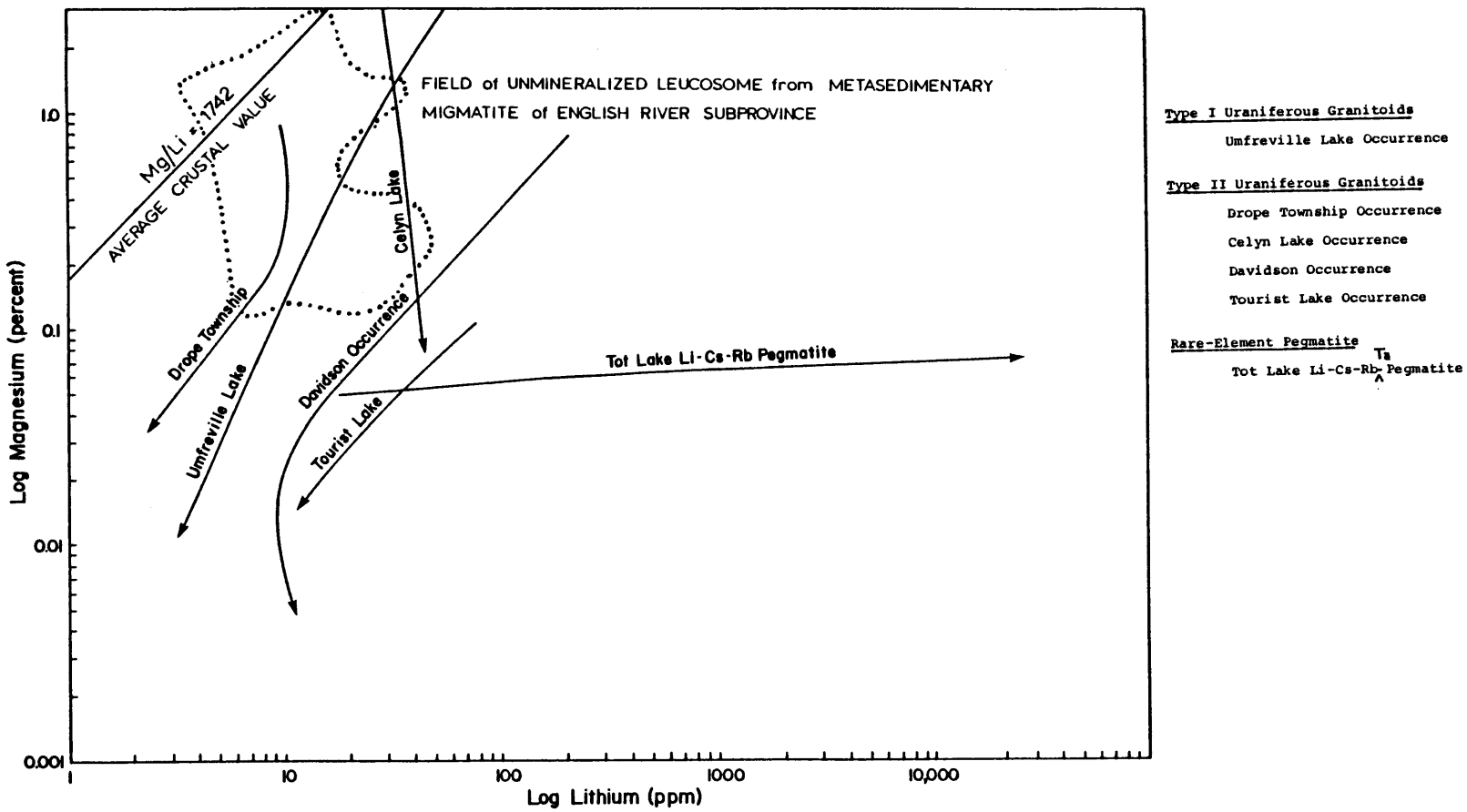


Figure 11. Comparison of Mg-Li Fractionation Patterns in Uranium and Spodumene Pegmatites

16-11

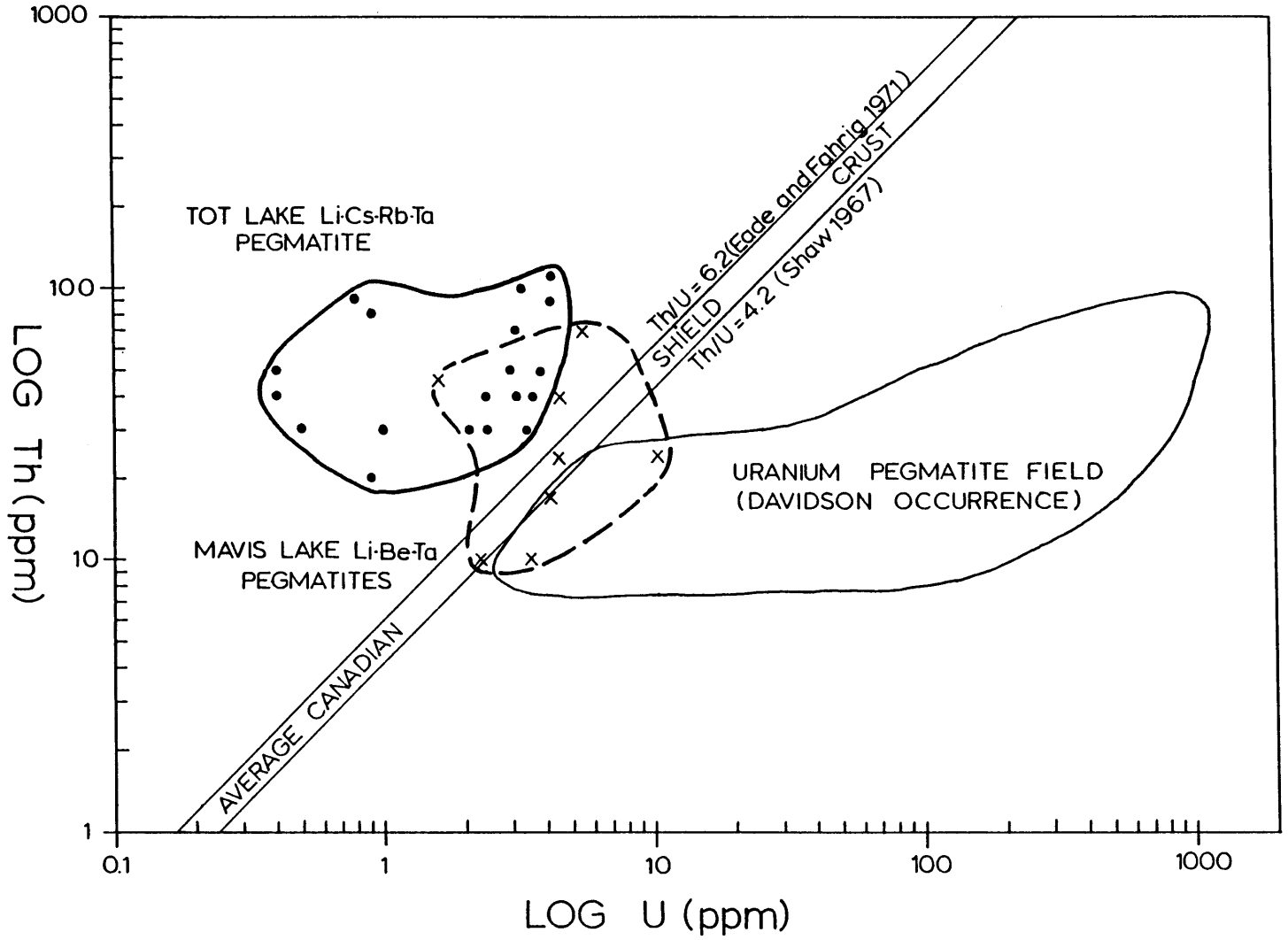


Figure 16 - 12 : Th-U Relations in Tot and Mavis Lakes Rare-Element Pegmatites and Comparison to a Uranium-Rich Pegmatite

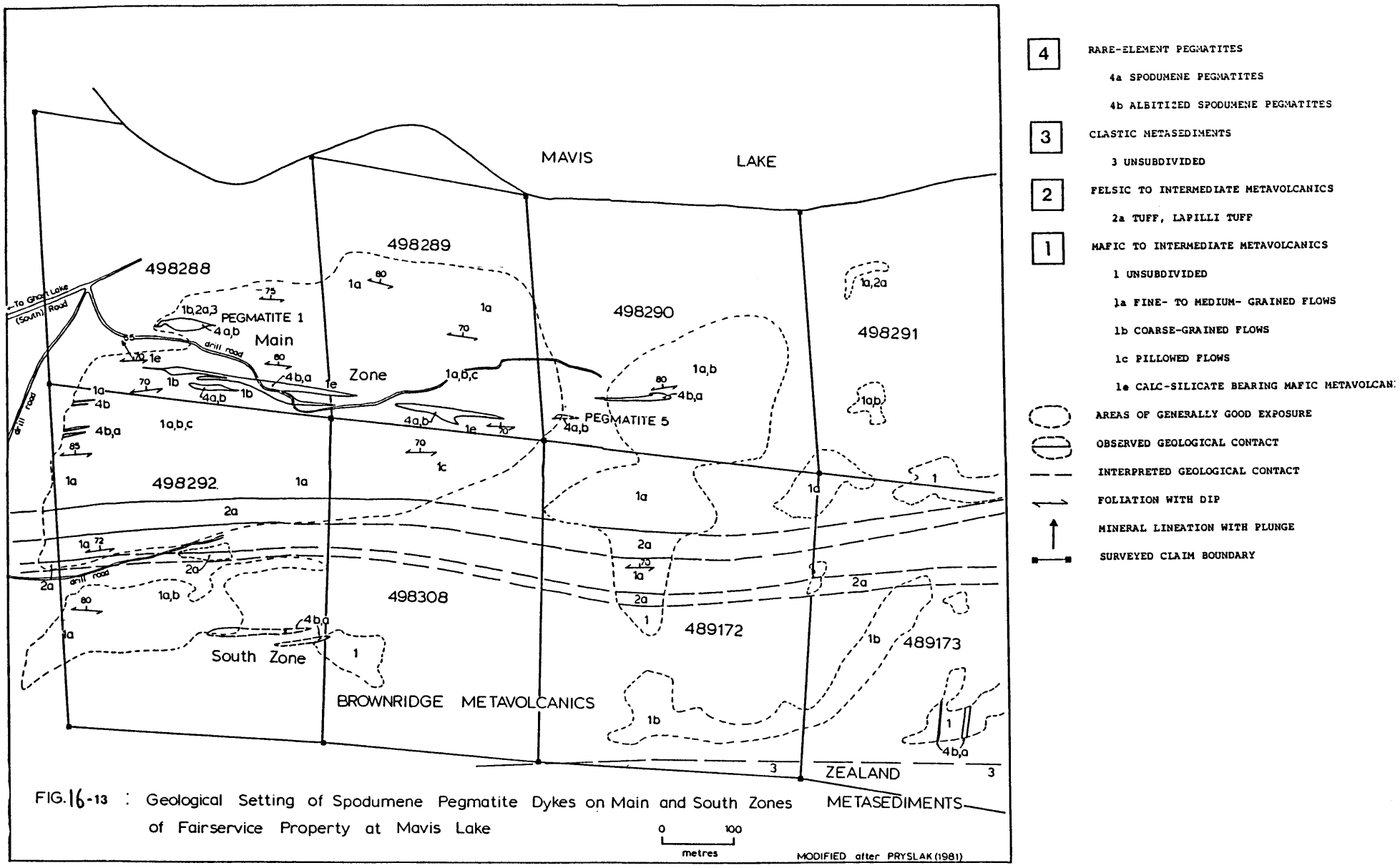


FIG. 16-13 : Geological Setting of Spodumene Pegmatite Dykes on Main and South Zones of Fairservice Property at Mavis Lake

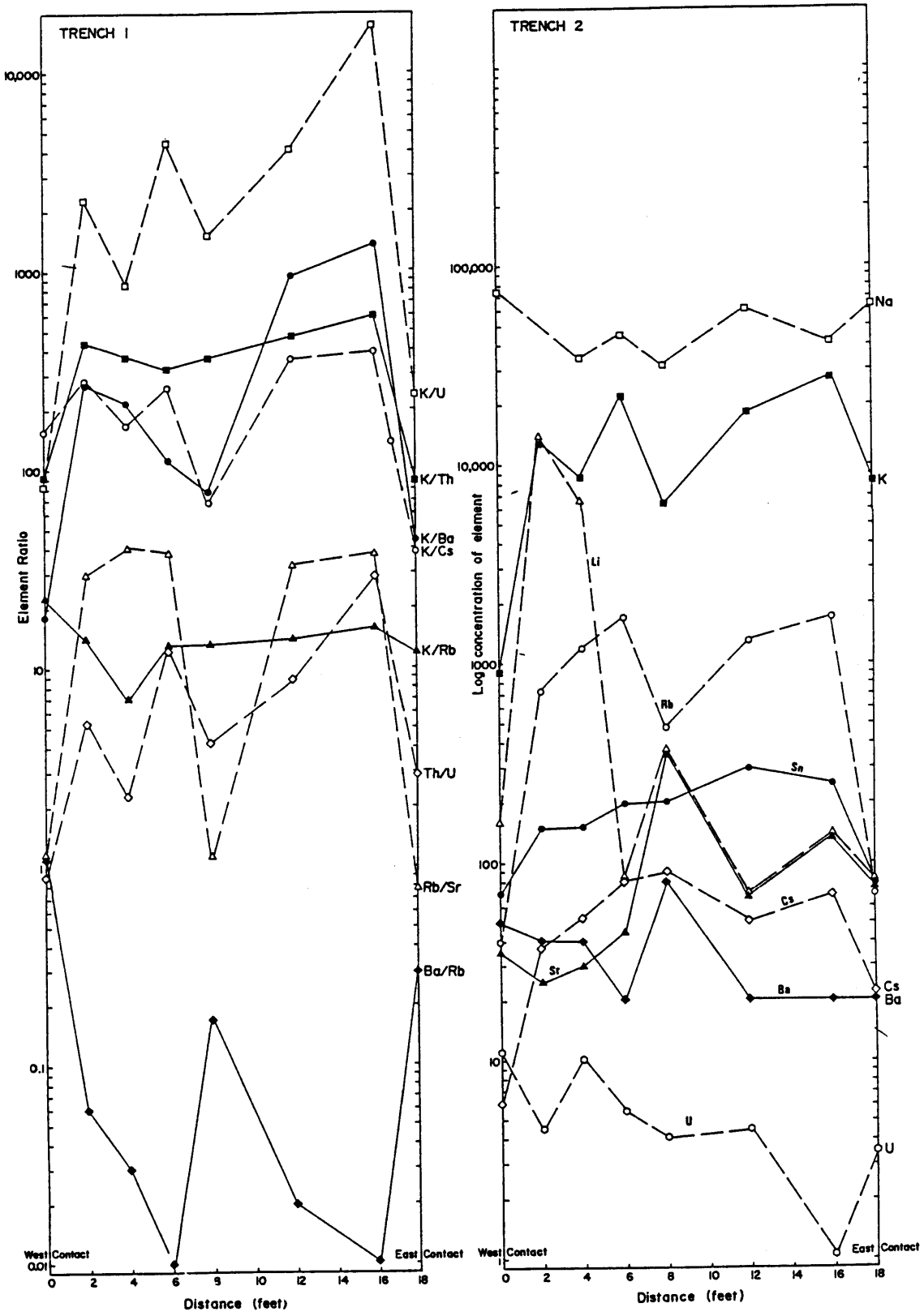


Fig. 16-14: K/Ba, K/Cs, K/Rb, K/Th, K/U, Th/U, Ba/Rb, Rb/Sr, and Ba, Cs, K, Li, Na, Rb, Sn, Sr, and U Petrochemical Variation Profiles across Mavis Lake

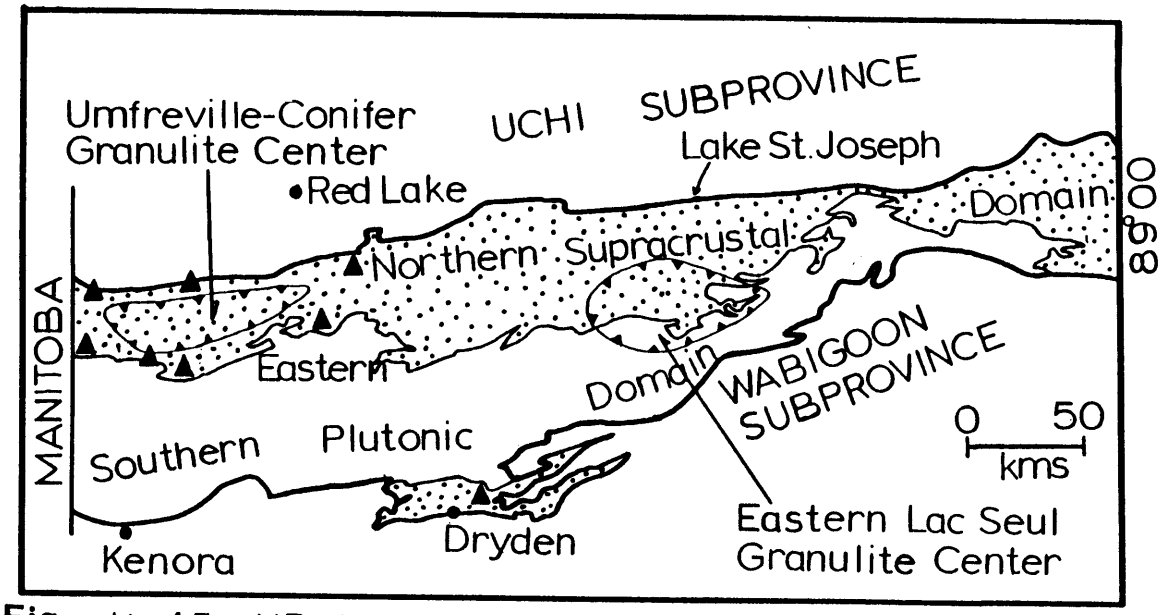


Fig. 16-15 URANIUM MINERALIZATION ASSOCIATED WITH METASEDIMENTARY MIGMATITE

▲ TYPE I URANIUM OCCURRENCE

METASEDIMENTS + DERIVED MIGMATITE

ORTHOPYROXENE ISOGRAD

SUBPROVINCE BOUNDARY

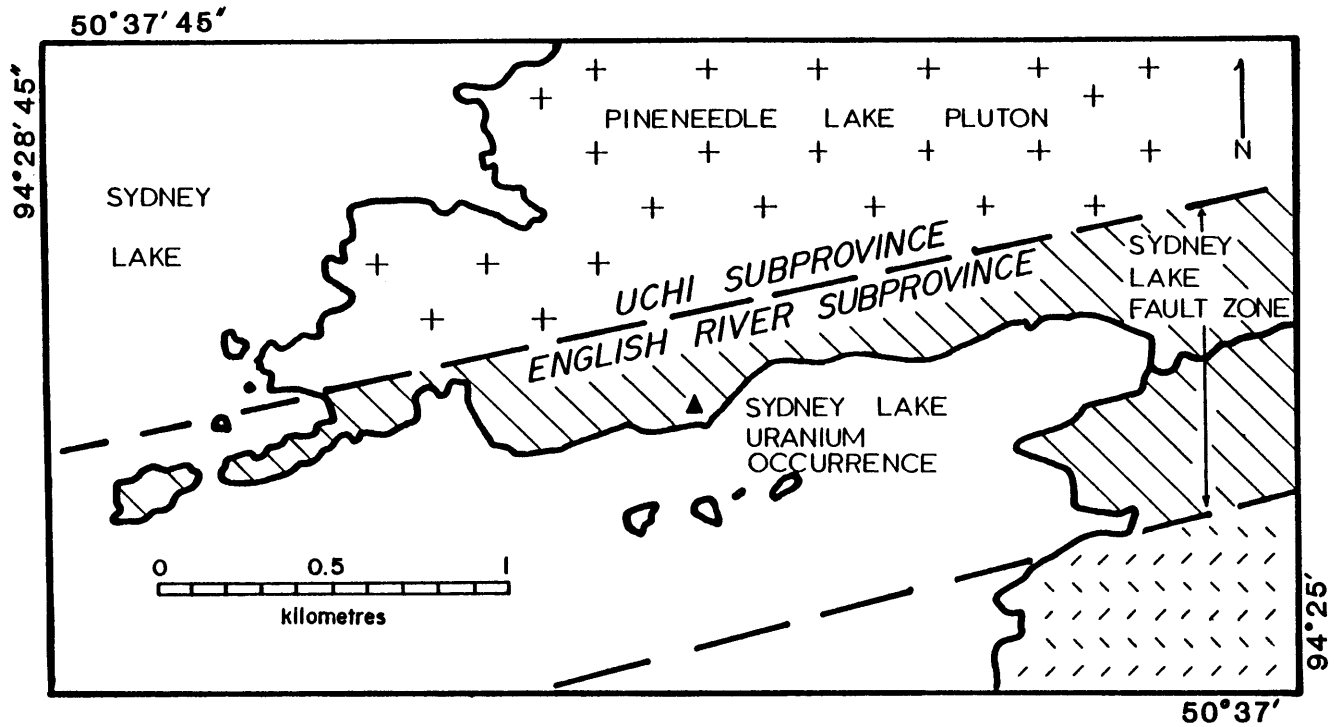
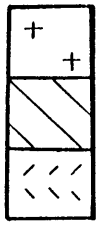


FIGURE 16-16 GEOLOGICAL SETTING OF SYDNEY LAKE URANIUM OCCURRENCE



MASSIVE LEUCOCRATIC BIOTITE QUARTZ MONZONITE
(PINENEEDLE LAKE PLUTON)

CATACLASTIC METASEDIMENTARY MIGMATITE
(SYDNEY LAKE FAULT ZONE)

METATEXITIC METASEDIMENTARY MIGMATITE
(GENERALLY NON-CATACLASTIC)

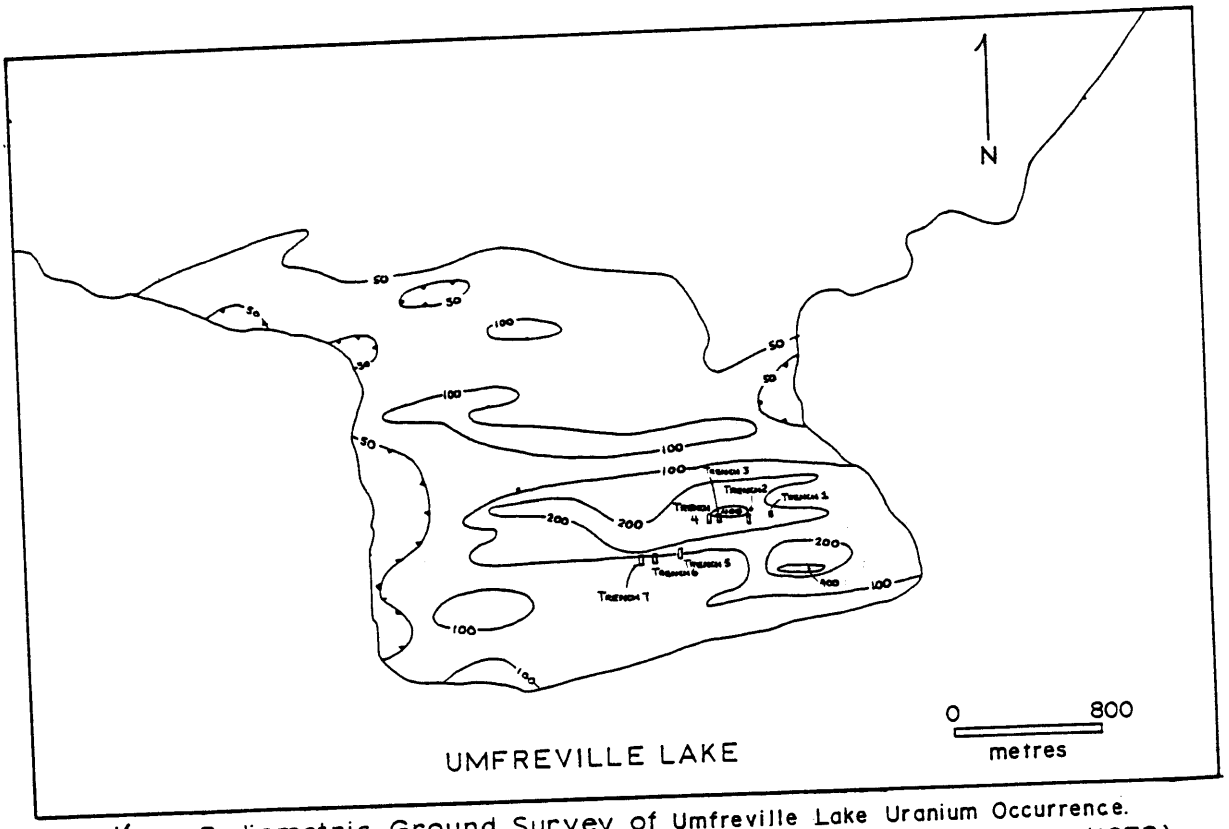


Fig. 16-17 : Radiometric Ground Survey of Umfreville Lake Uranium Occurrence. Based Upon Assessment Work by Noranda Mines Limited (1976). Contours Represent Radiometric Measurements in Total Counts Per Second With Exploranium Scintillometer Model GRS-101.

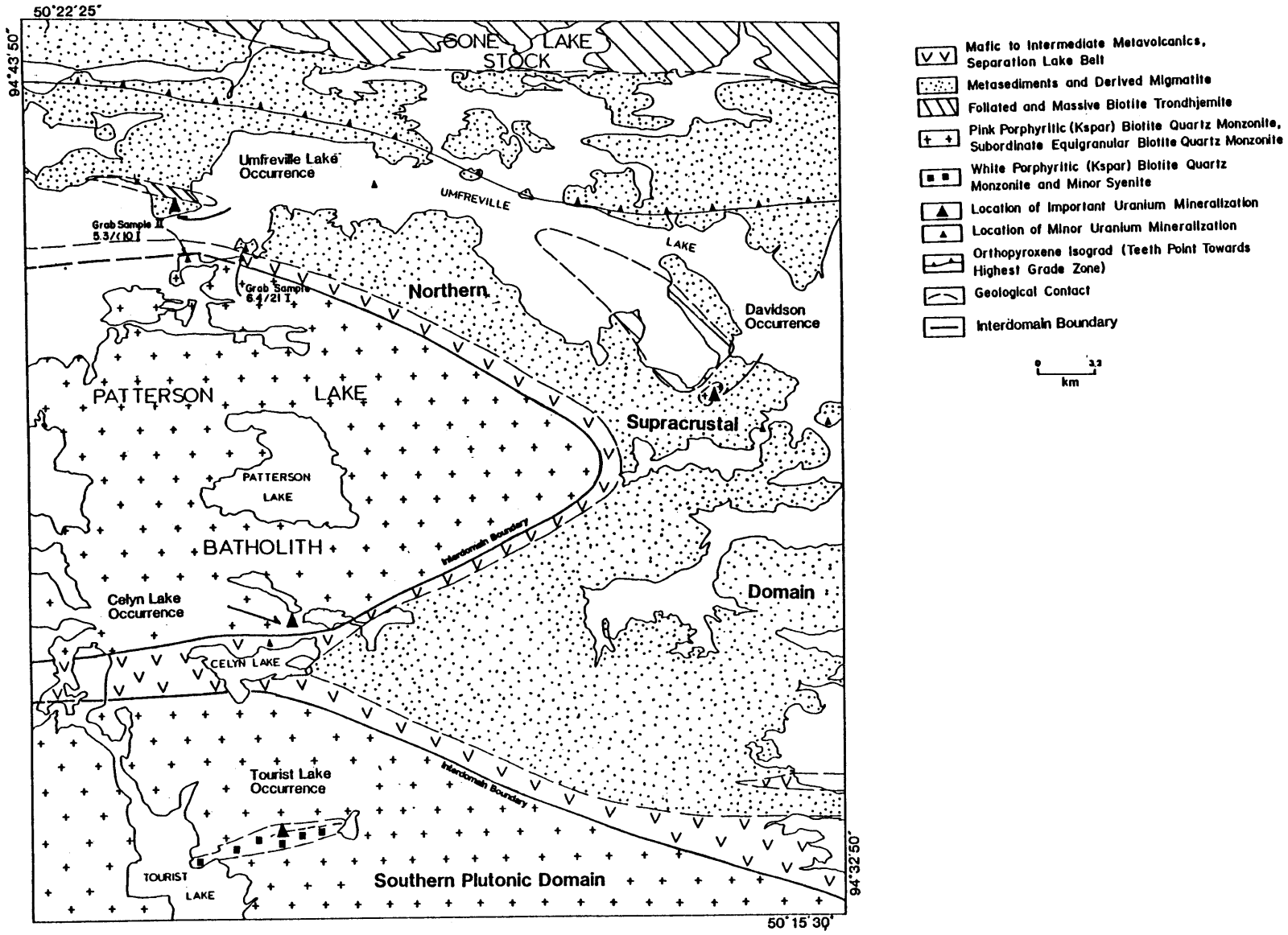


Fig. 18 : General Geology and Uranium Mineralization in Umfreville - Tourist Lake Area, English River Subprovince in Vicinity of Interdomain Boundary

16-18

799

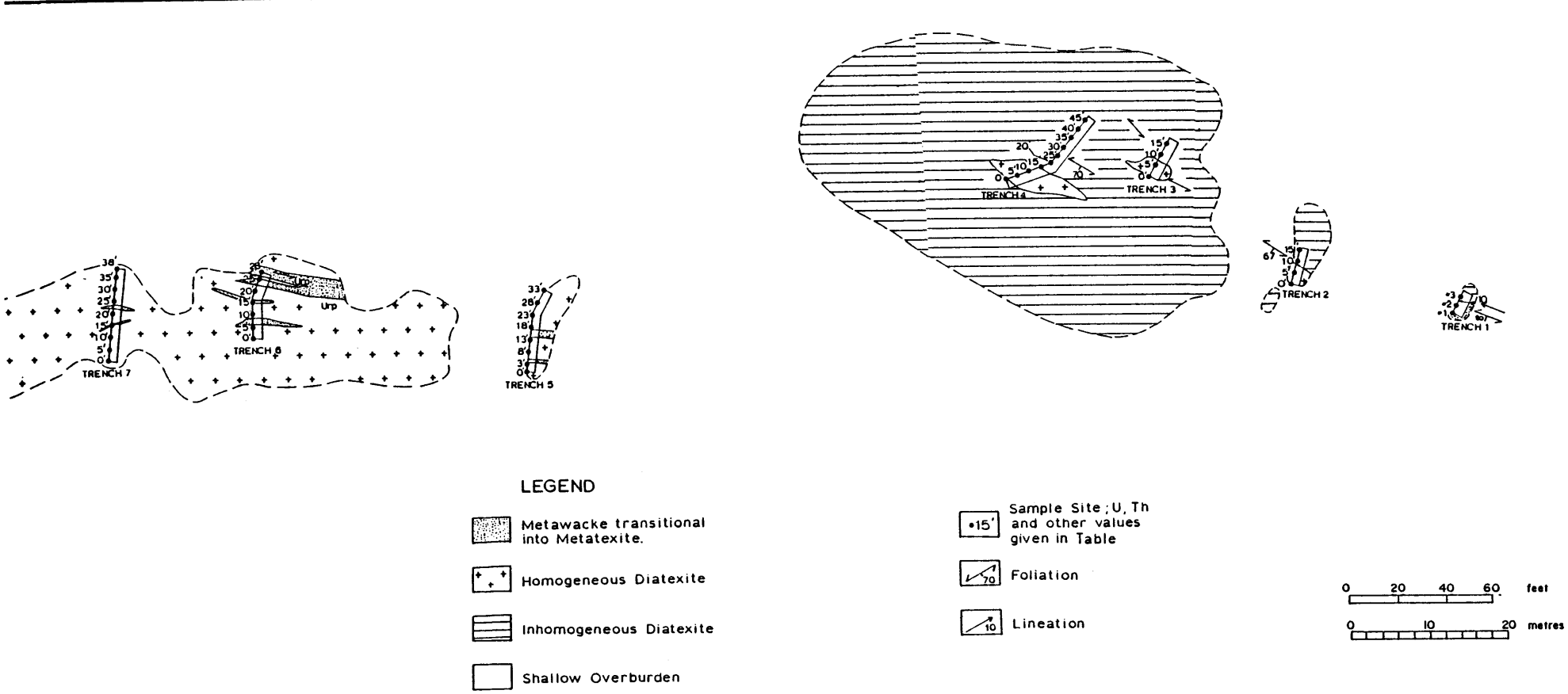


FIGURE 16-19: DETAILED GEOLOGY AND LOCATION OF TRENCHES' AND GEOCHEMISTRY SAMPLES AT UMFREVILLE URANIUM OCCURRENCE.

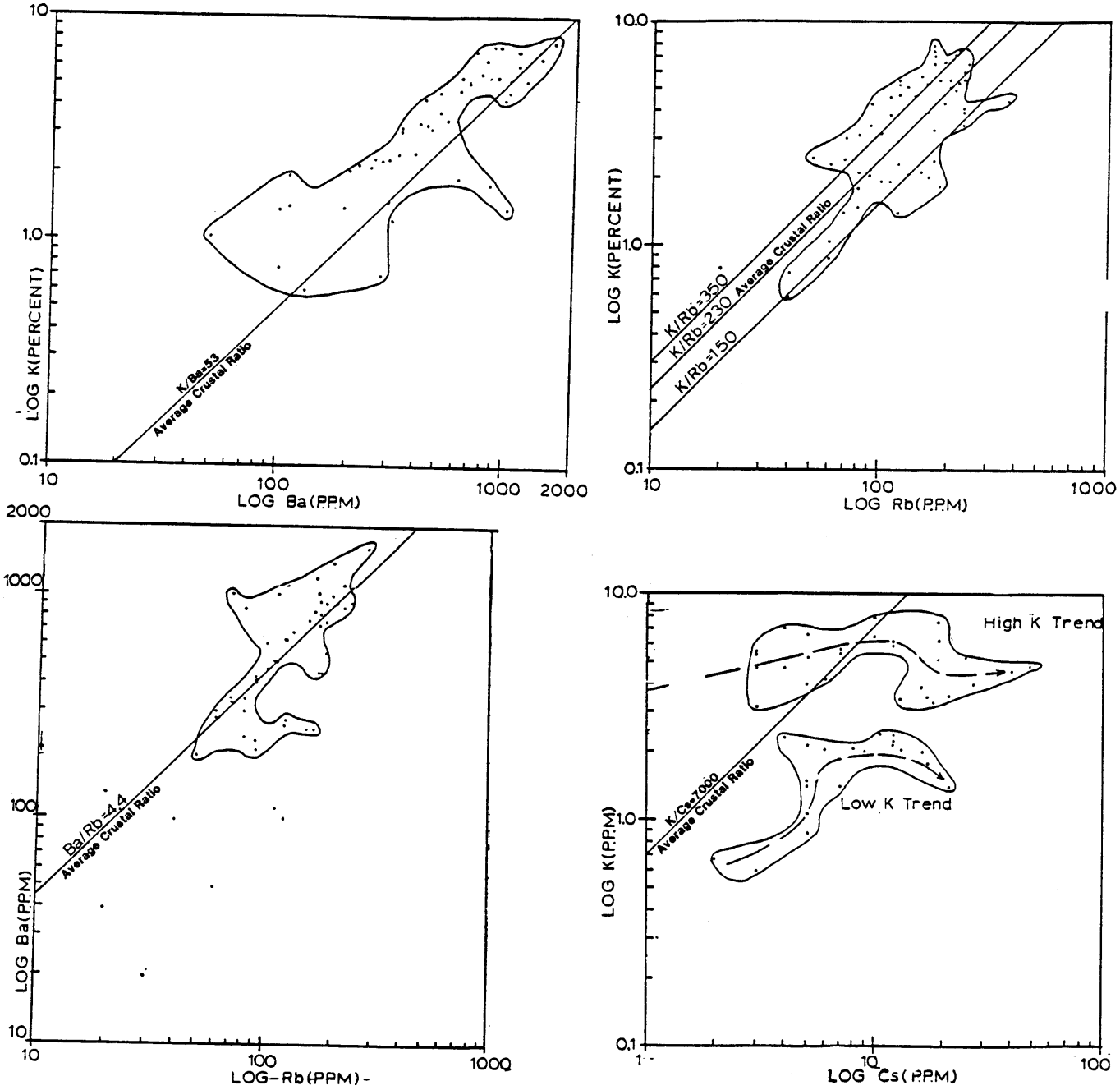


FIGURE 16-20 : K/Ba, K/Cs, K/Rb, Ba/Rb PETROCHEMICAL RELATIONS AT THE UMFREVILLE LAKE OCCURRENCE.

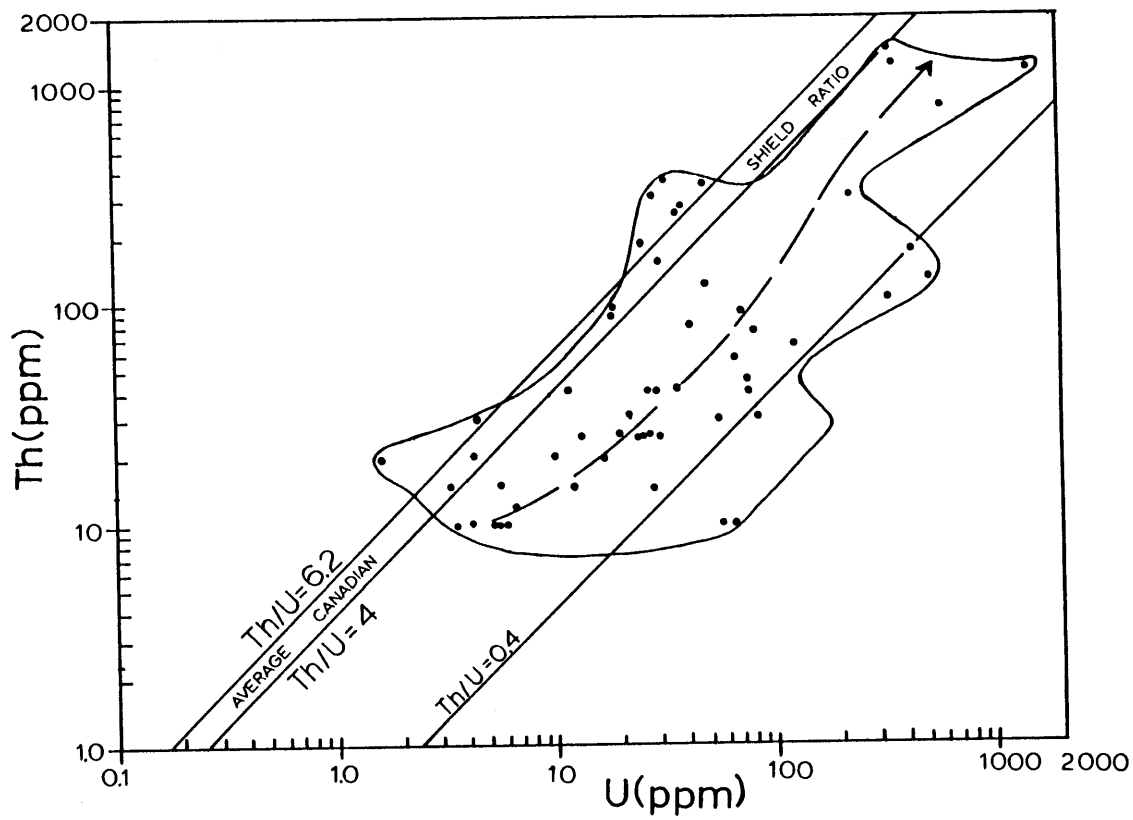


Figure 16-21 : Th-U RELATIONS IN TYPE I MINERALIZATION (UMFREVILLE LAKE OCCURRENCE). AVERAGE CANADIAN SHIELD Th/U RATIOS OF 4 AND 6.2 RESPECTIVELY FROM SHAW ET AL (1976) AND FAHRIG AND EADE (1968).

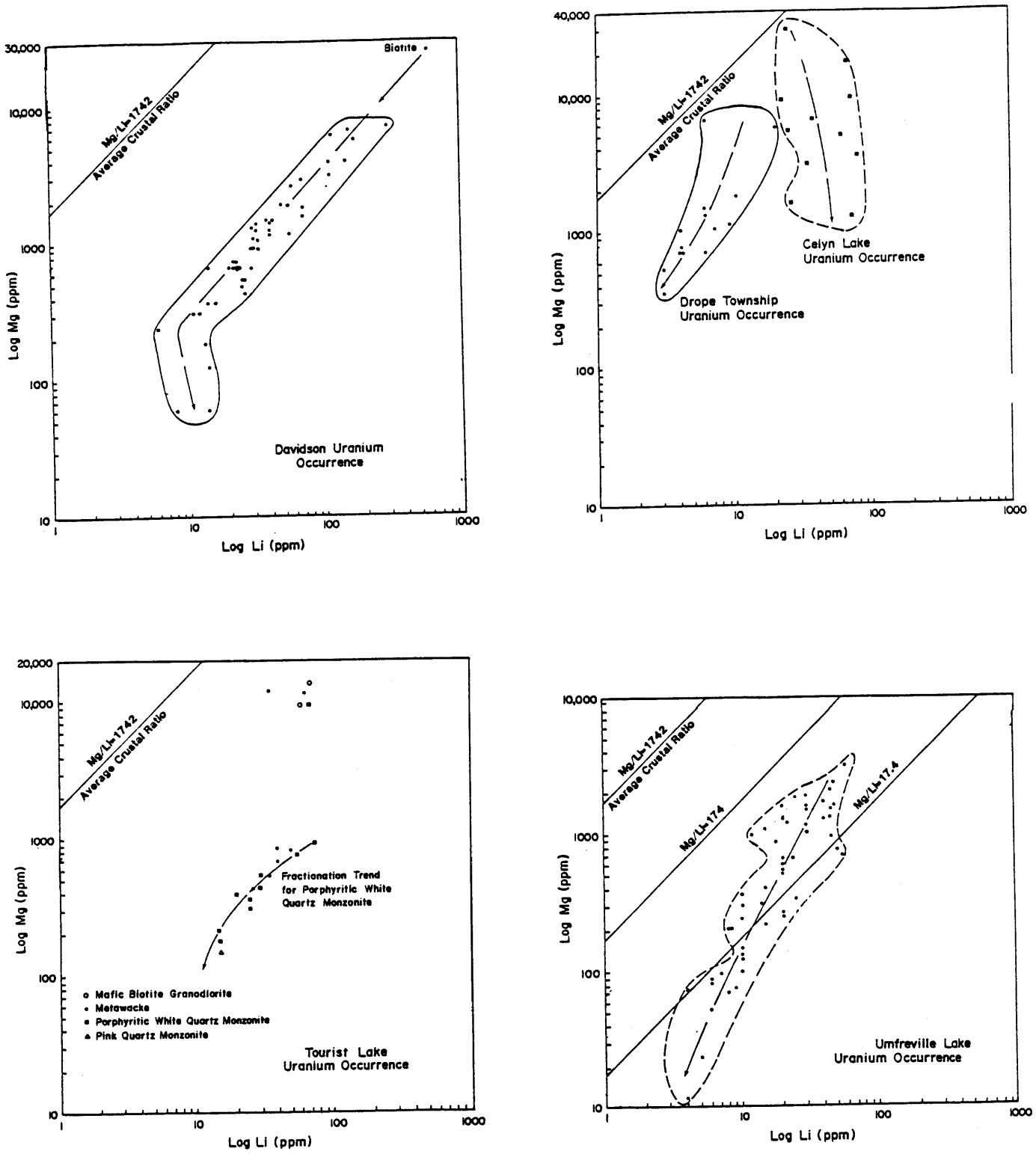


Fig. 16-22 Mg/Li Relations at Celyn Lake, Davidson, Drope Township, Tourist Lake, and Umfreville Lake Uranium Occurrences.

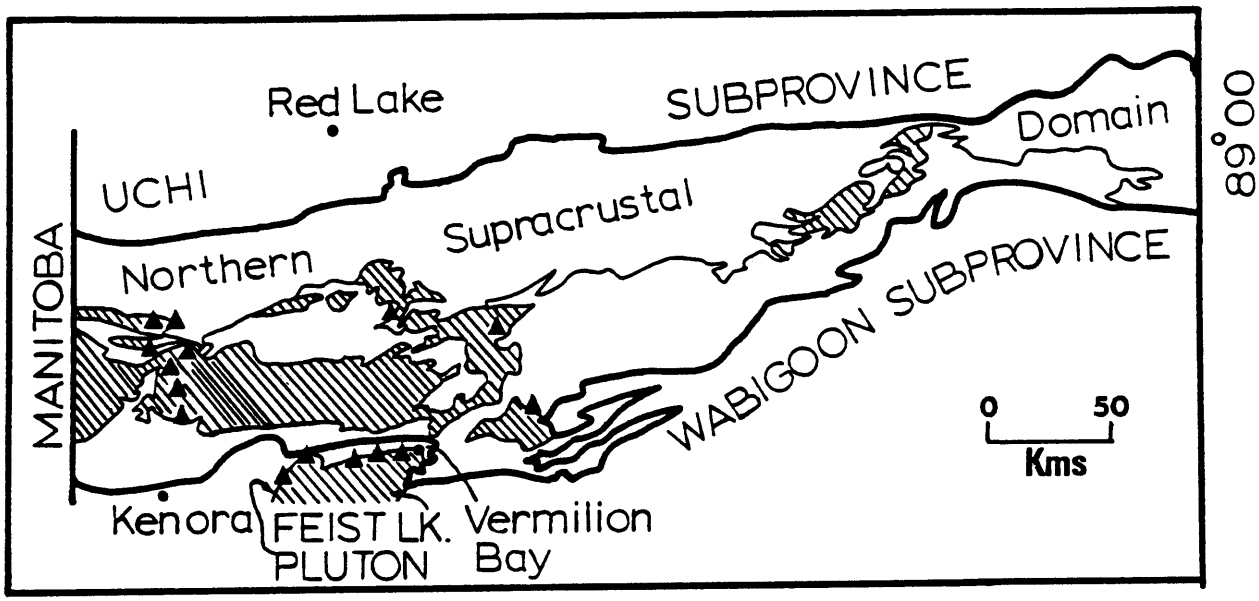


Fig. 16 - 23 : DISTRIBUTION of TYPE II URANIUM MINERALIZATION ASSOCIATED WITH POTASSIC GRANITOID SUITE ROCKS of SOUTHERN PLUTONIC DOMAIN(ENGLISH RIVER SUBPROVINCE) and WABIGOON SUBPROVINCE

▲ TYPE II URANIUM OCCURRENCE

POTASSIC GRANITOID SUITE

SUBPROVINCE BOUNDARY

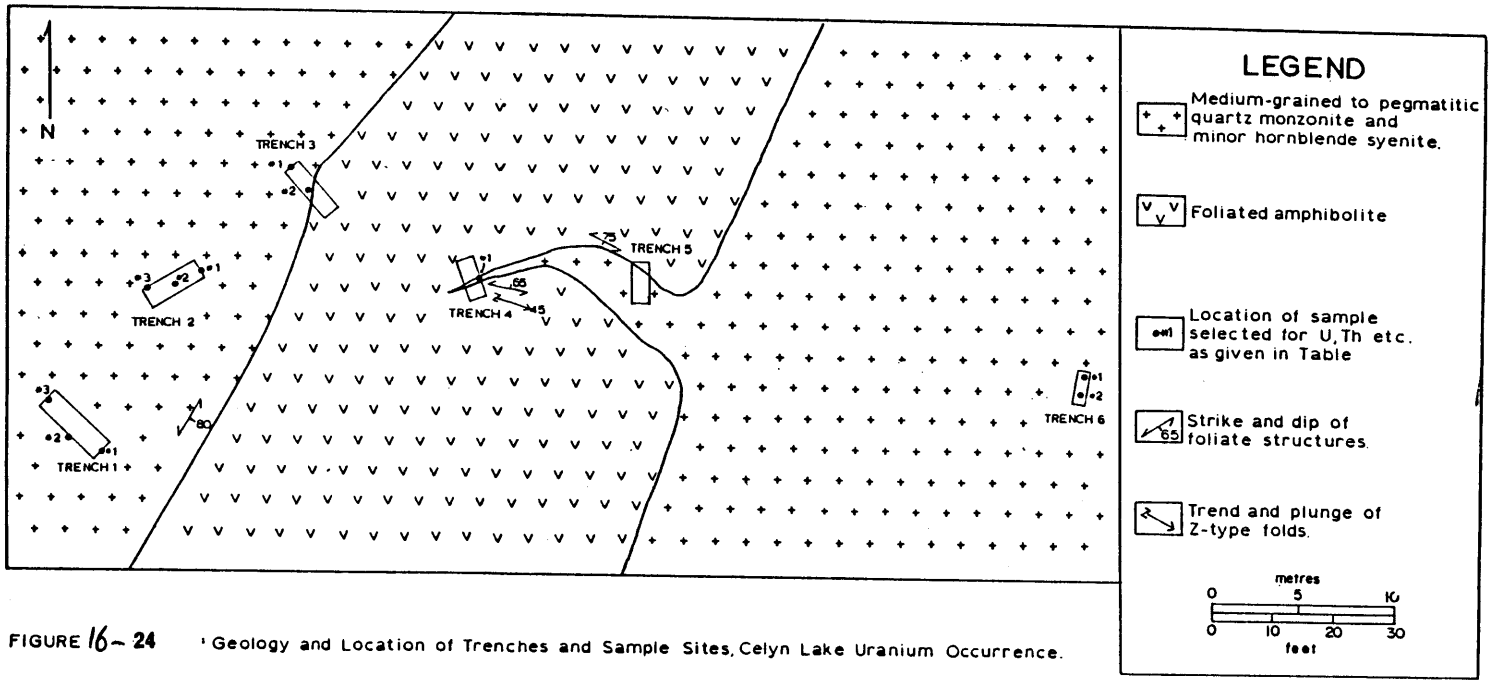


FIGURE 16 – 24 Geology and Location of Trenches and Sample Sites, Celyn Lake Uranium Occurrence.

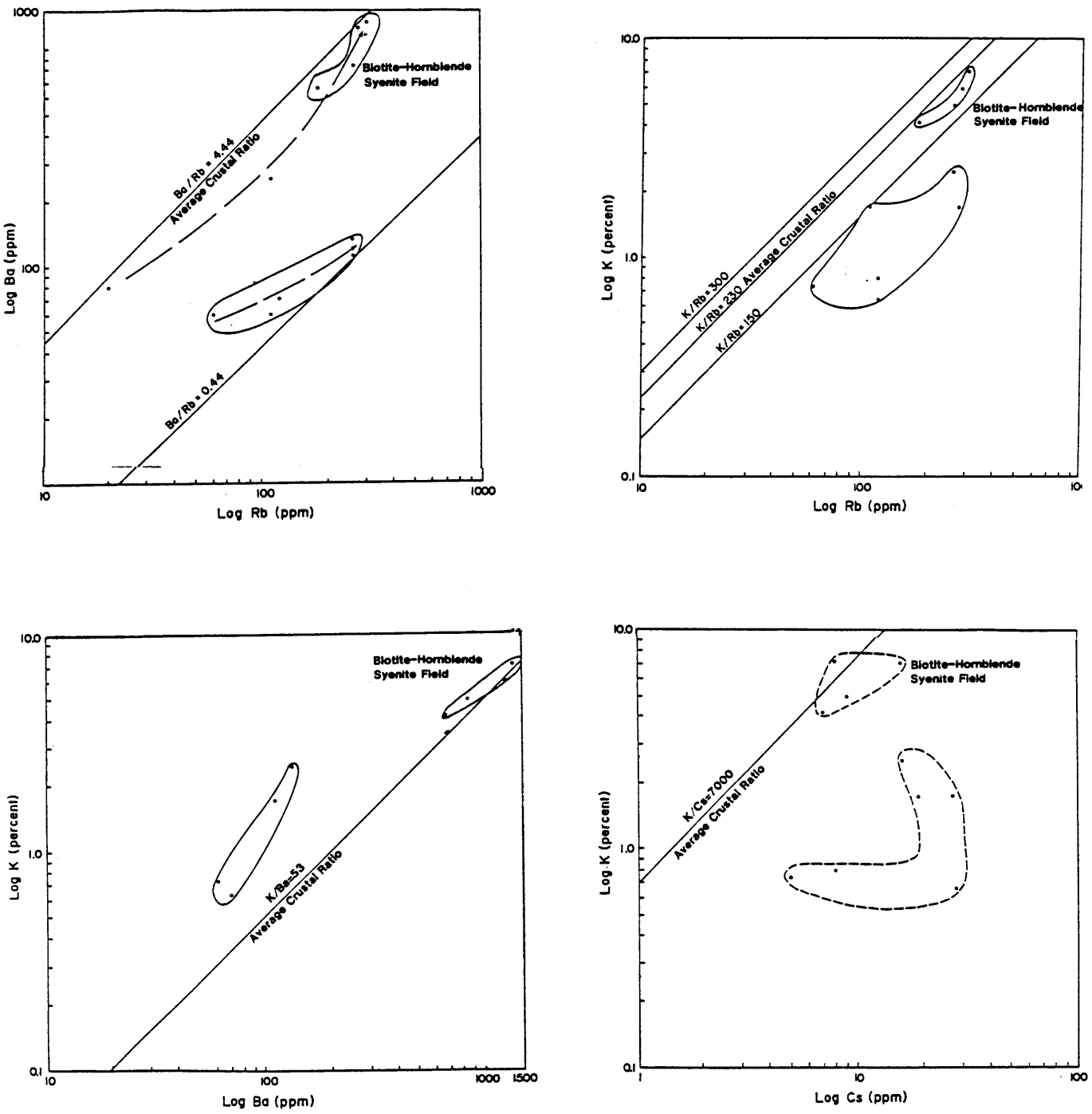


Fig. 16 -25 · K/Ba, K/Cs, K/Rb, and Ba/Rb from Potassic Granitoid Suite Rocks of Celyn Lake Uranium Occurrence, Southern Plutonic Domain

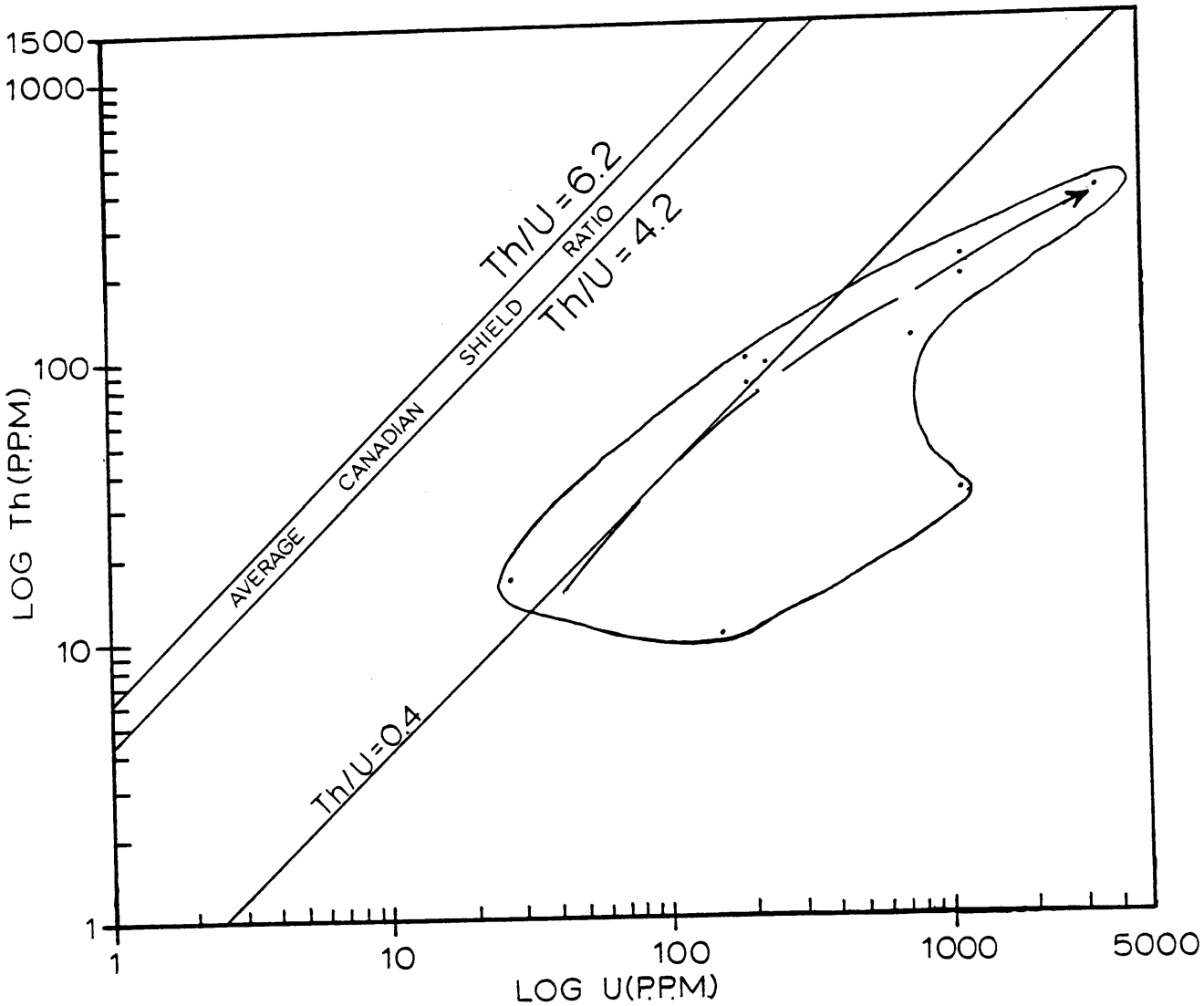


FIGURE 16-26: Th vs U Relations, Celyn Lake Uranium Occurrence.

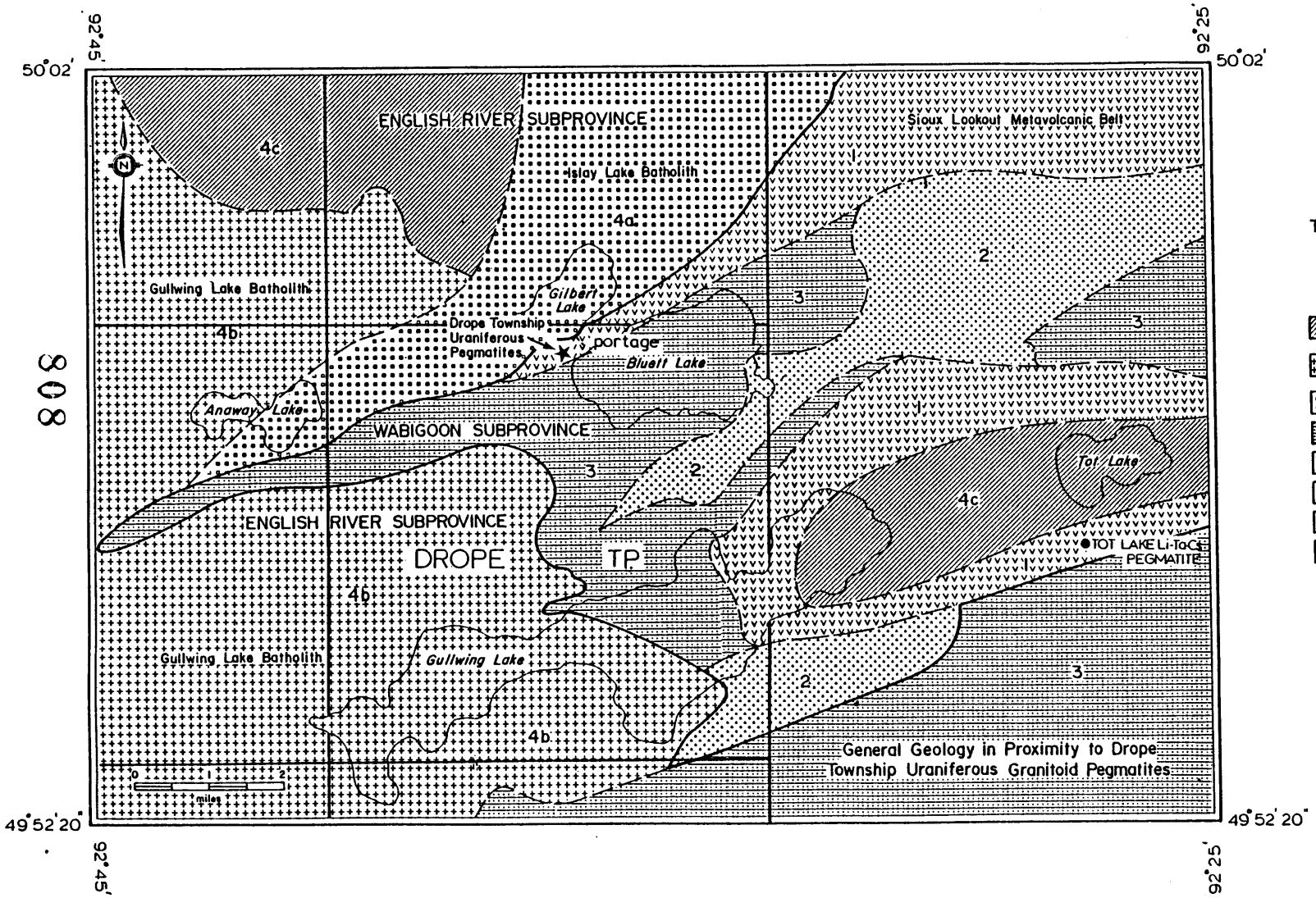


Fig. 16-27

General Geology in Proximity to Drope Township Uraniferous Granitoid Pegmatites

LEGEND

- 4c Foliated to Gneissic Trondhjemite
- 4b Equigranular, Coarse-grained to Pegmatitic Quartz Monzonite
- 4a Porphyritic (Kspar) Biotite Quartz Monzonite
- 3 Metasediments
- 2 Felsic to Intermediate Metavolcanics
- 1 Mafic to Intermediate Metavolcanics
- Subprovince Boundary
- Geological Boundary

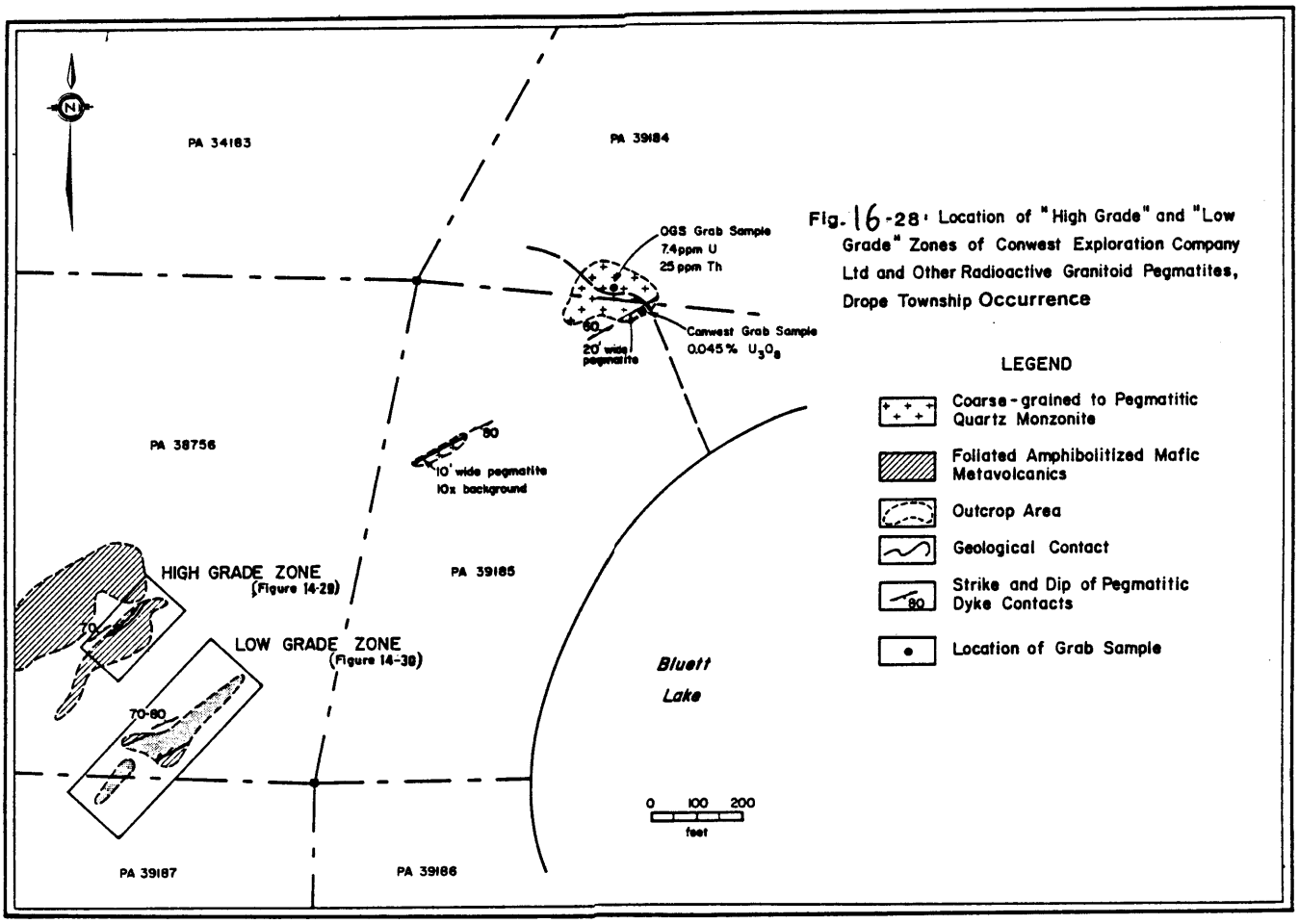


Fig. 16-28: Location of "High Grade" and "Low Grade" Zones of Conwest Exploration Company Ltd and Other Radioactive Granitoid Pegmatites, Drope Township Occurrence

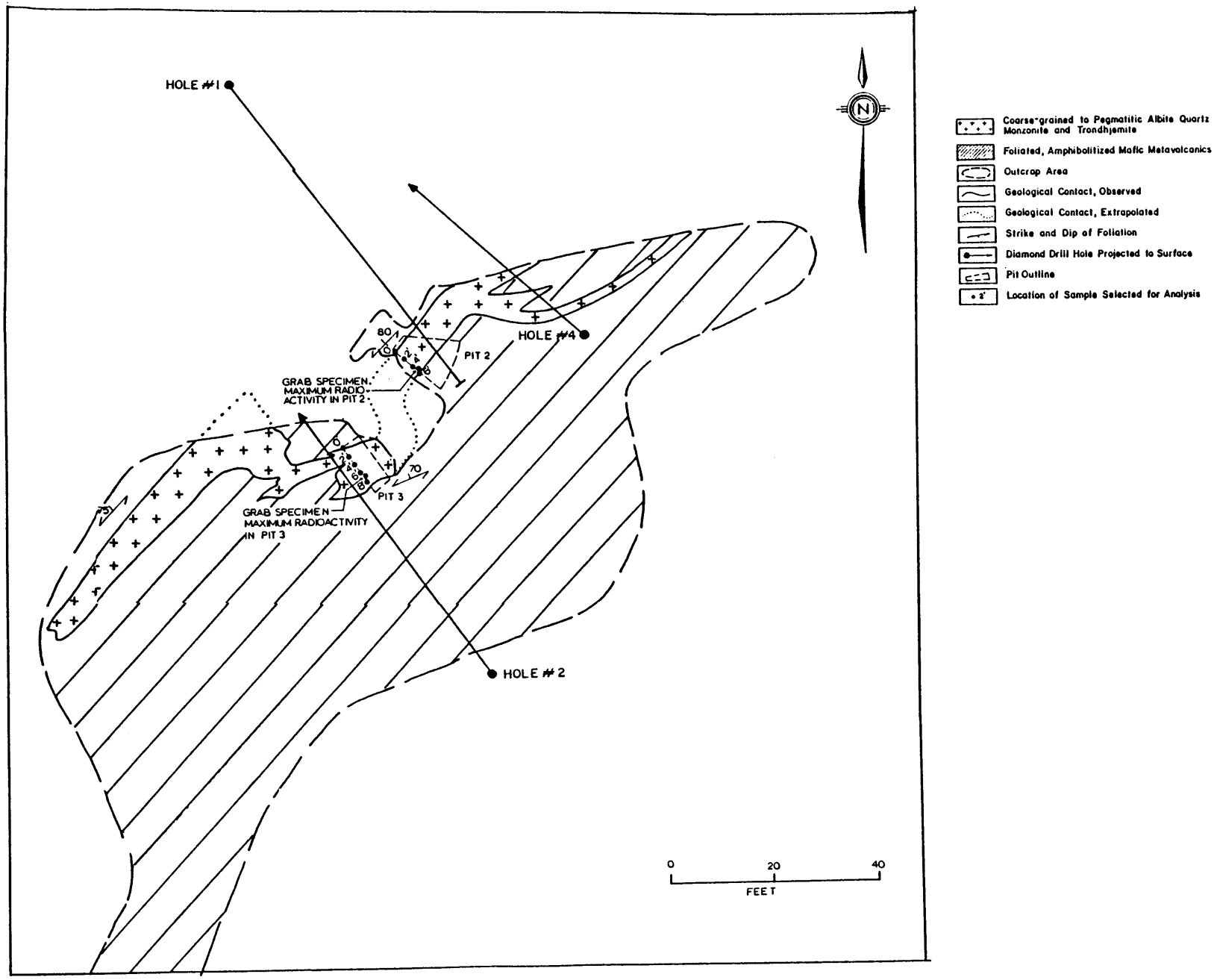


Fig. 29: Detailed Geology, Location of Diamond Drill Holes of Conwest Exploration Company Limited and Sample Locations, from "High Grade Zone", Drope Township Uranium Occurrence.

16-29

16-29

810

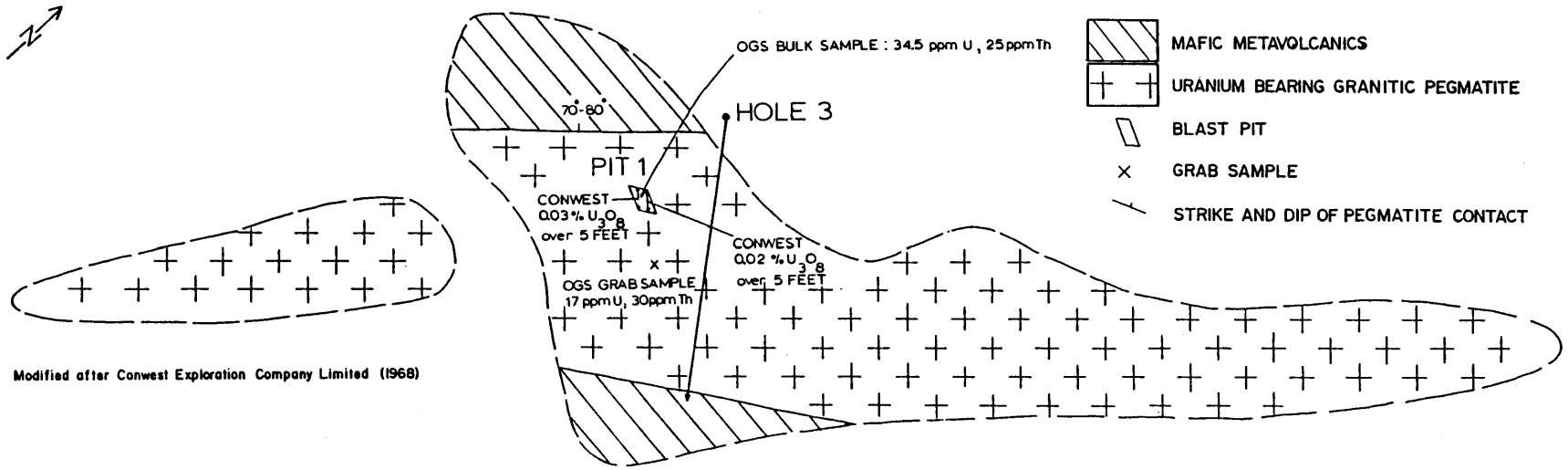


Fig. 16-30 : Geology and Location of Drill Hole 3 and Pit I, Low Grade Zone, Drope Township Occurrence

0 20
FEET

MODIFIED AFTER CONWEST EXPLORATION CO. LTD. (1968)

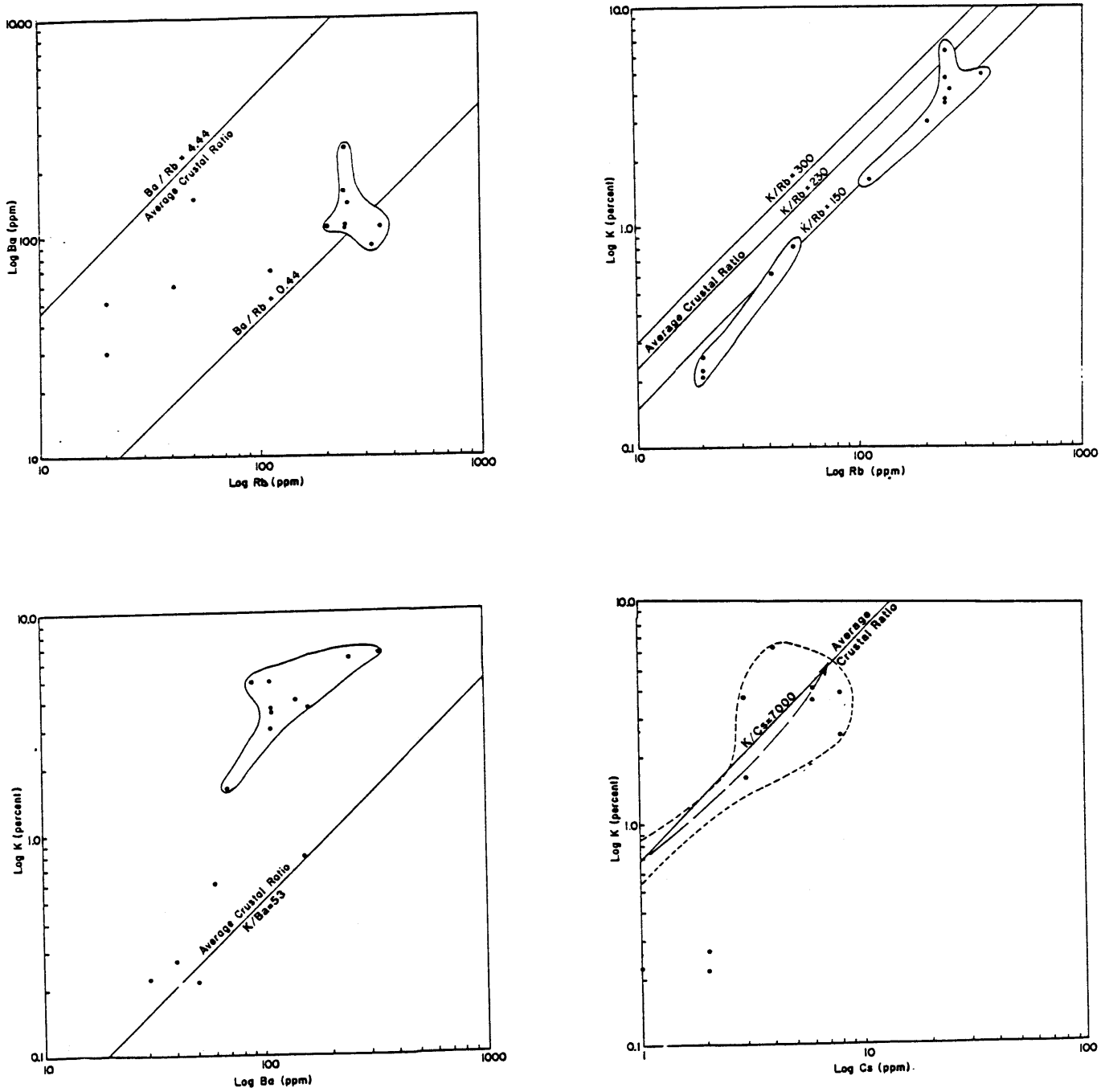


Fig. -31: K/Ba, K/Cs, K/Rb, and Ba/Rb Variation in Potassic Granitoid Suite Uraniferous Pegmatite from Drope Township Occurrence

16-31

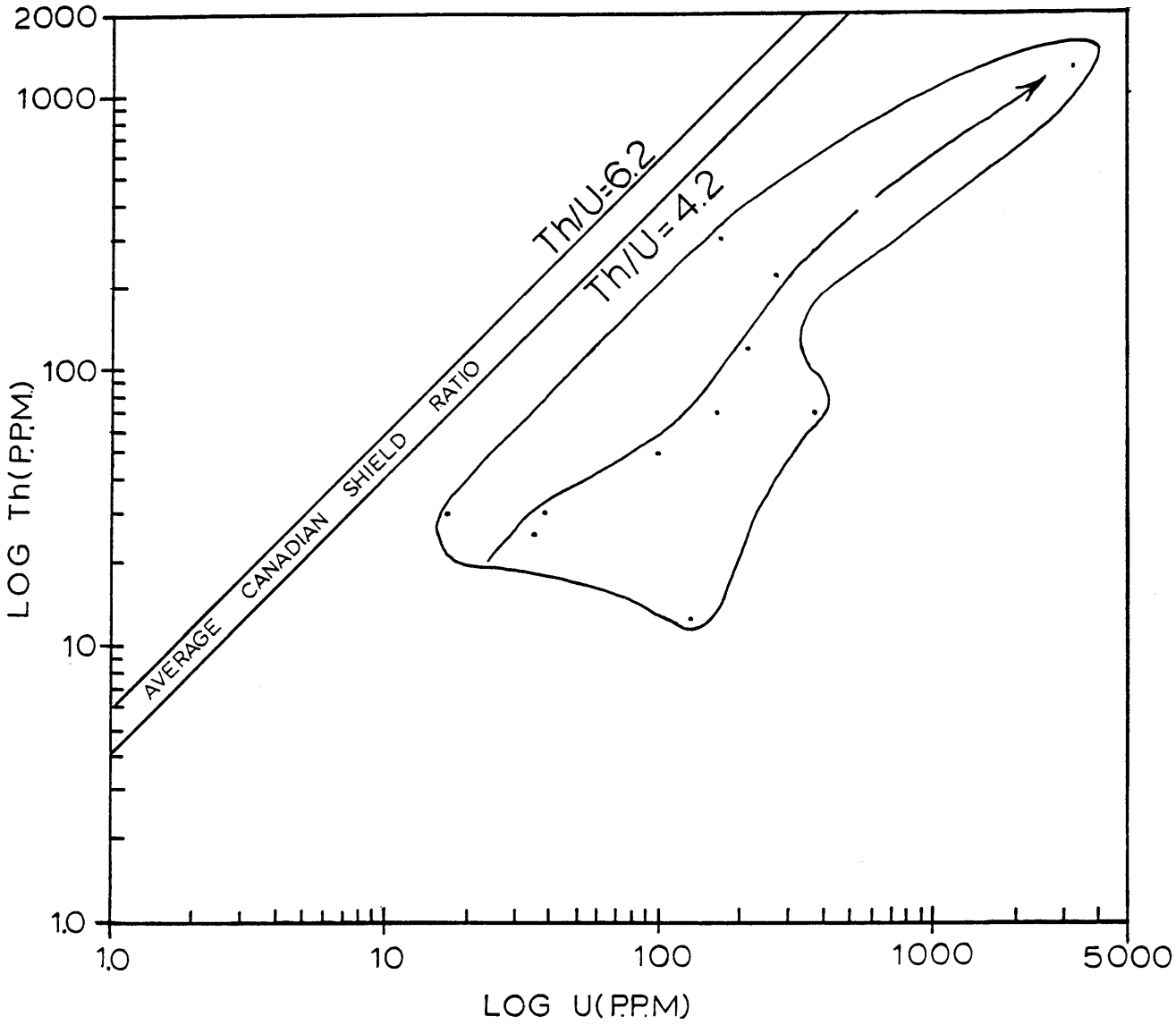
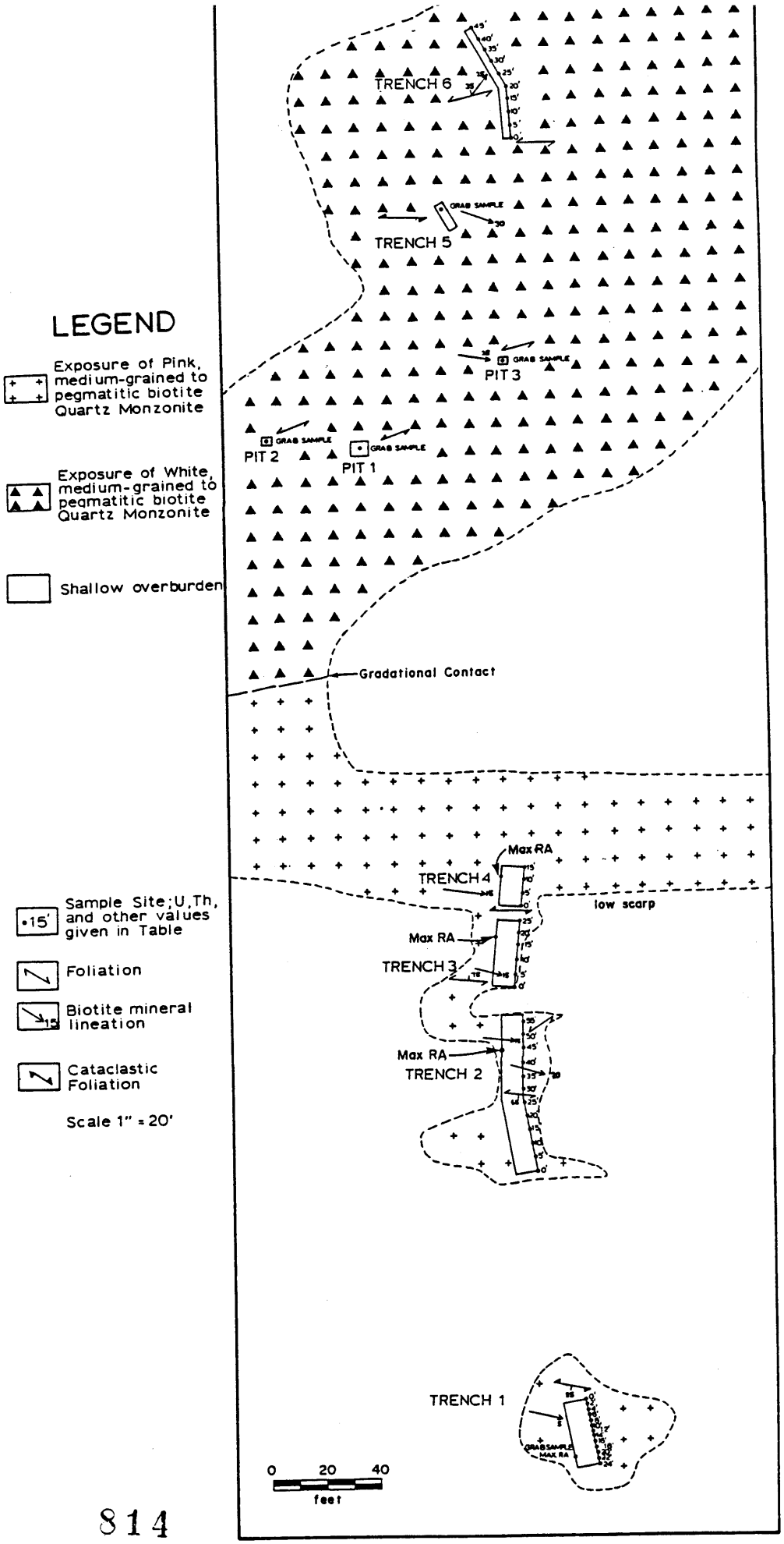


FIGURE 16-32 : Th vs U Relations, Drope Township Uranium Occurrence.



814

Figure 33 : Geology, Location of Trenches and Geochemistry Samples, Main Showing of Davidson

16-33

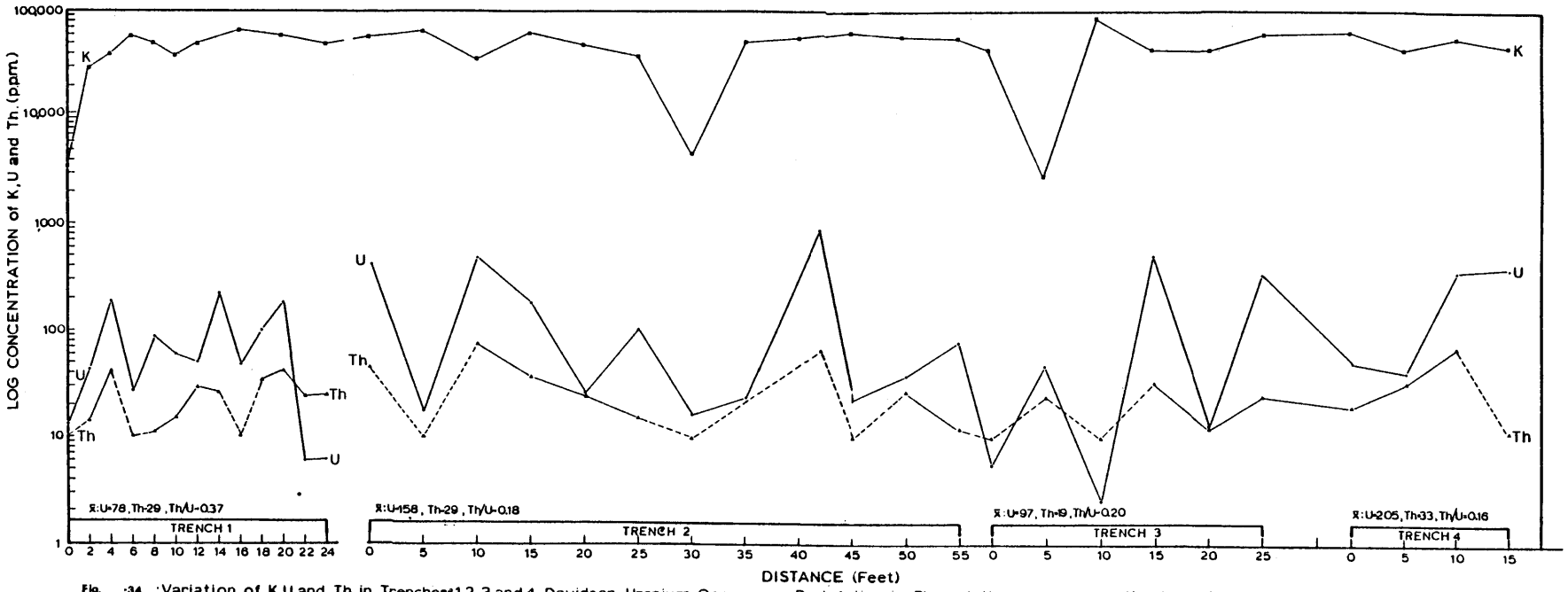


Fig. -34 :Variation of K,U,and Th in Trenches-1,2,3 and 4, Davidson Uranium Occurrence.Dashed line in Th variation curve are estimates only, owing to analytical sensitivity of 10 ppm

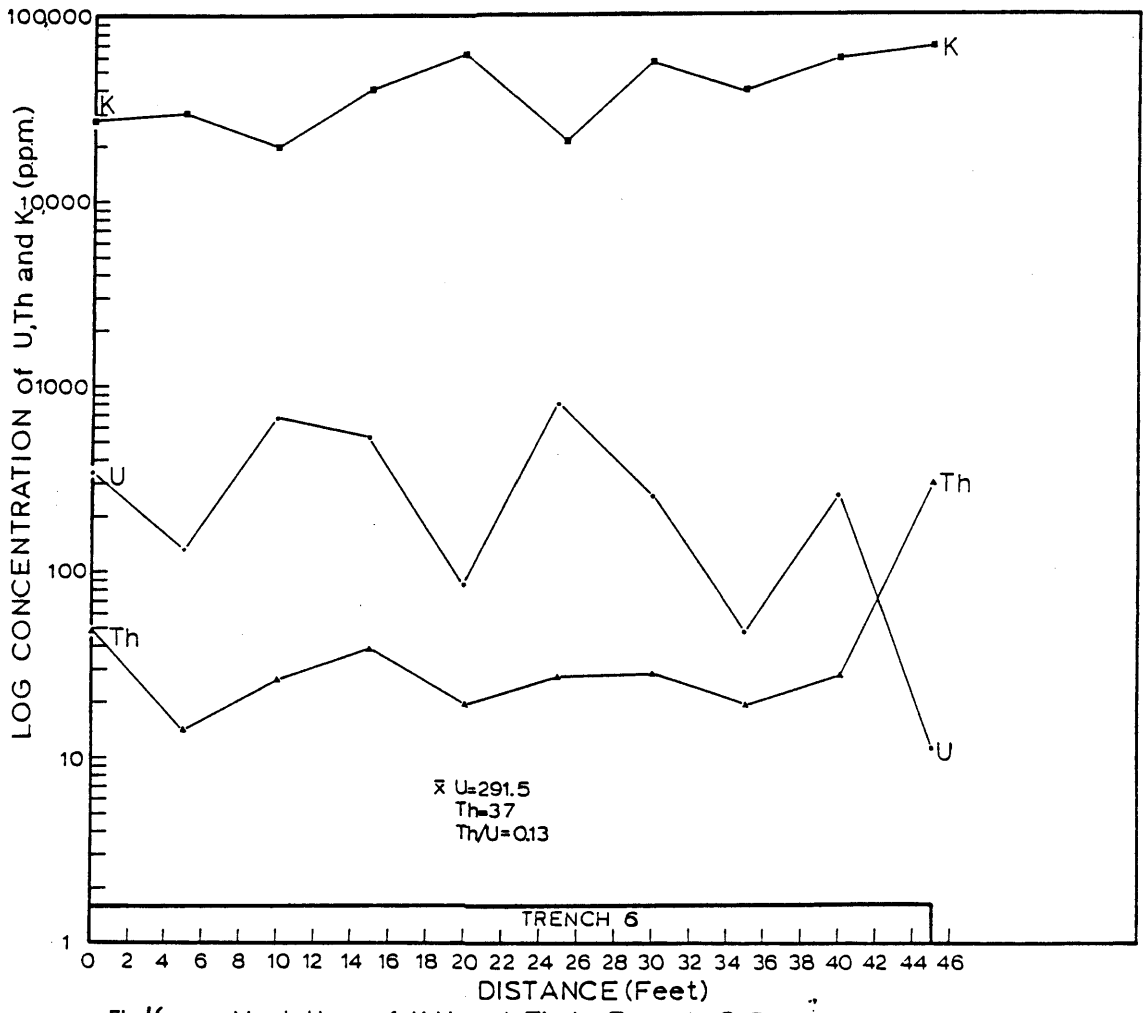


Fig. 16- 35 :Variation of K,U and Th in Trench 6, Davidson Uranium Occurrence.

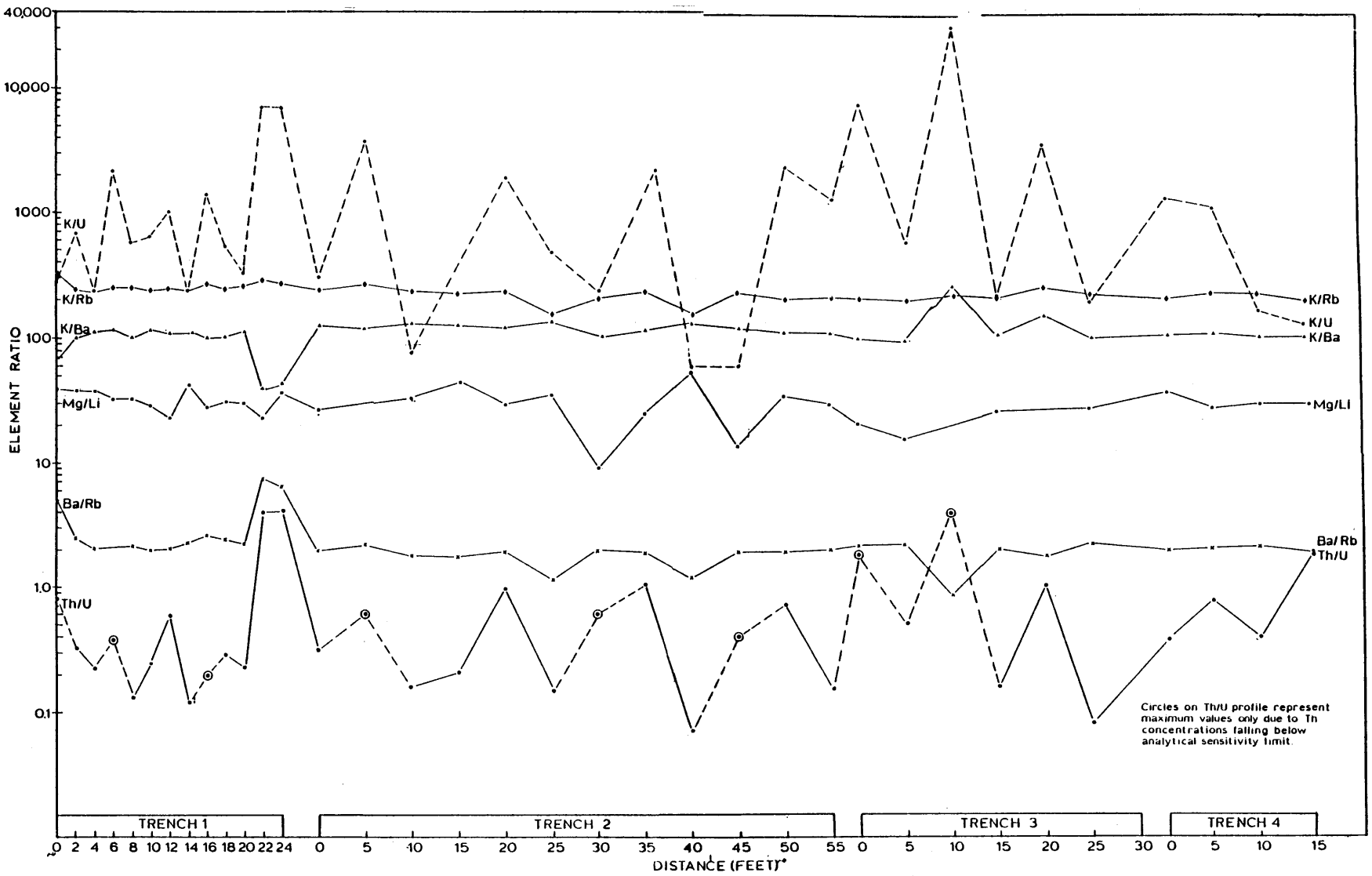


Fig. 36 Profiles of K/Ba, K/Rb, K/U, Th/U, Ba/Rb and Mg/Li along Trenches 1, 2, 3 and 4, Davidson Uranium Occurrence.

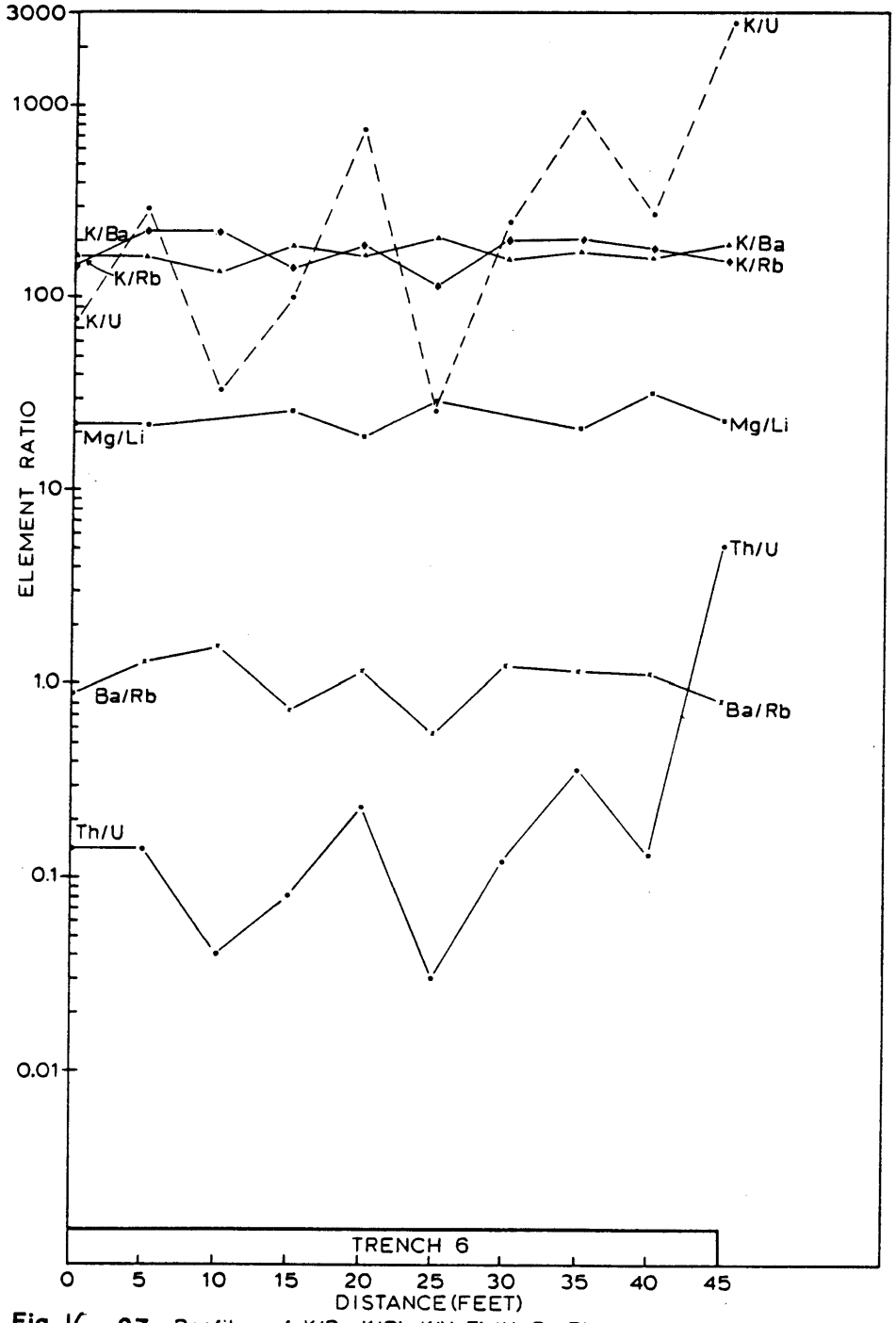


Fig. 16- 37 Profiles of K/Ba, K/Rb, K/U, Th/U, Ba/Rb and Mg/Li, Trench 6, Davidson Uranium Occurrence.

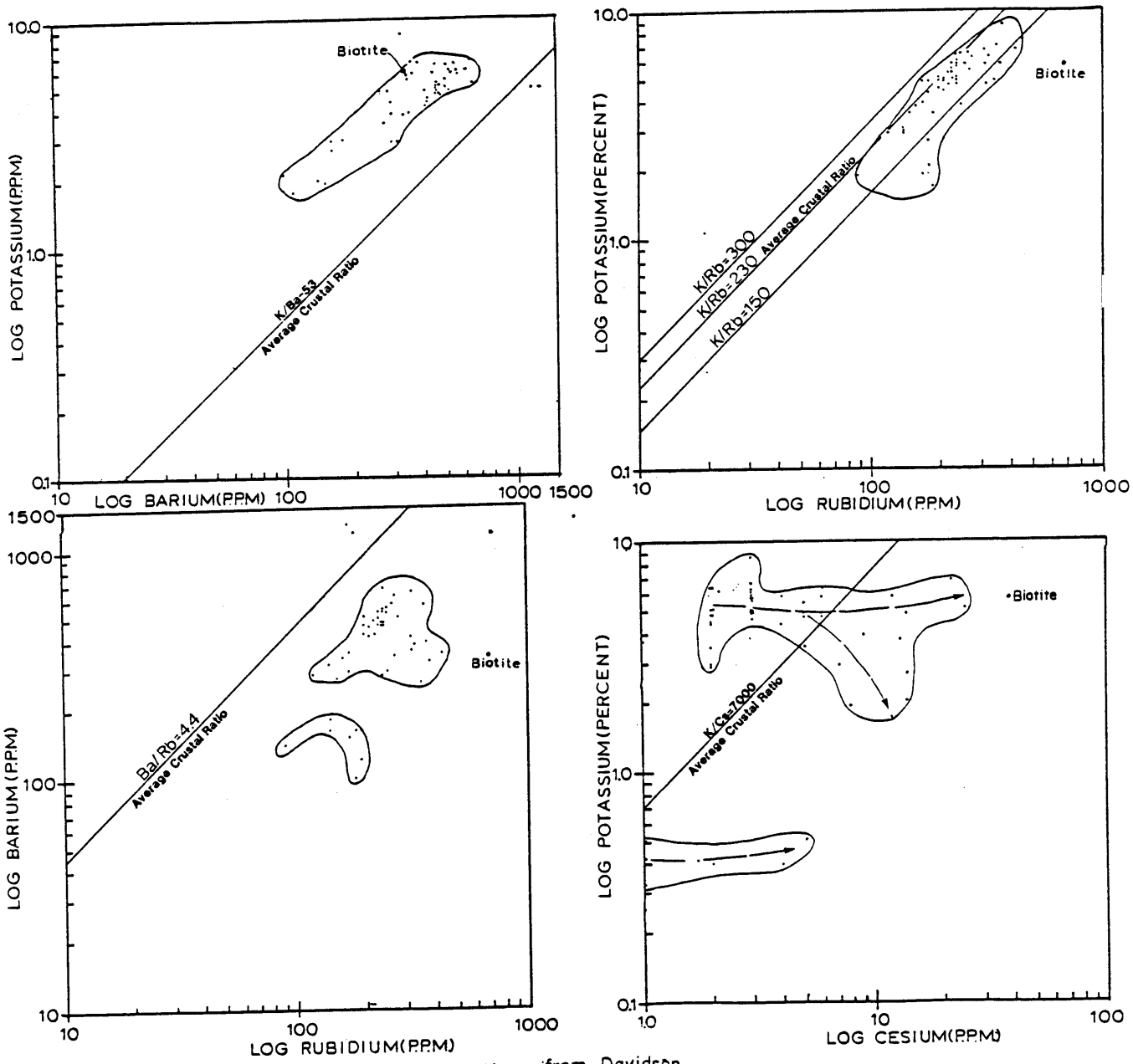


FIGURE 38: K/Ba K/Cs K/Rb and Ba/Rb Relations from Davidson Uranium Occurrence.

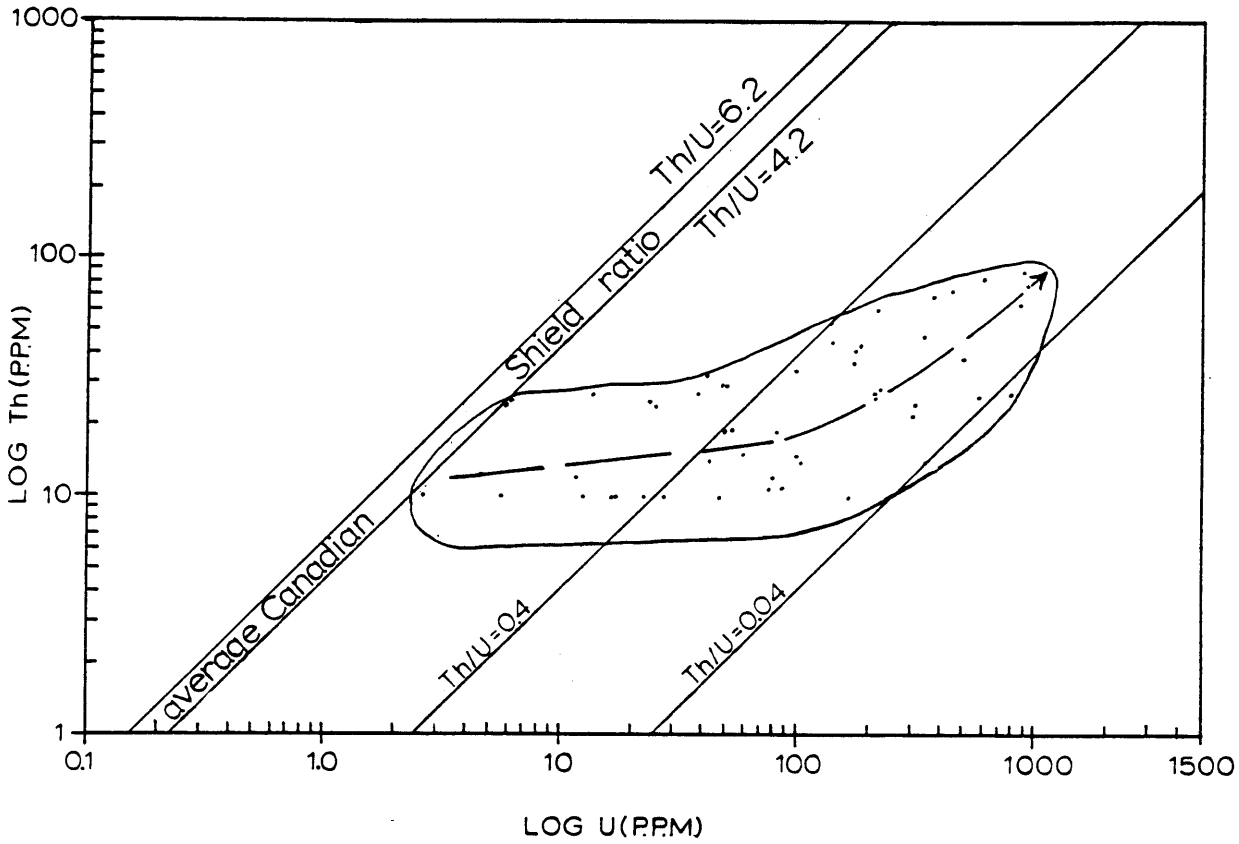


FIGURE 16 39: Th vs U Relations, Davidson Uranium Occurrence.

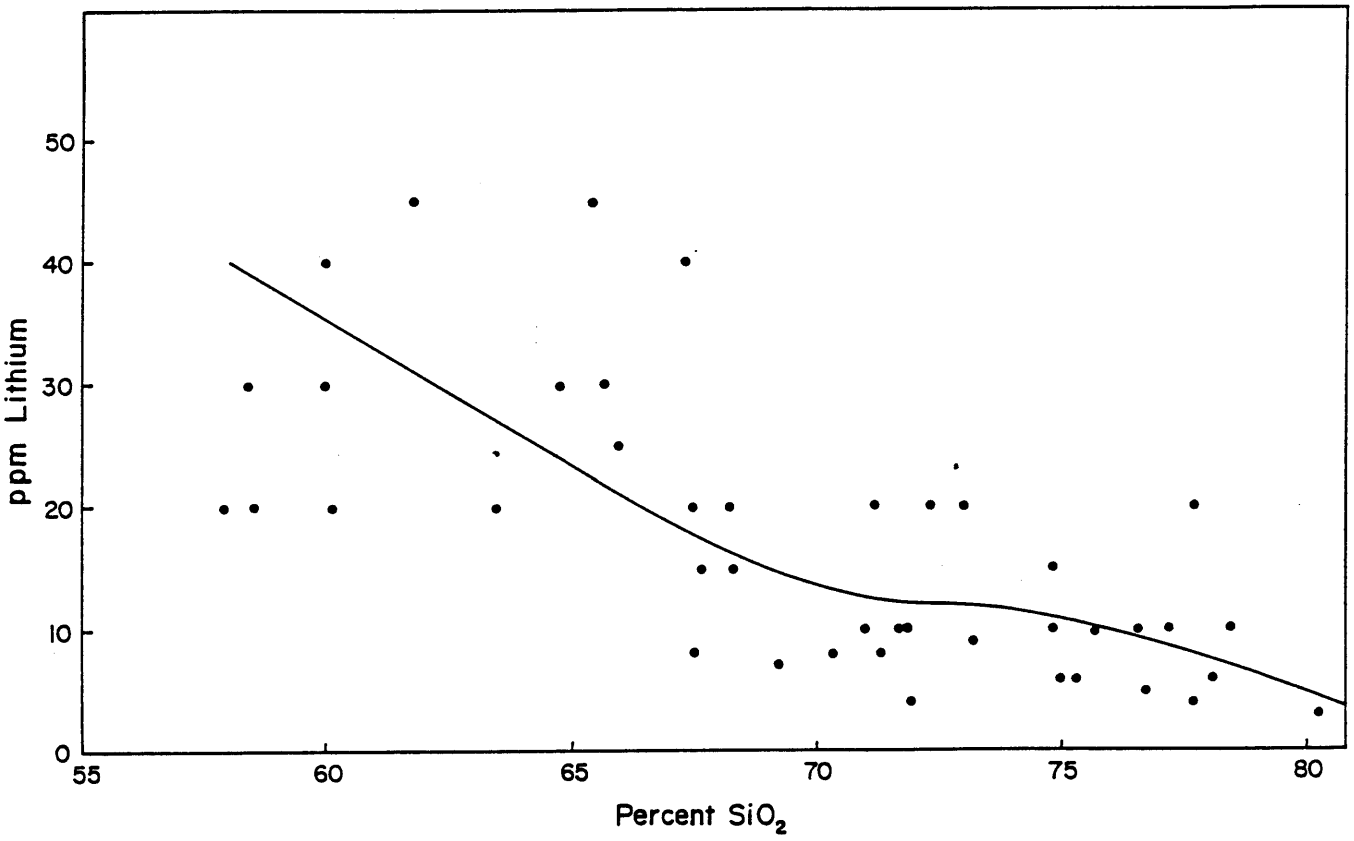


Fig. 16 -40 : SiO_2- Li Relationship in S-Type Uraniferous Granitoid Rocks From the Umfreville Lake Occurrence

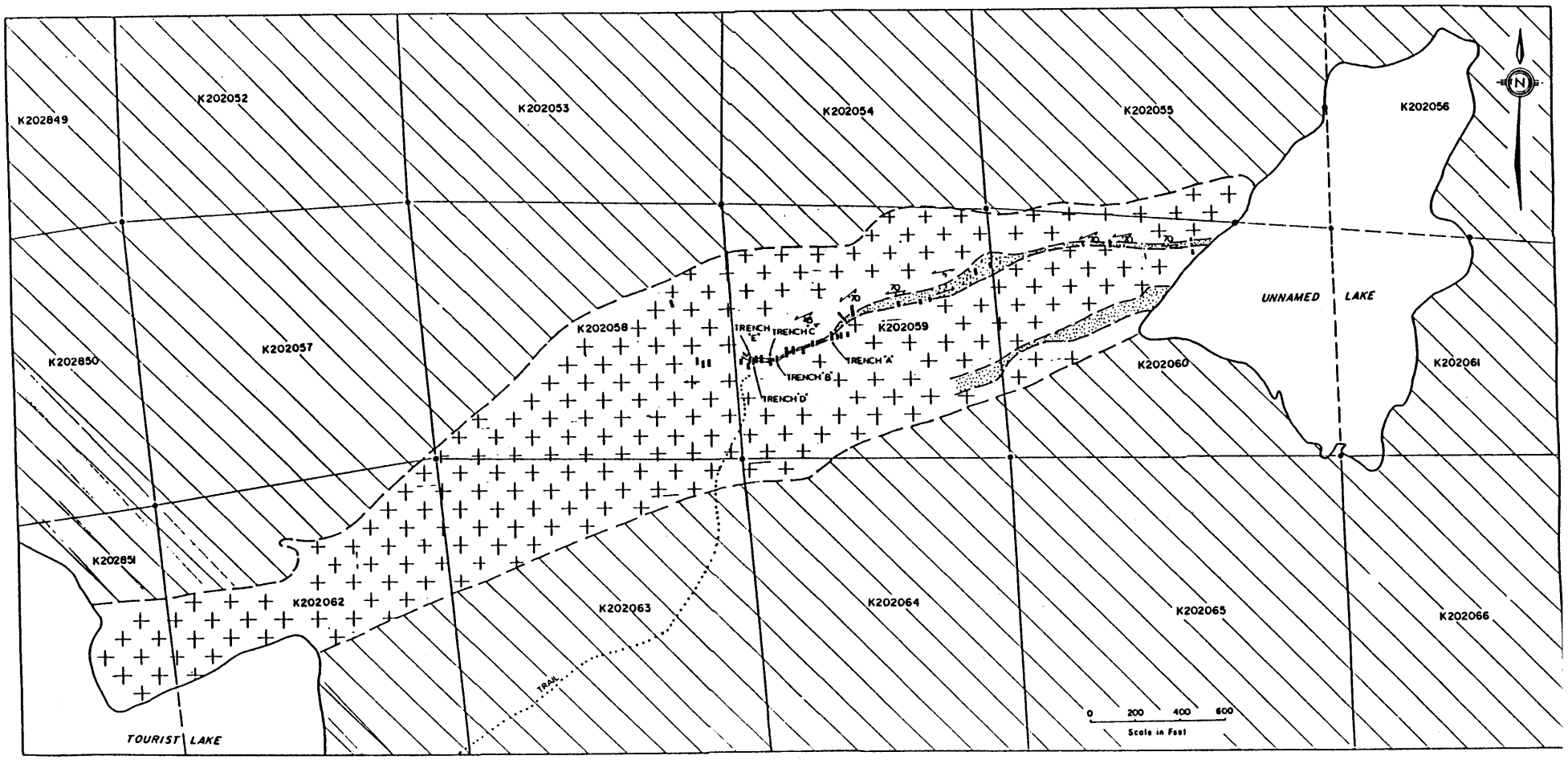


Figure 41: General Geology and Location of Trenches Sampled, Tourist Lake Uranium Occurrence. Mapping by Con Fer Expl. Syndicate, 1970 in File 2-307, AFRO, Toronto.

Pink Equigranular to Porphyritic (K-feldspar) Biotite Quartz Monzonite

White Porphyritic (K-feldspar) Biotite Quartz Monzonite, minor Syenite Cumulate Phases

Metawacke

Foliation with dip

Geological Contact

Trenched Area

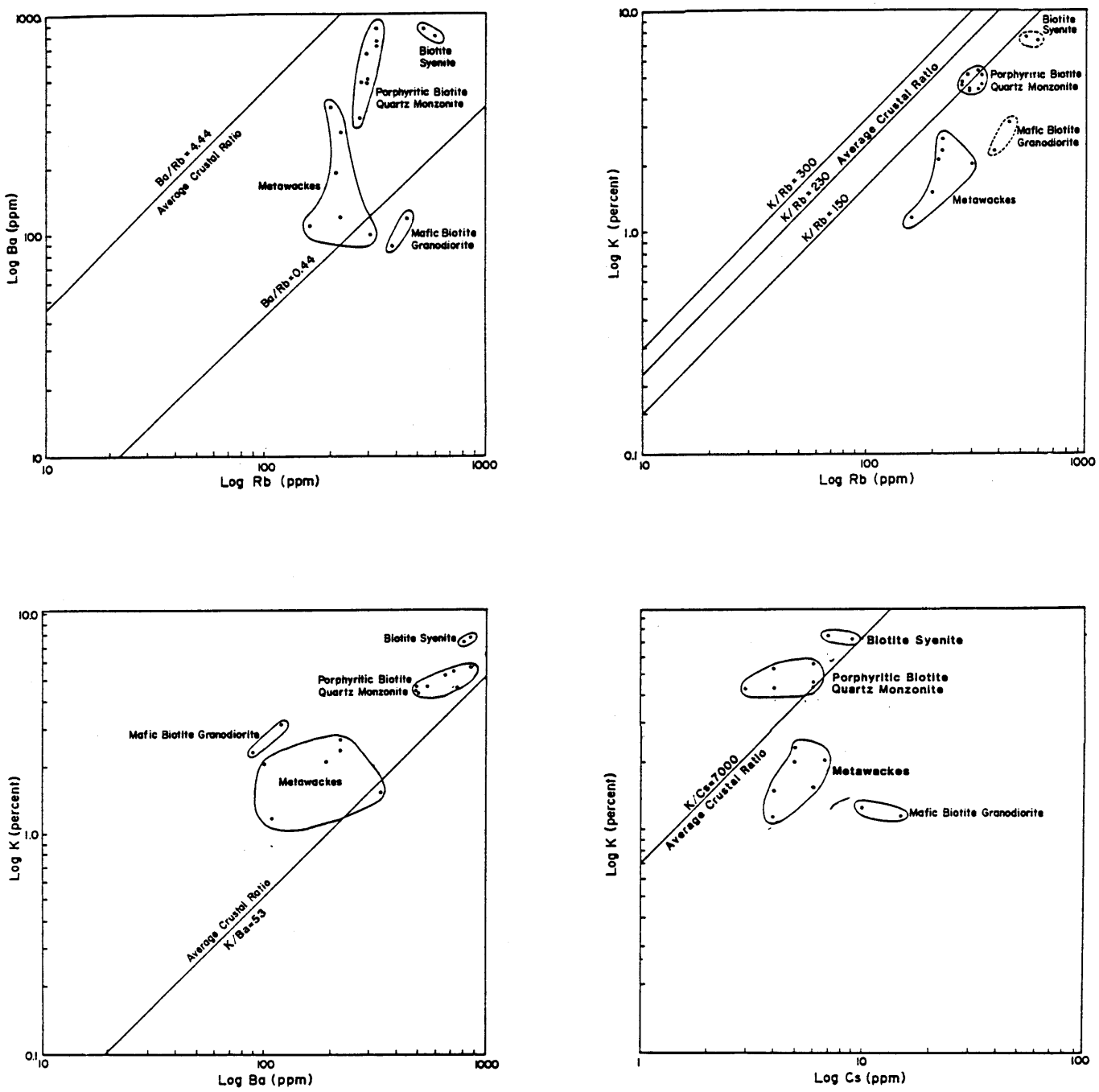


Figure 42 · K/Ba, K/Cs, K/Rb, and Ba/Rb Relations in Metawacke, Porphyritic Biotite Quartz Monzonite, Porphyritic Biotite Syenite, and Mafic Biotite Granodiorite at the Tourist Lake Uranium Occurrence, Southern Plutonic Domain

16-42

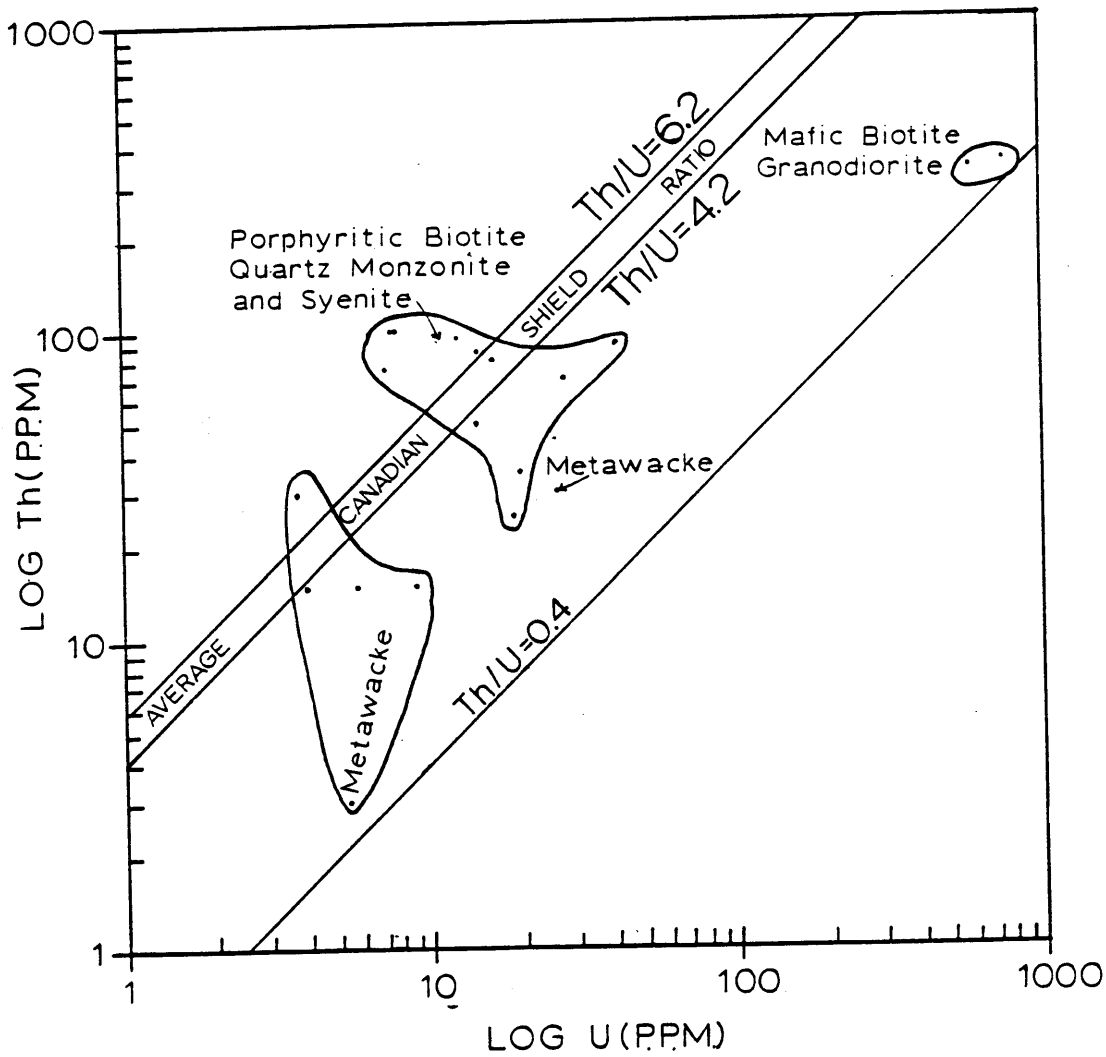


Fig. 16-43 : Th vs U Relations, Tourist Lake Uranium Occurrence.

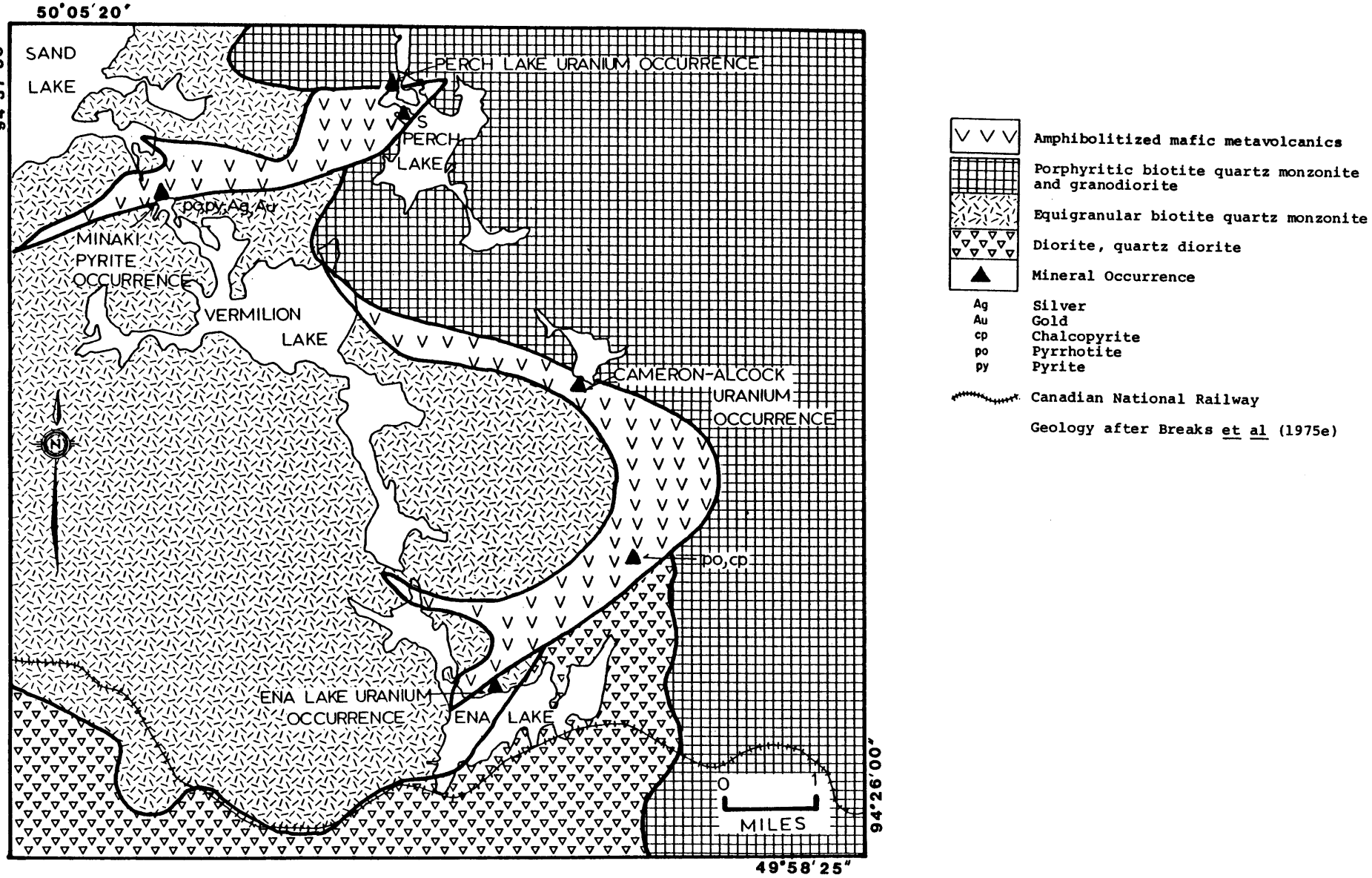


FIGURE :MINERAL OCCURRENCES IN THE ENA-VERMILION LAKES AREA

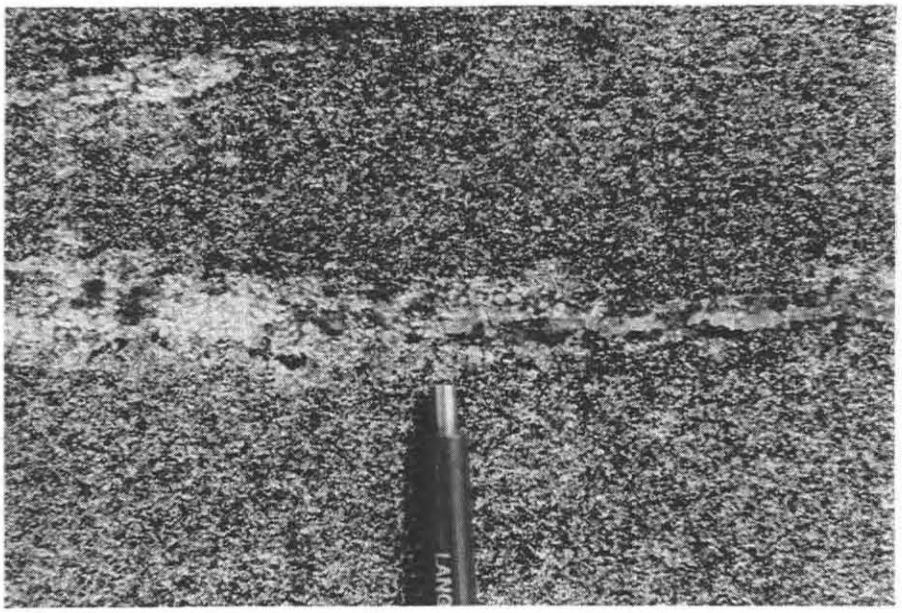


Photo 3-1 Diffuse, magnetite-diopside-hypersthene bearing felsic segregations (photo centre) contained within a magnetite-diopside-hypersthene-hornblende-plagioclase bearing, possible mafic metavolcanic host from Chamberlain Narrows, Lac Seul.

Photo 3-2 Mafic tuff breccia from Troutfly Lake area in the Sioux Lookout greenstone belt.

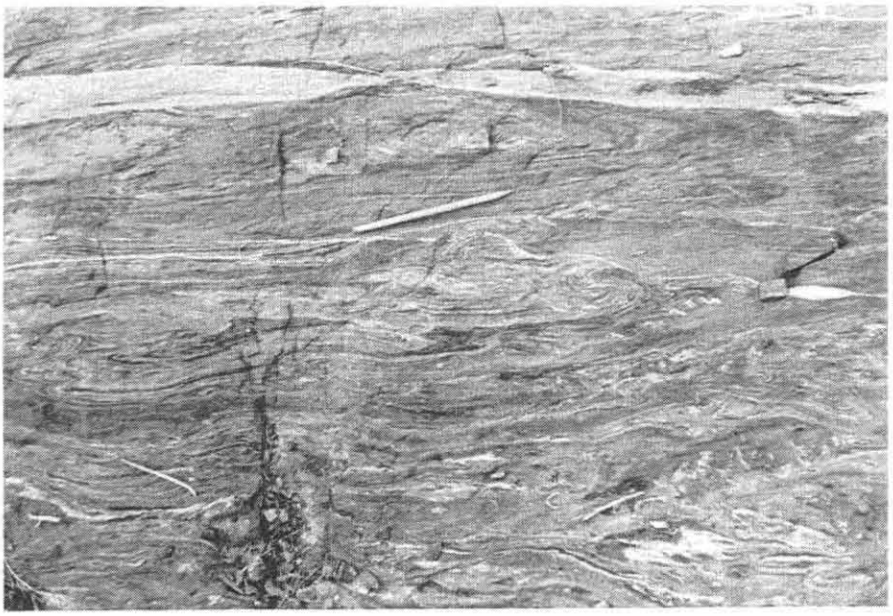


Photo 3-3 Gneissic mafic volcanics from the Papaonga Lake-Lake St. Joseph greenstone belt. The banding is likely secondary but could also represent deformed tuffaceous bedding or pillow selvedges. Boudins of granitoid dikes (at top of photo). Pencil = 22 cm.

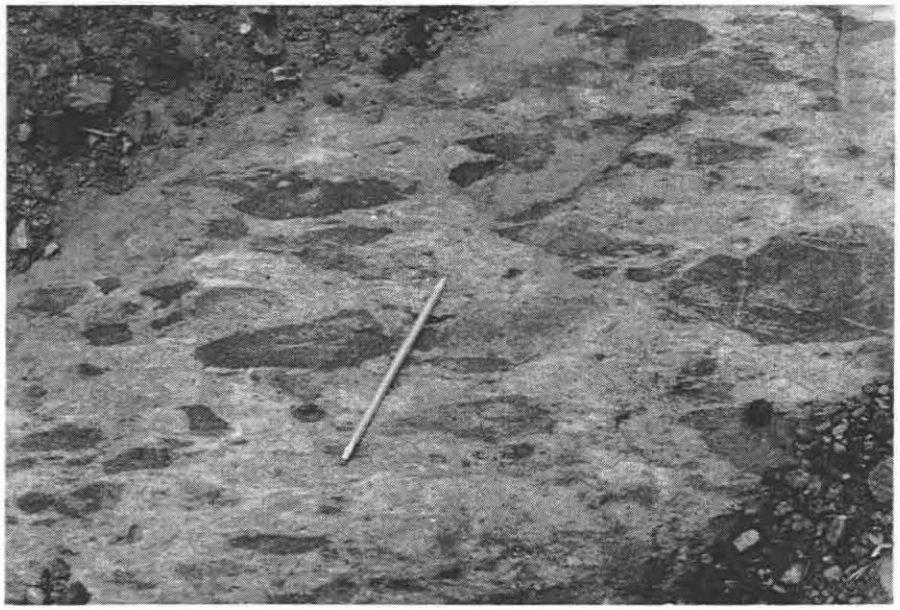


Photo 3-4 Intermediate tuff breccia containing fragments that are more mafic than the matrix. Outcrop located on the Ghost Lake road, southwest Webb Township.

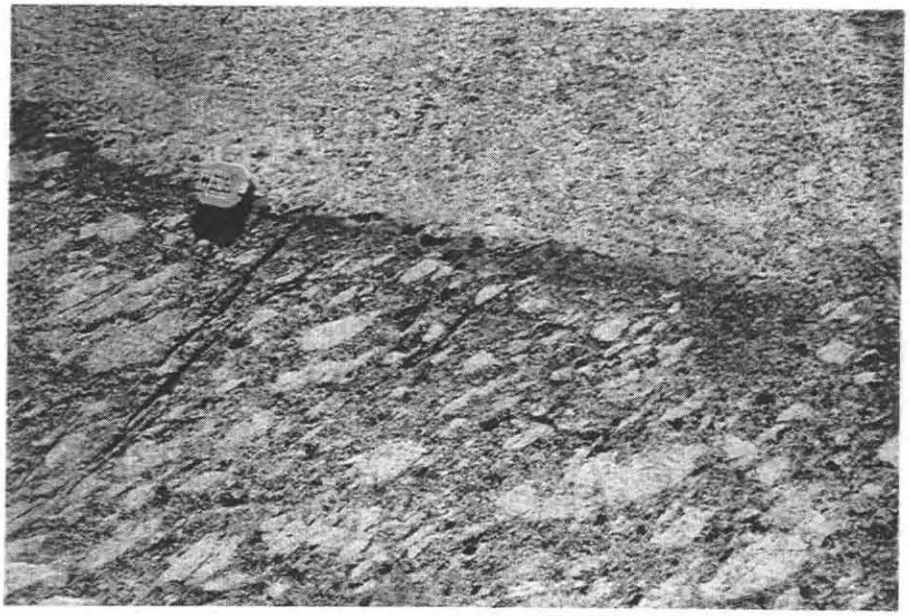


Photo 3-5 Contact between intermediate to felsic tuff (top of photo) and intermediate tuff breccia in the Lake St. Joseph greenstone belt. Compass (7 cm across) is at the contact.

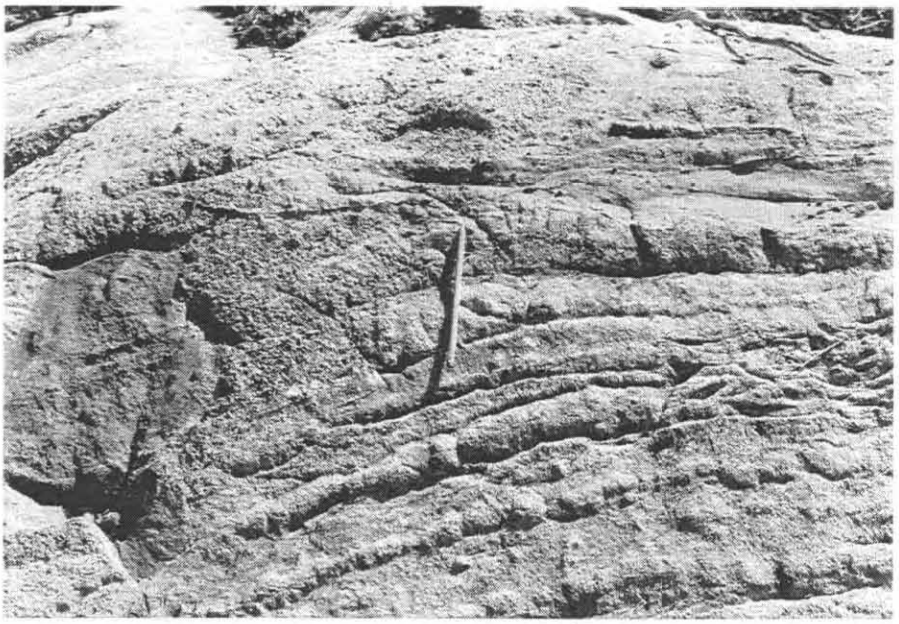


Photo 3-6 Felsic airfall tuff with mafic bomb (on left), situated about 3 km north of the eastern end of Gullwing Lake.

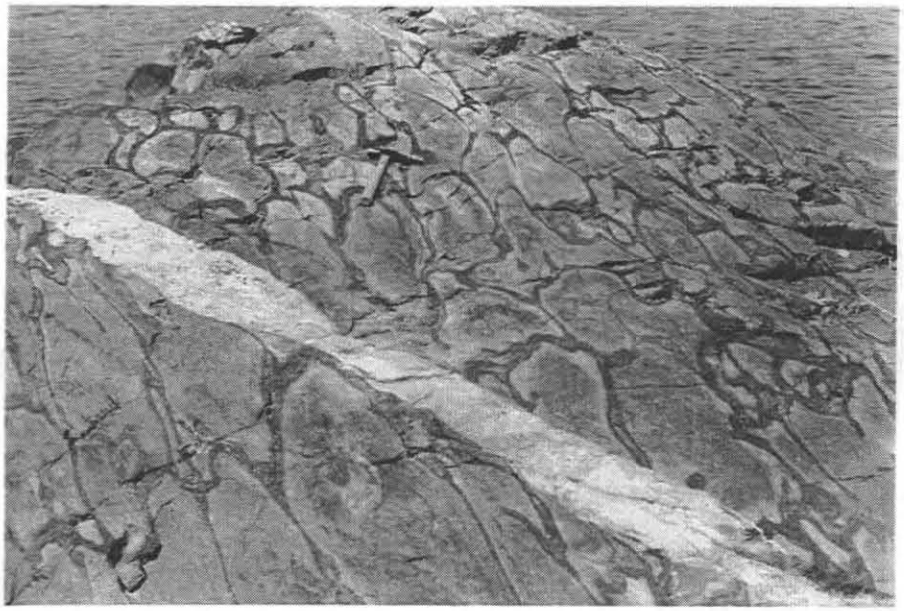


Photo 3-7 Pillowed mafic metavolcanic rocks cut by quartz monzonite dyke in the Separation Lake greenstone belt near the Separation Rapids.

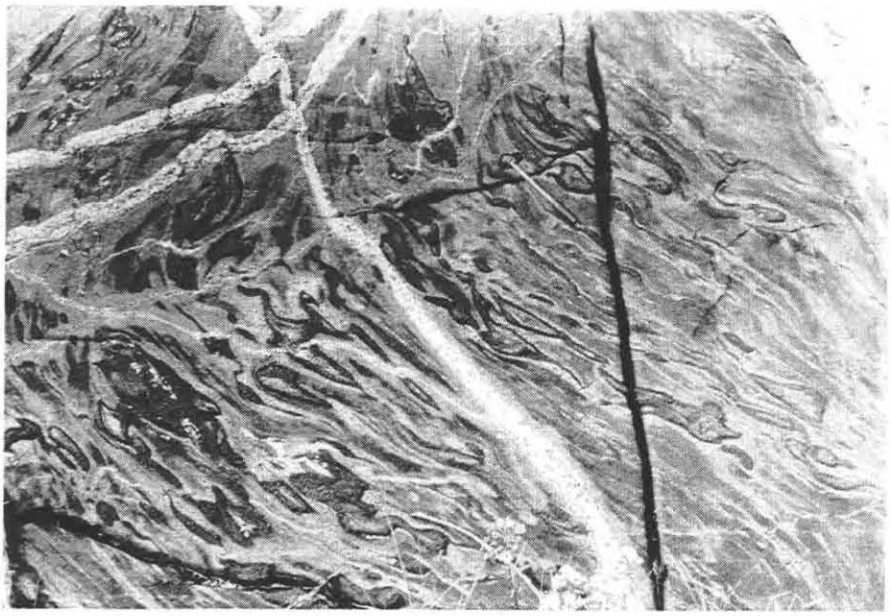


Photo 3-8 Complexely deformed, thin dark bands in mafic metavolcanic rocks just south of Chamberlain Narrows. These bands possibly represent relict pillow selvedges.

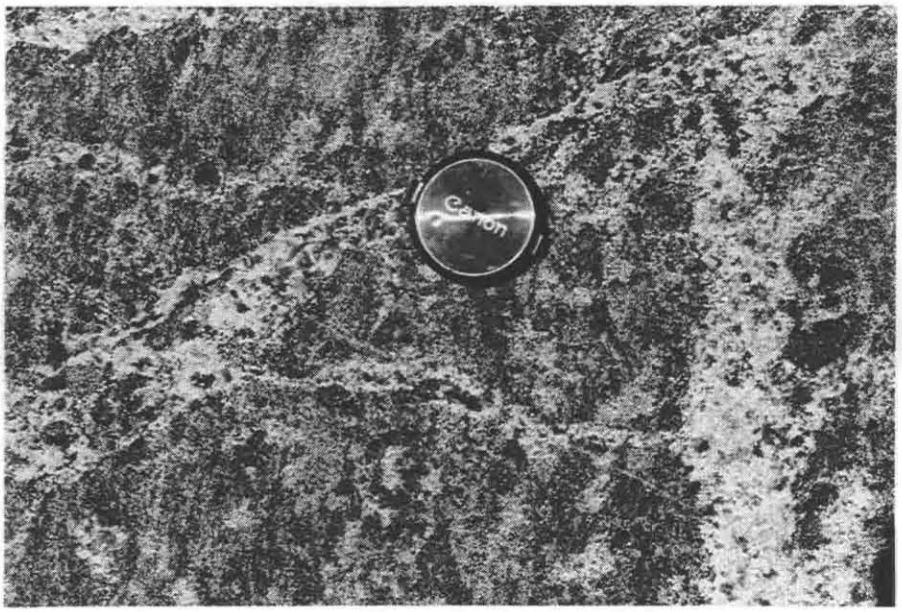


Photo 3-9 Diopside-hypersthene bearing, mafic metavolcanic rock with possible partial melt of trondhjemite composition from the Chamberlain Narrows area.

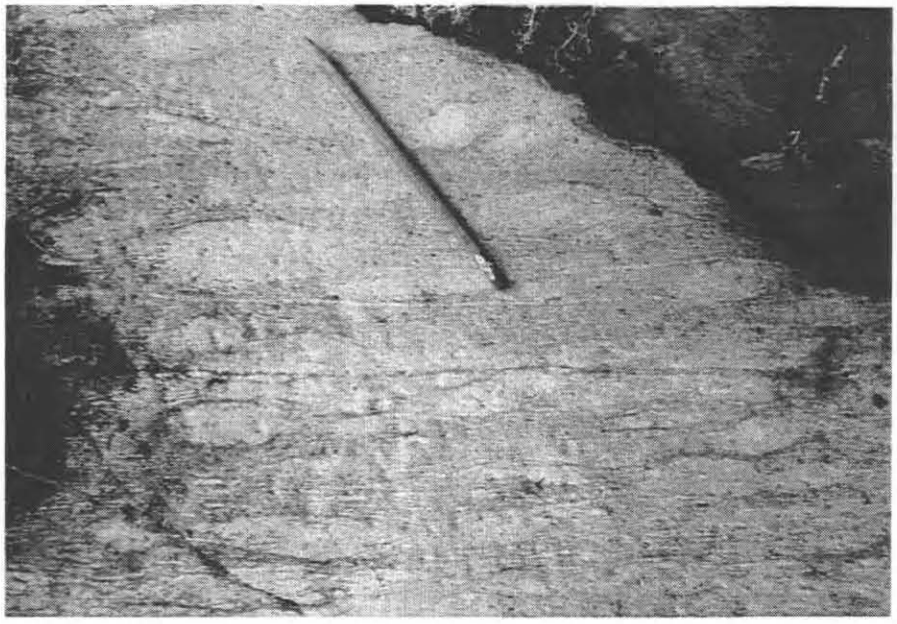


Photo 3-10 Intermediate tuff breccia located just west of Fredhart Lake. The subtle fragments are slightly more felsic than the matrix.

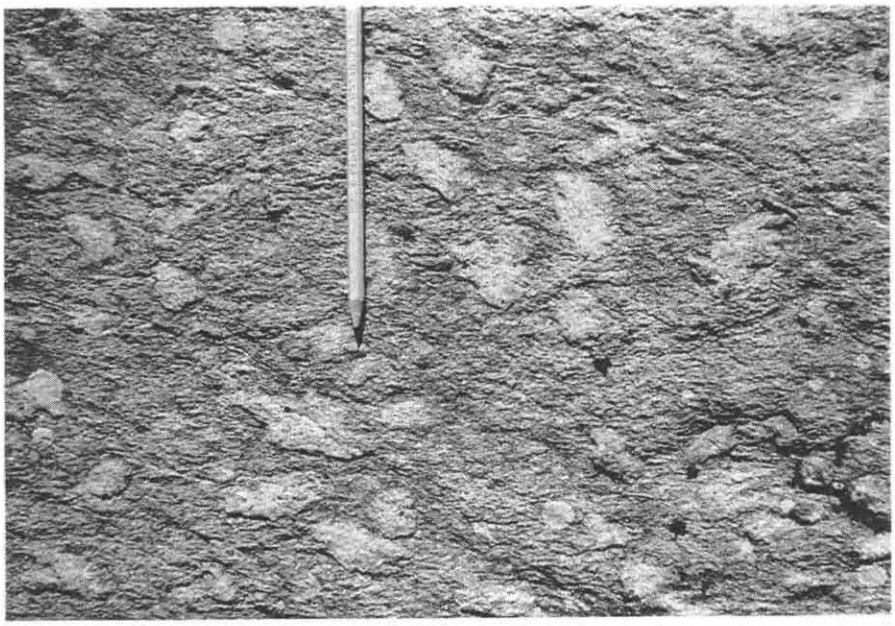


Photo 3-11 Porphyroblastic knots of andalusite in intermediate metavolcanic rocks southwest of Fredhart Lake.

Photo 3-12 Subvolcanic rock with brecciation possibly due to fumarolic degassing on the south shore of Fredhart Lake.

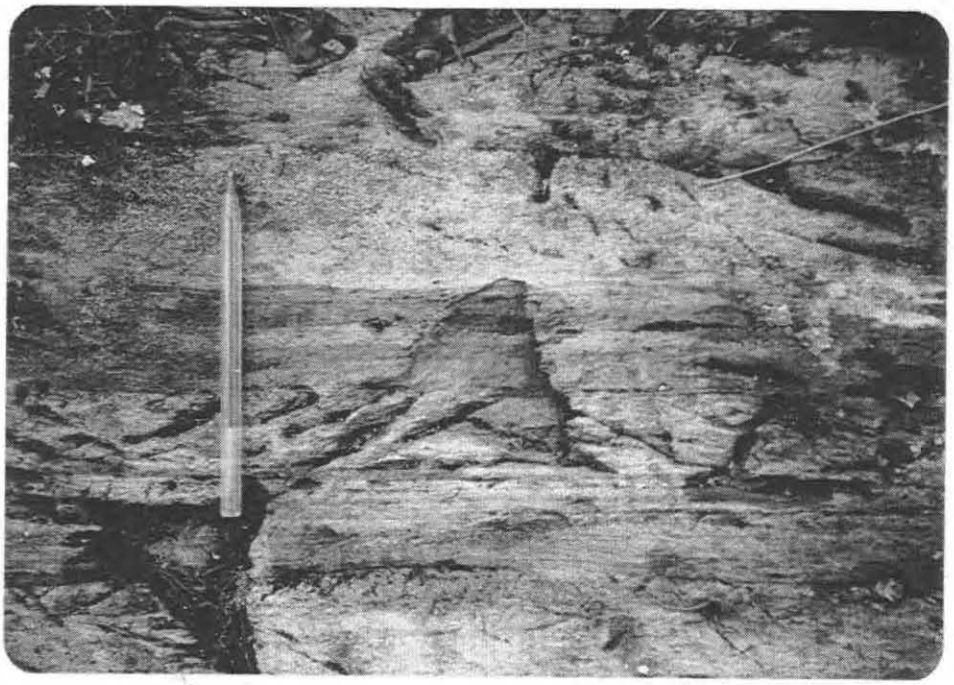


Photo 3-13 Reworked tuffs and tuffaceous metasedimentary rocks from Upper Slate Lake.

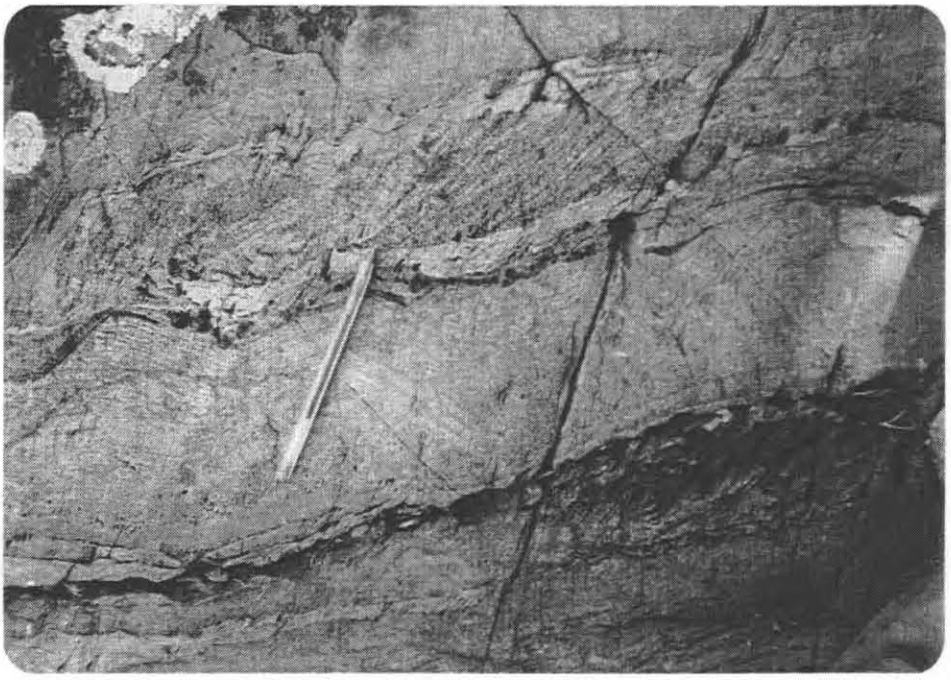


Photo 3-14 Cross-bedding in wacke metasedimentary rocks near Lower Slate Lake.

Photo 3-15 Lit-par-lit injection of mafic metavolcanic rocks northeast of Papaonga Lake. The white bands consist of quartz monzonite. Tree height averages 5 to 6 feet.

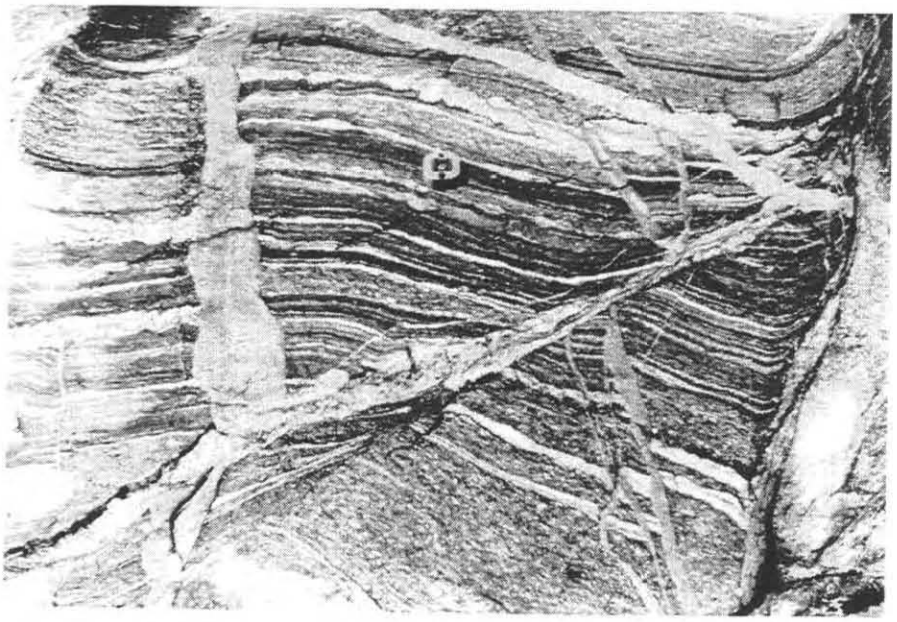


Photo 4-1 Polyphase granitic rocks from the Southern Plutonic Domain near Hudson.

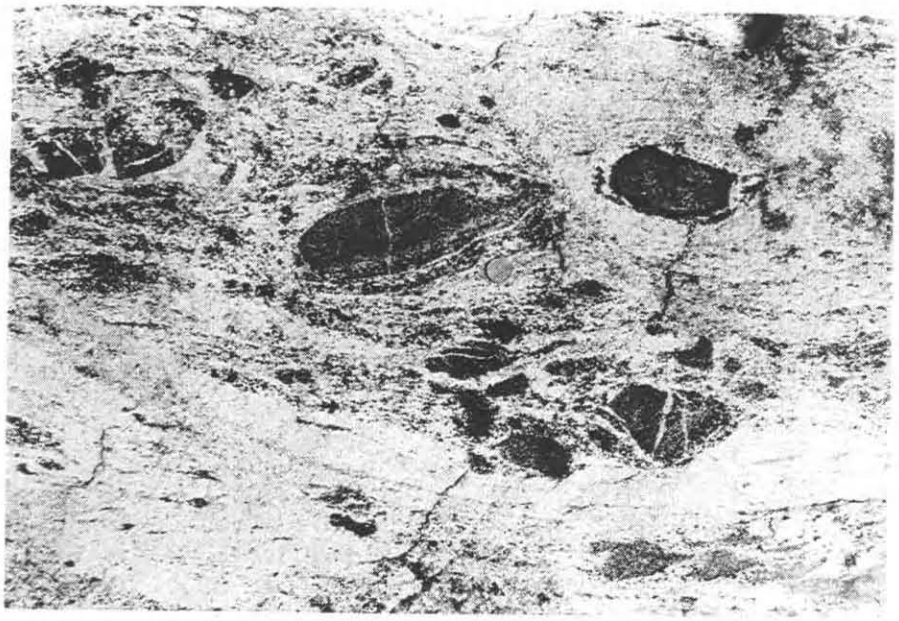


Photo 4-2 Inhomogeneous, meta-tonalite from the Sydney Lake area. Note the discrete to diffuse, mafic to ultramafic enclaves in varying states of reaction with the host and attendant, irregular zones of hybrid biotite-hornblende quartz diorite. Coin = 2.3 cm.

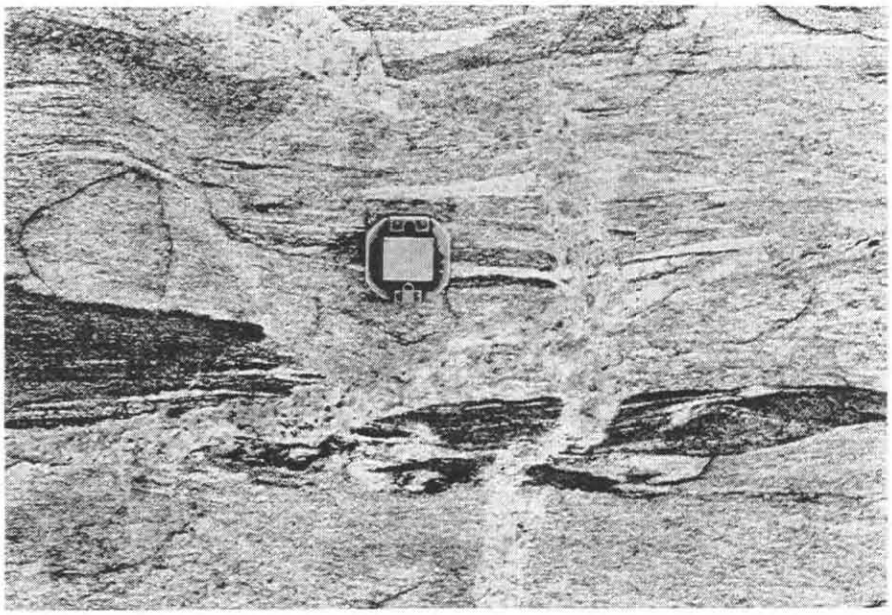


Photo 4-3 Polyphase granitoid exposure, west shore of Sydney Lake.

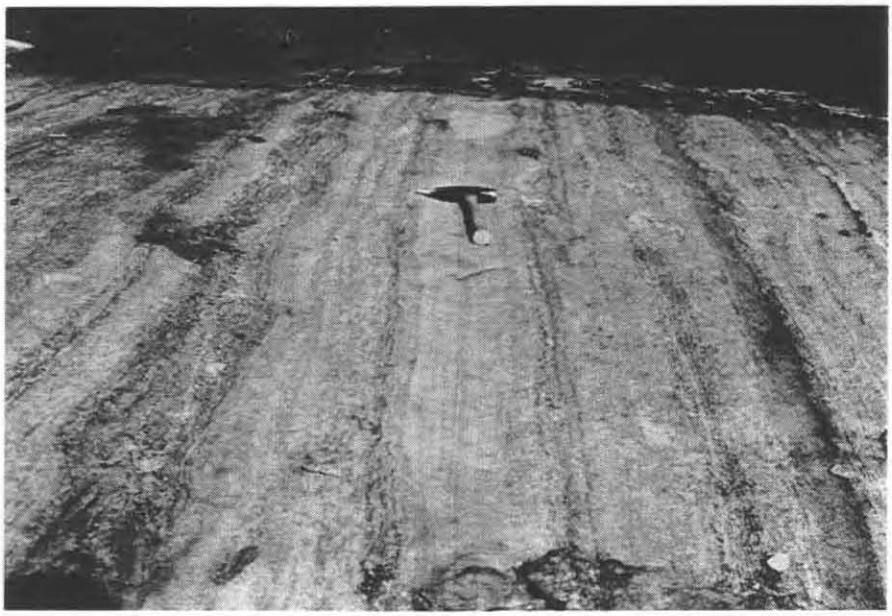


Photo 4-4 Protometatexite near Aerofoil Lake. Note the confinement of leucosome patches to the metamorphically coarsened pelitic paleosome layers. Metawacke layers have apparently resisted leucosome development and occasionally exhibit relict sedimentary laminae (marked by hammer).

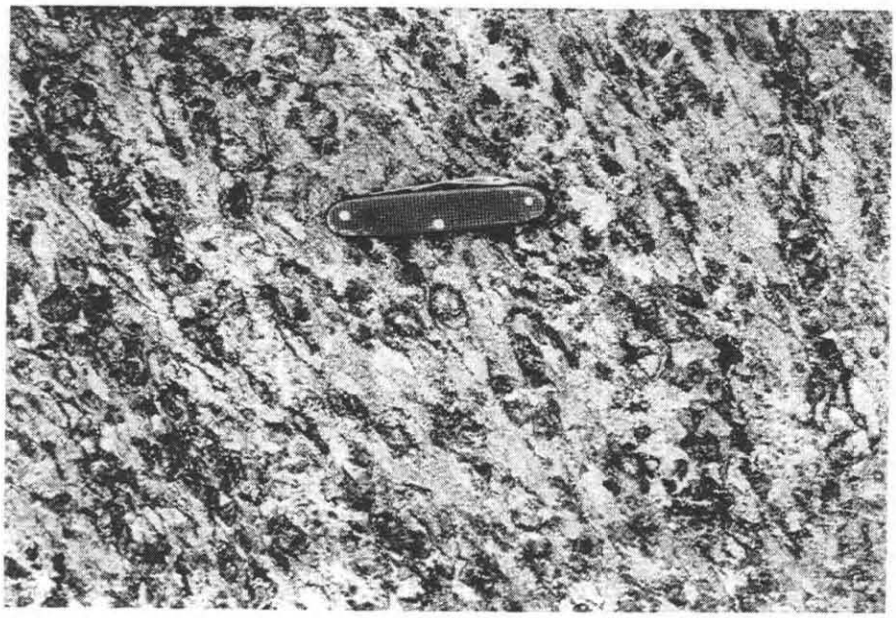


Photo 4-5 Close-up of metapelitic layer in protometatexite, from the Wegg Lake area, which illustrates the abundance of cordierite and garnet porphyroblasts and intermingled patches of leucosome.

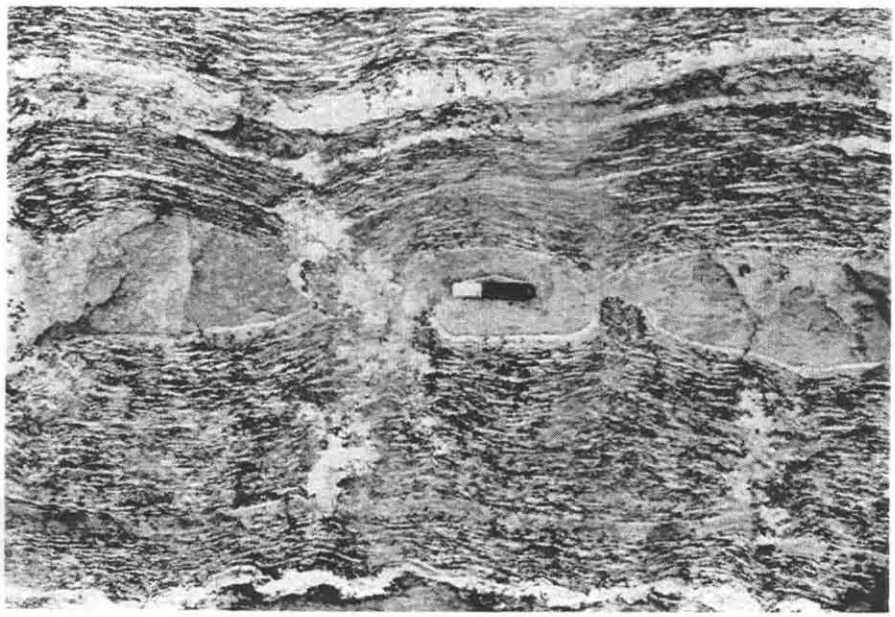


Photo 4-6 Combination of protometatexite and metatexite in metasedimentary migmatite at the Ear Falls damsite. Pen marks partial boudins of biotite metawacke within well foliated, coarser cordierite-biotite metapelite.

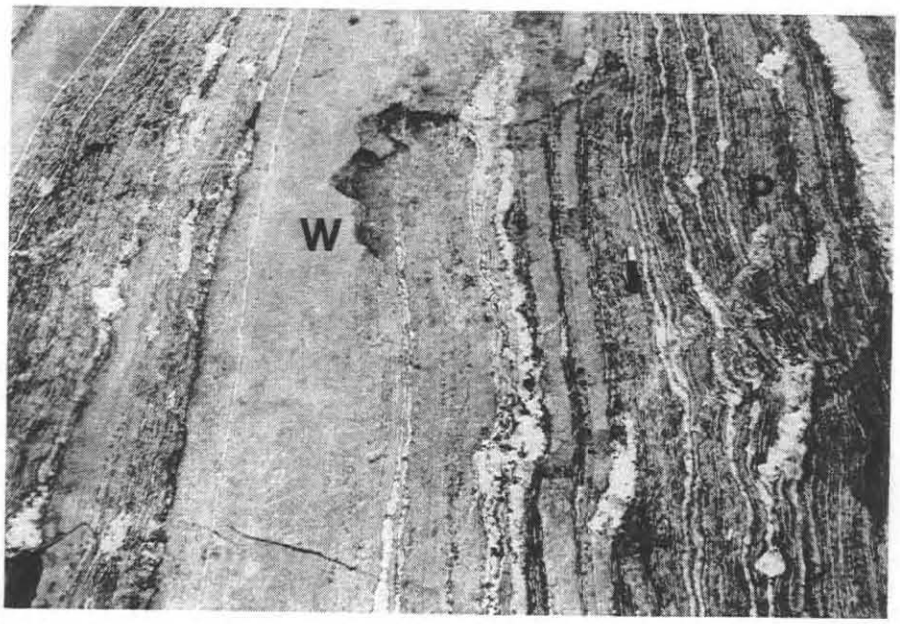


Photo 4-7 Metatexitic metasedimentary migmatite, Ontario Hydro damsite at Ear Falls. Note the greater abundance of leucosome in the metapelitic paleosome (P) along the right. Metawacke paleosome (W) contains relatively sparse leucosome.

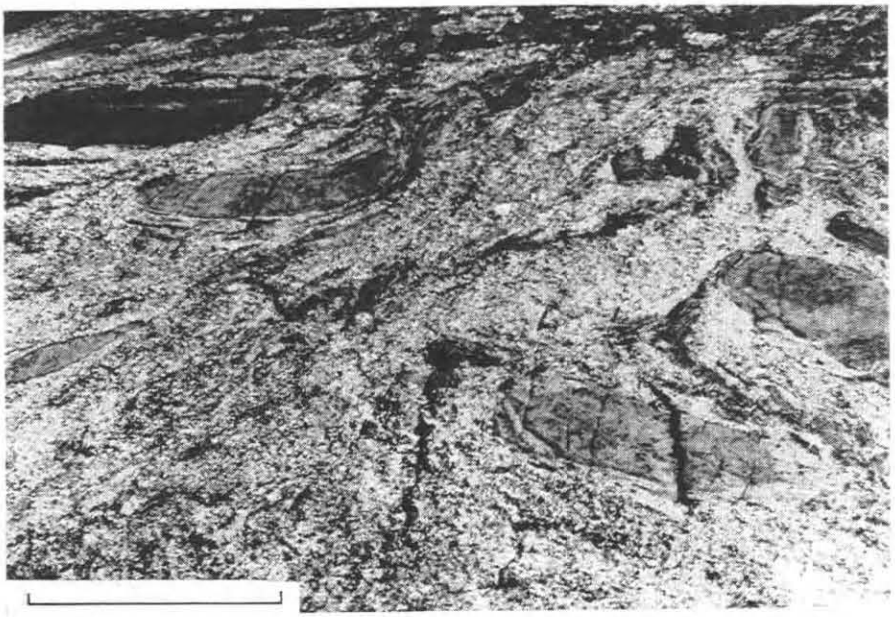


Photo 4-8 Inhomogeneous diatexite near Root Bay, Lake St. Joseph, illustrating schollen structure. Bar length = 1 m.

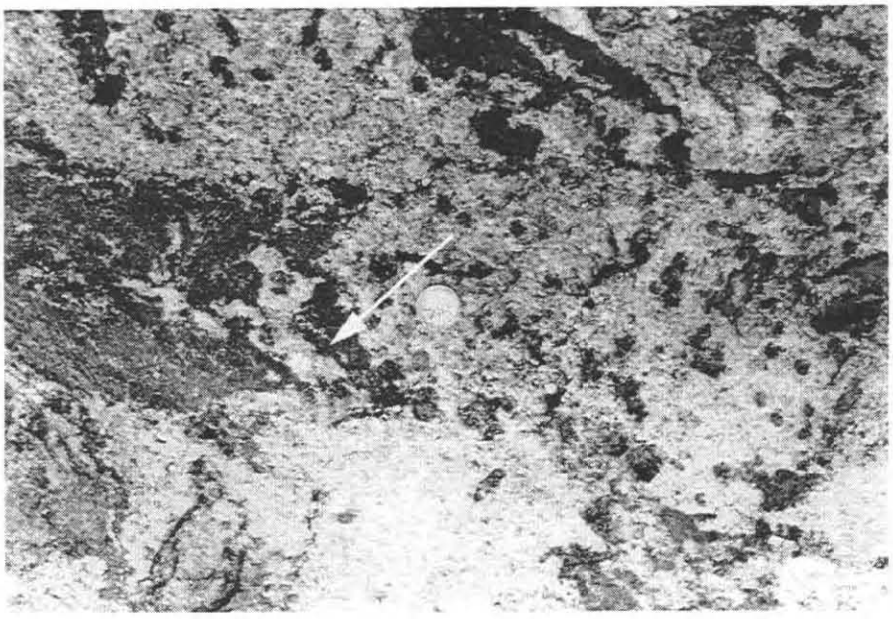


Photo 4-9 Melanosome clot in the process of separation from a larger mass of restite to left of coin) contained within inhomogeneous diatexite of garnet-cordierite-biotite quartz monzonite composition. Treelined Lake. Coin = 1.8 cm.

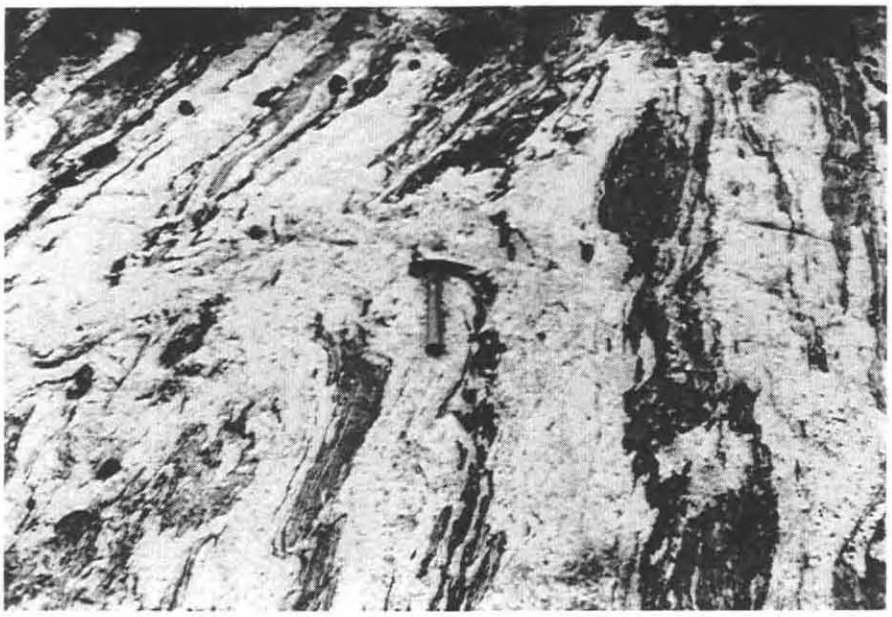


Photo 4-10 Transition from metatexite on right to inhomogeneous diatexite which contains twisted rafts of metawacke in cordierite-garnet-biotite leucosome at Treelined Lake.

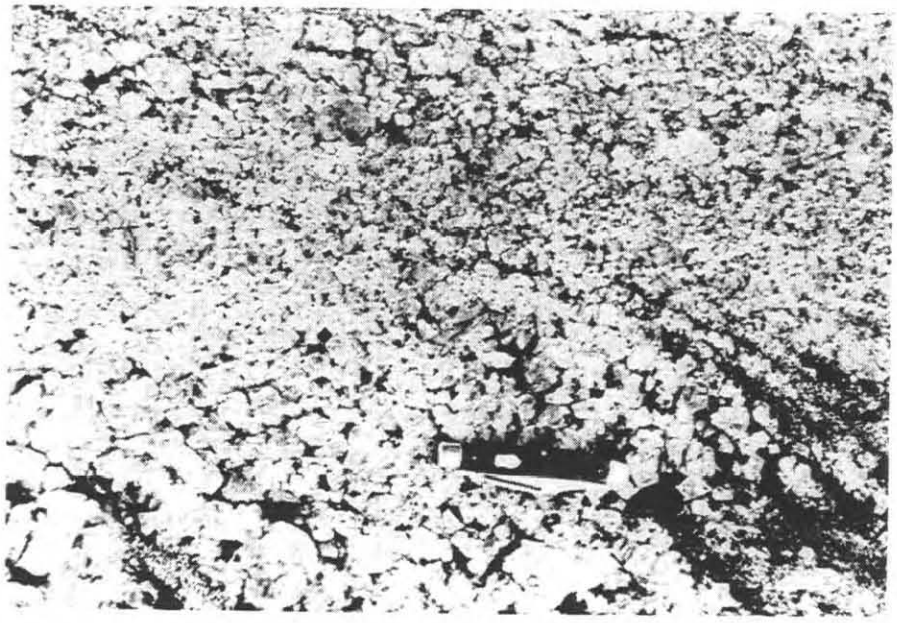


Photo 4-11 Syenite leucosome from the Bear Narrows of Lac Seul, exhibiting the large grain size range and hypidiomorphic-granular texture that is typical for the leucosome constituent.

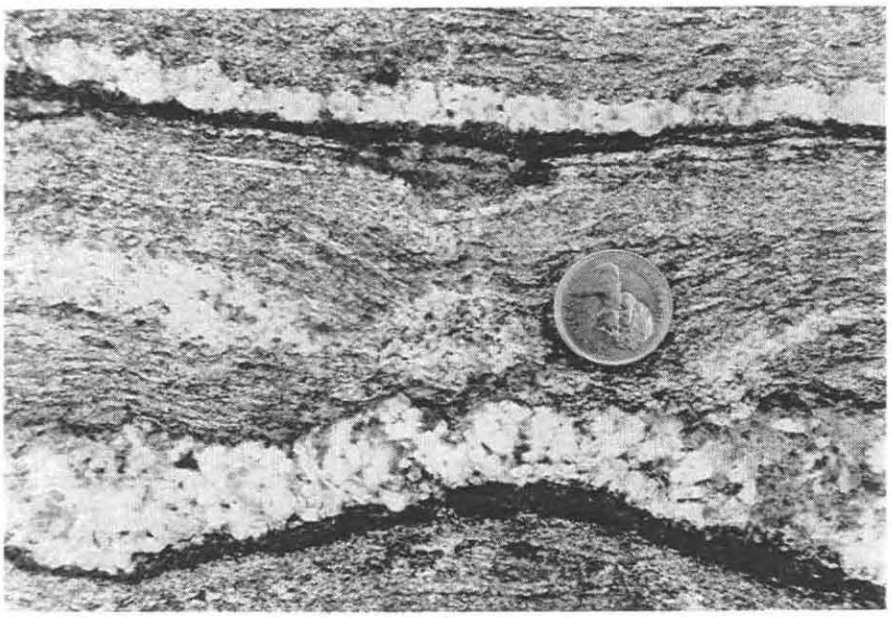


Photo 4-12 Metatexite metasedimentary migmatite with exceptionally thick melanosome selvedges distributed only along one side of the leucosome. Ministry of Natural Resources warehouse site at Ear Falls. Coin = 1.8 cm.

Photo 4-13 Granite leucosome pod in protometatexite from the Wegg Lake area. The leucosome was apparently in the process of engulfing a large garnet porphyroblast (G) which lies adjacent to large cordierite poikiloblasts (C). Bar = 2 cm.

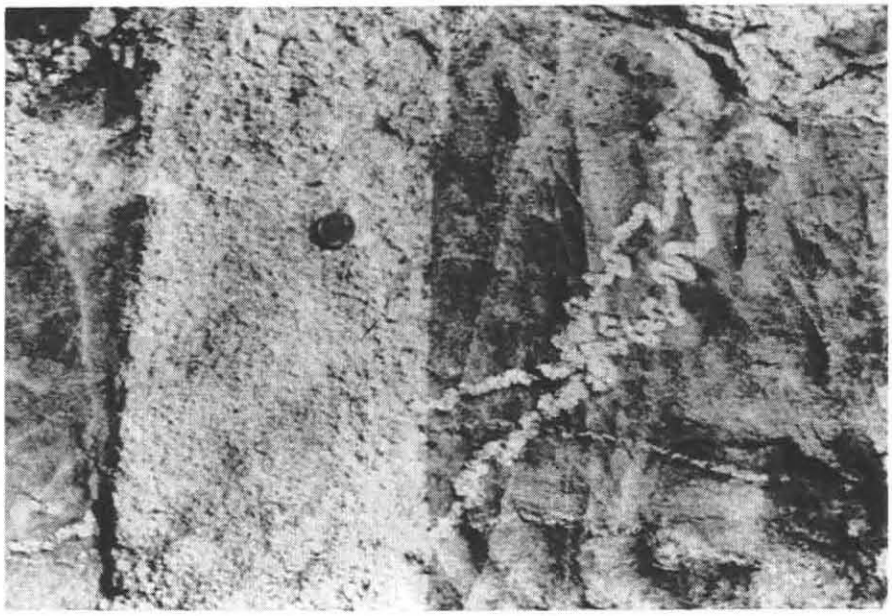


Photo 4-14 Dyke of "intrusive mobilizate" which sharply truncates ptygmatically-folded leucosome in metawacke at Rao Lake. Coin = 2.3 cm

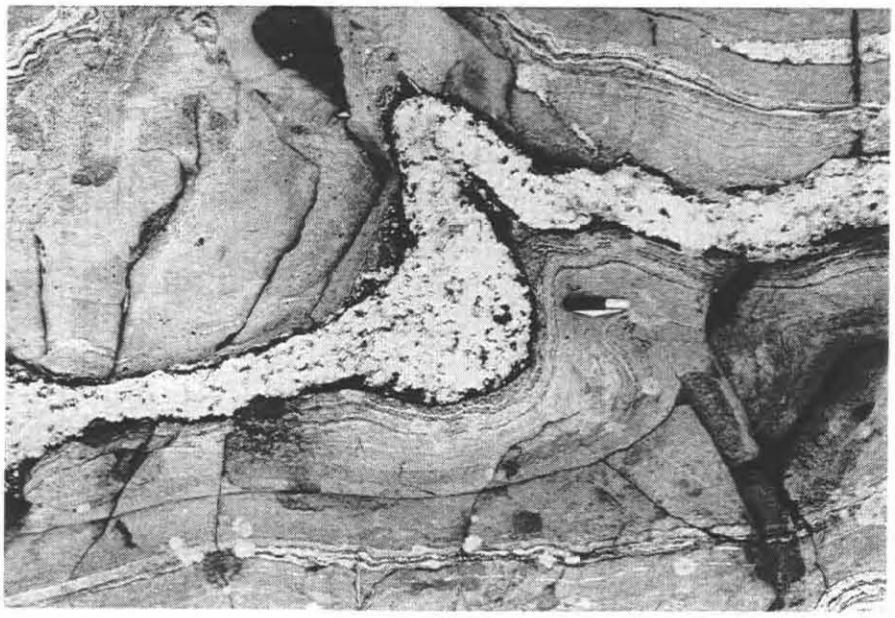


Photo 4-15 Apatite-biotite syenite leucosome in metatexite at the Ear Falls damsite. Note the symmetrical disposition of biotite-rich melanosome selvedges along both leucosome contacts.

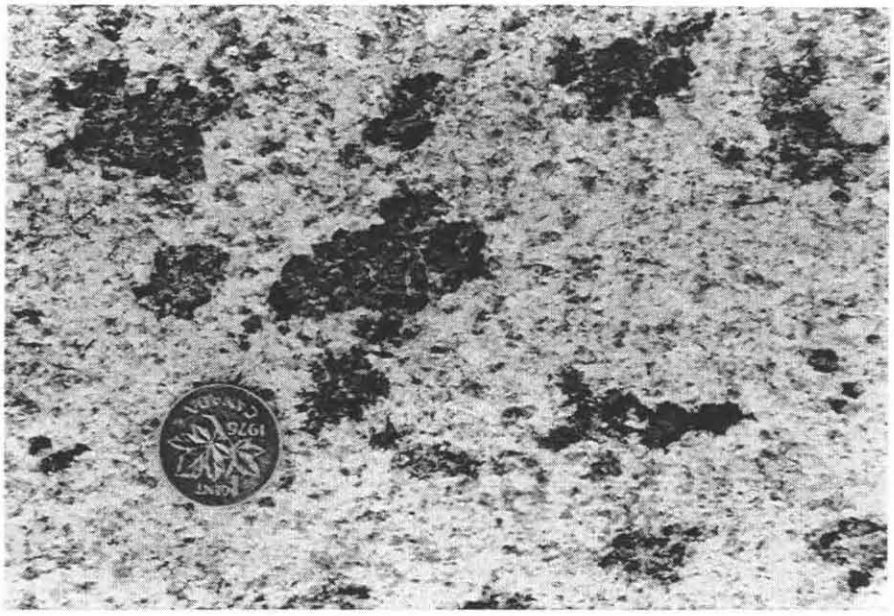


Photo 4-16 Biotite-cordierite-quartz clots in diatexite at Treelined Lake Coin = 1.8 cm.

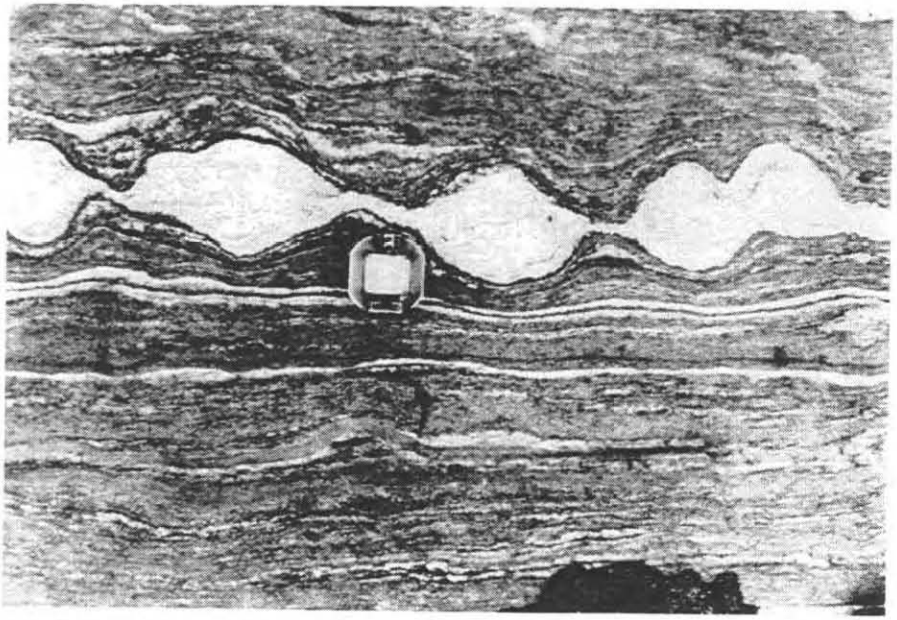


Photo 4-17 Boudinage structure in metatexite metasedimentary migmatite, Wapesi Bay of Lac Seul.

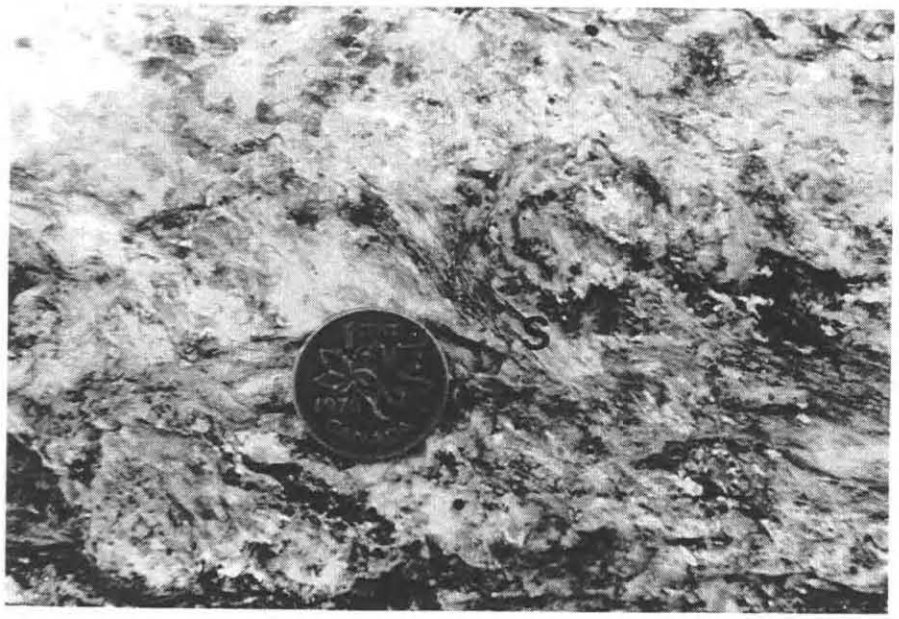


Photo 4-18 Fibrous mat of sillimanite (S) associated with muscovite in sillimanite-biotite-muscovite quartz monzonite in the Ghost Lake batholith. Highway 17 roadcut at Oxdrift. Coin = 1.8 cm.

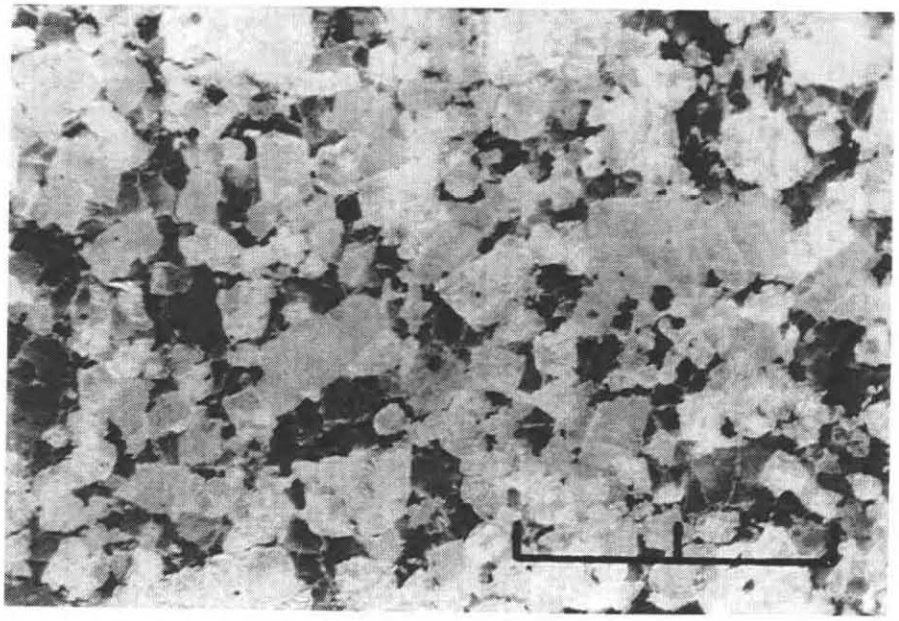


Photo 4-19 Cordierite-biotite quartz monzonite from Churchill Lake batholith near Sleen Lake. Euhedral cordierite indicated by arrow.

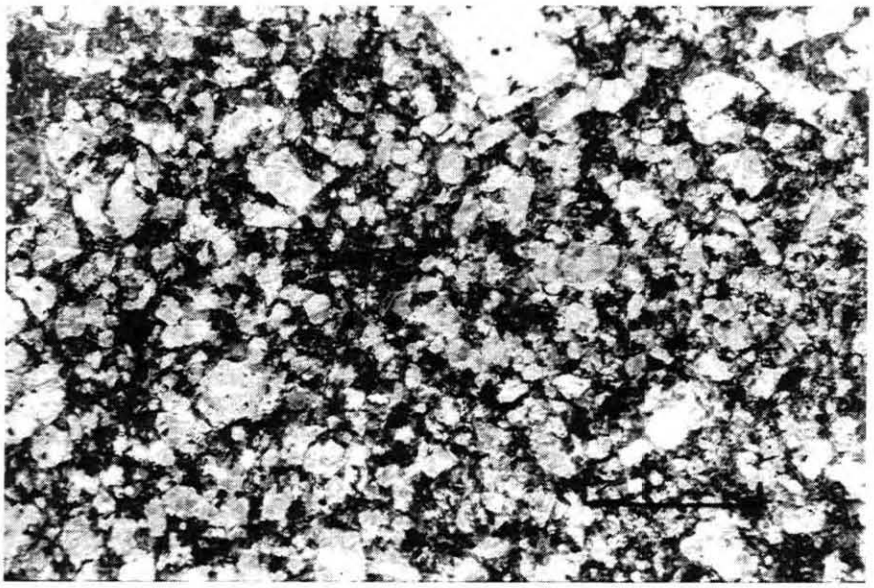


Photo 4-20 Hypidiomorphic-granular texture in biotite quartz monzonite homogeneous diatexite, Jackson Lake area. Bar = 2 cm.

Photo 4-21 Mafic diatexite of biotite tonalite composition near Conifer Lake. Bar = 1 cm.

Photo 4-22 Leucosome with abundant, euhedral cordierite, Ear Falls damsite. Coin = 1.8 cm.

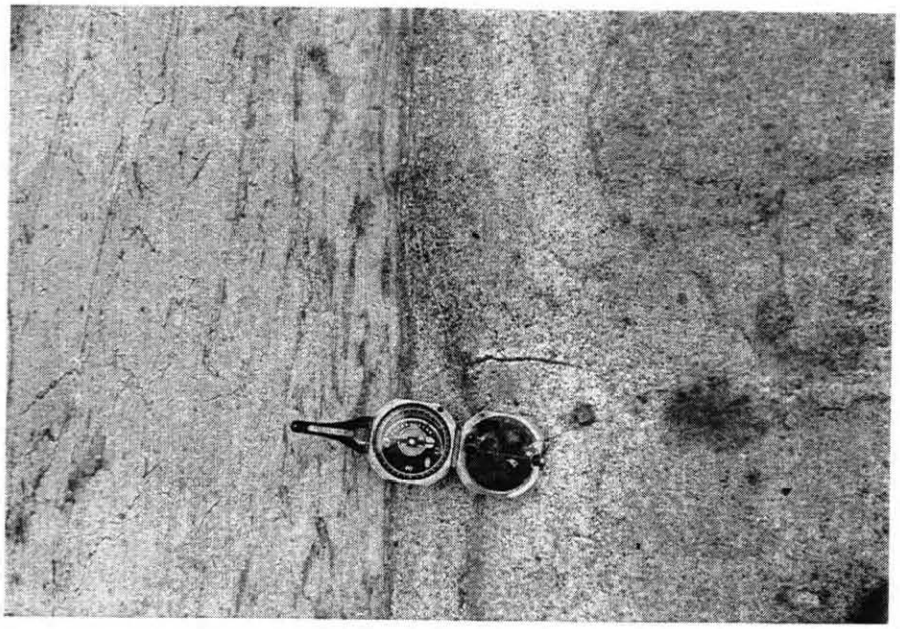


Photo 5-1 Medium-grained trondjemite, on right, intruded into quartz porphyry on Rexdale Property just southwest of Snakeweed Lake.

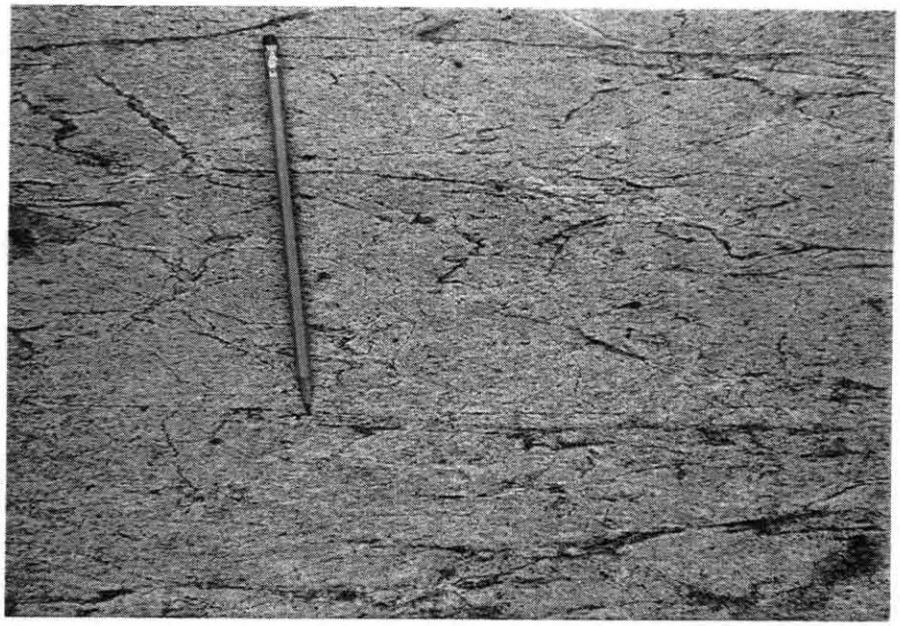


Photo 5-2 Irregular fracture pattern in subvolcanic intrusive (quartz porphyry) on the Rexdale Property.

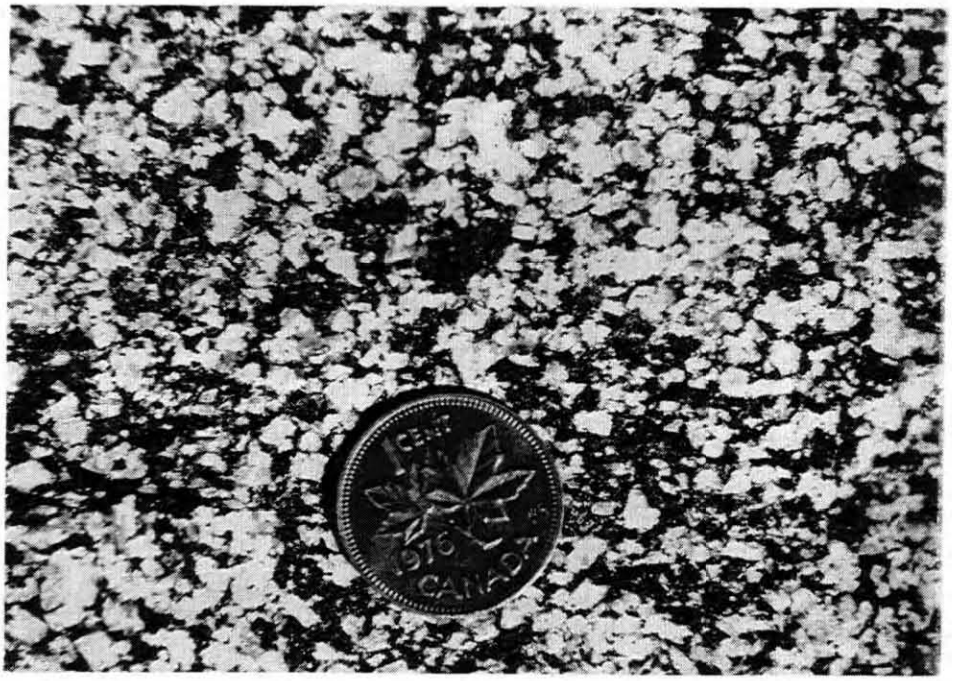


Photo 6-1 Massive, medium-grained diorite at Muriel Lake, Kenora area.

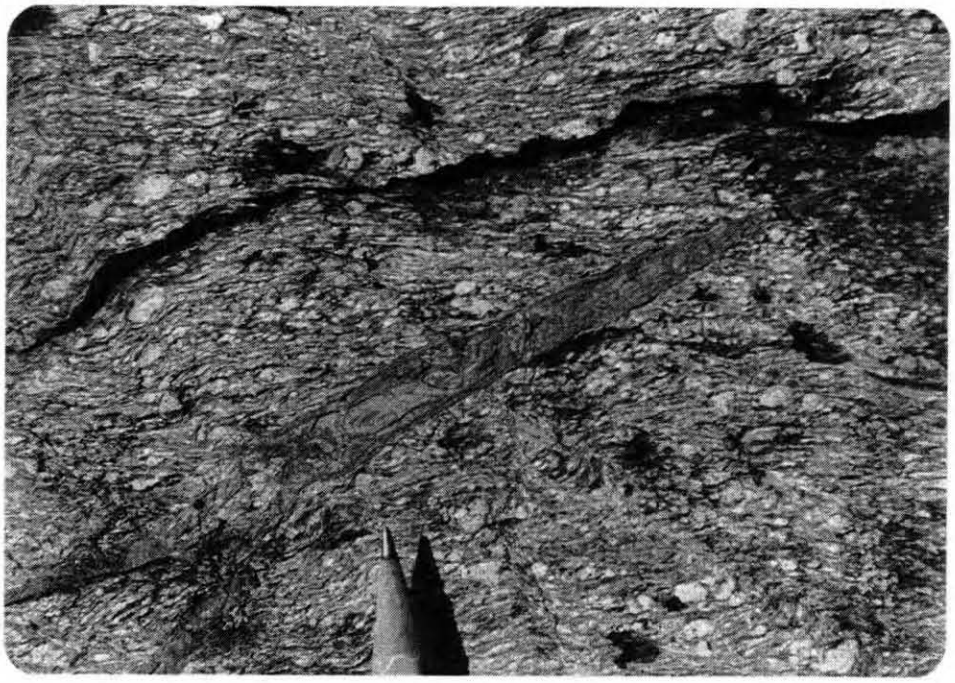


Photo 6-2 Cataclastic quartz diorite of the Bruce Lake pluton situated about 8 km northwest of Bluffy Lake. Note the small, cross-cutting mass of pseudotachylite with well developed flow lines (Centre).

Photo 6-3 Magmatic layering in unit 1D-i of the Lake St. Joseph mafic sill due to concentration of clots.

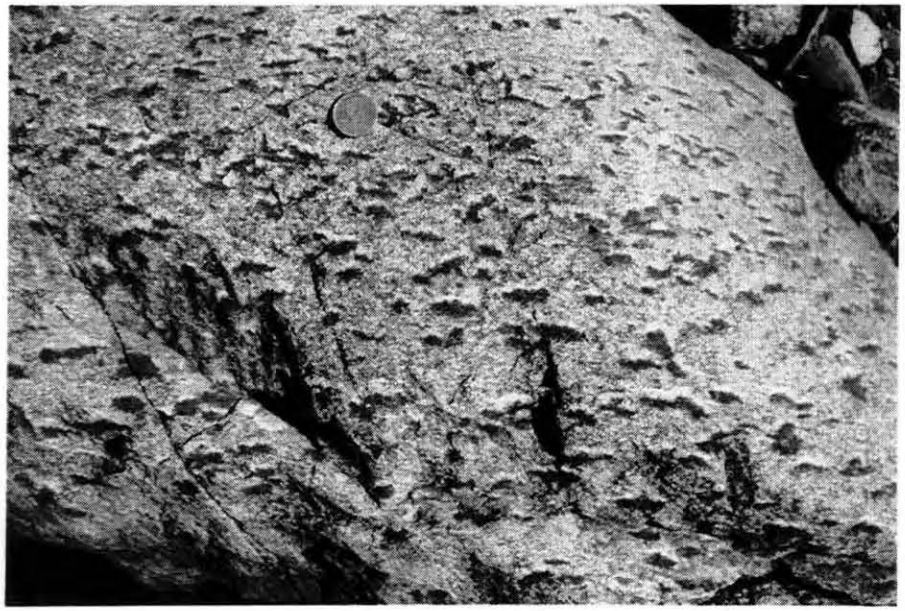


Photo 6-4 Clotty metagabbro of unit 1D-i of the Lake St. Joseph layered mafic sill. Note mafic-felsic mineral segregation suggesting top direction towards the photo top.

Photo 6-5 Mafic metagabbro dykes in the Bear Narrows area of Lac Seul.

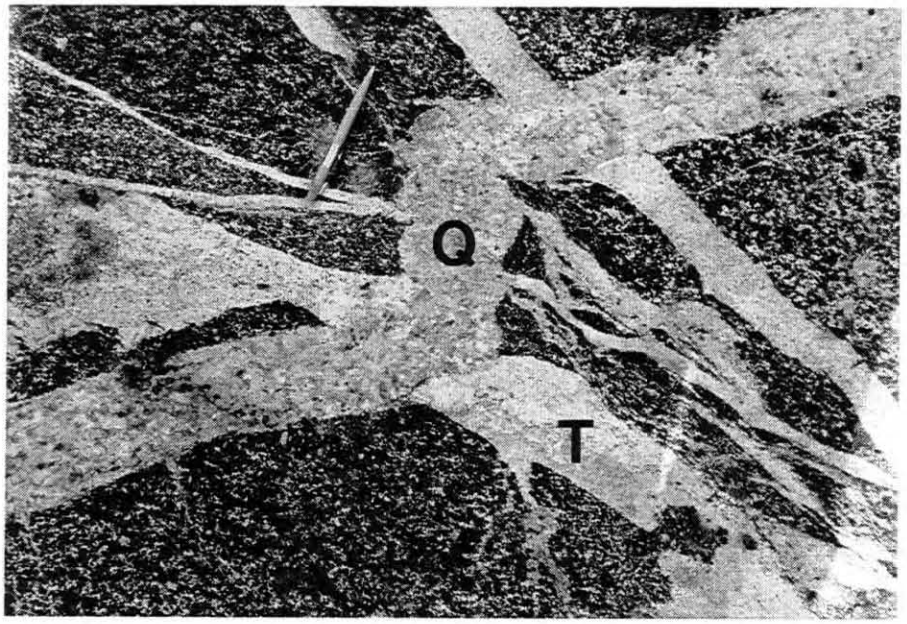


Photo 6-6 Dykes of trondhjemite (T) and later quartz monzonite (Q) intruded into massive, coarse-grained, equigranular amphibolite (mafic intrusive suite). On the Minaki-Umfreville Lake road near Pistol Lake.

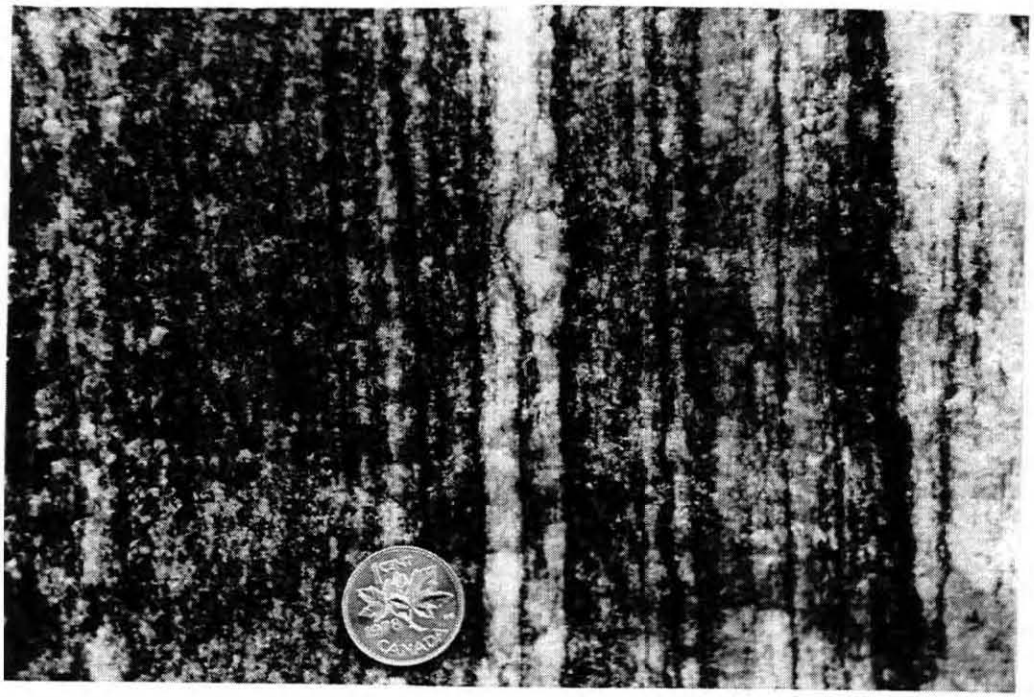


Photo 7-1 Gneissic granitoid suite with finely banded mafic aggregates, biotite tonalite, biotite trondhjemite and metasomatic K-feldspar (on left). Location is near the Wabigoon-English River subprovincial boundary at Kenora.

Photo 7-2 Intermediate gneiss from the Deception Bay area exhibiting diffuse, patchy hornblende diorite and small enclave of metaultramafic rock (on left).

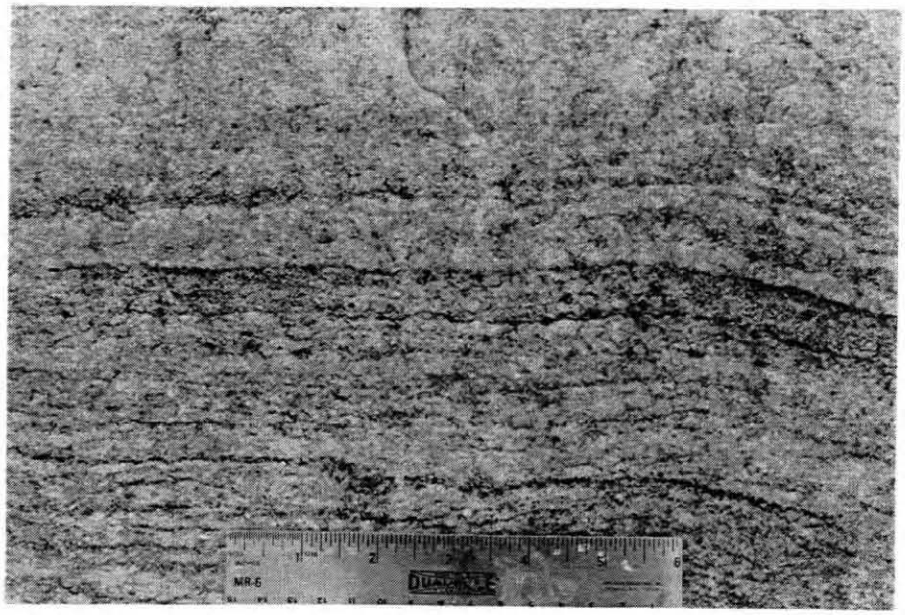


Photo 7-3 Leucocratic trondhjemite gneiss, south of Bear Narrows, containing thin, continuous trains of biotite.

Photo 7-4 Gneissic granitoid suite at Deception Bay of Lac Seul. Rock contains foliated to gneissic biotite-hornblende diorite to quartz diorite and concordant trondhjemite (T) which is discordantly intruded by fine-grained biotite trondhjemite.

Photo 7-5 Minor folds in gneissic granitoid suite from Pelican Lake near Sioux Lookout. Pen = 15 cm.

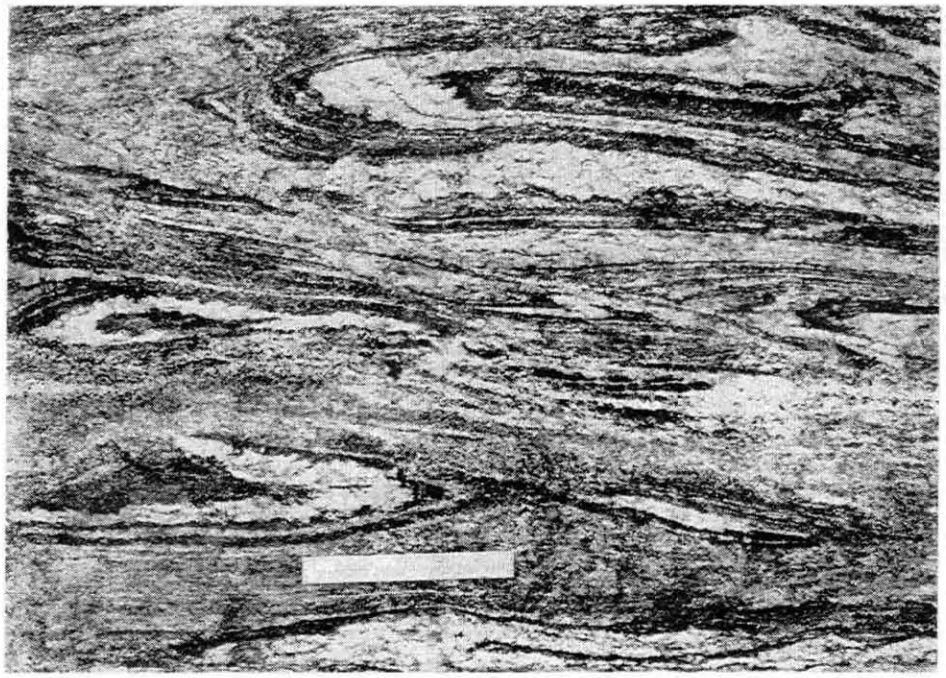


Photo 7-6 Rootless, intrafolial isoclinal folds in holo-leucocratic trndhjemite constituent of a gneissic granitoid exposure on Highway 105, just north of Vermillon Bay.

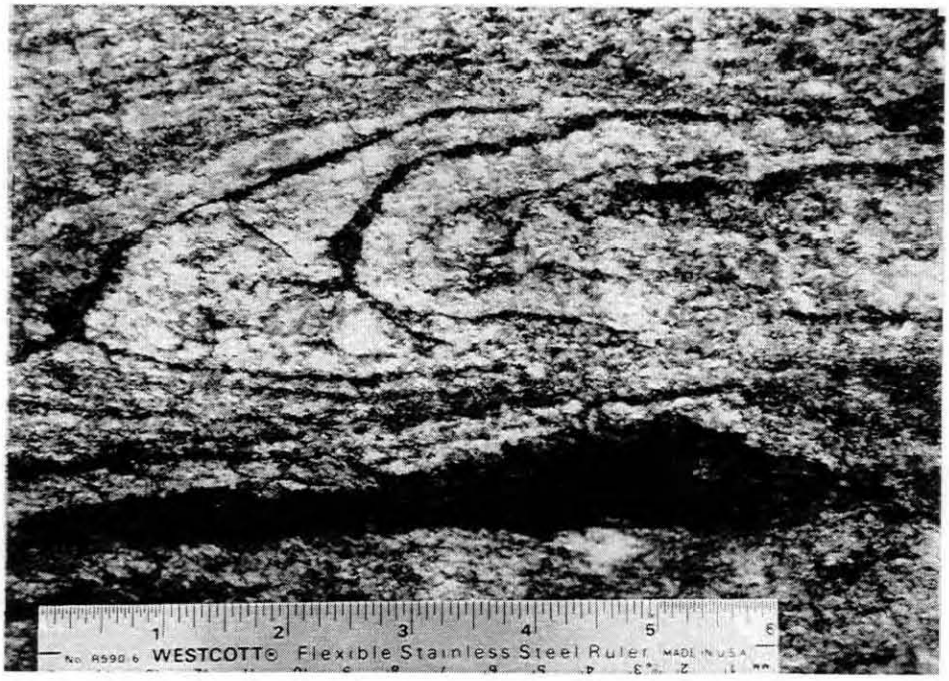


Photo 7-7 Rootless, intrafolial, isoclinal refolded fold defined by holo-leucocratic trondhjemite and biotite-rich laminae in the Cedar Lake gneisses. Highway 105 roadcut near Cedar Lake. Ruler = 15 cm.

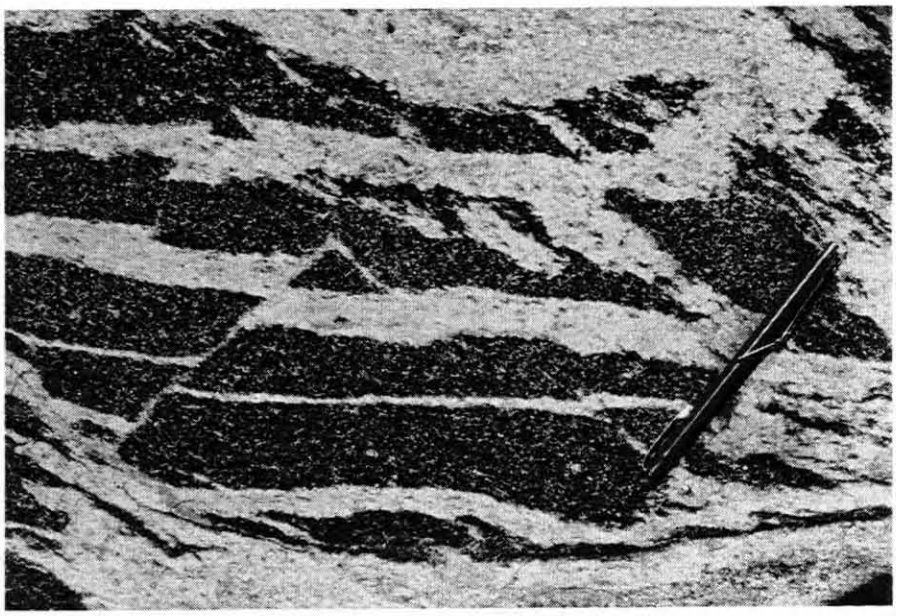


Photo 7-8 Enclave of mafic metavolcanic or metagabbro rock in the gneissic granitoid suite, Deception Bay.

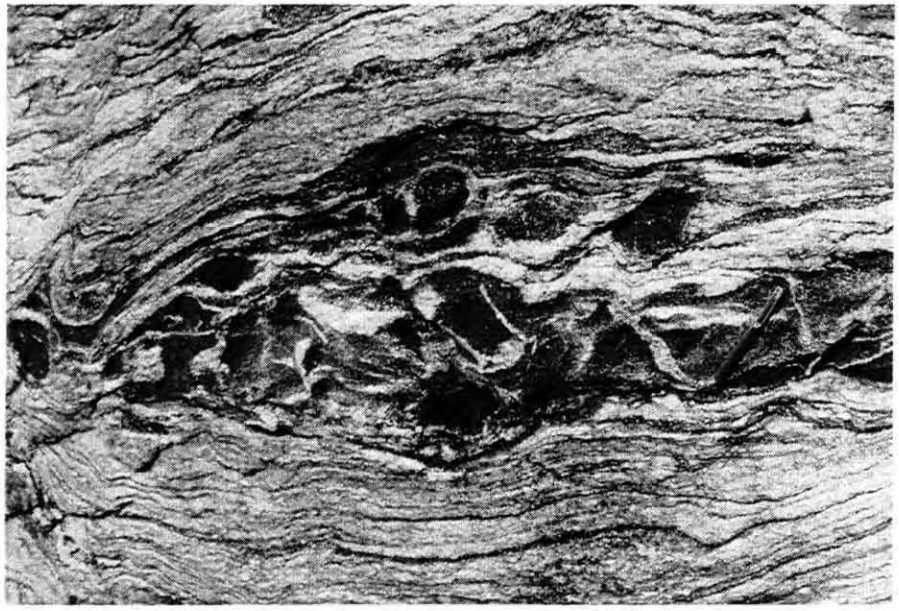


Photo 7-9 Highly disrupted, former dyke of mafic rock in intermediate gneiss from gneissic granitoid suite, Deception Bay area.

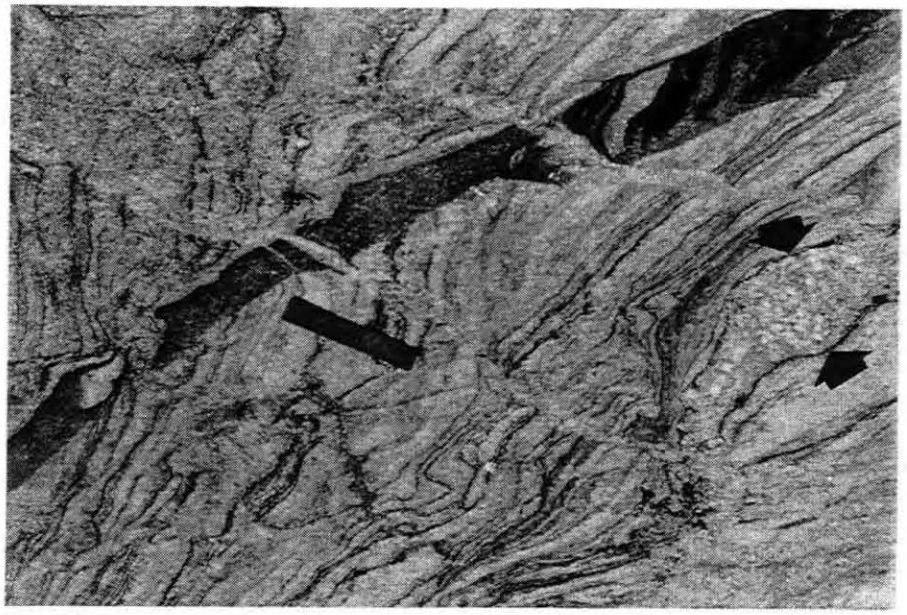


Photo 7-10 Interbanding in gneissic granitoid suite north of Tile Lake in the Deception Bay area. The main units comprise at least 3 units of trondhjemite, 2 units of quartz monzonite and a mafic dyke. Arrows point to thin, biotite-rich selvedges along the margins of some concordant quartz monzonite units. Ruler = 15 cm.

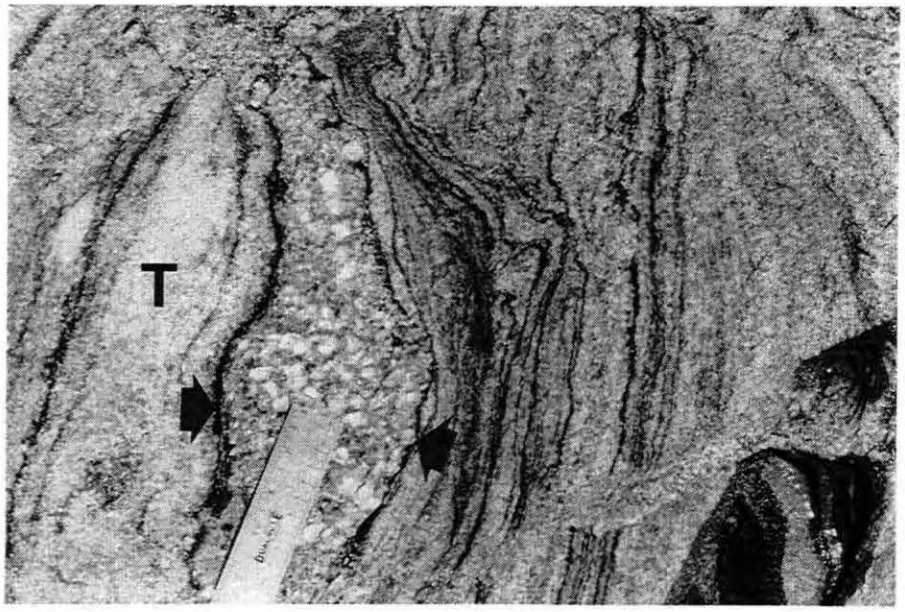


Photo 7-11 Gneissic granitoid suite from the Deception Bay area, revealing interleaved biotite trondhjemite, more leucocratic trondhjemite (T) and quartz monzonite, marked by 15 cm-long ruler, with biotite-rich selvedges.

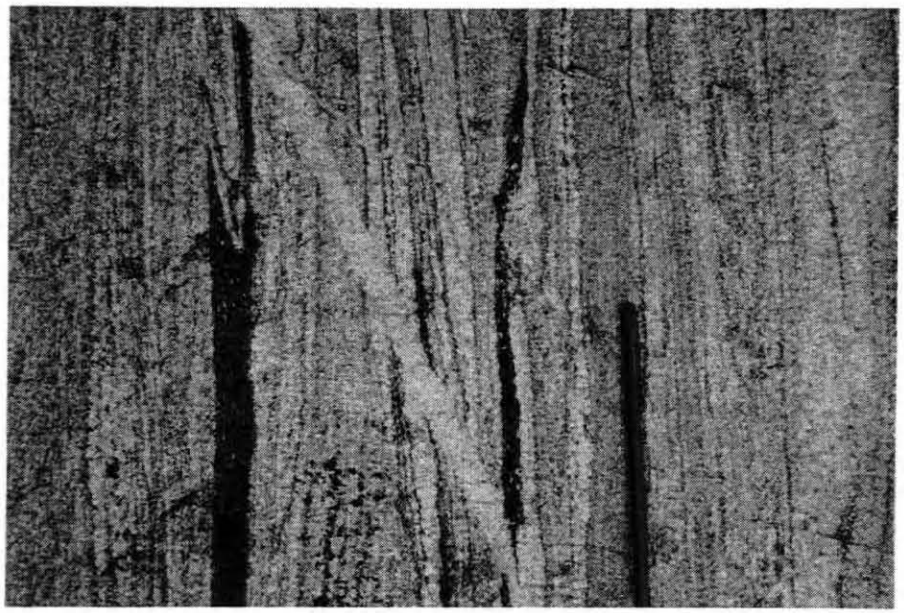


Photo 7-12 Gneissic granitoid suite near Wabigoon-English River subprovincial boundary, north shore of Pelican Lake. Outcrop contains several units of foliated biotite trondhjemite interleaved with a more leucocratic trondhjemite which are cut by a thin, discordant dyke of quartz monzonite. The mafic-rich enclaves may represent attenuated former dyke material. Pen = 15 cm.

Photo 7-13 An example of metamorphically-reworked mafic/felsic constituents in gneissic granitoid suite at Deception Bay.

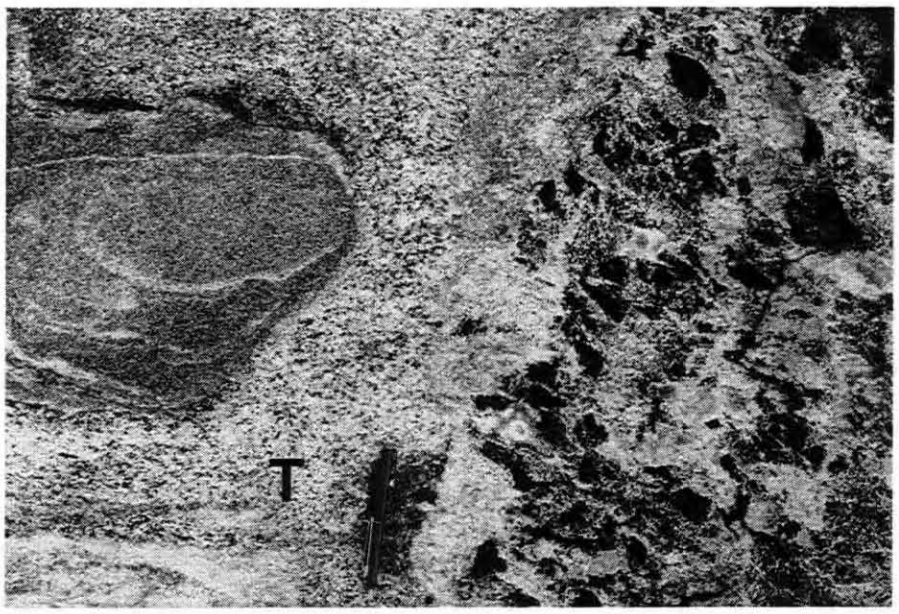


Photo 7-14 Mafic to ultramafic enclaves (on right) from the gneissic granitoid suite, Deception Bay. The trondhjemite unit (T) exhibits a wide colour index range.

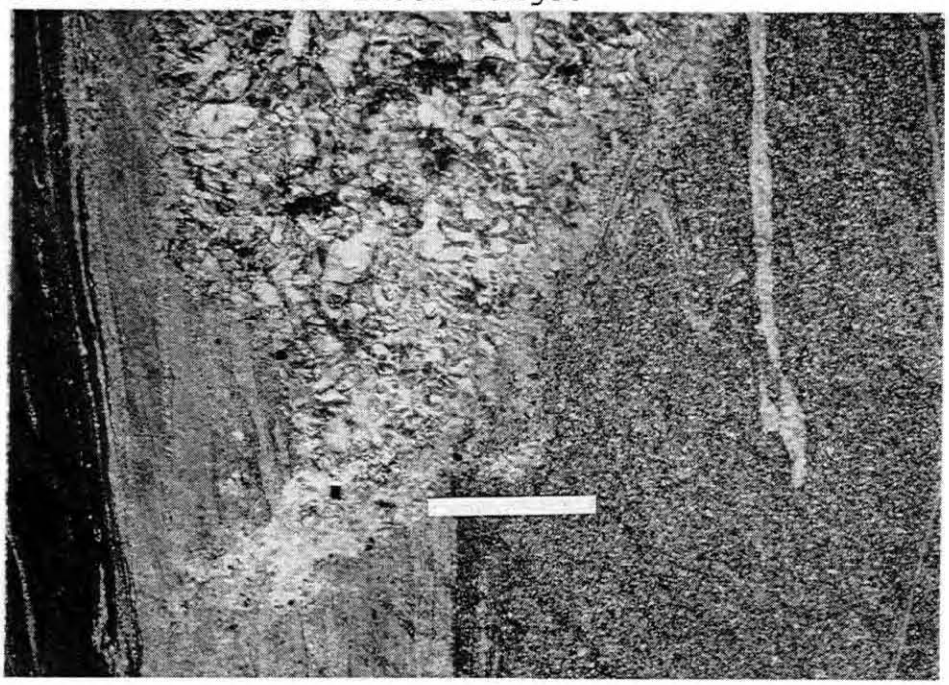


Photo 7-15 Medium-grained, biotite-hornblende trondhjemite to quartz diorite unit of the sodic granitoid suite which contain a mafic band (on left) which is intruded by fine-grained, biotite trondhjemite (right side) and by a discordant mass of inequigranular, quartz monzonite pegmatite. Outcrop is near the Wabigoon-English River subprovincial boundary just west of Highway 105. Ruler = 15 cm.

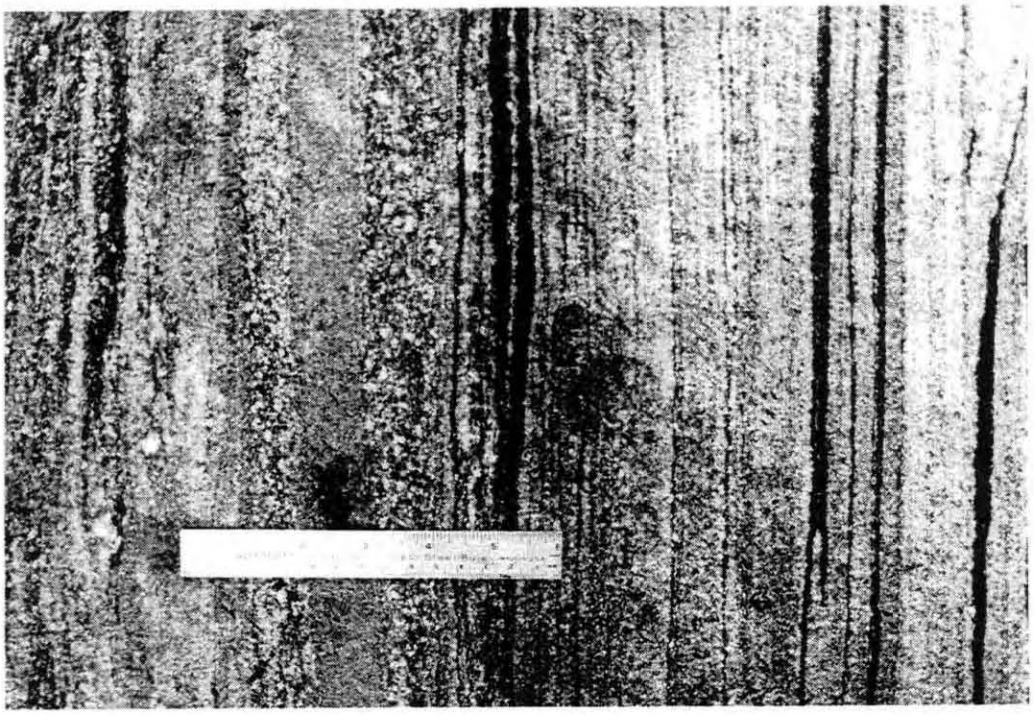


Photo 7-16 Typical gneissose structure produced by interleaved, medium- to coarse-grained biotite-hornblende trondhjemite to quartz diorite, fine-grained biotite trondhjemite, hornblende-rich mafic bands and minor, medium- to coarse-grained quartz monzonite. Photo located about 3 m from Photo 7-11.

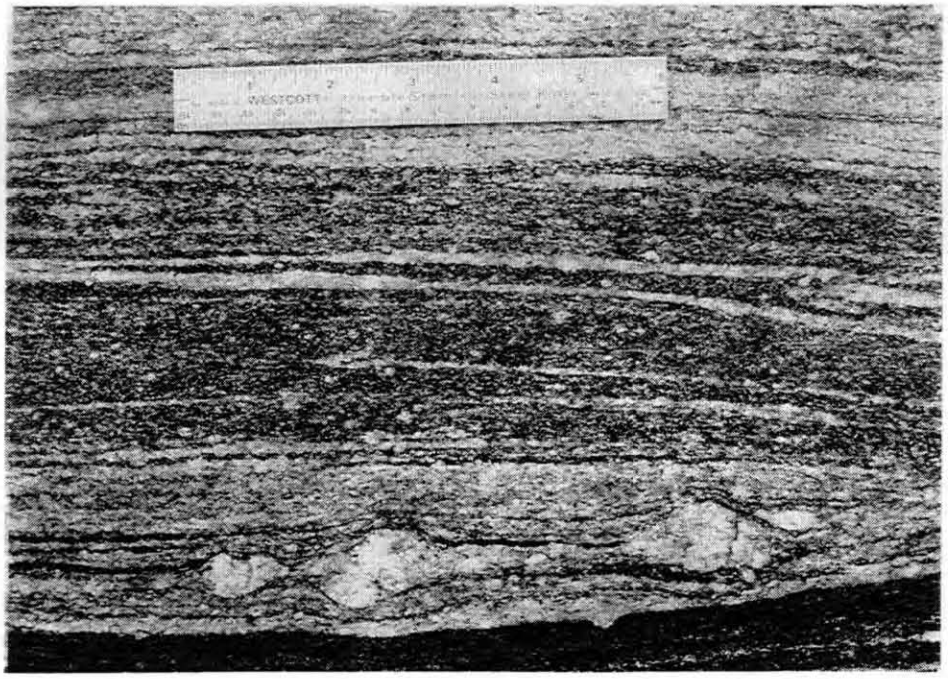


Photo 7-17 Cataclastic quartz monzonite veins in gneissic granitoid suite north of Wabigoon-English River subprovincial boundary just west of Highway 105. Photo from same outcrop as Photos 7-15 and 7-16.

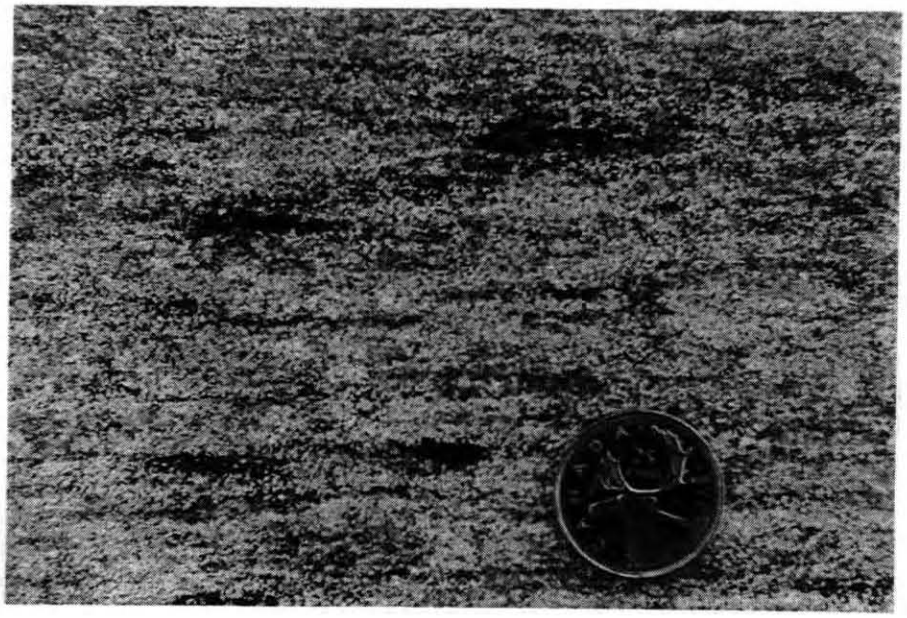


Photo 8-1 Foliated to gneissic, magnetite-diopside-hypersthene-biotite trondhjemite near Chamberlain Narrows of Lac Seul. Coin = 2.3 cm.

Photo 8-2 Stictolithic or fleck-textured hypersthene-biotite trondhjemite from just north of Chamberlain Narrows and marked by mafic segregations rich in magnetite enveloped by quartz-plagioclase leucocratic halos.

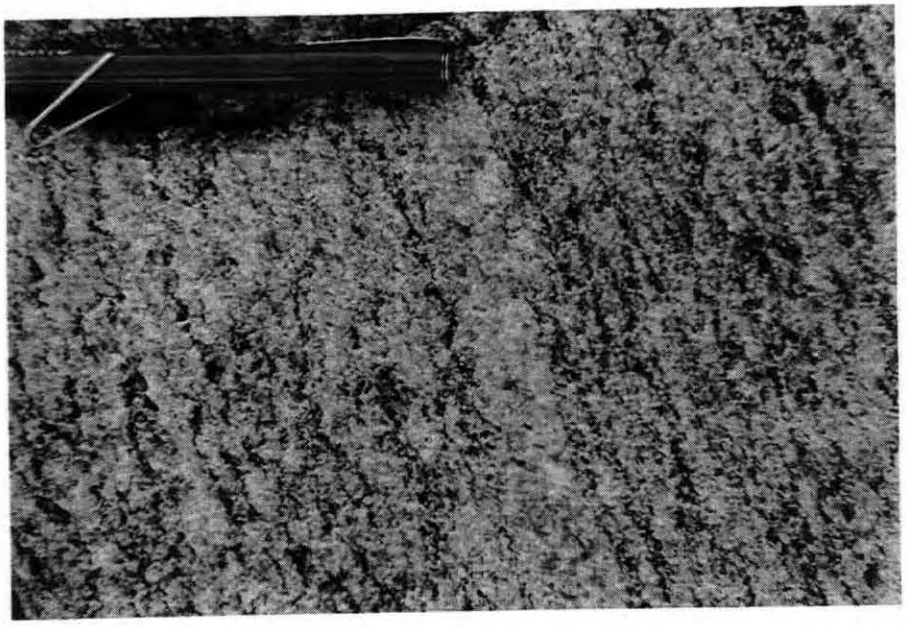
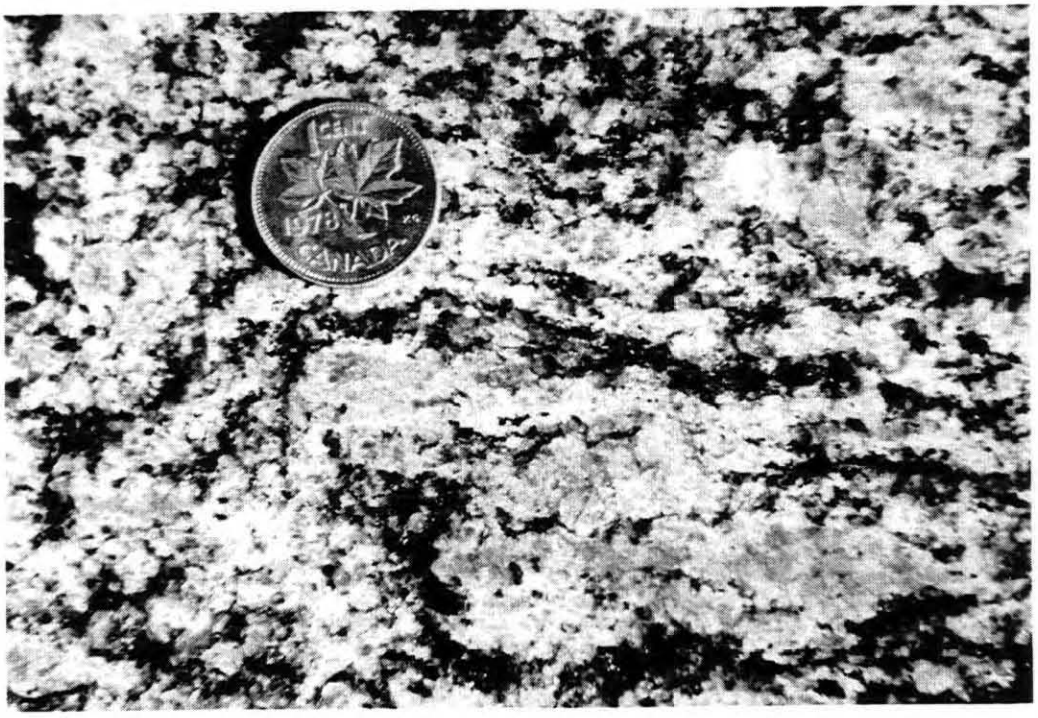


Photo 8-3 Foliated to gneissose biotite trondhjemite (sodic granitoid suite) with diffuse, leucocratic, concordant, quartz monzonite vein of possible metasomatic origin. Bear Narrows area of Lac Seul.

Photo 8-4 Kink bands in well foliated, hornblende-biotite trondhjemite to quartz diorite located on the Grassy Narrows-Oak Lake logging road, just north of Marshalok Lake.

Photo 8-5 Porphyroblastic, medium- to coarse-grained, hornblende-biotite granodiorite on the Gordon Lake road north of the Grassy Narrows Reserve and south of Oak Lake. Coin = 1.8 cm.



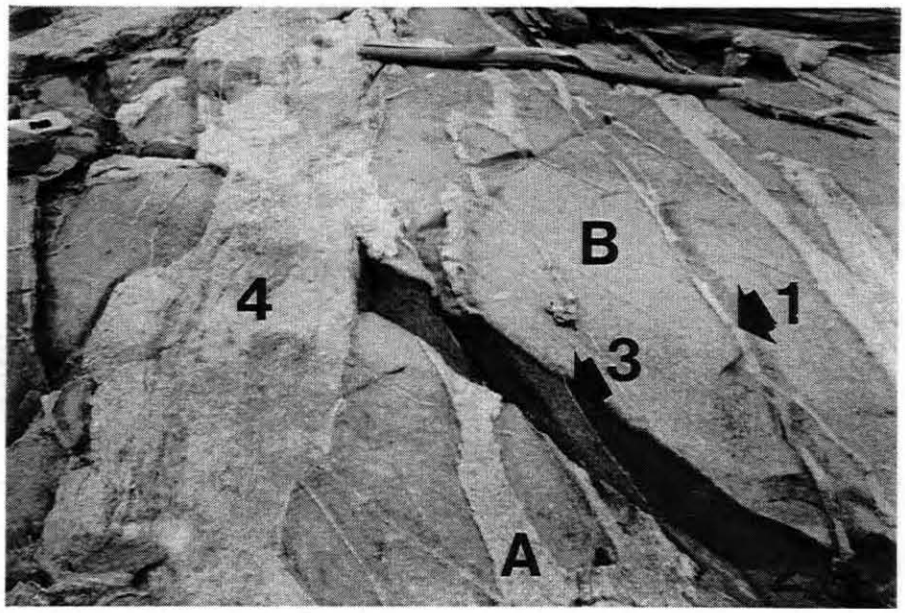


Photo 8-6 Sodic granitoid suite near Chamberlain Narrows (Lac Seul), revealing a complex medley of units: Fine- to medium-grained biotite trondhjemite (unit A); medium- to coarse-grained hornblende-biotite trondhjemite to quartz diorite (unit B) intruded in order of decreasing relative ages by:
1) leucocratic trondhjemite (parallel to foliation of major units)
2) metagabbro dyke (parallel to widely-spaced, weak cleavage)
3) thin veins of leucocratic trondhjemite (parallel to cleavage)
4) late quartz monzonite (cross-cuts all units and structures)

Photo 8-7 Stictolithic quartz diorite of the Sen Bay stock intruded by trondhjemite (sodic suite) and quartz monzonite dykes.

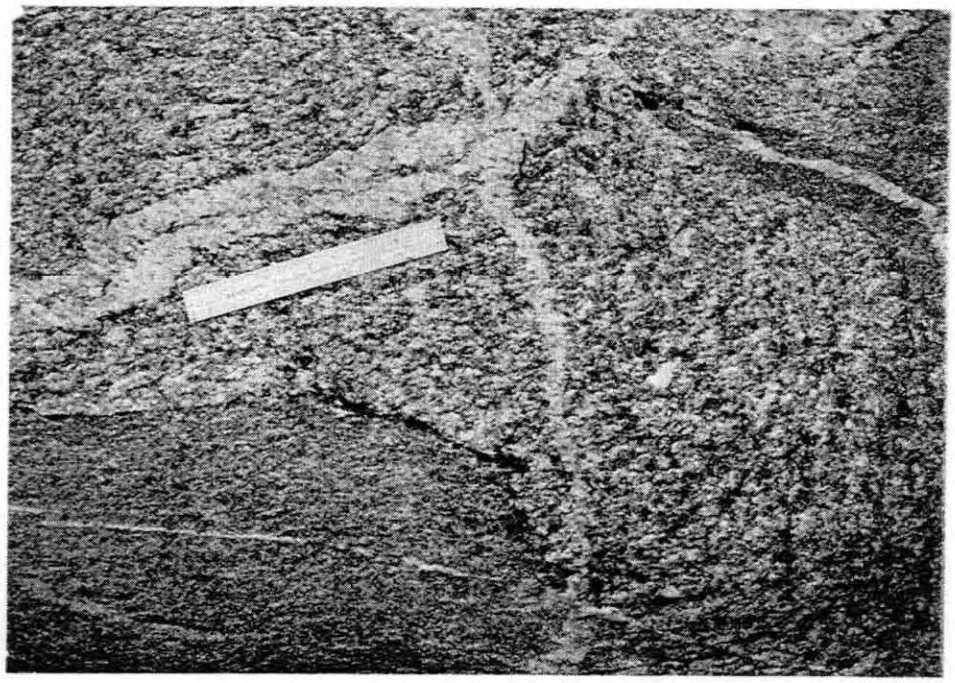


Photo 8-8 Medium- to coarse-grained magnetite-hornblende-biotite trondhjemite to quartz diorite from the Sen Bay stock with enclave of fine- to medium-grained biotite trondhjemite (left corner) which is intruded by inequigranular, quartz monzonite (potassic suite).

Photo 9-1 Massive, medium-grained, equigranular, unmetamorphosed biotite quartz monzonite from the Nelson granite quarry near Vermilion Bay.

Photo 9-2 Clotty quartz monzonite from Highway 105 roadcut at Perrault Falls.

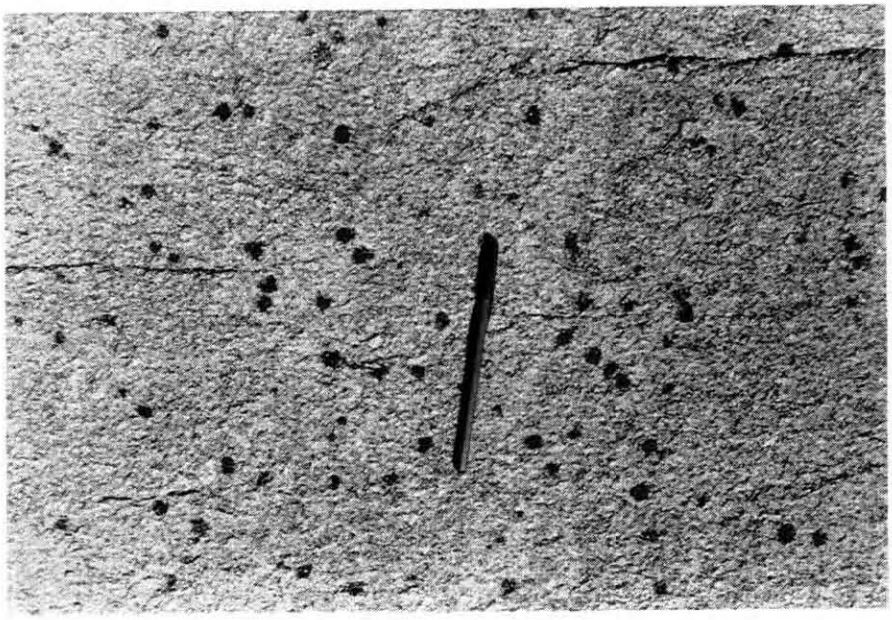


Photo 9-3 Clotty, garnet-bearing quartz monzonite northwest of Gymame Bay of Lac Seul.

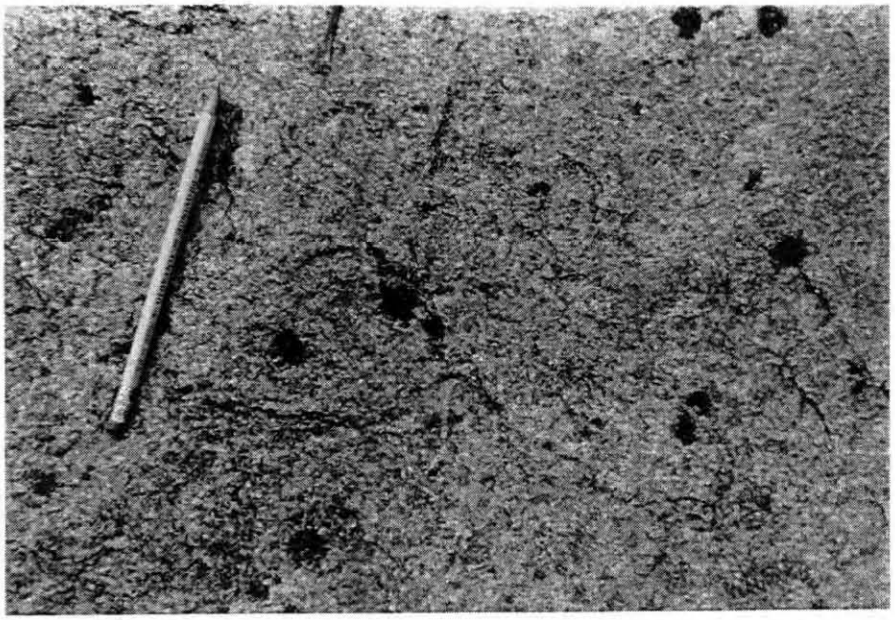


Photo 9-4 Equigranular, medium-grained quartz monzonite to granite (*sensu stricto*) with clots of garnet, quartz and biotite. Outcrop on the southern shore of Oak Lake.

Photo 9-5 Inequigranular biotite quartz monzonite with clots of magnetite, cordierite and quartz located near Gymame Bay of Lac Seul. Note the concentration of clots adjacent to an enclave of trondhjemite in the centre.

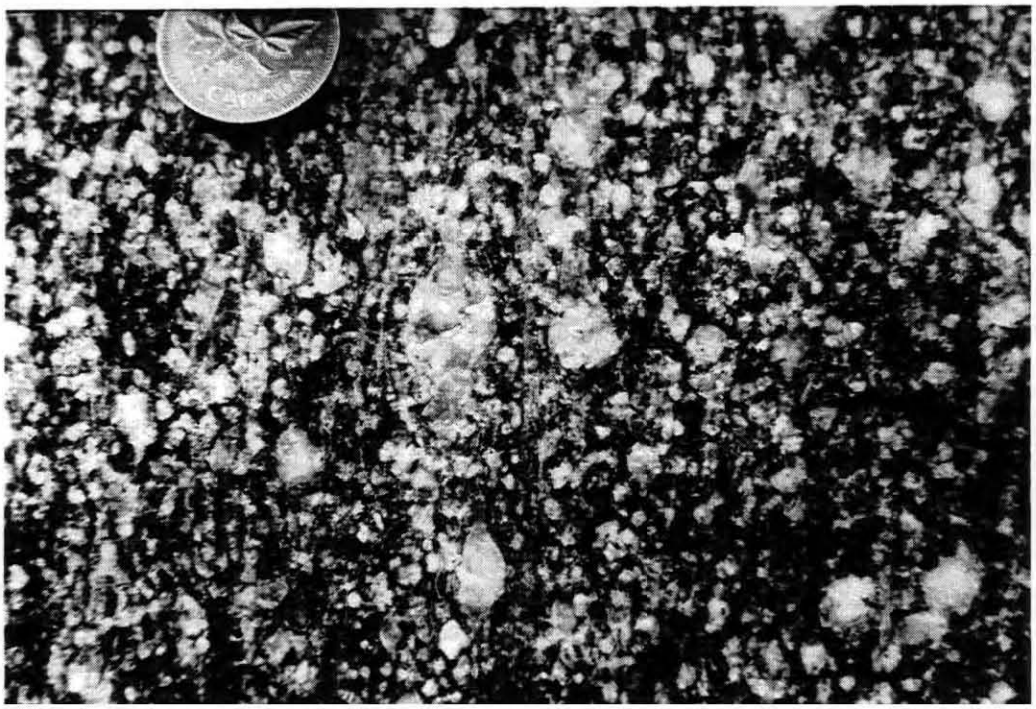


Photo 9-6 Weakly cataclastic, porphyritic granodiorite sill at the Wabigoon-English River subprovincial boundary at Kenora. Coin = 1.8 cm.

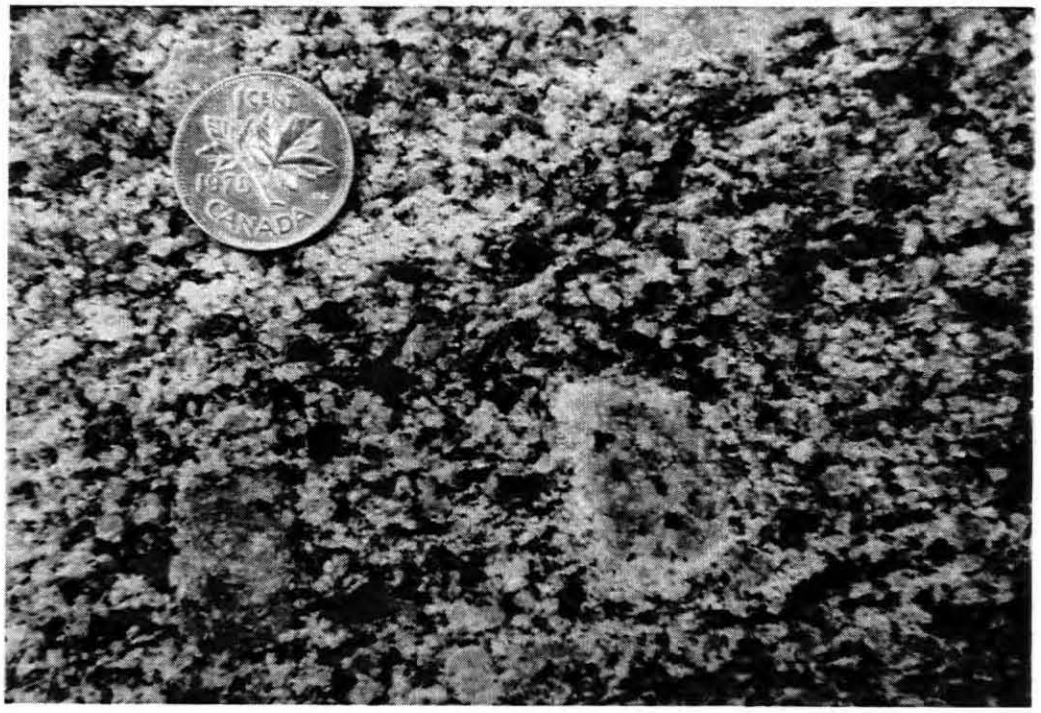


Photo 9-7 Possible rapakivi texture in porphyritic granodiorite of the Lount Lake batholith. Coin = 1.8 cm.

Photo 9-8 Porphyritic quartz monzonite from Lount Lake batholith in exposure on the Kenora-Grassy Narrows road between Havik and Keys Lakes. Note the alignment of K-feldspar megacrysts which may relate to magmatic flowage.

Photo 9-9 Dyke of magnetite-biotite syenite (potassic suite) intruded into foliated, biotite trondhjemite to quartz diorite, Chamberlain Narrows area of Lac Seul.

Photo 9-10 Gneissic, leucocratic trondhjemite with amphibolite bands cut by zoned pegmatite-aplite dyke (marked by hammer), Anenimus Bay area of Lac Seul.

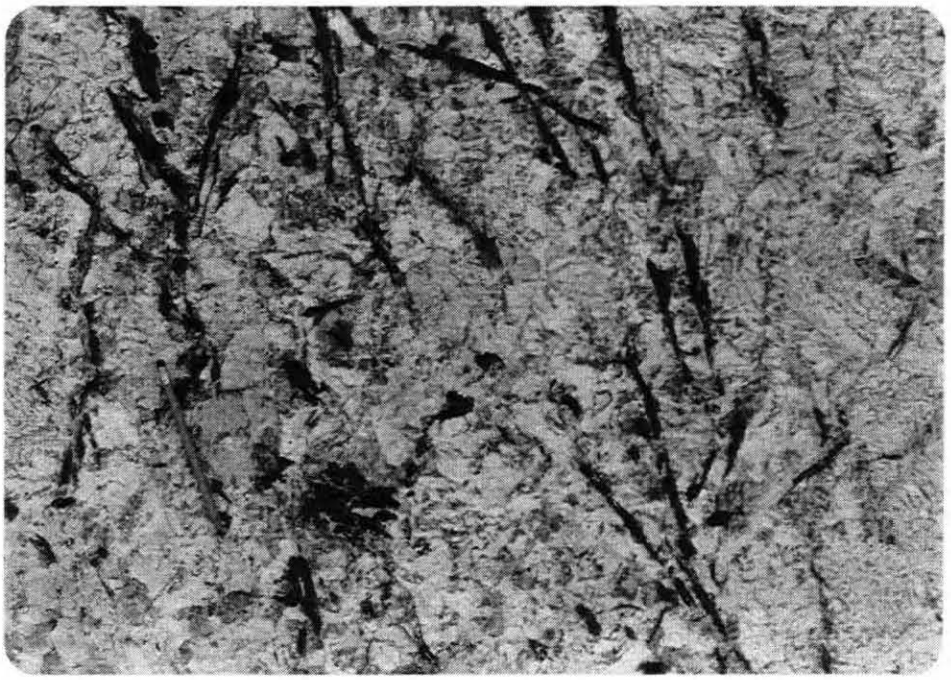


Photo 9-11 Border unit of pegmatitic granite in batholith north of Papaonga Lake. Blade-like aggregates consist of magnetite, tourmaline and biotite.

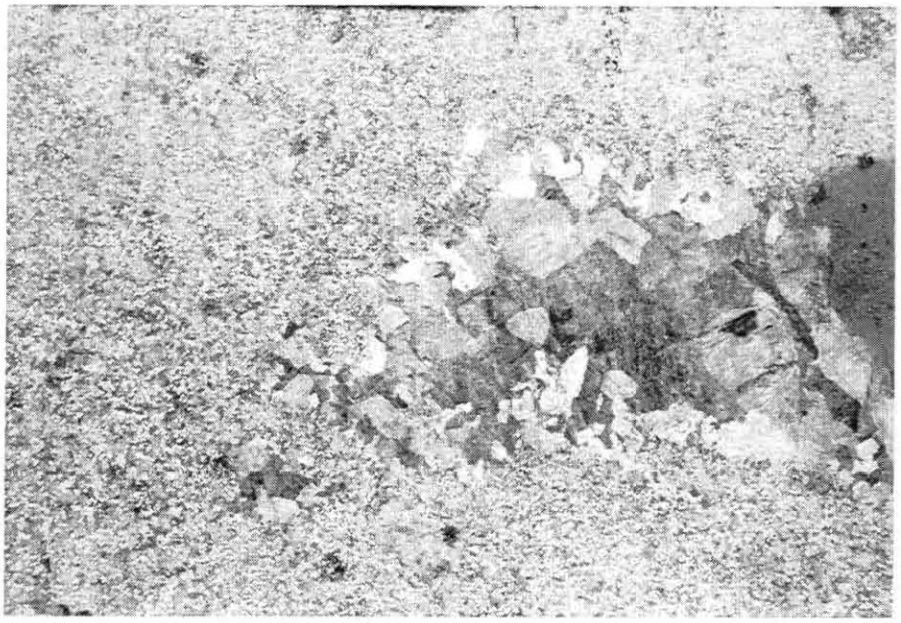


Photo 9-12 Medium-grained, equigranular, unmetamorphosed, biotite quartz monzonite to granite (*sensu stricto*) of the Tetu Lake batholith containing consanguineous, quartz monzonite pegmatite pocket. Outcrop on the Minaki-Umfreville Lake road near Sashawa Lake.

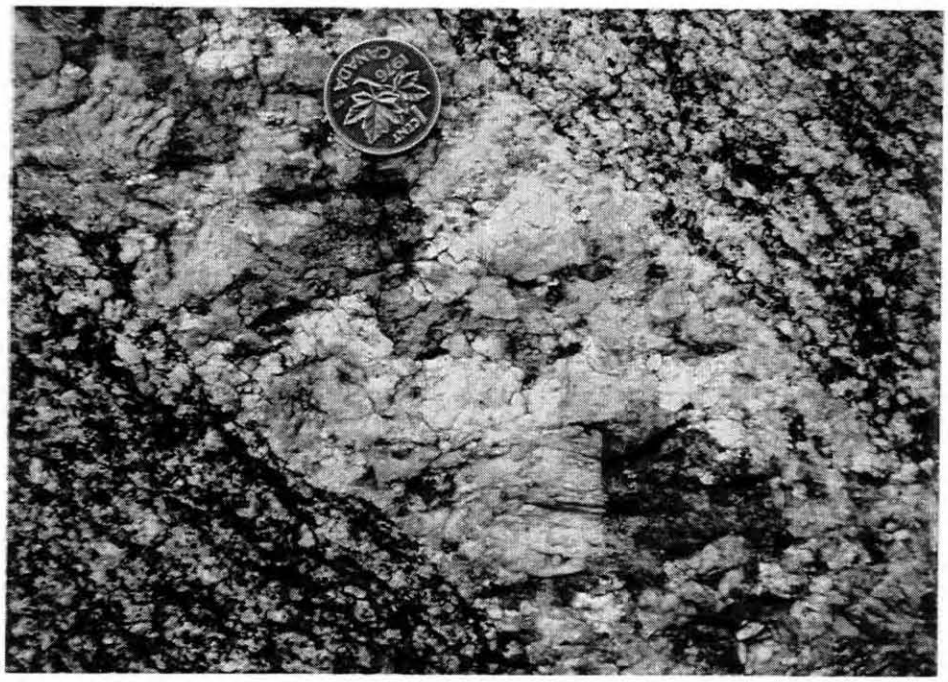


Photo 9-13 Pegmatite dyke in foliated hornblende-biotite trondhjemite. Note the perpendicular orientation of feldspar to the contacts and restriction of quartz masses to the dyke centre.

Photo 10-1 Massive, fine-grained biotite trondhjemite (sodic granitoid suite) intruded in cataclastic, homogeneous diatexite. Outcrop on South Bay Mine road, northwest of Wenasaga Lake.

Photo 10-2 Contact between the English River and Wabigoon Subprovinces at Kenora. The mafic metavolcanic rocks on left are intruded by a cataclastic, porphyritic granodiorite sill.

Photo 10-3 Amphibolitic enclave of possible volcanic origin embedded in deformed inhomogeneous diatexite. Outcrop on island in Helder Lake about 100 m north of boundary between northern and southern domains.

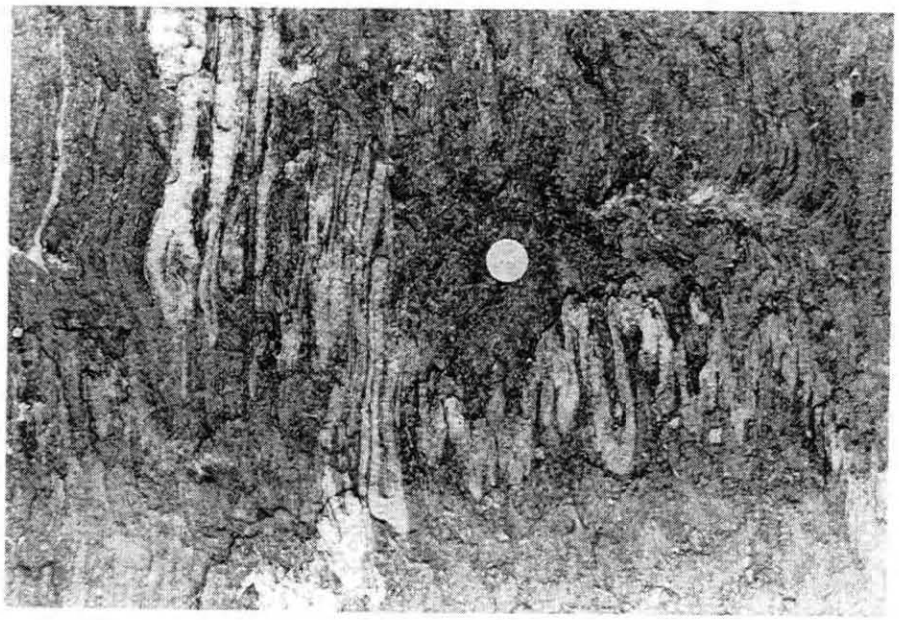


Photo 14-1 Intense Fa_1 fold of originally discordant leucosome vein within garnet-sillimanite-cordierite-K feldspar-biotite metapelite. Ministry of Natural Resources warehouse site at Ear Falls. Coin = 2.3 cm.

Photo 14-2 Fa_2 fold in metatexite metasedimentary migmatite on Wabaskang Lake.

Photo 14-3 Leucosome distributed along the axial surface of Fa_2 open fold in metatexite metasedimentary migmatite on Wapesi Bay of Lac Seul.

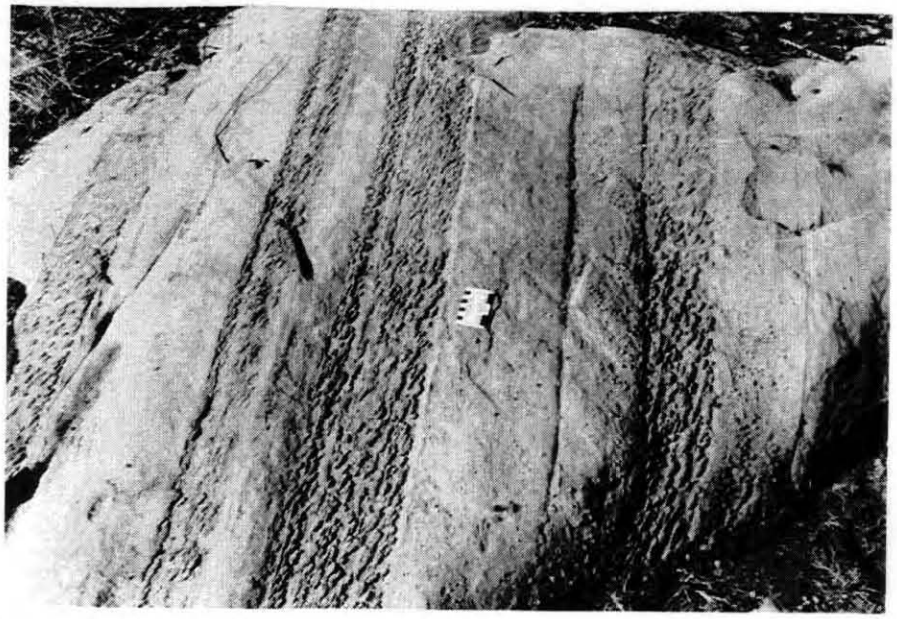


Photo 14-4 Interbedded fine-grained metawacke and highly porphyroblastic andalusite metapelite near Temple Bay of Eagle Lake. Note the secondary planar fabric oriented at low angle to bedding, especially in metapelite layer to the left of the 4 cm long scale.

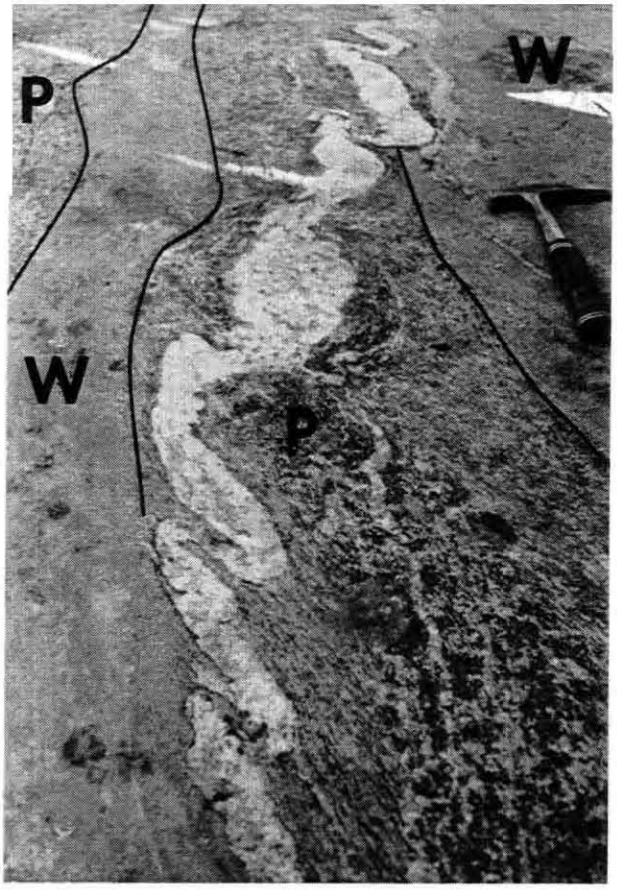


Photo 14-5 Asymmetric Fa_1 folds in intrusive mobilizate vein which was initially discordant to metawacke (W)-metapelite (P) bedding in the sillimanite-K feldspar-cordierite-garnet zone on Highway 17, 21 km west of Oxdrift. The left limbs of the two lowermost folds are almost detached along the strong axial planar fabric.

Photo 14-6 Metatexite metasedimentary migmatite on the west shore of Pakwash Lake revealing arteritic leucosomes deformed by Fa_1 boudinage followed by Fa_3 open fold. Coin = 2.3 cm.

Photo 14-7 Fb_2 isoclinal folds in leucotrondhjemite layers in gneissic granitoid suite rocks in the Deception Bay area of Lac Seul. Coin = 1.8 cm.

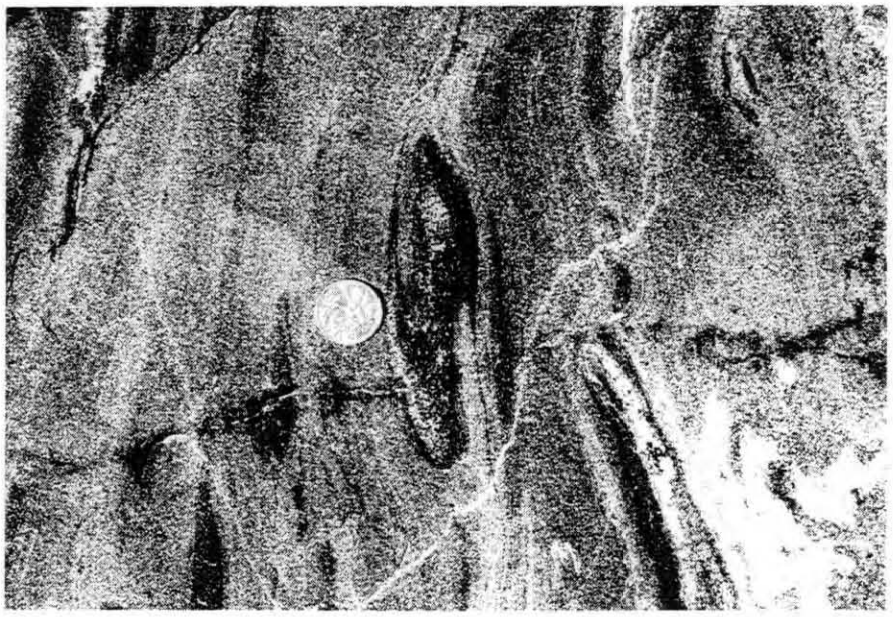


Photo 14-8 Rootless, intrafolial Fb_1 fold of severely disrupted more mafic unit (possible former pillow selvedges) in granulite grade amphibolite of the Bear Narrows area of Lac Seul. Coin = 2.3 cm.

Photo 14-9 Isoclinal Fb_2 folds in holo-leucocratic trondhjemite layers in amphibolite with superposed open folds (Fb_5?) from Deception Bay area. Coin = 1.8 cm.

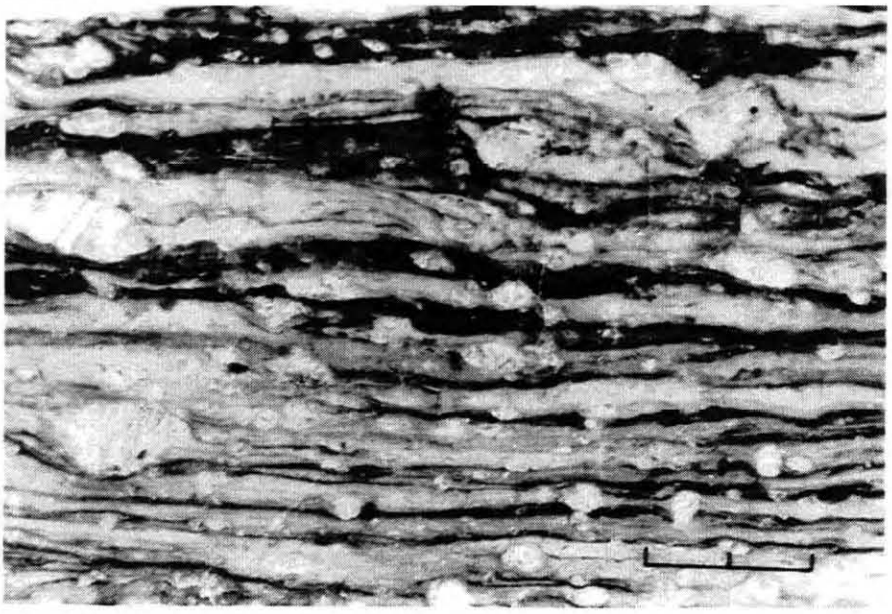


Photo 14-10 Mylonite derived from homogeneous diatexite on the Sydney Lake Fault, south shore of Sydney Lake. Note the well developed fluxion structure composed of dark, quartz-rich bands and light, finely comminuted feldspar-rich bands. Porphyroclasts consist of K-feldspar, garnet and cordierite. Bar = 2 cm.

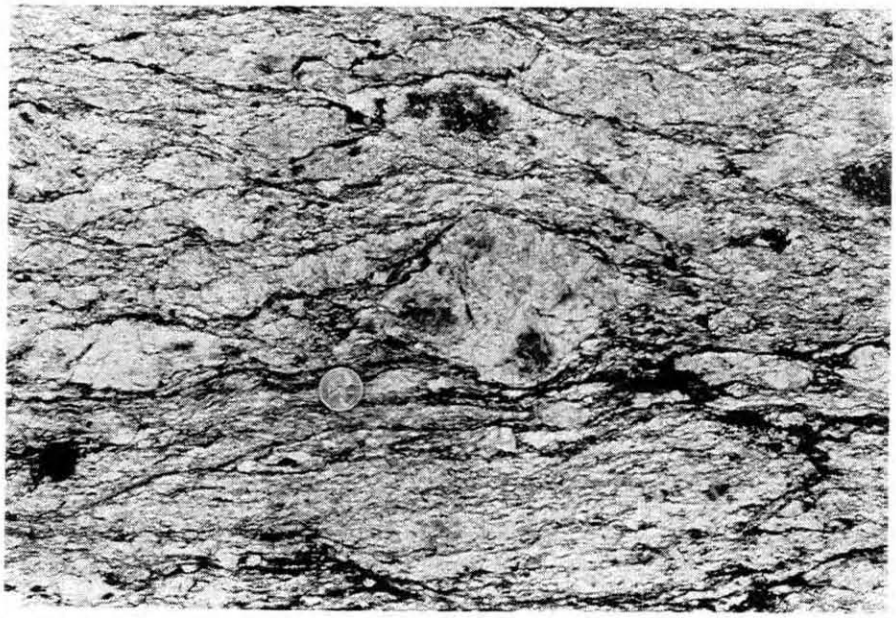


Photo 14-11 Protomylonite derived from homogeneoud diatexite at the Sydney Lake uranium occurrence, revealing the abundance of coarse porphyroclasts of quartz-feldspar and lack of a fluxion structure. Coin = 2.3 cm.

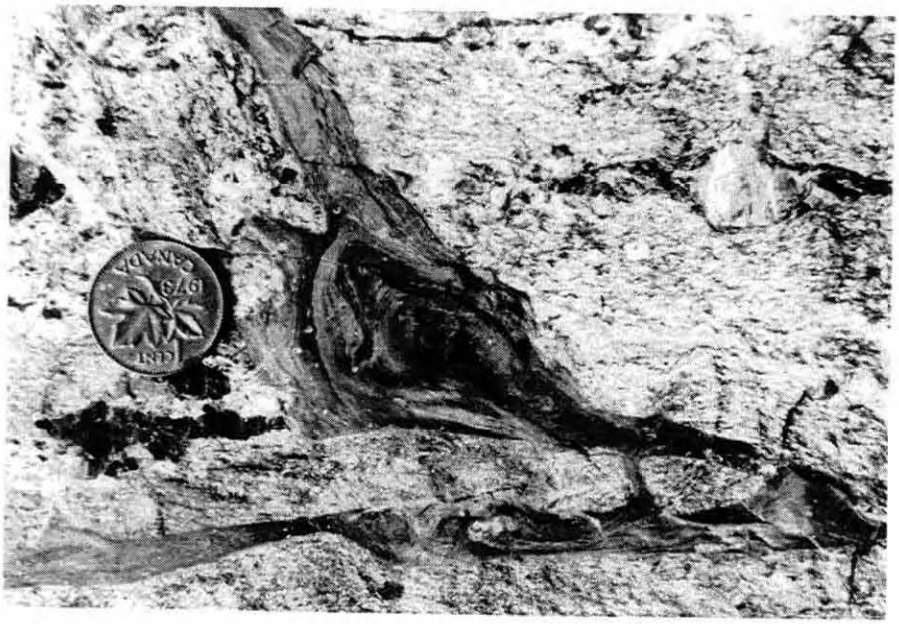


Photo 14-12 Pseudotachylite from the Sydney Lake Fault, south shore of Sydney Lake. Coin = 1.8 cm.

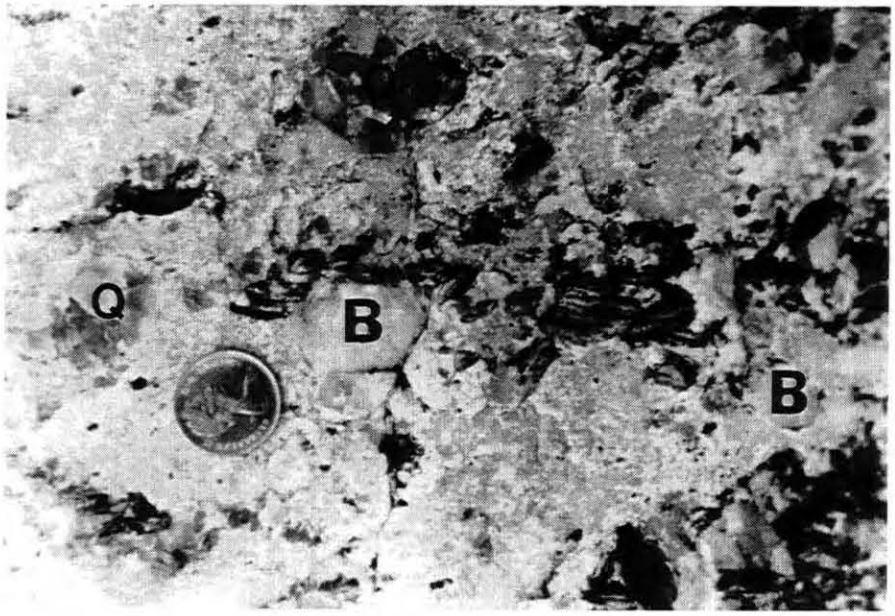


Photo 16-1 Sodic aplite from the Sandy Creek beryl pegmatite, revealing typical texture with megacrysts of euhedral beryl (near coin), quartz and books of muscovite. Coin = 1.7 cm.

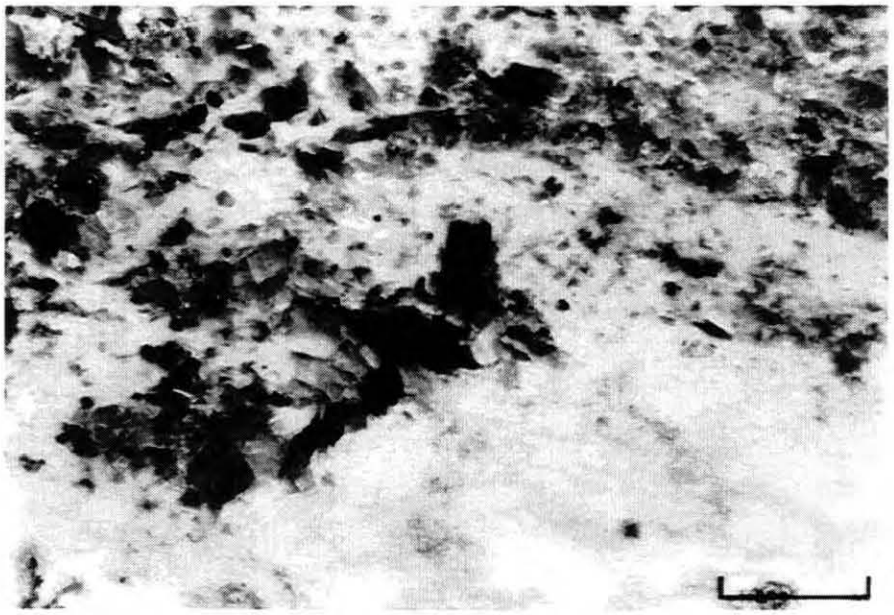


Photo 16-2 Gradation between sodic aplite (A) and apatite-muscovite rich pegmatite. Bar = 2 cm.

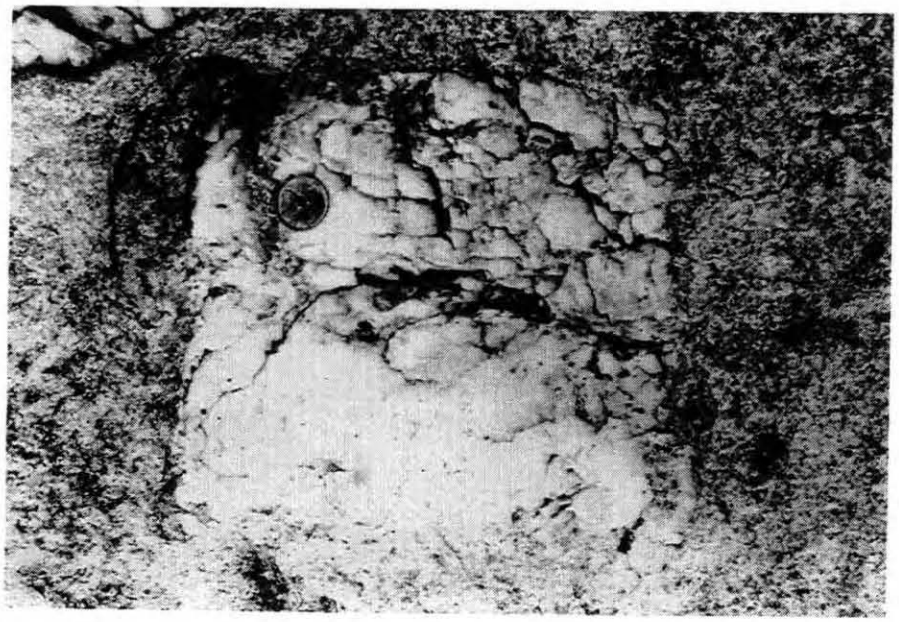


Photo 16-3 Blocky K-feldspar in aplite unit of Dyke #2 at McCombe property. Coin = 2.3 cm.

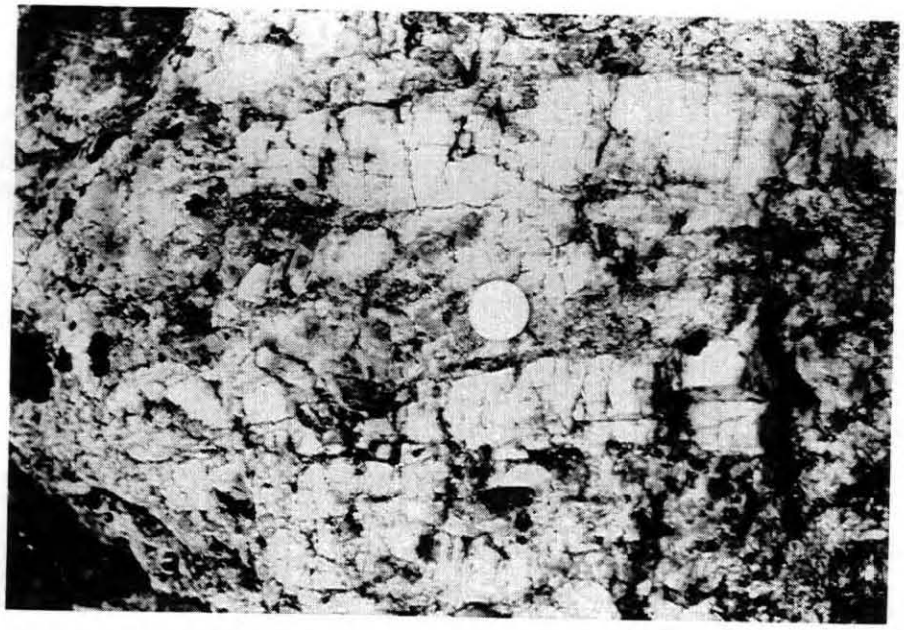


Photo 16-4 Spodumene pegmatite unit of Dyke #1 at McCombe property. Note primary lineation defined by the near vertically-plunging K-feldspar megacrysts. Coin = 2.3 cm.

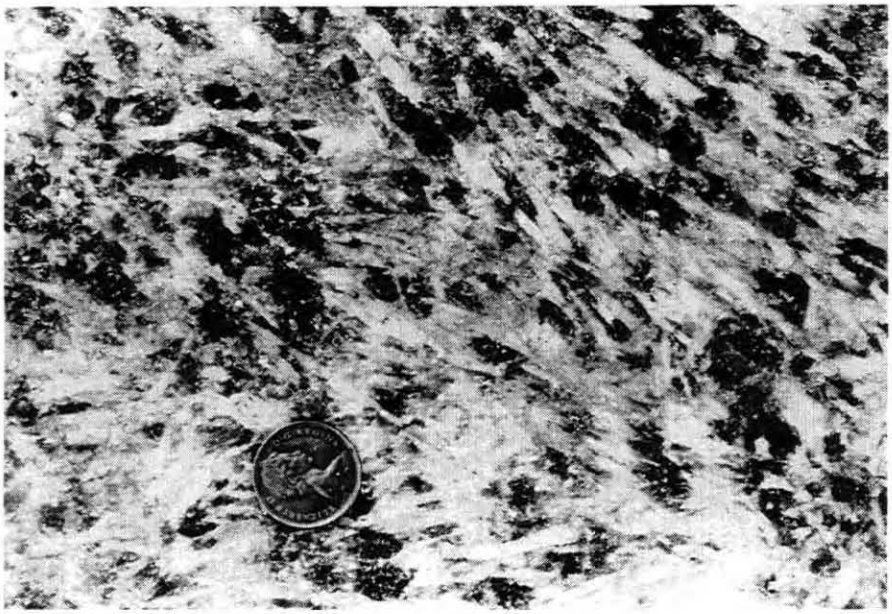


Photo 16-5 Spodumene-rich zone from Dyke #1 at the McCombe property. The relatively finer-grained spodumene exhibits a well defined linear fabric. Coin 2 cm.

Photo 16-6 Longitudinal layering at the Tot Lake pegmatite, marked by the transition from pegmatite layers containing subhorizontally aligned spodumene into finer-grained, equigranular, spodumene-layer (A). Quartz-rich core zone (Q) is situated along the upper left.

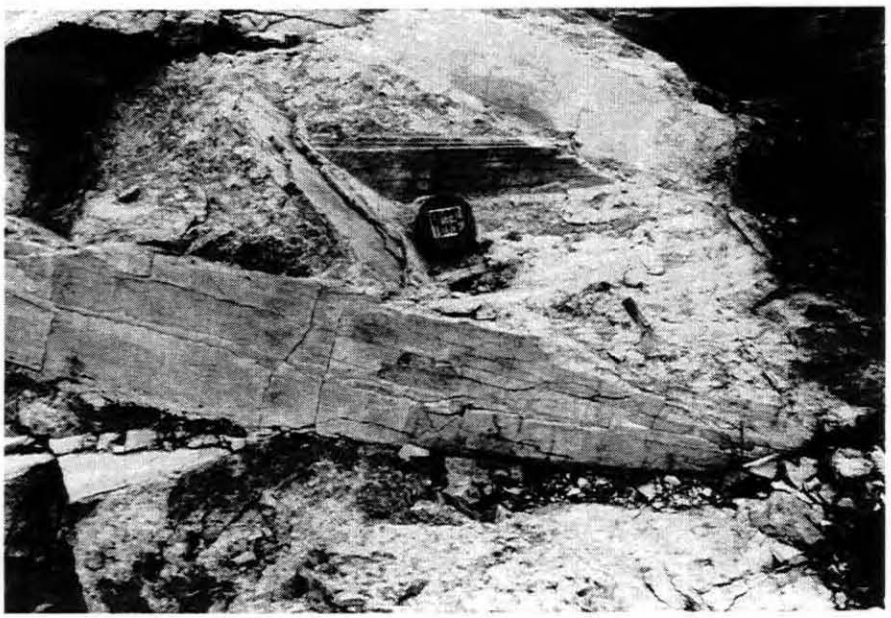


Photo 16-7 Megacryst blades of spodumene near the northwestern end of the Tot Lake pegmatite.

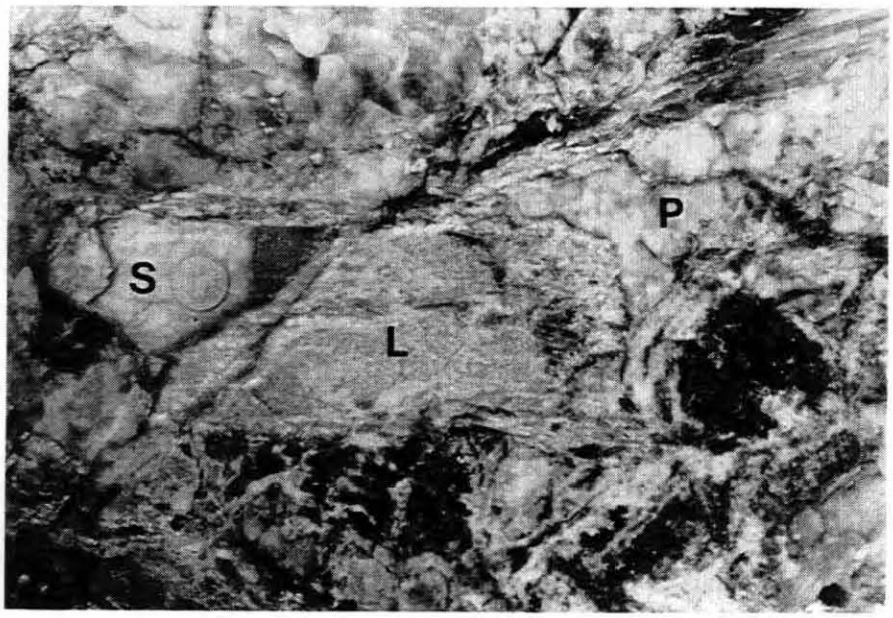


Photo 16-8 Partial replacement of pink spodumene megacryst (S) by lepidolite (L). Note the anhedral mass of pollucite (P) in contact with the spodumene. Coin = 2.3 cm.

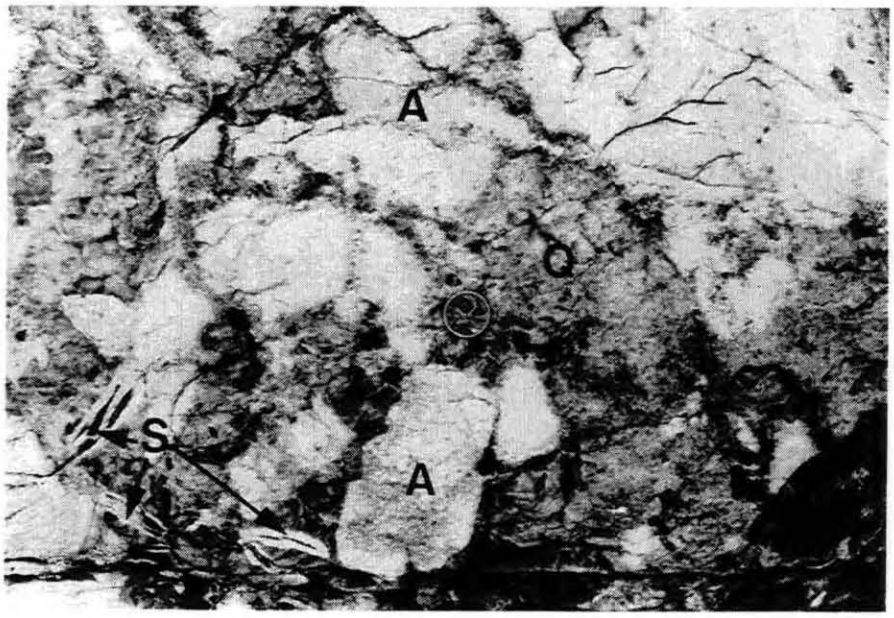


Photo 16-9 Tantalite mineralization associated with quartz-rich (Q), albitized spodumene (S) - K-feldspar zone near the northwestern end of the Tot Lake pegmatite. The tantalite normally displays a marginal relationship to the albitized K-feldspar (A) megacrysts. Coin = 2.3 cm.

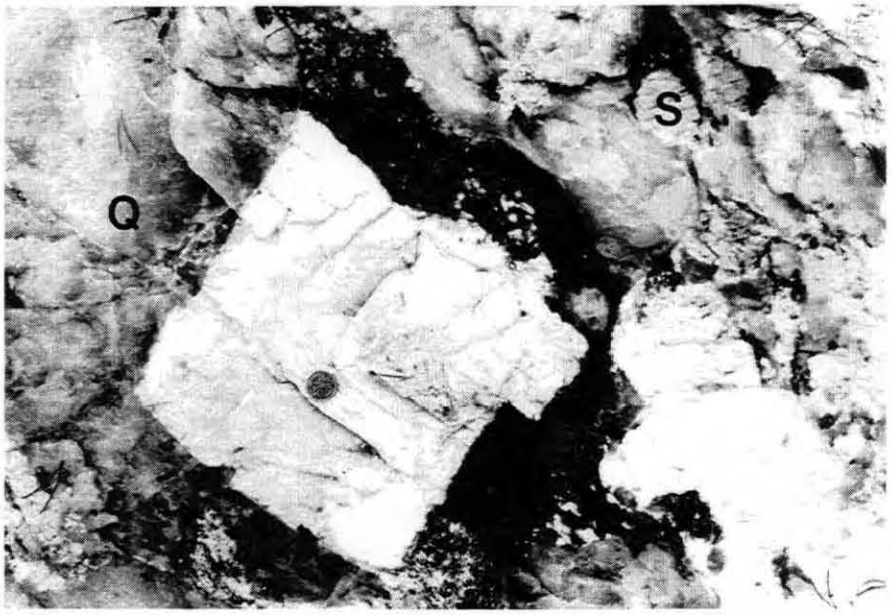


Photo 16-10 Blocky K-feldspar and local spodumene (S) in quartz-rich core zone (Q) at Pegmatite #1, Mavis Lake property. K-feldspar is partially enveloped by fine-grained green muscovite-albite aggregate (M). Coin = 1.8 cm.

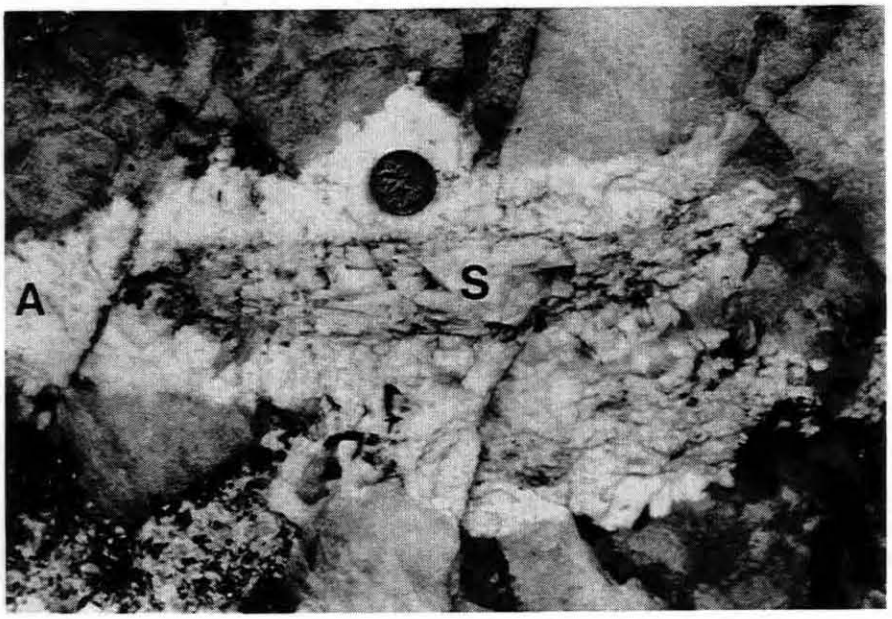


Photo 16-11 Spodumene (S) rimmed by albite (A) in the quartz-rich zone of pegmatite #1, Mavis Lake property. Coin = 1.8 cm.

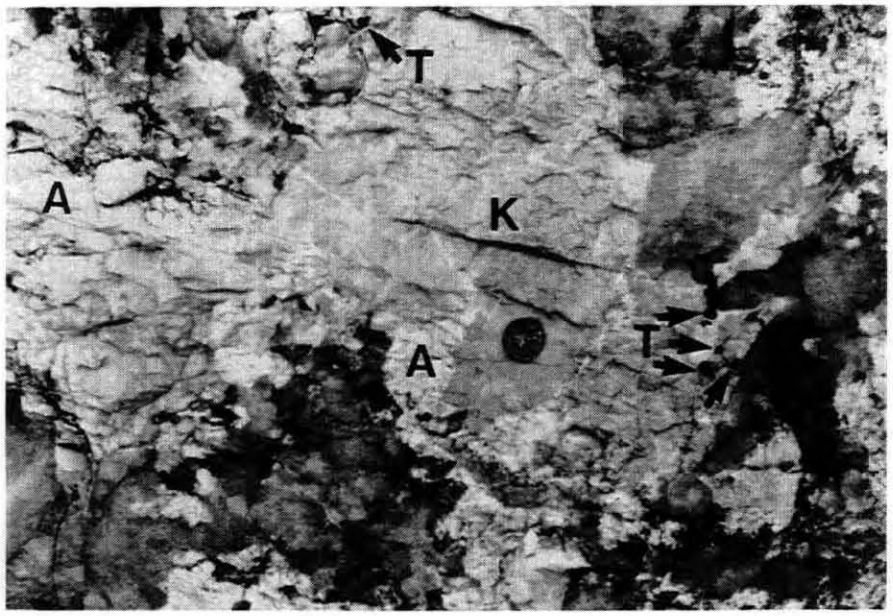


Photo 16-12 Partially albitized K-feldspar in quartz-rich core zone of Pegmatite #1, Mavis Lake property. Albitization (A) tends to occur along the margins of the K-feldspar rich (K) aggregate and commonly contains tantalite (T) as pointed by the arrows. Coin = 1.8 cm.

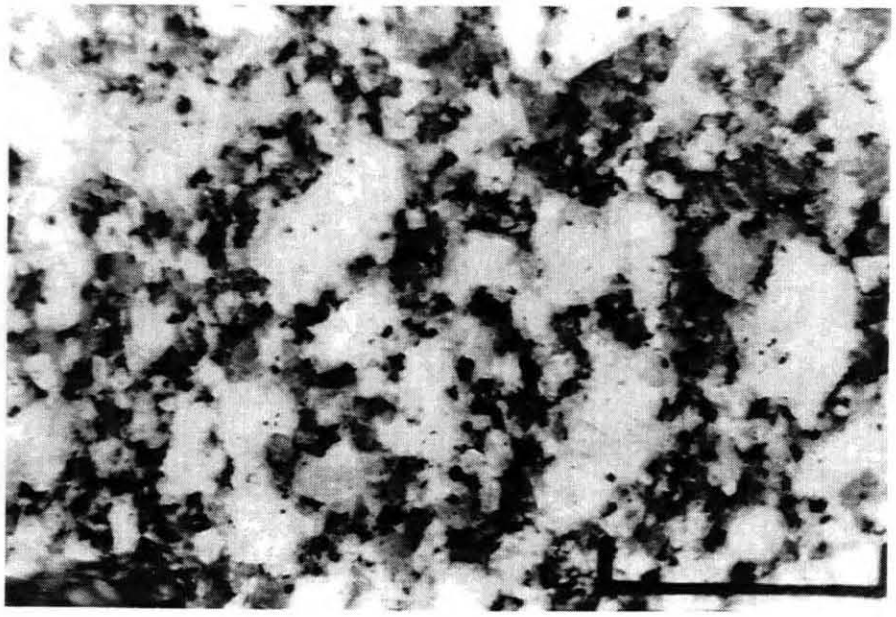


Photo 16-13 Porphyritic biotite quartz monzonite unit at the Tourist Lake uranium occurrence. Bar = 2 cm.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

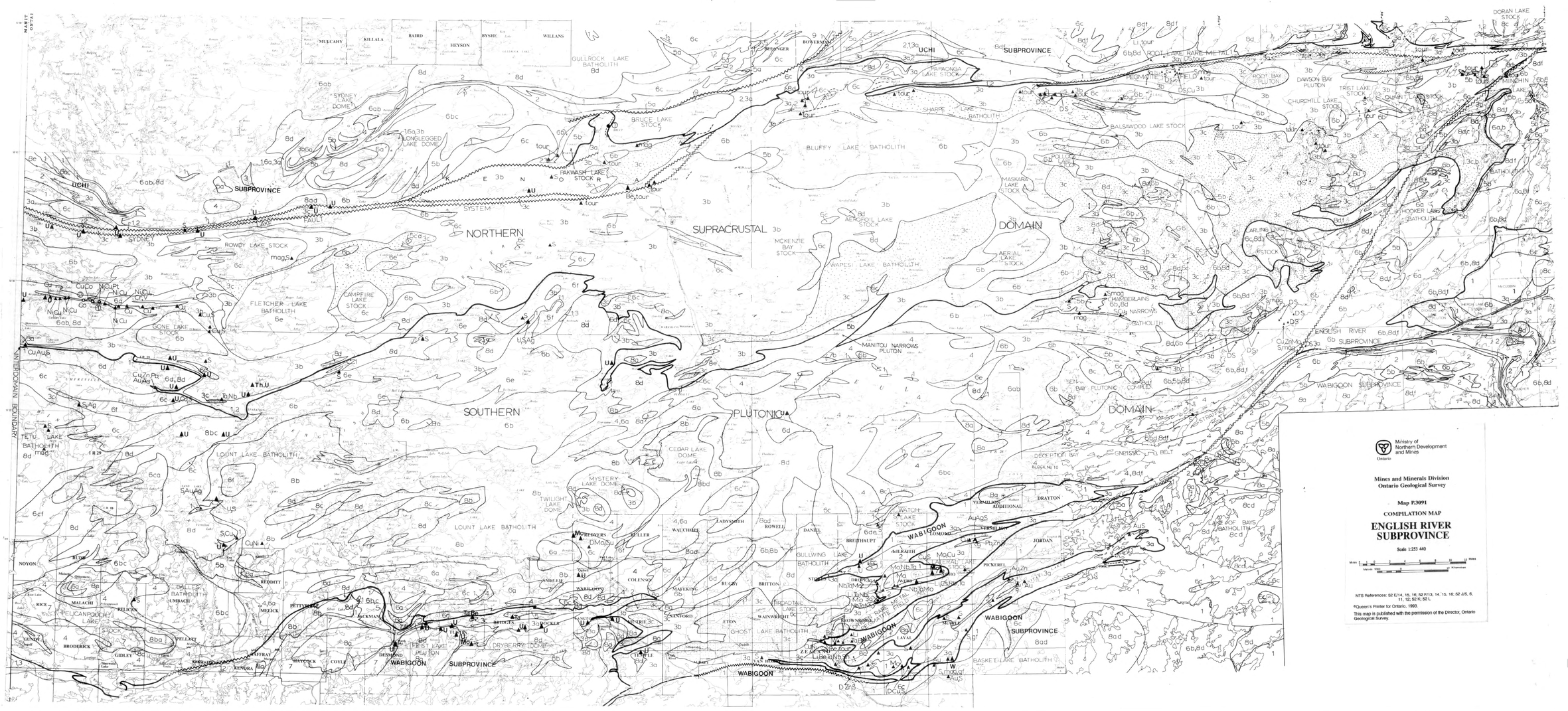
Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

3268
ISSN 0826-9580
ISBN 0-7778-1220-7



LEGEND

PHANEROZOIC

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Till, sand, gravel, and organic deposits

UNCONFORMITY

PRECAMBRIAN

9 **Felsic to Intermediate Subvolcanic Rocks**

8 **Unmetamorphosed Felsic to Intermediate Intrusive Rocks**

- 8a massive trondhjemite and tonalite
- 8b Massive porphyritic granodiorite
- 8c Massive porphyritic granite
- 8d Massive equigranular granite
- 8e Clotty granite
- 8f Granite pegmatite

INTRUSIVE CONTACT

7 **Unmetamorphosed Mafic Intrusive Rocks**

- 7a Massive diorite to quartz diorite

INTRUSIVE CONTACT

6 **Metamorphosed Felsic to Intermediate Intrusive Rocks**

- 6a Strongly foliated to gneissic trondhjemite, tonalite and granodiorite
- 6b Moderately foliated trondhjemite, tonalite and granodiorite
- 6c Weakly foliated to massive trondhjemite, tonalite and granodiorite
- 6d Weakly foliated porphyritic granodiorite
- 6e Weakly foliated porphyritic granite
- 6f Foliated granite

INTRUSIVE CONTACT

5 **Metamorphosed Mafic and Ultramafic Intrusive Rocks**

- 5a Gabbro
- 5b Foliated diorite and quartz diorite
- 5c Ultramafic rocks and altered equivalents

4 **Felsic to Intermediate Gneissic Rocks**

3 **Metasediments, Derived Migmatite and S-Type Granitoids**

- 3a Wacke, diffuse, local conglomerate
- 3b Metatextite metasedimentary migmatite
- 3c Diatexitic metasedimentary migmatite (S-type granitoid rocks)

2 **Felsic to Intermediate Metavolcanic Rocks**

1 **Mafic to Intermediate Metavolcanic Rocks**

ABBREVIATIONS

Ag	silver	Ni	nickel
As	arsenic	Pb	lead
Au	gold	pt	platinum
Be	beryllium	Rb	rubidium
Co	cobalt	S	sulphide mineralization
Cr	chromium	Sn	tin
Cs	cesium	Ta	tantalum
Cu	copper	Th	thorium
Fe	iron	tour	tourmaline
Li	lithium	U	uranium
mag	magnetite	V	vanadium
Mo	molybdenum	W	tungsten
Nb	niobium	Zn	zinc

The letter D (preceding a mineral or metal abbreviation, e.g., D Cu,S signifies identification from diamond-drill core.

PAST PRODUCING MINES

(1) Gordon Lake Mine (1962-1972), Consolidated Canadian Faraday Limited

(2) Werner Lake Cobalt Mine (1940-1944), Kenora Prospectors and Miners Limited

PRESENT PRODUCING MINES

(1) Griffith Mine, Steel Company of Canada

Symbols

- Location of mineralization
- Fault zone (in some cases forms part of subprovince boundary)
- Subprovince boundary and Winterdomain boundary within English River Subprovince
- Geological boundary
- Areas of S-type granitoid rocks
- Iron formation
- Synformal axis
- Antiformal axis

SOURCES OF INFORMATION

OGS Preliminary Maps P.1026, P.1027, P.1028, P.1029, P.1030, P.1031, P.1199, P.1200, P.1201, P.1202, P.1203, P.1204, P.2215, P.2216, P.2217, P.2218 and P.2260.

OGS Compilation Maps 2115, 2175 and 2442

CREDITS

Compiled by F.W. Breaks, W.D. Bond and C.J. Westerman 1978.

To enable rapid dissemination of information, this map is **unedited**. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Users should verify critical information.

Issued 1993.

Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Breaks, F.W., Bond, W.D. and Westerman, C.J. 1993. Compilation Map, English River Subprovince; Ontario Geological Survey, Preliminary Map P.3091, scale 1:253 440.