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Miscellaneous Paper 72

Preliminary Geological Synthesis of the English River Subprovince,

Northwestern Ontario and Its Bearing Upon Mineral Exploration

By

F.W. Breaks, W.D. Bond, and Denver Stone

1978

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ABSTRACT

This study, part of an on-going helicopter-supported survey of migmatitic terrains, comprises an area of 44 000 km^2, and involves parts of the English River, Uchi, and Wabigoon Subprovinces.

This study indicates that the English River Subprovince consists of a northern supracrustal, migmatized, metasedimentary domain and a southern, granitoid, intrusive, and gneissic domain.

An innovative scheme for mapping migmatized metasediments recognizes several discrete and enumerates stages of metatexis, diatexis, and anatexis. This scheme should aid in the reconnaissance delineation of other relict high grade metasedimentary belts.

Uranium/lead age dating of zircon from diatexite indicates that migmatization occurred at 2.68 B.Y. Trace element data suggests that tholeiitic basalt and trondhjemitic granitoid material augmented by felsic to intermediate volcanic rocks constituted the source material for the metasediments. Chemical analyses reveal that metatexite development is a geochemical splitting process involving the creation of a leucosome and a melanosome from the protolith. Staining of specimens reveals that pelitic paleosomes produce strongly potassic mobilizate, and the more feldspathic wackes are associated with sodic leucosomes.

The Southern Plutonic Domain consists of three major rock suites, the Gneissic Granitoid, Sodic Plutonic, and Potassic Plutonic Suites which are pre-, pre-to-syn-, and syn-to post-tectonic respectively. These complex suites were delineated by using a series of mappable components, discrete phases and intrusions, batholiths, and easily distinguished field parameters. A metamorphosed foliated hornblende-biotite trondhjemite phase, part of the sodic suite, is probably more than 3.04 B.Y. old. A member of the Potassic Plutonic Suite yielded a date of 2.652 B.Y. which overlaps the date of the metasediments. Chemical analyses of the three major suites in the Southern Plutonic Domain indicate that as the rocks become younger, potassium is enriched and that there is an accompanying decrease in iron, magnesium, and calcium content.

Along the contact between the Uchi subprovince and the Northern Domain extensive areas are underlain by Iron Formation. Metavolcanics of the Wabigoon subprovince mark the boundary of the Southern Plutonic Domain to the south. The northern boundary of this domain is marked by the eastward continuation of the Bird River Greenstone from Manitoba.

Several major Late Archean fault systems are recognized; the most notable are the Miniss and Sydney Lake Fault Systems. The Sydney Lake Fault System, an area of cataclasis and mylonitization, is arcuate, traceable for 190 km, continues westward into Manitoba, and has a right-handed strike separation.

Five metamorphic events affected rocks in the study area. Several areas were affected by granulite facies metamorphism during the Kenoran tectonic-metamorphic episode. Assuming Total Pressure is equal to water vapour pressure, estimates of pressure-temperature conditions are as follows: Medium Grade, 550-650°C, 3-4.5 kilobars; High Grade, 650-790°C, 3-7.5 kilobars, and Granulite Facies, 770°C, 72-5 kilobars.

Investigation is warranted into the concentration of uranium, lithium, tantalum, beryllium, and calcium. Lithogeochemical prospecting is recommended in the Western Lake St. Joseph, and the Mavis Lake-Tot Lake areas.

PRELIMINARY GEOLOGICAL SYNTHESIS OF THE ENGLISH RIVER SUBPROVINCE, NORTHWESTERN ONTARIO AND ITS BEARING UPON MINERAL EXPLORATION

by

F.W. Breaks, W.D. Bond, and Denver Stone[1]

INTRODUCTION

Division of the Superior Province into several distinctive lithological-structural-metamorphic subprovinces has been advocated for some time (Stockwell 1964). However, specific geological controls responsible for the characteristic striped distribution of contrasting subprovinces as exemplified by Northwestern Ontario, continues to remain an enigma. One of the factors presently inhibiting plausible crustal modelling studies bearing upon the origin of the mega-belt pattern lies in the virtual absence of systematic, rapid geological coverage of the poorly understood sialic gneissic subprovinces such as the Berens River Subprovince, the Quetico Subprovince, and the English River Subprovince. Additional problems relate to an underemphasis in the past upon granitoid areas in the various parts of the volcanic-rich subprovinces. Partly in this context, the Ontario Geological Survey instigated in 1973 a helicopter-supported, reconnaissance mapping programme in one particular high grade gneissic belt, herein termed the English River Subprovince.

This study examined a 400 km strike-length of the English River Subprovince and adjoining segments of Uchi and Wabigoon Subprovinces totalling over 44 000 km^2 *(Figure 1)*. Preliminary geological maps at scales of 1:126 720 (Operation Ignace-Armstrong, Sage *et al.* 1974) and 1:63 360 (Operation Kenora-Ear Falls; Breaks, Bond, Harris and Westerman 1975; Breaks, Bond, McWilliams, Gower, and Findlay 1975; Breaks and Bond *et al.* 1975a, b, c, d, and e; Breaks and Bond *et al.* 1976a and b; Breaks, Bond, Harris, and Desnoyers 1976; Breaks, Bond, Harris, Westerman, and Desnoyers 1976; Breaks, Bond, Westerman, and Desnoyers 1976; Breaks, Bond, Westerman, and Harris 1976) have been completed furnishing information from the 1973, 1974, 1975, and 1976 project areas. [Maps for the 1976 field season have yet to be published.] The 1977 field season was mainly devoted to synoptic mapping coverage of previous field areas coupled with detailed metallogenic investigation. In addition, a relatively small unmapped part of the English River Subprovince adjacent to Wabigoon Subprovince northeast of Sioux Lookout *(Figure 1)* was mapped. The geological data base provided by the Ontario Geological Survey investigations should be a considerable aid to future more detailed studies and a guide to future mineral exploration. The objective of the present paper is to outline some of the initial determinations of this ongoing project.

Acknowledgments

The authors wish to acknowledge Ray Pichette and John Malczak who contributed equally to the preparation of the figures. The following Ontario Geological Survey personnel contributed to the typing of the manuscript: Anna Branicky, Mathona O'Connor, and Margot Gunther. All chemical analyses pertaining to the immediate study were complexed by the Geoscience Laboratories, Ontario Geological Survey. Thanks are also due N.F. Trowell, Geologist with the Ontario Geological Survey for providing analyses of metavolcanics from the Sturgeon Lake Belt.

GENERAL GEOLOGY

A twofold subdivision of the English River Subprovince into lithologically contrasting domains has now been firmly established by areal mapping undertaken during the current investigation *(Figure 2)*, and are:

(1) A northern supracrustal, metasedimentary domain, and,
(2) A southern granitoid intrusive and gneissic domain.

A generalized picture of the lithological constitution of both domains is evident from results of planimetric analysis presented in *Table 1*. In addition, results from the numerous preliminary maps have been condensed in a geological compilation map, *Figure 3*.

The southern domain represents a complex zone of granitoid batholiths and stocks partly intrusive into, and replacing ancient polycyclic granitoid gneiss. As a result of this complexity a rather "patchy", macroscopic

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[1] Geologists, Precambrian Geology Section, Ontario Geological Survey, Toronto. Manuscript approved for publication by Chief Geologist 13th June 1978. This report is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

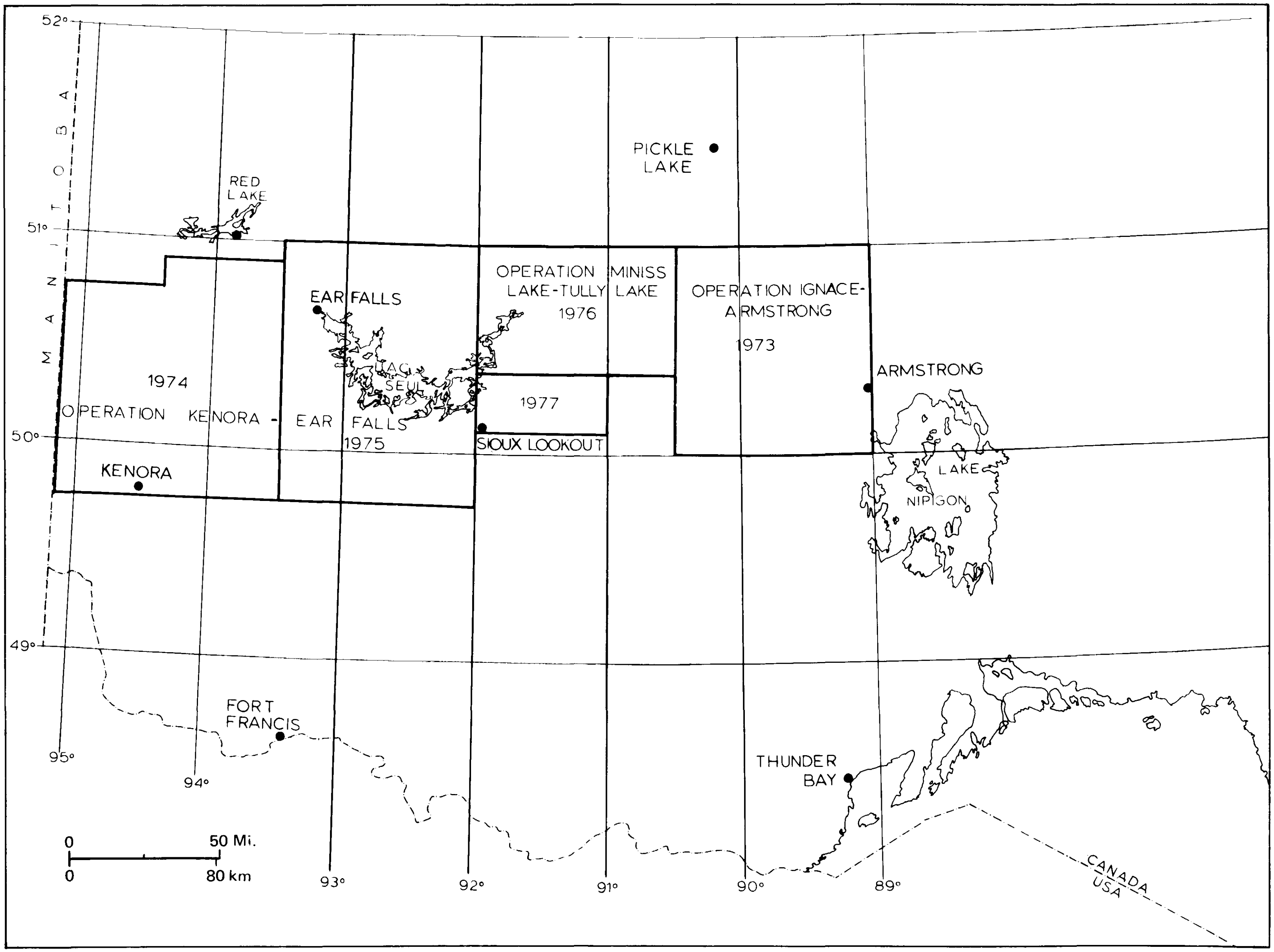

Figure 1 - General location of areas covered by helicopter-supported geological reconnaissance mapping projects undertaken by the Ontario Geological Survey in the English River Subprovince including that proposed for 1977.

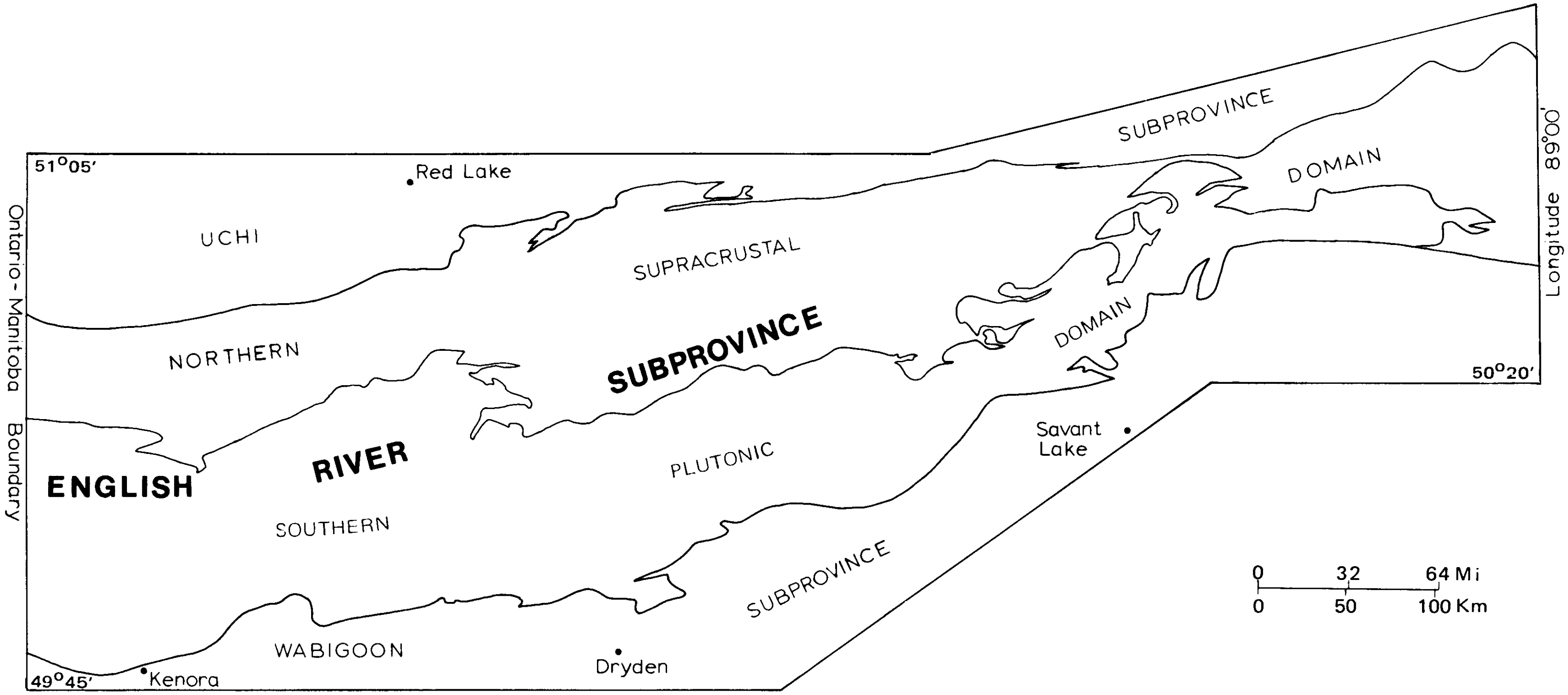

Figure 2. Generalized dichotomous geological aspect of the English River Subprovince, Northwestern Ontario, based upon mapping engendered by the present study.

TABLE 1 LITHOLOGICAL CONSTITUTION OF THE ENGLISH RIVER SUBPROVINCE.

Lithology	Northern Supracrustal Domain		Southern Plutonic Domain	
	A	B	A	B
Amphibolitized foliated to gneissic mafic metavolcanics		1.0		1.0
Felsic to Intermediate Metavolcanics		0.9		—
Metasediments and derived Migmatite		66.8		0.6
Metatexite	56.6			
Diatexite	10.2			
Metamorphosed mafic plutonic rocks		0.2		2.5
Felsic to intermediate granitoid gneisses		—		19.0
Metamorphosed felsic to intermediate massive and foliated granitoid plutonic rocks		28.9		37.9
Strongly foliated to gneissic trondhjemite and granodiorite	0.9		3.9	
Moderately to weakly foliated trondhjemite and granodiorite	23.4		24.0	
Porphyritic granodiorite	4.2		3.5	
Foliated quartz monzonite	1.5		4.8	
Unmetamorphosed felsic to intermediate massive to weakly foliated granitoid plutonic rocks		0.7		39.0
Equigranular trondhjemite and granodiorite	0.1		2.9	
Porphyritic granodiorite and quartz monzonite	—		17.4	
Equigranular quartz monzonite and granite	0.6		18.7	
Unmetamorphosed mafic plutonic rocks	1.5		—	

Column A where applicable gives subdivision of total percentage as expressed in column B.

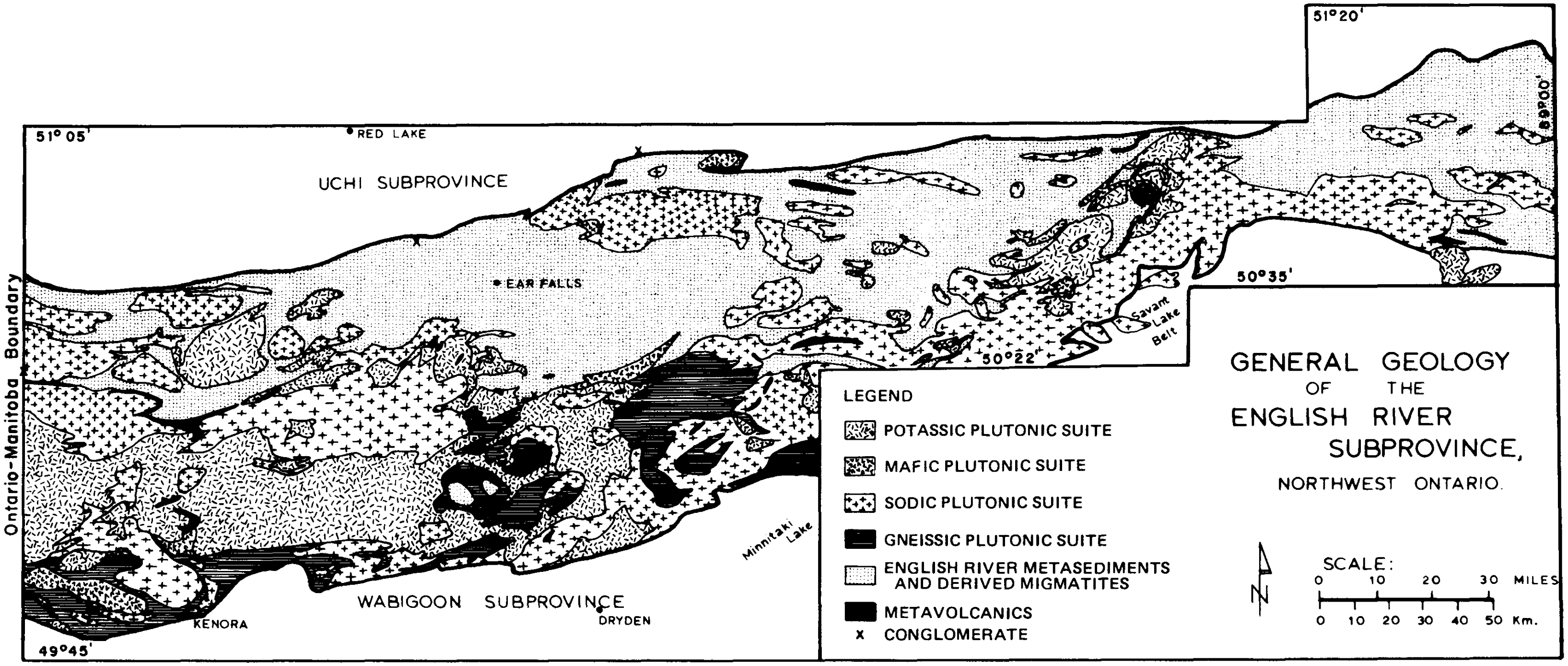

Figure 3. General geology of the English River Subprovince, Northwest Ontario

distribution of remnant gneissic areas now exists *(Figure* 3). These gneisses have probably undergone a protracted history of repeated deformation, partial melting, and arteritic plutonic addition. The southern domain has a maximum breadth of 70 km at the Ontario-Manitoba boundary, and gradually tapers eastwards before terminating near Longitude 89°00′. In contrast, the northern supracrustal domain comprises a migmatized clastic sedimentary assemblage containing a relatively low proportion of plutonic rocks and granitoid gneiss. A strike-length of approximately 1200 km may be postulated for the English River Subprovince, assuming continuance at least to the Kapuskasing Structure. This estimate includes the correlative Manigotagan gneisses of Manitoba (McRitchie and Weber 1971) and similar migmatitic metasediments mapped by Thurston and Carter (1970) east of Longitude 89°00′. The width of this supracrustal belt is highly variable, ranging from 1.5 to 51.2 km, and probably averages about 30 km. Anastomosing structural trends are evident in some areas, such as near Rowdy Lake and Wapesi Lake, are related to a local preponderance of metamorphosed plutonic rocks of the trondhjemite-quartz diorite suite. Pronounced narrowing of the migmatite belt is evident in the Miniss Lake-Medcalf Lake area and appears to be due mainly to the intersection of the northeast-striking Miniss River Fault Zone with a fault zone lying between Dawson Lake and Pashkokogan Lake along the north boundary of the English River Subprovince.

Contemporaneity between volcanism in the Uchi Subprovince and sedimentation in the northern domain has been established by the current study. Stratigraphic analysis across the interface between these two contrasting lithological regimes is not possible over large strike-lengths owing to extensive branching fault zones as exemplified by the Sydney Lake Fault System, currently under investigation by Denver Stone of the University of Toronto (see Denver Stone 1976 and 1978). These late Archean fault systems are superimposed and perhaps initially guided by the boundary between subprovinces. In the low to medium metamorphic grade rocks of the Papaonga Lake area conformable, cataclastically uninterrupted, stratigraphic relations indicate that the subprovince interface marks a major lithofacies transition, from distally deposited metavolcanics of the Uchi Subprovince to the mudstone sedimentary assemblages representing the northern domain of the English River Subprovince. The stratigraphic succession is substantiated by facing data from graded bedding and interdigitation of metasedimentary and metavolcanic units. A subaerial fluvial environment is postulated for the metavolcanic-metasedimentary succession in the Slate Lake area (Uchi Subprovince) lying immediately north of the English River Subprovince margin, and is based upon the appearance of cross-bedding in metasandstone.

Northern Supracrustal Domain

Migmatized metasediments, dubbed the "Miniss Series" by Dyer (1933), lithologically dominate the northern domain as indicated from *Figure 3* and *Table 1*, accounting for about 67 percent of all generalized rock groups. Structural trends of this predominantly east-west striking "cover" sequence are diverted by numerous intra-belt stocks and batholiths. These plutonic complexes comprise foliated to gneissic, metamorphosed trondhjemite-quartz diorite-diorite (29 percent), the largest is represented by the Bluffy Lake Batholith, ($700\ km^2$) situated northeast of Ear Falls.

Several other salient lithological features include:

(1) Paucity of unmetamorphosed late and post-tectonic potassic granitoid intrusions, in contrast to copious quantities of this material in the southern domain.
(2) Scarcity of metavolcanics, and mafic to ultramafic plutonic units.
(3) Widespread distribution of magnetite-wacke iron formation in the northern domain adjacent to southern margins of volcanic-rich Uchi Subprovince.

The delineation of the clearly perceptible relict, migmatized, metasedimentary belt constituting most of the northern domain required special attention. During field studies it became evident that rigorous classification of the derived migmatite strongly depended upon recognition of a multiplicity of migmatitic stages which collectively constitute a continuum of progressive anatectic degradations of a metasedimentary precursor. This migmatitic evolutionary sequence will be obscured during field investigations if classification focuses mainly upon petrological attributes of the paleosome and neglects the consanguineous neosome. Thus, workers in the past have tended to classify migmatitic members with low leucosome to leucosome and paleosome ratios as paragneisses or even just plain gneiss. Mobilizate dominant members, on the other hand, even though spatially related to the paragneiss, tended to be obscured by incorporation into granitic rock subdivisions of map legends, such as schlieritic, xenolithic, or hybrid types. Bearing these difficulties in mind, a more realistic system was developed *(Table 2)* during the study which depended on the works of Mehnert (1971) and Brown (1973) and which notably produced tangible results in other migmatitic terrains. This system should aid in effective reconnaissance delineation of other as yet unmapped, relict high grade metasedimentary belts.

Uranium/lead dating of zircons from diatexite indicates that pervasive migmatization of the metasedimentary percursor occurred at about 2.68 B.Y. (Krogh *et al.* 1976) thus giving a reasonable estimate for the age of the metamorphism related to the Kenoran tectonic-metamorphic episode. It should be stressed,

TABLE 2 CLASSIFICATION AND GENERAL FEATURES OF METASEDIMENTARY MIGMATITES FROM NORTHERN SUPRACRUSTAL DOMAIN ENGLISH RIVER SUBPROVINCE.

MIGMATITIC STAGE	LEUCOSOME:LEUCOSOME & PALEOSOME RATIO	DIAGNOSTIC MIGMATITIC STRUCTURE	GENERAL PROCESSES DOMINANT	GENERAL FIELD FEATURES
PROTO-METATEXITE	<0.1	Locally stromatic Sedimentary bedding or laminae may show preservation	Incipient, 'selective' anatexis. Metamorphic differentiation may be be important	Characterized by intercalated fgwacke and mg-cg porphyroblastic pelite components. Podiform and lensic potassic leucosomes exhibit confinement to pelitic horizons. Hydrothermal (qtz.veins) mobilizate may be important.
METATEXITE	0.1 to 0.6	Stromatic and/or Phlebitic	Local to moderate degree of anatexis	Mobilizate developed *in situ*, possesses biotitic melanosomes along leucosome-paleosome interface. Mobilizate (without melanosomes) also commonly injected along prevailing foliation or bedding surface of paleosome.
INHOMOGENEOUS DIATEXITE	0.6 to 0.9	Schollen structure especially characteristic Locally schlieritic or nebulitic	Anatexis relatively extensive; mobilizate essentially autochthnous	Repletion of disoriented paleosome and metatexite inclusions and melanosome clumps is diagnostic.
HOMOGENEOUS DIATEXITE	>0.9	Homogeneous usually massive. Locally schollen schlieritic ornebulitic structures apparent	Very advanced fusion; mobilizate probably allochthonous	Usually holo-leucocratic and severely seriate Rarely more mafic variants (CI 15 to 30) may represent cases of complete anatexis effecting resorption of melanosome component into magmatic phase

Abbreviations: fg — fine grained mg — medium grained cg — coarse grained CI — Colour Index > — greater than < — less than however, that field evidence indicates that separation of the leucosome component from the metasedimentary paleosome probably spanned a protracted period of time, both accompanying and outlasting at least two folding events. Geochronological studies in future will attempt to "bracket" this time span of migmatization more quantitatively. The Kenoran age of migmatization is also generally compatible with field characteristics of the mobilizate which is invariably unmetamorphosed and often exhibits well preserved igneous fractional crystallization textures.

As indicated in *Table 2*, classification of the metasedimentary migmatites is based primarily upon leucosome to paleosome ratio coupled with diagnostic migmatitic structures. The ensuing text will now focus upon petrological, petrochemical, and field idiosyncrasies of the various migmatitic stages and engendered components.

METATEXITE

The term metatexis was initially coined by Scheumann (1936, 1937) and recently modified by Brown (1973, p.374) to refer to a "process of segregation (usually of quartz and feldspar) by metamorphic differentiation or partial fusion". Thus, "a metatexite is a rock produced by metatexis and in which migmatitic banding (stromatic structure) is evident" (Brown 1973, p.374).

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 *(Photo 1)*. Most metatexites consist of three integral components; namely: paleosome, melansome, and leucosome. The latter two components collectively represent the neosome or "newly formed part of a migmatite", (Mehnert 1971, p.356). The leucosome can alternatively be designated as mobilizate or metatect, the latter term was introduced by Scheumann (1936, 1937).

When essentially undistorted and well developed a conspicuous banded appearance, or stromatic structure, represents the prime identifying criterion of metatexites, and is manifested by the interlayering of wacke paleosome and granitoid to pegmatoid mobilizate, often in a pervasive manner *(Photo 1)*. Generally, between 10 and 60 percent of metatexite outcrops consist of mobilizate.

Deformation in the form of flowage folding, buckling, and shearing occurred quasi-contemporaneously with the formation of the granitoid and pegmatoid metatects, and often contributes to obscuring the characteristic banded appearance in addition to "triggering" injections of intrusive mobilizate into the generally more competent paleosome. Intrusive mobilizate may occur on all scales varying from that of local filling of heterokinetic spaces[1] between the boudinaged metawacke paleosome to relatively large allochthonous anatectic plutons. Appearance of the intrusive mobilizate is virtually identical to mobilizate derived *in situ*.

The term "protometatexite" was coined by the writers in order to account for particular exposures that evolve during incipient stages of migmatization. This variant is typified by small quantities of irregular podiform and lensoidal mobilizate segregations specifically confined to pelitic layers *(Photos 2 and 3)*. These segregations have not amalgamated into continuous leucosome layers as is the case with metatexite displaying stromatic structures. Nevertheless, a layered distribution is apparent since the mobilizate is confined to pelitic layers intercalated with unmobilized wacke beds.

Paleosome

Two petrologically and petrochemically distinct metasedimentary rock types constitute the surviving paleosome and also the progenitor of mobilizate 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 *(Table 3)*. 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 have been substantially obliterated under high grade metamorphic conditions. During conditions of incipient anatexis, pelitic layers invariably represent the initial site of partial melting *(Photos 2 and 3)*.

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

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

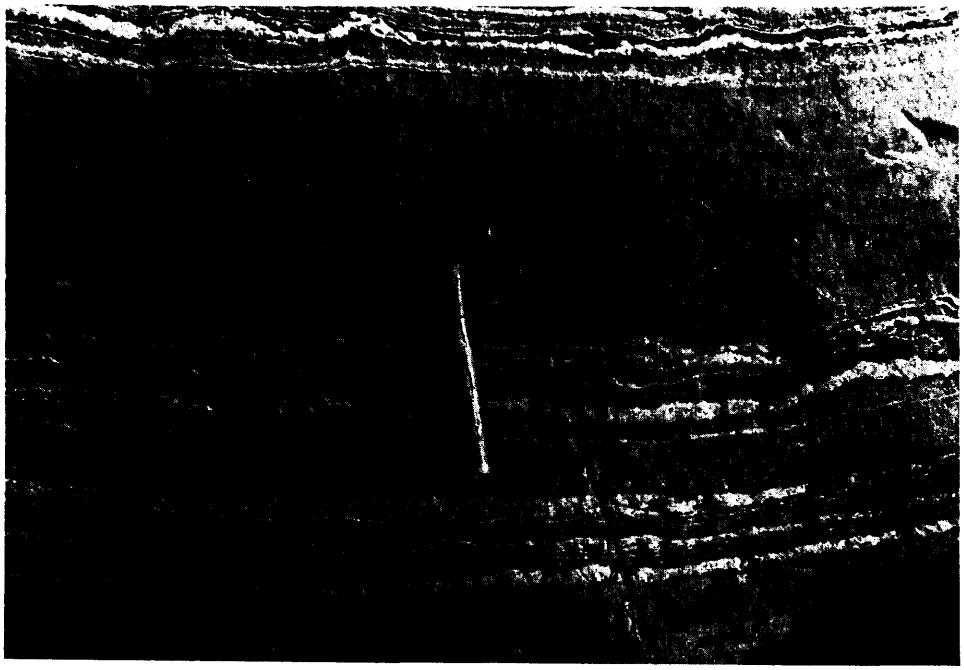

Photo 1. Well-developed metatexitic metasedimentary migmatite at damsite at Ear Falls. Note melanosome selvedges disposed along some of the leucosome layers.

TABLE 3 MEAN BULK CHEMICAL COMPOSITION OF METASEDIMENTARY PALEOSOME FROM NORTHERN SUPRACRUSTAL DOMAIN OF ENGLISH RIVER SUBPROVINCE AND VARIOUS SELECTED ROCK GROUPS.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	66.75	64.67	64.43	63.66	53.26	77.1	67.30	61.74	65.60	58.40	69.30
Al_2O_3	13.54	13.41	15.48	14.85	20.64	8.7	14.80	15.17	15.80	19.40	16.20
FeO	3.54	4.53	ND	4.67	7.13	0.7	3.44	5.74	3.65	6.75	1.30
Fe_2O_3	1.60	1.24	ND	1.01	1.26	1.5	1.17	1.87	1.50	1.60	1.44
Total Fe as Fe_2O_3	ND	ND	6.54	ND	ND	ND	ND	ND	ND	ND	ND
MgO	2.15	3.23	3.12	2.99	4.81	0.5	1.55	2.30	2.63	3.75	1.07
CaO	2.54	3.04	2.22	2.63	1.24	2.7	3.13	4.80	3.20	1.30	3.67
Na_2O	2.93	2.99	3.74	3.14	2.20	1.5	3.07	3.57	2.18	2.06	4.67
K_2O	1.99	2.02	2.44	2.30	3.53	2.8	1.40	0.54	1.79	3.82	1.28
TiO_2	0.63	0.57	0.62	0.63	0.93	0.3	0.51	1.22	0.88	0.84	0.43
P_2O_5	0.16	0.14	ND	0.16	0.16	0.1	0.07	0.32	0.12	0.12	0.08
S	0.07	ND	ND	ND	ND	ND	ND	ND	0.07	0.10	0.01
MnO	0.12	0.13	ND	0.12	0.09	0.2	0.08	0.14	0.08	0.09	0.03
CO_2	1.24	2.15	ND	1.24	0.10	3.0	0.98	0.47	0.13	0.07	0.13
H_2O^+	2.42	1.94	ND	2.17	4.62	0.9	1.56	1.87	0.63	1.19	0.38
H_2O^-	0.55	0.20	ND		0.11	ND	ND	ND	ND	0.45	0.30
TOTAL	100.23	100.26	98.59	99.99	99.98	100.0	99.06	99.73	98.26	99.94	100.29

ND = Not Determined

1 = Average of 61 greywackes of various ages, Pettijohn (1963, p.S15).
2 = Average of 12 greywackes of Precambrian age, Pettijohn (1963, p.S7).
3 = Average of 25 Archean greywackes from Wyoming, Condie (1967, p.2139).
4 = Average of 20 Archean greywackes from Slave Province, Henderson (1972, p.890).
5 = Average of 3 Archean mudstones from Slave Province, Henderson (1972, p.890).
6 = Average of 32 arkoses, Pettijohn (1963, p.S15).
7 = Average Superior Province rhyodacite, Goodwin (1968, p.75).
8 = Average of 3 Archean dacites, Wilson *et al.* (1965, p.167).
9 = Average wacke paleosome, English River Subprovince, based upon 21 analyses (this study).
10 = Average pelitic paleosome, English River Subprovince, based upon 15 analyses (this study).
11 = Average of 11 metamorphosed trondhjemite from within and contiguous to northern supracrustal domain, English River Subprovince (this study).

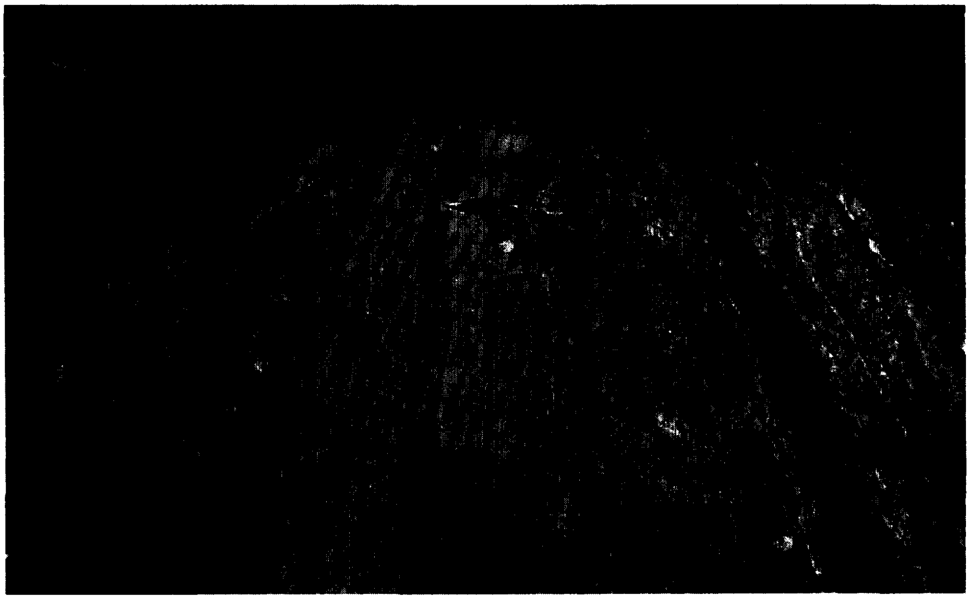

Photo 2. Good example of protometatexite located at Aerofoil Lake. Note confinement of mobilizate splotches to matrix coarsened pelitic horizons. Wacke beds (marked by hammer), however, have resisted partial melting and occasionally exhibit preserved sedimentary laminae.

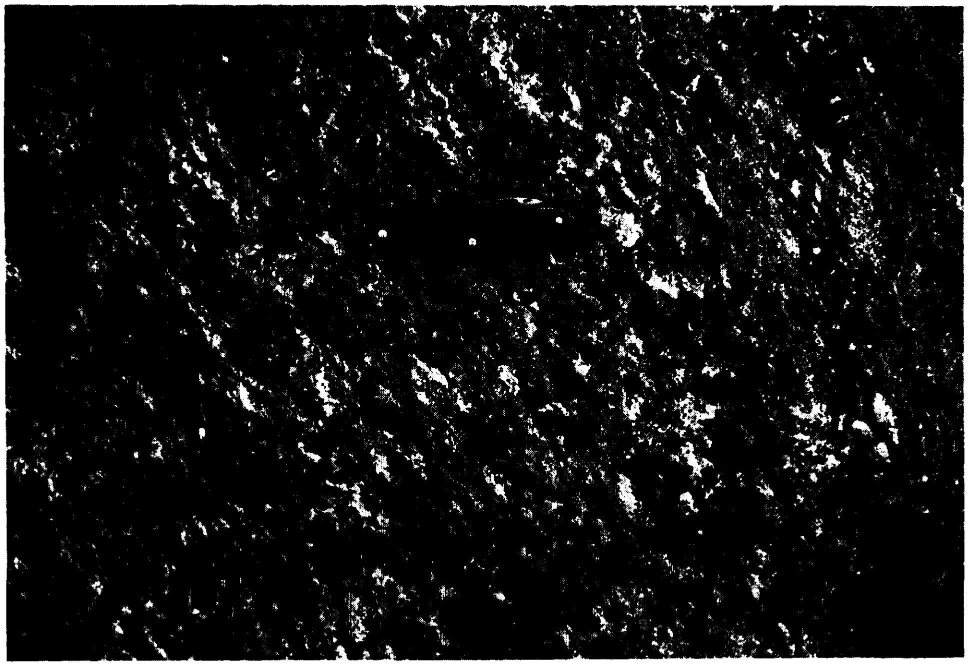

Photo 3. Close-up of metapelitic layer from protometatexite in the Wegg Lake area illustrating abundance of cordierite and almandine porphyroblasts and podiform leucosome development.

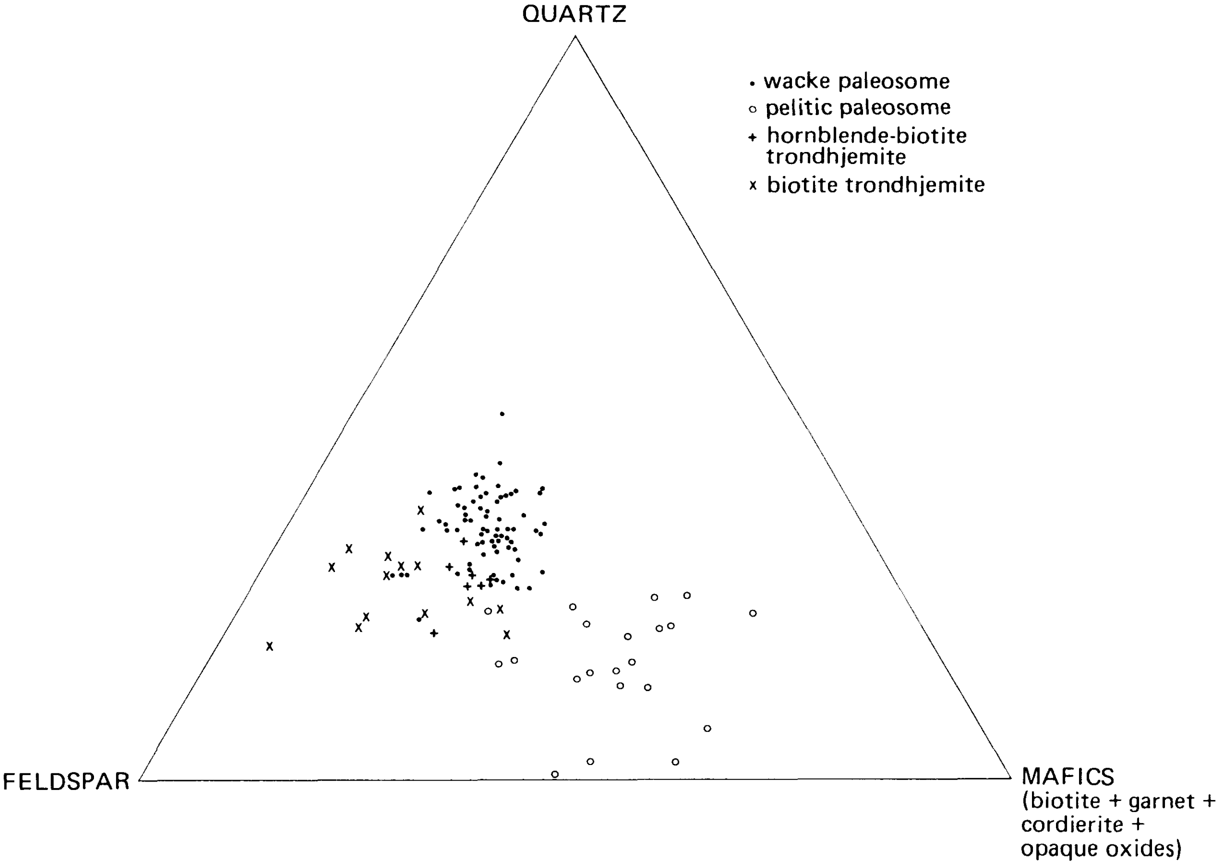

Figure 4. Modal variation of quartz, total feldspar, mafic minerals in paleosome of metasedimentary migmatite and trondhjemites from the Northern Domain, English River Subprovince.

In *Table 3,* mean bulk composition of wacke and pelitic paleosome from the northern domain is compared to several rock groups similar in composition and mainly of Early Precambrian (Archean) age. These rock groups are also plotted in *Figure 5.*

A distinct compositional field exists for the two distinctive paleosome types in terms of Na+K:Mg:Fe ratios marked by a chemical gradation between wacke and more iron-rich pelite. It can also be demonstrated here that a close chemical similarly exists between various average greywacke suites from the literature and wacke paleosomes from the study area. Additionally, wackes tend to be compositionally distinct from the average arkose, dacite, rhyodacite, and trondhjemite groups in terms of AFM and CNK diagrams. The pelitic rocks have Na:K ratios of less than one and thus occupy a field chemically distinct from that of the wacke paleosome in the CNK diagram. The average mudstone also plots within the pelitic field of this diagram, although in the AFM diagram the comparison is not as compelling.

The development of metatexite from metasedimentary protolithic material can essentially be considered a geochemical "splitting" process. The starting material represented by the paleosome field in terms of Na+K: Fe:Mg *(Figure 6)* undergoes transformation via anatexis into a melt represented by the leucosome and a crystalline mafic-rich residue constituting the melanosome. Each of these engendered migmatitic components now lies separated from the paleosome field by a petrochemical hiatus. In diatexitic systems, perhaps under conditions of protracted fusion or higher geothermal gradient, the melanosome component has been resorbed sequentially into the magmatic phase.

As indicated in *Figure 7,* more mafic compositions are encountered with advancing anatexis, and are particularly marked by iron and calcium enrichment and a moderate increase in magnesium. This trend is also expressed modally in the QFM plot of mobilizate compositions *(Figure 8).*

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 frequent. Colour index is commonly less than five and very often between one and two. Grain size usually ranges between medium and coarse, although pegmatoid segregations are often present. Usually alkali feldspar and plagioclase feldspar are earthy white on weathered surfaces rendering it somewhat hazardous to estimate specific granitic composition during outcrop examination. Rock composition should be verified in the field by hydrofluoric acid etching and feldspar staining.

These rocks exhibit a wide range in potassic feldspar to total feldspar ratios *(Figure 8)* which is compositionally equivalent to a complete transition from granite *sensu stricto* to trondhjemite. However, the vast majority of modally analysed specimens are quartz monzonite. There appears little doubt that the vast volume of mobilizate in the English River Subprovince represents crystallized anatectic melts because of the following attributes:

1) Ubiquity of hypidiomorphic-granular igneous fractional crystallization textures.
2) Omnipresence of coarse to pegmatitic grain sizes.
3) Widespread arteritic relations with surviving paleosome.
4) Presence of large batholithic masses.

The documented petrological diversity may in part be related to the presence of distinct paleosome compositional fields. Field staining studies reveal that pelitic paleosomes tend to produce strongly potassic mobilizate (granite and quartz monzonite), whilst the more feldspathic wackes are often 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, and sillimanite. One remarkable feature of the leucosome of English River Subprovince metasedimentary migmatites is the virtual universal occurrence of almandine garnet. Garnets in granitic rocks are normally quite rare, as noted by the writers in granitic terrains devoid of metasediments in several widely separated areas of the Uchi, English River, and Wabigoon Subprovinces. The ensuing explanation qualitatively attempts to reconcile the ubiquity of almandine within mobilizate of the various types of English River metasedimentary migmatite. During an event of medium to high grade regional metamorphism nucleation of blastic almandine garnet was initiated in compositionally favourable lithologies, such as in paleosome of wacke and pelitic composition. During metatectic and diatectic stages of migmatization at high grade metamorphism, this blastic garnet may have behaved as a relatively resistant metastable phase during fusion. Subsequently, diminutive almandine xenocrysts and/or relict crystals become incorporated within granitic mobilizate, thereby acting as nucleation centres or "seeds". Epitaxial addition of components to such xenocrysts ensued, forming idiomorphic to subidiomorphic relatively homogeneous crystals. This type of garnet strongly contrasts with spongy garnet-quartz aggregates which appeared relatively late and occasionally have been observed to overgrow contacts between diatexite and associated metatexitic rafts.

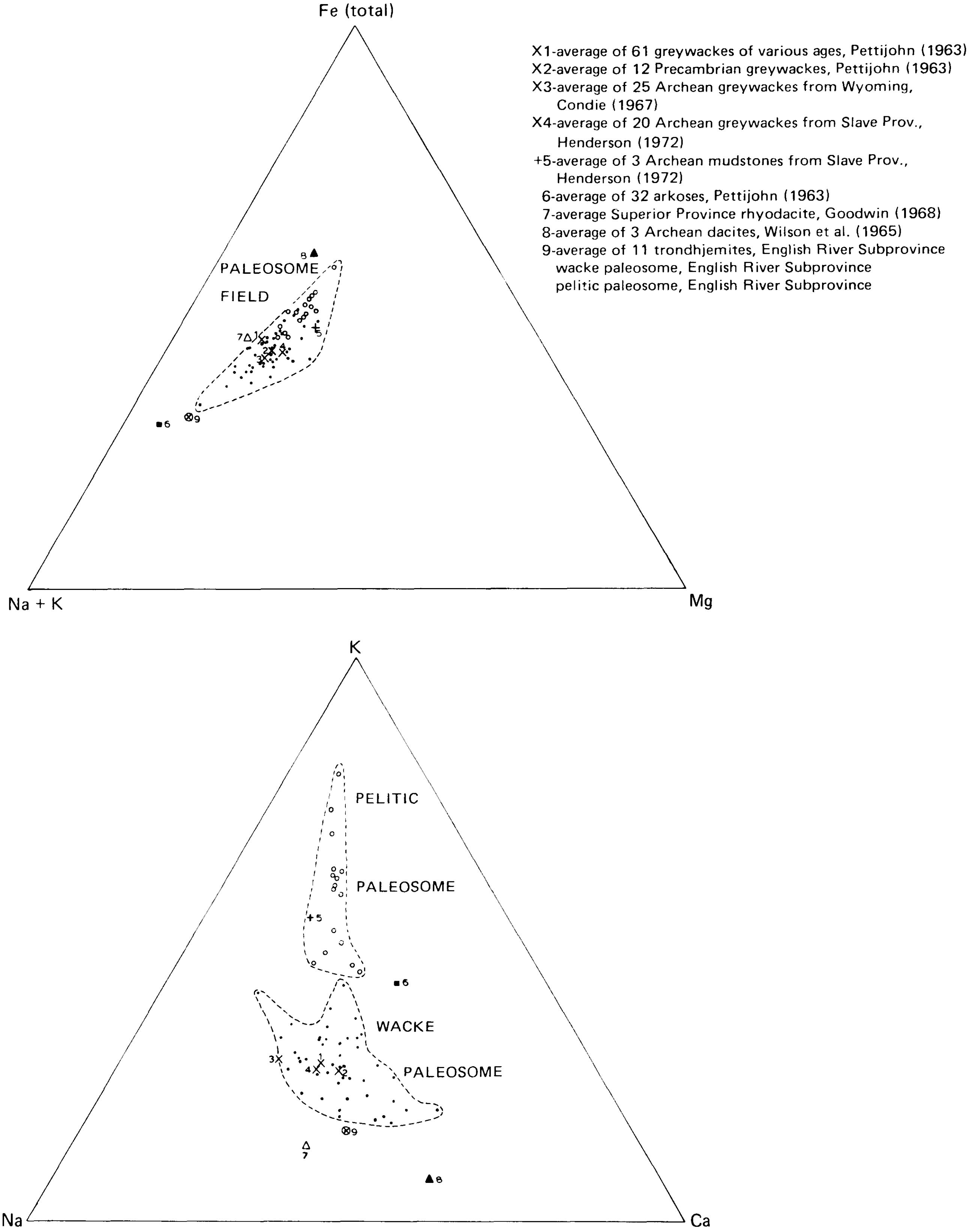

Figure 5. AFM and CNK plots (weight percent) illustrating compositional variation of metasedimentary paleosome from Northern Supracrustal Domain and comparison to selected mean rock compositions. Enumerated symbols correspond to analyses in Table 3.

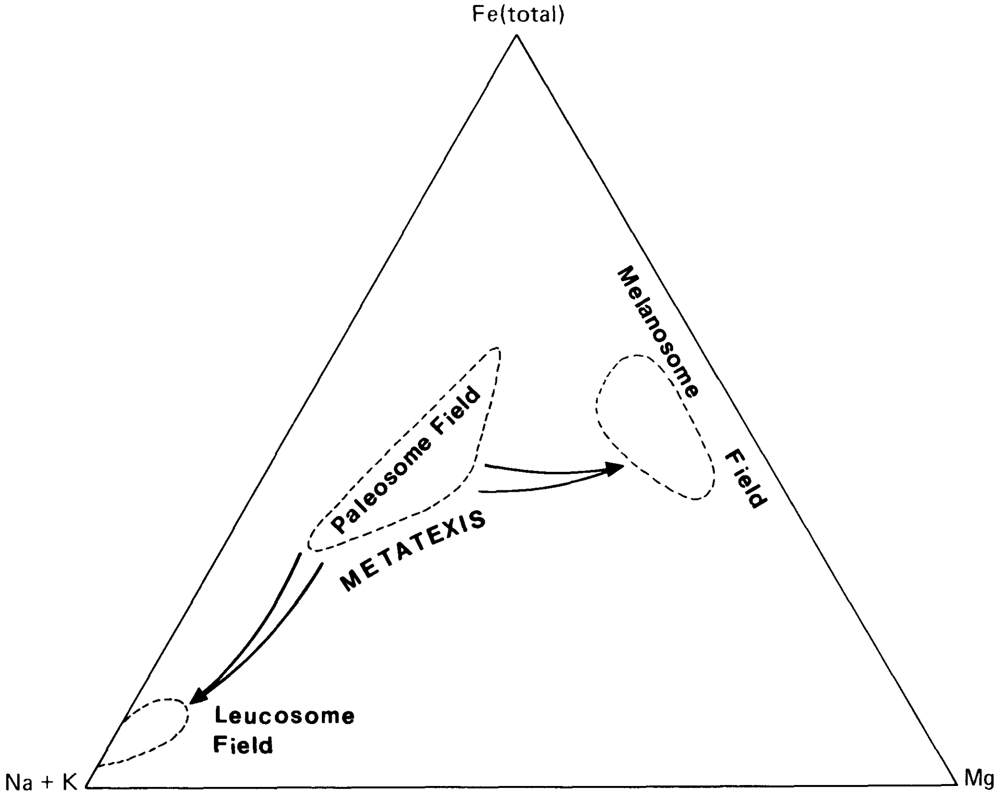

Figure 6. Petrochemical expression of metatexis, an anatectic degradation of paleosome forming neosome (leucosome and melanosome) based upon 85 analyses.

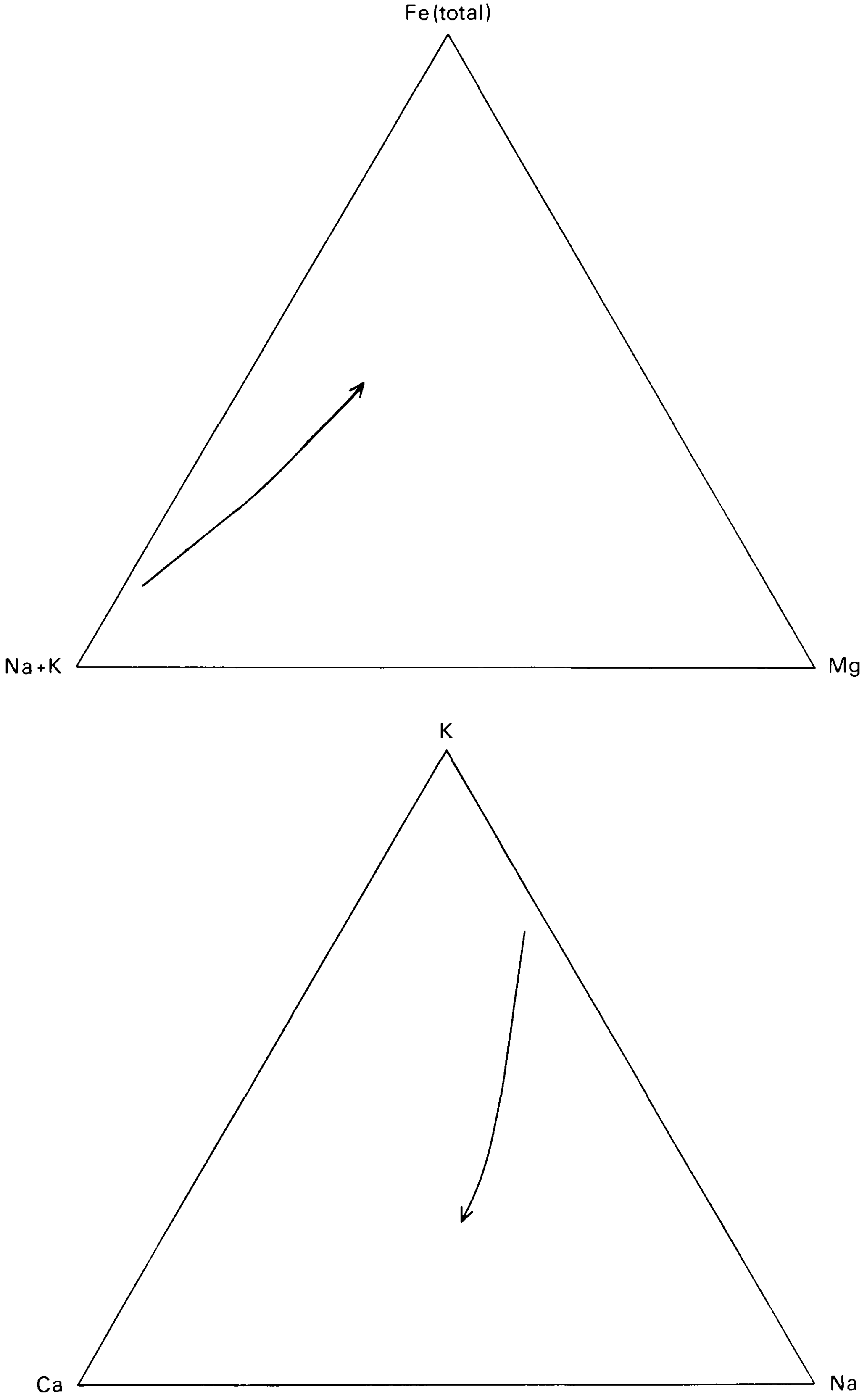

Figure 7. Curves of anatectic ascension-composition of diatexitic magmatic liquids attained during progressively greater degrees of fusion of metasedimentary protolith.

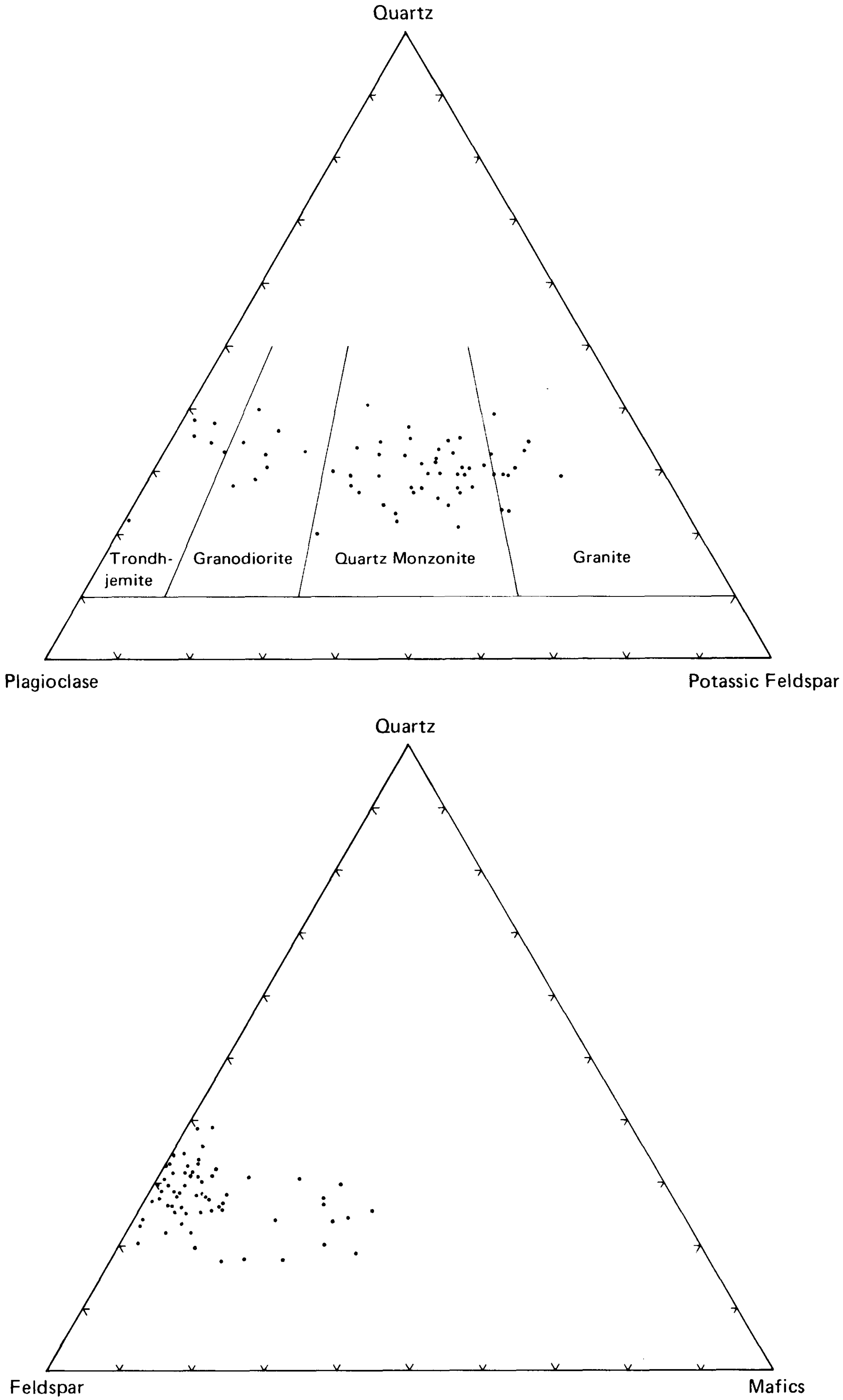

Figure 8. Modal variability of quartz: plagioclase: potassic-feldspar and quartz: total feldspar: mafic minerals for leucosome from metasedimentary migmatite of the English River Subprovince.

McRitchie and Weber (1971) working in adjacent correlative Manigotagan paragneisses in Manitoba provide some support for early tectonic/metamorphic development of garnet, which exhibits relict rotated foliation wrapped by a later schistosity. This documents that at least some garnet is pre-anatectic. Mehnert (1971) has remarked that a common feature in many migmatitic terrains is an initial blastic development of many minerals including garnet prior to incipient fusion.

Melanosome

The melanosome or restite component usually constitutes only 1 to 2 percent of most metatexites. In relatively undeformed exposures, the melanosome is usually preserved as a thin, continuous to partly continuous, mafic-rich selvedge occurring along the interface between the paleosome and leucosome. Such evidence usually supports a veinitic origin (Holmquist 1916) or *in situ* exudation of mobilizate from the paleosome. Mafic-rich rims have also been observed developed in a continuous peripheral fashion on metatexitic inclusions in inhomogeneous diatexite. However, here, the biotitic selvedge has obviously originated as a reaction rim. Mineralogically, the melanosomes consist dominantly of medium- to coarse-grained biotite, often exhibiting haphazard orientation, especially when perceptibly coarser grained than the adjacent paleosome counterparts. Subordinate amounts of quartz, plagioclase, garnet, and occasionally, sillimanite and cordierite are present. The melanosome is of particular potential petrological importance in that the metamorphic mineral assemblages may yield information with respect to pressure-temperature-chemical composition conditions prevailing during development of the migmatites.

DIATEXITE

As defined by Brown (1973, p.375), diatexis refers to "high-grade anatexis in which fusion may be complete". 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 almost always included in map legend subdivisions of the past dealing with granitic rocks. However, it must be realized at the outset of mapping that diatexites represent an integral and inextricable stage in the evolution of migmatitic metasediments of the English River Subprovince and elsewhere in the world (Mehnert 1971). Some workers, most notably Brown (1973) have refuted admission of the term diatexite to the migmatite spectrum, stemming from a highly restricted definition of term migmatite. Several important field idiosyncrasies serve as a rapid means of identification of diatexite compared to other common plutonic rocks appearing elsewhere in the English River Subprovince and are given as follows:

1) Remnants of paleosome are nearly always present, but vary greatly in quantity.
2) Evidence of varying degrees of mobility especially with respect to inhomogeneous diatexites. The rocks have a 'turbulent' character with abundant contorted, plastically deformed inclusions being often notable.
3) The wide range in grain size, even within a hand specimen. A medium- to coarse-grained average size is most prevalent, although pegmatitic[1] equivalents are quite common.
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 presence of unusual (for granitic rocks) characteristic accessory minerals such as almandine and/or cordierite and/or sillimanite may be present which are unusual for granitic rocks.
6) Complete destruction of stromatic structure.

Two subdivisions of diatexite can be effected in the field based upon volume of remnant material. These are as follows:

1) Inhomogeneous diatexite.
2) Homogeneous diatexite.

Inhomogeneous Diatexite

The overwhelming impression of this type of diatexite is that of a disoriented "mess", a conspicuous abundance, usually 10 to 40 percent, of paleosomatic and melanosomatic "debris" resulting respectively from mechanical incorporation during mobilization and incomplete fusion *(Photo 4)*. The most prevalent kinds of inclusions 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 each containing generally haphazardly oriented biotite, minor almandine, 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 inclusions and quartz fragments have been noted only in rare instances. A moderate variation

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[1] Average grain size in excess of 1 cm.

in grain size usually occurs, varying commonly from medium- to coarse-grained. Textures are characteristically hypidiomorphic-granular in which idiomorphic to subidiomorphic feldspars fractionally crystallized prior to quartz.

Homogeneous Diatexite

As the name implies this type of diatexite contains a relatively sparse volume of inclusions, less than 10 percent. In essence, the same petrological attributes of mobilizate of inhomogeneous diatexites apply to this category as well *(Photo 5).*

ORIGIN OF METASEDIMENTS

One of the foremost problems confronting workers in the English River Subprovince concerns evaluating the nature of the source region from which the voluminous quantities of clastic metasediment forming the northern domain were derived. Unravelling this fundamental problem is fraught with difficulties. These are mainly related 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 sedimentological mode of deposition of the rocks. Sporadically along the Uchi Subprovince-English River Subprovince interface minimal evidence exists in non-migmatized localities characterized by low and medium grade metamorphism. In these localities interbedded pelitic and wacke assemblages, coarse framework grains in wackes, and graded bedding have managed to survive metamorphic effects.

As a working model, the authors conceived that the northern terrain constituted an extensive, linear metasedimentary trough rimmed by two quasi-contemporaneous island-arc volcanic complexes, now respectively represented by the Uchi and Separation Lake Belts. These cyclical volcanic piles were in turn positioned along the flanks of older sialic forelands, dominated by sodic, calc-alkalic granitoid phases, namely trondhjemite-quartz diorite. Juxtaposition of these diverse tectonic elements could engender a mixed-source provenance for the ubiquitous wacke component in the northern domain. 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).*
2) The bulk composition exhibits Na:K ratios in excess of one.
3) The moderate concentrations of the lithophile elements barium, lubidium, and Zirconium.
4) The relatively high iron, magnesium, chromium, nickel and vanadium indicative of a mafic-ultramafic legacy.

Although dacitic and rhyodacitic rocks approximate the paleosome compositional field in *Figure 5,* several critical factors, dealt with below, militate against appealing to these rock types as solely representing the 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 metasediments of the Northern Supracrustal Domain. This relationship is evident 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 mass imbalance of felsic to intermediate metavolcanic material now exists in contradistinction to the extensive quantity of wacke contained within the northern supracrustal domain of the English River Subprovince.

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

Uchi Subprovince:
Mafic to intermediate, 90.2 percent
Felsic to intermediate, 9.8 percent
Wabigoon Subprovince:
Mafic to intermediate, 92.2 percent
Felsic to intermediate, 7.8 percent

It is additionally illuminating that between Longitude 89°00′ and the 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; Figure 9)* do not appear to favour a cratonic sialic provenance from a volcanogenic source region. Trace element data pertaining to major sandstone classes are generally scant in the literature, a situation only marginally improved since Pettijohn's chemical survey of sandstones in 1963. Such data may provide important constraints regarding chemical constitution of a particular source region as exemplified by the study of Condie *et al.* (1970) about Early Precambrian greywackes from the Fig Tree Group, Republic of South Africa. In *Table 4,* 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,

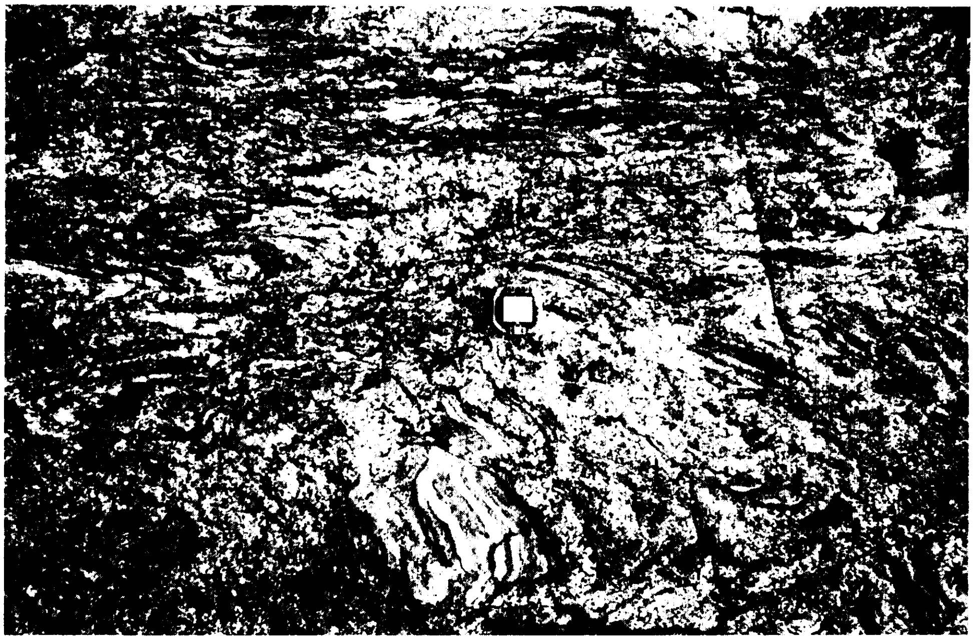


Photo 4. Inhomogeneous diatexite from Conifer Lake area. Note repletion of biotitic schlieren and a twisted metatexite inclusion.

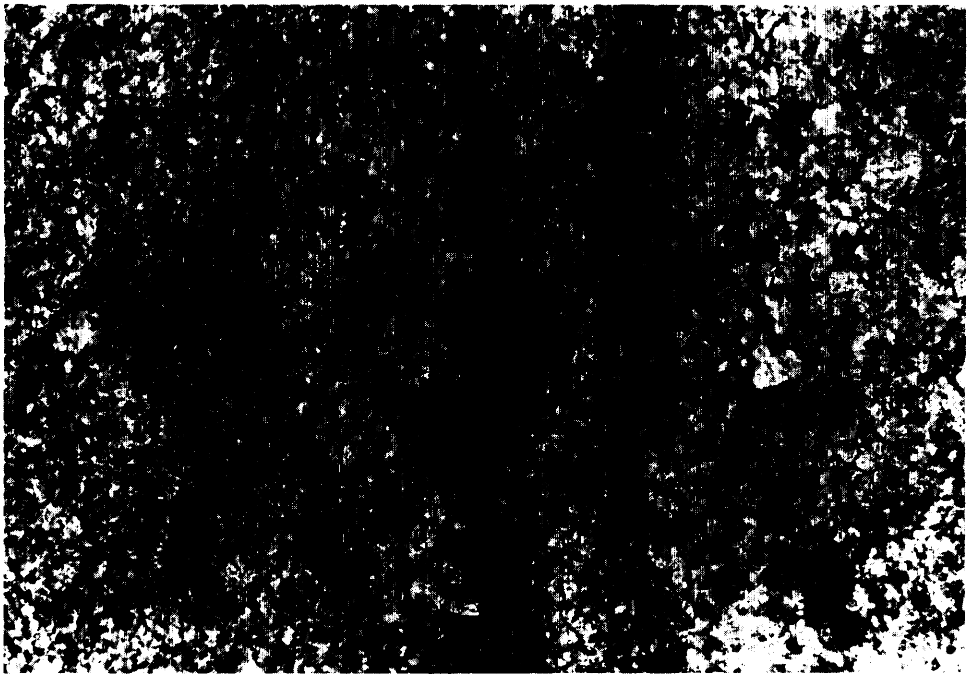


Photo 5. Homogeneous diatexite from Bear Narrows area of Lac Seul. Typically these rocks exhibit wide ranges in grain size and hypidiomorphic granular texture. Note biotitic schlieren near coin.

TABLE 4 RANGE AND MEAN ABUNDANCE OF SELECTED TRACE ELEMENTS FROM THE ENGLISH RIVER SUBPROVINCE WACKE, PALEOSOME, AND VARIOUS ARCHEAN ROCK GROUPS.

	1		2		3		4		5	
	mean	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**
Ba(A)	207	60-500	222	80-520	54	30-160	420	250-610	305	70-520
Co(A)	15	8-25	<7	<5-10	66	30-100	15	7-20	<11	<5-35
Cr(A)	177	5-320	12	5-30	279	40-620	56	10-100	19	5-65
Cu(A)	28	10-75	6	5-15	123	5-240	44	10-160	56	5-350
Ni(A)	37	5-115	<8	<5-25	124	45-270	49	10-100	<11	<5-35
Rb(A)	68	35-140	26	10-40	6.1		ND		ND	
Sc(S)	13	9-20	6	5-10	39	10-70	ND		ND	
V(S)	77	45-150	29	10-60	237	100-400	54	35-70	33	10-70
Zr(S)	103	50-200	68	10-150	43	10-140	130	80-200	133	20-400

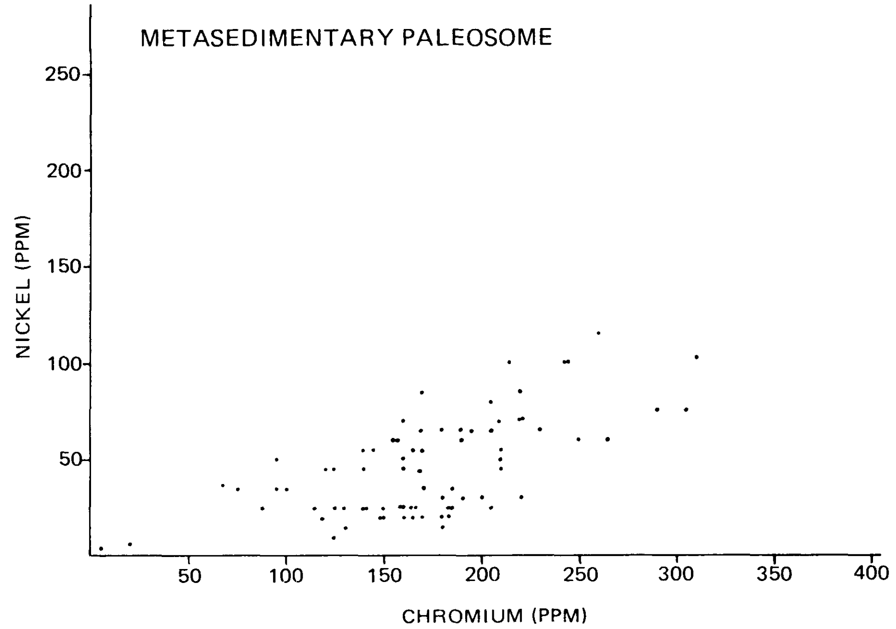
NOTES:

ND = not determined

1. Wacke paleosome from English River Subprovince (21 analyses).
2. Metamorphosed trondhjemite situated within and proximal to northern domain of ERS (11 analyses).
3. Tholeiitic metabasalts, Sturgeon Lake Belt, Wabigoon Subprovince (70 analyses) average Rb value from Hart *et al.* (1970, p.24).
4. Dacite, Uchi Subprovince (7 analyses) Sage and Breaks (1976).
5. Dacite, Wabigoon Subprovince, Sage and Breaks (In Press) (15 analyses).

(A) = atomic absorption spectrophotometry

(S) = emission spectroscopy



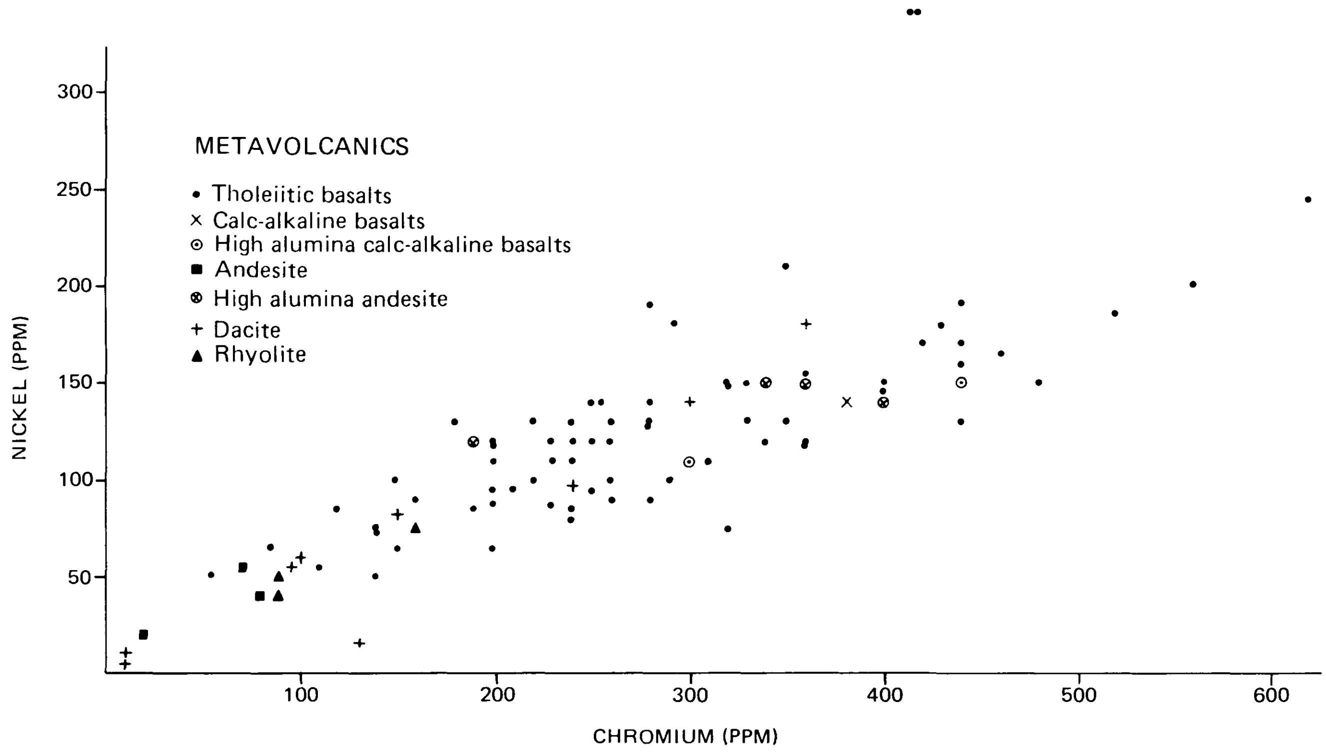


Figure 9. Chromium-nickel variation in metavolcanics from Uchi and Wabigoon Subprovinces and in metasedimentary paleosome from English River Subprovince.

(3) data for lithologies of Archean age that plausibly could have been involved as progenitors of the paleosome. Most notable here are consistently high levels of chromium coupled with a moderate concentration of vanadium, typical of a mafic and/or ultramafic lineage. These elements along with nickel exhibit a tendency towards moderate enrichment in tholeiitic basaltic flows of Superior Province volcanic successions. The concentration range of chromium in paleosome significantly overlaps that of tholeiitic basalts from the Sturgeon Lake Metavolcanic Belt *(Figure 9 and Table 4)*, and appreciably exceeds the mean level of chromium contained within metamorphosed trondhjemitic rocks. Trondhjemitic rocks represent a widespread and important constituent of sialic crust in the Superior Province of Northwestern Ontario. Mean chromium content of paleosome also significantly exceeds that in dacites from the Uchi and Wabigoon Subprovinces *(Table 4)*.

Nickel exhibits moderate concentration in the paleosome, but, nevertheless, is appreciably greater than trondhjemitic rocks and comparable to dacite from the Uchi Subprovince. Levels of chromium and vanadium comparable with the levels detected in the wacke paleosome may exist in metadiorite and metagabbro. However, these rock types comprise a relatively meager proportion of the exposed granitoid terrain in the southern domain of the English River Subprovince *(see Table 1)* or in the adjoining Uchi Subprovince (Sage *et al.* 1976).

Chromium and nickel exhibit a well defined correlation *(see Figure 9)* which appears valid for the gamut of Early Precambrian (Archean) metavolcanic compositions except ultramafic extrusive flows which are not plotted in *Figure 9*. A similar coherence is apparent in the paleosome analyses and is interpreted to represent involvement of appreciable volumes of tholeiitic basaltic detritus from the source area. Although granitic rocks, with the possible exception of diorite and quartz diorite, generally harbour small quantities of chromium, vanadium, and nickel, the presence of a felsic component in the source area must also be considered since levels of barium, rubidium, and zirconium are significantly high in comparison with the content of the elements in the average tholeiitic basalt. These elements possess pronounced lithophile tendencies and thus are notably incompatible with the crystal-chemical constitution of most basaltic rocks. Barium levels exhibit a wide range of abundance varying from 60 to 500 ppm and averaging 207 ppm, closely approximating both average (222 ppm) and range (from 80 to 520 ppm) of the metamorphosed trondhjemitic group. The mean abundance of zirconium in the wacke paleosome is intermediate between the two dacite groups and metamorphosed trondhjemite group, all significantly higher than the mean abundance in tholeiitic basalt. Rubidium appears generally depleted in the paleosome, with a mean concentration of 69 ppm versus the currently accepted mean crustal abundance of 90 (Taylor 1965). The relatively low levels of rubidium may be consequent upon derivation of wacke detritus from a source area exhibiting similar depletion trends. Average rubidium content of metamorphosed trondhjemitic rocks in *Table 4* also indicate depleted levels, although somewhat below that of the wacke paleosome.

Thus, the trace element character of wacke paleosome from the northern domain appears explicable if consideration is given to a heterolithologic provenance. This source area must have significant quantities of tholeiitic basalt and trondhjemitic granitoid material, the latter group probably augmented by felsic to intermediate volcanic rocks. A felsic component must be present in order to provide an ample supply of sand size quartz for the wacke paleosome. Basaltic lithologies are necessary for moderate chromium, vanadium, nickel, iron and magnesium levels but cannot solely fulfill the requirements for a relatively high quartz content. 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, amphibolitized mafic metavolcanic flows of the mobilized eastern extension of Separation Lake Belt are overlain by a clast-supported, cobble to boulder, polymictic conglomerate succeeded by migmatized wacke metasediments of the northern domain. Clasts of massive to foliated, coarse-grained, biotite and hornblende-biotite trondhjemite preponderate; subordinate mafic metavolcanic clasts are apparent. No strongly gneissic clasts comparable to the rocks of the gneissic domain located nearby to the south in the Cedar Lake area were apparent. Nevertheless, this exposure reveals the following important information:

1) Trondhjemitic and basaltic components were being simultaneously deposited in the northern domain basin.
2) An elevated granitic terrain of unknown extent was positioned within the southern granitoid intrusive and gneissic domain.

A maximum age of sedimentation will eventually be forthcoming as boulders from this conglomerate are currently being dated by Uranium/Lead methods (Krogh personal communication 1977). Overlap of trondhjemitic and wacke fields in the QFM plot *(see Figure 4)* appears to foster additional support for the existence of sialic trondhjemitic granitoid phases in the source area.

Southern Plutonic Domain

The southern half of the English River Subprovince, termed the "Southern Plutonic Domain" is characterized by felsic to intermediate plutonic and gneissic rocks of various ages. This domain *(see Figure 2)*, an eastward extension of the Winnipeg River Plutonic Complex in Manitoba (McRitchie 1971), extends eastward from the Manitoba/Ontario border to Whitewater Lake, a distance of approximately 410 km. The maximum width of the southern domain taken between Umfreville Lake and the town of Kenora is 70 km. Further east, to the northwest of the Savant Lake Greenstone Belt, the plutonic complex thins to about a width of 26 km.

The boundary of the Southern Plutonic Domain is arbitrarily marked in the south by the northern limit of the Wabigoon Subprovince metavolcanics. The northern limit of this plutonic-gneissic complex is marked by the appearance of metasedimentary and associated migmatitic rocks typical of the northern domain. Interposed between the two domains there is a band of mafic to intermediate metavolcanics that volumetrically forms a significant greenstone belt at Separation Lake. This Separation Lake Greenstone Belt is an eastward continuation of the Bird River Greenstone Belt (McRitchie and Weber 1971). East of Separation Lake, scattered remnants of this same volcanic belt, having a substantially less volume, are discontinuously scattered near or along the junction between the two domains for a further 180 km. Locally, these remnants have been separated from the boundary of the two domains by later intrusive plutonic rocks.

Reconnaissance mapping has shown that the Southern Plutonic Domain of the English River Subprovince consists of three major rock suites. The diagnostic characteristics of these three groups are based upon the nature of internal deformation and relative field relationships of the assemblages characterizing the suites. In order of decreasing relative ages, the three rock suites are:

1) Gneissic Granitoid Suite (pre-tectonic).
2) Sodic Plutonic Suite (pre- to syn-tectonic).
3) Potassic Plutonic Suite (syn- to post-tectonic).

DISTRIBUTION AND GENERAL NATURE OF THE THREE SUITES

Except for local discordances, the three rock suites trend approximately parallel to the boundaries of the English River Subprovince *(see Figure 3)*. West of Highway 105 which connects the towns of Vermilion Bay and Red Lake, the three suites trend approximately west (see Map P 1971, back pocket). East of Highway 105 this trend changes to east-northeast. Further east, at Sioux Lookout, the trend is again deflected to northeast as far as Pashkokogan Lake, where once again the trend is west. Overall, the trend of the southern domain varies essentially from west to northeast.

Relative abundance of rock suites in the southern domain *(see Table 1)* indicate the three main suites (gneissic, sodic, and potassic) constitute about 96 percent of this part of the English River Subprovince. The remaining 4 percent comprises supracrustal rocks (mafic to intermediate metavolcanics and metasedimentary migmatites) and mafic to intermediate plutonic rocks.

Ironically, the Gneissic Granitoid Suite composes only 20 percent of the Southern Plutonic Domain and probably constitutes less than 10 percent of the area underlying the area commonly termed the "English River Gneiss Belt" (Wilson 1971, p.45). Adoption of the term gneiss to the subprovince appears to be a misnomer. The Gneissic Granitoid suite is mainly restricted to the western part of the Southern Plutonic Domain *(see Figure 3)*. Except for large segmented tracts of gneissic rocks preserved in the Clay Lake-Cedar Lake area and in the central part of Lac Seul, the gneissic suite is found predominantly along the extreme southern contact of the Southern Plutonic Domain extending from west of the Manitoba-Ontario border to the southeast extension of Lac Seul, northeast of Sioux Lookout. A few screens of gneiss including a dome-like structure also occur north of the Savant Lake area. The relation of gneissic rocks in contact with the Wabigoon Subprovince is not continuous due to extensive segmentation of the former by intrusive rocks of the two later sodic and potassic suites. From field relations, the gneissic granitoid suite represents the oldest sequence in the English River Subprovince and is composed of a diorite-quartz diorite-trondhjemite locally granodiorite assemblage that has been severely deformed.

Occupying about 39 percent of the Southern Plutonic Domain, the Sodic Plutonic Suite is the most areally widespread of the three suites and is also present as discrete plutons and batholiths in the northern metasedimentary domain. Chemically, these rocks tend to be slightly less mafic but are essentially characterized by a similar diorite-quartz diorite-trondhjemite-granodiorite assemblage. They predominate as pre- to syn-tectonic sills, stocks, and batholiths that have been weakly to moderately deformed and recrystallized.

The youngest group of rocks is represented by the Potassic Plutonic Suite; this suite, accounting for 40 percent of the southern domain, is roughly as plentiful as the intermediate sodic suite. Excluding a small area northwest of the Savant Lake area, the potassic suite is restricted to the western part of the southern domain, the area west from Route Bay in Lac Seul. The potassic suite is essentially rare to absent in the northern domain. This suite is characterized by granodiorite-quartz monzonite-granite *sensu stricto* assemblages that are syn- to post-tectonic, and are undeformed and unmetamorphosed.

GNEISSIC GRANITOID SUITE

Due to their complexity and extreme variability in composition and fabric, the Gneissic Granitoid Suite is the least understood of all other rock suites within the English River Subprovince. The Gneissic Granitoid Suite, composed of a medly of assemblages including predominantly plutonic and subsidiary phases of possible supracrustal origin, characteristically displays a layered or gneissic fabric. Heterogeneity within the suite is influenced by the numerous, polycyclic, complexly intermixed, intrusive phases and by changes in fabric produced by chaotic differences in the following: 1) Degree of development of layering or foliation. 2) Continuity of layering. 3) Thickness of layering. 4) Percentages of complimentary mafic and felsic components. The Gneissic Granitoid Suite, composed of polycyclic intrusive phases that have been subjected to several periods of deformation and metamorphism, may be regarded as a migmatitic intrusive complex, but unlike the Northern Metasedimentary Migmatitic Complex, many of the component phases have been introduced from an external source. That is, the gneissic suite was generated in an open system in which magmatic material was not only reworked, but into which fresh magmatic material has been added periodically. Westerman (1978) has studied the Gneissic Granitoid Suite in the Clay Lake-Cedar Lake, and Vermilion Bay areas in detail and has indicated mappable units based upon dominant component associations. Mappable components outlined by Westerman (1978) within the Gneissic Granitoid Suite include:

(i) Amphibolite.
(ii) Mafic hornblende-biotite gneiss.
(iii) Foliated biotite-hornblende quartz diorite to trondhjemite.
(iv) Trondhjemitic and granodioritic gneiss.
(v) Foliated to gneissic trondhjemite and granodiorite.
(vi) Leucotrondhjemite.
(vii) Leucocratic quartz monzonite to granitic *sensu stricto.*
(viii) Biotite trondhjemite gneiss (strongly banded on a scale of mms).

From these components, Westerman (1978) arrived at the following mappable associations:

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) b (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 (1j) 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

In addition, all of the above associations contain variable proportions of components (vi) and (vii) which are genetically related to the later intermediate (sodic) and final (potassic) plutonic suites respectively. Locally, the above associations are complexly mixed together, in which case due to the reconnaissance scale, only broadly defineable dominant associations are indicated in the mapping. Except for locally discordant relations exhibited by components (vi) and (vii), the components composing the associations are conformable. Furthermore, where associations are themselves intermixed, their configuration also appears to be conformable with the result that no relative age relationships between the associations are evident.

Trondhjemitic and granodioritic gneiss (iv) is the most widespread component. The banding, defined by concentration of mafic minerals augmented by bands of quartzofeldspathic mineralogy that typically has an equigranular, allotriomorphic-granular texture, varies from diffuse to sharply defined and is commonly from 10 to 50 cm in width. It is felt by the authors that some of the potassic feldspar within the more granodioritic compositional phase may be metasomatic in origin, possibly related to the later injections of the potassic suite (component vii). Locally, the more trondhjemitic to quartz dioritic phases (iii) contain hornblende-biotite assemblages (ii). Leucocratic (colour index < 5), fine-grained trondhjemite (vi) characterized by an allotriomorphic-granular texture, is a major phase occurring throughout the gneissic suite as thin, conspicuous, concordant bands. Westerman (1978) has indicated that some of the leucocratic trondhjemite bands are strongly deformed and slightly discordant. Locally west of Daniels Lake and north of Kenora, the leucocratic-trondhjemite is regularly interbanded with mafic-rich bands suggesting that the two complimentary phases are anatectic derivatives. The authors believe that the leucocratic trondhjemite has originated by anatexis of existing phases and by intrusion from an external source. Leucocratic trondhjemite is also commonly associated with mafic amphibolite (i) lenses which are spotted throughout the gneissic suite. The amphibolite is present as: a) small, isolated enclaves, locally agmatized by leucocratic trondhjemite, b) diffuse, partly digested mafic biotite-hornblende schlieren and c) linear, boudinaged lenses some of which are continuous over tens of metres. Regardless of their form, the amphibolite lenses are always concordant to the other phases. Massive, late potassic sills and dikes including phases of biotite quartz monzonite to granite *sensu stricto* (vii) are the most easily recognized components within the gneisses. They occur both as concordant, deformed, and undeformed, recrystallized, and nonrecrystallized sills and as sharply defined, discordant, nonrecrystallized dikes. In some places, the margins of the concordant sills are diffuse and are thought to be metasomatic in part. The above differences suggest that the gneissic suite has been subjected to a lengthy period of potassic addition.

Layering or banding throughout the gneissic suite is generally concordant to the fabric of the surrounding rock suites including the metavolcanics exposed along the north margin of the Wabigoon Subprovince. The later phases are commonly injected along established lithologic or gneissic boundaries. North of Kenora, the layering is well-defined but in many places is diffuse and irregular.

Excluding the later potassic injections, the Gneissic Granitoid Suite is mineralogically composed of mainly quartz + plagioclase + biotite ± hornblende ± potassic feldspar, and chemically the suite is similar to, but slightly more mafic than the Sodic Plutonic Suite (*Figure 10*, AFM plots 2 and 3). The gneissic rocks do grade imperceptibly into rocks of the later sodic suite and many of the contacts between the two suites are subjective, based on the dominant fabric.

The Gneissic Granitoid Suite is considered by the authors to be a hybrid, catazonal, granitoid complex composed of numerous early granitoid phases which have been severely deformed and have suffered extensive and intimate penetration by *lit-par-lit* injected phases originating in part from the later two plutonic suites. Probably the intrusions were emplaced over a long period of time, and were severely complicated by metamorphism and deformation which caused reworking in the form of anatexis, metasomatism, and migmatization. Several periods of folding have been recognized by Westerman (1978) within the Gneissic Granitoid Suite. The fold structures are often displayed by one or more of the most conspicuous phases: amphibolite, holo-leucocratic trondhjemite, or potassic injections.

Banding in granitoid rocks as viewed by M. 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.
2) Metasomatic; 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 phases resulting in interlayering of holo-leucocratic melt with granitoid paleosome.
4) Primary; depositional or flowage controlled mineral banding.

A combination of all the above processes with emphasis on the first three is probably involved in the formation of the Gneissic Granitoid Suite.

The Gneissic Granitoid Suite has been modified and segmented by the later intrusives of the Sodic and Potassic Suites. Large domal structures in the Cedar and

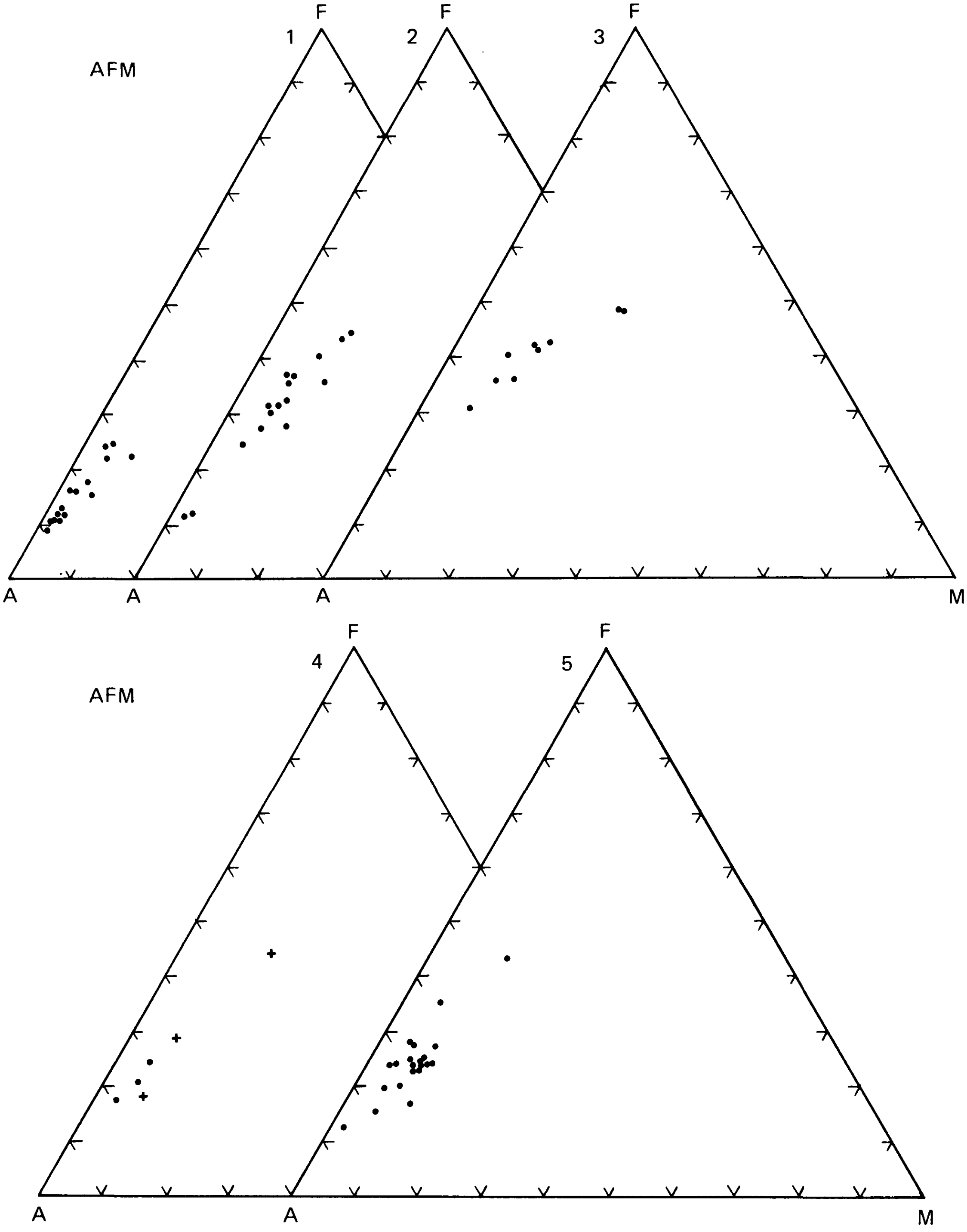


Figure 10. AFM plots showing chemical variation of the potassic suite (1), sodic suite (2) and gneissic suite (3) of the southern domain. AFM plot (4) indicates a Trondhjemite trend for the Campfire Lake Pluton (crosses) and the Daniels Lake Pluton (dot). Diagram 5 is an AFM plot for the Lount Lake Batholith.

Clay Lakes areas may be a result of upwelling by rocks of the younger Potassic Plutonic Suite.

Understanding the origin of the amphibolite enclaves is critical to any model. The more diffuse biotite-hornblende schlieren may represent a metamorphic transposition of mafic minerals within a parent igneous intrusive. The remaining massive lenses of amphibolite may represent inclusions from some earlier supracrustal sequence, or, in those cases where the enclaves are fairly linear and mildly discordant, may represent early mafic dikes similar to those proposed by Bridgewater *et al.* (1973) in the early gneissic suite in Greenland. The affinity of the leuco-trondhjemite to many of the amphibolite enclaves suggests this association could have been generated by igneous differentiation or partial melting of rocks of basaltic composition indicated by Barker and Arth (1976). This could occur if the Gneissic Granitoid Suite presently exposed had at some time in the past been formed at a considerable depth.

Contact Relations between the Gneissic Granitoid Suite and the Wabigoon Subprovince

Wilson (1971) proposed that a fault marked the southern contact of the English River Subprovince based on the presence of coincident strong linear magnetic features and topographic lineaments. No evidence of major cataclasis has been noted along this boundary or along several lineaments including a notable lineament at Canyon Lake which is situated north of the gneissic suite, north of the contact of the Tustin-Bridges Metavolcanic Belt. This lineament, 40 km in length and averaging 0.3 km in width, has proved to be neither fault-controlled nor lithologically controlled, but is instead related to late fracturing. The geological map *(see Figure 3)* indicates that the gneissic suite of the Southern Plutonic Domain of the English River Subprovince is 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 has been intruded by porphyritic granodiorite characterized by microcline augen hosted within a protomylonitic fabric. The cataclastic fabric is restricted to the sills; it is not apparent in either the adjacent mafic metavolcanics 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. North of Vermilion Bay and at 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) described the latter area and indicated that the Gneissic Granitoid Suite passes into the mafic metavolcanic rocks by depletion of the latter at the expense of the former. The position of the contact is arbitrarily drawn on the basis of dominant lithology, 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.

SUBDIVISION OF THE REMAINING SUITES

Approximately 40 individual plutonic phases have been recognized in association with the other two major suites. These phases have been identified on the basis of easily distinguished field parameters including differences in:

1) Texture.
2) Type and abundance of accessory minerals.
3) Colour index.
4) Degree of recrystallization.
5) Composition after Ayres (1972).

Initial mapping indicated that two structural styles of plutonism based on the presence or absence of metamorphism were apparent. Subsequent mapping of these pre-tectonic and post-tectonic phases has disclosed the former to be characteristically potassium-poor while the latter is potassium-rich, although these relationships are not entirely exclusive. In general, the degree of recrystallization varies substantially, and there is a complete spectrum ranging from highly recrystallized to weakly recrystallized to completely nonrecrystallized varieties. The extreme end members of this spectrum are easily classified but classification of the intermediate moderate to weakly recrystallized phases is somewhat subjective and generally depends upon whether the primary texture or the secondary texture is more pronounced. Phases giving the most trouble tend to be fine grained, characterized by allotriomorphic-granular-textures. According to Voll (1960), quartz is the most easily recrystallized rock-forming mineral, and the presence of recrystallized quartz in conjunction with development of secondary foliation are the major criteria in distinguishing the pre-tectonic metamorphosed phases from the post-tectonic unmetamorphosed phases. The Mafic Suite, composed of unmetamorphosed rocks ranging in composition from gabbro to quartz diorite, constitutes only a minor part of the English River Subprovince and will not be described further. The Mafic Suite was probably emplaced between the generation of the sodic and potassic suites.

SODIC SUITE

Phases within the Sodic Suite are dominantly trondhjemite to granodiorite in composition, but locally significant potassic (quartz monzonitic) phases such as at Oak Lake are apparent. In relation to the Gneissic Granitoid Suite, the Sodic Suite is compositionally more uniform, less complex, and, is relatively nonmigmatized 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, alignment of clots of randomly oriented mafic minerals, elongation of quartz, and diffuse linear patches of feldspar. In places, the latter may represent weakly deformed, recrystallized, relict porphyritic phenocrysts. Some phases may be syn-tectonic in that they lack foliation, but are recrystallized to a granular mosaic of predominantly quartz and feldspar with minor associated biotite. Rocks within the Sodic Suite are typically white to grey on both the weathered and fresh surfaces. Plagioclase + quartz + biotite ± hornblende ± microcline constitute the essential mineralogy. Colour index ranges from less than 1 up to 20, but commonly lies between 6 and 12. Hornblende is generally associated with the more mafic end, colour index 15 to 20, members of this range. Textures are mostly hypidiomorphic to allotriomorphic and medium-grained varieties are most common.

The Sodic Suite of rocks generally form large batholiths in the Southern Plutonic Domain, the two most notable being located as follows:

1) Immediately south of the northern domain, west of Highway 105 extending from Oak Lake to Umfreville Lake.
2) Between Chamberlain Narrows (eastern Lac Seul) and Whitewater Lake constituting almost the entire eastern part of the southern domain.

These two batholithic regions each occupy approximately 1550 to 2070 km^2. Between the two batholiths (between Highway 105 and Sioux Lookout) rocks of the Sodic Suite occur, but are highly segmented and disrupted by phases of the later Potassic Plutonic Suite. The two main batholithic zones strike approximately parallel to the trend of the southern domain; although there are local discordances, internal foliation generally conforms to these trends. The batholiths are composed of numerous phases, but only the most evident have been distinguished at the reconnaissance scale of mapping. More subtle phases will become apparent with follow-up detailed examination. Due partly to the reconnaissance nature of the programme, lack of critical exposures of cross-cutting relationships, and the widely separated nature of the phases, relative age relationships between the 17 individual units recognized thus far within the Sodic Suite are not known. The batholith extending from Oak Lake to Umfreville Lake is regionally divisible into two main phases: a northern zone consisting of metamorphosed porphyritic (potassic-feldspar) biotite granodiorite and a southern zone composed of metamorphosed, foliated biotite to hornblende-biotite trondhjemite. Foliated biotite trondhjemite with a colour index of 6 to 12 is the most widespread phase within the Sodic Suite; commonly present as inclusions in other phases of the Sodic Suite it may be one of the earliest formed phases.

The Sodic Suite also forms discrete intrusives ranging in size from stocks to batholiths. These bodies are most evident in the Northern Domain, but are also present within the Gneissic Granitoid Suite and within the main batholiths composed of similar sodic members. The Gneissic Granitoid Suite, deflected to envelop these intrusives, is commonly more structurally complex as observed in the Jaffray-Melick area, north of Kenora (Gower 1975) and in the Daniels Lake area north of the Tustin-Bridges area. Individual plutons of the Sodic Suite exhibit similar chemical trends (*Figure 10*, plot 4) to the batholithic regions (*Figure 10*, plot 2) although, as in the case of the Daniels Lake Pluton; the former commonly have lower colour indexes.

Intrusion of apophyses, dikes, and sills into the host rocks surrounding the batholiths and individual plutons of the Sodic Suite are exceedingly rare. The authors feel that much of this suite has been passively intruded in part by stoping and piecemeal assimilation.

Within the batholithic regions, the Sodic Suite is observed to contain sharply defined to diffuse inclusions of the gneissic suite. More commonly, the Sodic Suite is observed to grade imperceptibly into the Gneissic Granitoid Suite. This along with the fact that the Sodic Suite appears to be compositionally more variable than the other two suites (*Figure 10*, plots 1, 2, and 3; *Figure 11*), and that the degree of recrystallization varies substantially throughout, suggest this suite has evolved over a relatively long period of intrusion.

POTASSIC PLUTONIC SUITE

The Potassic Plutonic Suite is the youngest of the suites and culminated Early Precambrian (Archean) igneous activity in the English River Subprovince. The earliest phases within the suite are represented by the Lount Lake Batholith which is predominantly porphyritic (microcline feldspar) granodiorite in composition. The latest members of this suite, by far the most prominant and widespread in the Southern Plutonic Domain, are dominantly quartz monzonite to locally granite *sensu stricto* and have a fairly restricted composition field (*Figure 10*, plot 1).

Members of the Potassic Plutonic Suite are typically uniform in composition over vast areas; they are massive, nonrecrystallized, and are generally pink on both the weathered and fresh surfaces. Locally, grey to white members are present and can be deceiving. Their overall massive texture dictates that almost all flowage had ceased prior to crystallization. Unlike the Sodic Suite, this suite characteristically has apophyses branching out into the country rocks in the form of dikes and sills which have been controlled by pre-existing structural weaknesses. The volume of these potassic injections decreases proportionately away from the major potassic batholithic centres. Generally, the Potassic Plutonic Suite was highly mobile forming extensive dike-like swarms within the attendant Sodic and Gneissic Plutonic Suites, locally with associated metasomatic fronts. Grain size is more variable than in the Sodic Suite and ranges from medium-grain size to pegmatitic grain size. Pegmatite phases occur both as distending, sharply defined tentacles and as diffuse, consanguineous pods that developed *in situ*. Textures are mainly idiomorphic to hypidiomorphic. Overall, the style of intrusion is forceful, commonly the host rocks are warped around the intrusions. Mineralogically the intrusions are composed of a simple assemblage of plagioclase + potassic-feldspar + quartz + biotite. Colour index of the Potassic Plutonic Suite is generally less than 8 percent and tends to be lower than that of the Sodic Suite. Biotite is the dominant mafic component within the Potassic Plutonic Suite; the development of hornblende is rare to absent.

Emplacement of the Potassic Plutonic Suite ranges from extremely thin, highly mobile tongues up to stocks, plutons, and batholiths of huge dimensions. West of Highway 105, two major batholiths linked by potassic apophyses dominate the Southern Plutonic Domain. These two batholiths, the Tetu Lake Batholith and the Lount Lake Batholith are linked by narrow potassic apophyses, and together form an elongate potassic mass not less than 2600 km^2 in area. The trend of this potassic batholithic zone is west, parallel to the trend of the Southern Plutonic Domain. The Tetu Lake Batholith situated between Umfreville Lake and Kenora occupies 526 km^2 and is dominantly massive quartz monzonite. Its contacts, gradational over several kilometres is marked by a gradual depletion and interdigitation of the potassic phase at the expense of sodic or gneissic phases and are subjectively made on the basis of what is the dominant component. Subtle changes in texture and colour index imply that the batholith is a composite of numerous, roughly penecontemporaneous phases. The Lount Lake Batholith, covering 2058 km^2, is one of the largest discrete batholiths within the English River Subprovince; its west trend to the west is grossly eliptical, being approximately 120 km in length and averages 24 km in width. Approximately 80 percent of this batholith is composed of massive porphyritic (potassic-feldspar) granodiorite and is remarkably uniform in composition. The contacts are sharply defined and are not characterized by apophysis-like dikes. The phenocrysts of microcline average 2.0 to 2.5 cm in length, are randomly oriented situated in a medium- to coarse-grained, nonrecrystallized, trondhjemitic matrix. Fluctuations in the granodiorite composition are thus based totally on the percentage of megacrysts of potassic feldspar. Near the centre of the batholith, several sills of porphyritic (potassic-feldspar) quartz monzonite characterized by primary flow-aligned megaphenocrysts of potassium feldspar are present. The sills are approximately 16 to 19 km in length and average 1.6 to 3.2 km in breadth. The porphyritic granodiorite phase is believed to be the earliest formed phase within the Potassic Plutonic Suite, while the porphyritic quartz-monzonite sill is believed to be a later, genetically related, intrusive phase. Flowage alignment of the phenocrysts has been imposed by confinement of the sill to a narrow conduit that may actually represent the original feeder zone to the batholith. Subsequent sills of equal stature trending in approximately the same east-northeast trend as the porphyritic quartz monzonite sills, are composed of massive quartz monzonite and are typical of the latest potassic phase observed as dikes or sills throughout the Southern Plutonic Domain. *Figure 10* indicates the compositional fields of the early and late phases of the Lount Lake Batholith.

Many of the smaller apophyses associated with the Potassic Plutonic Suite are observed to be tectonically controlled along pre-existing planes of weaknesses including fractures, and lithologic boundaries within the Gneissic Granitoid Suite. From this it might be inferred that the batholiths themselves are tectonically controlled and that all evidence of this control has since been masked or effaced by the intrusive event, a situation similar to that recognized by Brindley (1973) in the Pyrenees. The fact that the latest sills of massive quartz monzonite within the Lount Lake Batholith are all trending east-northeast suggests some sort of tectonic control such as a late fracture pattern within the batholith itself. The origin of such volumes of potassic magma possessing such a uniform composition might best be explained by the tapping of a magma source at great depth and it being intruded along some pre-existing plane of weakness. The restricted compositional field suggests emplacement over a short interval of time. Achievement of the present configuration of the potassic batholithic regions is thus envisaged as intrusion, possibly facilitated along previous zones of structural weakness that with continued potassic addition formed by a process of dilation causing distension, displacement, and substantial reduction in the volume of the surrounding host rocks. The reason for the locus of such voluminous potassic magma within the western part of the Southern Plutonic Domain is not known.

Near the east margin of this potassic batholith in the Cedar Lake-Cliff Lake areas, the earlier formed gneissic and sodic suites have been severely disrupted by the later potassic phases. In the Cedar Lake area Westerman (1978) reported a structurally anomalous situation in which metasedimentary migmatitic assemblages, analogous to those in the Northern Domain, are structurally overlain by superincumbent highly deformed phases of the Gneissic Granitoid Suite. These two lithologic groups form dome-like structures. The Gneissic Granitoid Suite, by virtue of its greater deformational complexity, is regarded as older than the metasediments. Westerman (1978) 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 such sheets is syntectonic associated with dilation processes. The authors have observed protomylonitic textures in the granitoid gneisses at the periphery of these domes adding some support to this hypothesis.

Clotty Quartz Monzonite

Along the northern margin of the Southern Plutonic Domain adjacent to the metasedimentary migmatites of the Northern Domain are numerous stocks and/or sills of typical quartz monzonite to granite *sensu stricto* that contain clots characterized by assemblages of quartz + biotite + cordierite ± garnet ± sillimanite. Most of the known occurrences are characterized by assemblages of the quartz, biotite, and garnet. Cordierite and sillimanite occur within a clotty quartz monzonite phase at Perrault Falls (Morin and Turnock 1975). Generally, the clots at any given exposure are uniform in size precluding any notion that they are simply stoped inclusions. Morin and Turnock (1975) proposed an anatectic origin in which the clots represent broken up, relict, sedimentary layers that resisted complete melting. Although Morin and Turnock (1975) concluded that the true magma parentage remained equivocal (alumina rich sediment vs. igneous) it seems plausible that the clots represent remnants of partly melted inclusions stoped at depth during intrusion of the potassic phases localized along the southern contact of the Northern Supracrustal Domain.

RELATIVE AGES OF THE THREE SUITES

The Gneissic Granitoid Suite forms inclusions within phases of the sodic suite and is also intruded by phases of both the Sodic and Potassic Plutonic Suites. The above relationships and the complex history of deformation indicated by the Gneissic Granitoid Suite imply that they are the oldest suite in the map-area. Based in part on cross-cutting relationships, the Gneissic Granitoid Suite is succeeded in turn by phases of the Sodic, Mafic, and Potassic suites. Age dating of phases within the English River Subprovince by Krogh *et al.* (1976) have partly established the ages of the sodic and potassic suites as follows:

A metamorphosed, foliated hornblende-biotite trondhjemite phase that is part of the Sodic Suite was emplaced at least 3.008 B.Y. ago and is probably more than 3.04 B.Y. old. A member of the Potassic Plutonic Suite has yielded a date of 2.652 B.Y. which overlaps the date of anatexis of the metasediments. The youngest rock, dated at 2560 ± 40 M.Y. was a late, sharply defined, cross-cutting pegmatite dike.

CHEMICAL VARIATIONS

Chemical analyses *(Figures 10, 11 and 12)* of phases from the three major suites in the Southern Plutonic Domain indicate a progressive potassium enrichment and accompanying decrease in iron, magnesium, and calcium contents. Individual plutonic suites as exemplified by the Lount Lake Batholith *(Figure 10)* also exhibit similar potassium enrichment trends. Similar increases in potassium within and across magmatic cycles have been exhibited in various settings (Hietanen 1975) and is beginning to be accepted as a common evolutionary pattern.

Contact Relations of Northern and Southern Domains

At Separation Lake, the contact between the two domains is marked by a predominantly metavolcanic supracrustal sequence. East of this 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 metres to hundreds of metres. These units may be traced discontinuously eastward for a distance of approximately 176 km to the east end of Lac Seul. The supracrustal affiliation of these amphibolite remnants is indisputable due to preservation of primary structures and associated supracrustal facies rocks including the following: lapilli-tuff at Helder Lake; conglomerate at Perrault Lake; iron formation at Trail Lake, and between Tuktegweik Bay and Chamberlain Narrows in the eastern part of Lac Seul; and pillowed remnants at Wabaskang Lake and Lac Seul Settlement. Undoubtedly this belt was once continuous, but has since been extensively segmented by later intrusive phases. Only at about five localities have the supracrustal remnants remained at the contact between the two domains, while at all the

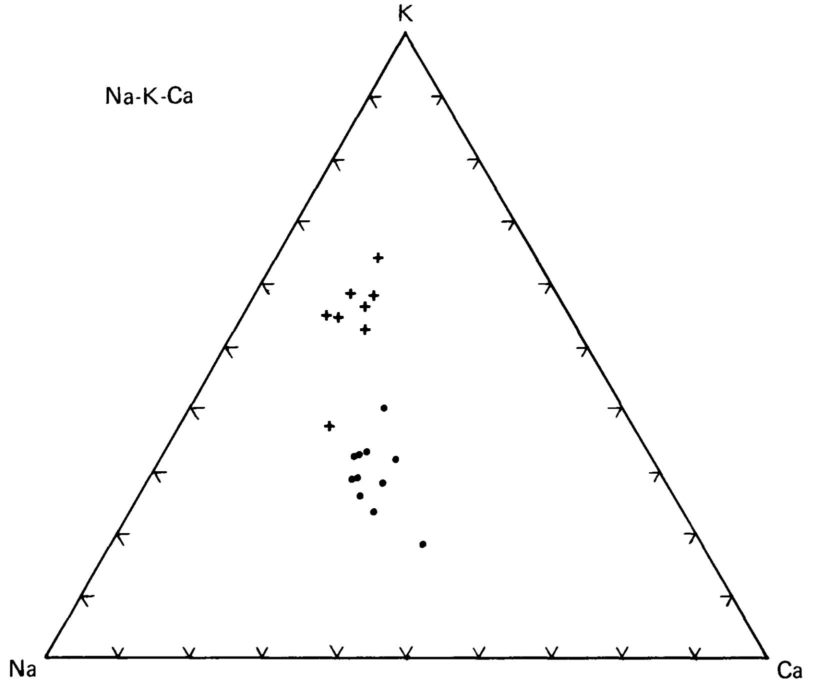


Figure 11. K-Na-Ca plot showing the increase in potassium content of the later phases (crosses) from the earlier phases (dot) within the Lount Lake Batholith.

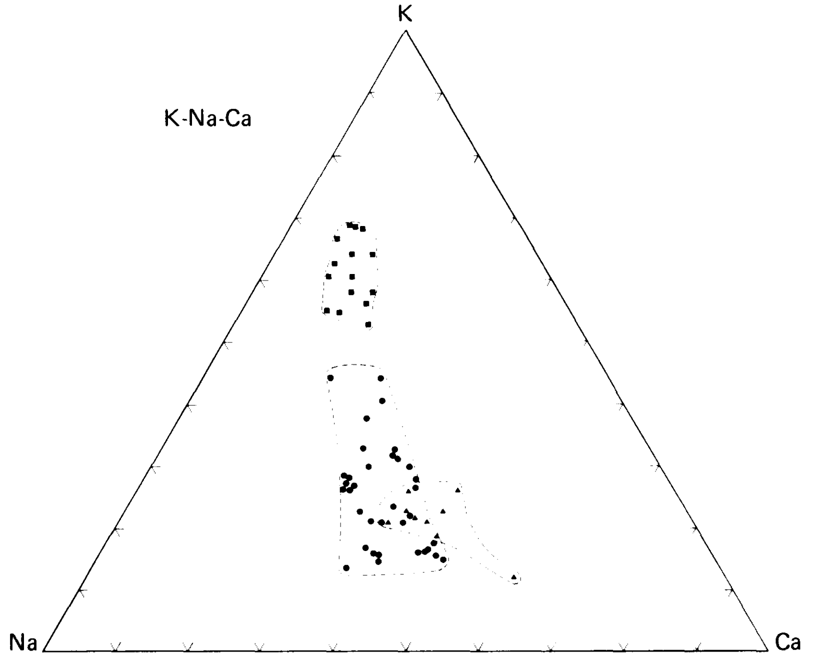


Figure 12. K-Na-Ca plot (weight percent) showing chemical variation of (dot) Potassic, (open circle) Trondhjemitic and (phi) Gneissic Suites from the Southern Plutonic Domain of the English River Subprovince.

other localities these remnants have been transposed by intrusive rocks. Therefore, although the contact is locally marked by the remnants of the extension of the Separation Lake Belt, it is predominantly intrusive in nature, and is marked by the presence of metasedimentary migmatites of the northern domain.

STRUCTURAL GEOLOGY

Late Archean Faulting

Several major Late Archean fault systems overprint various areas of the English River Subprovince *(Figure 13)* in addition to the Superior Province as a whole. The presence of several such fault zones was initially suspected by Parkinson (1962) based upon aerial photographic interpretation. These deformation systems represent the final significant structural event in the Early Precambrian (Archean) and have apparently been created by late displacement of large rigid blocks.

Differential displacement between these blocks appears to have been dissipated by mylonitic flow concentrated in the linear deformation zones. Generally, the fault systems are superimposed upon major geological boundaries and tend to follow regional trends of the country rocks.

The geological time interval occupied by the faulting is presently unknown. However, an Early Precambrian age possibly extending into Middle Precambrian time seems probable. This faulting has a possible maximum age of 2.65 B.Y. (Krogh *et al.* 1976) because the youngest members of the potassic granitoid intrusive suite are deformed by these fault zones.

One of the most notable of these deformation systems in the study area is the Sydney Lake Fault System, currently the subject of Ph.D. Thesis research by Denver Stone at the University of Toronto. Much of this section is largely based on earlier publications of Denver Stone (1976, 1977).

GEOLOGICAL SETTING OF THE SYDNEY LAKE FAULT SYSTEM

The Sydney Lake Fault is an arcuate fault system continuously traceable eastward for approximately 190 km from Lake Winnipeg to the east of Pakwash Lake.

The most intensely developed part of the fault in Ontario lies between the Manitoba-Ontario border and Sydney Lake. Geological mapping by McRitchie and Weber (1971) indicates that the fault splays to the west within Manitoba. A similar relationship has been documented at the eastern section of the fault system by the present study.

East of Pakwash Lake, the fault system becomes increasingly dicontinuous and is interpreted to eventually extend northeast into the Confederation-Uchi Lakes Metavolcanic-Metasedimentary Belt as the Uchi Lake Fault (Thurston 1976).

Between Pakwash Lake and the interprovincial boundary the fault represents an abrupt lithological discontinuity between low to medium grade metavolcanics (Bee Lake and Dixie Lake Belts) of the Uchi Subprovince and felsic granitoid plutonic rocks and metasediments of the English River Subprovince.

Description of the Fault Zone

The fault is generally marked by a 1 to 2 km wide zone containing protomylonitic and mylonitic equivalents of migmatized metasediments, felsic plutonic, and metavolcanic lithologies. Pseudotachylite is intermittently notable as at Sydney and Confusion Lakes.

Lithological units such as the Pineneedle Lake Pluton and Bee Lake metavolcanics can be traced into the fault zone, and the offset of these indicates right-handed strike separation. A ubiquity of asymmetrical Z-type drag folds within the fault zone, as opposed to S-shaped folds, additionally supports this sense of movement. Based upon observed slickenside attitudes *(Figure 14)* the direction of 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. Characteristically, the pseudotachylite is always located along the youngest shears. The displacement direction on all these features is statistically horizontal. 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 is most severe along the contact between English River Subprovince migmatized metasediments and metavolcanics 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 Denver Stone in *Figure 15*, can be traced into the fault zone. At the fault, these units are buckled slightly then abruptly caught, folded

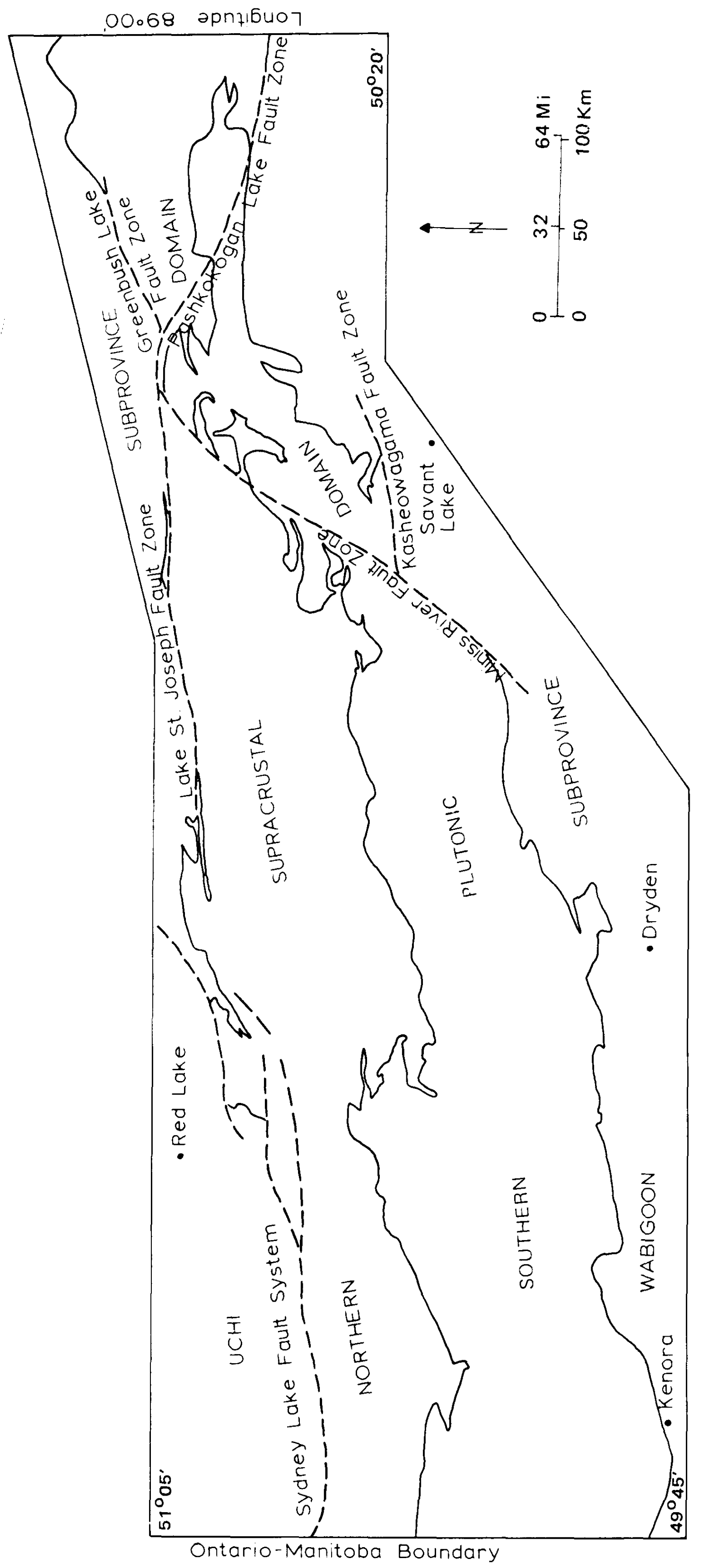
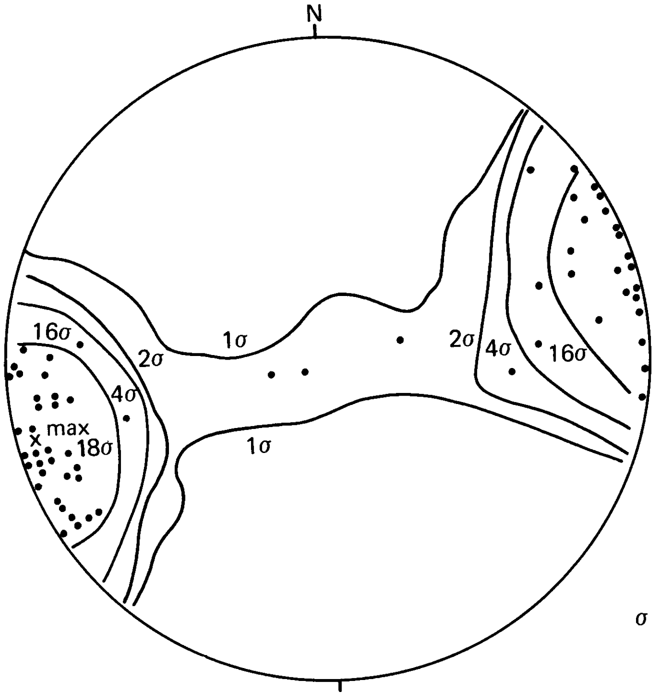


Figure 13. Distribution of major fault systems in the English River Subprovince and adjoining segments of Uchi and Wabigoon Subprovinces.



σ is standard deviation

Figure 14. Contoured equal area plot of slickensides within the fault between Sydney Lake and Chase Lake.

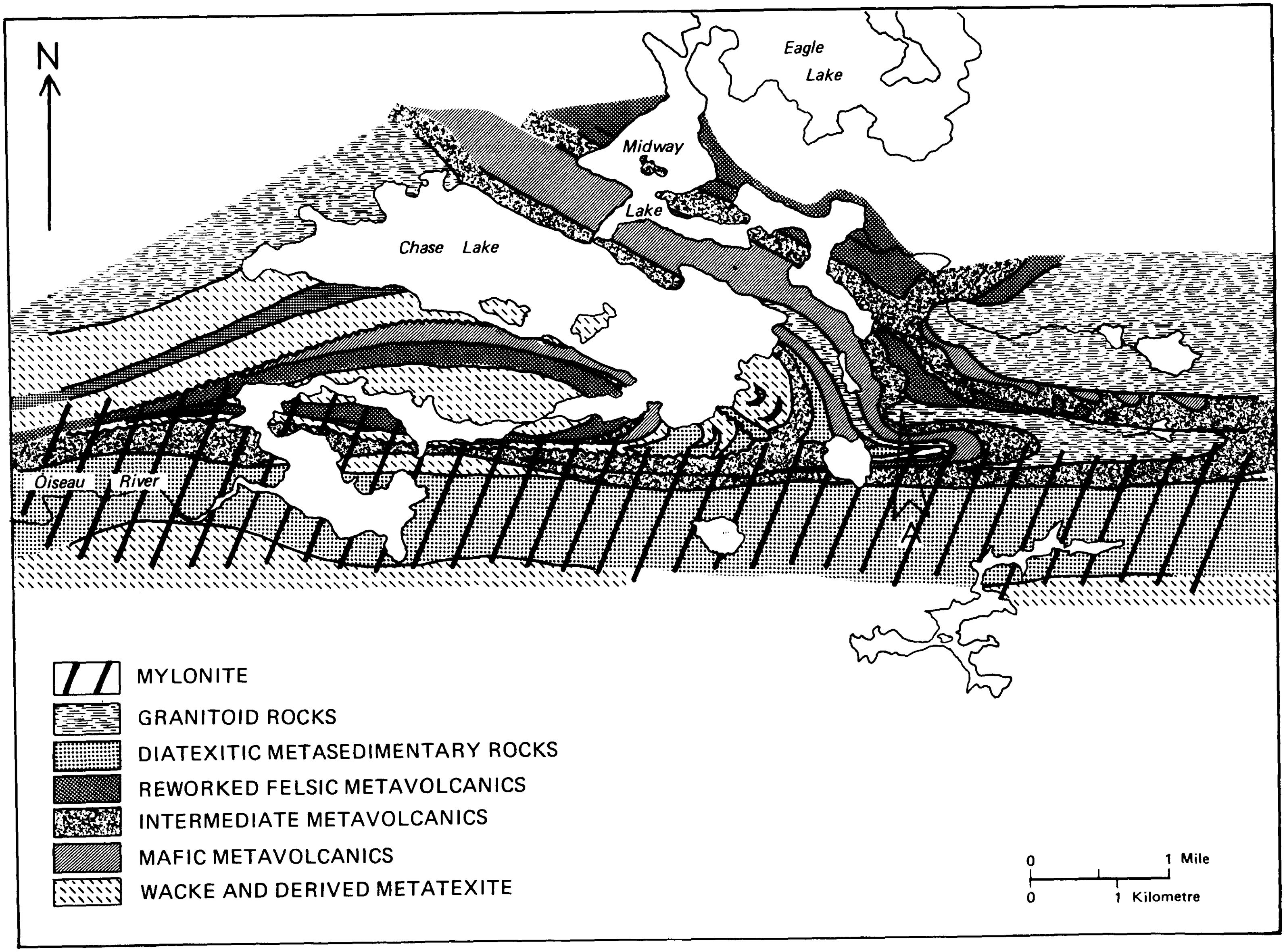


Figure 15. Geology of the Chase Lake Area. Mapping by Denver Stone 1976.

back and attenuated by the fault. The extreme western extent of these metavolcanic units within the fault zone is not known. A unit of amphibolitized mafic metavolcanics has been recognized with the fault zone 6 km west of where this lithology initially entered the zone. Assuming that the metavolcanic units originally extended to the southeast of point A in *Figure 15* and that displacement is due to simple shear, then it follows that faulting produced a minimum right lateral displacement of 6 km.

Origin of the Faulting

Displacement on 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 in the Quetico Fault. Similarly, right lateral displacement has been recently validated 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. Denver Stone (1976, 1977) examined three possible models of fault formation applied to the Sydney Lake Cataclastic Zone and contended that the fault zone formed first in the central region under the influence of the regional stress. It then propogated, splayed, and curved under the influence of the regional stress, the local secondary stresses, and the anisotropy of the rock.

Shearing and Flattening on the Fault Zone

The fault zone is not only an area of shearing, but also involves flattening across it. Relative components of shearing and flattening vary for different parts of the fault. Several field features indicate that the main part of the fault zone has a high component of shearing relative to flattening. Lithological 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 is a prime feature suggesting rotation.

Deformation within the northeasterly trending splays of the fault zone is markedly different. Folds within the mylonite are predominantly "M" type with no consistent asymmetry. Lithological contacts are frequently observed to trend at high angles to 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 flattened northeasterly segments of the fault system and the dominantly sheared main part suggest a regional compression from the northwest.

An estimate of the amount of shearing was made by Denver Stone (1977) from the reorientation of linear elements within the fault zone.

Other Fault Systems

The Miniss River Fault, named by Hudec (1965) constitutes another important fault system within the English River Subprovince. In contrast to the Sydney Lake and Lake St. Joseph Fault Zones, this particular fault trends northeasterly across the entire breadth of the English River Subprovince, transecting the northern and southern domains. Pronounced convergence of the northern domain is strikingly apparent in the Miniss Lake-Medcalf Lake area which probably relates to 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 pegmatoid boudins, feldspar megacrysts, and by right-hand offset of mafic inclusions by late minor faults. The strike slip component of displacement is estimated at 10 km, assuming that a biotite-hornblende trondhjemite to quartz diorite unit on the northwest fault side in the Miniss Lake area is correlative with a diorite unit on the southeast. As indicated in *Figure 13,* the Miniss River Fault Zone represents partly the boundary between the northern and southern domains. Lithologies occurring to the southeast of this 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 material.

Metatexites exhibiting relatively low degrees of partial melting occur along the northwestern side of the fault zone. These rocks lie in juxtaposition with 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 can be trigonometrically 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 advanced stage metasedimentary migmatites and the sporadic appearance of enderbitic charnockites both testifying to an increase in metamorphic grade.

METAMORPHISM IN THE ENGLISH RIVER SUBPROVINCE

Metamorphic and deformational histories of the Uchi Subprovince and the English River Subprovince are quite similar, involving a maximum of five metamorphic events *(Table 5)*. This interpretation is similar to that derived by McRitchie and Weber (1971) for the Manigotagan gneisses, and has been verified in detail in both the Uchi and English River Subprovinces (Thurston In Press; Thurston and Breaks In Press). The generalized distribution of metamorphic zones within the English River and adjoining Uchi Subprovinces as well as parts of the Wabigoon, Cross Lake, and Berens River Subprovinces are outlined in *Figure 16*. The metamorphic zones are based upon the classification of Winkler (1976).

The earliest metamorphism, M_1, resulted in the formation of porphyroblasts of staurolite, andalusite, biotite, and almandine garnet. These porphyroblasts with inclusion trains of biotite, quartz, and feldspar have been rotated by D2 deformation. Metamorphic event M_2 resulted in the coarsening of the matrix, particularly of the metasediments, and the growth of biotite and muscovite grains parallel to the axial plane of the D2 folds. Metamorphic event M_3 was largely retrograde in effect with the pinitization of cordierite and sericitization of andalusite, and alteration of amphiboles to chlorite. Metamorphic event M_4 is largely a local event associated with the generation of major faults such as the Sydney Lake Fault, separating the Uchi Subprovince and English River Subprovince and various major strike slip faults in the metavolcanic terrain. The main features of this event as observed immediately adjacent to the faults are recrystallization of muscovite and chlorite, and the formation of hematite, carbonate, epidote, and minor pyrite and the retrograde replacement of M_2 textures.

Transcurrent faults such as the Bear Lake Fault are later than the faults (Sydney Lake), and late recrystallization associated with these faults may mark a fifth metamorphic event, M_5 (Thurston In Press).

Northern Supracrustal Domain

Several workers have documented a progressive increase in metamorphic grade traversing from the metavolcanic-metasedimentary successions of Uchi Subprovince southwards into the metasedimentary domain of the English River Subprovince (McRitchie and Weber 1971; Jones 1973; Dwibedi 1966). The progressive regional metamorphic patterns are usually seriously interrupted by extensive post-metamorphic fault systems that appear to have been guided by the stratigraphic interface between the two subprovinces. For example, the Sydney Lake Fault System, currently under investigation by Denver Stone (1977) records an abrupt "jump" from medium grade, low pressure assemblages into conditions of widespread migmatization in rocks of the appropriate bulk composition. Similarly, at Pashkokogan Lake, some 320 km east of Sydney Lake, on the Miniss River-Pashkokogan Lake Fault System, an even greater sudden increase in metamorphic grade, is marked by the occurrence of low grade mafic metavolcanics in abrupt contact with metatexitic metasedimentary migmatite. Intact progressive metamorphic zonations are apparent in certain localities as in the Lake St. Joseph-Papaonga Lake area *(Figure 17)*. Combined with the earlier work, this indicates that the southerly increasing metamorphic grade from the Uchi Subprovince into the English River Subprovince constitutes a widespread phenomenon, involving at least 320 km of the subprovince interface.

Five major metamorphic zones have been delineated in the Lake St. Joseph area mainly based upon assemblages recorded in pelitic and wacke compositions and are as follows:

LOW GRADE
  (1) Chlorite-Biotite Zone
MEDIUM GRADE
  (2) Staurolite-Chlorite-Biotite Zone
  (3) Sillimanite-Muscovite Zone
HIGH GRADE
  (4) Sillimanite-Potassic Feldspar Zone
  (5) Cordierite-Almandine-Potassic Feldspar Zone

A plausible reaction for the formation of M_{1A} staurolites 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. Chloritoid does not appear to be a significant phase in the chlorite-biotite zone. 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, almandine, 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

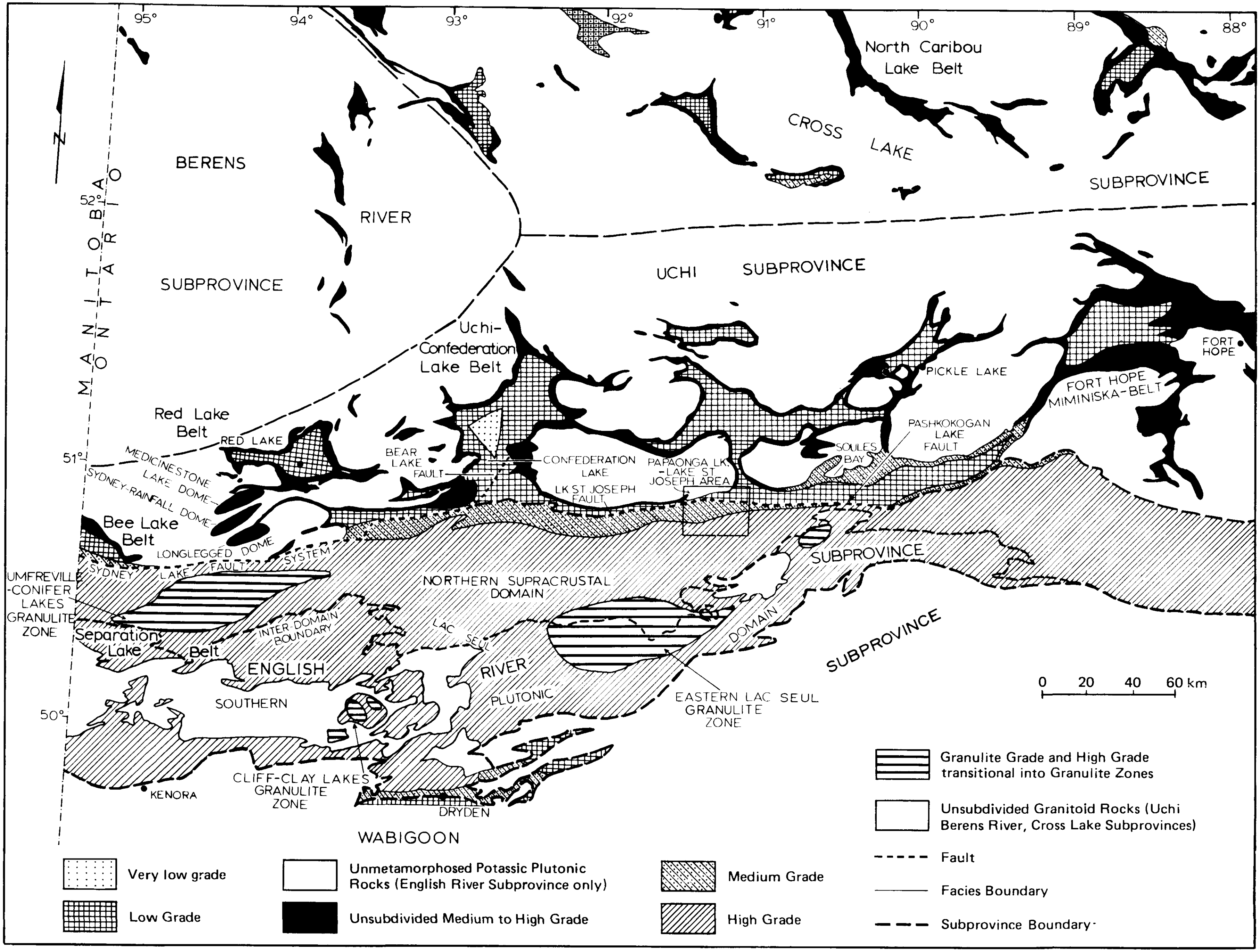


Figure 16 - Generalized distribution of metamorphic zones within the English River Uchi and parts of the Berens River and Cross Lake Subprovinces in Northwestern Ontario (from Thurston and Breaks In Press).

TABLE 5 METAMORPHIC AND DEFORMATIONAL EVENTS IN THE UCHI AND ENGLISH RIVER SUBPROVINCE (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 L. 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, rotation 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		Retrograde muscovite and chlorite in shear zones of D_4.
D_5		S_5	Late transcurrent faulting, Beur L. fault.
	M_5		Minor recrystallization assoc. with D_5.

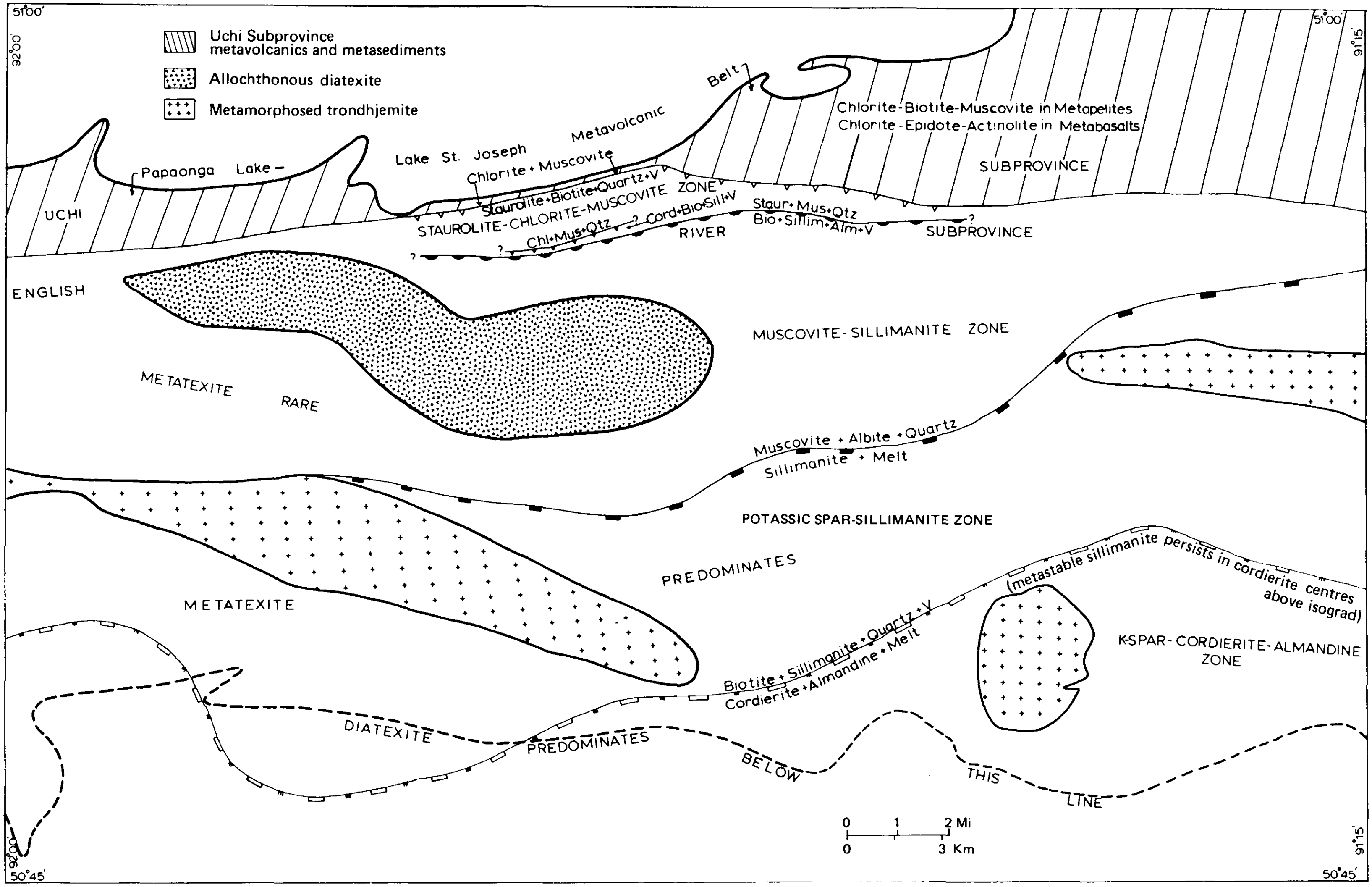


Figure 17. Distribution of metamorphic zones, isograds, and metasedimentary migmatite stages at Uchi Subprovince-English River Subprovince interface, Lake St. Joseph area.

involvement of staurolite in cordierite paragenesis is unclear. It is also uncertain whether M_{1A} staurolites developed under PRESSURE-TEMPERATURE 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 1976). 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 high level cataclastic deformation crosses the staurolite zone (Lake St. Joseph Fault Zone). This zone of brittle failure post dates regional metamorphism and the youngest Early Precambrian (Archean) granitoid phases (leucocratic quartz monzonite), although no significant change in metamorphic grade is apparent across the fault. The main effect of this fault was to facilite H_2O 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 much of the pelitic component is evident in the high grade zone related to anatexis and pervasive matrix coarsening.

Mineral assemblages corresponding to each of the zones as listed in *Table 6*, appears explicable in terms of experimentally and/or petrographically validated metamorphic reactions from the literature. The observed increase in grade also corroborates well 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 PRESSURE-TEMPERATURE conditions were inadequate to foster partial melting of compositionally appropriate lithologies. Thus, sedimentary bedding structures and framework grains in wackes generally show some degree of preservation. Layers, boudins, and rootless intrafolial folds of hydrothermal mobilizate (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 PRESSURE-TEMPERATURE conditions conducive to widespread development of *in situ* anatectic melts (metatexis). The metatexitic stage of migmatization generally corresponds to the Sillimanite-Potassic Feldspar Zone. Stromatically disposed leucosomes of granitoid to pegmatoid material are predominant. Dikes and discordant masses of tourmaline-muscovite mobilizate 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 17*.

Near the cordierite-almandine-potassic-feldspar isograd, the metatexite zone imperceptibly yields to higher grade conditions promoting an advanced stage at fusion (diatexis). The reaction, **Biotite + Sillimanite + Quartz + Vapour → Cordierite + Almandine + Melt** (Grant 1973) appears to 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 + Potassic Feldspar + Cordierite + Almandine** is widely evident in surviving metapelitic horizons. In the main, the part of the metapelitic paleosome decreases rapidly southwards from the second sillimanite isograd. A large proportion of this material has undergone wholesale conversion to leucosome and melanosome components.

Southern Plutonic Domain

The accounted variation and intensity of regional metamorphic grade attained within the Southern Plutonic Domain of the English River Subprovince is considerably more enigmatic mainly related to two factors:

(1) A prevailing dearth of bulk compositions necessary to record meaningful 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.

Amphibolitic inclusions such as those within the Deception Bay Gneiss Belt north of Sioux Lookout (Breaks and Bond 1977) are widespread. 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 are recorded in these rocks. It does appear that TOTAL PRESSURE was insufficient to stabilize almandine-producing reactions in most of these appropriate mafic compositions, in contradistinction to the omnipresence of this mineral in the Northern Supracrustal Domain.

Load pressures of at least 4 kilobars 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 (1976, p.215). Temperatures and vapour pressures appear substantial enough to foster localized 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 amphibolitic paleosome. This leucosome megascopically resembles the widespread mobilizate material prevalent in meta-

TABLE 6 METAMORPHIC MINERAL ASSEMBLAGES FROM LAKE ST. JOSEPH AND EASTERN LAC SEUL AREAS.

Zone	Assemblage	Rock Type
	LOW GRADE	
Chlorite-Biotite	Chl + Mu + Bio + Ep ± Gf	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

1. quartz and plagioclase common to all assemblages except those of UM bulk composition.

	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 Dykes; 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.

sedimentary migmatite of the Northern Supracrustal Domain.

LOW PRESSURE GRANULITE FACIES METAMORPHISM

Several significant 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 to date been delineated as indicated in *Figure 16* 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).

Field evidence indicates that the granulite facies overprint was engendered during the Kenoran tectonic-metamorphic episode. The individual zones vary in scale from singular occurrences to rather extensive, ovoidally disposed areas; the latter are exemplified by the Eastern Lac Seul Zone, which measures about 85 km in strike length and 30 km in breadth. 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 the presence of a further orthopyroxene zone of unspecified dimensions.

Several field and mineralogical features of the English River Subprovince granulites indicate that these assemblages originated under PRESSURE-TEMPERATURE conditions pertaining to the low pressure subdivision of Green and Ringwood (1967) and are listed as follows:[1]

1) Lithological domination by felsic rocks; intermediate and mafic bulk composition are present in low proportion.
2) Presence of cordierite, biotite, and almandine garnet.
3) Orthopyroxene is relatively restricted in distribution being mainly confined to mafic and intermediate rocks and only rarely developed in felsic composition.
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 numbers or rocks of charnockitic affinities.

The coexistence of cordierite and orthopyroxene is evident, albeit rare, in certain metasedimentary layers. It is usually more common to observe cordierite + almandine + quartz + plagioclase ± potassic-feldspar assemblages interlayered with orthopyroxene- ± diopside-bearing mafic dikes. Orthopyroxene and/or diopside are much more widespread in rocks of mafic and intermediate bulk composition. Field evidence clearly documents that reactions leading to elimination of hornblende constituted an important prograde reaction in amphibolitic horizons of the Eastern Lac Seul area and are qualitatively surmised as follows:

Hornblende + Quartz → Orthopyroxene + Diopside + Plagioclase + Iron-oxide (magnetite) + Melt.

Furthermore, the development of diopside and/or orthopyroxene-bearing medium- to coarse-grained, leucocratic granitoid partial melt phases in amphibolite and intermediate granitoid bulk composition attests to physical conditions in which TOTAL PRESSURE approximates WATER VAPOUR PRESSURE. Under these conditions, Binns (1969) has indicated experimentally 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, since this mineral is extremely uncommon in lower grade equivalents due to relatively low calcium contents, usually less than 3.5 percent. 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 17)* may actually represent a spatial continuation of the interpreted path of metamorphism as outlined in *Figure 18*, and as such, is highly reminiscent of the thermal anticlinal 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

Delineation of the path of progressive regional metamorphism southwards from across the Uchi Subprovince-English River Subprovince interface *(Figure 18)* 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

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[1] also see Lambert and Heier (1968).

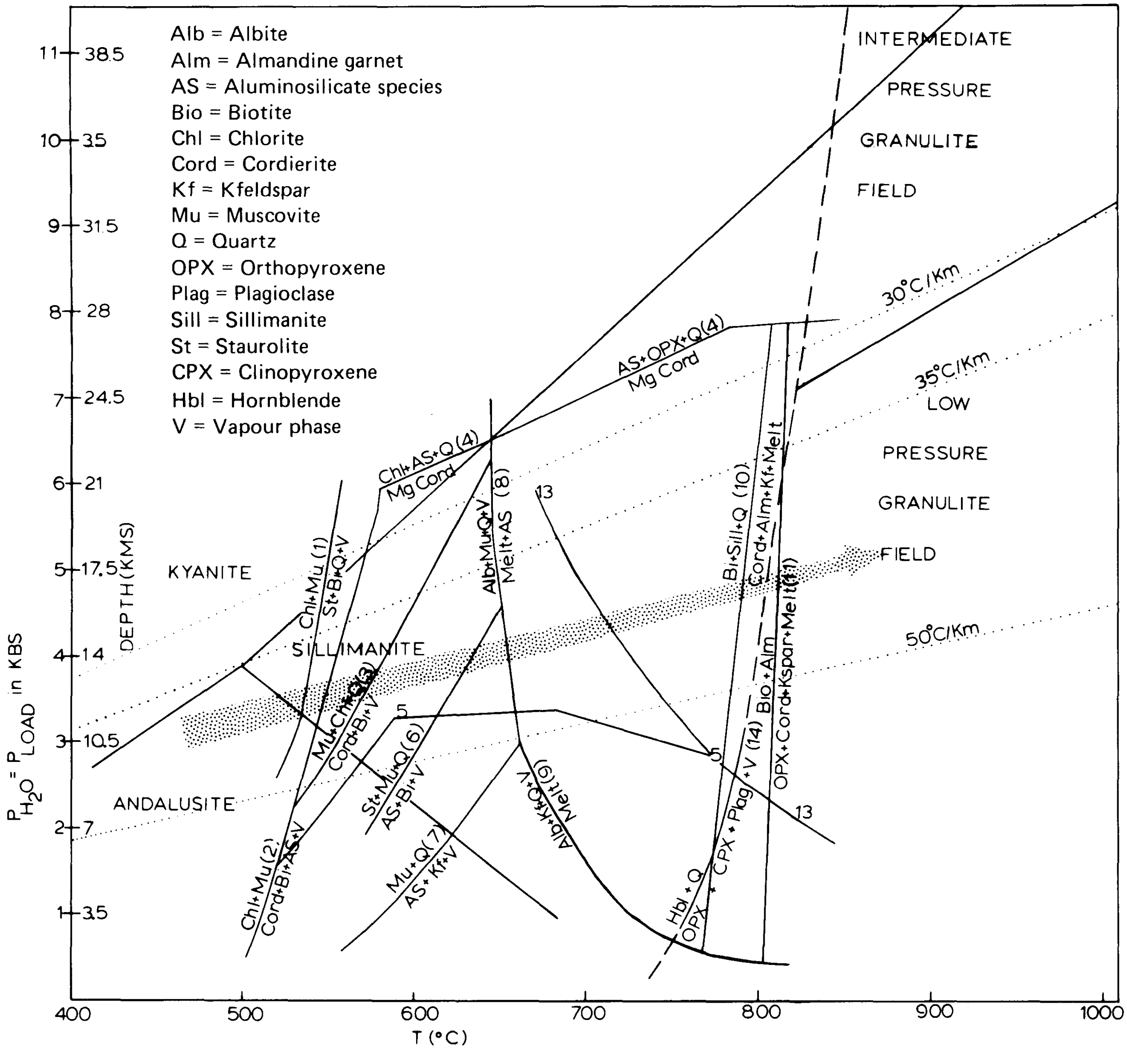

Figure 18. Inferred path of regional metamorphism from Uchi Subprovince transitional into English River Subprovince. 1=Hoschek (1969), 2=Hirschberg and Winkler (1968), 3=Schreyer and Seifert (1969), 4= upper pressure stability of magnesian cordierite after Schreyer and Seifert (1969) and Newton *et al.* (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 3K bars, 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.

temperature-high pressure phases such as sapphirine are unknown in the English River Subprovince.

(2) Cordierite is an exceedingly widespread phase in the northern supracrustal domain of the English River Subprovince especially in high grade metamorphism zones.

(3) Decomposition of staurolite does not coincide with the sudden appearance M_1A of metatexitic migmatization. The stability of staurolite, in other words, does not extend into regions where M_2 muscovite (potassic feldspar-ilmenite zone) is absent (TOTAL PRESSURE $\leqslant$ 4.5 kilobars; Winkler 1976).

(4) The disappearance of M_2 muscovite in the presence of quartz generally coincides with pervasive metatexitic migmatization of pelitic-wacke assemblages (TOTAL PRESSURE $>$ 3 kilobars).

(5) Appearance of mobilizate-dominant migmatite stages resulting from advanced stage fusion (diatexis) approximately coincides with the cordierite-almandine-potassic feldspar zone.

(6) Almandine 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 amphibolitic bulk compositions under low pressure granulite conditions indicates TOTAL PRESSURE approximates WATER VAPOUR PRESSURE and TOTAL PRESSURE then $>$ 2.5 kilobars, TEMPERATURE $>$ 770°C.

Assuming TOTAL PRESSURE = WATER VAPOUR PRESSURE estimates of PRESSURE-TEMPERATURE 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).

MINERAL EXPLORATION POSSIBILITIES IN THE ENGLISH RIVER SUBPROVINCE

Mineral exploration in the English River Subprovince has largely been desultory during the past mainly related to the assumed low mineral potential of the gneisses and the lack of a geological data base prior to the present survey. Metallogenic studies have not been completed but some important mineral associations have already been indicated (Breaks, Bond, Harris, and Westerman 1975, p.31-32). The English River Subprovince constitutes a terrain in which concentrations of elements exhibiting lithophile geochemical characteristics warrant consideration, and especially of uranium, lithium, tantalum, and caesium. On the other hand, a distinct paucity of well developed cyclical metavolcanic sequences within either the northern or southern domains *(see Table 1)* seems to minimize practical consideration of searching for massive sulfide deposits.

Uranium

Uranium mineralization within the English River Subprovince and adjoining Wabigoon Subprovince occurs in two distinct lithologic situations:

Type 1; Metasedimentary migmatite association (Northern Supracrustal Domain), and,
Type 2; Potassic granitoid intrusive suite association (Southern Plutonic Domain and the adjoining Wabigoon Subprovince).

The uraniferous occurrences presently known in the western English River Subprovince and adjoining Wabigoon Subprovince are indicated on the general geological map in the back pocket and may render this region a feasible exploration area particularly in view of anticipated increases in uranium price. Locations of these occurrences have been extracted from assessment reports, Ontario Geological Survey reports, in addition to observations of uranium staining during the present study.

TYPE 1. METASEDIMENTARY MIGMATITE ASSOCIATION

Uranium mineralization found in this environment is principally confined to the northern supracrustal domain, being generally contained within white weathering, coarse-grained to pegmatitic, inhomogeneous and homogeneous diatexite. Blue-green apatite has been noted to be a frequent accessory in these rock types. The first known occurrence to receive exploration attention is situated on Umfreville Lake (formerly Oneman Lake). Trenching and geological and magnetic surveys were carried out during 1969 by Can-Fer Mines Limited. Numerous occurrences of uranium staining have been observed during the author's field study within the Sydney Lake Fault System between Confusion Lake and the Ontario-Manitoba border. All of these occurrences are situated within an extensive narrow band of mylonitic to protomylonitic, almandine-biotite-muscovite homogeneous diatexite measuring at least 88 km in length and between 0.4 km and 2 km in breadth. The only evidence of exploration activity registered to date consists of a series of small blast 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. These pits were observed during the field survey in 1974, however, the party responsible for this activity remains unknown.

A chemical assay undertaken on a grab sample by the Geoscience Laboratories, Ontario Geological Survey registered 0.11 percent U_3O_8. X-ray powder studies identified the yellow radioactive material as Beta-Uranotil ($Ca(UO_2)_2Si_2O_7.6H_2O$). No primary mineral phase could be isolated. The radiometric 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. Interestingly, McRitchie and Weber (1971) report the presence of further such occurrences in adjacent Manitoba apparently within the same fault system.

Conceivably, prior to high grade metamorphism and anatectic conditions, uranium-bearing horizons were intermittently present within the sedimentary trough now represented by the Northern Metasedimentary Migmatite Domain. The initial mode of uranium concentration is, at present, not known. However, it would appear that either detrital concentration of uraniferous minerals and/or absorption by clay minerals constitute plausible mechanisms which controlled the primordial distribution of uranium and thorium within the clastic metasediments in the depositional basin. During anatectic degradation of wacke-pelite metasediments about 2.68 B.Y. ago this initial uranium would be released to minimum melt anatectic systems which are represented by the leucosome. Within these anatectic systems, uranium complexes would expectedly undergo concentration within the highly fractionated residual melt phase which generally exhibit pegmatitic grain sizes. Potential zones of such mineralization may be detected by reconnaissance lithogeochemical programmes, particularly if airborne radiometric response is muted due to either heavy vegetal cover or relatively poor exposure. In particular, this mineralization should theoretically be associated with anomalously low potassium:rubidium, potassium:caesium, barium:rubidium, and high lithium:magnesium ratios. This case has been established with certainty in regards to the lithium mineralization of the English River Subprovince and adjacent subprovince (see ensuing section).

Association of uraniferous mineralization with the diatexis stage of migmatization in the northern supracrustal domain represents an important observation. In particular this may possibly render a vast belt, at least 1200 km in strike-length, amenable to exploration consideration.

TYPE 2. POTASSIC GRANITOID INTRUSIVE SUITE ASSOCIATION

Several uraniferous occurrences diagnostic of this association have been investigated during the past years (Pryslak 1976; Beard 1977). Most of the known mineralization is situated in two areas:

1) Along the contact between English River and Wabigoon Subprovinces in Vermilion Bay-Willard Lake area.
2) North of Kenora between Ena Lake and Umfreville Lake.

Several salient features serve to distinguish between host rocks of Type 1 and Type 2 uranium deposits, despite a gross similarity in that both are associated with coarse-grained to pegmatitic, holo-leucocratic granitoid rocks:

1) Type 2 deposits generally do not contain metasedimentary paleosome and melanosome components.
2) Ubiquitous pink colouration characterizes host rocks of Type 2 deposits, whereas diatexitic host rocks of Type 1 deposits are pervasively white.
3) Type 2 granitoid host rocks lack the unusual accessory minerals sillimanite, cordierite, and almandine that characteristically occur in Type 1 host rocks.

Most exploration activity has focused upon the Bruin Lake-Edison Lake area between Kenora and Vermilion Bay (Pryslak 1976). Many of these occurrences appear to be geologically controlled by northern, northeastern, and northwestern contact zones of the potassic 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 1976, p.46). The uraniferous mineral phases isolated from this deposit are uraninite, uranothorite, allanite, and beta-uranotil (Robertson 1968, p.58).

Lithium-Caesium-Beryllium-Tantalum-Tin-Bearing Pegmatitic Diatexites

Another mineral association meriting some exploration attention consists of lithium, caesium, and beryllium mineralization (possibly accompanied by tantalum and/or tin) confined to highly fractionated residual diatexitic magmas. Several interesting occurrences containing lithium, caesium, and beryllium are known in the northern supracrustal domain of the English River Subprovince and contiguous segments of the Uchi and Wabigoon Subprovinces. Tantalum and tin mineralization has not been encountered in the metasedimentary migmatite environment to date, however, tantalum does occur associated with potassic granitoid rocks in the Bruin Lake-Edison Lake area (Pryslak 1976).

Lithium mineralization is presently known in two localities along the English River Subprovince-Uchi Subprovince interface, at Roadhouse River (west of Lake St. Joseph) and at East Pashkokogan Lake. Both localities contain spodumene as the principal lithium phase associated with coarse-grained to pegmatitic diatexitic masses intrusive into metavolcanics of the Uchi Subprovince. The property of Capital Lithium Mines Limited on the Roadhouse River was discovered *circa* 1955. This company undertook detailed geological mapping (1:2400 scale) and chip sampling which revealed LiO_2 values ranging from 0.43 percent to 3.06 percent over 1.5 m. The main claim group, 28 patented claims, was drilled by five diamond-drill holes totalling 794.2 m in an area about 0.4 km south of the main lithium showing. An estimated 2.3 million tons averaging 1.3 percent LiO_2 has been outlined to the 150 m level (Skinner 1969, p.8).

The second occurrence at East Pashkokogan Lake was discovered by Mr. D. Cooper *circa* 1955 (D. Cooper, personal communication, 1975) and consists of a pegmatitic diatexitic lens, 10 m by 100 m, enclosed by intermediate heterolithic tuff breccia. Grab samples from both occurrences have been analyzed for lithium and several trace constituents *(Table 7)*. Abundances of caesium, beryllium, niobium, rubidium, and tin are all anomalously high with respect to reported crustal average abundances of these elements (Taylor 1965). Exceedingly low potassium:rubidium, potassium:caesium, and barium:rubidium ratios and barium abundance reinforce the interpretation that these mineralized diatexitic masses constitute highly fractionated residual liquids.

Elsewhere, in the Dryden area of Wabigoon Subprovince several occurrences containing lithium, and beryllium and a single pollucite-spodumene showing, lie near the eastern end of a relatively extensive tourmaline-bearing homogeneous to inhomogeneous muscovite diatexite pluton situated between Vermilion Bay and Ghost Lake. Highly fractionated, mobile intrusive pegmatitic apophyses originating from this mass should be examined for further occurrences of these metals, in addition to the main mass itself.

Lithogeochemical prospecting represents the only current means of delineating these deposits, unless appreciable uranium is present. Emphasis should be placed upon absolute abundances of lithium, caesium, beryllium, niobium, tantalum, tin, and uranium and lithium:magnesium, potassium:rubidium and potassium: caesium ratios as a means to locate zones containing highly fractionated diatexitic phases. Exploration should initially focus on the "interface" zone where low- to medium-grade supracrustal assemblages are in contact with migmatized metasediments. Two areas are accordingly recommended:

1) Western Lake St. Joseph-Papaonga Lake area, and,
2) Mavis Lake-Tot Lake area, northeast of Dryden.

TABLE 7 TRACE ELEMENT ANALYSES AND SELECTED ELEMENT RATIOS OF LITHIUM-BEARING DIATEXITES FROM ENGLISH RIVER SUBPROVINCE-UCHI SUBPROVINCE INTERFACE AREA.

	In Percent	In Parts Per Million (ppm)							Ratios		
Sample Number	Li	Ba^A	Cs^X	Be^S	Nb^S	Ta^S	Rb^A	Sn^S	K/Rb	K/Cs	Ba/Rb
Roadhouse River No.1	0.7	20	100	150	60	$<$1000	510	20	12	60	0.04
Roadhouse River No.2	0.86	40	130	175	80	$<$1000	620	20	11	51	0.06
Roadhouse River No.3	1.0	40	70	125	200	$<$1000	990	28	9	126	0.04
East Pashkokogan Lake	1.3	60	120	30	45	$<$1000	540	55	29	132	0.11

Analyses by Geoscience Laboratories, Ontario Geological Survey. Results reported in ppm unless otherwise indicated.

A = Atomic Absorption Spectrophotometry S = Emission Spectroscopy X = X-ray Fluorescence

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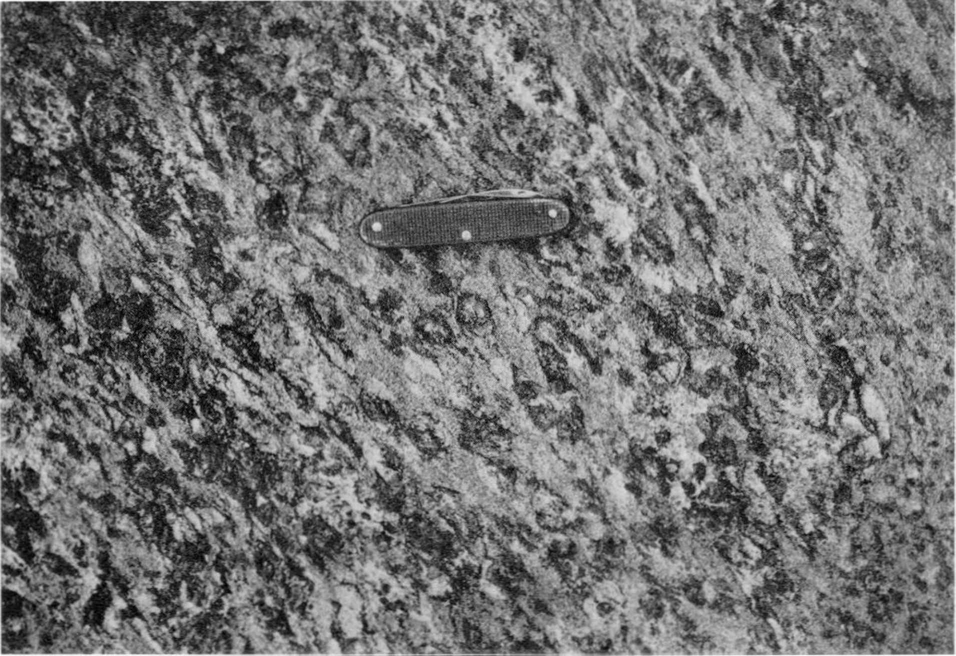

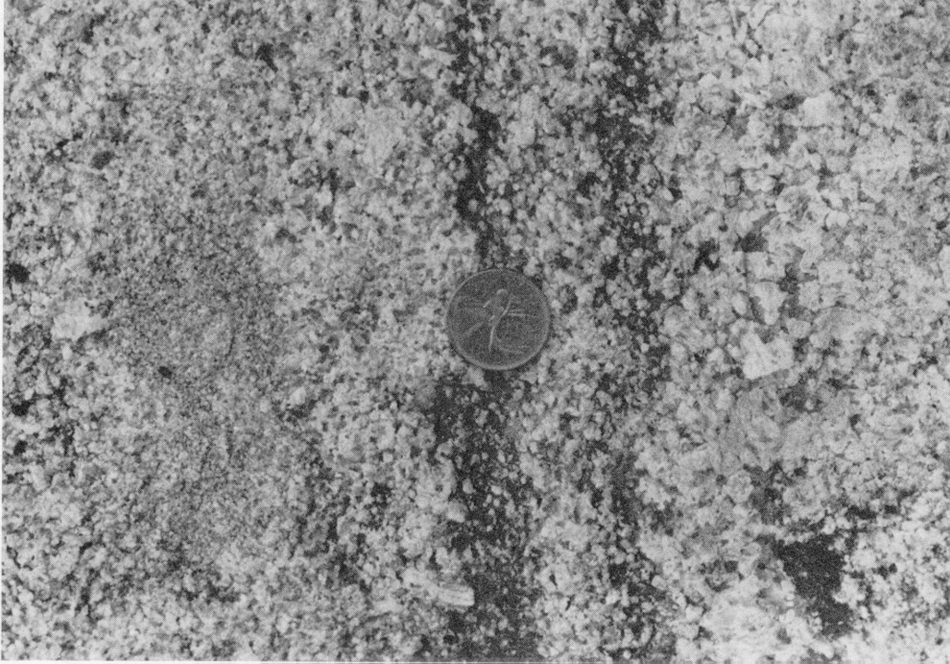

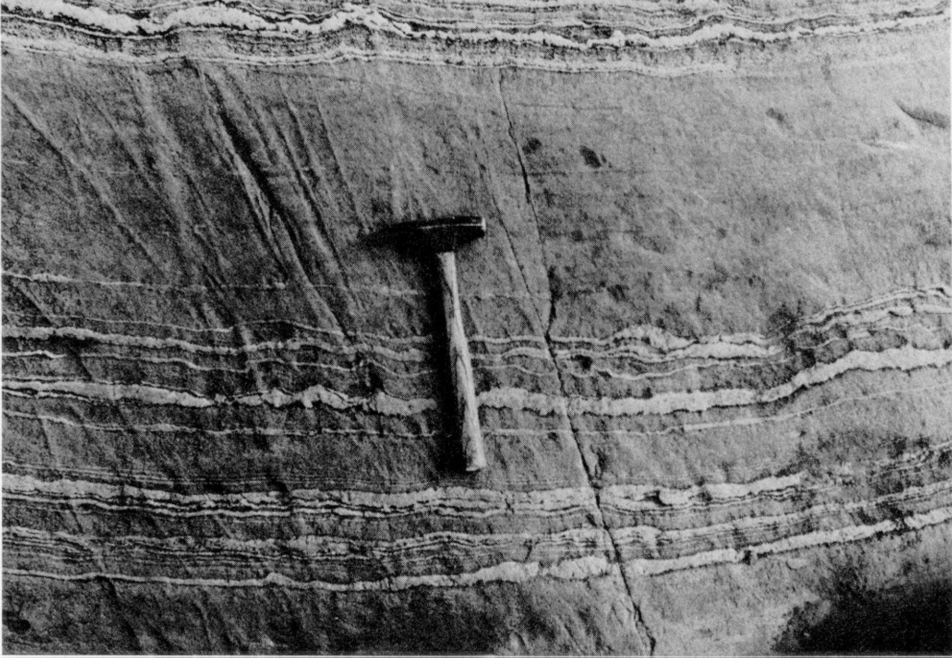

Ministry of Natural Resources
Ontario

Hon. Frank S. Miller
Minister

Dr. J.K. Reynolds
Deputy Minister

ONTARIO GEOLOGICAL SURVEY

PRELIMINARY MAP P. 1971

GEOLOGICAL SERIES

Western English River Subprovince & Parts of Uchi & Wabigoon Subprovinces, General Geology & Lithophile Type Mineralization

DISTRICTS OF KENORA AND
KENORA (PATRICIA PORTION)

Scale: 1:253 440

Miles 2 1 0 2 4 6 8 10 12 Miles
Metres 5000 0 10 Kilometres

NTS Reference: 52E/14E, 15, 16;
52F/13, 14, 15, 16; 52K; 52L
ODM Geological Compilation Maps: 2115, 2175

LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
PLEISTOCENE AND RECENT

Till, clay, sand, gravel

UNCONFORMITY

PRECAMBRIAN
EARLY PRECAMBRIAN

9 FELSIC TO INTERMEDIATE SUBVOLCANIC ROCKS

UNMETAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIVE ROCKS

8
- 8a Massive trondhjemite and quartz diorite
- 8b Massive porphyritic granodiorite
- 8c Massive porphyritic quartz monzonite
- 8d Massive equigranular quartz monzonite
- 8e Clotty quartz monzonite

UNMETAMORPHOSED MAFIC INTRUSIVE ROCKS

7
- 7 Massive diorite to quartz diorite

METAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIVE ROCKS

6
- 6a Strongly foliated to gneissic trondhjemite and granodiorite
- 6b Moderately foliated trondhjemite and granodiorite
- 6c Weakly foliated trondhjemite and granodiorite
- 6d Weakly foliated porphyritic granodiorite
- 6e Weakly foliated porphyritic quartz monzonite
- 6f Foliated quartz monzonite

METAMORPHOSED MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS

5
- 5a Gabbro
- 5b Foliated diorite and quartz diorite
- 5c Ultramafic rocks and altered equivalents

4 FELSIC TO INTERMEDIATE GNEISSIC ROCKS

METASEDIMENTS AND DERIVED MIGMATITE

3
- 3a Wacke, arkose, local conglomerate
- 3b Metatexitic metasedimentary migmatite
- 3c Diatexitic metasedimentary migmatite (S-Type granitoid rocks)

2 FELSIC TO INTERMEDIATE METAVOLCANICS

1 INTERMEDIATE TO MAFIC METAVOLCANICS

GEOLOGICAL SYMBOLS

▲U Location of lithophile mineralization

〰 Fault zone

━ Subprovince boundary, in some cases marked by fault zones

─ Geological boundary

METALS REFERENCE LIST

Be	Beryllium	Ta	Tantalum
Cs.	Cesium	Th	Thorium
Li.	Lithium	U	Uranium
Mo	Molybdenum	W	Tungsten
Sn	Tin		

SOURCES OF INFORMATION

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