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ONTARIO GEOLOGICAL SURVEY

Open File Report 5282

Geology of Renfrew County

by

S. B. Lumbers

1980

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Ontario Geological Survey

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E.G. Pye, Director
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Abstract

This report and accompanying maps at a scale of 1:126,720 provide a geological framework to relate in space and time regional petrological and tectonic features to known mineral deposits within a 9,324 km² area of the Grenville Province in southeastern Ontario. The area lies within latitudes 46°00'N and 45°00'N, and longitude 78°00'W and Ottawa River, and it consists mainly of Renfrew County together with small portions of neighbouring counties and the District of Nipissing. Data used to compile this summary consist of detailed and reconnaissance mapping by the author and others at scales ranging from 1:15,840 to 1:63,360, preliminary petrological and geochemical studies, and published geophysical data and inventories of known mineral deposits.

A review of the stratigraphic and tectonic framework of the Grenville Province of Ontario, together with a geological summary of the map-area, show that the map-area constitutes a 135 km section across the central part of the Grenville Province and straddles two major supracrustal accumulations of contrasting age and lithology. The older accumulation, consisting mainly of clastic siliceous meta-sediments and deposited between 2.5 and 1.8 b.y. ago, is confined to the northern two-thirds of the Province and extends into the northern part of the map-area. The younger

accumulation, which includes rocks commonly referred to as the "Grenville Supergroup" and was deposited between 1.5 and 1.25 b.y. ago, dominates the southern third of the Grenville Province and the southern part of the map-area. This accumulation consists mainly of carbonate metasediments, subordinate clastic siliceous metasediments, and local sequences of metavolcanics. The older accumulation was intruded by the Algonquin batholith, which dominates not only the central and northern parts of the map-area, but also the central part of the Grenville Province in Ontario. Composed of anorthosite suite rocks, the batholith was emplaced between 1.5 and 1.4 b.y. ago, and supracrustal rocks of the younger accumulation rest unconformably upon the southern and at least part of the western flanks of the batholith. The base of this accumulation consists of a coarse clastic sequence characterized by a basal arkose and impure sandstone facies locally containing coarse clasts lithologically similar to intrusive phases of the batholith. Between 1.3 and 1.0 b.y. ago, a large variety of plutonic rocks were emplaced within the carbonate-rich younger accumulation. In approximate order of decreasing age, the following five plutonic rock suites are recognized: 1) biotite diorite suite characterized by abundant dioritic rocks, tonalite, and sodic granitic and syenitic rocks, chiefly trondhjemite, grano-

diorite, albite granite, albite syenite; 2) anorthosite suite consisting of anorthositic and tonalitic rocks and associated monzonitic and granitic rocks; 3) quartz monzonite suite characterized by abundant quartz monzonite and only minor phases of other calc-alkalic intrusive rocks; 4) alkalic suite dominated by alkalic syenite and granite, but containing minor mafic alkalic rocks, nepheline syenite and carbonatite; and 5) syenite-monzonite suite characterized by abundant calc-alkalic syenite and minor monzonite, quartz monzonite, tonalite, and gabbro.

Between 1.1 and 1.0 b.y. ago, the supracrustal and most of the plutonic rocks underwent high rank regional metamorphism that converted these rocks into intensely deformed and coarsely recrystallized gneisses. During this metamorphism, the Algonquin batholith and smaller batholithic bodies within the younger accumulation became diapiric toward the overlying supracrustal rocks causing most of the tectonic deformation not only of the plutonic rocks, but also of rocks of the two supracrustal accumulations. This diapirism accounts for subhorizontal gneissic foliation and recumbent folding dominant in the supracrustal rocks for tens of km around the Algonquin batholith. Variations in metamorphic mineral assemblages developed in the various gneisses seem to correlate best with variations

in the level of strain in the gneisses and are indicative of middle to upper almandine amphibolite facies temperature and pressure conditions; locally, a few highly strained intrusive bodies contain granulite facies mineral assemblages. Some intrusions of the quartz monzonite and alkalic suites, most of the intrusions of the syenite-monzonite suite, and granite pegmatite dikes were emplaced during the waning stages of regional metamorphism. During this time, rocks of the alkalic suite, which are concentrated in a major complex close to the unconformity marking the base of the younger accumulation, underwent widespread fenitization marked by the presence of alkalic pyroxene veinlets and alkalic syenite pegmatite. Following termination of the high rank regional metamorphism, the map-area underwent uplift, faulting, mafic intrusive activity, erosion, and deposition of Lower Paleozoic sedimentary rocks. These rocks are now preserved only within the Ottawa-Bonnechere Graben that cuts eastward across all but the southwestern part of the area and is marked by prominent fault systems and subsidiary grabens, swarms of diabase dikes, zones of localized fenitization, and small mafic to ultramafic stocks.

Most mineralization of economic importance is confined to the late accumulation where, in the past, deposits of

apatite, asbestos, beryl, clay, corundum, feldspar, graphite, iron, lead, magnesium, mica, pyrite, stone, and strontium were mined or quarried. The only mineral production from the remainder of the area consists of small quantities of feldspar and mica mined from late granite pegmatite dikes cutting rocks of the Algonquin batholith, and stone quarried from rocks of the batholith for local construction purposes. Present production, all from deposits within the younger accumulation, is confined to Pleistocene clay, magnesium produced from dolomitic marble, rose quartz and beryl obtained from pegmatite bodies, and stone produced from outliers of Paleozoic limestone. Sand and gravel are quarried throughout the area for local construction purposes.

In spite of the complex geological history, results of the present study, combined with previous work, now allow recognition of the sequence of events recorded by rocks of the map-area and how these events are related in space and time to known mineralization. This is summarized graphically and supplies important relationships and guides for future mineral exploration and metallogenic studies.

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GEOLOGY OF RENFREW COUNTY

BY

S. B. LUMBERS

(1 Curator of Geology, Royal Ontario Museum)

INTRODUCTION

This report presents a summary of the regional ^gpetrologic and tectonic features of a 3,600 square ⁴miles (9,324 km²) area in the Grenville Province of southeastern Ontario and attempts to relate these features in space and time to known mineral deposits within the area. Most of the area consists of all but the extreme northern townships of Renfrew County, and it lies between Latitudes ^{6° 0'}45° 30' N and 45° 00' N, and between Longitude 78° 00' W and the Ottawa River (Figure 1). Small portions of the District of Nipissing and the Counties of Hastings, Lennox and Addington, Frontenac, Lanark, and Carleton are also included within the area. Major centres of population are Petawawa, Pembroke Caden, Forester Falls, Renfrew, Arnprior, Calabogie, Eganville, Golden Lake, Killaloe Station, Wilno, Barrys Bay, Madawaska, Combermere and Quadeville. Good access to most of the area is provided by numerous township roads, provincial highways, and main and branch railway lines of the Canadian National Railways and Canadian Pacific Railway. The northeastern part of the

area includes portions of Algonquin Provincial Park and Canada Forces Base, Petawawa, and travel in these areas is regulated.

Geologically, the area can be subdivided into two portions of contrasting age and lithology along a northeasterly trending zone of coarse clastic metasediments (Figure 1). The northwestern portion is dominated by anorthosite suite rocks of the Algonquin batholith which intruded Middle Precambrian metasediments. The southeastern portion is composed of a lithologically complex assemblage of Late Precambrian supracrustal and plutonic rocks, all younger than about 1.5 b.y. Most mineralization of economic importance is confined to the southeastern portion where, in the past, deposits of apatite, asbestos, beryl, clay, corundum, feldspar, graphite, iron, lead, magnesium, mica, pyrite, stone and strontium, were mined or quarried. The only mineral production from the northwestern portion consists of small quantities of feldspar and mica mined from late granite pegmatite dikes cutting rocks of the Algonquin batholith, and stone quarried from rocks of the batholith for local construction purposes. Present production, all from deposits within the south⁺eastern portion, is confined to clay (The Dechart Erick and Tile Company of Arrprior), magnesium produced from dolomitic marble in Ross Township by Chromasco Limited, rose quartz and beryl obtained from pegmatite boulders in Lyndoch Township by Wal Gen Lapidary Company of Quadeville, and stone produced from outliers of Paleozoic limestone near Arrprior by Smith Construction Company and Cavanagh Construction. Sand and gravel are quarried throughout the area for local construction

purposes.

Data for this study were obtained from: 1) geological mapping by the author over five field seasons between 1974 and 1978, 2) previous work (see below); 3) work on mineral deposits by the Mineral Deposit Section of the Ontario Geological Survey; and 4) petrologic and geochemical studies carried out by the author and others at the Department of Mineralogy and Geology, Royal Ontario Museum. (Petrologic and geochemical studies remain in progress). Data gained to date are sufficient to allow generalized subdivision of the rocks, and to synthesize the regional geology. (Presentation of modal and chemical data, and discussions of petrogenesis must await completion of the studies in progress).

PREVIOUS WORK

Geological investigations have been carried out in various parts of the map-area for over 100 years. Previous workers experienced great difficulty in subdividing and recognizing the primary lithologies of the Precambrian rocks because these rocks were subjected to Late Precambrian high rank regional metamorphism and are gneissic with only vestiges of their primary lithologies remaining. Several advances in interpreting the petrogenesis of such rocks have been made in recent years, but most of the previous workers did not have the advantage of this knowledge. They were therefore greatly hindered in attempts at synthesizing the geology which is so crucial to

metallogenic studies.

The earliest work was of a general reconnaissance and exploratory nature performed by geologists of the Geological Survey of Canada between 1850 and 1930 (see Satterly, 1945, p.3-4). Since 1930, several parts of the area have been mapped at various levels of detail by Kay (1942), Quinn (1952), Quinn et al. (1956), Hewitt (1954), Livingstone et al. (1974), and Theristocleous (1978; 1979). Satterly (1945) carried out reconnaissance geological studies and made a regional compilation of the geology of most of the present map-area during examination of mineral deposits in Renfrew County in 1943. Until now, Satterly's work was the only regional compilation of the Renfrew area available, and over the years, his work has proven invaluable to anyone interested in the geology and mineralization of Renfrew County.

Several reports have been published concerning mineral deposits in the area, and these are summarized in Satterly (1945), ^{Carter et al. (1979), Vos and Storey (1979)} and ~~in GSC~~ ^{Gordon and} ~~Gordon and~~ ^{Mason (in preparation)} (1977). Published geophysical and geochemical surveys covering either all or portions of the map-area consist of: 1) aeromagnetic maps (GSC, 1947; 1950; 1951; 1952a; 1952r; 1952c; 1953; 1955a; 1955r; 1962a; 1962b; 1962d); 2) airborne gamma-ray spectrometry surveys (GSC, 19⁷⁶); 3) geochemical reconnaissance surveys (^{GSS, GSC} ~~288-085~~, 19⁷⁷); and 4) gravity surveys (Earth Physics Branch, 1971). The northern extremity of Renfrew County (Townships of Clara, Maria, Head, Ralph, and portions of Wylie and Eucharan) are not covered by this report

but were mapped by the author between 1973 and 1975 (Lumbers, 1976). Most of the region adjacent to the southern and southwestern parts of Renfrew County was mapped by Hewitt (1955), Hewitt and James (1956), Evans (1964), Lumbers (1964; 1967), Smith (1958), Peach (1958), and Reinhardt (1973).

PRESENT GEOLOGICAL SURVEY

Most of the northwestern portion of the area, where geological units are relatively large, was traversed at 1 mile (1.6 km) intervals. Most of the southeastern portion of the area, where geological units are relatively small, was traversed at 1/2 mile (0.8 km) intervals. In addition, all lakes, streams, roads, railways, power lines, and other places containing clear outcrops relatively free of lichen and other vegetal cover were mapped in detail. Such outcrops allow the rocks to be accurately classified and described, and they provide most of the data for geological interpretation and synthesis. After examination on the ground, some well exposed areas were flown by aircraft at low altitudes to refine geological contacts.

Geological data were plotted in the field on transparent plastic film fitted to air photographs close to a scale of 1 inch to 1/2 mile (1:31,680). This data was transferred by sketchmaster to appropriate map sheets of the Forest Resources Inventory of the Ontario Division of Forests reduced photographically to 1 inch to 1/2 mile (1:31,680). Final geological interpretation was made on these sheets, and then

the sheets were reduced photographically to 1:63,360. The generalized geology and outcrop areas were transferred to 1:63,360 manuscript maps prepared by the Cartography Section of the Ontario Division of Lands from maps of the Forest Resources Inventory for the final maps (Maps +++++, back pocket) published on a scale of 1 inch to 2 miles (1:126,720). During the field work, any necessary topographic additions and corrections were made to the manuscript map by the author.

Liberal use was made of data collected and published by previous workers in the area. Original manuscript maps, field notes, and other data collected by Satterly (1945) and Hewitt (1954) were made available to the author by the Ontario Geological Survey, and this data proved invaluable in compiling the geology. (Field data and original interpretive maps with specimen locations compiled during this study are on file at the Department of Mineralogy and Geology, Royal Ontario Museum, and all specimens collected during the field work and their thin sections form part of the Department's petrology collection. Geologists interested in inspecting this data and the specimens can do so by contacting the Department for an appointment).

ROCK EXPOSURE

On the geological maps (Maps +++, back pocket), major drift-covered areas containing no outcrop are indicated by a stipple pattern. Elsewhere, rock exposure varies greatly and ranges between about 5

and 80 percent. Numerous factors control the density of outcrops, paramount among which are lithology, structure, and Quaternary deposits formed as a result of continental glaciation of the area.

Paleozoic rocks, which for the most part are flat lying and are preserved as unfaulted outliers within the Ottawa-Bonnechere Graben (Kay, 1942), show the poorest exposure. Most of the outcrop areas of these rocks shown on the maps consist of either flat bedding surfaces partly obscured by a thin soil mantle supporting a scrubby vegetal growth dominated by juniper shrubs, or concentrations of large blocks of Paleozoic rocks up to several metres in size lying on or near flat bedding surfaces. Most of the outcrops shown in Westmeath Township inland from Ottawa River are characterized by concentrations of large blocks, but elsewhere outcrop areas shown are mainly flat bedding surfaces. The only sections present are either in roadcuts and quarries, or along streams and lakeshores. The thickest sections preserved are along the Ottawa River, and these rarely exceed 10 m in height.

The Precambrian rocks are cut by numerous normal faults trending mainly west-northwest. Most of the faults are marked by prominent scarps and narrow to broad valleys which host the major streams draining highland areas centred over the Algonquin batholith and the region southwest of the Mt. St. Patrick Fault. Many of the valleys channelled melt waters toward the Ottawa Valley during deglaciation, so that near Ottawa River and in areas where the valleys broaden

because of secondary graben development, extensive deposits of sand and gravel obscure the bedrock. Sea waters of the Champlain Sea flooded the Ottawa Valley as far north as Pembroke and left extensive deposits of marine clay upon the bedrock in low lying areas along the Ottawa Valley. Near junctions of major valleys draining highland areas with the Ottawa Valley, extensive deltaic deposits formed, further obscuring the bedrock. During deglaciation, intrusive rocks between Pembroke and Arnprior within the Ottawa Valley formed topographic highs, so that much of the glacial and other debris was washed from them by melt waters and wave action of marine waters leaving them well exposed today. Intervening areas of carbonate metasediments are generally poorly exposed.

The Algonquin batholith is characterized by rough to irregular topography with numerous high hills commonly marked by steep to gentle slopes facing northward toward the direction of the advancing ice-sheet and steep rocky slopes and cliffs facing southward on the leeward side of the advancing ice-sheet. The northerly slopes are largely covered by glacial drift. Numerous areas within the batholith are marked by subhorizontal gneissic foliation which produces relatively flat hills partly surrounded by steep rocky slopes and cliffs and intervening, narrow, drift-covered valleys. Excellent exposures are generally present near most of the fault scarps and along most of the lakes and streams.

The highland area of Precambrian rocks southwest of the Mt. St.

Patrick Fault is generally well ^eexposed where intrusive rocks predominate, but many of the areas underlain mainly by carbonate rocks are poorly exposed. Excellent exposures of carbonate rocks are present in the vicinity of Black Scald and Centennial Lakes in Brougham and Matawatch^aen Townships where these rocks are in long ridges striking parallel to the gneissic ^ffoliation in the metasediments. The ridges locally contain thin units of siliceous metasediments and intrusive rocks relatively resistant to erosion. Rock exposure has also been enhanced in this area by flooding of the Madawaska River due to hydro electric power dam construction and by forest fires and logging operations which allowed much of the soil cover in high rocky ridges to be removed by erosion.

GENERAL GEOLOGY

INTRODUCTION

The map-area constitutes a 135 km section across the central part of the Grenville Province of Ontario and connects the geology of the older, predominantly Middle Precambrian¹ (2 For purposes of this report, Precambrian time is subdivided into three eras: Early, Middle and Late. The time boundary between Early and Middle is 2.5 b.y. and between Middle and Late, 1.6 b.y. Early Precambrian is synonymous with "Archean")* northwestern portion with the younger, predominantly Late Precambrian southeastern portion (Ayres et al. 1971). The present study combined with other work by the author in the

* Most in brackets a footnote

northwestern and southeastern parts of the Grenville^{Province} and recent and past work by others in the Georgian Bay and southeastern^P portions^O now allow a preliminary statement to be made concerning the stratigraphic and tectonic framework of the entire Grenville Province of Ontario. Such a framework is essential to metallogenic studies, and the more refined the framework, the more direct use it has in mineral exploration. The refinement process is long and exacting, especially in a region as geologically complex as the Grenville Province, so that occasional progress reports such as the present one are desirable to make use of accumulated knowledge and data. In discussing the general geology, the map-area will first be viewed in terms of the general framework in a "geological setting" section, and then some major aspects of the geology pertinent to mineral exploration will be summarized (Results of laboratory studies in progress and detailed accounts of lithology will be published at a later date).

GEOLOGICAL SETTING

The Grenville Province of Ontario is underlain by a variety of supracrustal and plutonic rocks that reflect a long, complex geological history spanning more than 2 b.y. Much of this history is reflected by rocks of the map-area, but interpretation of the history is difficult because most of the rocks were subjected to Late Precambrian high rank regional metamorphism which culminated between about 1.3 and 1.0 b.y. ago (Lukters, 1967; 1978) and which converted

nearly all the rocks into markedly recrystallized and deformed gneisses. This metamorphism, which is commonly referred to as the "Grenvillian Orogeny", affected the entire Grenville Province of the Canadian Shield and allows the Grenville^{Province} to be recognized as a unique, primary subdivision of the Shield. Major geological features forming the basic framework of the Grenville Province of Ontario are shown in Figure 1, together with the boundaries of the map-area. Data for Figure 1 are current to the end of 1978, and most of the data for the northern two-thirds of the Province are derived from published and unpublished work by the author and Schwerdtner^{and Waddington} (1978).

In Ontario and for an unknown distance northeastward across the Inter-provincial Boundary into Quebec, high metamorphic rank gneisses of the Grenville Province are separated from relatively low metamorphic rank rocks of the Superior and Southern Provinces by a fault zone, the Grenville Front Boundary Fault, which defines the northwestern boundary of the Grenville Province in Ontario (Figure 1). This fault is near the northwestern margin of the Grenville Front Tectonic Zone, details of which are summarized in Lumbers (1978).

Southeast of the Boundary Fault, the Grenville Province contains two geosynclinal supracrustal accumulations of contrasting age and lithology. The older accumulation, deposited during the Middle Precambrian between 2.5 and 1.8 b.y. ago, is confined to the northern two-thirds of the Province and consists mainly of clastic siliceous metasediments deposited in deep water below wave^{-base} (Figure 1). Near the

northwestern margin of the Grenville Province, the older accumulation rests unconformably upon Early Precambrian rocks extending across the Boundary Fault into the Grenville Province from the Superior Province (Figure 1 and Lumbers, 1978). The base of this accumulation is marked by a coarse clastic sequence (Figure 1) deposited largely in deep water below wave-base, probably in a submarine fan environment (Lumbers, 1978). The coarse facies gradually changes into thinly bedded, medium-grained meta^{gne}wacke and meta-argillite which could represent a facies change to outer fan turbidites. These rocks were deposited in a linear depression or trough along the northwestern margin of the Grenville Province and are correlative with the lower part of the Huronian Supergroup in the Southern Province (Lumbers, 1978). South of the trough metasediments, the supracrustal rocks contain several major units of moderately-to well-sorted arkose, subarkose, orthoquartzite, aluminous clay-rich material, and rare iron formation and marble deposited in a nearshore environment under the influence of wave action. These units are intercalated with thick sequences of impure metasediments and meta-argillite containing much more potassic feldspar than the deep water facies of the trough. ^{If these} ~~All~~ ^{rocks are part of the trough sequence, then they} ~~these rocks~~ mark an important change in the paleogeography of the ^{developing} Middle Precambrian geosynclinal accumulation; ^{Alternatively} ~~and~~ they could represent a younger Middle Precambrian sequence deposited upon the deep water facies of the trough. Impure metasediments and meta-argillite of this possibly younger sequence extends into the northern part of the map-area where they were intruded by the Algonquin batholith (Figure 1).

The younger accumulation, which includes rocks commonly referred to as the "Grenville Supergroup", is present mainly in the southern third of the Grenville Province (Figure 1) and consists mainly of carbonate metasediments, subordinate clastic siliceous metasediments, and locally thick sequences of metavolcanics. The Algonquin batholith, which intruded rocks of the older accumulation, is overlain unconformably by rocks of the younger accumulation along its southern flank and at least part of its western flank. Composed of anorthosite suite rocks, the batholith underlies the central part of the Grenville Province, and preliminary geochronological data suggest that its major phases are between 1.4 and 1.5 b.y. old (Krogh and Davis, 1969; Lumbers and Krogh, 1977). The batholith narrows greatly to the ~~southwest and~~ northeast and may be linked to similar batholiths under the St. Lawrence Platform and in the Grenville of Quebec (Schwerdtner and Lumbers, in ~~press~~^{press}). Moreover, the batholith appears to be part of a major tectonic event of continental proportions, about 1.4 to 1.5 b.y. old, that has been postulated throughout a broad area extending from Iarrador to Southern California (Silver et al., 1977).

The base of the younger accumulation is marked by a basal arkose and coarse clastic sequence (Figure 1) which has been studied only in the map-area, but which has been traced in a crude reconnaissance fashion by the author to the west as far as Lake Muskoka. The sequence contains local thin units of marble, calcareous and siliceous shaley

metasediments, and orthoquartzite, and it undergoes a facies change southeastward across ~~the~~ strike into the carbonate rocks dominating the younger accumulation. This carbonate marine basin can be traced across strike for over 240 km southeast into the Adirondack region of New York State, and along strike to the east, it crosses the Ottawa River where it deflects northwestward for several tens of km parallel to, ~~the~~ ^{and} east of, the river. Major volcanism occurred within the basin about 1.3 a.y. ago (Lumbers, 1967), but the volcanism appears to be restricted to the northwestern part, ^{in Ontario.} The base of the volcanic sequence is not exposed, but the earliest recognizable volcanism was basaltic and formed shield volcanic complexes which later evolved into strato volcanoes (Lumbers, 1967). Volcanic highlands were eroded supplying volcanoclastic detritus that formed aprons of turbidite deposits about the eroded highlands. The carbonate facies was deposited both during and after the volcanism, so that this facies is intercalated with most of the volcanic and volcanoclastic rocks (Lumbers, 1967). The thickest part of the exposed volcanic sequence is in the Bancroft-Madoc area southwest of the map-area, and this portion coincides with the only region of low rank metamorphism so far identified in the Grenville Province of the Canadian Shield (Lumbers, 1967). Geophysical data suggest that the volcanic rocks extend for an unknown distance southwest of the Bancroft-Madoc area beneath the Paleozoic cover of the St. Lawrence platform. To the northeast of the Bancroft-Madoc area, the volcanic rocks become scarce and appear to be absent near the Ottawa River south of Foss Township in the map-area. No basement rocks have been unequivocally

identified within the basin, and it appears that the Algonquin batholith was emplaced near the margin of a Middle Precambrian continental mass. The oldest plutonic rocks identified within the basin are about 1,2~~80~~⁵⁰ m.y. old (Lumbers, 1967), and this age provides an upper limit for the interval involved in deposition of the younger accumulation.

A second basin of supracrustal rocks possibly correlative with those of the carbonate-rich basin southeast of the Algonquin batholith extends northward from southeastern Georgian Bay to south of Lake Nipissing (Figure 1). These supracrustal rocks have been only partly mapped on a crude reconnaissance scale, but they appear to be characterized by abundant shaley metasediments containing intercalated thin marble units; metavolcanics have been noted at a few localities.

Most of the plutonic rocks cutting the older accumulation belong to the anorthosite suite and are late Precambrian, ranging in age from about 1.5 to 1.1 b.y. old (Lumbers, 1975; Lumbers and Krogh, 1977). The only older plutonic bodies consist mainly of quartz monzonite and minor granodiorite emplaced mainly within the Grenville Front Tectonic Zone and the deep water turbidite deposits during the Middle Precambrian, about 1.7 b.y. ago (Fig. 1 and Lumbers, 1978). Between 1.3 and 1.0 b.y. ago, a large variety of plutonic rocks were emplaced within the carbonate-rich younger accumulation southeast of the Algonquin batholith. Most of the plutonic rocks can be divided into

suites without prejudice as to genetic implications, with each suite consisting of rocks consistently associated in space and time. Moreover, the suites are characterized by certain chemical features, such as high alkali contents, or high soda and low potassium contents. More data are needed to prove that rocks comprising each suite are comagmatic, and some of the suites may be related genetically. A few of the suites recognized here, such as the biotite diorite suite, have also long been recognized within orogenic belts of diverse ages on a global scale (see Barth, 1952). Subdivision of the plutonic rocks into suites is also advantageous from the point of view of mineral exploration, because certain important relationships emerge with respect to associated mineral deposits that would otherwise be lost (Lumbers, 1964).

Five major plutonic rock suites are recognized, and all five are present in the map-area. Considerable petrologic data are necessary to assign a plutonic body to a particular suite, and unfortunately, such data are not available for all the plutonic bodies within the carbonate-rich accumulation. A generalized distribution of the various suites for which data are available is shown in Figure 2. In approximate order of decreasing age, the following suites are recognized: 1) biotite diorite suite characterized by abundant dioritic rocks, tonalite, and sodic granitic and syenitic rocks, chiefly trondhjemite, granodiorite, albite granite, albite syenite; 2) anorthosite suite consisting of anorthositic and tonalitic rocks and associated monzonitic and granitic rocks (Lumbers, 1975); 3)

quartz monzonite suite characterized by abundant quartz monzonite and only minor phases of other calc-alkalic intrusive rocks; 4) alkalic suite dominated by alkalic syenite and granite, but containing minor mafic alkalic rocks and nepheline syenite; and 5) syenite-monzonite suite characterized by abundant calc-alkalic syenite and minor monzonite, quartz monzonite, treralite and gabbro. Geochemical and geochronological investigations of the various rock suites in progress should aid in understanding their petrogenesis and refine their subdivision as outlined here. The alkalic suite is confined mainly to a major complex near the northwestern margin of the Late Precambrian supracrustal accumulation, but small intrusions of the suite also occur elsewhere (Figures 1 and 2). Minor phases of anorthosite suite rocks are common in the major alkalic complex and this spatial association of the two suites has also been recognized to the north of the Algonguin batholith in predominantly anorthosite suite intrusions in the Hurwash and Mattawa-Deep River areas (Lumbers, 1975; 1976a; 1976b). Perhaps a genetic link exists between the two suites (Lumbers, 1976b). Anorthosite suite rocks ^{are} also spatially associated with some quartz monzonite suite intrusions in North Canonic and Blithfield Townships in the map-area. Further work may also show a genetic link between these two suites.

The metamorphic history of the Grenville Province is difficult to determine in detail because the late high-rank regional metamorphism effectively obliterated evidence of any earlier metamorphic events. Nevertheless, some evidence suggests that the older supracrustal

accumulation near the northwestern margin of the Grenville Province was affected by the Penckean event that regionally metamorphosed rocks of the Southern Province near Sudbury and to the west between 2.16 and 1.8 b.y. ago (Lumbers, 1978). This metamorphism varied in intensity but rarely exceeded the temperature and pressure conditions of the lower almandine amphibolite facies. Mineral assemblages developed in the Grenville greisses during the late high-rank regional metamorphism are most indicative of temperature and pressure conditions existing in the middle to upper almandine amphibolite facies. Locally within a few highly strained granitic intrusions in the younger accumulation southeast of the Algonquin batholith, mineral assemblages suggestive of granulite facies temperature and pressure conditions exist. Many of the metamorphosed monzonitic and syenitic rocks of the anorthosite suite contain hypersthene, but the presence of this mineral is not indicative of granulite facies metamorphism of these rocks as claimed by some geologists (Lumbers, 1971; 1975). During the late metamorphism, the Algonquin batholith was reactivated and became diapiric toward the overlying rocks causing most of the tectonic deformation, not only of rocks of the batholith, but also of rocks of the two supracrustal accumulations (Schwerdtner and Lumbers, in ^{press} ~~prep.~~). Numerous oval diapiric structures outlined by lithology and replete with subhorizontal flattening gneissosity are present within the batholith (see Maps +++, back pocket). The long diameter of the batholith parallels the overall trend of the folded unconformity marking the base of the younger supracrustal accumulation (figure 1). This diapirism accounts

for subhorizontal gneissic foliation and recumbent folding dominant in the supracrustal rocks for tens of km around the batholith.

The latest tectonism to affect the Grenville Province is related to activity along the Ottawa-Ferrière Graben (Figure 3) which crosses the Grenville Province westward along the Ottawa and Mattawa Valleys and continues westward across the Grenville Front Tectonic Zone to join the Murray Fault System south of Sudbury. The graben, which is part of the St. Lawrence Rift System (Kumarapeli and Saull, 1966) was probably initiated early in Archean time (Lumbers, in press) and has remained active to the present eastward from Lake Nipissing. The graben is marked by prominent fault systems on the north (Mattawa River Fault and Ottawa System, Figure 3), by swarms of diabase dikes and a prominent zone of normal faulting and small subsidiary grabens on the south, and widely scattered zones of localized fenitization. Most of the diabase dikes postdate the late high rank regional metamorphism in the Grenville Province, but some were intruded while this metamorphism was on the wane. Lamprophyre and trachyte dikes, small peridotite bodies, one late gabbro body, and a few alkalic rock-carbonatite complexes and cryptovolcanic structures, all ranging in age from Late Precambrian to Early ~~Pre~~^Cambrian, are localized within the graben. All but the southern part of the map-area, southwest of the prominent zone of faulting extending west-northwest/south of the Mt. St. Patrick Fault through the northern part of Kamaniskeg Lake and Ayler Lake (Maps +++, back pocket) lies within the graben. Representations^{ves}~~ions~~ of most of the various late


intrusions associated with the graben are present in the map-area.

GEOLOGICAL SUMMARY OF THE MAI-AREA

Figure 4 summarizes the sequence of events recorded by rocks of the map-area, and the relationship of these events in space and time to known mineralization. Mineralization aspects will be discussed below after the rocks comprising the events are briefly summarized in this section. In positioning events shown in Figure 4 in a time framework, most weight was given to relative age relationships visible in the field, particularly cross-cutting relationships shown by plutonic rocks and ages of plutonic rocks relative to the late high rank regional metamorphism. Available geochronological data on the rocks involved, chiefly from Silver and Lumbers (1966), Krogh et al. (1968), Krogh and Hurley (1968), Krogh and Davis (1969), and unpublished data by Krogh, has been obtained mainly from portions of the plutonic rock suites and metavolcanics outside the map-area and are too incomplete and preliminary in nature to provide more than a general time reference. Thus, most events cannot be given precise time limits, but the duration and overlap of events can be estimated. Events of regional nature recorded by rocks both within and outside the map-area are shown by heavy lines. The light lines indicate events that are either restricted in their distribution, such as faulting and associated intrusive activity along the Ottawa-Bonnechere Graben, or inferred, such as metamorphism of the Middle Precambrian rocks as a result of intrusion of the Algonquin

ortholith.

MIDDLE PRECAMBRIAN SEDIMENTATION

The oldest rocks exposed in the map-area consist of Middle Precambrian metasedimentary gneisses derived from two main types of sequences: 1) intercalated impure sandstone, feldspathic sandstone, and siliceous and calcareous mudstone, and 2) sequences dominated by siliceous mudstone containing intercalated, thinly bedded impure sandstone, feldspathic sandstone, and siliceous and calcareous mudstone, and 2) sequences dominated by siliceous mudstone containing intercalated, thinly bedded impure sandstone, feldspathic sandstone and calcareous mudstone. Metamorphism converted the calcareous mudstone of both sequences into rocks rich in amphibole, quartz, plagioclase, and minor diopside, epidote, and biotite; marble is absent but is associated rarely with both sequences in the Mattawa-Deep River area to the north of the map-area (Lumbers, 1976). The metasandstones generally contain abundant potassic feldspar in marked contrast to metasandstones of the trough metasediments mentioned above in the "Geological Setting" section. Near the east end of Grand Lake in southwestern Stratton Township (Map ^{P2355} , back pocket), the metasediments are mainly feldspathic and quartzose metasandstone with a few intercalated thin units up to 3' cm thick of a metasediment possibly derived from iron formation. This metasediment is essentially a muscovite-biotite-plagioclase-quartz gneiss with up to 50 percent magnetite concentrated in dismembered

micaceous layers up to 3 cm thick and separated by slightly thicker quartz-rich layers.

The age of the Middle Precambrian metasediments is poorly known. Regionally, they are intruded by plutonic rocks as old as 1.7 b.y. (Lumbers, 1978), and in the map-area, they are cut by rocks of the Algonquin batholith emplaced between 1.4 and 1.5 b.y. ago. As discussed above, the metasediments may be younger than Middle Precambrian supracrustal rocks near the northwestern margin of the Grenville Province that are correlative with the lower part of the Huronian Supergroup deposited between about 2.5 and 2.2 b.y. ago. In Figure 4, the age is estimated at about 2 b.y. with a large margin of uncertainty.

ALGONQUIN BATHOLITH

Rocks of the Algonquin batholith are highly strained and metamorphosed so that for the most part they consist of augen gneiss and gneiss containing prominent layering. Nevertheless, well exposed outcrops generally reveal isolated, slightly gneissic phases displaying relict primary textures and, rarely relict primary feldspar indicating that the gneisses were originally massive igneous rocks. Lithologically, the batholith consists of anorthosite suite rocks (Map Units 2 to 4), mainly gneissic quartz monzonite, with several large units of monzonitic and syenitic rocks and scattered small units of anorthositic and related mafic rocks. The southern

part of the batholith between Bark Lake and Southwestern Hagarty Township (Maps ~~P1838, P2355, P2356, P2357~~ ~~Map A, back pocket~~) is relatively rich in gneissic tonalite. Petrographically, the rocks are similar to anorthosite suite rocks in the Burwash area (Lumbers, 1975).

~~(Lumbers, 1975)~~ Most of the anorthositic rocks are relatively mafic and contain between 20 and 30 percent ferromagnesian minerals (mainly biotite and amphibole, but some phases contain clinopyroxene). Plagioclase ranges in composition between about An25 and An45. North of Golden Lake and east of Ferricke, relatively small units containing anorthositic rocks are composed largely of gneissic diorite. Gneissic tonalite is essentially a quartz-ferromagnesian sodic andesine rock containing 10 to 20 percent quartz, 15 to 40 percent biotite, amphibole, and, rarely, clinopyroxene, and accessory garnet, potassic feldspar, iron-titanium oxide minerals, apatite, and zircon. ^{anorthositic, and dioritic units is rich in highly stretched xenoliths of amphibolite and tonalitic} Gneissic quartz monzonite in the vicinity of tonalitic rocks and contains up to 15 percent amphibole as the chief ferromagnesian mineral. Such xenolith-rich phases also occur locally where large units of the more mafic phases are absent. Where the xenoliths are minor or absent in the quartz monzonite, biotite is the chief ferromagnesian constituent. Where intensely sheared, the xenolith-rich quartz monzonite is extremely heterogeneous and except for a larger grain size and typical auger structure, it resembles some of the Middle Precambrian metasediments. Cross-cutting relationships of the various phases suggest that the mafic rocks are the oldest followed in order by the monzonitic and syenitic rocks and

quartz monzonite.

The intensely strained nature of the batholith rocks can be attributed to diapirism during the late Precambrian high rank regional metamorphism (Schwerdtner and Lumbers, in ^{press} ~~prep.~~). As shown on the accompanying maps (MapSA ~~****~~, ^{P1836, P1365, P1356, P1357} ~~back pocket~~), numerous oval diapiric structures are outlined by subhorizontal flattening gneissosity and by lithology. An excellent example is in northern Guthrie Township where an oval structure cored by quartz monzonite is surrounded by monzonitic rocks. The core rocks dip subhorizontally, but have superimposed open folds producing dips up to 35 degrees. These folds are ubiquitous throughout the map-area and appear to represent open folding and warping during uplift following culmination of the high-rank regional metamorphism. This origin for the folds is also supported by the facts that the emplacement of many late pegmatite dikes (Map Unit 27) was structurally controlled by the open folds, and structural surfaces related to the folds show slickensides and late cataclasis. All the batholith rocks in areas of subhorizontal gneissosity are markedly strained and show a prominent gneissic layering. In the monzonitic rocks, the layering is commonly reflected by numerous rusty schist zones up to a few metres thick containing graphite and minor amounts of pyrite and pyrrhotite scattered in a sericitic and chloritic quartzo-feldspathic matrix. The rusty zones grade into auger gneiss recognizable as highly strained monzonitic rocks. In quartz monzonite and the mafic rocks, the layering is mainly reflected by biotite-rich zones, generally

less than one metre thick (Photo 1), and rusty schist layers are rare to absent.

Late pegmatite dikes (Map Unit 27) are common throughout the batholith, but the largest dikes are present in the mafic phases, and some of these dikes have been exploited for feldspar and mica. Traces of uranium-bearing minerals are common in the pegmatites, but none appear to be sufficiently rich in uranium to be of economic interest.

LATE PRECAMBRIAN SUPRACRUSTAL ROCKS

COARSE CLASTIC SEQUENCE

The Late Precambrian supracrustal accumulation is dominated by carbonate metasediments and rests unconformably upon rocks of the Algonquin batholith. The base of the accumulation consists of a coarse clastic sequence characterized by a basal arkose and impure sandstone facies locally containing coarse clasts lithologically similar to intrusive phases of the batholith. The upper part of the sequence grades into the carbonate facies by a progressive increase in the amount of intercalated units, derived from calcareous and siliceous mudstones and siliceous limestone.

Typical exposures of the main lithologies found in the sequence are shown in Photos 2 to 5. From Ferris southwest to northern Brudenell Township, the underlying batholith is composed mainly of quartz

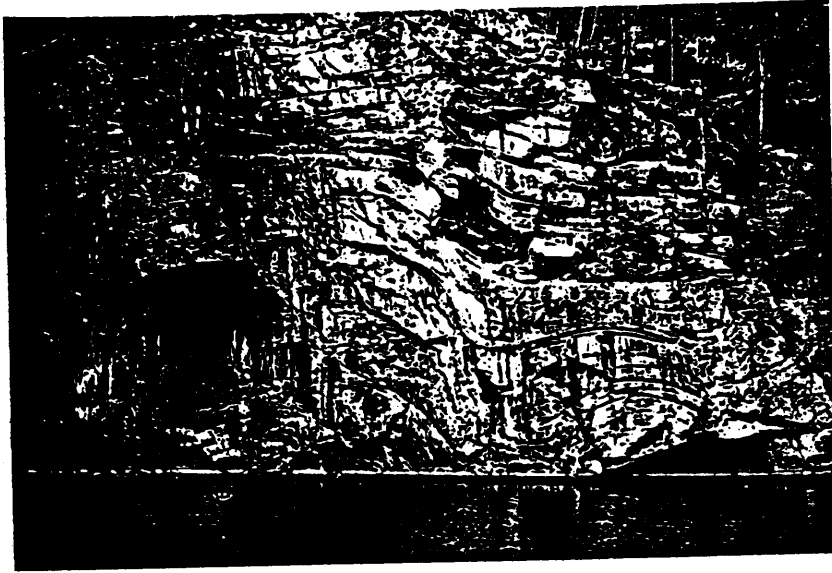


Photo 1



Photo 2

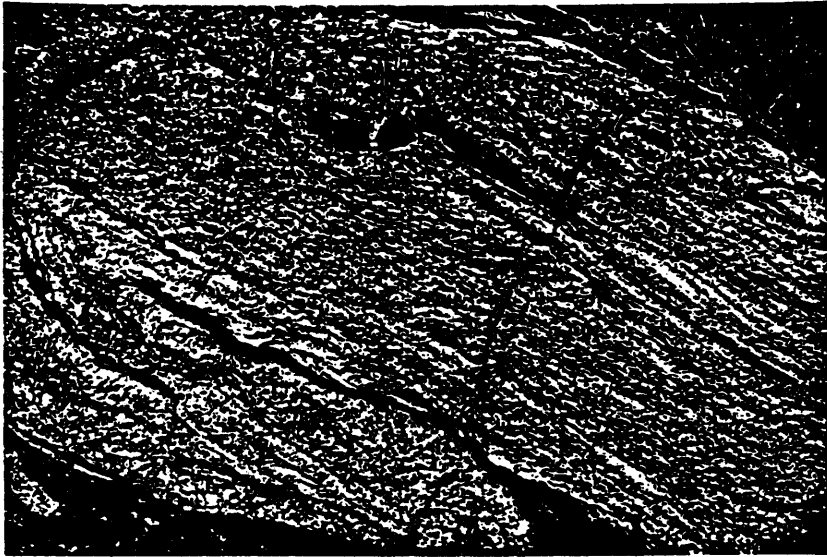


Photo 3

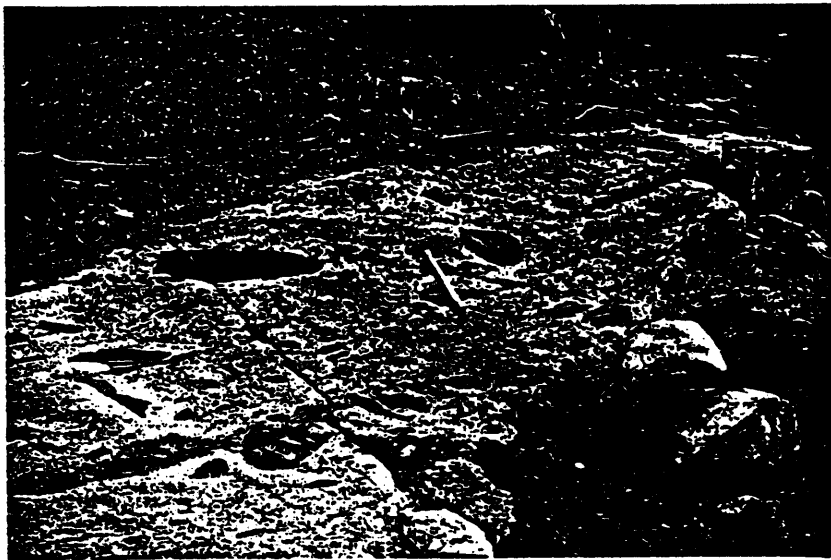


Photo 4

25c



- Photo 5

monzonite, and the sequence is dominated by medium- to coarse-grained gneissic arkose and subarkose locally containing intercalated thin units of siliceous marble and gneiss and schist derived from impure sandstone and calcareous and siliceous mudstone (Photos 2 and 3). Coarse clasts are rare to absent. Southwest from northern Bruderell Township, the underlying batholith is rich in tonalite, and the lowest part of the sequence contains several, thin, lensoid units of gneissic arkosic conglomerate rich in tonalite clasts (Photo 4). Most of the sequence is dominated by micaceous arkosic metasandstone containing isolated coarse clasts of gneissic granitic rocks and local units of gneiss derived from medium to coarse-grained arkose and subarkose and calcareous and siliceous mudstone (Photo 5). Petrographically, variations in plagioclase and potassic feldspar in the arkose and subarkose seem to reflect closely the nature of the underlying batholith rocks; potassic feldspar greatly predominates over plagioclase where quartz monzonite dominates the basement, and the reverse is so where tonalitic rocks are dominant in the basement. Evidently, the sequence reflects detritus derived from the underlying batholith and is largely a residue resulting from the reworking of an arkosic regolith. Further work in progress will help to confirm these preliminary conclusions.

Outliers of the coarse sequence occur within the batholith up to 30 miles (48 km) northwest of the exposed margin of the batholith suggesting that the batholith was once covered by at least part of the Late Precambrian supracrustal accumulation. Metamorphism obscured

or destroyed most primary sedimentary structures in the sequence severely limiting analysis of the environment of deposition.

Recumbent folding of the sequence due to diapirism of the batholith is responsible for irregular boundaries between the batholith and the sequence, and the presence of inliers of batholith rocks within the sequence. In fact, the contact shown on the maps (Maps ~~P1838, P2355, P2356, P2357~~ back pocket) is greatly generalized and in detail, is considerably more irregular than shown.

Further work, including additional mapping of its eastward and westward continuation, could prove the sequence to be of economic importance because it appears to represent one major environment in which concentrations of uranium are known to form. No such concentrations were found in the sequence during the present study, and the amount of uranium concentrated in the underlying batholith is unknown.

CARBONATE METASEDIMENTS

Carbonate metasediments (Map Unit 10) consist of marbles derived from impure limestone and dolostone. Most of the marble is calcite rich and contains at least 5 percent siliceous impurities. Two main varieties of calcite-rich marble are distinguished on the maps (Maps ~~+++, back pocket~~): 1) calcitic marble containing less than 20 percent siliceous impurities; and 2) siliceous marble containing 20 to 50 percent siliceous impurities. Both varieties contain the

following impurities: phlogopite, chlorite, pyrite, pyrrhotite, graphite, quartz, apatite, titanite, tremolite, potassic feldspar, plagioclase, brown tourmaline and zircon. The siliceous variety also contains scapolite, diopside, epidote, allanite, and biotite. Most commonly, the two varieties are intercalated, and variations in the amount of impurities reflect original bedding. Thin units of amphibole-rich metasediments and minor calcareous and siliceous shaley metasediments are commonly intercalated with siliceous marble and also serve to indicate original bedding. Some calcitic marble contains up to 5 percent very fine-grained pyrite, and when struck by a hammer, it gives a strong odor of H₂S. Such marble contains minor intercalated dolomitic marble and is most common near Ottawa^w River in Ross and Horton Townships. Rarely, units up to several metres thick of orthoquartzite and subarkose are intercalated with calcitic marble. Most of the marble is coarsely recrystallized and grey to light grey with average grain sizes ranging between 2 and 5 mm. Locally in highly strained zones in marble-rich terrains containing recumbent folds and subhorizontal gneissosity such as north of LeClaire Lake in Matawahan and Erougham Townships, very coarse calcitic marble with average grain sizes up to 1 cm predominate. In the marble-rich terrain of McNab Township where gneissic foliation dips subvertically, the marbles are locally distinctly less strained and recrystallized than elsewhere. Fine grained, dark grey calcitic and siliceous marbles intercalated with coarser marbles show well-preserved bedding features. They contain abundant very fine-grained graphite which causes the dark grey

colour, and diopside, scapolite, epidote, and allanite are rare to absent.

Most of the dolomitic marble occurs southeast of the alkalic complex, and except for minor unmappable thin units in calcitic marble and moderately thin units near Centennial and Black Donald Lakes in Matawahan, Brougham, and North Canonte Townships, all major units of dolomitic marble show some spatial association with metavolcanics. Such an association has also been recognized elsewhere within the late Precambrian supracrustal accumulation (Lumbers, 1964, 1969). Two main varieties of dolomitic marble are present: 1) medium to coarse-grained, white to greenish dolomitic marble relatively free of impurities; and 2) medium to coarse-grained cherty dolomitic marble containing numerous thin beds of coarsely recrystallized chert and siliceous zones rich in tremolite. The main impurities in both varieties are phlogopite, chondrodite (commonly partly to completely serpentinized), quartz, chlorite, graphite, tremolite, apatite, diopside, talc, scapolite, titanite, pyrite, and pyrrhotite. Cataclastic deformation of tremolite-rich dolomitic marble along fault zones produced fibrous tremolite, a form of asbestos. Southwest of Renfrew in Admaston Township, a thick unit of dolomitic marble and cherty dolomitic marble locally contains concentrations of sphalerite accompanied by minor pyrite and rare galena confined to relict beds ~~and appear to be primary constituents in the marble.~~ indicating that this mineralization formed either during, or shortly after, deposition of ~~and appear to be primary constituents in the marble.~~ The relatively thick dolomitic marble unit in southern Foss Township contains several zones with only minor impurities, and some of these are

quarried for building stone, and the production of magnesium.

Skarn, a light to dark green, medium to coarse-grained rock rich in diopside and amphibole, is commonly developed in the carbonate metasediments near contacts with intrusive rocks and in the vicinity of late pegmatite dikes. This rock is particularly abundant in the alkalic complex which contains numerous arcuate screens and xenoliths of carbonate metasediments. Most of the skarns are massive to only slightly gneissic, but some have undergone extreme deformation and recrystallization. In addition to diopside and amphibole, the other major minerals present are scapolite, carbonate, titanite, and potassic feldspar. Minor minerals, some of which are major constituents in a few skarns, are pyrite, pyrrhotite, chalcopyrite, molybdenite, magnetite, vesuvianite, fluorite, phlogopite, plagioclase, zircon, biotite, epidote, chlorite, apatite, garnet, magnetite and allanite. A few skarns are radioactive and possibly contain uranium minerals. The distribution, mineralogy and field relationships of the skarns suggest that most were formed by the reaction of carbonate metasediments with either fluids, ^{rich} in Si, Al, Fe and Mg derived from adjacent intrusive rocks, or fluids responsible for pegmatite dike formation.

In Bayot Township north of Calatogie Lake on the abandoned railway line, an exposure of siliceous marble contains a few thin units of feldspar-quartz-scapolite-carbonate gneiss containing layers rich in pyrite and pyrrhotite. This rock could be derived from sulphide

facies iron formation. Similar rocks also occur near the northern end of Centennial Lake in Matawacha Township.

OTHER METASEDIMENTS

Other metasediments in the map-area are derived from either calcareous and siliceous mudstones containing minor sandy and carbonate sediments, or from clay-rich to quartz-rich sandstones. Mappable units of rocks derived from calcareous mudstone are intercalated with the carbonate metasediments and are associated with units of clastic siliceous metasediments. Calcareous mudstone represents facies changes from predominantly chemical and biochemical sedimentation to clastic sedimentation. Thus, original carbonate and siliceous components in this rock varied considerably, and upon metamorphism, this variation produced a variety of petrographic types. These rocks show prominent lithologic layering due to large variations in mineralogy, but in general, they contain abundant amphibole and plagioclase and are referred to herein as amphibole-rich metasediments (Map Unit 9). In addition to amphibole and plagioclase, individual layers contain accessory to essential amounts of diopside, potassic feldspar, biotite, scapolite, epidote, carbonate, titanite, apatite, zircon, garnet, tourmaline, pyrite, pyrrhotite, and iron-titanium oxide minerals. The mineralogical layering reflects original bedding, and other types of metasediments are intercalated with these rocks as subordinate thin units paralleling the layering. In amphibole-rich metasedimentary units

within carbonate metasediment sequences, the subordinate facies is commonly siliceous marble. Where amphibole-rich metasediments are associated with thicker sequences of clastic siliceous metasediments, the subordinate facies is dominated by clastic siliceous metasediments. Near Calabogie Lake in Bagot Township, amphibole-rich metasediments intercalated with rocks derived mainly from siliceous mudstones (Map Unit 8) locally contain thin, coarsely recrystallized cherty layers and layers up to a few centimetres thick rich in iron-titanium oxide minerals and pyrite. These ferruginous rocks were probably derived from iron formation.

Rocks derived from siliceous mudstone differ from the amphibole-rich metasediments in containing minor or no amphibole, generally abundant quartz, plagioclase, and biotite, and coarse porphyroblasts of garnet. They also vary considerably in mineralogy and in addition to the aforementioned minerals, they contain accessory to essential amounts of potassic feldspar, muscovite, sillimanite, scapolite, diopside, carbonate and iron-titanium oxide minerals; titanite, apatite, graphite, pyrite, pyrrotite, tourmaline, chlorite, allanite and zircon are the main accessory minerals. Diopside, scapolite, and
 → *** * * see page 31a** ←
 (up to 70 percent) and the feldspar is either predominantly
 plagioclase or potassic feldspar; most contains less than 10 percent amphibole, biotite, and muscovite. Some subarkose is relatively rich in biotite and muscovite, with coarse porphyroblasts of garnet.

Thinly bedded, biotitic metasandstone and biotite-rich shaly

carbonate are present only in rocks containing amphibole; sillimanite is confined to quartz-rich phases lacking calc-silicate minerals. One occurrence of siliceous mudstone intercalated with metawacke on the west shore of Ottawa River, about 1.5 miles (2.4 km) north of Muskrat Rapids in Ross Township, contains minor cordierite. The siliceous mudstones occur in thinly bedded sequences containing subordinate amounts of intercalated quartzose and feldspathic metasandstones, amphibole-rich metasediments, and siliceous marble (Photo 6), and they form subordinate layers in sequences of amphibole rich metasediments and rocks of units 6a and 6b. Sequences composed mainly of siliceous mudstone are designated as map unit 8 on the accompanying maps (Maps ~~A++++~~, ^{P1838*, P2355, P2356, P2357} back pocket), and are included under the calcareous metasediments because of a high content of amphibole rich metasediments and locally abundant siliceous marble.

A few sequences composed mainly of metamorphosed arkose and subarkose (Map Unit 7) were mapped in various parts of the area, commonly in association with amphibole-rich metasediments and calcareous and shaly metasediments. Locally, the sequences contain intercalated impure metasandstone, siliceous marble, and rarely, orthoquartzite. One of the thickest and most persistent of these sequences is in southern Lyndoch Township. This sequence also contains locally abundant, coarse-grained arkose similar to that found in the coarse clastic sequence, and abundant intercalated amphibole-rich metasediments and rocks derived from siliceous mudstone. The metasubarkose is mainly a quartzo-feldspathic rock dominated by quartz *

32b

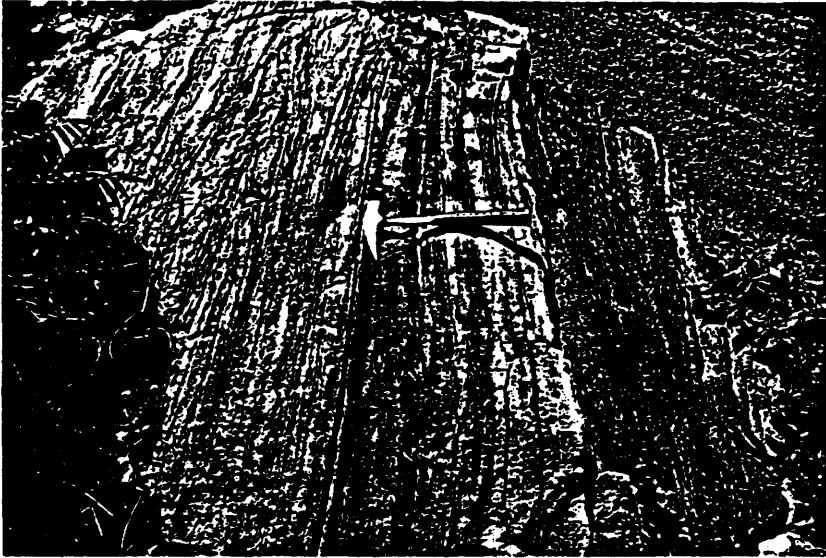


Photo 6

metasediments from several thin to relatively thick units in Ross and Horton Townships near Ottawa River, in Admaston and eastern Grattan Townships, and extending southward from Calatogie Lake in Blithfield, North Canoto, and Bagot Townships. These rocks appear to represent thinly bedded ^{grey}wacke sequences, similar to ^{grey}meta^{wacke} sequences interpreted as volcanoclastic aprons deposited about eroded volcanic highlands in the Bancroft-Madoc area (Lumbers, 1967; 1969). Most, but not all, of the units in the map-area show some spatial association with metavolcanics, so that these units may also represent apron deposits. Lithologically, the rocks consist mainly of biotite, quartz and oligoclase. Amphibole is locally abundant in some of the rocks and absent in others; potassic feldspar is either absent, or rare, in marked contrast with most of the other clastic siliceous metasediments in the map-area. Scarcity of potassic feldspar is also characteristic of the volcanoclastic apron deposits. Common accessory constituents are pyrite, pyrrhotite, iron-titanium oxide minerals, allanite, garnet, apatite, titanite, zircon, epidote, tourmaline, and carbonate. A few rocks rich in amphibole also contain scapolite and diopside, and garnet is most abundant in kicite-rich shaly portions. Sequences of these rocks in North Canoto and Blithfield Townships and locally in Admaston and eastern Grattan Townships were intruded by a variety of igneous rocks and contain dikes and sills of these rocks in addition to porphyroclasts of alkalic feldspar and irregularly developed lenses of quartz feldspathic material. Such rocks are designated by a separate code (6b) on the accompanying maps (P1838, P1355, P1356, P1357 (Maps + + + +, back pocket)).

On the eastern shore of Mile Lake in southern Elithfield Township, silty, biotitic units less than one metre thick and intercalated with ^{grey} meta-wacke contain a few layers generally less than one centimetre thick rich in magnetite. This rock probably is derived from iron formation.

One occurrence of intraformational metaconglomerate was mapped on an island in Black Donald Lake near the eastern boundary of Matawahan Township. This rock contains a variety of clastic siliceous metasedimentary clasts and coarsely recrystallized quartz clasts in a biotite-rich matrix containing sillimanite, quartz, plagioclase, and garnet.

METAVOLCANICS

Rocks most likely derived from metavolcanics are scarce in the map-area and are confined to the following: 1) predominantly felsic to intermediate metavolcanics of the Oak Lake formation (Lumbers, 1967) near the southwestern corner of the area in Haglan, Mayo and Ashby Townships; 2) mafic metavolcanics in northern Denbigh Township; 3) two thin units of felsic to intermediate, and mafic metavolcanics in the dolomitic marble sequence containing zinc mineralization southwest of Renfrew in Admaston Township; 4) predominantly mafic metavolcanics near Ottawa River in Foss Township; and 5) mafic metavolcanics near the southern shore of White Lake and the southern

end of the White Lake ^{Trondhjemite} ~~basaltic~~ in Eagct and Darling Townships. This last unit is part of an extensive sequence of metavolcanics trending southwestward beyond the map area (Figure 1). The metavolcanics are highly deformed and recrystallized, so that only vestiges of primary volcanic structures are preserved. The mafic metavolcanics are amphibolite, rich in plagioclase, amphibole, iron-titanium oxide minerals, and titanite. Relic pillows and stretched plagioclase phenocrysts and amygdaloidal structures are the main primary volcanic structures preserved. Felsic and intermediate metavolcanics consist mainly of fine-grained, leucocratic, quartz-feldspathic gneiss and schist and micaceous quartz-feldspathic schist. Micaceous varieties commonly contain both biotite and muscovite and minor garnet and amphibole; sillimanite occurs rarely. Many of the units contain abundant potassic feldspar, but in some, sodic oligoclase is the dominant feldspar. Fragmental facies are present in felsic units in Admaston Township (Photo 7) and at the southwestern boundary of the map-area. This facies and the micaceous facies may represent pyroclastic deposits. The leucocratic quartz-feldspathic facies may represent original felsic flows, but relic primary structures indicative of this origin were not found in these rocks.

East of Calabogie Lake in Eagct Township and in northern Denbigh and southern Lyndoch Townships, units of amphibolite and quartz amphibole-plagioclase gneiss may, in part, be derived from mafic metavolcanics. The Eagct Township unit contains abundant intercalated siliceous marble and impure metasediment units



Photo 7

generally less than two metres thick, whereas the other unit consists mainly of prominently layered amphibolite with layering reflected by variations in amphibole, quartz, and plagioclase contents. No unequivocal primary volcanic structures were found in either unit, and on the accompanying maps (Maps ~~A-1-1-1-1~~, ^{P1838, P2366, P2356, P2357} Lack pocket) the rocks are designated by a separate code (Map Unit 9e) under amphibole-rich metasediments. Highly strained and recrystallized phases of metagabbro and metadiorite bodies are similar in appearance to the unit in Lyndoch and Denbigh Townships, and this unit is at the margin of such a mafic intrusive body. Recognizable mafic metavolcanics were also mapped near this unit in northern Denbigh Township.

RUSTY SCHIST

Rusty weathering, graphitic schist is widespread throughout the Late Precambrian supracrustal rocks and is particularly common at contacts between carbonate metasediments and both more siliceous metasediments and plutonic rocks. Such contacts containing rusty schist show evidence of late shearing. The schist also occurs as isolated pods up to a few metres long in siliceous marble and in shear zones near major faults. Only a few units are sufficiently large to be shown on the accompanying maps (Maps ~~A-1-1-1-1~~, ^{P1838, P2365, P2356, P2357} Lack pocket). The schist is similar lithologically to rusty schist developed in the Algonquin batholith and mapped in the Bancroft-Madoc area southwest of the map-area (Lumbers, 1967). Locally, the schist is rich in pyrite and pyrrhotite, and one unit in southeastern Bagot Township was mined for

pyrite. Many occurrences of the schist show evidence of a replacement origin at a late stage during the high rank regional metamorphism. Much of the schist is developed in irregular zones that ~~cut~~ ^{cut} across ¹⁾ bedding and gneissosity in the metasediments; and 2) lithologic layering and gneissosity both at the margins and within the interior of metamorphosed intrusive bodies. Much of the rusty schist in the Bancroft-Madoc area also shows evidence of a replacement origin, but some also appears to be derived from pyritic black shale (Lumbers, 1967; 1968; 1969). Further work is necessary before these rocks can be satisfactorily interpreted.

BIOTITE DIORITE SUITE

Rocks of the biotite diorite suite can be subdivided into three main groups (Map Units 13, 14 and 15): 1) diorite and related mafic rocks; 2) syenitic rocks; and 3) granitic rocks. The main rock types comprising each group are classified according to the scheme shown in Table 1. This classification scheme differs from many of the current plutonic rock schemes based upon mineral content, chiefly in a more detailed subdivision of the syenitic and granitic rocks. Such a subdivision is necessary in order to distinguish among the common rock-types found in the various plutonic suites and to relate these rocks to mineral deposits. Many current schemes do not distinguish granodiorite, trondhjemite, and tonalite, three of the most abundant rocks of the biotite diorite suite. Although the classification used here may prove useful in a more general context, it is designed

TABLE 1 - MODAL CLASSIFICATION OF NON-FELDSPATHOIDAL PLUTONIC ROCKS

Quartz	Potassic Feldspar Total Feldspar	ESSENTIAL FELDSPAR Composition of Plagioclase				MONOMINERALIC	LESS THAN 10% FELDSPAR
		Albite An ₀₋₁₀	Oligoclase An ₁₀₋₃₀	Andesine An ₃₀₋₅₀	Labradorite, etc. An ₅₀₋₉₀		
			Quartz				
QUARTZ GREATER THAN 10%	$> \frac{2}{3}$	Alkalic	Monzonite				
	$\frac{1}{3} - \frac{2}{3}$	Granite	Granodiorite				
	$\frac{1}{8} - \frac{1}{3}$	Sodic Granite	Trondhjemite	Tonalite	Quartz Gabbro		
	$< \frac{1}{8}$	Albite Granite					
QUARTZ LESS THAN 10%	$> \frac{2}{3}$	Alkalic	Calc-alkalic syenite			Anorthosite	
	$\frac{1}{3} - \frac{2}{3}$	Syenite	Monzonite			Hornblende	
	$\frac{1}{8} - \frac{1}{3}$	Sodic Syenite	Syenodiorite			Pyroxenite	Peridotite
	$< \frac{1}{8}$	Albite Syenite	Oligoclase Diorite	Diorite	Gabbro	Dunite	

Note: Common varieties of gabbro and anorthosite are:

1. Norite: a gabbro with more orthopyroxene than clinopyroxene.
2. Anorthositic gabbro: a gabbro with 22.5% to 35% ferromagnesian minerals.
3. Gabbroic anorthosite: an anorthosite with 10% to 22.5% ferromagnesian minerals.
4. Plagioclase content of anorthosite ranges between oligoclase and anorthite. Quartz content of tonalite is rarely > 20%, and of quartz gabbro, rarely > 10%. Granites, quartz monzonite, granodiorite, and trondhjemite generally contain > 20% quartz. Quartz syenite refers to syenites containing between 10 and 20% quartz.

specifically to facilitate discussion of the various members of the plutonic rock suites present in the map-area.

Rocks of the biotite diorite suite form several sill-like bodies, stocks, and small batholiths throughout the southeastern part of the area, south and east of the large complex of alkalic suite intrusive rocks. Most of the intrusions are dominated by either diorite, or trondhjemite, but a few, such as the Slate Falls Complex, are rich in both mafic and granitic phases. Rocks of the syenite group are mainly confined to the Norway Lake Complex in Bagot Township, the stock north of the Hurds Lake Trondhjemite in Adiraston and Horton Townships, and the dioritic stocks south of Calabogie Lake in Bagot Township and west of Colton Lake in Adiraston Township. All the intrusions of the suite are regionally metamorphosed, but the level of strain and recrystallization of the rocks varies greatly. In general, the most highly strained and recrystallized rocks coincide with areas where gneissic foliation dips less than 60 degrees. The Norway Lake Complex, which for the most part displays subhorizontal gneissosity is perhaps the most highly strained and recrystallized intrusion. Moderately strained and recrystallized portions of the intrusions are characterized by augen structure, and relict primary igneous textures are commonly preserved. Zones of high strain are characterized by prominent gneissic layering, and primary igneous textures are largely destroyed.

Mafic rocks of the suite are dominated by diorite and tonalite. Where

least deformed, diorite consists mainly of plagioclase and amphibole (in part, altered pyroxene), whereas tonalite contains visible quartz and biotite in addition to plagioclase and amphibole. Both rocks generally contain at least 30 percent mafic minerals, but relatively leucocratic phases are found containing only 10 to 15 percent mafic minerals. Leucocratic tonalite is difficult to distinguish from trondhjemite in the field; most of the leucotonalite appears to be confined to the Slate Falls Complex in southern Lyndoch and northern Denbigh Townships. Minor gabbro containing sodic labradorite (An50 to An55) is commonly associated with diorite, but the two rocks cannot be reliably distinguished in the field. Locally in some diorite intrusions, such as the Eagle Hills body, recrystallized pyroxenite and peridotite form small irregularly shaped masses that cut across the diorite. Plagioclase in diorite ranges in composition from An30 to An50, and in tonalite, from An30 to An40. Highly strained phases of both diorite and tonalite commonly contain garnet porphyroblasts generally less than 5 mm across. One highly strained diorite and gabbro body near the northern end of Lac Du Rocher Fenou on Ottawa River, Ross Township, contains abundant garnet up to a few centimetres in size. Cordierite, hypersthene, and garnet are present in highly strained tonalite forming part of a trondhjemitic stock near the southern end of Lac Du Rocher Fenou. Associated trondhjemite contains cordierite and garnet where highly strained. This is the only occurrence of cordierite and hypersthene observed in rocks of the biotite diorite suite, and the only occurrence of the assemblage garnet-cordierite-hypersthene found in the map-area. Such an

assemblage is commonly regarded as indicative of granulite facies metamorphism.

Syenitic rocks consist mainly of greissic, leucocratic albite syenite in which quartz is lacking or rare. Locally, the quartz content increases to form albite quartz syenite and albite granite. Potassic feldspar is rare or lacking in all these rocks. Some of the rocks containing quartz also contain minor pyroxene intergrown with amphibole, and this aggregate forms peculiar arcuate wisps prominent on weathered surfaces. The stock containing syenitic rocks just north of the Hurds Lake Trenchjferite in Admaston and Horton Townships is lithologically extremely complex with heterogeneous mixtures of albite syenite and sodic granitic rocks rich in screens and xenoliths of metasediments. Near the southeastern part, the stock is relatively homogeneous and consists mainly of trenchjferite, granodiorite, and sodic quartz syenite. Tourmaline is a common accessory mineral in most of the rocks, and this is the only intrusion of biotite dicrite suite rocks in which accessory tourmaline was identified. Further work is required to satisfactorily interpret the intrusion, and on the accompanying map (Map ^{P1838*} ~~A~~, back pocket), the complex rock assemblage is designated by map unit 14b. One possible explanation for the heterogeneous lithology is that the present erosion surface intersects the roof zone of the intrusion exposing contaminated intrusive phases formed by the reaction of the magma with the enclosing metasediments.

Granitic rocks of the suite consist of trondhjemite, granodiorite, and minor albite granite and quartz monzonite. Potassic feldspar forms less than 5 percent of the trondhjemite which is generally a grey to pink, medium to rarely coarse-grained rock generally containing no more than 15 percent biotite, amphibole and epidote as the main mafic constituents. Trondhjemite locally grades into leucotonalite described above, and near contacts with marble, trondhjemite containing up to 30 percent amphibole is developed, commonly with numerous skarn and calc-silicate xenoliths. This mafic trondhjemite closely resembles tonalite in hand specimen. The amphibole content of trondhjemite crudely reflects the composition of plagioclase. Trondhjemite, in which the plagioclase composition is between An₁₀ and An₂₀, contains little or no amphibole and is not associated with leucotonalite. Trondhjemite in which the plagioclase composition is between An₂₀ and An₃₀ commonly contains amphibole as the main mafic constituent, and such trondhjemite locally grades into leucotonalite by a slight increase in the anorthite content of plagioclase. Quartz generally forms between 20 and 35 percent of the trondhjemite. Granodiorite is similar to trondhjemite, except for a higher content of potassic feldspar. Some granodiorite is markedly porphyritic with relict plagioclase and potassic feldspar crystals up to a few centimeters in size. Such rocks are best developed in the Griffith batholith ~~biotite diorite suite intrusions~~ in Griffith Township. Albite granite and quartz monzonite generally form late dikes in trondhjemite and granodiorite, but in some intrusions in Matawathan Township major phases of intermixed granodiorite and quartz monzonite are present.

Gneissic granite pegmatite dikes are common in some intrusions rich in granitic rocks, and the dikes were most likely formed at a late stage during the emplacement of the intrusions.

Most of the mineralization associated with the biotite diorite suite occurs in dioritic intrusions. Minor copper and nickel are concentrated in mafic gabbro or pyroxenite and peridotite, and small contact metasomatic iron deposits are present in marble bordering some dioritic intrusions containing syenitic phases. Concentrations of molybdenite occur in metasomatized carbonate metasediments occurring in screens or at the borders of some trondhjemite-rich intrusions.

MAFIC SILLS AND DIKES

Small dikes and sills of amphibolite derived from gabbro are common in the metasediments and many of the intrusive rocks throughout the map-area. Most of these mafic bodies are too small to be shown on the accompanying maps (Maps ^{P1818, P1819, P1820, P1821} A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, back pocket), but they are particularly common in marble-rich portions of the Late Precambrian supracrustal accumulation where they form relatively large bodies in Horton, McNab, Ross, and Lyndoch Townships. The age of the intrusions is unknown, except that they predate the late high rank regional metamorphism. They most likely represent multiple ages. Some of the intrusions in the Late Precambrian supracrustal rocks could be related to volcanism, whereas others in the Algonquin batholith and

Middle Precambrian metasediments could be older than the deposition of the Late Precambrian supracrustal rocks.

ANORTHOSITE SUITE

Anorthosite suite intrusive rocks that intruded the Late Precambrian supracrustal rocks can be subdivided into two main groups: 1) anorthosite and related mafic rocks (Map unit 17); and 2) monzonitic and syenitic rocks (map unit 18). Granitic phases are rare in marked contrast to anorthosite suite rocks forming the Algonquin batholith. Most of the anorthosite suite rocks are associated spatially with the large alkalic complex, and although they are scattered throughout the complex, they are most abundant in that part lying northeast of Brudenell Township. ~~Three~~ ^{Four} small bodies of these rocks occur southeast of the complex, one trending southwestward from Colton Lake in Admaston Township, another, the Elbow Anorthosite, that straddles Madawaska River in Blithfield Township, ~~and~~ a third at the southern end of Norcan Lake, North Carleton Township, ~~and a fourth, the Burns Lake Complex, in northeastern Griffith Township.~~

Lithologically, the anorthosite suite rocks are similar to those of the Algonquin batholith and others mapped elsewhere in the Grenville Province of Ontario (Lumbers, 1971; 1975; 1976a; 1967b; Lumbers and Krogh, 1977). The rocks are strained and recrystallized due to superimposed high rank regional metamorphism, and the most highly metamorphosed phases coincide with zones of shallow dipping to subhorizontal gneissosity. Where least metamorphosed, the rocks are

augen gneisses displaying relict primary igneous textures. Gneissic phases showing prominent mineralogical layering and little or no relict primary igneous textures are confined to areas of subhorizontal to shallowly dipping gneissosity.

Most of the anorthositic rocks contain oligoclase or andesine and about 10 to 25 percent ferromagnesian minerals, and dioritic phases, containing up to 45 percent ferromagnesian minerals, are commonly associated with the anorthositic rocks. Labradorite-bearing anorthosite is confined mainly to the Elbow Anorthosite in Blithfield Township and is associated with minor gabbroic anorthosite and locally abundant tonalite which is concentrated mainly near the margins of the body. Plagioclase in the anorthositic phases ranges in composition from about An55 to An70. Ferromagnesian constituents in all the anorthositic rocks are mainly amphibole and biotite, but a few contain minor clinopyroxene and epidote. Many of the oligoclase and andesine anorthosites contain a trace to about two percent potassic feldspar, and all the anorthositic rocks contain scapolite and less than one percent quartz intergrown with amphibole and biotite. Corundum-bearing andesine anorthosite, containing less than 10 percent biotite as the only ferromagnesian mineral, is confined to the alkalic complex as xenoliths in alkalic syenite. Gneissic tonalite is common in the alkalic complex where it forms relatively large bodies intruded by alkalic granite-rich portions of the complex. Most of the tonalite is similar to tonalite of the Alouquin batholith and the biotite diorite suite, but a garnet-rich variety

occurs sparingly in the alkalic complex ^{and} is best developed in central Grattan Township. This rock is essentially a garnet-biotite-quartz-andesine gneiss with quartz constituting 15 to 20 percent of the rock, and garnet 8 to 15 percent.

Monzonitic and syenitic rocks are associated mainly with anorthositic rocks south of Mink Lake in Wolferforce Township and east and north of Muskrat Lake in Westmeath Township. ^{Two} ~~CPE~~ intrusion^{s, one} trending southwest from Colton Lake in Adiraston Township, ^{and the Burns Lake Complex, are.} is rich in monzonitic and syenitic rocks and containing minor late phases of alkalic syenite.

The age of the anorthosite suite rocks cutting the Late Precambrian supracrustal rocks is poorly known. Field relationships indicate that they are older than alkalic syenite and granite of the alkalic suite, and two bodies are cut by rocks of the quartz monzonite suite. No rocks of the anorthosite suite are in contact with rocks of the biotite diorite suite, so that relative age relationships between these two suites cannot be established in the field. The abundance of anorthosite suite rocks in the alkalic complex may be fortuitous, but elsewhere in the Grenville Province of Ontario alkalic rocks are also closely associated with anorthosite suite rocks suggesting that a genetic link may exist between the two suites (Lumbers, 1975; 1976b).

QUARTZ MONZONITE SUITE

The quartz monzonite suite is mainly expressed as a series of

intrusions extending northward from North Canonto Township to Horton Township. Other intrusions of the suite are present in southeastern Lynnoch Township and at the southwestern corner of the map-area in Mayo and Ashby Townships. Most intrusions of the suite are regionally metamorphosed and gneissic, but a few are only slightly metamorphosed and are predominantly massive, suggesting that they were emplaced during the waning stages of the regional metamorphism. The massive intrusions are confined to Breughart Township in the vicinity of the Mt. St. Patrick Syenite, and to the McArthur Mills pluton in Mayo and Ashby Townships at the southwest corner of the map-area. The McArthur Mills pluton has been dated isotopically at about 1080 m.y. old (Silver and Lumbers, 1966).

Lithologically, the suite consists mainly of leucocratic quartz monzonite, but phases containing up to 20 percent ferromagnesian minerals are locally common. Plagioclase ranges in composition from about An10 to An25, but in some intrusions composed mainly of leucocratic quartz monzonite, plagioclase is slightly more sodic than An10 producing alkalic granite. Potassic feldspar varies in abundance within some intrusions, so that locally, granodiorite is present. Muscovite, biotite, and amphibole are the only other abundant minerals in rocks of the suite. Titanite, epidote, apatite, iron-titanium oxide minerals, allanite, and zircon are the main accessory constituents. Amphibole is most abundant in granodiorite phases and in quartz monzonite containing skarn or amphibolite xenoliths. Otherwise, biotite and muscovite either greatly

predominate over amphibole, or amphibole is absent.

The large area of quartz monzonite suite rocks in North Canonic and Blithfield Townships cuts anorthosite suite rocks, and lithologically, the quartz-monzonite contains abundant xenoliths of amphibolite and tonalitic rocks, much the same as quartz monzonite of the Algonquin batholith. Perhaps further work may provide data to genetically connect some of the quartz monzonite suite intrusions with the anorthosite suite. Massive to only slightly gneissic quartz monzonite near the Mt. St. Patrick syenite could be related to the syenite, but further work is also needed to prove such a relationship.

ALKALIC SUITE

The alkalic suite is the most variable of the various plutonic rock suites recognized. Lithologically, rocks of the suite can be subdivided into four major groups: 1) alkalic granite; 2) alkalic syenite; 3) nepheline syenite; and 4) mafic ^aalkalic rocks. Except for nepheline syenite pegmatite formed during the latter stages of the late high rank regional metamorphism, rocks of the nepheline syenite group were completely recrystallized and highly deformed during this metamorphism. Some rocks of the other three groups were only slightly recrystallized and deformed during the regional metamorphism, whereas others are completely recrystallized gneisses. Thus, the suite was apparently emplaced over an interval encompassing the waning stages

of the regional metamorphism. Rocks of the suite are concentrated mainly in one major complex lying just south of the Algonquin gneiss. Minor occurrences of the suite also occur south of the main complex in southern Baglar and Lyndoch Townships and near Calabogie Lake in Bagot Township. Portions of the alkalic complex have been studied over the years, and most of the studies have concentrated upon associated chromium mineralization and the distribution and petrogenesis of the nepheline syenites (see, for example, Hewitt, 1960; Carlscr, 1957; Appleyard, 1967). Until the present study, the existence and rock associations of the alkalic complex remained largely unknown. Only a few of the major features of the complex will be summarized here; more detailed accounts will be given following completion of studies in progress.

Mafic rocks of the suite consist of gabbroic and dioritic rocks, ijolite, mafic scapolite-bearing gneisses of complicated mineralogy possibly derived in part from ijolitic rocks, and magnetite-rich rocks. Both massive and gneissic phases of the gabbroic and dioritic rocks are present. Massive phases containing primary igneous textures and mineralogy are found only locally within gabbroic and dioritic bodies and consist mainly of 40 to 85 percent biotite, clinopyroxene (partly altered to amphibole), and clinovine, and 15 to 60 percent sodic plagioclase ranging in composition from about An15 to An45. Some of these rocks also contain minor potassic feldspar. Olivine is confined to mafic-rich, melanocratic phases which also contain the most calcic plagioclase. Metamorphosed phases of the gabbroic and

dioritic rocks^k consist mainly of plagioclase (sofic oligoclase to andesine), 25 to 50 percent amphibole, clinopyroxene, and biotite, and generally abundant titanite and apatite; minor potassic feldspar is present in some of these rocks and absent in others. In the field, these rocks are similar in appearance to metagabbro present in some of the other plutonic rock suites. The mafic alkalic body east of Calabogie Lake in Bagot Township is one of the largest of the alkalic gabbro and diorite bodies, and like many of these bodies, it is cut by a few alkalic syenite dikes. Such dikes, if present, are the best clue in the field to suggest the alkalic nature of the mafic rocks. Only one occurrence of massive ijolite was mapped and this is in northeastern Raglan Township on the east side of Little Mississippi River near its junction with York River in the Conroy Marsh. The rock is coarse-grained and consists mainly of nepheline and dark brown titanite which is partly enveloped corona-fashion by fine-grained garnet and amphibole. Mafic scapolite-bearing gneiss is associated with rocks of the nepheline syenite group and is most abundant in the Wolf nepheline syenite body in Lyndoch Township described by Appleyard (1967). Magnetite-rich rocks occur in the alkalic gabbro body in Bagot Township east of Calabogie Lake, in alkalic granite in Grattan Township east of Highway 41, and sparingly in the Wolf nepheline syenite body (Appleyard, 1967). The occurrences in Bagot and Grattan Townships have been mined as iron deposits. The Bagot Township occurrence appears to be a contact metasomatic deposit developed in marble. The Grattan Township occurrence consists mainly of various mixtures of magnetite, titanite, quartz, clinopyroxene,

albite, potassic feldspar, rictite, and zircon, and it occurs as a series of lenses in alkalic granite.

Rocks of the nepheline syenite group form only a minor part of the alkalic complex and are found in Sebastopol, Griffith, Brudenell, Lyndoch, and Raglan Townships. Most of these occurrences were mapped previously (Hewitt, 1960; Appleyard, 1967; Themistocleous, 1978, 1979), but one occurrence in Lyndoch Township at the northeastern margin of the alkalic granite body containing the Jamieson Mine (No. 14, Map back pocket) was not mapped previously. In addition, a few boulders of gneissic nepheline syenite were found in the southeast corner of Lyndoch Township east of the McCoy Mine (No. 17, Map ^{p257} ~~back pocket~~, back pocket), but the gneiss was not found in outcrop. The nepheline syenite consists of two main lithologic types; 1) perthitic, rictite, nepheline syenite, which is generally leucocratic with muscovite, carbonate, plagioclase, iron-titanium oxide minerals, apatite, and titanite as the main accessory constituents; and 2) plagioclase nepheline syenite which varies greatly in mineralogy and contains various amounts of scapolite, rictite, titanite, iron titanium oxide minerals, vesuvianite, carbonate, muscovite, corundum, apatite, garnet, amphibole, sodic pyroxene, fluorite, and rarely, minor potassic feldspar. Plagioclase in both varieties ranges in composition from An0 to An25, the perthitic variety generally contains albite or sodic oligoclase. Nepheline syenite pegmatite is a massive, coarse-grained rock composed mainly of nepheline, sodic plagioclase (commonly albite), and locally, carbonate. It occurs as

lenses, both cross-cutting, and subparallel to, the gneissic foliation in the nepheline syenite and as irregularly shaped masses in mafic scapolite-bearing gneiss.

The most common lithology present in the alkalic syenite group consists of massive to gneissic, medium to coarse-grained, sodic pyroxene-albite-perthite syenite (Phtc 8) containing variable amounts of amphibole (generally an alteration product of pyroxene), biotite, titanite, apatite, iron-titanium oxide minerals, allanite, zircon, carbonate, and muscovite; garnet, scapolite, tourmaline, graphite, and nepheline are rarely present in trace amounts. One occurrence of this syenite rich in graphite flakes up to 1.5 cm across was mapped just east of Heid Lake near the east-central boundary of Brudenell Township. Optical determinations indicate that the pyroxene is in the soda hedenbergite-aegirine-augite compositional range. Titanite is generally abundant (up to 10 percent) in most of the syenite, and locally, the syenite contains quartz and grades into alkalic granite containing sodic pyroxene. Gneissic syenites containing little or no sodic pyroxene and generally only minor potassic feldspar, are found sparingly as xenoliths in the sodic pyroxene syenite and are particularly common in association with nepheline syenite. These syenites are generally leucocratic and dominated by albite or sodic oligoclase, and various mixtures of biotite, muscovite, amphibole, corundum, titanite, iron titanium oxide minerals, carbonate, and zircon. Many occurrences of these leucocratic syenites are characterized by heterogeneous

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Photo 8

mixtures of sodic pyroxene and amphibole syenites, leucocratic syenite pegmatite (locally containing nepheline and corundum), mafic scapolite-bearing gneiss, and gneissic andesine anorthosite. Many of the corundum occurrences are in this type of lithology which is designated as map unit 22c.

The alkalic granite is mainly a massive to gneissic, pink, leucocratic, medium to coarse-grained rock composed of albite, quartz, and perthitic potassic feldspar with accessory biotite, sodic clinopyroxene, titanite, apatite, carbonate, iron-titanium oxide minerals, zircon, allanite, amphibole, muscovite, and rarely, fluorite and tourmaline. Iron-titanium oxide minerals (mainly magnetite) are commonly abundant and form as much as 12 percent of the rock. In places, particularly within some major units of sodic pyroxene syenite and near Lake Clear in Setastopol Township, sodic pyroxene forms 10 to 15 percent of the alkalic granite. Although potassic feldspar greatly predominates over albite in most of the occurrences of the granite, local phases of sodic granite containing more albite than potassic feldspar are not uncommon. Massive varieties, which were only slightly affected by regional metamorphism, contain a few micritic cavities containing quartz and feldspar crystals, and, rarely, fluorite.

Throughout most of the alkalic complex, sodic pyroxene alkalic syenite and sodic pyroxene alkalic granite commonly contain numerous patches and intersecting veinlets of coarse-grained sodic pyroxene

(mainly aegirine and aegirine-augite) locally containing intergrown sodic amphibole and coarse-grained apatite and calcite (Photo 9), and dikes and nests of sodic pyroxene syenite pegmatite and granite pegmatite (map unit 27). Sodic pyroxene syenite and sodic pyroxene alkalic granite rich in the pyroxene veinlets locally contain scattered lenses of apatite-calcite pegmatite (Photo 10) up to several meters long and generally only a few meters across. This pegmatite is rare to absent in that portion of the complex in Baglan, Lyndoch, and all but the eastern part of Erudenell Townships. The pegmatite contains numerous coarse crystals of green, red, and brown apatite up to 30 cm long, amphibole and sodic pyroxene crystals and aggregates up to one meter in size, titanite crystals up to several centimeters in size, potassic feldspar crystals up to 30 cm across, minor scapolite crystals, and some fluorite generally intergrown with calcite; zircon and biotite crystals are rarely present. All of these rocks were emplaced during the waning stages of regional metamorphism after rocks forming the bulk of the complex were emplaced, and they form an integral part of the complex suggesting that they are genetically related to the complex, particularly sodic pyroxene syenite and alkalic granite phases. Pyroxene veinlets and sodic pyroxene syenite pegmatite are also abundant in supracrustal rocks enveloping the complex and occurring as screens within the complex. A few occurrences of sodic pyroxene syenite pegmatite were mapped south of the complex in Lyndoch and southern Baglan Townships, but the pyroxene veinlets are confined to the complex and its immediate envelope of supracrustal rocks. Granite pegmatite dikes are also



Photo 9



Photo 10

widespread throughout the Precambrian rocks of the map-area, but they are particularly abundant in the alkalic complex. Similar sodic pyroxene veinlets and syenite pegmatite bodies are typical products of fenitization - associated with alkalic rock-carbonatite complexes within the Ottawa-Bonnechere Graben (Lumbers, 1971) and are also developed in association with lenses of carbonatite cutting metasediments in Sullivan Island in Ottawa River, Westmeath Township (see below). Perhaps the veinlets and syenite pegmatites associated with the complex also reflect a late stage fenitization. Relative to the pyroxene veinlets, at least two generations of granite pegmatite are present because some of the veinlets cut this pegmatite, whereas others are cut by the pegmatite.

In the past, a few apatite-calcite pegmatites were mined for apatite, and they remain a major attraction for mineral collectors and mineralogists. Sodic pyroxene syenite pegmatite occurring south of Bruceton in the southwestern corner of Lyndoch Township contains coarse flakes of molybdenite up to 4 cm across and was mined in the early 1900s (No. 17, Map ^{P2357} ~~17~~, rack pocket). Minor uranium mineralization is associated with pegmatitic and siliceous phases of the alkalic complex in Sebastopol Township (Themistocleous, 1978).

SYENITE-MONZONITE SUITE

Rocks of the syenite-monzonite suite are mainly only partly deformed and recrystallized and were emplaced at a late stage relative to the

high rank regional metamorphism. The suite is represented by only a few stocks in Griffith, Brougham, Bagot, McMab, Admaston, and South Algoma Townships. The largest stocks are in Griffith and Brougham Townships. Most of the stocks are predominantly composed of medium to coarse-grained, grey to pink, equigranular to porphyritic, leucosyenite and biotite syenite containing abundant mesoperthite and minor oligoclase. Phases containing ferrohastingsite and minor augite are present in many of the intrusives, together with minor monzonite and early tonalite, diorite, and gabbro. Syenites containing amphibole and pyroxene generally contain xenoliths of skarn and calc-silicate rocks. Locally, within some of the intrusions, quartz is a minor to major constituent, and the syenites grade into quartz syenite and quartz monzonite. Titanite, iron titanium oxide minerals, epidote, carbon^bate, muscovite, and zircon are common accessory minerals in the syenitic^a and granitic phases. A few of the stocks are cut by late granite pegmatite dikes (map unit 27) suggesting that the suite is older than the late pegmatites.

The only mineralization associated with rocks of this suite consists of minor magnetite concentrations in skarn developed at the margin of the stock immediately east of Calatogie Lake in Bagot Township.

LATE MAFIC INTRUSIVE ROCKS

A few dikes of partly recrystallized and cataclastic metadiabase emplaced during the waning stages of the high rank regional

metamorphism were mapped in various parts of the area, but mainly in the Late Precambrian supracrustal portion. ~~The dikes are particularly abundant in Griffith Township where they cut rocks of the Burns Lake Complex and rocks of the syenite-monzonite suite in Griffith Township suggesting the Griffith batholith. That the dikes postdate this suite.~~ The age of the dikes relative to the late pegmatite dikes is unknown, but the two varieties of dikes could overlap in age because both varieties were emplaced during the waning stages of the high rank regional metamorphism.

LATE PEGMATITE

Late granite pegmatite dikes are abundant in all the gneisses of the map-area, but most of the dikes are small, lenticular bodies generally less than a few meters long and one meter wide. They commonly formed in dilatant zones within the gneisses, and many of the dikes follow late open folds formed during uplift of the metamorphic complex after culmination of the late high rank regional metamorphism. A small proportion of the dikes are relatively large and are mainly spatially associated with older gneissic intrusive rocks. Large dikes up to tens of meters long and several meters across are relatively common in anorthositic and tonalitic rocks of the Algonquin batholith, and a few of these dikes were mined for feldspar and mica. Large dikes are also present in mafic rocks of the biotite diorite suite, the anorthosite suite cutting the Late Precambrian supracrustal rocks, and in syenitic and granitic rocks of the alkalic suite. With few exceptions, the largest dikes, some of which can be traced along strike for nearly 3 km, are in carbonate-rich

supracrustal rocks within less than 0.6 km of contacts of relatively large intrusive bodies, mainly rocks of the biotite diorite suite and the quartz monzonite suite. A major exception to this general mode of occurrence of the largest dikes is a 3 km-long dike extending northward from Miller Lake in southeastern Admaston Township; this dike cuts siliceous metasediments, and the closest intrusive stocks or larger ^b bodies are 2 km or more from the dike.

The dikes are composed of alkalic feldspar, quartz, and mica (mainly biotite, but abundant muscovite in some dikes) as the major constituents, and a large variety of accessory constituents, chief among which are amphibole, garnet, apatite, calcite, zircon, tourmaline, molybdenite, iron-titanium oxide minerals, pyrite, pyrrhotite, and traces of uranium and rare earth minerals. Graphic intergrowths of quartz and feldspar are common; some dikes are zoned with quartz-rich cores, and some dikes contain crystals of feldspar and micas up to 60 cm across. Most of the dikes are partly hematitized, which produces pink hues in the rock, but dikes in marble-rich sequences are generally white and lack hematitization. Some of the accessory constituents listed above are rarely concentrated within the dikes. The large dike in southeastern Admaston Township contains abundant concentrations of tourmaline, and a few dikes near rocks of the biotite diorite suite in southeastern Baglan Township contain concentrations of uraninite and minor uranothorite associated with small biotite-rich patches and pyritic zones near the margins of the dikes. These dikes appear to contain

the largest concentrations of uranium found to date in the map-area. Small concentrations of molybdenite occur in a few dikes, and beryl is concentrated in two dikes associated with alkalic granite of the alkalic suite near Quadeville in Lyndoch Township.

Field evidence suggests that the late pegmatite dikes were emplaced over an undefined interval of time during the waning stages of the high rank regional metamorphism. Some of the dikes are cataclastic, whereas others are massive and completely undeformed. Mention was made above of at least two generations of late pegmatite in the alkalic complex relative to the pyroxene veinlets. Elsewhere, intersecting pegmatite dikes were observed in a few places. Several late pegmatite dikes from various parts of the Crenville Province surrounding the map-area have been dated radiometrically (Shillibeer and Cumming, 1956; Silver and Irbbers, 1966) and although the ages are close to 1.0 b.y., there is a spread which also suggests emplacement of the dikes over an interval, probably not exceeding a few tens of millions of years.

HIGH RANK REGIONAL METAMORPHISM

Most of the deformation and recrystallization displayed by the gneisses in the map-area can be attributed to the late high rank regional metamorphism which culminated about 1.1 b.y. ago. Most likely, the supracrustal rocks were subjected to folding and low rank regional metamorphism prior to the high rank event; evidence for such

a metamorphism is mainly confined to the Bancroft-Madoc area to the southwest of the map-area (Lumbers, 1967). The intensity of the high rank metamorphism, measured in terms of both mineralogical and structural adjustments of the rocks to physical and chemical conditions which were imposed upon them at depth, varies throughout the area. The most highly metamorphosed rocks coincide with zones of low dipping to subhorizontal gneissosity, and the least metamorphosed rocks are found in zones with steeply dipping to subvertical gneissosity. From a mineral assemblage viewpoint, the gneisses were metamorphosed under the temperature and pressure conditions of the middle to upper almandine amphibolite facies; the only exception is the cordierite-bearing rocks of the biotite diorite suite along Ottawa River in Ross Township which contain mineral assemblages indicative of the granulite facies. Mineral assemblages in the various gneisses seem to correlate mainly with the bulk composition of the rocks and the degree of strain exhibited by the rocks. Establishment of isograds using specific index minerals or mineral reactions would be difficult at best in the map-area. The difficulty of performing such an exercise is well illustrated by the marble-rich terrain in McNab Township where fine-grained marble showing relatively well preserved primary sedimentary structures is complexly intercalated with medium to coarse-grained, coarsely recrystallized marble in which primary sedimentary structures are largely destroyed. Zones of low dipping to subhorizontal gneissosity contain highly strained rocks, and deformation may have promoted relatively higher heat flow than in zones of more steeply dipping gneisses which are

less strained. As mentioned previously, the low dipping to subhorizontal gneissosity reflects recurrent folding related to diapirism of the Algonquin batholith during the high rank metamorphism.

Various minerals of economic interest were formed in the metasediments as a result of the high rank metamorphism. Concentrations of graphite developed locally in the marbles, but unfortunately, the factors involved in controlling the concentration of graphite in these rocks are largely unknown. Garnet and sillimanite developed in shaley metasediments and garnet is locally abundant in some of the gneissic intrusive rocks. Pyrite and graphite were concentrated in rusty schists, most of which developed at a late stage during the high rank metamorphism. Asbestos developed locally in siliceous dolomitic matrix in response to shearing along fault zones. A variety of gneisses suitable for building stone were also produced by the high rank metamorphism, but to date, only some of the marbles have been exploited for this purpose.

OTTAWA-BONNECHERE GRABEN INTRUSIONS

Following the late high rank regional metamorphism, major faulting occurred along the Ottawa-Bonnechere Graben and several small intrusions were emplaced, mainly in the form of dikes localized along the faults. A gabbroic stock and an alkalic rock-carbonatite complex also were emplaced within the graben. These intrusions are

briefly described below.

ALKALIC INTRUSIVE ROCKS

An alkalic rock-carbonatite complex is exposed in the vicinity of Sullivan Island in Ottawa River, about 5 km south of La Pêche, Westmeath Township. Most of the complex consists of partly fenitized clastic siliceous metasediments, mainly rocks of map unit 6a. Fenitization is expressed as zones of intense hematitization localized by abundant fractures in which coarse-grained aggregates and crystals of alkalic amphibole, alkalic pyroxene, and alkalic feldspar have grown metasomatically. Small lenses of aegirine syenite pegmatite are associated with some of the fractures. Where fenitization is most intense, dike-like bodies of two main rock types are present: 1) pegmatitic aegirine syenite; and 2) silicocarbonatite rich in silicate minerals and rounded fragments of fenite (Photo 11). Aegirine syenite consists mainly of coarsely perthitic potassic feldspar, aegirine, titanite, and minor amounts of garnet, pyrite, iron-titanium oxide minerals, sodic plagioclase, calcite, and biotite. A few irregularly shaped masses of very coarse-grained, dark grey to almost black calcite containing as much as 30 percent apatite crystals up to one centimeter long are associated with the syenite. The silicocarbonatite consists mainly of calcite, apatite, titanite, sodic pyroxene, amphibole, phlogopite, and perthitic potassic feldspar; biotite, allanite, pyrite, hematite, and iron-titanium oxide minerals are locally abundant. In places, lenses of carbonatite

relatively poor in the above listed minerals, but containing coarse crystals of brownish to red apatite are present in the carbonatite. Zircon as euhedral crystals up to 2 mm across is invariably present in the silicocarbonatite and carbonatite and forms up to two percent of these rocks. Rounded fragments in the silicocarbonatite consist mainly of highly fenitized metasediments, but fragments of fenitized granitic rocks and late granite pegmatite also occur. A few large granite pegmatite dikes cut the metasediments in the zone of fenitization and are also partly fenitized. The complex is therefore younger than the late pegmatite dikes, and preliminary geochronologic data by T.E. Krogh (personal communication, 1978), on zircons from the silicocarbonatite indicate that this rock has a minimum age of about 1050 m.y. A diabase dike cuts the southern part of the complex, and one silicocarbonatite dike contains a few small mafic-rich dikes composed mainly of calcic plagioclase (An70), lizardite and talc in part pseudomorphous after pyroxene, and iron-titanium oxide minerals. Minor uranium mineralization in pegmatitic aegirine syenite and fenite has been investigated by a few pits and trenches in the southern part of the complex.

Although the complex lies within the Ottawa-Bonnechere Graben which contains several widely scattered alkalic rock-carbonatite complexes (Figure 2), it is also spatially associated with the complex of alkalic suite intrusive rocks. This spatial association plus the widespread fenitization in the alkalic complex in the form of sodic pyroxene veinlets suggests that the Sullivan Island complex may be

related to the alkalic complex.

MAFIC TO ULTRAMAFIC INTRUSIVE ROCKS

The Chenaux Gabbro in Horton and Ross Townships is dominated by partly unalitized gabbro consisting of labradorite, and clinopyroxene with accessory iron-titanium oxide minerals, apatite, and, rarely, traces of quartz. Locally, the gabbro contains coarse-grained, pegmatitic patches containing coarse-grained intergrowths of sodic plagioclase, amphibole, and minor quartz. The pegmatitic patches are widespread throughout the body, but are particularly abundant near the margins. The pyroxene content of the gabbro varies throughout the body, so that in places the rocks are anorthositic, and in ~~at~~ other places they display igneous layering with alternating gabbro, anorthositic, and pyroxene-rich layers. Dikes and irregularly shaped masses of unalitized pyroxenite cut the gabbro locally and contain minor concentrations of pyrite, pyrrhotite, pentlandite, and chalcopyrite. A few dikes of medium-to coarse-grained, porphyritic quartz monzonite and syenite cut the gabbro near the margin of the body. Small, irregular zones of skarn rich in diopside, epidote, and amphibole are common at contacts between the intrusion and the enveloping marbles.

A small intrusion of partly unalitized and serpentized peridotite containing accessory tiny crystals of light blue spinel occurs about 5.0 km west of the Chenaux Gabbro in the northeast corner of Adiraston

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Photoll

Township. The peridotite intrusion cuts marble and is exposed over a width of less than 90 m.

Diabase dikes are common both along, and nearby, the various faults of the Ottawa-Bonnechere Graben north of the Mt. St. Patrick and Arabis Lake Faults. Only a few diabase dikes are present to the south of these faults. The diabase is tholeiitic and consists of oscillating^{ery} zoned andesine-latrocorite, calcic clinopyroxene and pigeonite, minor iron-titanium oxide minerals, biotite, and apatite, and rare interstitial quartz in graphic intergrowth with plagioclase. Some dikes contain a few olivine grains armoured by clinopyroxene. Pyroxene and olivine are slightly altered; the chief secondary minerals are amphibole, serpentine, biotite, and carbonate. A few dikes are sheared and brecciated by post-dike faulting.

A few highly hematitized trachyte dikes dominated by alkalic feldspar were mapped near Calabogie Lake in Bagot Township, and along Barron River in the northeast corner of Master Township. These dikes are tentatively assigned to the Cambrian because similar dikes to the north of the map-area are known to be Cambrian in age (Lumbers, 1971; 1976a).

PALAEZOIC SEDIMENTARY ROCKS

Paleozoic sedimentary rocks are preserved as downfaulted outliers within the Ottawa-Bonnechere Graben. The rocks are subdivided

lithologically, rather than by formations, because their stratigraphy has not been established unequivocally. The oldest unit consists of Lower Ordovician yellow to brown, silty dolostone containing minor partings and interbeds of shale. A few lenses of quartz-pebble conglomerate occur at the base of the unit. Rocks of this unit are exposed only in the vicinity of Arnprior in McNab and Fitzroy Townships and west of Pembroke on the north side of Cotnam Island near Highway 62. A second unit, not in contact with the first, consists of Middle Ordovician green and red shale and siltstone locally with intercalated cross-bedded quartz sandstone. Near the base of the unit, lensoid beds of green glauconitic sandstone and quartz-pebble conglomerate are present. The unit is exposed near Arnprior along Ottawa River in McNab Township and along Ottawa River near Pembroke. The unit is overlain by Middle Ordovician grey fossiliferous bioclastic limestone containing minor dark grey to black shale partings and interbeds. Interbeds of buff dolostone are rarely present in the limestone, and calcareous quartz sandstone is present near the base. A discontinuity may separate the shaley unit from the limestone unit. The limestone unit accounts for all the exposures of Paleozoic sedimentary rocks inland from Ottawa River.

LATE FISSURE VEINS

Late fissure veins of three main types cut both the Precambrian and Paleozoic rocks in the southeastern part of the map-area southeast of Calabogie Lake, in the vicinity of White Lake, and in McNab and

Fitzroy Townships. The fissure veins southeast of Calabogie are composed mainly of dolomite and barite, whereas those in the vicinity of White Lake are hematite-rich. In McNab and Fitzroy Townships, calcite-barite fissure veins locally containing concentrations of galena, sphalerite, fluorite, and hematite are present. Veins of this type were mined for galena at the Kingdom Mine north of Galetta in Fitzroy Township.

SUMMARY OF THE MINERALIZATION

Mineralization related to the various events recorded by rocks of the map-area is summarized in Figure 4, and the distribution of the various deposits is shown on Maps + + + + (rack pocket). Detailed description of the deposits are given by Satterly (1945), Quinn (1952), Newitt (1954), ^{Carter et al. (1979), Gordon and Mason (1979), and Vas and Storey (1979).} and ~~O.G.S. (1979)~~. In Figure 4, mineralization shown in brackets does not occur in the map-area but is known to be present to the southwest in the Bancroft-Madoc area (Lumbers, 1964; 1967). Concentrations of iron associated with faults of the Ottawa-Bonnechere Graben are present in the ^NNorth Bay area (Lumbers, 1971).

Although a large variety of mineral deposits are present in the area, available data suggest that only a few of the deposits are of current economic interest. Nevertheless, the available data are scanty, and much more data, particularly on the mineralogy and chemistry of the deposits and their associated rocks, are needed to properly assess the mineral potential. The present study provides a geological

framework for collecting the additional data. A few general observations on the mineralization are given below.

BASE METAL MINERALIZATION

COPPER AND NICKEL

Concentrations of copper and nickel are confined mainly to mafic intrusive bodies of the biotite diorite suite and the Chenaux Gabbro. Copper and nickel deposits in these intrusions appear to be magmatic segregations developed in mafic gabbro and pyroxenite phases. Of the various mafic intrusive bodies of the biotite diorite suite in the map-area, only the Raglan Hills body is known to contain magmatic segregation copper-nickel deposits. Such deposits are also known in dioritic intrusions of the suite southwest of the map-area, and from studies of these deposits, the author concluded that trace element analyses of magnetic opaque fractions from gabbro and dioritic phases may prove useful in indicating the presence or absence of copper and nickel concentrations in associated mafic gabbro and pyroxenite phases (Lumbers, 1964; 1969). Mineralogically, the deposits are dominated by disseminated chalcopyrite, pyrrhotite, pentlandite, and minor to locally abundant pyrite. Chukanite and sphalerite occur in trace amounts, and chalcopyrite is generally much less abundant than pentlandite and the iron sulphide minerals.

Two small bodies of copper and minor zinc and iron mineralization in

the form of disseminated to massive chalcocopyrite, sphalerite, and magnetite are associated with amphibolite near the margin of the Slate Falls Complex at the southern boundary of Lyndoch Township. Some of the amphibolite may be derived from mafic metavolcanics, but some is derived from gabbro and diorite. Further work is required to determine if the deposits are related to the complex or to some other event, such as mafic volcanism. Minor copper mineralization in the form of sparsely to locally abundant disseminated chalcocopyrite is present in some skarns associated with the alkalic complex and rocks of the biotite diorite suite. Sparsely disseminated chalcocopyrite also occurs in some of the rusty schist units developed in various parts of the map-area.

In summary, present data indicate that the mafic intrusions of the biotite diorite suite and the Chenux Gabbro are the most favourable units for the discovery of copper and nickel deposits in the map-area.

IRON AND TITANIUM

Concentrations of iron in the map-area occur as: 1) contact metasomatic deposits associated with mafic intrusions of the biotite diorite suite and the alkalic suite, and, rarely, rocks of the syenite-monzonite suite; 2) magmatic segregations in gabbro of the biotite diorite suite and in the Chenux Gabbro; 3) concentrations of magnetite associated with alkalic granite of the alkalic suite; 4)

iron formation associated with Middle and Late Precambrian metasediments; and 5) hematite-rich fissure veins. The largest concentrations are developed in contact metasomatic deposits at the margins of mafic intrusions of the tictite diorite suite and the alkalic suite. Iron concentrations in alkalic granite occur as magnetite-rich lenses known only at the Fadner Mine (No. 19, Map ^{P 2357} ~~XXXX~~, back pocket) in Griffith Township and as abundant accessory magnetite in some units of alkalic granite, particularly in southeastern Brudenell and Sebastopol Townships.

Concentrations of titanium are rare in the map-area. Much of the alkalic syenite of the alkalic suite and silicocarbonatite of the alkalic rock-carbonatite complex in Sullivan Island are relatively rich in accessory titanite. Small, localized magmatic segregation iron deposits in gabbroic rocks of the tictite diorite suite and Cheneaux Gabbro are dominated by ilmenomagnetite and contain traces of vanadium. Titanite is also concentrated locally in some skarns and calcite-rich pegmatites associated with the alkalic complex. These various rocks contain the largest concentrations of titanium known in the map-area, and all are too small and too low grade to be of current economic interest.

LEAD

Concentrations of lead are known only in late calcite-barite fissure veins confined to marble-rich terrains in McNab and Fitzroy

Townships. Galena is the chief lead mineral and is generally accompanied by small amounts of sphalerite, hematite, pyrite, barytoceladonite, fluorite, and quartz. Traces of a variety of sulphosalt minerals are present in some of the veins and the galena is commonly argentiferous. The veins appear to be localized along faults related to the Ottawa-Ecnechere Graben, and they show most of the features described by the author for late calcite and quartz fissure veins to the southwest of the map-area (Lumbers, 1964; 1969). Two of the veins were mined for lead (Kingdon Mine, No. 15, Map ^{P 1030*} ←→, back pocket) but most of the known veins are too small and poorly mineralized to be of economic interest. Nevertheless, rock exposure is poor in the marble-rich terrains favourable for the veins, and many others could be present but not exposed. The veins therefore remain as a potential source of lead, if efficient exploration techniques can be devised to locate them.

MOLYBDENUM

Molybdenum, occurring as molybdenite, is concentrated mainly in skarns and pyritic zones developed at contacts between marble and iron-jenite-rich intrusions of the biotite diorite suite and between marble and late granite pegmatite dikes. Traces of molybdenite are common within the late granite pegmatite dikes, but relatively rare in the late sodic pyroxene syenite pegmatite dikes of the alkalic suite. Nevertheless, one syenite pegmatite dike (McCoy Mine, No. 17, Map ^{P 2357} ←→, back pocket) contains numerous large flakes of molybdenite.

The skarn deposits offer the best potential for mineable concentrations of molybdenite, but work on several such deposits to date has failed to reveal sufficient tonnages of ore grade material.

ZINC

Zinc mineralization in the form of sphalerite occurs in association with copper and nickel mineralization, in some of the calcite-barite fissure veins, and in dolomitic marble southwest of Renfrew in Admaston Township. Of these three main occurrences of zinc mineralization, that in dolomitic marble in Admaston Township has the greatest economic potential. The zinc mineralization is in layers conformable with gneissic layering in the host marble and lies on strike between two thin units of metavolcanics. Locally, the dolomitic marble contains relict chert beds. The mineralization, which is similar to that of the Falcat-Edwards district of New York State (Lea and Dill, 1968) within the Late ^P Precambrian carbonate basin, perhaps formed during sedimentation and volcanism. Moreover, the association of zinc and lead mineralization with cherty dolomitic carbonate rocks of both Precambrian and Phanerozoic age is well established. Thus, other main units of dolomitic marble present in the map-area are indicated by separate codes on the accompanying maps (Maps ^{P1136, P1135, P1134, P1137} A ← ← ←, back pocket) and these should be examined for possible concentrations of sphalerite and galena.

~~PRECIOUS METALS~~

PRECIOUS METALS

Concentrations of precious metals of possible economic importance appear to be lacking within the map-area. Trace amounts of gold have been reported from a few quartz veins, and minor silver is associated with the late calcite-barite fissure veins. To the south and southwest of the map-area, gold and silver concentrations of possible economic importance are known in late fissure veins and in calcite and quartz veins (Lumbers, 1964). The main area of gold mineralization within the Late Precambrian carbonate basin is confined to the low metamorphic rank terrain between Bancroft and Madoc characterized by thick deposits of mafic metavolcanics (Lumbers, 1964). Most of the gold mineralization is in quartz-rich veins in metavolcanic sequences near the margins of intrusive rocks of the biotite diorite suite.

URANIUM AND RARE EARTH MINERALIZATION

Uranium and rare earth mineralization is widespread throughout the map-area, but most of the known occurrences are small and not of economic importance. On the accompanying maps (Maps ^{P1315, P1316, P1316, P1317} ~~1315, 1316~~, back pocket), only those occurrences are shown that contain at least local concentrations of uranium and rare earth minerals. Occurrences containing traces of radioactive minerals that are merely of mineralogical interest are omitted. Such occurrences are abundant, and a high probability exists that a detailed search of almost any late granite pegmatite dike would reveal a crystal or two of

radioactive minerals. All the occurrences shown are within the Late Precambrian accumulation south of the Algonquin batholith. Most of the occurrences are in late granite pegmatite dikes, but some are associated with: 1) late phases of the alkalic complex (mainly sodic pyroxene syenite pegmatite, granite pegmatite, and calcite-rich pegmatite); 2) the alkalic rock-carbonatite complex in Sullivan Island; 3) skarns associated with late phases of the alkalic complex; 4) skarns associated with late granite pegmatite dikes; and 5) rarely in late fault zones. Traces of uranium mineralization are common in the various molybdenite deposits developed in association with late granite pegmatite dikes and skarns. Field evidence therefore shows that the uranium and rare earth mineralization was formed late in the plutonic and metamorphic history of the area, and radiometric age determinations on uranium-rich minerals confirm this conclusion (Shillibeer and Cumming, 1956).

In the Algonquin batholith and the Middle Precambrian metasediments, uranium and rare earth mineralization is confined to late granite pegmatite bodies. Radioactive minerals within the various pegmatites are mainly uranium-bearing rare earth species such as euxenite, allanite, fergusonite, and aeschynite. Thorianite and monazite are present in some dikes, but ^{235}U zirconite and uranochlorite, which are common in occurrences south of the Algonquin batholith within the Late Precambrian accumulation, are relatively rare.

An airborne gamma-ray spectrometry survey covering the map-area

(G.S.C., 1976) reveals several areas of anomalously high uranium and thorium concentrations within the late Precambrian accumulation. These areas are: 1) centered over the quartz monzonite body on the western side of Calabogie Lake; 2) centered over the Hurds Lake Trondhjemite; 3) along the Miller-South Carleton Townships boundary; 4) centered over the quartz monzonite body in Elithfield Township, about 3 km southwest of Mile Lake; 5) centered over the region containing the Hunt Mine (No. 12) in Ercingham Township; and 6) that portion of the alkalic complex rich in alkalic granite northeast and southwest of Lake Clear. Most of the anomalies are of low intensity, but the anomaly along the Miller-South Carleton Townships boundary is relatively intense. The anomaly lies just south of the map-area and is underlain mainly by gneissic quartz monzonite containing abundant granite pegmatite dikes according to mapping by Smith (1958). The various anomalies appear to be caused mainly by minor uranium and thorium mineralization in local concentrations of late granite pegmatite dikes and in skarns spatially associated with concentrations of these dikes. The mineralization is mainly in uraninite and uranothorite, but traces of uranium-bearing rare earth minerals are common, especially in occurrences spatially associated with the alkalic complex. Uranium is also concentrated in late granite pegmatite dikes not revealed by the airborne survey, and work to date suggests that the greatest concentrations of uranium and thorium in the map-area are in relatively large granite pegmatite dikes developed in marble-rich supracrustal rocks near the margins of biotite diorite suite intrusives. In all the pegmatite dikes, the

best uranium mineralization is invariably associated with local concentrations of biotite, local pyritic zones, or local concentrations of magnetite, all of which are most commonly developed near the margins of the dikes.

Allanite is a common accessory constituent in alkalic syenite and granite of the alkalic complex, and rarely, the alkalic granite contains traces of uraninite and uranothorite. These minerals are most common in pegmatitic portions of the alkalic granite, especially where the granite contains alkalic pyroxene and local alkalic syenite phases. The alkalic complex extends southwestward beyond the map-area into the Bancroft area where the largest concentrations of uranium and thorium minerals known in the Grenville Province of Ontario (Satterly, 1957) are spatially associated with phases of the complex. Further work is required to determine if the mineralization is genetically related to the complex. Moreover, factors controlling both the concentration of uranium and thorium in the various deposits and the formation of the coarsest pegmatites and associated skarns are largely unknown. Knowledge of these factors would greatly aid in the exploration of known deposits and in the search for new deposits.

The coarse clastic sequence at the base of the Late Precambrian accumulation represents a major unconformity, and such an environment can be favourable for the concentration of uranium. Assessment of this sequence for possible uranium concentrations must await further regional mapping and detailed petrologic and geochemical studies.

Nevertheless, it remains a potential target for uranium exploration.

OTHER METALLIC MINERALIZATION

Other metallic mineralization within the map-area consists of beryllium, magnesium, and zirconium. Beryllium and zirconium mineralization are confined to the alkalic complex. Beryl occurs in two zoned granite pegmatite bodies enclosed within alkalic granite in Lyndoch Township (No. 5, Map ^{P2357} ~~1-1-1~~, back pocket) and is currently mined, chiefly for the lapidary trade. No other concentrations of beryl have been found in the alkalic complex. Trace amounts of lyndochite, columbite, columbian anatase, cyrtolite, monazite, and euxenite accompany the beryl in the pegmatites (Hewitt, 1954). Although traces of zirconium, in the form of zircon, are present in most of the plutonic rocks, pegmatites, and some of the metasediments of the map-area, the only concentrations are in late syenite and calcite-rich and syenite pegmatites of the alkalic complex; some of the carbonatite in Sullivan Island also contains abundant accessory zircon. All of the concentrations appear to be too small to be utilized as a source of zirconium, but one occurrence at the eastern end of Kuehl Lake in Brudenell Township contains scattered zircon crystals up to 7 cm long, some of which are of good hyacinth colour suitable for faceting.

magnesium is produced by Chromasco Limited from dolomitic marl in Ross Township (No. 2, Map ^{P2356} ~~1-1-1~~, back pocket). The dolomitic marl

mined by Chromasco is relatively free of siliceous impurities, and other parts of the unit have been utilized in the past for use as dimension stone and crushed aggregate.

NON-METALLIC MINERALIZATION

DEPOSITS ASSOCIATED MAINLY WITH THE ALKALIC COMPLEX

Most of the known concentrations of apatite and fluorite, and all the concentrations of corundum and nepheline are found in the alkalic complex. Although apatite is a common accessory mineral in most of the rocks of the map-area, the only concentrations are in calcite-rich pegmatites of the alkalic complex and in carbonatite in Sullivan Island which is possibly related to the alkalic complex. Fluorite is also locally concentrated in calcite-rich pegmatites, but it also occurs as an accessory constituent in skarns, nepheline syenite, alkalic granite, and some of the late calcite fissure veins. Present data suggest that the apatite and fluorite-bearing calcite pegmatites are too scattered and small to be mined for apatite and fluorite.

Corundum occurs in gneissic, alkali-rich syenite and pegmatitic syenite, gneissic nepheline syenite, and gneissic anorthosite of the alkalic complex. The corundum formed during deformation and recrystallization of these rocks and is commonly concentrated in narrow layers as barrel-shaped to tapered crystals up to several centimeters long. The known corundum occurrences have proved to be

too small and scattered to be mined profitably. Most of the past production comes from the Craigmont Mine (No. 11, Map ^{P2357} ~~11~~, back pocket) in the northwest corner of Baglan Township (Satterly, 1945).

None of the known occurrences of nepheline syenite and nepheline syenite pegmatite are of sufficient purity and size to be of current economic interest. Some of the larger occurrences have been explored, but no production has resulted (Satterly, 1945; Hewitt, 1960).

ASBESTOS

Asbestos, in the form of fibrous tremolite, is confined to siliceous dolomitic marble that underwent shearing along fault zones. The asbestos occurs as slip-fibre in veins from one mm to 5 cm in width. The fibres rarely exceed about 6 cm in length. A minor amount of asbestos was mined from one occurrence in lot 22, concession IV, Blithfield Township (Hewitt and Satterly, 1953), but none of the occurrences appear to be of current economic interest because of their small size and confinement to narrow fault zones.

BARITE AND CELESTITE

Barite and celestite are confined to the late fissure veins. All the known veins contain only minor amounts of barite of no commercial interest. One fissure vein in lot 27, concession X, Bagot Township, consists mainly of dolomite, celestite, and minor calcite. The

celestite is relatively rich in barium, and minor amounts of this mineral have been mined for use as a filler in the print, paper, and rubber trades with poor results (Satterly, 1945).

FELDSPAR AND MICA

Some of the larger late granite pegmatite dikes have been mined for feldspar and mica, with quartz as a by-product. Most of the production has been achieved from dikes cutting anorthosite and related mafic rocks of the Algouair batholith. Phlogopite was mined from a narrow vein up to 18 cm wide in rusty schist associated with marble in lot 2, concession IV, Ercingham Township. Rose quartz is produced from the beryl-bearing pegmatite-dike in lots 30 and 31, concession XV, Lyndoch Township by Wal-Gen Lapidary Company.

GRAPHITE

Graphite is a common accessory constituent of the marbles and rarely forms small massive lenses within these rocks. An exceptionally large concentration of graphite at the Black Donald Mine (No. 8) was the only source of high quality flake graphite in North America until the mine closed due to flooding. The graphite zone is 1.5 to 1.8 m thick and is conformable with relict bedding in host intercalated calc-silicate metasediments and dolomitic and calcitic marbles. The origin of the graphite zone is unknown, and no comparable graphite concentration has been found in the map-area.

Since the closing of the Black-Ecnald Mine, the only producer of high-purity graphite in North America is the Southwest Graphite Company whose deposit is in Barret County, Texas (Barnes, 1958; Dietrich and Lonsdale, 1958; Zaffaric et al., 1972). The deposit consists of a rusty schist unit, similar in all major aspects to rusty schist units within the map-area, and is developed in metasediments at the margin of a granitic pluton, a setting also common to most of the largest rusty schist units within the map area. Both the rusty schist and the host rocks are in the Llano Uplift, a Precambrian inlier consisting of supracrustal and plutonic rocks comparable in age to those of the late Precambrian accumulation of the map-area and probably forming an extension of the Grenville Province of the Canadian Shield (Barnes et al. 1972). The supracrustal rocks in the vicinity of the deposit are dominated by intercalated marble and calcareous and siliceous shaley metasediments much like those of the map-area, but less metamorphosed. In both the rusty schist of the deposit and the rusty schists of the map-area, graphite is relatively fine-grained (rarely forming flakes more than 10 μ m across) and generally forms no more than 10 to 15 percent of the rock. Local concentrations of massive graphite along shears or in highly strained portions of micro folds are common. Because of the close similarities of the rusty schists of the map-area and the Texas deposit, consideration should be given to exploration of the map-area rusty schists for their graphite content.

The only other rock in the map-area known to contain concentrations of graphite is an exceptionally uncommon occurrence in massive alkalic syenite found by the author just east of Reid Lake in west-central Brudenell Township. The syenite consists mainly of primary, igneous mesoperthite and minor biotite with up to about 10 percent graphite flakes as much as 1.5 cm across, intergrown with the mesoperthite, both along grain boundaries and in fractures. The size of the graphitic syenite is unknown, but it appears to be worthy of exploration.

NEPHELINE SYENITE

Several small bodies of nepheline syenite and nepheline syenite pegmatite are associated with the alkalic complex. Petrographic data indicate that none of these bodies are suitable for the glass, ceramic, or mineral filler industries.

STONE

Several quarries have been operated at various times in the area to obtain stone for the manufacture of lime, building stone, and road metal. Over half the quarries are in Middle Ordovician limestone, and most of the remainder are in Precambrian marble. A few quarries have been opened in the Precambrian gneissic plutonic rocks and siliceous metasediments for road metal. The Middle Ordovician limestone is locally relatively pure containing from 2 to 3 percent $MgCO_3$ (Guge,

1933; Hewitt, 1964), and it has been used for making lime. Currently, the limestone is quarried for crushed aggregate. Precambrian calcitic marble has been used for making lime, but this marble generally contains at least 5 percent $MgCO_3$ and variable amounts of siliceous impurities mainly concentrated in relict beds. The thickest and most abundant sequences of calcitic marble relatively free of siliceous impurities are in the marble-rich terrains in McMab Township and in the vicinity of Leclair Lake in Matawatchan and Brougham Townships. Elsewhere, the calcitic marble is mainly siliceous with only local thin units relatively free of siliceous impurities. The thickest units of dolomitic marble relatively free of siliceous impurities are in Ross Township. Most of the marble quarried for building stone has been white, coarsely recrystallized dolomitic marble low in siliceous impurities because this marble is less friable and wears better than coarsely recrystallized white calcitic marble. Moreover, thick sequences of white calcitic marble low in impurities and suitable for quarrying are rare to absent.

No attempt has been made to utilize the various Precambrian gneisses as an ornamental and building stone. Some of these gneisses could prove suitable for these purposes because the complex metamorphic and tectonic history produced several varieties of the gneisses, particularly the plutonic rocks, that take a good polish and have interesting combinations of colors and textures. Gneissic plutonic rocks similar to some of those in the map-area are quarried elsewhere outside Ontario and marketed in Canada's large urban centers. The

only massive plutonic rock in the area with consistent colour and texture is the McArthur Mills pluton at the extreme southwestern corner in Mayo and Ashby Townships.

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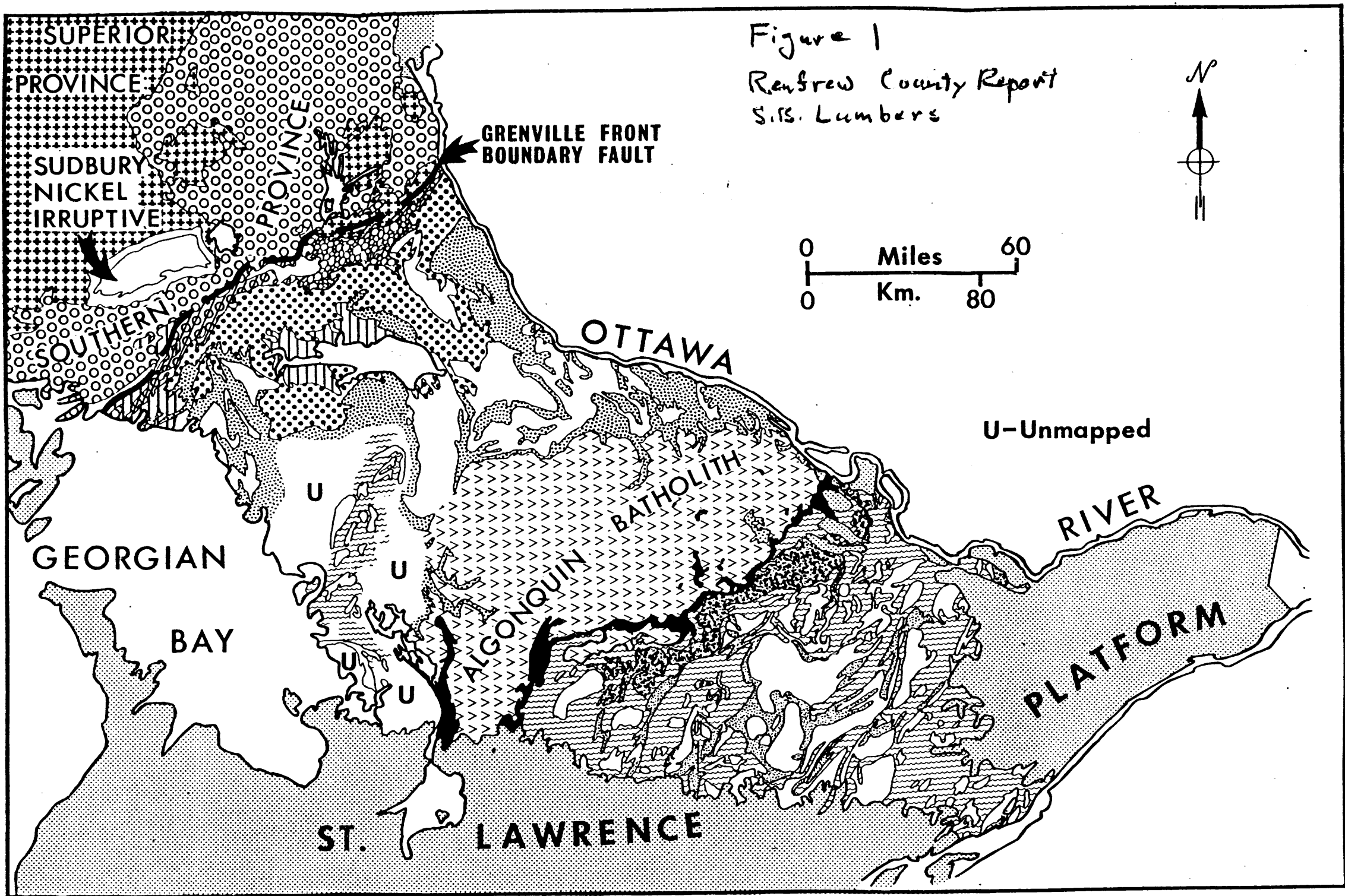
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1 < + & + 2520



LEGEND

PHANEROZOIC

 Unsubdivided Paleozoic sedimentary rocks

PRECAMBRIAN

Grenville Province

Late Proterozoic

 Alkalic plutonic rocks

 Unsubdivided plutonic rocks

 Metavolcanics

 Carbonate and other metasediments

 Coarse clastic sequence

Unconformity

 Algonquin batholith (unsubdivided)

Early Proterozoic

 Unsubdivided plutonic rocks

 Shallow to deep water metasediments and other metasediments

 Deep water turbidite deposits (mainly greywacke-siltstone)

 Gneissic metasediments derived from the Huronian Supergroup

 Coarse clastic sequence


Unconformity

Archean

 Gneissic Archean plutonic and supracrustal rocks

Grenville and Superior Provinces

 Unsubdivided early Proterozoic rocks of the Southern Province

 Unsubdivided Archean rocks of the Superior Province

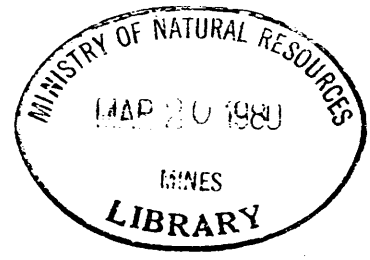
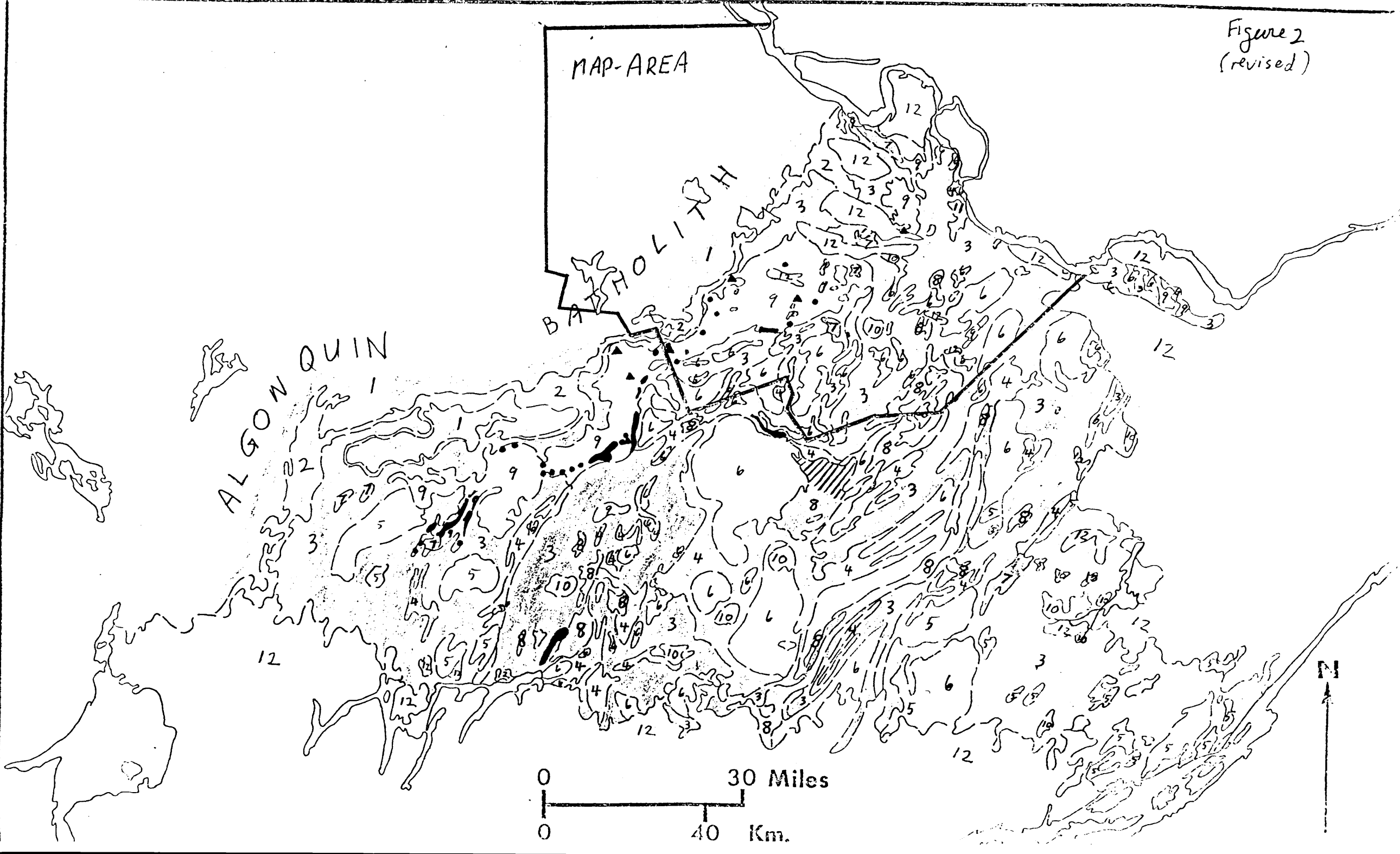


Figure 2
(revised)



Explanation - Fig. 2

- 12 Paleogene Sedimentary Rocks
- 11 Late Gabbro
- 10 Syenite-Monzonite Suite
- 9 Alkalie Suite
Nepheline Syenite (small occurrences in solid ◦)
- 8 Quartz Monzonite Suite
Rich in alkalic granite
- 7 Anorthosit Suite (small occurrences in solid ▲)
- 6 Biotite Diorite Suite
- 5 Unsubdivided Plutonic Rocks
- 4 Metavolcanics
- 3 Unsubdivided Metasediments; minor metavolcanics and plutonic rocks
- 2 Coarse clastic Sequence.
- 1 Pliocene Batholith

Figure 3

Figure 3
Renfrew County

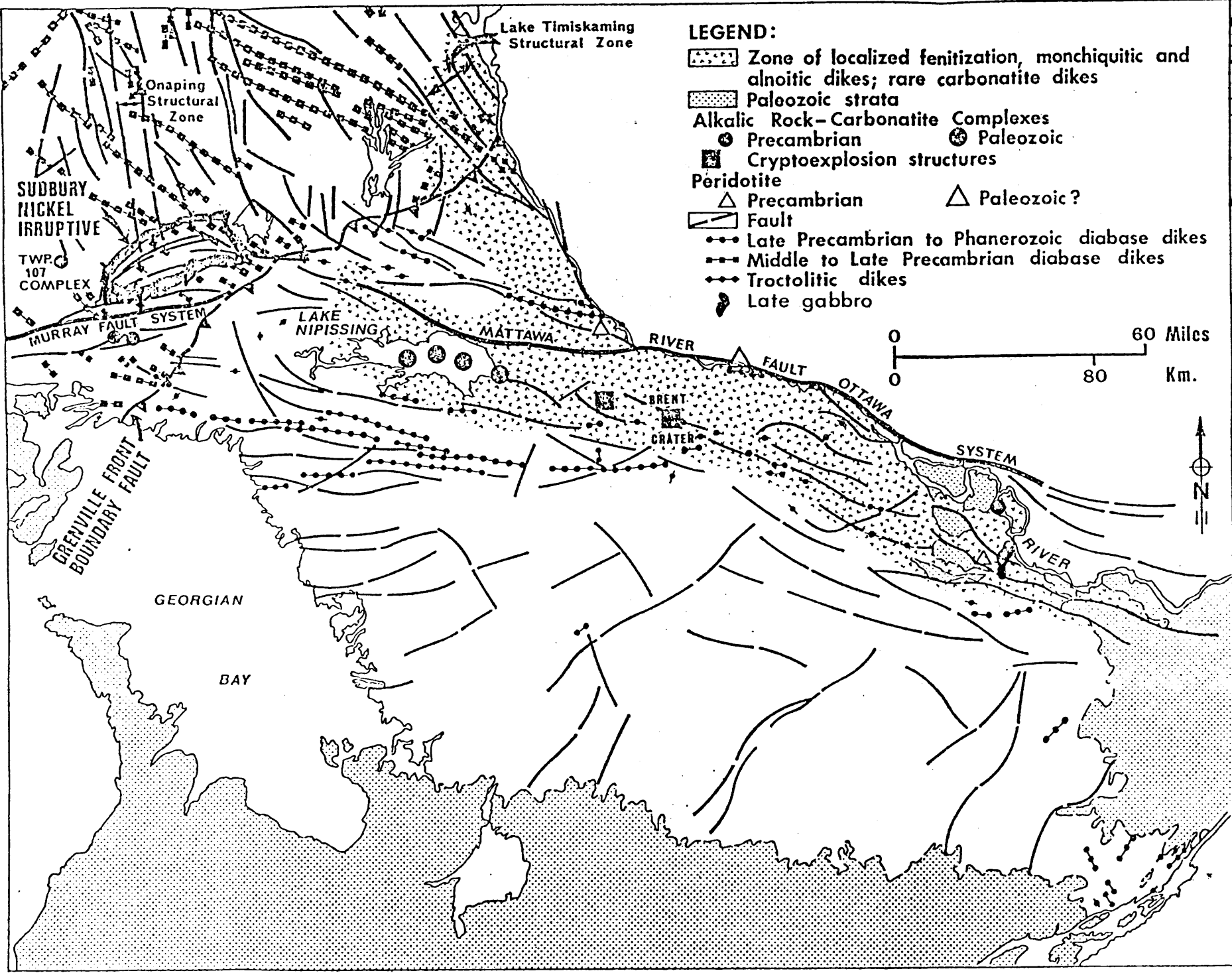
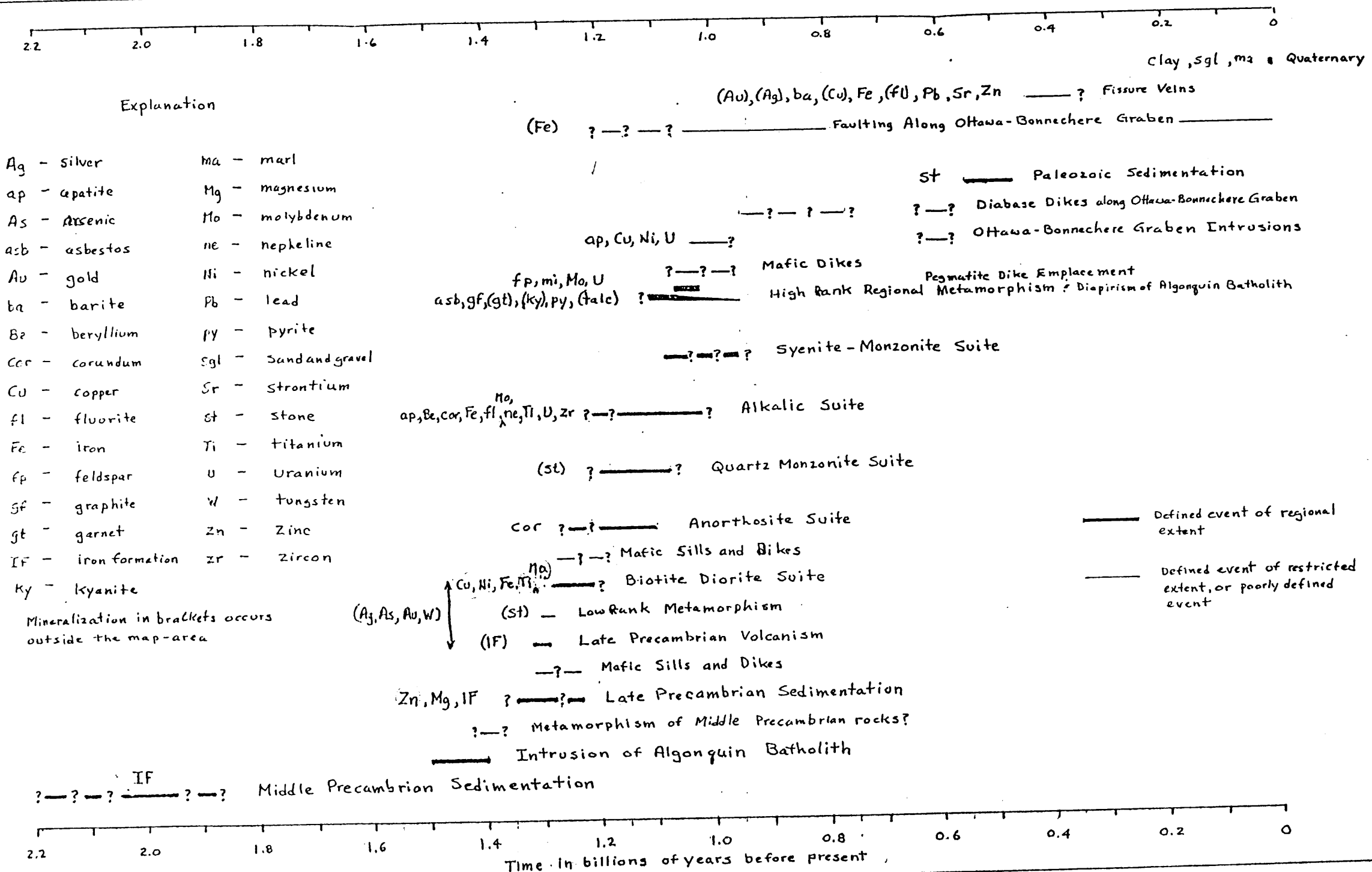


Figure 4



LEGEND

Note: This legend is common for National Geochemical Reconnaissance Map 17-1977, Open File 506 and Map 18-1977, Open File 507.

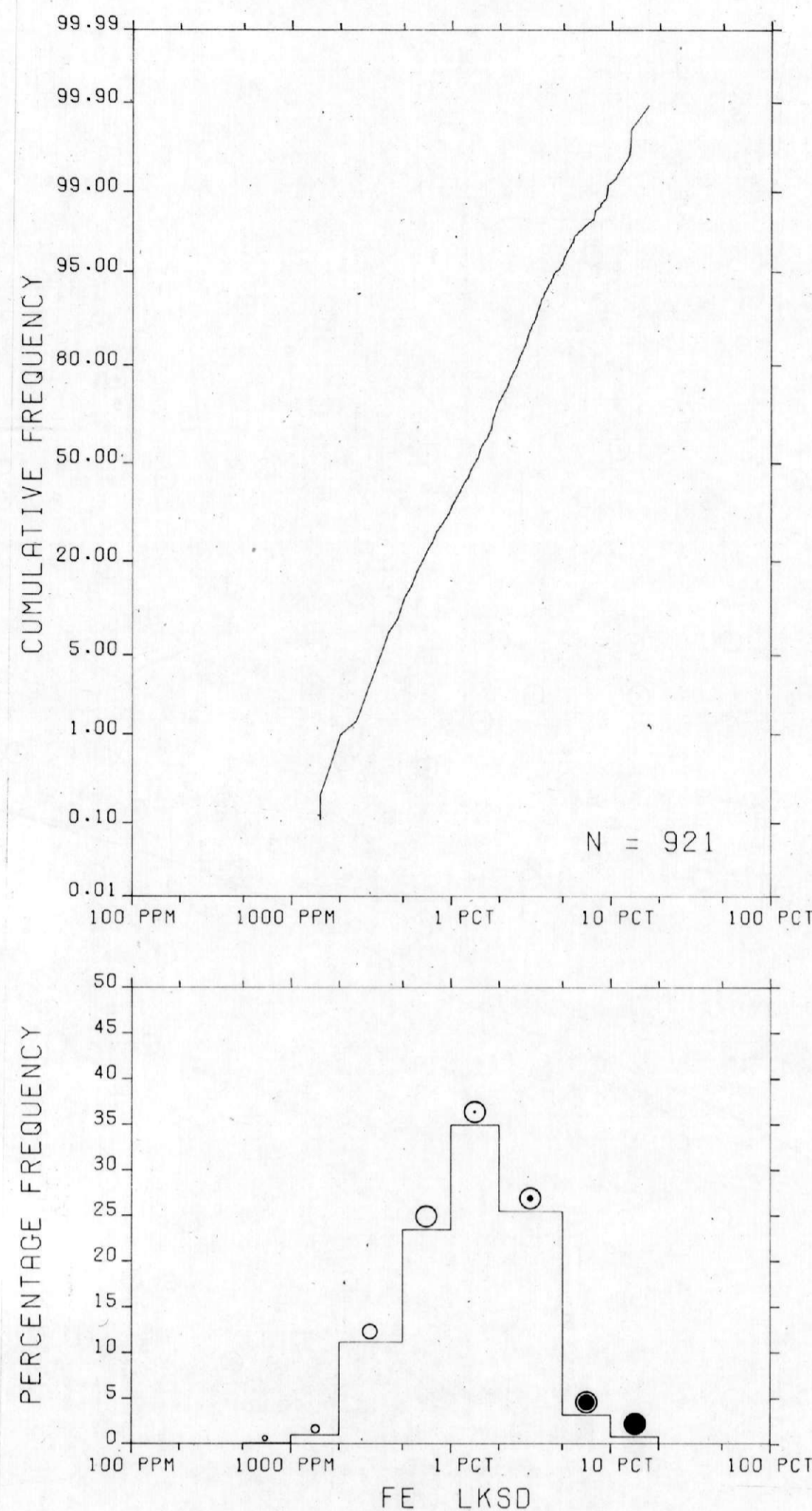
- PRECAMBRIAN**
LATE PRECAMBRIAN (HELIKIAN)
KENEENAWAN
- 13 CARBONATITE - ALKALIC COMPLEXES [AKRK]*
 Carbonatites: nepheline, hornblende, augite syenites, gabbro; olivine, nepheline gabbro
 - 12 LATE MAFIC IGNEOUS ROCKS
 Diabase, gabbro, anorthosite
 - OSLER GROUP
 - 11 Porphyritic rhyolite or dacite, quartz porphyry, felsite
 - 10 Diabase, basalt, minor pyroclastic rocks, conglomerate, sandstone
 - MAFIC IGNEOUS ROCKS
 - 9 Diabase (DIBS), porphyritic diabase, gabbro, anorthositic gabbro (sills and dykes)
 - SIBLEY GROUP [SMRK]
 - 8 Conglomerate, sandstone, chert, shale, carbonate rocks
 - MIDDLE PRECAMBRIAN (APHEBIAN)**
ANIMIKIE
 - 7 Rove Formation [ARGL]: argillite, shale, greywacke
 - 6 Gunflint Formation: chert [CHRT], chert-carbonate, carbonate rocks, argillite, tuff, taconite
 - EARLY PRECAMBRIAN (ARCHEAN)**
FELSIC IGNEOUS AND METAMORPHIC ROCKS
 - 5 Granite [GRNT], granite gneiss [GRNG], granodiorite [GRDR], quartz-feldspar porphyry [QZFP], monzonite, magmatite [MGMT], syenite, pegmatite
 - MAFIC AND ULTRAMAFIC IGNEOUS ROCKS [UMFC]
 - 4 Gabbro, diorite, serpentine, hornblende, amphibolite
 - METASEDIMENTS**
 - 3 Conglomerate [CGLM], greywacke [GRCK], arkose, quartzite, argillite, slate, mica schist and gneiss, quartz-feldspar schist and gneiss [SCST], garnet-feldspar schist and gneiss [GRSC].
 - METAVOLCANICS**
 - 2 Felsic to intermediate metavolcanics [AEXV]: rhyolite, pillow lava, porphyritic lava, pyroclastic rocks, derived schists
 - 1 Intermediate to mafic metavolcanics [BEXV]: massive, schistose, pillow lava, porphyritic and amygdaloidal lava, pyroclastic rocks and derived schists, undifferentiated metavolcanics with some metasediments [MWCC]

* A four letter mnemonic name recorded as rock type as part of field observations
 Geological boundary.....
 Fault.....
 Limit of geological mapping [UKWN].....
 The legend modified and geology derived for this geochemical map from Geology Compilation Series maps 2220 and 2232, Ontario Division of Mines and map 2065, Ontario Department of Mines

Geological Survey of Canada
 Resource Geophysics and Geochemistry Division
 and
 Ontario Ministry of Natural Resources
 Ontario Geological Survey

CONTRACTORS
 Sample collection by Marshall Macklin Monaghan Ltd.
 Sample preparation by Golder Associates.
 Uranium in sediment chemical analyses by Atomic Energy of Canada Ltd.
 Other sediment chemical analyses by Chemex Labs Ltd.
 Water chemical analyses by Barringer Research Ltd.

This map forms one of a series of 28 sheets released under the Geological Survey of Canada, Open Files 506 and 507. The Open Files consist of maps for 11 elements, each for lake sediments, 2 elements for lake waters and sample site location.
IRON (%)
 OPEN FILE 507
 THUNDER BAY AREA 1977



Geochemical Symbol and Data Presentation

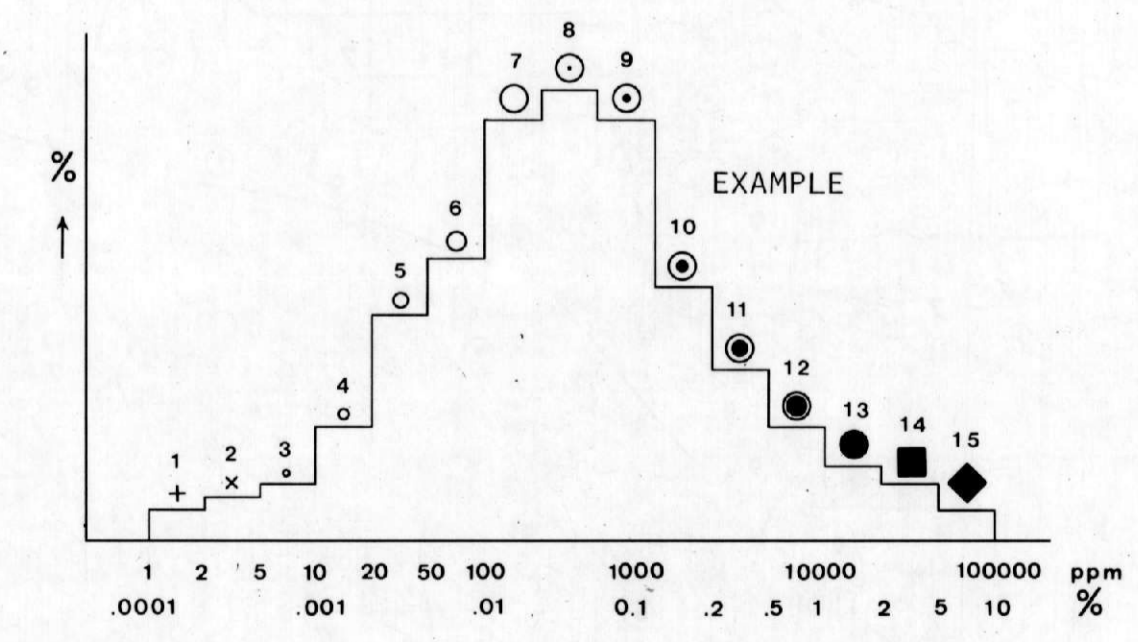
The concentration of an element at a sample site is graphically represented as one of 15 symbols. If a sample was collected but there is no data available a dot is plotted. The symbols are symmetrically arranged so that they first increase in size to the eighth symbol and then increase in blackness to the fifteenth. The two small crosses at the low end of the scale are used to respectively denote concentrations below the analytical detection limit, or, in the data group containing the detection limit. The data are grouped on a semi-logarithmic scale, i.e. 1,2,5,10,20,50,100 etc. Five decades can be spanned and this arbitrary division has been chosen for the continuing Canada wide series of maps constituting the National Geochemical Reconnaissance.

The choice of symbols and the data groups they represent for any specific element is based on the histogram and cumulative frequency plot for the total survey data from one, or more contiguous, open file sheets covered in one field season (above). The eighth symbol is used for the model group as defined by the histogram. This group usually includes the median of the data as defined by the 0.5 (50%) point on the cumulative frequency plot. Some, or all, of the remaining 14 symbols are chosen so as to achieve an appropriate graphical impact. An example of all 15 symbols is given below.

The symbol maps, being based on the total survey data distributions, are unaffected by the availability of ever increasing levels of knowledge in bedrock and surficial geology, and other environmental factors. Therefore, the raw data symbol maps are only intended to assist the rapid inspection of the data for gross regional features. To fulfill the needs of a more specific and thorough interpretation, the raw symbol maps should be modified using the field and analytical data provided in the data listings and any other knowledge available.

The data listings contain notes on survey and analytical methods, raw data listing with legend and statistics for total data as well as for data grouped on the basis of rock type.

To comprehensively study an area, all available geological, environmental and recorded data should be utilized. The data separation by bedrock type can often be improved by constructing new data subsets and deriving local threshold levels based on the most detailed and up-to-date knowledge available.

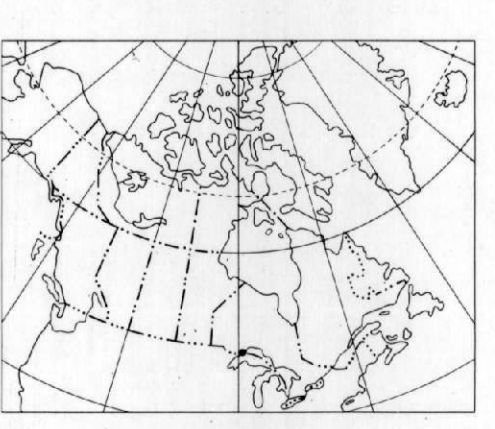
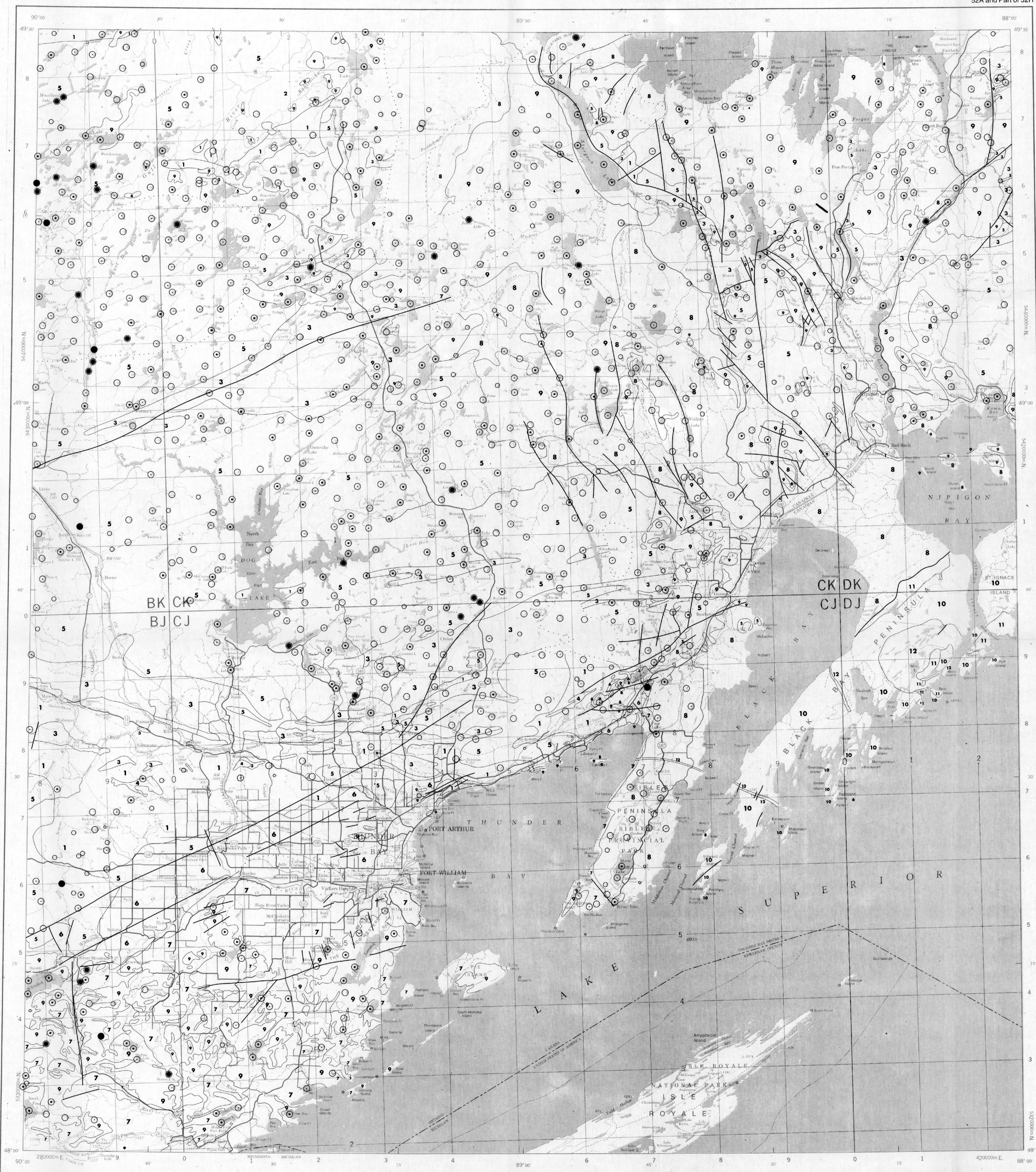


Copies of map material and listings of field observations and analytical data from which the material was prepared may be available at users expense by application to:

K.S. Campbell Corporation
 880 Wellington Street
 Bay No. 238
 Ottawa, Ontario
 K1R 6K7

The data is also available in digital form. For further information please contact:

The Director
 Computer Science Centre
 Department of Energy, Mines and Resources
 Ottawa, Ontario
 K1A 0E4

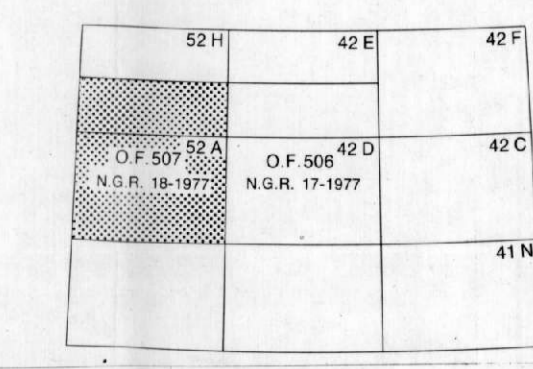


Elevations in feet above mean sea level

Mean magnetic declination 1978, 15.9° East, decreasing 2.7' annually. Readings vary from 37.2' in the SE corner to 1013.8' in the NW corner of the map-area

IRON (%)
 OPEN FILE 507
 NATIONAL GEOCHEMICAL RECONNAISSANCE MAP 18-1977
URANIUM RECONNAISSANCE PROGRAM
 THUNDER BAY AREA 1977
 Scale 1:250,000
 Kilometres 0 2 4 6 8 10 12 14 16
 Miles 0 2 4 6 8 10 12 14 16
 Universal Transverse Mercator Projection
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Base-map assembled by the Geological Cartography Unit from maps published at the same scale by the Surveys and Mapping Branch in 1969, 1974



- LEGEND**
- PHANEROZOIC GEOSYNCLINE**
- QUATERNARY**
- PLEISTOCENE AND RECENT**
- Unconsolidated alluvium, bog and peat accumulation; marl; fluvial and lacustrine silt, sand, gravel; lacustrine and marine clay, silt, and sand; glacial till; sand, gravel, boulders; sandy bouldery glacial till.
- UNCONFORMITY**
- PRECAMBRIAN AND PHANEROZOIC**
- 34 Fault gneiss, cataclastic and mylonitic rocks; intensely hematitized.
- POST MIDDLE ORDOVICIAN**
- 33a Calcarenite fissure veins locally containing concentrations of galena, sphalerite, fluorite, hematite.
- 33b Dolomite-baryte-calcite fissure veins.
- 33c Hematite-rich fissure veins.
- FAULT CONTACT**
- PALEOZOIC ORDOVICIAN**
- MIDDLE ORDOVICIAN**
- 32a Grey, fossiliferous biotitic limestone with minor dark grey to black shale gabbro and marl; rare interbeds of buff dolomite and calcareous quartz sandstone.
- 32b Green and red shale, siltstone; minor to locally abundant cross-bedded quartz sandstone, green siliceous sandstone, quartzite conglomerate.
- LOWER ORDOVICIAN**
- 31 Yellow to brown silty dolomite with minor part grey and marl; red shale; rare quartz pebbles conglomerate.
- UNCONFORMITY**
- CAMBRIAN**
- 30 Altered trachyte dikes.
- INTRUSIVE CONTACT**
- PRECAMBRIAN LATE PRECAMBRIAN**
- MAFIC TO ULTRAMAFIC INTRUSIVE ROCKS**
- 29a Troctolite diabase and cataclastic theobitic diabase dikes.
- 29b Partly crystallized theobitic gabbro and diorite; locally contain pegmatite, diorite, pyroxene, and rare granitic dikes.
- 29c Partly crystallized and uncrystallized peridotite.
- INTRUSIVE CONTACT**
- ALKALIC INTRUSIVE ROCKS**
- 28a Felsite, minor alkali syenite and carbonite (28a).
- INTRUSIVE CONTACT**
- LATE PEGMATITE**
- 27a Pink, red, and white granite pegmatite locally containing associated coarse-grained alkalic granite.
- HIGH GRADE REGIONAL METAMORPHISM**
- LATE MAFIC INTRUSIVE ROCKS**
- 26a Calcic metabasite.
- SYENITIC MONZONITE SUITE INTRUSIVE ROCKS**
- 25a Massive to granitic, biotite syenite, hornblende-biotite syenite; minor pyroxene syenite.
- 25b Massive to granitic quartz syenite, minor quartz monzonite.
- 25c Massive to granitic monzonite.
- Tonalitic to Gabbroic Rocks**
- 24a Massive to granitic tonalite.
- 24b Massive to granitic gabbro, minor gabbro.
- ALKALIC SUITE INTRUSIVE ROCKS**
- 23a Granitic alkalic granite and sodic pyroxene alkalic granite containing local phases of unit 22a, commonly rich in iron-titanium oxide mineral.
- 23b Massive to granitic, leucocratic alkalic granite, minor sodic pyroxene alkalic granite and granitic pegmatite dikes (unit 27).
- 23c Massive to slightly granitic, medium to coarse-grained, alkalic granite containing abundant granitic pegmatite dikes (unit 27).
- 23d Intensely aphanitic and carbonized alkalic granite.
- Alkalic Syenite**
- 22a Granitic to locally massive sodic pyroxene syenite commonly containing sodic pyroxene alkalic syenite and patches of sodic pyroxene syenite and granitic pegmatite dikes; minor calcic syenite pegmatite lenses; alkalic granite phases, and skarn and siliceous marble xenoliths.
- 22b Heterogeneous mixtures of sodic pyroxene syenite, amphibole syenite, alkalic syenite, albite-cordierite syenite, leucocratic syenite, pegmatite, skarn, and rocks of units 20a and 17c.
- 22c Granitic sodic pyroxene syenite, minor alkalic syenite and skarn xenoliths.
- Nepheline Syenite**
- 21a Granitic, orthitic, biotite nepheline syenite, locally containing granitic, biotite-rich, potassic feldspar alkali syenite.
- 21b Greenish, feldspathic nepheline syenite locally containing 10 percent or more garnet, potassic feldspar, amphibole, biotite.
- 21c Nepheline syenite pegmatite.
- Mafic Alkalic Rocks**
- 20a Massive to granitic alkalic gabbro and diorite.
- 20b Massive to granitic, melanocratic, alkalic gabbro and diorite.
- 20c Massive to granitic, melanocratic, alkalic gabbro and diorite.
- 20d Mafic scapolite-bearing gneiss containing various mixtures of sodic pyroxene, amphibole, garnet, nepheline, and other minerals (metamorphosed locally).
- 20e Magnetite-rich rocks containing various mixtures of clinopyroxene, amphibole, apatite, plagioclase, potassic feldspar and other minerals.
- QUARTZ MONZONITE SUITE INTRUSIVE ROCKS**
- 19a Massive to slightly granitic, leucocratic quartz monzonite.
- 19b Granitic quartz monzonite containing abundant granitic pegmatite dikes (unit 27); minor alkalic granite.
- 19c Granitic quartz monzonite, minor sodic alkalic granite and granodiorite, xenoliths of skarn and siliceous marble.
- 19d Granitic quartz monzonite containing xenoliths of amphibolite and gneiss tonalite.
- ANORTHOSITE SUITE INTRUSIVE ROCKS**
- 18a Grey to pink, granitic, ferrobasaltic-bearing quartz syenite, minor quartz monzonite.
- 18b Pink and grey, granitic, garnet-ferrobasaltic monzonitic rocks, minor green, pyroxene-bearing monzonitic rocks.
- 18c Grey to green, massive to phasitic, ferrobasaltic-pyroxene amphibolite and monzonite, minor biotite syenite and amphibole syenite.
- 18d Grey to pink, massive to granitic, pyroxene-ferrobasaltic syenite, minor biotite syenite and amphibole syenite.
- Anorthosite and Related Mafic Rocks**
- 17a Granitic, labradorite anorthosite, gabbroic anorthosite, minor gabbro.
- 17b Granitic and oligoclase gabbroic anorthosite and anorthosite gabbro, locally containing mafic alkalis with up to 65 percent ferromagnesian minerals.
- 17c Granitic anorthosite locally containing cordierite.
- 17d Granitic tonalite, minor granitic andesite and oligoclase anorthosite gabbro.
- MAFIC SILLS AND DIKES**
- 16a Granitic gabbro, diorite; amphibolite derived from gabbro and diorite.
- BIOTITE DIORITE SUITE INTRUSIVE ROCKS**
- 15a Granitic, trondhjemite and leucocratic tonalite.
- 15b Granitic trondhjemite containing garnet and cordierite.
- 15c Granitic trondhjemite, minor granodiorite.
- 15d Granitic granodiorite, minor trondhjemite and quartz monzonite.
- 15e Granitic quartz monzonite and albite granite.
- 15f Granitic trondhjemite, granodiorite containing numerous granitic tonalite xenoliths and amphibole-rich xenoliths.
- 15g Granitic, cordierite-bearing, orthopyroxene-rich in skarn and calcic xenoliths.
- 15h Granitic granite pegmatite.
- Syenitic Rocks**
- 14a Granitic alkali syenite, albite-quartz syenite, minor alkali granite.
- 14b Granitic syenite and granitic rocks contaminated by metasediments and rich in tourmaline; trondhjemite, pyroxenite and rich in tourmaline; trondhjemite, pyroxenite and rich in tourmaline; trondhjemite, pyroxenite and rich in tourmaline.
- Diorite and Related Mafic Rocks**
- 13a Granitic diorite, tonalite; minor granitic gabbro.
- 13b Amphibolite locally containing relict granitic diorite and gabbro phases.
- 13c Granitic tonalite, minor granitic trondhjemite, diorite.
- 13d Diorite to massive, leucocratic tonalite.
- 13e Granitic, cordierite-bearing, orthopyroxene tonalite.
- INTRUSIVE CONTACT**
- METAVOLCANICS**
- FELSIC TO INTERMEDIATE METAVOLCANICS**
- 12a Fine-grained quartz-feldspathic and micaceous schist and gneiss possibly derived from felsic volcanic rocks.
- 12b Fragmental quartz-feldspathic schist and gneiss possibly derived from felsic pyroclastic rocks.

- MAFIC METAVOLCANICS**
- 11a Fine-grained amphibolitic schist and gneiss, locally containing relict primary volcanic structures.
- METASEDIMENTS**
- CALCAREOUS METASEDIMENTS**
- Carbonate Metasediments**
- 10a Medium to coarse-grained, grey, granitic, calcitic marble containing up to 20 percent siliceous impurities; locally contains intercalated thin units of siliceous marble.
- 10b Fine to medium-grained, dark grey, calcitic marble with well preserved bedding and local thin interbeds of fine to medium-grained siliceous marble rich in plagioclase and tremolite.
- 10c Medium to coarse-grained, white to greenish, dolomitic marble containing up to 20 percent siliceous impurities; local intercalations of tremolite-rich dolomitic marble and ortho-quartzite.
- 10d Medium to coarse-grained, cherry, dolomitic marble containing numerous discontinuous layers of coarsely recrystallized chert.
- 10e Medium to coarse-grained, granitic, siliceous marble containing 20 to 60 percent siliceous impurities; commonly contains thin intercalated units of amphibole-rich metasediments.
- 10f Medium to coarse-grained, light to dark green skarn dominated by various mixtures of diopside, amphibole, cordierite, titanite, calcite, feldspar, scapolite, calcite, biotite, and quartz.
- 10g Fine-grained, feldspar-quartz-calcite-carbonate gneiss containing layers rich in pyrite and pyrrhotite.
- Amphibole-rich Metasediments**
- 9a Metamorphosed calcareous mudstone and sandstone (diopside-amphibole-plagioclase gneiss) locally containing phases rich in potassic feldspar, quartz, biotite, scapolite, epidote, carbonite, titanite, pyrite, and iron titanate (rare mineral); intercalated thin units of siliceous marble.
- 9b Unit 9a containing intercalated thin units of calcareous and micaceous metasediments (unit 8).
- 9c Unit 9a containing intercalated thin units of quartzite and feldspathic metasediments (unit 7).
- 9d Unit 9a containing coarsely recrystallized chert layers and local concentrations of pyrite and iron-titanium oxide mineral.
- 9e Fine-grained quartz amphibole-plagioclase gneiss locally containing abundant thin units (1 m or less) of calcic siliceous metasediments and carbonaceous metasediments.
- Calcareous and Siliceous Shaly Metasediments**
- 8a Interbedded, shaly bedded, siliceous and calcareous mudstone (garnet-feldspar-biotite-quartz gneiss) and shaly locally containing abundant thin units of calcic siliceous metasediments and carbonaceous metasediments.
- 8b Unit 8a rich in intercalated units of impure sandstone and rocks of units 7 and 8.
- 8c Granitic alkalic conglomerate with stretched fragments of gneiss tonalite, quartz monzonite and other gneiss rocks of units 2, 3 and 4.
- 8d Intercalated rocks of units 5b and 5c, and coarse-grained, iron-rich, micaceous, white sandstone containing isolated boulders of granitic quartz monzonite and tonalitic rocks.
- CLASTIC SILICEOUS METASSEDIMENTS**
- Quartzose and Feldspathic Metasediments**
- 7a Intercalated, metamorphosed arkose, subarkose, and minor coarse-grained arkose and ortho-quartzite, locally containing intercalated thin units of siliceous marble, impure sandstone, amphibole-rich metasediments, and calcareous and siliceous shaly metasediments.
- Micaceous Sandy and Conglomeratic Metasediments**
- 6a Thinly bedded greywacke, impure sandstone and biotite-rich mudstone; locally contains intercalated thin units of amphibole-rich metasediments and quartzose and feldspathic metasediments.
- 6b Unit 6a containing numerous granitic dikes or quartzite beds formed during rock migration.
- 6c Fine-grained impure sandstone and quartz-rich sandstone.
- 6d Intrazonal conglomerate rich in meta-sedimentary and quartz dikes set in a siliceous arkose host-feldspar-quartz gneiss matrix.
- Coarse Clastic Sequence**
- 5a Medium to coarse-grained, granitic arkose and subarkose locally containing intercalated thin units of siliceous marble, impure sandstone and rocks of units 7 and 8.
- 5b Unit 5a rich in intercalated units of impure sandstone and rocks of units 7 and 8.
- 5c Granitic alkalic conglomerate with stretched fragments of gneiss tonalite, quartz monzonite and other gneiss rocks of units 2, 3 and 4.
- 5d Intercalated rocks of units 5b and 5c, and coarse-grained, iron-rich, micaceous, white sandstone containing isolated boulders of granitic quartz monzonite and tonalitic rocks.
- UNCONFORMITY**
- ANORTHOSITE SUITE INTRUSIVE ROCKS**
- ALGONQUIN BATHOLITH**
- Granitic Rocks**
- 4a Pink, granitic, biotite quartz monzonite containing local phases of unit 4b; numerous biotite-rich shears common in zones of high strain marked by subhorizontal gneissosity.
- 4b Pink, granitic, amphibole quartz monzonite locally rich in highly stretched amphibole and granitic tonalite xenoliths; numerous biotite-rich shears common in zones of high strain marked by subhorizontal gneissosity.
- Monzonitic and Syenitic Rocks**
- 3a Grey to pink, granitic, ferrobasaltic-bearing quartz syenite and minor ferrobasaltic-bearing sodic syenite.
- 3b Pink and grey, granitic, garnet-ferrobasaltic monzonitic rocks and minor granitic rocks of units 2 and 4; abundant mafic granitic alkalis common in zones of high strain marked by subhorizontal gneissosity.
- 3c Green, granitic, pyroxene-bearing garnet-ferrobasaltic monzonitic rocks and minor rocks of hastigite monzonitic rocks and minor rocks of hastigite monzonitic rocks and minor rocks of hastigite monzonitic rocks.
- 3d Shaly, almost entirely granitic phase common in zones of high strain marked by subhorizontal gneissosity.
- Anorthosite and Related Mafic Rocks**
- 2a Granitic gabbro, diorite, and amphibolite locally with green, anorthosite gabbro, tonalite and rocks of unit 4.
- 2b Granitic tonalite commonly containing dikes of units 3 and 4, minor granitic diorite.
- INTRUSIVE CONTACT**
- MIDDLE PRECAMBRIAN**
- METASSEDIMENTS**
- CLASTIC SILICEOUS METASSEDIMENTS**
- Impure Sandy and Shaly Metasediments**
- 1a Fine to medium-grained, impure sandstone (biotite-feldspar-quartz gneiss) containing intercalated thin units of calcic siliceous metasediments (unit 10), biotite-rich mudstone (fine-grained, greenish, biotite-amphibole-quartz-plagioclase gneiss and schist), calcic siliceous gneiss, and, rarely, quartz-rich sandstone; locally voided by quartz-feldspar material.
- 1b Unit 1a containing abundant intercalated thickly bedded, medium to coarse-grained impure sandstone.
- 1c Intercalated biotite-rich mudstone (garnet-feldspar-biotite-quartz gneiss) and shaly, calcic siliceous metasediments (dark green to dark grey, fine to medium-grained, garnet-ferrous biotite-amphibole-quartz-plagioclase gneiss and schist); minor rocks of unit 1a, rare scapolite-bearing orthopyroxene gneiss.
- Rusty-weathering, granitic, pyrite and pyrrhotite-bearing schist.**
- Iron Formation associated with units 1, 6, 9 and 10.**

- NOTES**
- a. Only the thickest and most extensive Cambrian deposits, in which bedrock outcrops are absent or scarce, are shown.
- b. The history of fault zones containing these rocks is complex and largely unknown, but the rocks are believed to have formed during Precambrian time and underwent reactivation during Late Precambrian Post-Macdonald Orogeny. The rocks are shown as present activity is presently recorded near some of these faults. Although not shown, these rocks are also present along most of the narrow fault zones indicated by thick broken lines.
- c. No radiometric age data are available for these rocks, but limited paleomagnetic data suggest that some of the diabase dikes may be Early Palaeozoic in age.
- d. Common throughout the greater Precambrian rocks; only the largest known dikes and areas of marked dike concentrations are shown. These dikes and other types of late pegmatite are associated with units 23, 22, and 20. Contain relict primary microtextures and mineralogy. Emphasized over an interval that probably encompasses the culmination and waning stages of regional metamorphism. Major varieties of these rocks (diabase) containing relict primary microtexture and mineralogy.
- e. Multiple ages represented.
- f. Rocks of these groups are subdivided lithologically and the order does not imply age relationships either within or between groups.
- g. Forms the base of the Late Precambrian supercrustal accumulation.
- h. Most mafic schists are probably hydrothermal replacement deposits in shear zones, but some may represent tuffaceous iron sulphide-bearing sediments or black shales.



PRODUCING MINES AND QUARRIES

1. Canarugh Construction	Shale
2. Chromato Limited	Magnesium
3. Duchart Brick and Tile Company Limited	Clay
4. Smith Construction	Shale
5. Wal Gem Lapidary Company	Beryl, Quartz

PAST PRODUCERS

6. Algoma Steel Corporation Limited, The (Campanell and Colwell Mines)	Iron
7. Bar Mine	Feldspar
8. Black Donald Mine	Graphite
9. Bull Point Mine	Iron
10. Caldwell Mine	Pyrite
11. Cragmont Corundum Mine	Corundum
12. Hunt Mine	Molybdenum
13. Jameson Lime Company	Lime
14. Jameson Mine	Molybdenum
15. Kindon Mine	Lead
16. Marol Mine	Molybdenum
17. McCoy Mine	Molybdenum
18. O'Brien Mine	Molybdenum
19. Ralston Mine	Molybdenum
20. Ross Mine	Iron
21. Share Lime and Chemical Company Limited	Lime
22. Span Mine	Molybdenum
23. Williams Mine	Iron
24. Zenith Molybdenum Corporation Limited	Molybdenum

GEOLOGICAL AND MINING SYMBOLS

[Symbol]	Glacial Striae
[Symbol]	Esker
[Symbol]	Small bedrock outcrop
[Symbol]	Cross-slopes, (horizontal, inclined, vertical)
[Symbol]	Lineation with plunge
[Symbol]	Geological boundary, observed
[Symbol]	Geological boundary, inferred
[Symbol]	Fault: (observed, assumed). Spot indicates down throw side; arrow indicates horizontal movement
[Symbol]	Lava flow; top in direction of arrow
[Symbol]	Direction of palaeocurrent
[Symbol]	Foliation: (horizontal, inclined, vertical)
[Symbol]	Lineation with plunge
[Symbol]	Siltified zone

METAL AND MINERAL ABBREVIATIONS

all.	Alignite	mo.	Molybdenite
ap.	Apatite	ni.	Nickel
as.	Asbestos	np.	Nepheline
au.	Gold	pb.	Lead
co.	Corundum	py.	Pyrite
cu.	Copper	s.	Sulphide mineralization
fe.	Feldspar	st.	Staurolite
fl.	Fluorite	br.	Bromellite
gt.	Granite	u.	Uranium
he.	Hematite	z.	Zircon
mi.	Mica		

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Preliminary map P-1838, Renfrew Area (Eastern Part), scale 1:15 360, 1979.

Base-map derived from maps of Forest Resources Inventory, Ontario Ministry of Natural Resources, Lands and Waters Group, air photographs, and maps and material supplied by Survey and Mapping Branch, Department of Energy, Mines and Resources.

Other: Additional information by S.B. Lumbers.

Magnetic declination in the area varied from 10°00'W in the southwestern part to 12°50'W in the eastern part in 1978.

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