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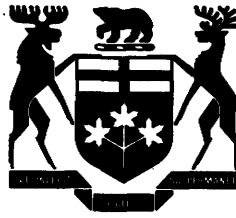
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Geology
of the
Burwash Area
Districts of Nipissing, Parry Sound,
and Sudbury

By

S.B. Lumbers

Geological Report 116

TORONTO
1975

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GEOLOGICAL MAP

(back pocket)

Map 2271 (coloured)—Burwash, Districts of Nipissing, Parry Sound and Sudbury. Scale, 1 inch to 2 miles.

ABSTRACT

The Burwash area covers about 1,700 square miles (4400 square km) of the Canadian Precambrian Shield just north of Georgian Bay in central Ontario, from Latitudes 46°00'N to 46°30'N, and from Longitudes 80°00'W to 81°00'W. Reconnaissance mapping, at a scale of 1 inch to 1 mile (final map at 1 inch to 2 miles or 1:126720), and geochronologic data show that most of the area is underlain by clastic siliceous metasediments deposited in a Middle Precambrian geosyncline between 2,500 and 2,150 million years ago. A variety of igneous rocks are present, and much of the area is underlain by high metamorphic rank gneisses of the Grenville Province; greenschist facies rocks of the Southern Province are present in the northwest corner. The two provinces are separated by a major fault zone, the Grenville Front Boundary Fault, situated near the northwestern margin of a major northeasterly trending tectonic zone, the Grenville Front Tectonic Zone, that is superimposed upon earlier structures in rocks of both provinces. Igneous activity and metamorphism in the Southern Province are Middle Precambrian in age, whereas the Grenville Province reflects a more complex history, with igneous activity and metamorphism ranging in age from Middle to Late Precambrian.



Figure 1—Key map showing location and extent of the Burwash area.

Metasediments of the Southern Province are assigned to the lower part of the Huronian Supergroup, and were derived mainly from a conformable sequence of fine to coarse clastic debris at least 15,000 feet (4600 m) thick. The oldest sedimentary rocks are mainly argillite and greywacke deposited by turbidity currents in relatively deep water with little reworking by wave action. These are overlain by a miogeosynclinal sequence deposited above wave base, comprising relatively thin lower units of pebbly to bouldery sandstone and conglomerate that pass upward into a thick, extensive unit of quartzose sandstone. The Grenville Front Tectonic

Zone is the site of a major facies change whereby the sandstone becomes richer in argillaceous material and greywacke.

Metasediments in the Grenville Province lack an exposed base and are dominated by gneisses derived from a relatively thick sequence of thinly bedded greywacke and argillite deposited in deep water below wave base, with intercalated subordinate shallow water (miogeosynclinal) sediments and rare coarse clastic debris, especially near the Southern Province. These rocks were possibly deposited in a deep trough that subsequently influenced the location and development of the Grenville Front Tectonic Zone. Present data suggest that the meta-sedimentary sequence of the Grenville Province is a thicker, predominantly deeper water facies of the Elliot Lake and Hough Lake Groups of the Huronian Supergroup in the Southern Province. The Grenville Front Tectonic Zone appears to coincide with a paleogeographic boundary or hinge line within the Middle Precambrian geosyncline that separates thin, predominantly shallow water clastic deposits in the Southern Province from relatively thick, deeper water clastic deposits in the Grenville Province.

Among the oldest intrusive rocks in the map-area are tabular gabbroic bodies of Nipissing diabase, emplaced about 2,150 million years ago in both the Southern and Grenville Provinces, but in the Grenville Province, these intrusions are present only near the Grenville Front Boundary Fault. Rocks of the Southern Province were metamorphosed to the greenschist facies and folded about easterly trending axes, possibly about 1,800 million years ago. Evidence for this metamorphism is scanty within the Grenville Province, but gneissic granite pegmatite dikes, locally present in the Tectonic Zone, could reflect a relatively high rank regional metamorphic event during the Middle Precambrian. The Grenville Province was subjected to major plutonism about $1,700 \pm 150$ million years ago; this was most likely accompanied by regional metamorphism. During this event, several stocks and an elongate batholithic complex of granitic rocks, extending from Georgian Bay to south of Sudbury, intruded both the Southern and Grenville Provinces. These granitic rocks postdate the Middle Precambrian greenschist facies metamorphism and deformation in the Southern Province and reflect major tectonic activity within the Grenville Province.

A second, Late Precambrian major plutonic event, affecting only rocks of the Grenville Province took place between about 1,500 and 1,200 million years ago. At this time, anorthosite suite rocks were intruded and metamorphosed, but they are less intensely deformed than the older granitic rocks. Nearly the complete anorthosite suite is represented in several, small, widely scattered plutons. It consists of minor gabbro and ultramafic rocks, anorthositic gabbro, gabbroic anorthosite, anorthosite, diorite, tonalite, and a variety of more felsic rocks ranging in modal composition from sodic syenite to quartz monzonite. The suite shows most of the major chemical features of the anorthosite-charnockite series, but orthopyroxene is rare, and there is only moderate iron enrichment in the intermediate rocks. Intermediate and siliceous members are particularly rich in barium and zirconium; high zirconium contents are reflected by abundant accessory zircon.

All the rocks of the Grenville Province underwent Late Precambrian high rank regional metamorphism between 1,400 and 1,200 million years ago, with emplacement of granite pegmatite dikes during the waning stages about 1,000 million years ago. Migmatitic phases of the metasedimentary and felsic plutonic gneisses were developed by a combination of partial melting and metamorphic differentiation. Metamorphic mineral assemblages in the gneisses are most typical of the kyanite-almandine-muscovite subfacies of the almandine-amphibolite facies, but within the Grenville Front Tectonic Zone, mineral assemblages suggest a slightly higher metamorphic grade, in the sillimanite-almandine-orthoclase subfacies.

In the Grenville Province metamorphosed mafic intrusive rocks of several ages form sills, dikes, and stocks in metasediments and rarely in Middle Precambrian granitic rocks. Gneissic alkalic syenite and nepheline syenite form an elongate complex, intrusive into metasediments and syenitic anorthosite suite rocks in the southwestern part of the area. Some of the mafic intrusions are cut by Middle Precambrian granitic rocks, but others are younger and were only partly recrystallized by the last, Late Precambrian metamorphism. The younger mafic bodies are mainly confined to the Grenville Front Tectonic Zone. Both the Southern and Grenville Provinces contain Late Precambrian diabase dikes that postdate regional metamorphism and deformation.

Major deformation occurred within the trough of eugeosynclinal metasediments after the culmination of Late Precambrian high rank metamorphism but before emplacement of the late pegmatite dikes. The Grenville Front Tectonic Zone came into being, its location and orientation apparently controlled in part by a paleogeographic hinge line within the geosyncline

that was earlier the site of a major facies change in the sedimentary rocks. The Tectonic Zone is up to 20 miles wide and is superimposed upon earlier structures in both the Grenville and Southern Provinces. It is characterized by a prominent southeasterly plunging rodding lineation and by northeasterly trending cataclastic foliation that gradually decreases in intensity toward the margins of the Tectonic Zone, so that the boundaries of the Zone cannot be mapped precisely. Near its northwestern margin, high metamorphic rank gneisses of the Grenville Province are in fault contact, along the Grenville Front Boundary Fault, with low metamorphic rank rocks of the Southern Province. This fault provides the only mappable boundary for the Grenville Province. Rocks of the Grenville Province were flattened against the Southern Province block, with only minor apparent vertical and lateral offset along the Boundary Fault, despite the contrast in metamorphic grade across the Fault. Early folds in the Southern Province were tightened and rotated subparallel to the northeasterly trending Grenville Front Tectonic Zone.

Following this major deformation, the region was subjected to faulting and minor intrusive activity of Late Precambrian and at least early Paleozoic age. Two major fault systems are present that trend west-northwest and northeast. Intrusive activity emplaced a gabbroic stock in the southeastern corner of the area, a few small peridotite stocks within and near the Tectonic Zone, two generations of diabase dikes in both the Southern and Grenville Provinces, and lamprophyre dikes in the eastern part of the area. The lamprophyre dikes, of probable Cambrian age, are related to a westward extension of the Ottawa-Bonnechere Graben, which appears to die out as an identifiable structure in the east-central part of the map-area.

Metallic mineralization in the Burwash area consists mainly of: iron, associated with well sorted shallow water metasandstone and to a lesser extent with anorthositic rocks and late pegmatite dikes in the Grenville Province; copper and nickel, confined to mafic and ultramafic bodies; and uranium and rare earths in late pegmatite dikes of the Grenville Province. Mineral production in the map-area has been confined mainly to Pleistocene sand and gravel, ortho-quartzite and minor building stone from some of the Grenville Province gneisses, and feldspar and mica from late pegmatite dikes. A few kyanite deposits in the Grenville Front Tectonic Zone have been explored, but have not achieved production. Many of the Grenville Province gneisses are potential sources of building stone, and further exploration of mafic intrusions within the Grenville Front Tectonic Zone could reveal additional copper and nickel mineralization.

Geology

of the

Burwash Area

Districts of Nipissing, Sudbury, and Parry Sound

by

S.B. Lumbers¹

INTRODUCTION

The Burwash map-area covers about 1,700 square miles (4400 km) just north of Georgian Bay in central Ontario from Latitudes 46°00'N to 46°30'N, and from Longitudes 80°00'W to 81°00'W (Figure 1). The area is shown on the Noelville, Verner, Coniston, and Delamere map sheets of the National Topographic Series and includes the western one-third of Lake Nipissing and most of the French River region. The City of Sudbury lies partly within the northwestern corner of the area.

The present report, the second of a series describing the regional geology and mineral potential of the northwestern part of the Grenville Province in Ontario (Lumbers 1971a), concentrates upon a region that has received little systematic geological mapping since early exploration and reconnaissance surveys carried out between the 1820s and 1920s. Deposits of copper, nickel, iron, rare earth minerals (mainly allanite), apatite, corundum, feldspar, graphite, kyanite, mica, silica (metamorphosed orthoquartzite), vermiculite, industrially useful rocks, and sand and gravel have been either explored or utilized in the region, but present production is confined to sand and gravel and small tonnages of crushed stone. The northwestern corner of the area is only a few miles southeast of the Sudbury nickel irruptive, renowned for its nickel and copper mineralization, and is also traversed by a major, northeasterly trending tectonic zone, the Grenville Front Tectonic Zone, that marks the northwestern margin of the Grenville Province (Lumbers 1971b). Within the Burwash map-area, Middle Precambrian (approximately 2,500-1,500 million years ago), relatively low metamorphic rank rocks

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Burwash Area

of the Southern Province underlie the area northwest of the Grenville Province, and no rocks of the Early Precambrian (older than 2,500 million years) Superior Province are present as in some areas to the northeast (Lumbers 1971c; 1971d; 1971e).

From the present work in the Grenville Province portion of the Burwash area, several features of the regional geology heretofore unrecognized became apparent. For example, much of the Grenville Province is underlain by metasediments in which gross primary characteristics are decipherable. For the most part, these metasediments appear to represent a relatively deeper water, less well-sorted facies of the lower part of the Middle Precambrian, Huronian Supergroup (Robertson *et al.* 1969) exposed in the immediately adjacent Southern Province. The metasediments were subjected to Middle and Late (younger than 2,500 million years) Precambrian plutonic and regional metamorphic events, but the Middle Precambrian regional metamorphism was largely obscured by an intense Late Precambrian regional metamorphism which deformed and recrystallized the Late Precambrian and older plutonic rocks. Middle Precambrian plutonic masses consist mainly of gneissic quartz monzonite, whereas Late Precambrian plutonic masses consist mainly of gneissic rocks of the anorthosite suite.

Near the northwestern margin of the Grenville Front Tectonic Zone, relatively high rank metamorphic rocks of the Grenville Province are in fault contact with relatively low rank metamorphic rocks of the Southern Province, and this fault zone is the only mappable boundary of the Grenville Province. Moreover, relative horizontal and vertical offset along the Fault appears to be small, in spite of the contrast in metamorphism on either side of the Fault. Major deformation along the Grenville Front Tectonic Zone took place relatively late in the history of the region and is superimposed upon earlier deformation within both the Grenville and Southern Provinces. Nevertheless, other evidence, including the localization of Middle to Late Precambrian, felsic to ultramafic intrusions within the zone, suggest a long, complex history for the zone, extending back into early Middle Precambrian time. Mineralization within the region can be related to stratigraphy and to the complex plutonic, metamorphic, and deformational history. Industrial minerals constitute the main mineral potential of the area. Concentrations of base metals are rare and are found mainly in mafic intrusions, particularly within the Grenville Front Tectonic Zone.

Present Geological Survey

Geologic mapping of the Burwash area was accomplished in eight months by the author and his assistants during parts of the 1965, 1967, 1968, and 1969 field seasons. Mapping methods and procedures followed those developed by the author for the adjacent North Bay area (Lumbers 1971a). In general, the region was traversed at 1 mile (1.6 km) intervals with geological data plotted in the field on transparent plastic film fitted to 1 inch to 1 mile (1:63,360) air photographs. This data was transferred to a 1 inch to 1 mile (1:63,360) base map printed on transparent plastic film and fitted to 1 inch to 1 mile (1:63,360) photomosaics of Operation Overthrust (Parkinson 1962). The base map was prepared by the Cartography Section of the Ontario Division of Lands from maps of the Forest Resources Inventory of the Ontario Division of Forests. During the field work any necessary topographic additions and corrections were made to the base map by the author.

Much of the geology of the Southern Province in Broder, Dill, Neelon, and Dryden Townships was generalized from Grant *et al.* (1962), and except for selected traverses.

to study specific lithologic and structural relations, no systematic traversing was done during the present study in the Southern Province portions of these townships.

After a geological interpretation was made from the data on the base map, the geology was generalized to produce a manuscript copy for the final map (Map 2271, back pocket) published on a scale of 1 inch to 2 miles (1:126720). Petrographic and chemical examination of rock specimens collected during the field mapping supplemented field observations and aided in preparing the classification of the rocks shown by symbols on Map 2271 (back pocket).

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Except where stated otherwise, all chemical analyses that appear in this report were done by the Mineral Research Branch, Ontario Division of Mines.

Means of Access

Except for the southeastern and southwestern part, the area is accessible by provincial highways, township roads, and forest access roads. Highway 17 extends westward across the northern part of the area, and Highway 69 extends north-northwest across the western part of the area, Highways 64, 528, and 535 give access to the central and much of the eastern parts of the area, and Highway 637 gives access to the west-central part of the area west of Highway 69. Most parts of the area not accessible by motor roads can be reached either by water, or by logging roads. Northern and western parts of the area also are crossed by main railway lines of the Canadian National Railways and the Canadian Pacific Railway.

Periodically during the present study, forest access motor roads were constructed, under the direction of the Ontario Division of Lands, in various parts of the area and other roads may be completed in the future. Map 2271 (back pocket) includes all those roads completed to September, 1969. Information concerning any additional forest access roads completed after this date could be obtained from Ontario Division of Lands offices within the area.

Previous Geological Work

The earliest recorded observations from the Burwash area were made by Bigsby (1821). Early exploration and reconnaissance surveys by Murray (1849; 1857a; 1857b), Bell (1891a, 1891b, 1898), and Barlow (1893; 1899; 1907), covered large parts of the area, chiefly in the Grenville Province portion. Murray and Bell concluded that most of the gneissic rocks of the Grenville Province are metasediments because of their well defined stratiform foliation, but both geologists recognized that plutonic rocks are widespread and locally predominate over the metasediments. Murray did not attempt to subdivide the gneisses and classified them as Laurentian, but Bell assigned these rocks to the upper Laurentian (equivalent to the Grenville series of later workers). Bell noted that marble is virtually absent in the metasediments within the map-area and in this respect he felt that the metasediments here differ markedly from the typical marble-rich upper Laurentian (Grenville Group) of southeastern Ontario and southwestern Quebec. In contrast to Murray and Bell, Barlow considered all the gneisses to be igneous in origin and assigned them to the lower Laurentian, supposedly the oldest Precambrian rocks recognized within the Canadian Shield.

Coleman (1914), working in the northwestern part of the area, described several metasedimentary units near the northwestern boundary of the Grenville Province and assigned these rocks to the Grenville series, mainly because he found a few thin, intercalated marble units. Nevertheless, most of the gneissic rocks of the Grenville Province southeast of Sudbury were considered by Coleman to be Laurentian plutonic rocks, intrusive into the metasediments. He considered his Grenville series metasediments to be older than the Huronian metasediments northwest of the Grenville Province, and to be possibly among the oldest rocks in the Canadian Shield. In contrast to his predecessors (who considered all metasediments adjacent to the Grenville Province on the northwest to be Huronian), Coleman placed most metasediments and other rocks in the Southern Province stratigraphically below the Ramsay Lake Formation (his basal unit of the Huronian Supergroup). Thus the metasediments of the Southern Province adjacent to the Grenville Province were considered older than the Huronian, but younger than the Grenville series. He assigned these supposedly pre-Huronian rocks to a new unit, the Sudbury series, which he correlated with the Temiskaming series, recognized at this time as a younger metasedimentary-rich group unconformably overlying Keewatin meta-volcanic-rich sequences in the Superior Province. Plutonic rocks intrusive into the Sudbury series were also assigned to the Laurentian and were thought to be older than the Huronian metasediments. Coleman's usage of Laurentian differed from that of Murray, Bell, and Barlow, and eventually confusion in the use and meaning of this term led to its abandonment.

In the 1920s Quirke (1924; 1926; 1929; 1930a) mapped the Delamere sheet, comprising the southwestern quarter of the map-area. This regional study, carried out partly with Collins (Quirke and Collins 1930), was aimed at determining the relationships between rocks of the Grenville Province and rocks of the Southern Province. Quirke (1924) and Collins (in Quirke and Collins 1930) disagreed with most of Coleman's major conclusions concerning the stratigraphy and presented evidence that Coleman's Sudbury series south of Sudbury is actually part of the Huronian sequence. Metasedimentary gneisses of the Grenville Province were correlated with the Huronian metasediments, and plutonic rocks intrusive into metasediments of both the Grenville and Southern Provinces were considered to be of the same age and among the youngest

plutonic rocks in the Canadian Shield. Quirke (1924) grouped the plutonic rocks under a new division, the Killarnean, described as a Late Precambrian (Keweenawan) orogenic, plutonic, and metamorphic event that affected rocks of both the Southern and Grenville Provinces. Metamorphism in the Grenville Province was attributed to the emplacement of the Killarnean plutons.

From 1929 to 1939, several geologists studied rocks of the Southern and Grenville Provinces in the northwestern corner of the map-area in conjunction with regional investigations of the Sudbury area, and several conflicting views were published concerning the stratigraphy of the Huronian Supergroup and the validity of Coleman's Sudbury series. This work is summarized by Cooke (1946) who considered most of Coleman's Sudbury series exposed in the area to be part of the Huronian Supergroup. Nevertheless, Cooke assigned some rocks from Coleman's Sudbury series, exposed along a narrow strip next to the Grenville Province from south of Coniston to Daisy Lake in Neelon Township, to a new unit, the Coniston group. Rocks of the Coniston group were thought by Cooke to be older than the Huronian and to continue southeastward for an unknown distance into the Grenville Province where they are intruded and granitized by Killarnean granite. Cooke questioned Quirke's and Collins' contention that metasediments of the Grenville Province are an extension of the Huronian sequence and concluded that at least some of these metasediments may be pre-Huronian in age.

From 1953 to 1959, Phemister (1960; 1961) and Grant *et al.* (1962) carried out a detailed study of parts of Dryden and Dill Townships and all of Neelon and Broder Townships. This work covered most of those parts of the Southern Province and the Grenville Front Tectonic Zone exposed in the map-area. It was the first detailed description of the northwestern boundary of the Grenville Province, and resulted in reclassification of Cooke's Huronian metasediments and Coniston group with the pre-Huronian Sudbury series of Coleman (1914); Phemister (1960; 1961) concluded that, in places, the northwestern boundary of the Grenville Province is a faulted contact and in other places an irregular metamorphic boundary, whereby partly granitized metasedimentary gneisses of the Grenville Province pass, by a metamorphic transition, into quartz-rich metasediments of the Sudbury group (series). Within the metamorphic transition, rocks of the Sudbury group were supposedly granitized by granitic material derived from the Grenville Province.

Other investigations of the Grenville Front Tectonic Zone within the map-area were stimulated by this detailed work, and since 1960, several studies have been completed by Brown (1967), Henderson (1967a; 1967b), Dalziel and Bailey (1968), Dalziel *et al.* (1969), Clifford *et al.* (1970), and Kwak (1971). This recent work will be discussed in later sections of this report, but in general, the recent workers disagree with Phemister (1960) and Grant *et al.* (1962) concerning the age of the Sudbury group and have assigned these metasediments to the Huronian Supergroup. Widespread granitization of metasediments near the Grenville Province as postulated by Phemister (1960; 1961) is also refuted by the recent workers.

In 1957, Hewitt (1960) mapped Bigwood Township during a detailed study of nepheline syenite deposits in southern Ontario, and he briefly summarized earlier work on the nepheline syenite intrusion within this township. Hewitt (1962) also described some regional structural features in the vicinity of Bigwood Township. Part of the Grenville Province portion of the region surrounding the Burwash area has been mapped (Lumbers 1971a; 1971e; Quirke 1930b; Quirke and Collins 1930; Frarey and Cannon 1969) and a preliminary geological map of the area was issued (Lumbers 1971f; 1971g).

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Krogh (in Davis *et al.* 1967; 1970; Krogh 1966; Krogh and Davis 1967; 1969a; 1969b; Krogh *et al.* 1968) presented some results of his continuing geochronologic studies in the Grenville Province portion of the area; geochronologic studies in the Southern Province part are summarized by Fairbairn *et al.* (1965; 1969). The area is covered by Geological Survey of Canada Aeromagnetic Maps published in 1965 (GSC 1965a; 1965b; 1965c; 1965d), and is included in a recent regional gravity study of the Sudbury region (Popelar 1971).

Physiography

The physiographic features of the Burwash area, like those of the North Bay area (Lumbers 1971a) to the east, were formed by various geologic processes active over a long interval of time, probably in excess of 1,000 million years. Bedrock formations in the map-area were formed during Middle and Late Precambrian time. Following Late Precambrian high grade regional metamorphism, the rocks were subjected to faulting and minor intrusive activity during the latest Precambrian and at least the early Paleozoic, and were eroded to a peneplane by the Middle Ordovician time (Lumbers 1971a). This peneplane was subsequently re-exposed by post-Ordovician erosion and by Pleistocene continental glaciation with attendant rise of the land surface following the retreat of the last ice-sheet, the Wisconsin, to form the present land surface. Throughout much of the area, Pleistocene and Recent deposits of unconsolidated sediments form a thin discontinuous mantle over the bedrock or are locally absent so that drainage and topography are largely controlled by Precambrian and younger structures in the bedrock. Nevertheless, in a few places such as in the northeastern quarter of the area, the Pleistocene and Recent deposits are sufficiently thick and widespread to exert major control on drainage and topography.

RELIEF

The highest part of the Burwash area is represented by a few hills, a little over 1,000 feet (300 m) in elevation in Broder, Dryden, and southwestern Awrey Townships. The French River west of Flowerpot Bay in Allen Township, with an average elevation of 583 feet (178 m), is the lowest part. Maximum relief in the area as a whole is thus about 450 feet (137 m), but bedrock relief may be greater, because some waterways such as the French River and Amateewakea River probably cover relatively deep, pre-Pleistocene valleys in fault zones.

Most of the area lies within the drainage basin of Lake Nipissing and the French River, but in the western part, a northerly trending divide separates the French River drainage basin from the Wanapitei River drainage basin (Figure 7). Both drainage basins merge in southeastern Struthers Township, to flow southward through a myriad of channels into Georgian Bay. In the northwestern corner of the area, two other water partings (Figure 7) trend southwestward beyond the map-area and separate the drainage basins of the Whitefish River, the Spanish River, and the Wanapitei River. Elevations along the three water partings generally range from about 600 feet to 900 feet (180 m to 270 m) with local elevations in the northwestern part of the area up to 1,000 feet (300 m).

Local relief throughout most of the area rarely exceeds 50 feet (15 m), but in the northwestern part, local relief of 100 to 200 feet (30 to 60 m) is common. Some stretches of the North and Main Channels of the French River have steep cliffs up to 100 feet (30 m) high that probably mark fault zones. The eastern and central parts of the area are dominated by the western part of Lake Nipissing which has an average elevation of 644 feet (196 m) and is in most places less than 60 feet (18 m) deep. Local relief near the lake is generally less than 50 feet (15 m), and elevations of the surrounding terrain do not exceed 750 feet (230 m). North and west of Lake Nipissing and the Amateewakea River, the land surface rises gradually to between 800 (244 m) and 900 feet (274 m), but southwest of Lake Nipissing, the land surface slopes gently towards the southwestern corner of the area where, in general, elevations range from 600 to 700 feet (180 to 210 m). Near the southeastern corner of the area, south of Memesagamesing River, elevations increase slightly to a little over 800 feet (244 m). Thus, as pointed out by Quirke (1936), the French River and Lake Nipissing regions together form a prominent topographic trough or depression which slopes gently southwestward towards the northeast corner of Georgian Bay.

In southeastern Delamere Township near Lower Sturgeon Lake, the gentle southwestward slope of the French River-Lake Nipissing depression is interrupted by a prominent series of northwesterly trending hills or monadnocks underlain by quartz-rich metasediments, that rise 200 to 300 feet (60 to 90 m) above the surrounding terrain. From the highest peak, 913 feet (278 m) in elevation, the only other visible hills of comparable size are those of the LaCloche Mountains about 35 miles (56 km) to the west of the Burwash area; these rise to more than 1,000 feet (300 m) above the North Channel of Lake Huron.

DRAINAGE

Drainage within the map-area is accomplished mainly by four drainage systems: the Lake Nipissing-French River system, the Wanapitei River system, the Whitefish River system, and the Spanish River system. All four systems are part of the Georgian Bay and Lake Huron drainage basin, and the outlets of the Lake Nipissing-French River system and the Wanapitei River system merge in the southwestern corner of the area, just north of Georgian Bay. Attlee and Broker Lakes and Twin Lake in the southwestern corner of the area drain directly into Georgian Bay via the Mahzenazing River and Beaverstone River respectively. Major tributaries of the Lake Nipissing-French River system draining the area are Cache River, Veuve River, Nepewassi River, Amateewakea River, Wolseley River, Hall River, Memesagamesing River, Murdock River, Pillow River, and Pickerel River; Sturgeon River, another tributary of this system northeast of the map-area, drains the northeastern corner of the area. Ramsey Lake in the northwestern corner of the area drains southwest via Junction Creek into the Vermilion River, a major tributary of the Spanish River system. The Whitefish River south of Ramsey Lake drains only a small part of the area and flows southwestward through Lake Panache into Bay of Islands in the North Channel of Lake Huron.

In recent years beaver have increased in numbers in most parts of the area and have dammed many of the small streams to create numerous ponds and swampy areas. Such flooding is particularly extensive near Lake Nipissing and the French River where local relief is low.

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ROCK EXPOSURE

Rock exposure in the area ranges between 10 and 70 percent, but locally, deposits of Pleistocene and Recent sediments cover most of the bedrock. The more extensive covered areas are shown on Map 2271 (back pocket) and in Figure 7; within these areas outcrops are either scarce or lacking. The best rock exposure is in the eastern half of the map-area south of Highway 17 and in the western half of the area south of Trout Lake and Highway 637 where up to 70 percent of the terrain consists of low, bare, rocky ridges with intervening swampy to thinly drift covered valleys and depressions (see Figure 7).

Much of the northwestern part of the area, as far south as northern Tilton, Secord, and Burwash Townships, and as far east as western Awrey and Hawley Townships also consists of up to 70 percent bare rocky ridges (Figure 7), due to destruction of most of the vegetation by fumes from smelters in the Sudbury area and subsequent erosion of the soil cover. Nevertheless, in marked contrast to the well exposed parts of the area to the south and east where outcrops are virtually free of alteration, the bare rock outcrops here have been blackened and partly leached by the smelter fumes, making rock identification time-consuming and difficult. Elsewhere in the area, the bedrock is covered by a thin, discontinuous mantle of Pleistocene and Recent sediments, and rock exposure rarely exceeds 40 percent. Moss and lichen overgrowths on outcrops are absent to sparse within range of the Sudbury area smelter fumes and along shore lines, and sparse to thin below elevations of about 800 feet (244 m). At elevations between 800 (244 m) and 1,000 feet (305 m) this vegetal overgrowth thickens, but rarely obscures outcrops.

In general, the grain of the topography closely conforms to layering and foliation of the bedrock so that many structural details such as large scale folds and faults can be traced out on air photographs, especially where rock exposure exceeds about 30 percent. Some intrusions, particularly metamorphosed mafic intrusions and relatively late felsic intrusions with massive to slightly foliated interiors, are commonly characterized on air photographs by rugged, irregular topography and by prominent joint sets. Calc-silicate gneiss, marble, and late, unmetamorphosed diabase dikes weather more rapidly than other rock types and form hollows or linear depressions; anorthosite, quartz-rich and quartzofeldspathic metasandstones, and some felsic plutonic rocks are among the most resistant rocks to weathering and commonly form prominent ridges and topographically high areas.

GENERAL GEOLOGY

TERMINOLOGY

A few terms used in the following discussion of the general geology have been used differently by past authors. For the sake of clarity brief discussions of these terms, together with definitions adhered to in this report, are given below.

Precambrian Time Scale

The Precambrian time scale used is that suggested by the author and his co-workers for the recent Geological Map of Ontario (Ayres *et al.* 1971a). Precambrian time is subdivided into three eras: Early, Middle, and Late Precambrian. This subdivision is similar to one proposed by Goldich (1968), but time boundaries between Early and Middle at 2,500 million years and between Middle and Late Precambrian at 1,500 million years differ slightly from those adopted by Goldich. Revisions of the time boundaries and of the time scale can be anticipated as more data become available.

Killarnean and Killarney Batholithic Complex

Some previous workers in the region such as Phemister (1960) and Grant *et al.* (1962) considered rocks of the Grenville Province to be Killarnean in age, to have undergone a Killarnean orogeny, and to constitute a Killarnean Group. As pointed out above in the discussion of previous geological work, Killarnean was introduced by Quirke (1924) to refer to plutonic rocks of supposedly Late Precambrian (Keweena-wan) age, intrusive into supracrustal rocks of both the Southern and Grenville Provinces. Because Quirke considered the metamorphism in the Grenville Province to be due largely to the emplacement of Killarnean plutons, this metamorphism was also referred to as Killarnean. Subsequent geologic and geochronologic data, including data to be presented in the report, show that Quirke's Killarnean plutons range in age from Middle to Late Precambrian and in the Grenville Province these plutons are invariably metamorphosed by a high rank, Late Precambrian regional metamorphism that has no spatial or temporal association with the plutons. Thus from a consideration of the original use of the term and of recent data, Killarnean is misleading when applied to a major geological event or events in the Grenville Province, and further use of the term in this context should be discontinued.

"Killarney" has been applied correctly, however, as a stratigraphic term for a complex group of granitic intrusions forming an elongate mass extending northeastward from the Village of Killarney near the northeastern corner of Georgian Bay to south of Sudbury in the present map-area. This batholithic complex probably contains intrusions of various ages and is related spatially and possibly temporally to the Grenville Front Tectonic Zone.

Foliation, Schistosity, Gneissosity

Foliation is used in the sense of Turner and Weiss (1963, p.97), to cover all types of megascopically recognizable structural surfaces of metamorphic origin. Several varieties of foliation can be distinguished, based upon the development of such diverse structural features as lithologic layering, preferred dimensional orientation of mineral grains, and localized slip features. Two common varieties of foliation in the map-area that have been defined in several ways in the past are schistosity and gneissosity. As used in this report, schistosity denotes a planar structure in a metamorphic rock due to abundant, preferentially oriented grain boundaries, especially those of tabular crystals such as micas. Schistosity commonly imparts a fissility to the rock and is best developed in medium-

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grained rocks rich in micaceous minerals. Nevertheless, schistose rocks can be of any grain size and composition. Gneissosity denotes a layering of metamorphic origin defined by the alternation of layers, streaks, or lenticles of contrasting mineralogical composition or texture.

Gneiss

Gneiss is a metamorphic rock possessing gneissosity. Layers of contrasting mineralogy commonly consist of equidimensional grains without preferential orientation of grain boundaries, but small amounts of tabular and prismatic minerals such as micas and amphiboles can define a schistosity or lineation. Gneiss can split either parallel to or transverse to the layering, and although cleavability parallel to the layering is generally less regular than in schists, gneiss can possess schistosity, especially in layers rich in micaceous minerals.

Migmatite

Migmatite is defined according to Deitrich and Mehnert (1961) and is essentially a megascopically composite rock that consists of igneous or igneous-appearing material and metamorphic material. The igneous material is generally granitic in composition, and four main hypotheses have been put forward to account for the granitic material: 1) bodily injection of granitic magma from an adjacent igneous intrusion (injection migmatite); 2) metasomatism with the granitic rock-forming elements derived either from an adjacent granitic body in the form of granitic ichors, or from unknown depths as an aqueous fluid, or by ionic diffusion; 3) partial melting (anatexis) and subsequent segregation of those constituents having the lowest melting point during high rank regional metamorphism; and 4) metamorphic differentiation. Migmatitic rocks are common throughout the Grenville Province portion of the area; most previous workers appealed to regional metasomatism to explain these rocks and emphasized widespread granitization to account for most of the granitic plutons in the area. No data were presented by the previous workers to substantiate their claims of regional metasomatism and widespread granitization, and the present study indicates that many intensely granitized rocks of the previous workers are either arkosic metasandstone, or metamorphosed granitic intrusions. Moreover, field and petrographic data indicate that the migmatitic rocks formed mainly by a combination of partial melting and metamorphic differentiation, but minor injection migmatite is present adjacent to some intrusive bodies.

GEOLOGICAL SUMMARY

Except for the northwestern corner, which is underlain by relatively low metamorphic rank rocks of the Southern Province, most of the Burwash area is underlain by high metamorphic rank gneisses of the Grenville Province. The two geologic provinces are separated by a major, northeasterly trending tectonic zone, the Grenville Front Tectonic Zone, one of the major regional structures recognized within the Canadian Precambrian

Shield. Although both provinces contain Late Precambrian diabase dikes that postdate regional metamorphism, the low metamorphic rank rocks of the Southern Province are Middle Precambrian in age, whereas the high metamorphic rank gneisses of the Grenville Province reflect a more complex history and range in age from Middle to Late Precambrian. The general succession of the rocks for both provinces is summarized in Table 1.

In the Southern Province, the oldest rocks consist of a relatively thick succession of metamorphosed quartz-rich sandstone, argillite, some greywacke, and minor pebbly to bouldery sandstone and conglomerate, all of which are correlative with the lower part of the Huronian Supergroup. These metasediments were intruded by tabular-shaped gabbroic bodies which are probably related to the extensive Nipissing diabase intrusions present throughout the Southern Province, west and north of the map-area. Between about 2,150 and 1,700 million years ago, the metasediments and mafic intrusions were subjected to deformation and to relatively low rank regional metamorphism (Fairbairn *et al.* 1969). Near the present Grenville Province, these rocks were intruded by granitic bodies forming the northeastern end of the Killarney batholithic complex. These granitic intrusions were emplaced at relatively high crustal levels (see below) and straddle the boundary between the Southern and Grenville Provinces.

In the Grenville Province, host rocks for the intrusions are intensely deformed and recrystallized clastic siliceous metasediments containing early mafic sills and dikes. All of these rocks appear to be high metamorphic rank age-equivalents of the metasediments and mafic intrusions in the Southern Province. Although the Southern Province metasediments appear to continue into the Grenville Province, a major facies change probably occurs within the metasedimentary sequence near the Grenville Front Tectonic Zone. The equivalent metasediments in the Grenville Province were mainly derived from poorly-sorted sandstone and argillite rather than the relatively well-sorted quartz-rich sandstone characteristic of the Southern Province.

During the Late Precambrian, rocks of the Southern Province underwent extensive faulting, cataclasis, and mylonitization and were refolded into relatively tight folds with northeasterly trending axes. This deformation, which decreases in intensity toward the northwest and which apparently culminated when high rank regional metamorphism was on the wane in the Grenville Province, caused the rocks of the Grenville Province to be faulted and flattened against the relatively rigid Southern Province, effectively obscuring the nature of the facies change in the metasediments near the Grenville Province boundary. Following this deformation, late diabase dikes, possibly of two ages, were emplaced. Northwesterly trending dikes, relatively rich in olivine, do not extend from the Southern Province into the Grenville Province. These dikes appear to end abruptly at northeast-trending faults near the Grenville Province boundary. Essentially olivine-free (possibly younger) dikes are present locally along easterly to northeasterly trending faults that cut across rocks and structures of both the Southern and Grenville Provinces.

In the Grenville Province, the oldest and most abundant rocks are the metasediments. These are mainly siliceous sandstones and siltstones that probably represent a less well-sorted, deeper water facies equivalent of the metasediments in the adjacent Southern Province. Nevertheless, quartzo-feldspathic and quartzose metasandstones, representing relatively well-sorted and shallow water facies, are locally abundant in the western half of the map-area, and are especially widespread as thin intercalations in the poorly sorted metasandstone and metasilstone near the boundary of the Grenville Province. Calc-silicate gneiss and rare marble, the products of both clastic and chemical sedimentation, are locally interlayered with the clastic siliceous metasediments.

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Table 1

TABLE OF LITHOLOGIC UNITS FOR THE BURWASH AREA

CENOZOIC
QUATERNARY
RECENT
Swamp, lake, and stream deposits
PLEISTOCENE
Varved clay, sandy and silty boulder clay, fine sand, sand, pebble gravel, boulder gravel
<i>Unconformity</i>
PALEOZOIC
CAMBRIAN
MAFIC INTRUSIVE ROCKS
Lamprophyre Dikes
<i>Intrusive Contact</i>
PRECAMBRIAN
LATE PRECAMBRIAN
MAFIC INTRUSIVE ROCKS^a
Diabase Dikes
Diabase, olivine diabase ^b
<i>Intrusive Contact</i>
Mafic to Ultramafic Stocks
Norite, olivine gabbro, serpentized peridotite
<i>Intrusive Contact</i>
GRENVILLE PROVINCE
LATE PRECAMBRIAN
LATE PEGMATITE
Massive granite pegmatite dikes
<i>High Rank Regional Metamorphism</i>
LATE MAFIC INTRUSIVE ROCKS
Metadiabase, metagabbro, metadiorite, metamorphosed ultra- mafic rocks and associated granitic dikes
ALKALIC INTRUSIVE ROCKS
Gneissic alkalic syenite, gneissic hastingsite nepheline syenite, gneissic biotite nepheline syenite
<i>Intrusive Contact</i>
ANORTHOSITE SUITE INTRUSIVE ROCKS^c
Anorthosite and Related Mafic Rocks
Gneissic anorthosite, gabbroic anorthosite, anorthositic gabbro, gabbro, diorite, tonalite
Monzonitic to Granitic Rocks
Pink, grey, and green, gneissic monzonitic rocks with minor associated gneissic tonalite and diorite; gneissic sodic syenite, gneissic quartz syenite, gneissic quartz monzonite; rare gneissic granite and enderbite dikes

a. Some mafic intrusive rocks may be early Paleozoic in age.

b. Olivine diabase dikes are present only in the Southern Province and may be older than Late Precambrian diabase dikes.

c. Multiple ages represented.

MIDDLE TO LATE PRECAMBRIAN

EARLY MAFIC INTRUSIVE ROCKS^c

Gneissic gabbro, diorite, tonalite, and minor associated granitic rocks; fine-grained and medium-grained amphibolite dikes and sills

MIDDLE PRECAMBRIAN

EARLY PEGMATITE

Gneissic granite pegmatite dikes

GRANITIC INTRUSIVE ROCKS (SOUTHERN AND GRENVILLE PROVINCES)^c

Massive to slightly cataclastic, equigranular to porphyritic quartz monzonite, granodiorite, trondhjemite; cataclastic and mylonitic quartz monzonite and granodiorite; migmatitic and gneissic quartz monzonite, hornblende-bearing quartz monzonite, and granodiorite; gneissic albite granite, trondhjemite, and tonalite

Intrusive and Metamorphic Contact

METASEDIMENTS

Calcareous Metasediments

Carbonate metasediments, hornblende gneiss

Clastic Siliceous Metasediments

Muscovitic and quartzose gneiss, feldspathic gneiss, biotite gneiss, rare gneissic metaconglomerate; migmatitic varieties present

Fault Contact

SOUTHERN PROVINCE

MIDDLE PRECAMBRIAN

Low Rank Regional Metamorphism

MAFIC INTRUSIVE ROCKS

Massive to cataclastic metagabbro; minor ultramafic rocks and granophyre

Intrusive Contact

HURONIAN SUPERGROUP

HOUGH LAKE GROUP

Mississagi Formation

Metamorphosed arkose, subarkose, protoquartzite, subgreywacke, greywacke, argillite; minor lensoid units of intraformational pebbly sandstone and conglomerate

Pecors Formation

Interbedded, metamorphosed argillite, lithic greywacke, subgreywacke, protoquartzite, arkose

Ramsay Lake Formation

Metamorphosed pebbly to bouldery, coarse-grained sandstone and polymictic conglomerate; minor interbedded protoquartzite and argillite

ELLIOT LAKE GROUP

McKim Formation

Laminated to thick-bedded, metamorphosed argillite, lithic and feldspathic greywacke, arkose, protoquartzite, and pebbly sandstone

^c. Multiple ages represented.

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Some of the siliceous metasediments, especially those close to granite in modal composition, are migmatitic, particularly in zones of intense deformation; granitic material in the migmatitic varieties is present mainly as discontinuous veins and lenses, commonly isolated in three dimensions, and apparently formed by a combination of partial anatexis and metamorphic differentiation. The high rank metamorphism and complex folding to which the metasediments were subjected destroyed or obscured primary structures indicative of tops of beds so that detailed structural studies would be needed to establish the stratigraphic succession. At the present time these rocks are subdivided on a lithologic basis only.

A large variety of plutonic rocks, ranging in age from Middle to Late Precambrian, were emplaced within the Grenville Province metasediments before the high rank regional metamorphism and accompanying deformation ended, and are themselves metamorphosed. Of the various plutonic rocks, gneissic felsic varieties, forming stocks, sheets, and batholiths, are most abundant. Several ages of felsic plutonic rocks can be recognized by the relative intensity of deformation and regional metamorphism and by geochronologic studies. The oldest felsic plutonic rocks are Middle Precambrian in age and granitic in composition, whereas the youngest felsic plutonic rocks are Late Precambrian in age and belong to the anorthosite suite. The anorthosite suite rocks range in composition from syenitic and monzonitic to granitic and occur either in complex intrusions with gneissic anorthosite and related metamorphosed mafic intrusive rocks, or as separate anorthosite-free bodies. Only a few intrusions that are predominantly anorthosite and related mafic rocks are present, but in the eastern half of the area, two such bodies intruded a large batholith of Middle Precambrian granitic rocks. Most of the anorthosite suite intrusions are relatively small stocks and sheet-like bodies, but there is one intrusion of batholithic dimensions (Cosby batholith) that consists of felsic anorthosite suite rocks.

Metamorphosed mafic intrusive rocks of several ages, apparently unrelated to the anorthosite suite intrusions, form sills, dikes, stocks, and small irregularly shaped bodies in the metasediments and, rarely, in the Middle Precambrian granitic rocks. Most of these mafic intrusions are within the Grenville Front Tectonic Zone. Some are intruded by Middle Precambrian granitic rocks, but others are much younger and were only partly recrystallized by the Late Precambrian regional metamorphism. Metamorphosed, gneissic granite pegmatite dikes, rarely showing internal zoning, are present locally in the Grenville Front Tectonic Zone where they cut across only the metasediments and oldest mafic intrusive rocks. Gneissic alkalic syenite and nepheline syenite form an elongate complex, intrusive into felsic anorthosite suite rocks and metasediments, in the southwestern part of the area. The youngest plutonic rocks are small dikes of massive granite pegmatite, commonly with internal zoning and rarely containing radioactive minerals, that were emplaced during the waning stages of regional metamorphism.

Northwest of the Grenville Front Tectonic Zone, in the Southern Province, mineral assemblages in argillaceous metasediments are typical of the quartz-albite-epidote-biotite subfacies of the greenschist facies described by Turner and Verhoogen (1960) and Winkler (1967). This metamorphic event culminated about 1,800 million years ago (Fairbairn *et al.* 1965; 1969), before the intrusion of the Killarney granitic rocks. Rocks of the Grenville Province were subjected to Late Precambrian, high rank regional metamorphism. In the western half of the area, between the Grenville Front Boundary Fault and the southeastern limit of the Grenville Front Tectonic Zone, some of the metasediments and mafic intrusive rocks contain mineral assemblages most typical

of the sillimanite-almandine-orthoclase subfacies of the almandine-amphibolite facies. Locally, assemblages characteristic of the staurolite-almandine subfacies are present in argillaceous metasediments near the Boundary Fault (Kwak 1971). In the eastern half of the area, mineral associations in the various gneisses indicate that pressure and temperature conditions during the Late Precambrian regional metamorphism were uniform. Mineral assemblages are most typical of the kyanite-almandine-muscovite subfacies of the almandine-amphibolite facies.

Following the high rank regional metamorphism and plutonism, the region was subjected to faulting during the Late Precambrian, and at least the early Paleozoic. During this tectonism, a gabbroic stock, a few small ultramafic stocks, and dikes of diabase and lamprophyre intruded rocks of the older metamorphic complex. A few lamprophyre dikes, probably of Cambrian age, and found only in the eastern part of the area, are related to the Ottawa-Bonnechere Graben that trends through Lake Nipissing and the central part of the adjacent North Bay area (Lumbers 1971a); the Graben appears to die out as an identifiable structure in the east-central part of the Burwash map-area.

Southern Province

MIDDLE PRECAMBRIAN

Huronian Supergroup

As discussed above, the metasediments of the Southern Province in the northwestern corner of the map-area have been considered by previous workers as: 1) correlative with the lower part of the Huronian Supergroup; 2) to belong to the Sudbury group, supposedly older than the Huronian Supergroup; and 3) to belong partly to the lower part of the Huronian Supergroup and partly to the Sudbury group. From recent regional compilations and work in neighbouring areas to the west by Card (1968; 1971a; 1971b), Frarey and Cannon (1969), Roscoe (1969), Henderson (1967a), Young and Church (1966), and others, and from work by the author on the extension of these metasediments north of the map-area (Lumbers 1971e), the sequence has now been established as belonging to the lower part of the Huronian Supergroup. Essentially conformable, the metasedimentary sequence can be subdivided into four formations as shown by Card (1968; 1971a; 1971b) and other workers to the west; stratigraphic nomenclature used by the author is that recommended by the Federal-Provincial Committee on Huronian Stratigraphy (Robertson *et al.* 1969). From oldest to youngest, the four formations comprising the sequence in the map-area are: McKim Formation, Ramsay Lake Formation, Pecors Formation, and Mississagi Formation. The McKim Formation forms the upper part of the Elliot Lake Group, whereas the other three formations comprise the Hough Lake Group (Robertson *et al.* 1969). The Mississagi Formation corresponds to the Wanapitei quartzite of previous workers and includes Cooke's (1946) Coniston group.

Burwash Area

ELLIOT LAKE GROUP

McKim Formation

The McKim Formation is exposed north of Ramsey Lake, within the city limits of Sudbury, in McKim Township, where it is intruded by a large gabbroic body. The formation consists of metamorphosed argillaceous rocks and fine-grained sandstone with variable amounts of medium- to coarse-grained sandstone and pebbly sandstone. The metasandstones range in composition from lithic and feldspathic greywacke to proto-quartzite and arkose,¹ and are composed mainly of quartz, muscovite, chlorite, biotite, and plagioclase. Metamorphosed argillaceous rocks contain essentially the same minerals as the metasandstones but are much richer in muscovite and chlorite. Mineral assemblages indicate that the rocks were regionally metamorphosed under conditions corresponding to the greenschist facies.

Bedding thicknesses vary considerably, with units up to 10 feet (3 m) thick of laminated to thin-bedded² argillite and fine-grained metasandstone alternating with units, up to 15 feet (4.5 m) thick, of medium-bedded to thick-bedded metasandstone and pebbly metasandstone. Primary sedimentary structures such as grain gradation, ripple marks, small-scale crossbedding, and soft-sediment deformation structures are common and indicate a possible turbidity current origin for the McKim rocks (Card *et al.* 1971). Primary sedimentary structures indicate that, except for a few minor folds, the metasediments dip and face southeastward. Secondary structures such as schistosity and lineations are locally well developed but, in general, do not obliterate original sedimentary structures and textures.

According to Card (1968), the McKim Formation is up to 7,000 feet (2130 m) thick in Graham and Waters Townships to the west of the map-area and lies conformably upon underlying metavolcanics of the Copper Cliff, Stobie, and Elsie Mountain Formations.

HOUGH LAKE GROUP

Ramsay Lake Formation

The Ramsay Lake Formation, previously termed the Ramsay Lake Conglomerate by Coleman (1914), is exposed along the north shore and at the southwestern end of Ramsey Lake in McKim Township. The formation consists of pebbly to bouldery, coarse-grained metasandstone that locally grades into polymictic metaconglomerate; in places, particularly near the base of the formation, thin lensoid units of argillaceous rocks and medium-grained, quartz-rich metasandstones are present. Coarse clasts, comprising 5 to 60 percent of the formation and ranging in size from 0.5 inch (13 mm) to about 5 feet (1.5 m), consist of quartz-rich metasandstone, quartz, granitic rocks.

¹Sandstones are classified according to Pettijohn (1957).

²Bedding is classified according to Dunbar and Rogers (1957, p. 97).

(which form the largest clasts), mafic metavolcanics, and rare felsic metavolcanics. The matrix consists mainly of white to black quartz grains ranging in size from less than 1 mm to 5 mm, and minor plagioclase, potassic feldspar, and rock fragments in a fine-grained recrystallized groundmass rich in muscovite and biotite. Internal structure is rare, but lenses of laminated argillaceous rocks and thin-bedded, medium-grained metasandstone locally produce stratification. In places, stratification in the coarse pebbly metasandstone and metaconglomerate is indicated by local variations in grain size of the matrix and coarse clasts. Most of the quartz clasts are subrounded to rounded, but the metasedimentary, granitic, and metavolcanic clasts are commonly subangular to angular. Although metamorphism has caused extensive recrystallization in the matrix, the coarse clasts are relatively undeformed and show only minor strain effects.

As pointed out by Cooke (1946) and Card (1968) among others, the Ramsay Lake Formation conformably overlies the McKim Formation. Near the contact in the map-area, the two formations are complexly intercalated over thicknesses of 10 feet (3 m) or more. The McKim Formation commonly contains a few relatively thick beds of pebbly, quartz-rich metasandstone for a few feet below the contact, and a few thin units of argillaceous rocks are interbedded with pebbly to bouldery, coarse-grained metasandstone near the base of the Ramsay Lake Formation.

Pecors Formation

Most previous workers included the Pecors Formation with the Wanapitei Quartzite or Mississagi Formation, but Card (1968) recognized that a distinctive unit of argillaceous rocks and quartz-rich metasandstones, up to 1,400 feet (425 m) thick, lies conformably above the Ramsay Lake Formation and grades into the overlying Mississagi Formation. This unit has now been correlated with the Pecors Formation (Card 1971a; 1971b; Card *et al.* 1971). Within the map-area, the formation is exposed over a width of about 700 feet (210 m) near the southwestern end of Ramsey Lake in McKim Township, where the lower and upper contacts are conformable and gradational with the Ramsay Lake and Mississagi Formations. Continuation of the formation to the northeast is obscured by Ramsey Lake and by the large gabbroic intrusion north of Ramsey Lake, but near the northern boundary of the map-area, rocks of the formation outcrop near the eastern contact of the gabbroic intrusion.

The lower part of the Pecors Formation consists mainly of laminated to thin-bedded micaceous schists derived from argillite and fine-grained sandstone, but towards the upper part of the formation, fine-grained to medium-grained metasandstone beds increase in abundance and the sequence becomes more thickly bedded. Primary structures indicate probable deposition by turbidity currents (Card *et al.* 1971). The contact with the overlying Mississagi Formation is arbitrarily placed where medium-grained, quartz-rich metasandstone beds predominate over the fine-grained metasediments. The metasandstones range in composition from lithic greywacke to subgreywacke and protoquartzite with some arkosic units in the upper part of the formation.

Burwash Area

Mississagi Formation

Metasediments of the Mississagi Formation underlie most of the Southern Province portion of the map-area and extend into the Grenville Front Tectonic Zone, where they are in fault contact with rocks of the Grenville Province. Middle Precambrian granitic intrusions (mapped by Phemister 1960, and Grant *et al.* 1962, as feldspathized quartzite) and gabbroic intrusions are abundant in the formation near the Grenville Province boundary in Neelon, Dill, Broder, and Tilton Townships. Locally, near the granitic intrusions, rocks of the formation are intensely altered due to contact metamorphism and injection of granitic material. These contact metamorphic effects are partly obscured by superimposed cataclasis and mylonitization associated with Late Precambrian deformation along the Grenville Front Tectonic Zone. The complex Late Precambrian igneous and deformational events produced several textural and structural varieties of the metasediments and meta-igneous rocks.

Interpretation of the complex lithology of the Mississagi Formation within the Grenville Front Tectonic Zone is possible, because of the gradual decrease in intensity of the deformation of metamorphism which caused the complexities toward the northwest, across the Tectonic Zone. Near the northwest margin of the Zone, the metasediments were altered mainly by the Middle Precambrian low rank regional metamorphism and deformation. The various conflicting interpretations of the stratigraphic position and lithology of the Mississagi Formation by previous workers are due in part to their failure to recognize the complex sequence of events affecting rocks of the formation near the Grenville Province. For example, Cooke's (1946) Coniston group, supposedly a pre-Huronian sequence of thin-bedded cherts and intercalated dark mafic rocks that passes southeastward into the Grenville Province, is actually the cataclastic and mylonitic quartz-rich metasandstone, with minor interbedded argillaceous metasediments and meta-greywacke of the Mississagi Formation, and intercalated sills and dikes of metagabbro. Cooke (1946, p.11), in discussing the microtexture of his "chert", was unable to reconcile the texture with that found in other cherts, and although he gave a relatively accurate description of the cataclastic quartz-rich metasandstone, he failed to recognize the correct origin of the rock.

The Mississagi Formation mainly consists of quartz-rich metasandstone with abundant thin interbeds and partings of argillaceous metasediments producing a well-bedded sequence in which individual sandy beds range in thickness from about 3 inches (8 cm) to 4 feet (1.2 m). The sequence is remarkably even-bedded with only rare scour surfaces evident within metasandstone units, but both planar and trough crossbedding and grain gradation are common in the metasandstone. Argillaceous interbeds are most abundant near the base of the sequence, where they are accompanied by some greywacke interbeds. Near the Grenville Province boundary, argillite interbeds and a few thin lensoid units of intraformational metaconglomerate are present (see Photo 1). In Broder, Dill, and Tilton Townships near the Grenville Province boundary, the Mississagi Formation is relatively rich in argillaceous interbeds and also contains several lensoid units of meta-greywacke with quartz-rich metasandstone interbeds and rare lensoid units of pebbly, coarse-grained metasandstone that locally grade into metaconglomerate. These units in Broder and Dill Townships were assigned by Henderson (1967a) to the McKim and Ramsay Lake Formations, but their lensoid, discontinuous nature suggests that they are most likely a facies of the Mississagi Formation. Although the metasedimentary sequence between the Grenville Province and the Chief Lake batholith in Tilton Township is



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Photo 1—Lensoid unit of intensely deformed, cataclastic intraformational metaconglomerate in cataclastic, quartz-rich metasandstone of the Mississagi Formation; about ¼ mile (0.4 km) northwest of the Grenville Front in lot 9, concession III, Dryden Township.

intensely deformed, injected by granitic rocks of the batholith, and cut off from the rest of the formation to the north, it consists largely of interbedded metagreywacke, micaceous schists, and quartz-rich metasandstone that could also be a facies in the Mississagi Formation.

Within about 1,000 feet (300 m) of the Grenville Province boundary, deformation has largely obscured primary sedimentary structures, but elsewhere these structures are sufficiently well preserved to provide abundant top determinations, indicating that the Mississagi Formation is complexly folded and faulted. Near the Grenville Province, the sequence is tightly folded about northeasterly trending axes into a complex synclinorium dismembered by numerous faults and slightly overturned toward the northwest (see Map 2271, back pocket; Henderson 1967a, Figure 3). The Boundary Fault marking the northwestern margin of the Grenville Province cuts across the southeastern limb of the synclinorium at a low angle and appears to cut off the lower part of the sequence. In the southeastern limb in Dill and Broder Townships, the sequence is richer in argillaceous metasediments and metagreywacke than in the northwestern limb, suggesting that a facies change may take place within the formation between Ramsey Lake and the Grenville Province. Metasediments in the adjacent Grenville Province largely represent an interbedded sequence of greywacke and shale that contains numerous thin units

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of quartz-rich sandstone, a sequence lithologically similar to the southeastern limb of the synclinorium in Dill and Broder Townships. These sequences may therefore be equivalent in age and may reflect a major change in depositional environment within the Grenville Front Tectonic Zone.

Quartz-rich metasandstone of the Mississagi Formation generally consists of 60 to 90 percent quartz, up to 25 percent feldspar, up to 10 percent muscovite, and accessory biotite, chlorite, opaque minerals, apatite, and zircon; some of these metasediments contain a few identifiable rock fragments, mainly granitic rocks, metasediments, and possibly felsic metavolcanics. Most of the metasandstone is arkosic or subarkosic, although some subgreywacke and protoquartzite equivalents are present. Plagioclase is the major feldspar in some of the metasandstones, whereas in others potassic feldspar predominates, and in still others both feldspars are about equally abundant.

Argillaceous metasediments are essentially micaceous schists rich in muscovite, biotite, and chlorite; metagreywacke is essentially a biotite-feldspar-quartz schist locally containing muscovite porphyroblasts. Within a few thousand feet (1000 m) of the Grenville Province, chloritization and hematitization of the metasediments is common. Metasediments bordering granitic intrusions and as inclusions within the intrusions are more completely recrystallized than elsewhere and were injected by sills and dikes of granitic rocks; metagreywacke locally contains partly altered porphyroblasts of staurolite and garnet, and possible other altered metamorphic minerals. Within a few feet of granitic intrusion contacts, quartz-rich metasandstone locally contains potassic feldspar porphyroblasts.

Near the Grenville Province where deformation was most intense, schistosity is developed in all the metasediments (see Photo 1), but elsewhere schistosity is generally well developed only in the argillaceous metasediments and metagreywacke. Strain effects in the metasediments due to the late cataclasis and mylonitization near the Grenville Province are particularly spectacular in the quartz-rich metasandstone.

The thickness of the Mississagi Formation is extremely difficult to estimate because of the complex structure and stratigraphic duplication due to folding. Card (1968) estimated the formation to be more than 3,000 feet (915 m) thick in Waters Township to the west of Broder Township, whereas Henderson (1967a) estimated the formation be at least 4,500 feet (1370 m) thick west of the Grenville Province boundary in southern Broder, Tilton, and Eden Townships. In the map-area, Grant *et al.* (1962) gave an estimated thickness of at least 7,400 feet (2255 m). These estimated thicknesses suggest that the formation may thicken eastward toward the Grenville Province in addition to undergoing a facies change to a sequence relatively rich in argillite and greywacke. In this connection, Card *et al.* (1971), working in the Louise-Eden area west of Tilton Township, also concluded that the formation thickens eastward toward the Grenville Province, but that overlying metasediments of the Quirke Lake and Cobalt Groups thin eastward and some units rich in coarse clastic debris become progressively finer grained. Card (1968), Card *et al.* (1971), and Roscoe (1969), among others, showed from bedding-crossbedding relations that bimodal paleocurrent patterns are present in the quartz-rich metasandstone of the formation; these resulted from primary deposition by southerly flowing currents, with secondary reworking by east-west longshore currents. This paleocurrent pattern, which is general throughout most of the metasediments of the Huronian Supergroup (Card *et al.* 1971), corresponds with the direction of general thickening in the Mississagi Formation and indicates that the main source area lay to the north, probably in the granitic terrain of the Superior Province.

SUMMARY OF THE HURONIAN STRATIGRAPHY

Metasediments in the Southern Province portion of the Burwash area belong to the lower part of the Huronian Supergroup, which was deposited between about 2,500 and 2,150 million years ago, according to geochronologic data summarized by Fairbairn *et al.* (1969). The metasediments represent a conformable sequence of fine to coarse clastic debris at least 15,000 feet (4600 m) thick, deposited conformably upon a meta-volcanic-rich assemblage that forms the oldest part of the Huronian Supergroup in the Sudbury area (Roscoe 1969). The metasediments were deposited by southerly flowing currents, probably near the northern margin of an arcuate geosyncline that was the site of volcanism. Rocks of the McKim and Pecors Formation display many primary features in common with turbidites (Card *et al.* 1971) and were probably deposited by turbidity currents in relatively deep water with little reworking by wave-action. Rocks of the Ramsay Lake Formation, derived mainly from pebbly to bouldery coarse sand, gravel, and rubble indicate that relatively shallow water conditions existed between deposition of the McKim and Pecors Formations, and possibly, tectonic activity in the source area to the north. Some previous workers interpreted the Ramsay Lake Formation as glacial in origin, but as pointed out by Card *et al.* (1971), such an origin is difficult to reconcile with the lithology and primary structural features of the formation. Most of the Mississagi Formation, rich in quartzose metasandstone, was probably deposited in relatively shallow waters under the influence of wave action, possibly in a deltaic or littoral environment (Card *et al.* 1971). The eastward thickening toward the Grenville Province and the increase in the amount of argillaceous metasediments and metagreywacke in the Mississagi Formation suggest a facies change to deeper water conditions in the vicinity of the Grenville Front Tectonic Zone. A paleogeographic boundary, or hinge line within the Tectonic Zone during deposition of metasediments of the Huronian Supergroup is also suggested by Card *et al.* (1971) to explain facies and thickness changes near the Tectonic Zone in the Louise-Eden area.

Mafic Intrusive Rocks

Several large tabular intrusions of gabbroic rocks in the metasediments of the Huronian Supergroup are deformed, low metamorphic rank equivalents of the Nipissing diabase intrusions commonly found throughout the Southern Province (Card and Pattison 1973). These intrusions are Middle Precambrian in age (about $2,160 \pm 50$ million years old according to Fairbairn *et al.* 1969), and are tholeiitic in composition, commonly with segregations of sodic granophyre (Card and Pattison 1973).

Within the map-area, the gabbroic intrusions appear to be slightly discordant sill-like bodies that underwent the same deformational and metamorphic histories as their enclosing metasediments. Some of the intrusions appear to be folded sill-like bodies and show only a slight superimposed foliation, whereas others, particularly near the Grenville Province where deformation is most intense, are elongated parallel to stratigraphic and structural trends in the metasediments and are locally cataclastic. Margins of most intrusions, regardless of their position relative to the Grenville Province, display secondary foliation, but most intrusions more than about 1 mile (1.6 km) northwest of the Grenville Province boundary contain massive phases with primary textures and mineralogy in their interiors.

Burwash Area



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Photo 2—Contaminated intrusive breccia of the Chief Lake batholith consisting of angular fragments of intensely recrystallized metagabbro (black) in a granitic matrix; about 1 mile (1.6 km) southeast of Rheault in lot 3, concession III, Broder Township.

Contacts with the metasediments are sharp with only narrow contact metamorphic aureoles (generally less than 2 feet (0.6 m) across) in the metasediments. Locally, thin relict chilled zones are present at the borders of the intrusions. In detail, transgressive contacts are common; contacts locally cut across bedding and fold axes in the metasediments. Some contacts are marked by breccias similar to the breccias found near the Sudbury nickel irruptive to the northwest (Grant *et al.* 1962), and small blocks of quartz-rich metasandstone are locally present within a few intrusions. Near the Grenville Province boundary, in Neelon, Dill, and Broder Townships, Middle Precambrian granitic rocks intruded the gabbroic bodies and formed locally extensive zones of contaminated intrusive breccia. The breccia consists of abundant, angular fragments of intensely recrystallized metagabbro in a granitic matrix ranging in composition from quartz monzonite to trondhjemite (Photo 2).

One of the gabbroic intrusions in Neelon Township is cut by the Grenville Front Boundary Fault (see Map 2271, back pocket). Many of the widespread sill-like bodies of metagabbro in metasediments concentrated in the Grenville Province near the Grenville Province boundary could be high metamorphic rank equivalents of the Nipissing diabase (see discussion on "Early Mafic Intrusive Rocks" of the Grenville Province).

The intrusions are mainly composed of metamorphosed, dark green, medium-grained gabbro, consisting of partly saussuritized plagioclase, uralitized pyroxene (mainly an aggregate of pale green to bluish green amphiboles, chlorite, carbonate, and minor

epidote and opaque minerals), and accessory apatite and opaque minerals. Traces of quartz, generally as micrographic intergrowths with plagioclase, are present in some gabbros, and plagioclase, ranging in composition from about An₄₀ to An₇₀, shows relict primary normal and oscillatory zoning. Primary igneous microtextures, particularly subophitic and isogranular textures, are poorly preserved in foliated phases and relatively well preserved in massive phases that contain variable amounts of relict clinopyroxene and orthopyroxene. Massive phases contain a criss-cross pattern of alteration veinlets generally less than 2 inches (5 cm) across, developed in variously oriented fractures. The veinlets consist of saussuritized and uralitized gabbro rich in chlorite, amphiboles, and epidote, and were probably formed during the Middle Precambrian low rank regional metamorphism (Card 1968). Pyroxene to plagioclase ratios range from about 2:3 to 8:1, and local variations in plagioclase and pyroxene contents reflect poorly developed, primary, igneous layering in some intrusions. Microscopic strain features become increasingly apparent in the major minerals of the rocks towards the Grenville Province and are particularly well developed in plagioclase grains in intrusions near the Boundary Fault.

Some intrusions locally contain up to 5 percent disseminated sulphide minerals, chiefly pyrrhotite and pyrite with minor chalcopyrite and pentlandite and segregations and dikelets of fine-grained to coarse-grained granophyre. The granophyre consists of sodic plagioclase and quartz in micrographic intergrowths and as separate grains, some amphibole, and minor biotite, chlorite, epidote, apatite, sphene, and opaque minerals. Potassic feldspar appears to be rare in the granophyre, and chemical analyses of granophyre from various widely separated intrusions of Nipissing diabase given by Card and Pattison (1973) show that these rocks are commonly very rich in soda and poor in potassia.

Primary structural and textural features of the gabbroic bodies show that they are relatively high level epizonal intrusions, which are generally emplaced within about 4 miles (6.5 km) of the earth's surface (Buddington 1959). Granophyric phases and poorly developed primary igneous layering are due to magmatic differentiation. Card and Pattison (1973), among others, have found evidence in the Sudbury region that the Nipissing diabase intrusions were emplaced after early faulting, but during initial folding of the Huronian Supergroup. No evidence for this sequence of events is apparent in the map-area, but the complex deformational history to which the metasediments and intrusions were subjected could have obscured such evidence.

Other Intrusive Rocks

Middle Precambrian granitic rocks intrusive into metasediments and the gabbroic intrusions of the Southern Province straddle the boundary between the Southern and Grenville Provinces and are discussed below under the "Grenville Province". Similarly, Late Precambrian diabase dikes are described below in a separate section on Late Precambrian mafic intrusive rocks.

Metamorphism of the Southern Province

In this section most of the emphasis is placed upon the Middle Precambrian metamorphism of the metasediments and gabbroic intrusions; although Late Precambrian events connected with the Grenville Front Tectonic Zone are briefly summarized, these are discussed in greater detail in the "Structural Geology" section.

Field relationships and geochronologic data show that rocks of the Southern Province underwent a complicated history of deformation, igneous activity, and metamorphism during the Middle and Late Precambrian. Late Precambrian cataclasis, mylonitization, and accompanying recrystallization related to the Grenville Front Tectonic Zone extend up to 2 miles (3 km) into the Southern Province from the Grenville Province Boundary Fault. The northwestern limit of the Tectonic Zone cannot be mapped precisely because cataclasis and mylonitization characteristic of the zone gradually decrease in intensity towards the northwest, and near the northwestern limit of the Zone, rocks that appear to be free of cataclasis macroscopically show evidence of cataclasis microscopically. Narrow zones of cataclasis and mylonitization are associated with many of the numerous faults that cut across rocks of the Southern Province; most of these faults were active following formation of the Grenville Front Tectonic Zone (see discussion of faulting in the "Structural Geology" section). Deformation related to the Tectonic Zone and to the later faulting is superimposed upon metamorphic and tectonic features formed during the Middle Precambrian.

The metasediments and gabbroic intrusions were folded about easterly trending axes and metamorphosed under greenschist facies conditions prior to emplacement of the Middle Precambrian granitic rocks. Near the Grenville Province boundary, these early folds were subsequently tightened and rotated subparallel to the northeasterly trending boundary of the Grenville Province (Henderson 1967a). Although the granitic intrusions and their host rocks lie mainly within the Grenville Front Tectonic Zone and are consequently cataclastic and mylonitic, the Huronian metasediments and Middle Precambrian gabbroic rocks near the granitic intrusions are more recrystallized than elsewhere, probably because of contact metamorphism caused by the intrusion of the granitic rocks. Staurolite and garnet are locally developed in metasedimentary inclusions within the granitic intrusions and in some metasediments bordering the intrusions and probably formed during contact metamorphism.

Because of the complex deformational and metamorphic events within the Grenville Front Tectonic Zone, data concerning the intensity of the Middle Precambrian regional metamorphism in the Southern Province should be sought in the region northwest of the zone. In this region, argillaceous metasediments, found throughout the metasedimentary sequence, invariably contain chlorite, biotite, muscovite, and albite; garnet and chloritoid are rare and generally absent. Mineral assemblages of these rocks are most typical of the quartz-albite-epidote-biotite subfacies of the greenschist facies described by Turner and Verhoogen (1960) and Winkler (1967). Metamorphic mineral assemblages developed in other metasediments and in the gabbroic rocks are generally compatible with this subfacies, but more data are necessary to prove that temperature and pressure conditions during the Middle Precambrian metamorphism were uniform

throughout the area. Mineral assemblages in Southern Province metasediments and gabbroic rocks within the Tectonic Zone also indicate metamorphism under greenschist facies conditions, but superimposed cataclasis and mylonitization could have obscured higher grade assemblages.

Approximate limits can be placed on the age of the Middle Precambrian regional metamorphism. The metamorphism occurred after intrusion of the Nipissing diabase bodies, about 2,160 million years ago (Fairbairn *et al.* 1969), and before intrusion of the granitic rocks, about 1,590 to 1,700 million years ago (Davis *et al.* 1970). Some geochronological data on metamorphic minerals summarized by Fairbairn *et al.* (1965; 1969) suggest that the metamorphism may have culminated about 1,800 million years ago, following development of the major easterly trending fold pattern.

Grenville Province

MIDDLE PRECAMBRIAN

Metasediments

Metasediments of the Grenville Province are older than 1,700 million years (Davis *et al.* 1970), and for reasons to be discussed below (see section on "Summary of the Metasedimentary Sequence"), they are probably equivalent in age to at least the lower part of the Middle Precambrian Huronian Supergroup. Most of the metasediments are derived from clastic siliceous sandstones, siltstones, and argillaceous rocks, but narrow interlayers of calcareous metasediments are widespread and consist mainly of hornblende-rich gneisses probably derived from calcareous sandstones and siltstones that originally contained as much as 50 percent carbonate minerals. Rare marble units, derived from impure limestone and dolostone, are interlayered with hornblende gneiss and clastic siliceous metasediments near the Southern Province in Dill and Nee'lon Townships. The clastic siliceous metasediments show the same general lithologic variations as those in the adjacent North Bay area to the east (Lumbers 1971a) and are subdivided in a similar manner into four major units: 1) biotite gneiss; 2) migmatitic biotite gneiss; 3) feldspathic gneiss; and 4) muscovitic and quartzose gneiss. Each of the four units can be further subdivided into various sub-units on the basis of mineralogic, metamorphic, and relict primary features; some of these sub-units were not recognized in the adjacent North Bay area. The biotite gneisses greatly predominate over feldspathic gneiss and muscovitic and quartzose gneiss and probably represent sequences similar to those of the McKim and Pecors Formations, consisting mainly of interbedded greywacke and argillite with minor interbeds of quartz-rich and arkosic sandstones. Feldspathic gneiss is derived mainly from arkosic sandstone, whereas muscovitic and quartzose gneiss is derived mainly from quartz-rich sandstones that ranged in composition from quartz-rich arkose and subarkose to orthoquartzite. Geologic boundaries drawn in the metasedimentary gneiss are necessarily somewhat subjective because individual units commonly have gradational contacts and contain abundant interlayers of other units.

Burwash Area

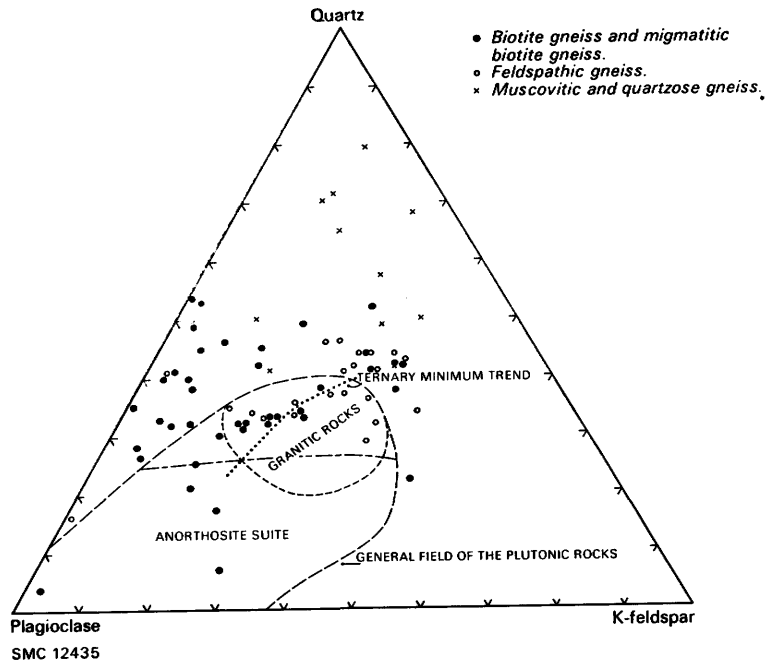


Figure 2A—Modal quartz, plagioclase, and potassic feldspar from 73 thin sections of clastic siliceous metasediments from the Burwash and North Bay areas. The general field of the felsic plutonic rocks from these areas, taken from Figures 3 and 5A is shown for comparison. The dotted line represents the trend in the ternary minimum of the granite system from 500 to 10,000 bars (Luth *et al.* 1964).

CLASTIC SILICEOUS METASEDIMENTS

Due to recrystallization during high rank regional metamorphism, the clastic siliceous metasediments are more coarse-grained than their counterparts in the Southern Province, but they characteristically show a similar granular texture that reflects their original clastic nature. The metasediments are now gneisses of various types, marked by prominent compositional layering that reflects original bedding. This is indicated by: 1) preservation of a few primary sedimentary features; 2) persistence of the layering along strike for hundreds of feet (50 to 100 m); 3) folds that are outlined by the layering; 4) the existence of several diverse mineralogic compositions within a given sequence of layers; 5) repetition, throughout a given sequence, of layers that have similar mineralogical compositions and textures, and show the same degree of metamorphism; and 6) persistence of primary stratigraphic facies changes in some sequences of layers, whereby one unit of layers, having a certain range in composition and texture, gradually predominates over another unit of layers with a different range in composition and texture, either across or along strike. Recrystallization has obscured

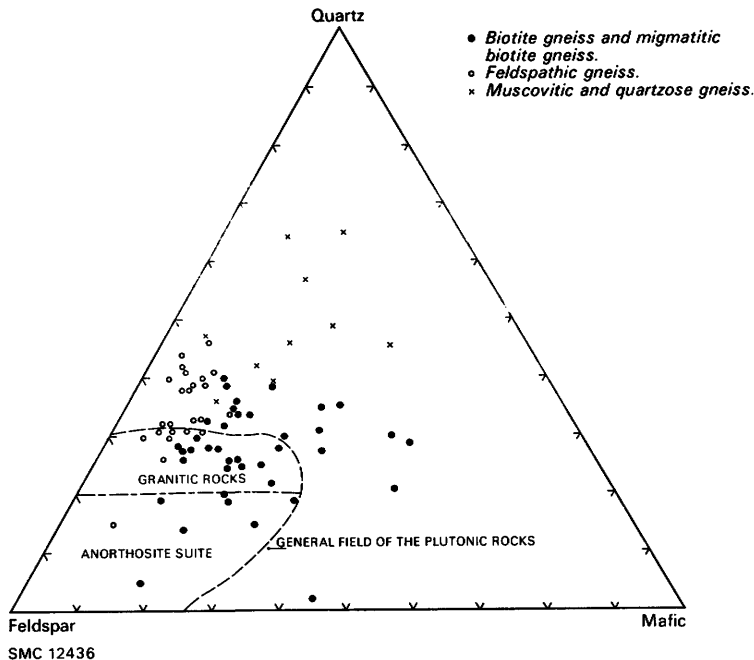


Figure 2B—Modal quartz, feldspar, and mafic minerals from 73 thin sections of clastic siliceous metasediments from the Burwash and North Bay areas. The general field of the felsic plutonic rocks from these areas, taken from Figure 4, is shown for comparison.

most microscopic primary sedimentary features. A few macroscopic primary sedimentary structures such as scour-and-fill features, crossbedding, and coarse clasts, are preserved in some of the relatively coarse metasediments, but these are too modified by metamorphism to give facing directions.

Compared with the felsic plutonic rocks in the Grenville Province, the clastic siliceous metasediments are not only distinctive macroscopically, but also modally. In Figure 2A, the modal compositions of 73 specimens of clastic siliceous metasediments from the North Bay and Burwash areas are expressed in terms of volume percent of quartz, plagioclase, and potassic feldspar, recalculated to 100 percent. In Figure 2B, modes of the same 73 specimens are expressed in terms of volume percent of quartz, feldspar, and mafic minerals recalculated to 100 percent; biotite gneiss and migmatitic biotite gneiss, feldspathic gneiss, and muscovitic and quartzose gneiss are designated in both figures by separate symbols. Both figures also show the general field of the felsic plutonic rocks that intrude the clastic siliceous metasediments in the North Bay and Burwash areas, subdivided into anorthosite suite rocks and granitic rocks; data for the plutonic rocks are taken from Figures 3, 4, and 5A¹. Although there is some

¹In determining the general field of the felsic plutonic rocks for Figures 2A and 2B, trondhjemite was omitted because trondhjemites that intrude the clastic siliceous metasediments are essentially absent in most of the northwestern part of the Grenville Province (see the section on Granitic Intrusive Rocks—Distribution).

Burwash Area

overlap in the modal compositions of the granitic rocks and the biotite gneisses and feldspathic gneiss, most of the metasediments are richer in quartz than the plutonic rocks and show major differences in their feldspar and mafic mineral contents.

Microscopically, the clastic siliceous metasediments can be distinguished from the felsic plutonic rocks, because all these metasediments contain at least a trace of detrital zircon grains rarely more than a fraction of a millimetre in size (see Table 2A). Most commonly, at least some of the detrital zircon contains subhedral to euhedral metamorphic overgrowths, partly to completely surrounding a rounded to irregularly shaped detrital core. The cores and detrital grains show a variation in grain size and in radioactivity reflected in variable degrees of clouding and discolouration. Zircon grains in the felsic plutonic rocks, on the other hand, are generally larger (some are up to 0.5 mm long) than in the metasediments; the grains are commonly subhedral to euhedral with no detrital cores and show various degrees of corrosion and discolouration near their boundaries. Some euhedral grains display primary igneous zoning (see Photo 17), and metamorphic overgrowths are relatively rare.

Tables 2A and 2B present modal compositions of the metasediments in the Burwash area. The average modal compositions shown approximate the compositional range found in the rocks. In Table 2A, rock types (columns) 1A-5 are biotite gneisses, rock types 6-8 are feldspathic gneisses, rock types 9-10 are muscovitic and quartzose gneisses, and rock type 11 is hornblende gneiss. The numbers used to describe the various rock types in Tables 2A and 2B are used to refer to the individual rock types throughout the descriptions of the clastic siliceous metasediments.

In the North Bay area, evidence was presented (Lumbers 1971a) to indicate that migmatitic phases of the metasediments are confined to those compositions that lie close to the ternary minimum in the synthetic granite system. This relationship also generally holds for the metasediments in the Burwash area, and from Figure 2A, showing the trend in the ternary minimum from 500 bars to 10,000 bars (Luth *et al.* 1964), only those metasediments that plot close to the eutectic and well within the field of the granitic rocks are commonly migmatitic.

Biotite Gneiss and Migmatitic Biotite Gneiss

Most of the metasediments underlying the Grenville Province in the Burwash area are light to dark grey, fine- to coarse-grained, biotite-quartz-feldspar gneisses that contain 10 to 35 percent biotite, up to 15 percent garnet, less than 10 percent hornblende, and generally more plagioclase than potassic feldspar. These gneisses characteristically show prominent compositional layering, reflecting in part, original bedding (Photos 3, 4, 6, and 7), and in part, migmatitic layering developed during metamorphism and deformation (Photos 3, 6 and 7). The relict beds are continuous on a large scale, but because of metamorphism and deformation, they are disrupted on a small scale and are variable in thickness (Photos 3 and 6). Metamorphism accentuated the original bedding, and some evidence of metamorphic reaction (diffusion of material) is common at the contacts of the relict beds, particularly where felsic beds are next to mafic beds. Most of the metamorphic layering is subparallel to the relict bedding and consists of: 1) streaks and minor lenticular mineral segregations no more than a few centimetres long and a few millimetres wide within layers (these consist of either fine- to medium-grained quartz

and feldspar, or biotite and minor hornblende); 2) discontinuous, subparallel veins and lenses of medium- to coarse-grained granitic material (these are isolated in three dimensions and are generally no more than a few inches thick, Photos 3 and 7); and 3) zones of tectonic breccia that consists of hornblende gneiss or fine- to medium-grained biotite-rich metasediments, in a matrix of medium- to coarse-grained metasediments with abundant granitic veins and lenses (Photo 7). Where 10 percent or more of the sequence contains granitic veins and lenses, the sequence is mapped as migmatitic biotite gneiss (map unit 6).

The granitic veins consist mainly of medium- to coarse-grained quartz, potassic feldspar, and minor plagioclase (commonly the same composition as plagioclase in the surrounding host), with accessory biotite, opaque minerals, and rare muscovite. Migmatitic veins are generally only developed in layers containing abundant biotite and more than about 15 percent potassic feldspar; layers containing less than 10 percent potassic feldspar are rarely migmatitic. In general, the veins are parallel-sided, and in places they pinch and swell like small-scale boudins; swells commonly contain lenticular potassic feldspar crystals (*dents du cheval*), up to 1 inch (2.5 cm) or more in size. Biotite-rich selvages are invariably present along the boundaries of the veins and lenses, and potassic feldspar is rare or absent in the immediately surrounding host rock. Where the granitic veins are abundant, the layering is more intricately deformed than where they are rare or absent (Photo 3). Brecciated zones, such as those illustrated in Photo 7, are confined to sequences rich in granitic veins.

Most of the layers in the biotite gneiss and migmatitic biotite gneiss can be subdivided into five major rock types, as shown in Table 2B. The most probable parent sedimentary rock for each of the rock types is also shown in the table. Average modal compositions of the five types of biotite gneiss, which approximate the compositional range found in the rocks, are given in Table 2A, Columns 1 to 5; modal compositions of rock types 1A and 1B are similar. The major rock types occur together in various combinations with other metasediments, to produce several distinctive sequences. On the accompanying map (Map 2271, back pocket), the biotite gneisses (map unit 7) are subdivided according to the various sequences recognized. Map unit 6 comprises the migmatitic equivalents of the sequences in map unit 7. Only those sequences sufficiently large to be shown at the scale of reproduction are designated separately on the map, but places where small units of one or more sequences are relatively abundant within a large mappable unit are indicated by combined map codes.

Rock types 1A, 1B, and 2 (Tables 2A and 2B) probably represent relatively coarsely recrystallized, fine- to coarse-grained greywackes, and the large variation in grain size of quartz and feldspar in these rocks could reflect poor sorting in the parent greywacke. Most other primary microfeatures of the original greywacke have been destroyed by recrystallization, and no relict microscopic lithic fragments are apparent. Rock types 1A and 1B are similar in composition and differ mainly in grain size. Rock type 1B is commonly coarser grained and slightly richer in quartz than rock type 1A and contains sparse macroscopic lithic fragments. Thus, the rocks may represent mainly feldspathic greywacke largely free from lithic fragments, or recrystallization could have destroyed or obscured microscopic fragments in rocks that were originally lithic greywacke. Rock types 2 and 4 locally contain rare, fine-grained flakes of graphite and minor disseminated pyrite, which produces a rusty weathering surface.

Potassic feldspar is rare in rock type 2, which is generally migmatitic only where the potassic feldspar content exceeds 15 percent and is unevenly distributed throughout the rocks. In rock type 3, potassic feldspar generally forms more than 15 per cent of the

Burwash Area

Table 2A

AVERAGE MODES (VOLUME PERCENT) OF

ROCK TYPE	1A, 1B		2		3		4	
NO. OF THIN SECTION(S)	14		6		4		5	
	Average	Range	Average	Range	Average	Range	Average	Range
Quartz	24.9	18-35	29.1	20-30	16.2	5-30	30.0	
Plagioclase	48.0	39-52	41.8	34-50	42.0	30-52	18.9	
Percent An	22	20-30	32	27-38	21	20-25	25	
K-feldspar	8.0	2-18	2.2	1-4	20.2	15-25	14.3	
Biotite	12.1	10-15	15.5	12-25	11.1	9-12	27.2	
Hornblende	5.3	0-10	5.5	0-9	.....	.....	1.2	
Garnet	0.1	.....	3.6	trace-9	0.1	.....	5.1	
Muscovite	trace	.....	trace	.....	3.3	trace-6	1.4	
Kyanite	.....	.....	trace	.....	.....	.....	.....
Sillimanite	.....	.....	trace	.....	2.4	0-6	trace	
Staurolite	.....	.....	.....	.....	.....	.....	.....
Opaque Minerals*	0.8	0-3	1.2	0.5-2	3.9	trace-6	1.0	
Apatite	0.4	trace-1	0.4	0.2-1	0.1	.....	0.3	
Zircon	0.1	.....	0.1	.....	0.5	0.1-0.6	0.4	
Others**	0.3	.....	0.6	.....	0.2	.....	0.2	
Totals	100.0		100.0		100.0		100.0	

* Iron-titanium oxides, minor pyrite and pyrrhotite

**See rock type descriptions

Table 2A (Continued)

ROCK TYPES

Biotite Gneisses

- 1A, 1B. Medium- to coarse-grained metagreywacke (biotite-quartz-plagioclase gneiss)
 2. Fine-grained metagreywacke (garnetiferous biotite-quartz-plagioclase gneiss)
 3. Medium- to coarse-grained metasandstone (biotite-potassium feldspar-plagioclase biotite-quartz gneiss).
 4. Fine-grained meta-argillite (garnet-potassium feldspar-plagioclase-biotite gneiss).
 5. Medium- to coarse-grained garnet-potassium feldspar-biotite-plagioclase gneiss.
- **epidote, scapolite, carbonate, sphene, allanite, chlorite, graphite.

Feldspathic Gneiss

6. Fine- to medium-grained, grey to pink meta-arkose (potassium feldspar plagioclase gneiss), intercalated with biotite gneiss.

SEDIMENTS IN THE BURWASH AREA

6		7		8	9		10	11	
5		12		1	5		42	14	
Average	Range	Average	Range		Average	Range	Range	Average	Range
33.2	28-40	35.3	25-50	15.0	58.6	45-90	0-58	12.8	2-25
45.6	40-55	27.5	20-41	76.0	16.0	2-35	0-51	32.1	18-50
24	15-35	12	4-20	42	28	25-35	25	27	20-45
13.1	2-20	28.0	12-40	0.5	11.7	10-20	0-32	2.9	trace-10
5.4	3-10	3.9	1-9	3.7	5.0	1-10	1-50	10.2	1-22
0.5	0-2	0.6	0-4	.....	trace	.....	.....	30.0	18-40
trace	.....	0.1	.....	.....	0.5	0-2	0-27	4.4	0-16
trace	.....	1.0	0-8	0.4	0.8	0-2	0-65	.....	.....
.....	.....	.....	.....	.....	trace	.....	0-43	.....	.....
.....	.....	trace	.....	.....	4.4	trace-20	0-16	.....	.....
.....	.....	.....	.....	.....	.....	.....	0-2	.....	.....
0.5	0.1-1	2.5	1-5	trace	2.0	0-5	0-1.5	2.5	0.1-7
0.1	.....	0.2	.....	trace	0.5	0.2-1	0-3	0.8	0.2-2
0.1	.....	0.4	trace-0.7	0.4	0.5	0.3-0.7	present	trace	.....
1.5	.....	0.5	.....	4.0	trace	.....	0-3	4.3	0-17
100.0		100.0		100.0	100.0			100.0	

Fine- to medium-grained, pink meta-arkose (plagioclase-potassium feldspar-quartz gneiss); forms relatively thick sequences.

Fine- to medium-grained, grey meta-arkose (quartz-plagioclase gneiss).

**epidote, carbonate, sphene, hypersthene, clinopyroxene, allanite, chlorite.

Muscovitic and Quartzose Gneiss

Fine- to medium-grained, grey to pinkish, metasubarkose and quartz-rich meta-arkose (potassium feldspar-plagioclase-quartz gneiss).

Fine- to medium-grained meta-argillite (garnet-kyanite-muscovite-biotite-plagioclase-quartz gneiss); data from Kwak (1971).

**carbonate, allanite, pyroxene, graphite, rutile.

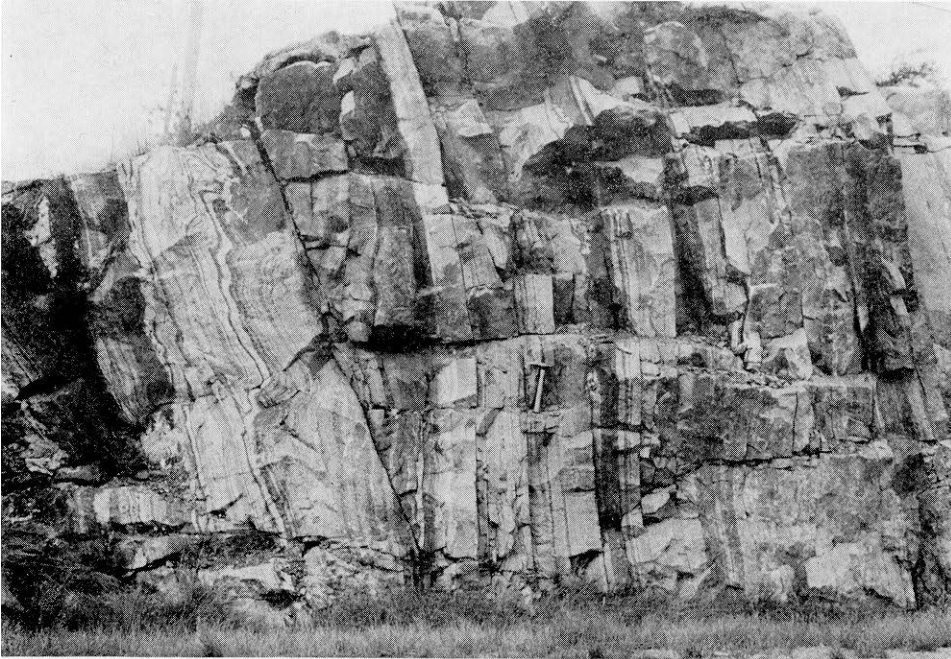
Hornblende Gneiss

Calc-silicate gneiss

**epidote, diopside, scapolite, carbonate, sphene, chlorite.

Table 2B | GENERALIZED SUBDIVISION OF THE MAJOR BIOTITE GNEISS AND MIGMATITIC BIOTITE GNEISS ROCK TYPES IN THE BURWASH AREA

ROCK TYPE	MAJOR MINERAL CONSTITUENTS (in order of increasing abundance)	AVERAGE MODE IN TABLE 2A	AVERAGE GRAIN SIZE (in mm)	COLOUR	TEXTURE	PRIMARY SEDIMENTARY ROCK
1A	Biotite-quartz-plagioclase	Column 1	1-2	Grey	Gneissic with inequigranular quartz and feldspar; rare porphyroblasts of hornblende and allanite	Medium-grained greywacke
1B	Biotite-quartz-plagioclase	Column 1	3-5	Light grey to grey	Gneissic with inequigranular quartz and feldspar; rarely contains scattered fragments of quartz and quartz-feldspar aggregates	Coarse-grained greywacke
2	Garnet-biotite-quartz-plagioclase	Column 2	0.5	Dark grey	Gneissic to schistose with inequigranular quartz and feldspar; porphyroblasts of garnet, hornblende, and biotite common	Fine-grained greywacke
3	Biotite-K-feldspar-quartz-plagioclase	Column 3	1-3	Light grey to pinkish	Gneissic with equigranular quartz and feldspar	Medium-to coarse-grained impure sandstone
4	Garnet-K-feldspar-plagioclase-biotite-quartz	Column 4	0.5	Dark grey	Gneissic to schistose with equigranular quartz and feldspar; coarse garnet porphyroblasts; quartzofeldspathic veinlets up to 1 cm wide and lenticular K-feldspar porphyroblasts up to several cm in size common	Argillite



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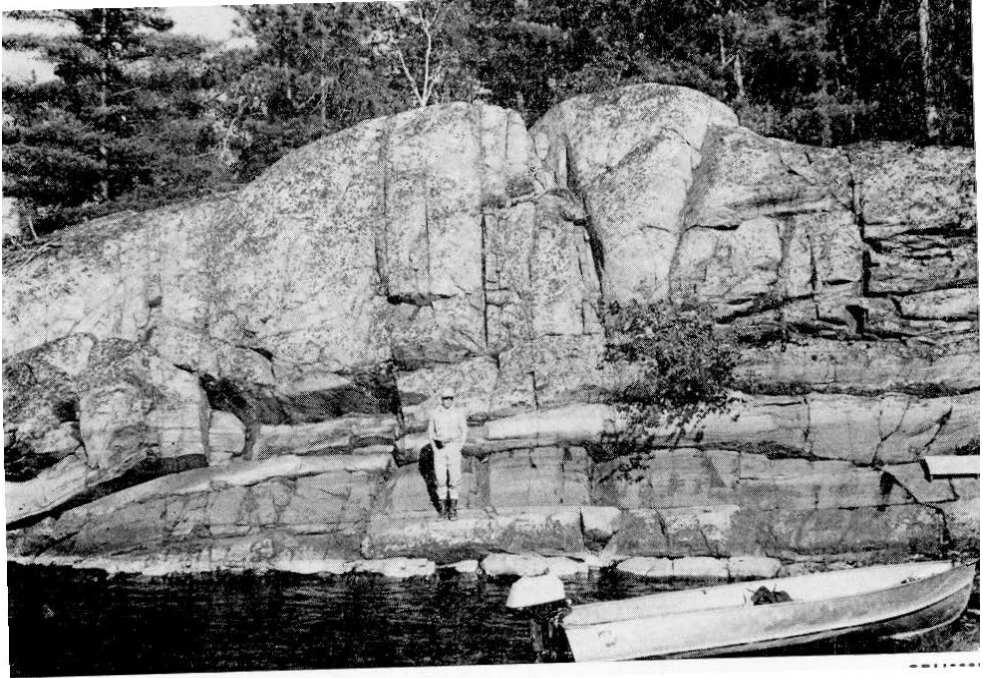
Photo 3—Typical, partly migmatitic, thinly bedded metagreywacke sequence containing a few units of calc-silicate gneiss (dark grey) and rare meta-arkose layers. Note the discontinuous, subparallel veins and lenses of granitic material in some layers, and the complex deformation in the migmatitic zone on the left side of the outcrop; Highway 64, about 2 miles (3.2 km) south of Verner, Caldwell Township.

rock, but is commonly evenly distributed, and migmatitic phases are rare. Thus, there are compositional and possibly structural controls on the development of migmatitic biotite gneiss.

Rock type 3 was possibly better sorted than the metagreywacke and appears to have been derived from a sandstone with characteristics intermediate between greywacke and arkose. Rock type 4, relatively rich in garnet and biotite, probably represents argillite rich in clay minerals, silty quartz, and feldspar.

Some of the rock sequences formed by various combinations of the five major rock types resemble metagreywacke sequences of the Huronian Supergroup in the adjacent Southern Province. In general, four major sequences predominate. The most common sequence (see map unit 7a and its migmatitic equivalent units, 6a and 6c) consists of alternating thinly bedded layers of rock types 1A, 2, and 4 (Photo 3), in which layers of rock Type 1A are generally less than 1 foot (30 cm) thick and layers of rock types 2 and 4 are generally less than 1 inch (2.5 cm) thick. Some layers of rock types 1A and 4 are migmatitic. Minor layers of rock type 1B, together with a few layers of hornblende gneiss and feldspathic gneiss are commonly present. The sequence reflects original rhythmically bedded deposits of medium- to fine-grained greywacke (rock types 1A and 2) and argillite (rock type 4), with either graded sand-silt couplets, or alternating sand and silt beds, or both. Thinly bedded metagreywacke sequences commonly grade, over widths of a few tens of feet, into feldspathic gneiss units, by a gradual

Burwash Area



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Photo 4—Thinly bedded metagreywacke sequence dipping 40 degrees away from the observer and capped by a very thick-bedded, coarse-grained metagreywacke unit; French River, Mason Township, about 1 mile (1.6 km) south of Lost Child Bend.

increase in interlayers of feldspathic gneiss and rock type 3. Many of the feldspathic gneiss units also contain local intercalated sequences of rock types 3 and 4. A relatively high detrital zircon content in rock types 3 and 4 (Table 2A) and their common association with moderately well sorted metasediments, represented by feldspathic gneiss and quartzose gneiss, suggest that these rocks were derived from better sorted deposits than the other biotite gneisses.

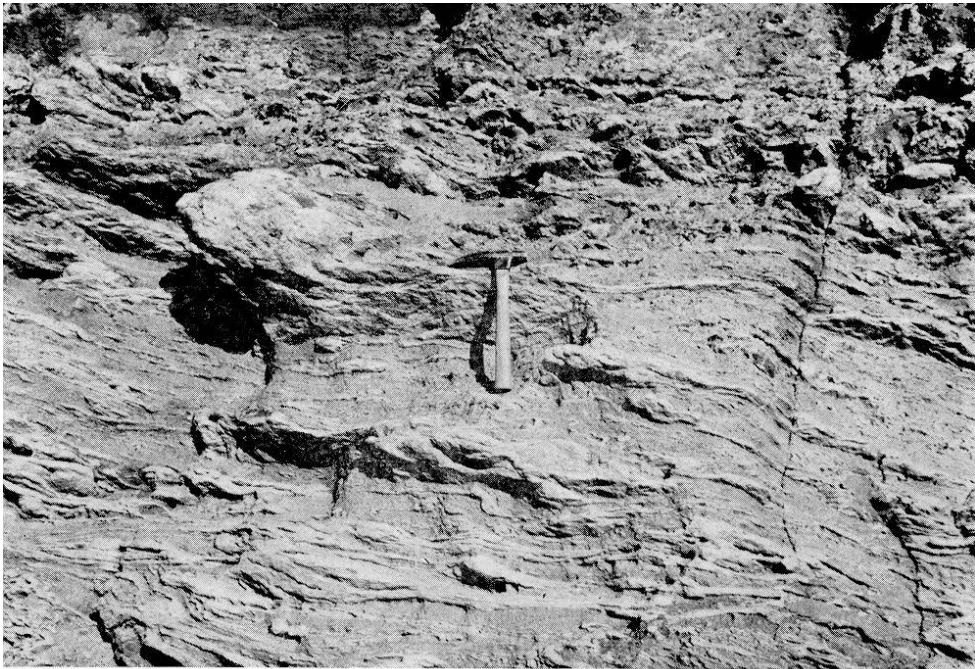
A second major sequence consists of thick-bedded, fine- to medium-grained sequences (map unit 7a) that contain interlayered units of rock type 1B, thick-bedded to very thick-bedded coarse-grained metagreywacke (map unit 7b and its migmatitic equivalent, 6b; Photo 4). Locally, relict scour-and-fill features are present at the base of the thickly bedded coarse-grained units, whereby the coarse-grained metagreywacke truncates bedding in the thinly bedded metagreywacke. Most of these thickly bedded units are too small to be mapped separately, but a few sequences of coarse-grained metagreywacke are mappable and contain minor, intercalated, thinly bedded units of hornblende gneiss and rock types 1A and 2. Coarse-grained metagreywacke is most abundant in the western half of the area, and locally contains stretched pebbles of quartz and quartz-feldspathic rocks (Photo 5).

A third major sequence consists of rock type 4, meta-argillite (map units 7c and 8a), generally with abundant intercalated, fine- to medium-grained quartzose gneiss and feldspathic gneiss, forming thin, dismembered relict beds (Photo 6). This sequence is rarely mappable, but is relatively common in thinly bedded metagreywacke sequences



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Photo 5—Quartz-rich fragments in coarse-grained metagreywacke; Highway 535, Appleby Township, about 2.5 miles (4 km) south of Hagar Village.



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Photo 6—Gneissic, argillaceous metasediments containing thin, dismembered beds of feldspathic and quartz-rich metasandstone; Bearsden Bay; Allen Township.

Burwash Area

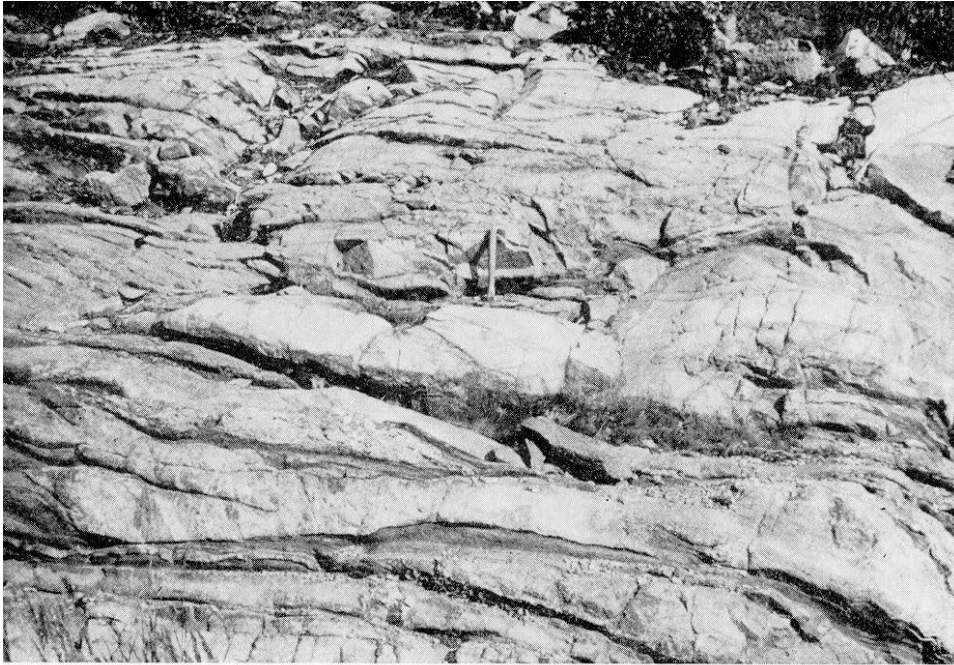


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Photo 7—Tectonic breccia consisting of dark grey, silty metasedimentary fragments in a light grey, migmatitic metagreywacke host; Wanapitit River, lot 5, concession IV, Waldie Township.

in the western half of the area, where several thin to relatively thick units of feldspathic gneiss and quartzose and muscovitic gneiss are intercalated with the biotite gneisses. The sequence represents original silty and argillaceous deposits containing thin beds of relatively well-sorted, mature sandstones.

The fourth major sequence consists of thin beds of metagreywacke and meta-argillite (rock types 1A, 2, and 4), with several intercalated thin- to thick-bedded units of quartzose gneiss (Photo 8) and minor amounts of aluminum silicate-bearing schists and gneisses. This sequence comprises map unit 6d and is confined to a zone up to 6 miles (10 km) wide, adjacent to the Southern Province. It appears to represent an original sequence of interbedded fine- to medium-grained greywacke, silty argillite, aluminous argillaceous rocks, and relatively well-sorted quartz-rich sandstone. In general, the intercalated quartz-rich metasandstone units increase in abundance towards the Southern Province and in a few places near the Grenville Front Boundary Fault, such as between Alice and Baby Lakes in Neelon Township (see map unit 9b), these units predominate over the metagreywacke and argillaceous metasediments. The sequence is therefore similar to that of the Mississagi Formation adjacent to the Grenville Province, and may represent a more impure, poorly sorted facies of the formation within the Grenville Province. In Neelon and Dryden Townships, this sequence contains local intercalations of a rock type not identified in the other biotite gneiss sequences. A modal analysis of the rock is given in Table 2A, Column 5. The rock is a coarsely recrystallized, migmatitic, garnet-potassic feldspar-biotite-plagioclase-quartz gneiss, containing numerous



ODM8899

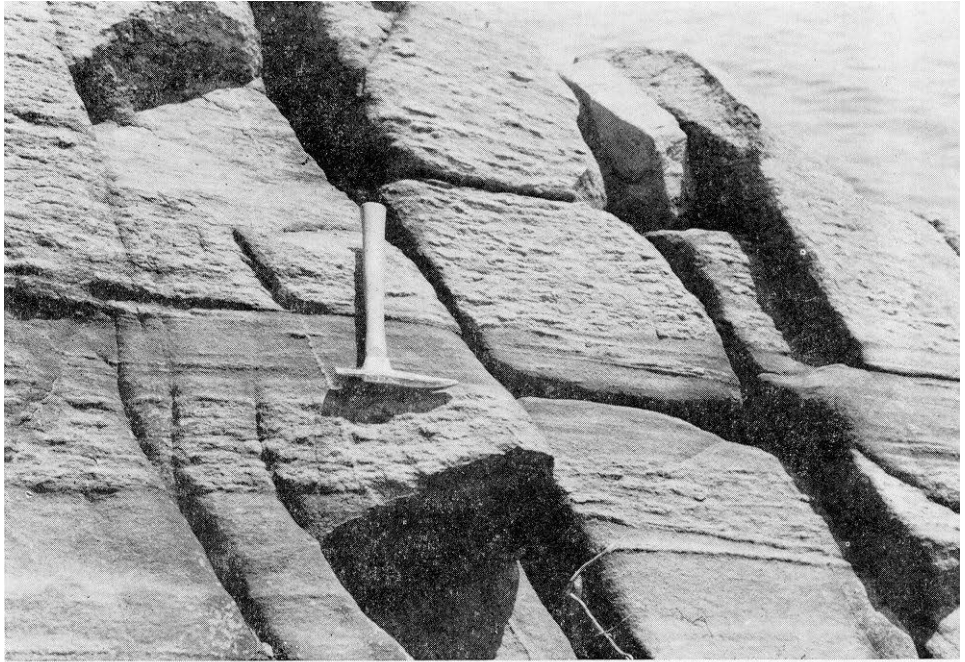
Photo 8—Thinly bedded metagreywacke and meta-argillite sequence containing dismembered layers of muscovitic and quartzose metasediments (light grey to white); Highway 69, Dill Township, south of the Wanapitei River.

thin layers (up to 3 cm thick) rich in biotite, alternating with slightly thicker layers rich in medium- to coarse-grained quartz and feldspar. It may be derived from a siltstone.

Two other biotite gneiss sequences with distinctive lithologies are locally present in the western half of the area. One sequence (map unit 7d), is confined mainly to the region north of Nepewassi Lake in Burwash, eastern Cleland, Hawley, and Awrey Townships, and consists of relict thick- to very thick-bedded metaconglomerate intercalated with rock types 1A, 1B, and 2 (Photo 9). The sequence occurs either near the margins of feldspathic gneiss units or within biotite gneiss sequences containing abundant intercalated feldspathic gneiss. The metaconglomerate of map unit 7d consists of over 50 percent elliptical fragments of feldspathic gneiss (some of which contain detrital zircon) up to 8 inches (20 cm) long, aligned parallel to the gneissic layering in a matrix similar to rock types 1A and 1B. Scattered lenticular porphyroblasts of potassic feldspar up to 5 cm across are present in many of the metaconglomerate layers. The restricted composition of the relict coarse clasts, the mode of occurrence, and the restricted distribution suggest that the metaconglomerate is intraformational in origin and does not reflect a major unconformity within the metasedimentary sequence.

A second type of fragmental metasediment (map unit 7e), also probably intraformational in origin, is exposed within a biotite gneiss unit that crosses Highway 637 in Attlee Township, north of Gainey Lake. The rock consists of a variety of biotite gneiss and feldspathic gneiss fragments in a fine- to medium-grained matrix similar to rock types 1A and 2 (Photo 10). Most of the rock is a pebbly metasandstone containing less

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ODM8900

Photo 9—Intraformational, gneissic metaconglomerate units, consisting of feldspathic gneiss fragments in a metagreywacke matrix, intercalated with metagreywacke; north shore of Nepewass Lake, Burwash Township.



ODM8901

Photo 10—Gneissic, intraformational, pebbly metagreywacke containing a variety of meta-sedimentary fragments; Highway 637, Atlee Township, north of Galney Lake.

than 50 percent fragments, but locally, the rock is a metaconglomerate containing 50 percent or more fragments. Several thin units of the rock are concentrated near the central part of the biotite gneiss sequence, which here consists of thinly bedded metagreywacke with abundant hornblende gneiss layers and widespread, but minor, feldspathic gneiss layers.

In the southwestern part of the Burwash area, Quirke (1930a) mapped extensive metaconglomerate-bearing units that he correlated with the Gowganda and Lorrain Formations of the Huronian Supergroup in the Southern Province. Except for the fragmental metasediment exposed on Highway 637, no metaconglomerate was found within Quirke's units, which actually consist of a variety of metasedimentary gneisses. Quirke possibly misinterpreted metamorphic features in these rocks, such as coarse porphyroblasts of potassic feldspar or intensely deformed and disrupted bedding, as indicative of primary conglomerate deposits.

In summary, the main sequences recognized are: 1) thinly bedded, fine- to medium-grained metagreywacke and argillaceous metasediments with minor intercalated hornblende gneiss, feldspathic gneiss, and thick- to very thick-bedded, coarse-grained metagreywacke (map units 7a, 6a, and 6c); 2) thick- to very thick-bedded, coarse-grained metagreywacke with minor intercalated thinly bedded, fine- to medium-grained metagreywacke and hornblende gneiss (map units 7b and 6b); 3) argillaceous metasediments containing thin beds of feldspathic gneiss and muscovitic and quartzose gneiss (map units 7c and 8a); and 4) thinly bedded metagreywacke and argillaceous metasediments containing thin beds of feldspathic gneiss and muscovitic and quartzose gneiss (map unit 6d). Locally present minor sequences are intraformational gneissic metaconglomerate, consisting of feldspathic gneiss fragments in a medium- to coarse-grained metagreywacke matrix (map unit 7d); and intraformational gneissic, pebbly metagreywacke and minor metaconglomerate containing a variety of metasedimentary fragments (map unit 7e).

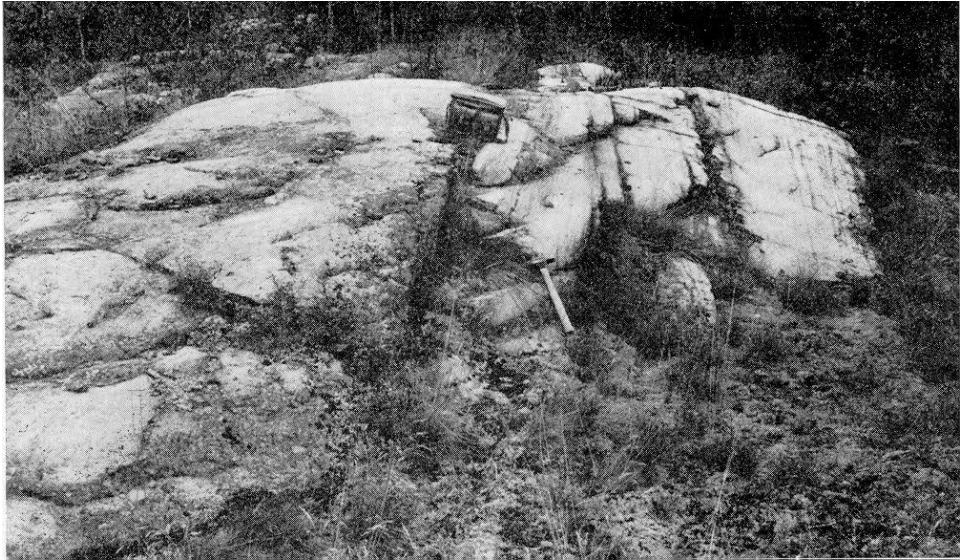
The first, third, and fourth sequences commonly contain 10 percent or more migmatitic zones, whereas the remaining sequences are rarely migmatitic. As discussed above, the migmatitic facies are controlled in part by the bulk composition of the original rock; because the bulk composition within sequences is variable, the distribution shown on the map for migmatitic and non-migmatitic sequences is greatly generalized, with some non-migmatitic zones invariably intercalated with migmatitic zones, locally forming as much as 50 percent of the migmatitic sequences. Places where non-migmatitic sequences are abundant within migmatitic sequences are indicated on the map by the combination of map codes.

Abundant sills and dikes of metagabbro, and gneissic pegmatite dikes, too small to be mappable, are concentrated in a broad zone extending southeastward from the Grenville Front Boundary Fault. In order to show their distribution, separate symbols are used for biotite gneiss sequences that contain these bodies (map unit 6c); one sequence (map unit 6d) contains numerous intercalated muscovitic and quartzose gneiss units and occurs only within this zone.

Feldspathic Gneiss

Pink to light grey, fine- to medium-grained feldspathic gneiss, containing as much as 50 percent quartz and less than 10 percent biotite, forms several mappable units in

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Photo 11—Meta-arkose (grey) that grades into quartz-rich metasandstone (light grey) near the camera case; west side of the Murdock River, just south of Highway 64, Bigwood Township.

the western and northern parts of the area and is interbedded locally throughout the area with both biotite gneiss and muscovitic and quartzose gneiss. As outlined previously by the author in the North Bay area (Lumbers 1971a, p.13-15) the feldspathic gneiss represents original arkosic sandstone and siltstone. Its derivation from sedimentary deposits is shown by the presence of relict bedding, by macroscopic vestiges of a clastic texture, and by gradations into biotite gneiss in some places and into muscovitic and quartzose gneiss in other places (Photo 11). The gneiss also contains detrital zircon grains, and in several of the mappable units in the southwestern part of the area, deformed, relict crossbedding is visible within individual beds. Moreover, most of the feldspathic gneiss differs markedly in modal composition from the granitic plutonic rocks (see Figures 2A and 2B).

Previous workers mapped the large feldspathic gneiss units either as granitic gneisses, or granitized gneiss of unspecified origin. Thin layers of the gneiss intercalated with other metasediments were generally interpreted either as injected granitic material or as products of granitization. Consequently, many non-migmatitic metasedimentary sequences containing feldspathic gneiss layers were mapped in the past as various types of migmatite or hybrid granitic gneisses. Relict gradational primary facies changes from feldspathic gneiss to quartzose gneiss, such as depicted in Photo 11, have been interpreted in the past as progressive granitization of quartz-rich metasediments (see for example, Hewitt 1960, p.168-169).

Relict bedding in the feldspathic gneiss is defined most commonly by 1) variations in grain size and in quartz and biotite contents, 2) thin layers and seams of biotite, and

3) layers of other types of metasediments, particularly hornblende gneiss, biotite gneiss rock type 3 (biotite-potassic feldspar-quartz-plagioclase gneiss) and biotite gneiss rock type 4 (garnet-potassic feldspar-plagioclase-biotite-quartz gneiss). Locally in some feldspathic gneiss units, bedding is defined by grey, plagioclase-rich, arkose layers. In general, the feldspathic gneiss is thinly to relatively thickly bedded, with individual relict beds ranging in thickness from a few inches to a few feet. The relict bedding is relatively continuous, but is disrupted on a small scale and complexly deformed.

Metamorphic layering subparallel to the relict bedding is commonly present within individual beds and consists of: 1) local streaks and lenses of biotite, iron-titanium oxide minerals, or quartz-feldspathic material slightly coarser in grain size than the host rock; and 2) medium- to coarse-grained granitic veins and lenses generally only 1 inch or so (2 or 3 cm) wide and a few inches (5 or 10 cm) long which are isolated in three dimensions. The granitic veins and lenses show the same textural and mineralogical features as those in the biotite gneisses, but migmatitic facies of the feldspathic gneiss are less abundant than migmatitic facies of the biotite gneiss, even though the feldspathic gneiss is considerably richer in potassic feldspar.

In general, migmatitic facies are developed only in feldspathic gneiss that has abundant potassic feldspar, less than 40 percent quartz, and an uneven distribution of potassic feldspar and plagioclase. Non-migmatitic feldspathic gneiss generally contains: 1) evenly distributed potassic feldspar; and 2) plagioclase to potassic feldspar ratios of 1:1 or greater. Coarse porphyroblasts of potassic feldspar, up to a few centimetres in diameter, are common in the migmatitic varieties, but in non-migmatitic varieties porphyroblasts are rare and where present are mainly garnet and iron-titanium oxide minerals. In the northwestern part of the area, some feldspathic gneiss relatively rich in quartz contains sillimanite streaks and lenses subparallel to the foliation. This sillimanite-bearing feldspathic gneiss also is particularly common near contacts with muscovitic and quartzose gneiss in southeastern Delamere and northeastern Bigwood Townships.

Microscopically, the feldspathic gneiss is essentially a quartz-feldspar rock in which the relative proportions of quartz, plagioclase, and potassic feldspar vary considerably. Most of the petrographic varieties of the gneiss recognized in the adjacent North Bay area (Lumbers 1971a, p.14) are also present in the Burwash area, but three major rock types predominate (Table 2A):

Rock type 6. Fine- to medium-grained, grey to pink, potassic feldspar-quartz-plagioclase gneiss

Rock type 7. Fine- to medium-grained, pink, plagioclase-potassic feldspar-quartz gneiss

Rock type 8. Fine- to medium-grained, grey, quartz-plagioclase gneiss

Average modal compositions of the rock types are given in Table 2A, Columns 6, 7, and 8.

Rocks similar to rock type 6, are typically intercalated with biotite gneisses and like those rocks, are much richer in plagioclase than in potassic feldspar; plagioclase ranges in composition from oligoclase to andesine. Only minor detrital zircon is present. Rocks comparable to rock type 7, are typical of the large units of feldspathic gneiss (map unit 8a) and occur intercalated with muscovitic and quartzose gneiss, but are rare in sequences of biotite gneiss. Rock type 7 contains much more potassic feldspar than rock type 6, and plagioclase is notably more sodic. In most of the mappable feldspathic gneiss sequences, rock type 7 locally contains intercalated units of the third major type of feldspathic gneiss, rock type 8, and argillaceous metasediments (biotite-potassic feldspar-quartz-plagioclase gneiss), particularly near the margins of the sequences. Rock type 8 is rare in muscovitic and quartzose gneiss sequences, and was not

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recognized in biotite gneiss sequences. Thin units of hornblende gneiss commonly occur throughout all the sequences.

Ferruginous feldspathic gneiss (map unit 8b) occurs, sparingly intercalated with muscovitic and quartzose gneiss, near Jamot and the North Channel of French River in southeastern Delamere and in northeastern Bigwood Townships. It is a fine- to medium-grained, dark grey quartz-potassic feldspar-plagioclase gneiss that contains up to 12 percent specularite and up to 10 percent biotite. Minor specularite is disseminated throughout the rock, but most is concentrated in thin, discontinuous layers, only a few centimetres thick, that contain most of the biotite in the rock. Although most of the rock is rich in feldspar, some thin, discontinuous, quartz-rich layers are present. This rock is discussed further in the "Economic Geology" section.

Rock types 7 and 8 contain more detrital zircon than rock type 6 or all of the biotite gneiss types except biotite gneiss rock type 3 (biotite-potassic feldspar-quartz-plagioclase gneiss), which occurs mainly in feldspathic gneiss units and near transitional contacts between these units and biotite gneiss sequences. The detrital zircon contents appear to reflect the degree of sorting and maturity of the metasediments, with the better sorted and more mature deposits containing a much higher proportion of detrital zircon. In all of the feldspathic gneisses, plagioclase is generally slightly antiperthitic, potassic feldspar is slightly perthitic and displays grid twinning, and the average grain size is variable. Rock type 6 is inequigranular to equigranular and has an average grain size between 0.5 mm and 1.5 mm, but the other two types of feldspathic gneiss are relatively equigranular and have average grain sizes between 0.5 mm and 2 mm, with the coarser rocks richest in quartz and plagioclase.

Variations in grain size of the gneiss could reflect original sandy and silty arkosic detritus, and the local abundance of iron-titanium oxides may indicate that the original sandstone and siltstone were locally ferruginous. Feldspathic gneiss associated with biotite gneiss sequences has plagioclase to potassic feldspar ratios and detrital zircon contents similar to the biotite gneisses and could represent reworked portions of the poorly sorted sands and silts that gave rise to the biotite gneiss. The widespread sequences of feldspathic gneiss, on the other hand, represent relatively shallow water deposits formed above wave base, as shown by the presence of relict crossbedding, local gradations into mature, well-sorted quartz-rich metasandstones, and the equigranular nature of the rocks that probably reflects originally well-sorted deposits. Nevertheless, in contrast to the arkosic metasediments in the adjacent Southern Province which were probably deposited relatively close to their source area, those feldspathic metasediments that form large sequences in the Grenville Province appear to be richer in feldspar, finer in grain size, and lacking in rock fragments both macroscopically and microscopically. Although some of these differences could be partly due to the higher grade of metamorphism in the Grenville Province, they most likely reflect primary features of the deposits and may indicate that meta-arkoses in the Grenville Province were deposited farther from the source area than meta-arkoses in the Southern Province. The various relict primary features of the feldspathic gneiss suggest that none of these rocks represent original felsic volcanic flow or pyroclastic material, but some of the rocks could represent material eroded from a volcanic terrain.



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Photo 12—Thin- to thick-bedded, quartz-rich metasandstone and minor arkosic metasandstone with abundant thin interbeds and partings of micaceous schist and gneiss rich in muscovite; island, northern end of Eighteen Mile Bay, Mason Township.

Muscovitic and Quartzose Gneiss

White, grey, and pinkish, medium-grained, quartz-rich gneiss (with 45 to over 95 percent quartz) and minor amounts of dark grey aluminous, micaceous gneiss and schist (containing more than 10 percent muscovite and commonly some kyanite and sillimanite) form several extensive units in the western half of the area. As discussed above, these rocks are particularly abundant as thin units, no more than a few tens of feet thick, in biotite gneiss sequences near the Southern Province. These muscovitic and quartzose gneisses are largely absent in the eastern half of the area, but in a few places, biotite gneiss sequences contain thinly bedded units composed of alternating layers of hornblende gneiss, feldspathic gneiss, and a quartz-rich rock composed mainly of quartz and only rare biotite, specularite, and muscovite.

Most of the muscovitic and quartzose gneiss resembles quartz-rich metasandstone facies of the Mississagi Formation in the adjacent Southern Province. The gneiss forms well-bedded sequences (Photo 12) consisting mainly of thin- to thick-bedded quartz-rich metasandstone and minor arkosic metasandstone with abundant thin interbeds and partings of micaceous schist and gneiss. Although beds are locally disrupted and contorted, the bedding is generally less deformed and more even than in the biotite gneiss

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and feldspathic gneiss sequences. The quartz-rich metasandstone beds show a well preserved relict clastic texture and poorly preserved relict crossbedding, commonly outlined by slight concentrations of specularite and biotite. Micaceous gneiss, rich in muscovite, is generally intercalated with the quartzose gneiss and rarely forms mappable units, but in Dryden Township near the northern boundary of the map-area, micaceous gneiss containing abundant kyanite as well as muscovite is sufficiently extensive to form mappable units (map unit 9d). Unlike the biotite gneiss and feldspathic gneiss, the muscovitic and quartzose gneiss is rarely migmatitic, although micaceous varieties generally contain a few coarse-grained granitic veins and lenses. Metamorphic layering sub-parallel to bedding is common in beds of quartzose gneiss and is generally marked by faint streaks of biotite and specularite, by segregations of sillimanite along fractures, or by irregularly shaped masses of biotite and sillimanite up to a few centimetres in size which are concentrated in crude zones. Previous workers invariably recognized the sedimentary origin of this gneiss, mainly because of its distinctive modal composition, relict primary sedimentary features, and scarcity of granitic veins and lenses.

Lithologically, the gneiss is similar to muscovitic and quartzose gneiss in the adjacent North Bay area (Lumbers 1971a, p.16-18) with the exception that quartzose varieties in the Burwash area commonly contain sillimanite and much less muscovite, and micaceous varieties are richer in kyanite and also contain sillimanite. In the Burwash area, the gneiss consists of the following major rock types:

- a. Medium- to coarse-grained, white to pinkish, metamorphosed orthoquartzite containing at least 95 percent quartz (map unit 9a).
- b. Fine- to medium-grained, grey to pinkish, potassic feldspar-plagioclase-quartz gneiss locally with abundant sillimanite and up to 10 percent biotite (map unit 9b).
- c. Fine-grained, garnetiferous, grey to dark grey, muscovite-potassic feldspar-plagioclase-biotite-quartz gneiss and schist (map unit 9c).
- d. Fine- to coarse-grained, grey to dark grey, garnet-kyanite-muscovite-biotite-plagioclase-quartz gneiss and schist locally with abundant sillimanite (map unit 9d).

Most sequences of the gneiss are composed mainly of the first and second rock types, and an average modal composition of the second rock type (map unit 9b), which approximates the compositional range found in the rock, is given in Table 2A, column 9. Pearson (1959; 1962) and Kwak (1971) made a detailed petrological study of the fourth rock type and found the rock to vary greatly in modal composition but to have a relatively constant chemical composition typical of aluminous shales; the range in modal composition found by Kwak (1971) is given in Table 2A, column 10.

Metamorphosed orthoquartzite consists mainly of medium- to coarse-grained quartz, with less than 5 percent muscovite, biotite, specularite, sillimanite, plagioclase, and potassic feldspar. Some units of this rock consist almost entirely of quartz and have been explored as a possible source of silica for flux (see the "Economic Geology" section). All gradations exist between metamorphosed orthoquartzite and rocks of map unit 9b and between rocks of map unit 9b and the feldspathic gneiss relatively rich in potassic feldspar (rock type 7, Table 2A). Except for porphyroblasts of biotite and sillimanite, rocks of map units 9a and 9b are generally equigranular, with an average grain size generally between 2 mm and 5 mm in metamorphosed orthoquartzite (unit 9a) and between 1 mm and 2mm in rocks of unit 9b. Rocks of both units, like the associated feldspathic gneiss, contain relatively high proportions of detrital zircon, and pinkish hues are due to the

common presence of fine- to medium-grained flakes of specular hematite and coatings of earthy hematite along fracture surfaces. Potassic feldspar in these rocks is generally coarsely perthitic with grid twinning, and plagioclase is antiperthitic and commonly more calcic than in the feldspathic gneiss. Rocks of map unit 9b probably represent subarkose and quartz-rich arkose rather than protoquartzite and subgreywacke, because relict lithic fragments appear to be lacking both macroscopically and microscopically.

Map unit 9c is similar to the meta-argillite associated with biotite gneiss sequences (rock type 4, Tables 2A and 2B), but the greater abundance of muscovite in map unit 9c may indicate that the original argillite contained a relatively high proportion of aluminous and potassic clay minerals. Both kyanite and sillimanite are rarely found in rocks of map unit 9c and some facies contain up to 5 percent disseminated pyrite and minor pyrrhotite. Rocks of map unit 9d also represent original aluminous argillaceous rocks (Pearson 1959; Kwak 1971); they contain more garnet and sillimanite, and generally abundant kyanite in comparison to rocks of map unit 9c. Kwak (1971) reported minor staurolite in rocks comparable to map unit 9d near the Grenville Front Boundary Fault, and in places sillimanite is intergrown with quartz in lenses up to a few feet (1 m) long and up to 1 inch or so (2 or 3 cm) across that apparently formed in fractures (see Pearson 1962, p.35). The kyanite-rich gneiss is discussed further in the "Economic Geology" section.

The extensive unit of muscovite and quartzose gneiss along the southwestern border of the Cosby batholith in Mason, Cosby, Bigwood, and Delamere Townships consists mainly of intercalated, metamorphosed orthoquartzite and subarkose, locally with intercalated quartz-rich arkose and argillite now rich in muscovite (map units 9b, 9a); thin units of hornblende gneiss, too small to be mapped separately, occur sparingly throughout the unit. Compared to this large unit, most of the other mappable units of the muscovitic and quartzose gneiss contain much less metamorphosed orthoquartzite (map unit 9a) but this rock is relatively abundant in two thin units in central Secord Township and in a prominent unit straddling the boundary between Dill and Cleland Townships near the Wanapitei River. Elsewhere, other units of muscovitic and quartzose gneiss consist mainly of metamorphosed subarkose, quartz-rich arkose, and locally abundant argillaceous rocks with abundant muscovite. Locally, these units also contain intercalated hornblende gneiss, arkosic metasediments of the type forming the extensive feldspathic gneiss units, and biotite-rich argillaceous metasediments and biotite-potassic feldspar-quartz-plagioclase gneiss associated with biotite gneiss sequences.

Quartz-rich rocks that could represent original deposits of chert occur with hornblende gneiss and feldspathic gneiss in thinly bedded units intercalated with biotite gneiss in a few places in the eastern half of the area. The quartz-rich layers are generally in sharp contact with adjacent hornblende gneiss and feldspathic gneiss layers, and locally contain faint streaks of iron-titanium oxide minerals. The feldspathic gneiss is similar in appearance and in modal composition to feldspathic gneiss intercalated elsewhere with the biotite gneisses (Table 2A, rock type 6) and locally, thin layers of argillaceous metasediments (Tables 2A and 2B, rock type 4) are present within the units. In north-eastern Hendrie Township in the western half of the area, quartz-rich stringers possibly derived from thin cherty layers are associated with minor concentrations of magnetite in calc-silicate gneiss (see the discussion of "Iron" in the "Economic Geology" section) and the deposit could represent a thin unit of iron formation.

Muscovite and quartzose gneiss represents mature, well sorted sands that originally contained thin beds of aluminous and potassic clay-rich deposits, now represented by the micaceous schists and gneisses, and a few intercalated units of calcareous sands and

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silts, now represented by intercalated hornblende gneiss. The environment of deposition was probably similar to that which gave rise to the quartzose metasediments of the Mississagi Formation; a shallow water deltaic or littoral environment where the sands underwent repeated washing and winnowing. Lithic fragments are apparently lacking in the quartzose metasediments and like the meta-arkose of the large feldspathic gneiss units, these rocks were probably deposited relatively far from their source area. The common presence of specularite in the sandy varieties of the gneiss suggests that the original sandstones were ferruginous and possibly contained a secondary iron cement.

CALCAREOUS METASEDIMENTS

Hornblende Gneiss

Fine- to medium-grained, dark green to black, foliated rocks, having hornblende as an essential constituent and containing discontinuous, alternating mafic and felsic layers generally less than 1 inch (2 cm) thick, are intercalated with the clastic siliceous metasediments throughout the area and are grouped together for mapping purposes as hornblende gneiss (map unit 10). This gneiss is identical to hornblende gneiss in the adjoining North Bay area (Lumbers 1971a, p. 18-20) and is only briefly described here. Two major lithologies comprise the gneiss: calc-silicate gneiss and amphibolite, with calc-silicate gneiss greatly predominating over amphibolite. These lithologies most commonly form thin layers and discontinuous masses, generally less than 6 feet (2 m) thick, within biotite gneiss sequences, but thin layers are also present in the other metasediments. Thicker mappable units are rare, and are mainly intercalated with biotite gneiss sequences in Cleland, Appleby, Jennings, Ratter, Caldwell, Haddo, Martland, and Allen Townships. Other places where thin unmappable units are particularly abundant in the biotite gneisses are shown on Map 2271 (back pocket) by the appropriate combined map codes.

Sequences of non-migmatitic biotite gneiss, composed of thinly bedded metagreywacke and argillaceous metasediments, generally contain more thin layers and lenticular patches of calc-silicate gneiss than do sequences of predominantly migmatitic biotite gneiss, although because of the thinness of the layers this doesn't show on Map 2271 (back pocket). Commonly, in many biotite gneiss sequences containing calc-silicate gneiss layers, medium-grained, biotite-quartz-plagioclase gneiss and fine-grained, garnetiferous biotite-quartz-plagioclase gneiss locally grade into calc-silicate gneiss by a gradual increase in hornblende. The gneiss is also intercalated with minor marble units in Dill and southeastern Neelon Townships, and as shown previously (Lumbers 1971a, p.20) the gneiss is probably derived from calcareous sandstones and siltstones.

The major mineral assemblages recognized in the calc-silicate gneiss in the North Bay area also are present in the Burwash area, but epidote is generally less abundant in the gneiss in the western half of the map-area than in the eastern half and in the North Bay area. An average modal analysis of the most common varieties of calc-silicate gneiss in the map-area is given in Table 2A, rock type 11.

Metasedimentary amphibolite, composed chiefly of equal amounts of plagioclase and hornblende, is found mainly as locally developed lenticular masses in calc-silicate gneiss units; garnetiferous and biotitic varieties are locally present. This amphibolite probably developed during regional metamorphism by metamorphic differentiation of calc-silicate gneiss (Lumbers 1971a, p. 20).

Carbonate Metasediments

Carbonate metasediments (map unit 11) are rare in the area, and only three occurrences were recognized in Dill and southeastern Neelon Townships, within a few miles (5 km) of the northwestern boundary of the Grenville Province. All of the occurrences consist of medium- to coarse-grained siliceous marble, composed of at least 50 percent carbonate minerals (mainly calcite and minor dolomite) and variable amounts of plagioclase, potassic feldspar, quartz, diopside, amphibole, scapolite, sphene, apatite, vesuvianite, and garnet. The only mappable marble units are exposed on the Canadian Pacific railway, near the eastern boundary of Dill Township, where they are intercalated with calc-silicate gneiss and thinly bedded metagreywacke with local thin units of quartzose metasandstone. These units were first mapped by Coleman (1914, p.208-209), and as indicated by Grant *et al.* (1962), the marble locally contains minor amounts of brucite. Two exposures of marble were mapped by Grant *et al.* (1962, p.13) in roadcuts on Highway 69 in central Dill Township, but resurfacing of the highway during the present study largely obscured one exposure and destroyed the other. A thin, contorted layer of marble intercalated with quartzose metasandstone is present near the northwestern margin of the Grenville Province in Neelon Township, about ½ mile (0.8 km) southwest of the northern end of Alice Lake.

METASEDIMENTARY INCLUSIONS IN PLUTONIC ROCKS

Plutonic rocks emplaced within the metasedimentary gneisses locally contain relatively small metasedimentary inclusions (generally no more than a few feet across) that are less severely deformed with better-preserved primary features than the metasedimentary gneisses, even though the plutonic rocks also underwent high rank regional metamorphism. The inclusions were not examined in detail during the present study, but from field observations, the inclusions provide further confirmation of the sedimentary origin of the gneisses. The inclusions are commonly hornfelsic and are non-migmatitic, although they show various degrees of assimilation by the host plutonic rock. These relationships suggest that the regionally developed migmatitic facies of the metasedimentary gneisses formed after the emplacement of the plutons, and probably during the same high rank regional metamorphism that recrystallized and deformed the plutons.

In contrast to these small metasedimentary inclusions, large roof pendants and screens of biotite gneiss and feldspathic gneiss, present in some felsic plutons of batholithic dimensions, are locally more migmatitic than elsewhere. Migmatitic facies of these metasediments were developed not only by high rank regional metamorphism, but also by injection of granitic sills and dikes from the associated plutons. The sills and dikes underwent the same high rank regional metamorphism as the host metasediments and are now gneissic granitic rocks that have mineralogical compositions similar to phases in the associated plutons.

No exotic inclusions with lithologies markedly different from those of the host metasediments and minor early mafic intrusions were recognized within the plutonic rocks, and in general, the lithology of the metasedimentary inclusions closely reflects the lithology of the immediately surrounding metasediments.

SUMMARY OF THE METASEDIMENTARY SEQUENCE

The metasedimentary sequence is a westward continuation of the relatively thick, geosynclinal accumulation of siliceous sandstone and siltstone mapped previously in the North Bay area to the east (Lumbers 1971a). The base of the sequence is not exposed in either map-area, but in both areas, the sequence is dominated by a eugeosynclinal sedimentary facies¹, now represented by the biotite gneisses, consisting mainly of thinly bedded greywacke and argillite, rarely with thin intercalated units of chert. This facies was deposited by turbidity currents in relatively deep water with little reworking by wave action. Subordinate miogeosynclinal deposits¹, now represented by the feldspathic gneiss and muscovitic and quartzose gneiss, are intercalated with the sedimentary eugeosynclinal deposits and consist essentially of moderately to well sorted, slightly ferruginous, arkose, subarkose, and minor orthoquartzite with some intercalated aluminous, clay-rich material deposited in a near-shore environment under the influence of wave action. Carbonate sediments are scarce to absent, but calcareous sandstone and siltstone, now represented by calc-silicate gneiss, is widespread in the siliceous gneiss and is particularly abundant in the eugeosynclinal deposits. Coarse clastic debris is mainly lacking, but coarse-grained, thick- to very thick-bedded greywacke, rarely with coarse lithic fragments, is intercalated with the eugeosynclinal deposits and appears to increase in abundance in the western half of the Burwash area, particularly in the northwestern quarter of the area near the Southern Province boundary where minor units of intraformational pebbly sandstone and conglomerate are locally present.

In the northwestern corner of the Burwash area, the Grenville Province metasedimentary sequence is flattened against the relatively rigid Southern Province (see the "Structural Geology" section), which is composed mainly of Middle Precambrian siliceous sandstone, siltstone, and argillite of the lower part of the Huronian Supergroup. As discussed above in the "Southern Province" section, this Middle Precambrian sequence was deposited by southerly flowing currents, probably near the northern margin of an arcuate geosyncline that was the site of volcanism (Copper Cliff, Stobie, and Elsie Mountain Formations). Metasediments of the lower part of the sequence (the McKim and Pecors Formations) are lithologically similar to the eugeosynclinal sedimentary facies in the Grenville Province, but this part of the sequence is not exposed near the Grenville Province although it may thicken southeastward toward the Grenville Province under the overlying, shallow water, miogeosynclinal deposits of the Mississagi Formation. The Mississagi Formation, on the other hand, does appear to thicken eastward toward the Grenville Province and undergoes a facies change, becoming richer in greywacke and argillite. In contrast to the metasedimentary sequence in the Grenville Province, the Huronian rocks of the Southern Province contain locally abundant coarse clastic debris, and many of the sandstones are rich in lithic fragments. Nevertheless, the coarse detritus and lithic fragments gradually decrease in abundance toward the south and east away from the Superior Province, which was the source area for most of the Middle Precambrian metasediments.

Metasediments of the Grenville Province near the Southern Province reflect the same type of facies change evident in the Mississagi Formation, and therefore, the metasedi-

¹Eugeosynclinal sedimentary facies is used to refer to sedimentary detritus deposited in relatively deep water below wave base, whereas miogeosynclinal sedimentary facies refers to sedimentary detritus deposited in relatively shallow water, above wave base.

mentary sequences in both provinces are most likely part of the same geosynclinal accumulation. In the eastern half of the Burwash area, metasediments of the Grenville Province are almost exclusively eugeosynclinal, but in the western half, intercalated miogeosynclinal metasediments become increasingly abundant toward the Southern Province, and within a few miles (5 km) of the Grenville Front Boundary Fault, the eugeosynclinal metasediments contain abundant, intercalated, thin units of quartz-rich meta-sandstone which locally, near the Boundary Fault, predominate over the eugeosynclinal rocks. Moreover, the facts that coarse detritus and lithic fragments are scarce in metasediments of the Grenville Province and those present are concentrated mainly near the Southern Province, are in harmony with the apparent decrease in abundance of this type of debris in the Southern Province away from the source area. These important stratigraphic relationships confirm speculations by the author and others (Lumbers 1971a, p.22) that the metasedimentary sequence in this part of the Grenville Province is Middle Precambrian in age and equivalent to at least the lower part of the Huronian Supergroup.

Further speculation concerning the interrelationships and paleogeography of the metasedimentary sequences of the Southern and Grenville Provinces requires more study, but present data allow a few general comments. Detailed stratigraphic correlations between metasediments of the Grenville and Southern Provinces such as proposed by Quirke (1930a) and Quirke and Collins (1930) are unjustified, according to results of the present study. The eugeosynclinal and some miogeosynclinal metasediments in the Southern Province show many lithologic similarities to the eugeosynclinal and miogeosynclinal metasediments in the Grenville Province, but these similarities provide no basis for detailed correlations because criteria for primary facing directions were largely obliterated in the intensely deformed metasediments of the Grenville Province, and a major facies change within the geosynclinal accumulation appears to coincide with the Grenville Front Tectonic Zone. Nevertheless, lithologic similarities are useful on a large scale, if the primary lithologies of the metasedimentary gneisses are correctly interpreted. Present data suggest that the metasedimentary sequence of the Grenville Province is most likely a thicker, predominantly eugeosynclinal, sedimentary facies of the Elliot Lake and Hough Lake Groups of the Huronian Supergroup, and that within the Grenville Province, rocks of the younger Quirke Lake and Cobalt Groups are either absent, or are represented by different sedimentary facies. The Grenville Front Tectonic Zone cuts diagonally southward across the Middle Precambrian geosynclinal accumulation, from east of Wanapitei Lake to Georgian Bay, and may coincide with a paleogeographic boundary or hinge line within the geosyncline that separates relatively thick, predominantly eugeosynclinal deposits to the east in the Grenville Province from possibly thinner, predominantly miogeosynclinal deposits to the west in the Southern Province. These relationships suggest that the eugeosynclinal metasedimentary deposits may have formed in a prominent trough that developed along what is now the northwestern margin of the Grenville Province, and that this trough subsequently influenced the location and development of the Grenville Front Tectonic Zone. Evidence for such a trough filled with eugeosynclinal sediments is also present to the north and east of the map-area (Lumbers 1971b; 1971c; 1971d; 1971e), and the trough may have formed in part along an ancient Early Precambrian continental margin. The eugeosynclinal metasediments may represent a former continental rise prism and the miogeosynclinal metasediments of the Southern Province may represent a complimentary monoclinial wedge, as outlined previously by Dietz and Holden (1966) and the author (Lumbers 1971a, p.21-22). Nevertheless, the facts that both the Grenville Front Tectonic Zone and the probable trough of eugeosynclinal metasediments cut diagonally across the Middle

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Precambrian geosyncline, rather than following the northern margin of the geosyncline westward from Sudbury, suggest additional complications in the evolution of the geosyncline, yet to be elucidated. In this connection, the Sudbury basin area and the area to the east appear to be particularly critical because many major structures and lithologic units associated with the geosyncline converge in this region.

Granitic Intrusive Rocks (Southern and Grenville Provinces)

During the Middle Precambrian, following intrusion of the Nipissing diabase bodies and the subsequent deformation and low rank regional metamorphism in the Southern Province, granitic rocks (map unit 12), forming an elongate, 65-mile (105 km) long mass extending from Georgian Bay to Coniston, were emplaced along what is now the northwestern margin of the Grenville Province. The granitic rocks, ranging in age from about 1,590 to 1,700 million years (Davis *et al.* 1970), lie mainly within the Southern Province, but locally extend into the Grenville Province (see Ayres *et al.* 1971b) and are collectively referred to as the Killarney batholithic complex; in the map-area, the granitic rocks of the Chief Lake batholith in Broder Township, and those in southern Neelon and northern Dill Townships near the Grenville Front Boundary Fault constitute the northeastern end of the complex. An important feature of the complex is its localization near the northwestern margin of the probable trough of eugeosynclinal metasediments outlined in the previous section, suggesting that this trough played an active role in the localization of the complex.

The Killarney plutonism was one of the early manifestations of tectonic activity that culminated during the Late Precambrian in the formation of the Grenville Front Tectonic Zone. Nevertheless, this plutonic event was not confined to the Grenville Front region, and can be recognized throughout the northwestern part of the Grenville Province (Krogh and Davis 1969a). Although some granitic rocks of the Grenville Province in the map-area are Late Precambrian in age and form part of the anorthosite suite (see the section on "Anorthosite Suite Intrusive Rocks"), most were emplaced during this Middle Precambrian plutonism and are gneissic due to Late Precambrian high rank regional metamorphism with locally superimposed cataclasis and mylonitization near the Boundary Fault. In the Southern Province, on the other hand, the Middle Precambrian granitic rocks suffered only low rank metamorphism, largely cataclasis and mylonitization related to the Late Precambrian deformation along the Grenville Front Tectonic Zone. In both provinces, the granitic rocks range in modal composition from quartz monzonite to tonalite, but most of the granitic plutons are composed of quartz monzonite and minor granodiorite.

In the Grenville Province, the granitic rocks underwent regional metamorphism and marked differences in texture exist between the granitic rocks and the metasediments, as outlined previously by the author in the North Bay area (Lumbers 1971a, p.23-24). The granitic rocks are mainly medium- to coarse-grained and gneissic with a pronounced augen structure; medium-grained constituents are concentrated in thin, discontinuous layers that deflect around lenticular augen up to a few inches (5 cm) long. The augen are composed of medium- to coarse-grained aggregates of either quartz, or feldspar, or both (Photo 13).



ODM8904

Photo 13—Gneissic, hornblende-bearing quartz monzonite showing the typical augen structure of the gneissic granitic rocks and cut by a late pegmatite dike containing large crystals of hornblende; Gull Islands, Lake Nipissing.

Locally, the granitic rocks are massive and display relict, primary igneous textures, with numerous coarse-grained, euhedral phenocrysts of partly recrystallized feldspar in a fine- to medium-grained, recrystallized granular groundmass of quartz, feldspar, and mafic minerals (Photo 14). This porphyritic variety commonly grades into augen gneiss, and augen of granular feldspar probably represent original feldspar phenocrysts. Equigranular, metamorphosed aplitic phases of the granitic rocks are commonly present, generally as dikes and irregularly shaped masses in augen gneiss (Photo 14). Some granitic plutons contain gneissic, recrystallized granite pegmatite dikes, presumably formed during the latter stages of emplacement of the plutonic masses. Younger, massive granite pegmatites, which postdate regional deformation and the culmination of the regional metamorphism, are also common in the granitic and other plutonic rocks (Photo 13), and in the metasediments. These pegmatites are discussed below in a separate section; only the largest are shown on Map 2271 (back pocket).

The granitic rocks were emplaced as magmatic intrusions and were not formed in place by granitization. Evidence for magmatic emplacement is identical to that presented previously by the author for felsic plutonic rocks in the North Bay area (Lumbers 1971a, p. 26-28) and is best preserved in massive to slightly foliated rocks with relict feldspar phenocrysts. Such rocks commonly contain angular, rotated inclusions of country rocks and early intrusive phases and oriented feldspar phenocrysts, with long axes that define a primary flow pattern. The plutonic rocks show sharp contacts with country rocks, and metasedimentary gneiss next to the felsic plutons contains dikes and sills of plutonic

Burwash Area



ODM8905

Photo 14—Massive quartz monzonite containing coarse-grained euhedral phenocrysts of partly recrystallized feldspar, a narrow dikelet of recrystallized aplite, and an inclusion of metagreywacke; large island in Trout Lake, southern Cherriman Township.

rocks, and is more extensively migmatitic than elsewhere, suggesting original contact metamorphism. Evidence of an igneous history for the felsic plutonic rocks is also reflected by their accessory zircon grains (Lumbers 1971a, p. 26-28).

Some of the gneissic granitic rocks are migmatitic with lenticular, discontinuous veins of massive to slightly foliated coarse-grained granitic material developed subparallel to the gneissosity (Photo 15). Migmatitic facies are common in intensely deformed, gneissic quartz monzonite, minor in granodiorite, and rare to absent in trondhjemite and tonalite. Generally, the granitic veins form less than 10 percent of the rock, but zones of intense deformation in many outcrops of migmatitic granitic rocks contain a higher proportion of complexly contorted granitic veins (Photo 15). As discussed elsewhere (Lumbers 1971a), migmatitic facies of the granitic rocks probably developed in response to high rank regional metamorphism, by partial melting controlled in part by the original composition of the rocks involved, and in part by deformation. Some plutons of partly migmatitic granitic rocks in Dill Township were mapped by Plemister (1960) and Grant *et al.* (1962) as injection and permeation gneisses, consisting of variable amounts of banded gneiss and granitic material.

In the Southern Province, the granitic rocks were previously mapped as feldspathized quartzite by Plemister (1960) and Grant *et al.* (1962), but evidence initially reported by the author (Lumbers 1965, p.54) and subsequent work on the Chief Lake batholith by Henderson (1967a) and Card *et al.* (1971) among others, indicate an intrusive



ODM8906

Photo 15—Typical migmatitic, gneissic quartz monzonite containing lenticular, discontinuous veins and masses of coarse-grained granitic material developed subparallel to the gneissosity; West Bay batholith, lot 5, concession VI, Casimir Township.

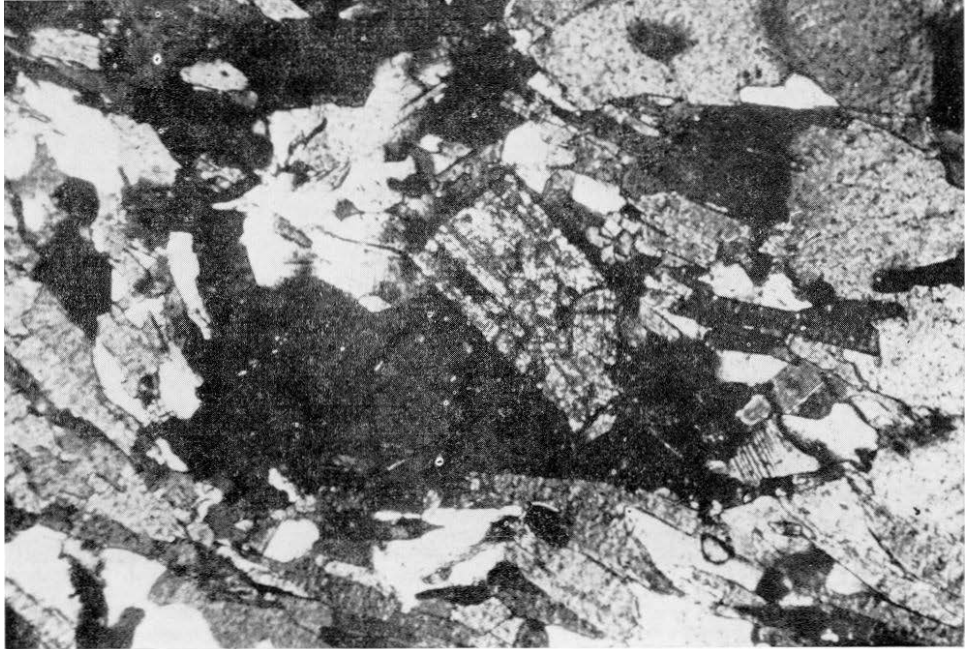


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Photo 16—Contact between cataclastic, porphyritic quartz monzonite of the Chief Lake batholith and quartz-rich metasandstone of the Mississagi Formation (light grey to white). Note the discordant nature of the contact and the raft of metasandstone in the quartz monzonite (above the hammer); lot 5, concession I, Neelon Township.

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ODM8908

Photo 17—Photomicrograph (crossed polarizers) of gneissic quartz monzonite from the Chief Lake batholith showing primary igneous growth zoning in an euhedral zircon grain (at photo centre). Width of photo represents approximately 1 mm.

origin for these rocks, although feldspathization of metasediments and Nipissing diabase has occurred locally as a result of contact metamorphism by the granitic rocks. Plemister (1960) correlated the feldspathization with high rank regional metamorphism in the adjacent Grenville Province, but in southeastern Broder and northern Tilton Townships, southeast of where the Grenville Boundary Fault cuts across the granitic rocks of the Chief Lake batholith, the granitic rocks are regionally metamorphosed to a high rank along with their host metasediments indicating that the high rank regional metamorphism in the Grenville Province is actually younger than the granitic rocks.

Several features of the granitic rocks in the Southern Province point to an igneous origin, among which the following are most outstanding: 1) sharp, discordant contacts with marked differences in grain size between host metasediments and the granitic rocks (Photo 16); 2) rotation of metasedimentary inclusions which also have sharp contacts; 3) dikes and apophyses from the granitic rock masses that cut across the strike of the enclosing country rock; 4) intrusion breccias of granitic material into gabbroic bodies, with gabbro fragments in the granitic rocks showing all degrees of metasomatism and mainly angular outlines with sharp contacts (Photo 2); 5) hornfelsed, but not feldspathized metagreywacke inclusions; 6) primary, igneous growth zoning in plagioclase (Photo 19) and euhedral zircon grains (Photo 17); and 7) a restricted compositional range in the granitic rocks (Henderson 1967a), which cannot be accounted for by wholesale transformation by alkalic metasomatism of large volumes of rocks ranging in composition from pure quartz sandstone to gabbro. In addition, there is no evidence, within or near the outer contact of the proposed zone of feldspathization, of passage-

Table 3

**MODAL COMPOSITION (VOLUME PERCENT) OF GRANITIC ROCKS OF THE CHIEF LAKE BATHOLITH
IN THE SOUTHERN AND GRENVILLE PROVINCES IN THE BURWASH AREA**

ROCK TYPE	SOUTHERN PROVINCE			GRENVILLE PROVINCE		
	QUARTZ MONZONITE (Average of 5 modes)	Estimated range	GRANODIORITE	QUARTZ MONZONITE (Average of 5 modes)	Estimated range	GRANODIORITE
Quartz	27.4	26-29	23.5	26.8	25-28	25.2
Plagioclase	27.2	22-33	44.8	29.2	26-33	32.7
percent An	20	15-25	25	20	20-25	27
K-feldspar	24.4	21-28	17.0	22.9	21-25	10.9
Biotite-Chlorite	11.0	4-16	11.8	....	....	....
Biotite	....	....	....	15.1	8-18	18.1
Amphibole	....	....	....	....	....	7.2
Muscovite	4.4	3-6	1.4	2.3	1-3	....
Epidote	4.4	2-8	0.8	1.5	0.5-3	....
Sphene	0.5	0.1-1	0.4	0.6	0-2	3.2
Opaque minerals	0.2	....	trace	0.6	trace-1	1.4
Apatite	0.3	0.2	0.4	trace-1	1.1
Allanite	trace	0.3	0.1
Zircon	0.2	0.1	0.3	0.1
	<u>100.0</u>		<u>100.0</u>	<u>100.0</u>		<u>100.0</u>

Burwash Area



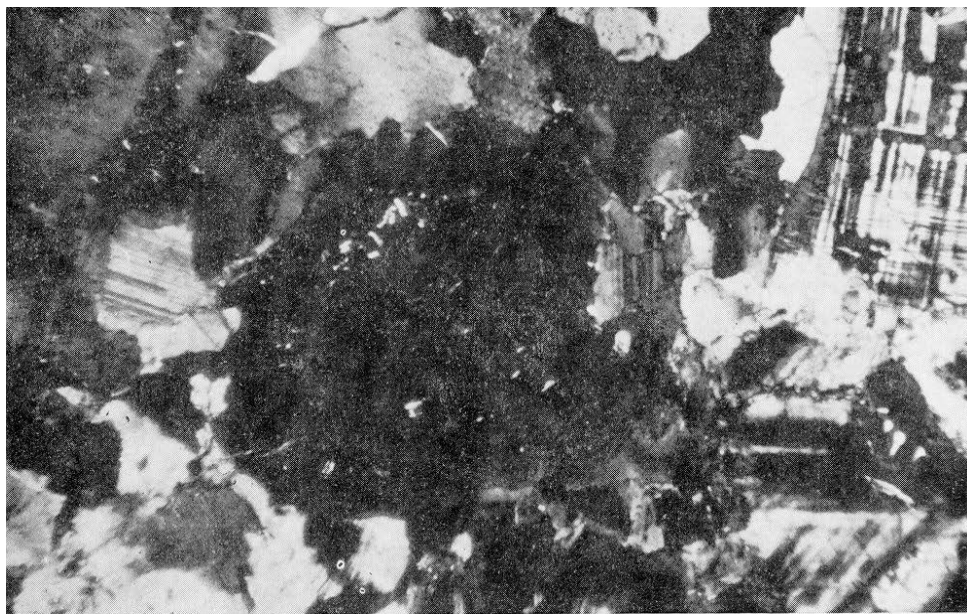
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Photo 18—Typical cataclastic, porphyritic quartz monzonite from the Chief Lake batholith containing an aplite dike and a few inclusions of quartz-rich metasandstone elongated subparallel to the cataclastic foliation; lot 1, concession II, Broder Township.

ways for solutions migrating into the host metasediments and gabbroic rocks. Except along post-granitic faults, widespread silicification necessitated by feldspathization of the quartz-rich metasediments of the Mississagi Formation is absent.

RECOGNITION OF THE GRENVILLE FRONT BOUNDARY FAULT IN THE GRANITIC ROCKS

Misinterpretation of the origin of the granitic rocks by Phemister (1960) and Grant *et al.* (1962) was largely due to their failure to recognize the Grenville Front Boundary Fault within the Chief Lake batholith, and the presence of extensive cataclasis and mylonitization in the granitic rocks northwest of the fault; most of the cataclastic and mylonitic features were taken by these workers to indicate relict sedimentary features. In both provinces, the granitic rocks of the batholith are mainly quartz monzonite with local granodioritic phases, but on either side of the Boundary Fault they show major metamorphic and textural differences, partly reflected in their modal compositions. These differences are discussed below, and in Table 3, average modes, together with estimated ranges of each constituent in quartz monzonite, and a single mode of granodiorite from the batholith on either side of the Boundary Fault are compared.



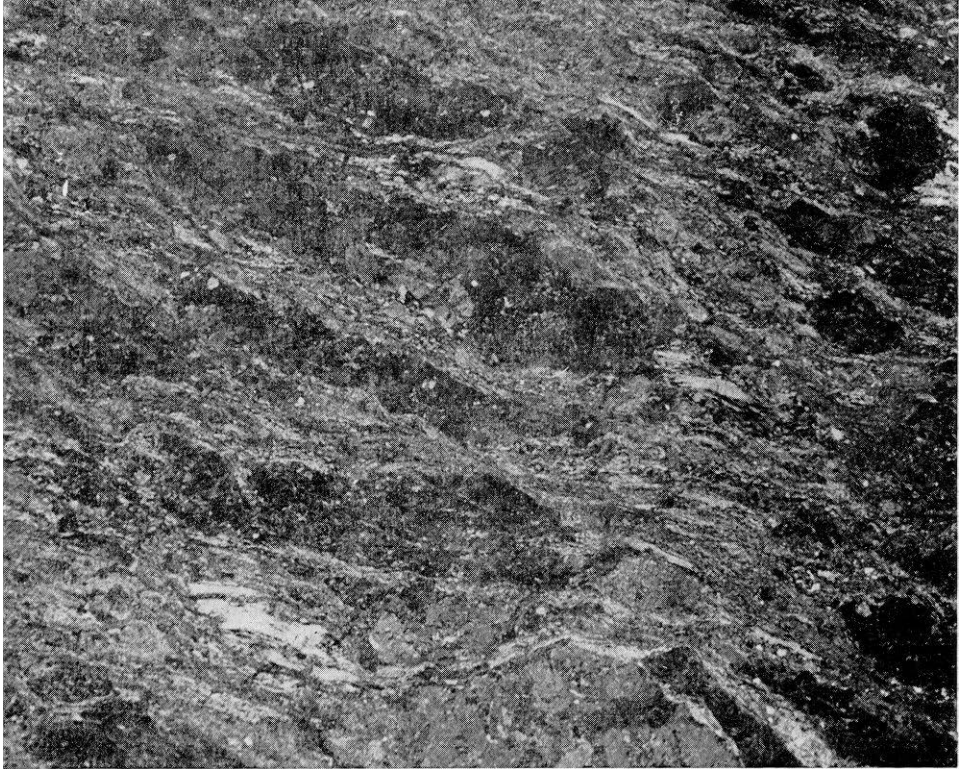
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Photo 19—Photomicrograph (crossed polarizers) of slightly cataclastic quartz monzonite from the Chief Lake batholith showing primary igneous growth zoning in plagioclase (at photo centre). Width of photo represents approximately 3 mm.

Southwest of Raft Lake in Broder Township, the granitic rocks of the Chief Lake batholith in the Southern Province macroscopically show hypidiomorphic-granular to porphyritic textures common in many intrusive granitic rocks (Photo 2). Generally only microscopic evidence of cataclasis, chiefly slightly strained quartz and feldspar, is present (Photo 19). Minor zones of cataclasis and mylonitization, no more than a few feet (1 m) wide, are visible locally in some outcrops, but towards the southeast and elsewhere in granitic rocks in Dill and Neelon Townships, these zones increase in abundance and the rocks are macroscopically cataclastic (Photo 18). In thin section, relict feldspar phenocrysts are bent, fractured and veined, and partly rimmed by very fine-grained, granular feldspar to form coarse lenticular augen (up to 1 inch or so (2 or 3 cm) in size) in a very fine-grained groundmass of comminuted and recrystallized quartz and feldspar, muscovite, minor epidote, and abundant intergrown chlorite and biotite (Photo 20). A few fine-grained porphyroblasts of epidote and sphene are present in the groundmass, which shows a prominent foliation due to planar and linear alignment of the constituent minerals. Lenses and discontinuous layers of intensely strained quartz and broken feldspar grains, no more than a few millimetres wide, are aligned parallel to the foliation, and the groundmass is generally green to dark green due to the presence of chlorite and epidote.

In the Grenville Province at the Boundary Fault, the granitic rocks also are cataclastic with feldspar augen, but recrystallization is much more pronounced (Photo 21); the fine-grained groundmass is distinctly coarser in grain size than in the Southern Province and is grey to dark grey due to abundant biotite. Many feldspar augen, particularly plagioclase, show a distinctive macroscopic granular texture indicative of recrystallization and are more flattened and contorted than in the Southern Province. Microscopically, plagioclase and potassic feldspar are completely recrystallized with no relict primary

Burwash Area

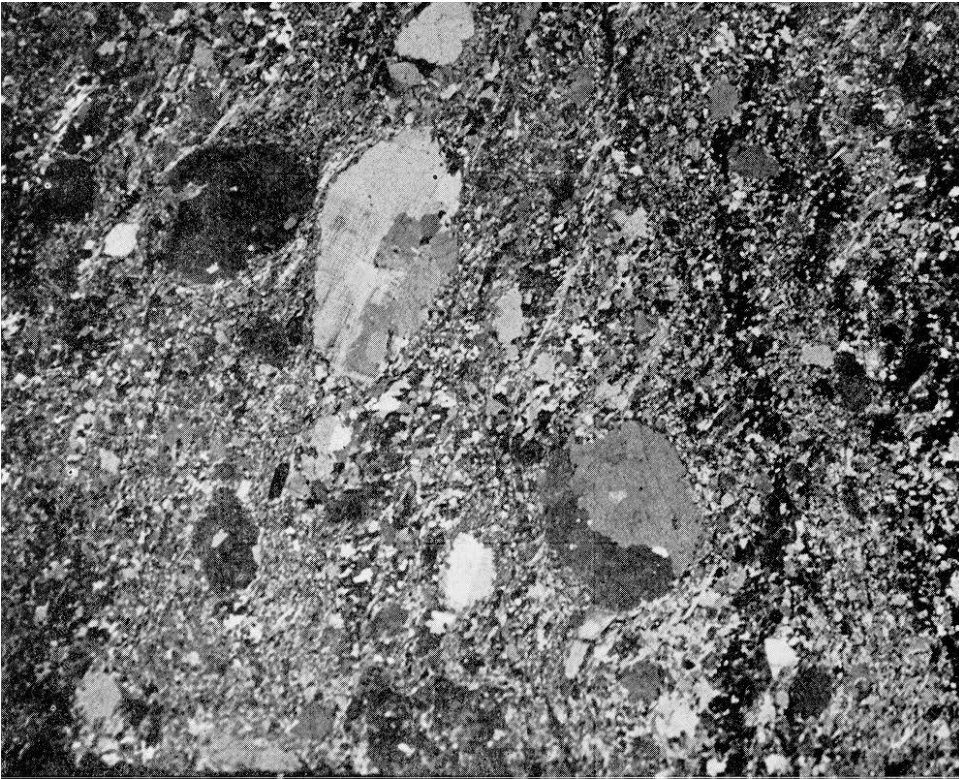


ODM8911

Photo 20—Photomicrograph (crossed polarizers) of typical cataclastic quartz monzonite from the Chief Lake batholith in the Southern Province; lot 1, concession II, Broder Township. Width of photo represents approximately 2 cm. Photo by Department of Photography, Royal Ontario Museum.

igneous features, chlorite occurs only rarely as a secondary alteration product of mafic minerals, epidote and sphene form relatively coarse porphyroblasts, epidote is much less abundant than in the Southern Province, and all the minerals show only minor strain effects. Within 1,000 feet (300 m) southeast of the Boundary Fault, the granitic rocks gradually lose their cataclastic appearance and are similar to the granitic rocks found elsewhere in the Grenville Province. Nevertheless, several narrow zones of late cataclasis that trend subparallel to the Boundary Fault cut across the granitic rocks further from the Boundary Fault.

Major differences are also shown by accessory apatite and zircon in the granitic rocks on either side of the Boundary Fault. In the Southern Province, apatite is only slightly recrystallized, and many grains are broken with wisps of biotite along their margins, whereas in the Grenville Province, apatite is completely recrystallized into euhedral grains that have grown across recrystallized biotite, feldspar, and quartz grains. Zircon in the Southern Province forms euhedral crystals generally with straight grain boundaries, but one or more crystal faces are commonly slightly embayed or corroded and metamorphic overgrowths are absent. In the Grenville Province, zircon forms subhedral grains with scalloped grain boundaries; a few grains are euhedral due to metamorphic overgrowths.



ODM8912

Photo 21—Photomicrograph (crossed polarizers) of gneissic quartz monzonite from the Chief Lake batholith in the Grenville Province; lot 1, concession II, Broder Township. Width of photo represents approximately 2 cm. Photo by Department of Photography, Royal Ontario Museum.

MODAL DATA

Most of the granitic rocks in that part of the Southern Province within the map-area are part of the Chief Lake batholith and consist mainly of slightly to intensely cataclastic to mylonitic quartz monzonite and minor granodiorite, as discussed in the preceding section. Most of the quartz monzonite is porphyritic with phenocrysts of perthitic potassic feldspar and minor plagioclase. Rocks of the small granitic bodies northeast of the batholith in southern Neelon and northern Dill Townships are essentially identical to the cataclastic and mylonitic quartz monzonite of the batholith. Comparison of Tables 3 and 4 shows that the quartz monzonites of the Chief Lake batholith in both the Southern and Grenville Provinces are slightly richer in biotite and contain more muscovite and epidote than quartz monzonite elsewhere in the Grenville Province, but otherwise, the rocks are similar in modal composition.

In the Grenville Province, the gneissic granitic rocks consist of four major varieties: quartz monzonite, hornblende-bearing quartz monzonite, granodiorite, and trondhjemite; minor albite granite is associated with the quartz monzonites and minor tonalite is

Table 4

AVERAGE MODES (VOLUME PERCENT) OF THE GRANITIC ROCKS OF
THE GRENVILLE PROVINCE IN THE BURWASH AREA

ROCK TYPE	QUARTZ MONZONITE		HORNBLENDE-BEARING QUARTZ MONZONITE		GRANODIORITE		TRONDHJEMITE
	Average of 7 modes	Estimated range	Average of 6 modes	Estimated range	Average of 4 modes	Estimated range	Average of 3 modes
Quartz	27.2	22-32	27.7	24-30	22.5	18-26	27.1
Plagioclase	34.0	28-38	34.2	29-38	37.1	32-40	50.4
percent An	12	5-20	14	10-20	23	12-35	27
K-feldspar	27.4	22-30	26.8	20-31	18.2	11-24	3.8
Biotite	8.9	2-16	6.1	3-10	11.1	4-22	9.9
Hornblende	trace	.....	3.4	1-6	7.6	1-15	4.8
Epidote	0.2	.....	.....	.....	0.4	trace-1	trace
Garnet	trace	.....	trace	.....	.....	.....	.....
Sphene	0.5	0-0.7	0.4	0-1	0.2	.....	.....
Opaque minerals	0.8	trace-2	0.7	trace-2	1.7	1-3	2.5
Apatite	0.4	trace-1	0.4	trace-1	0.9	0.5-1	1.3
Zircon	0.3	.....	0.2	.....	0.2	.....	0.2
Others*	0.3	.....	0.1	.....	0.1	.....	trace
Totals	100.0		100.0		100.0		100.0

*Muscovite, carbonate, allanite

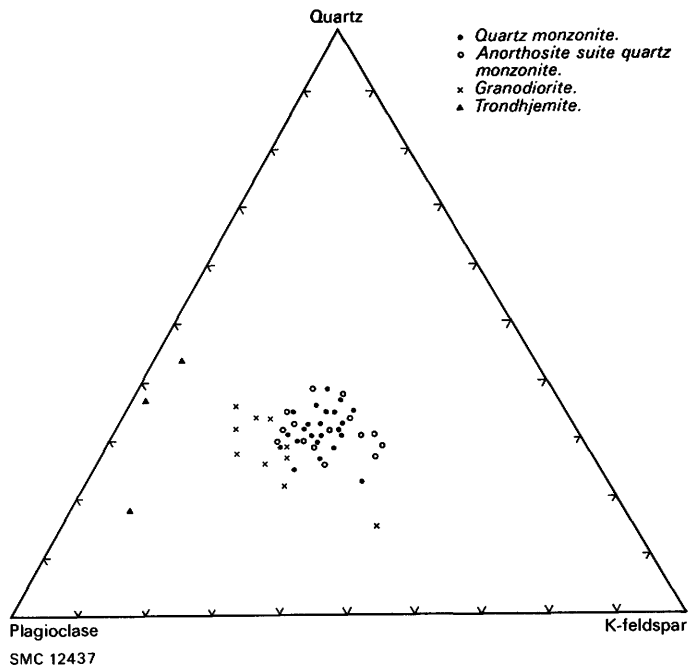


Figure 3—Modal quartz, plagioclase, and potassic feldspar from 35 thin sections of granitic rocks and 14 thin sections of quartz monzonites of the anorthosite suite from the Burwash and North Bay areas.

associated with trondhjemite. Migmatitic varieties of the quartz monzonites and albite granite are common, although hornblende-bearing quartz monzonite is generally only slightly migmatitic; migmatitic varieties of granodiorite are rare, and trondhjemite and tonalite are nonmigmatitic. In the adjacent North Bay area, trondhjemite is absent, quartz monzonite and albite were mapped as biotite granite, and hornblende-bearing quartz monzonite and granodiorite were mapped as hornblende-biotite granite. With more data now available, the granitic rocks in the Burwash area can be subdivided according to primary rock types. Albite granite differs from quartz monzonite only in containing albite rather than sodic oligoclase, and macroscopically, the two rocks are indistinguishable. Macroscopically, granodiorite is pale pink to grey and contains more than 5 percent hornblende, abundant visible plagioclase, and relatively minor visible potassic feldspar and quartz, whereas the quartz monzonites are invariably pink, and the hornblende-bearing variety commonly contains less than 5 percent hornblende and abundant visible potassic feldspar and quartz. Trondhjemite is invariably grey and differs from granodiorite chiefly in containing no visible potassic feldspar; tonalite is similar to trondhjemite but richer in hornblende and biotite. Trondhjemite and greyish granodiorite are confined to the Frances Lake batholith and Broker pluton at the western boundary of the area.

Average modes based on typical specimens of the four major types of granitic rocks are given in Table 4 together with estimated ranges of each constituent in the quartz monzonites and granodiorite. Potassic feldspar in all of the granitic rocks shows grid twinning and, except in trondhjemite, is perthitic. Plagioclase is unzoned and is rarely

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antiperthitic, containing tiny spindles of potassic feldspar. In the quartz monzonites, relict feldspar phenocrysts are generally perthitic potassic feldspar, but some are plagioclase in hornblende-bearing quartz monzonite; in trondhjemite and most of the granodiorite, feldspar phenocrysts are plagioclase. Opaque minerals are mainly iron-titanium oxides partly surrounded by sphene. Pinkish hues typical of the quartz monzonites are due mainly to hematite coatings on quartz and feldspar grains and along fractures.

In Figure 3, modal data for 35 granitic rocks in the Burwash and North Bay areas and 14 quartz monzonites of the anorthosite suite (see section on "Anorthosite Suite Intrusive Rocks") are expressed in terms of volume percent quartz, plagioclase, and potassic feldspar recalculated to 100 percent. Except for trondhjemite, the granitic rocks show a restricted compositional range with respect to quartz, potassic feldspar, and plagioclase, comparable to minimum melting compositions in the experimental granitic system of Tuttle and Bowen (1958). Thus the granitic rocks may not only have formed by crystallization from a melt, but their restricted compositional range may also indicate that they were generated by fusion of crustal material rather than derived from the mantle. Trace element and isotopic data necessary to properly evaluate the origin of the granitic rocks are scarce, but initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratios obtained by Krogh (see Davis *et al.* 1967; 1970; Krogh *et al.* 1968; Krogh and Davis 1969a; 1969b) from the granitic rocks are low (generally near 0.705), and there is generally a high degree of fit of the rubidium-strontium isotopic data to individual isochrons for the granitic rocks. These data suggest that the granitic rocks had at most only a short pre-emplacment crustal history and were most likely derived from the mantle.

DISTRIBUTION

Middle Precambrian granitic rocks are widespread throughout the Grenville Province portion of the area and form large batholiths near Lake Nipissing in the eastern part of the area and in Struthers, Kilpatrick, and Travers Townships in the southwestern corner of the area. They also form dike swarms, small sheets, and several stocks within the metasedimentary gneisses. Granitic rocks north of Lake Nipissing near the eastern boundary of the area are the westernmost extension of the Sturgeon Falls batholith mapped previously in the North Bay area (Lumbers 1971a, p. 32-33).

Only the largest of the minor granitic bodies can be shown separately on the map (Map 2271, back pocket), but other bodies are indicated by appropriate symbols. Because of the reconnaissance nature of the mapping, some minor bodies shown are necessarily generalized. Moreover, the detailed distribution of the various lithologies within a given body could not be determined. Migmatitic phases are common throughout all the bodies and are best developed in narrow sheets and near the borders of the larger bodies. All bodies are complexly deformed, syntectonic or pre-tectonic intrusions that underwent Late Precambrian high rank regional metamorphism and deformation, and most of the large bodies, such as the West Bay batholith, are characterized by complex dome and basin structures. Brief descriptions of some of the larger bodies are given below. Work to date by the author and Frarey and Cannon (1969) in the Grenville Province and by numerous other investigators in the Southern Province shows that the only granitic bodies relatively rich in granodiorite and trondhjemite and which intrude the Middle Precambrian metasedimentary sequences of both provinces are the

Chief Lake, Broker (Attlee Township), and Frances Lake (Kirkpatrick Township) bodies that lie partly within the western margin of the map-area, and the Eden Lake intrusions (Card *et al.* 1971) west of the map-area. These bodies are Middle Precambrian in age and lie within a few miles to the northwest and southeast of the Grenville Front Boundary Fault.

Chief Lake Batholith

The Chief Lake batholith, has an area of at least 50 square miles (130 square km), and extends southwestward from the western boundary of the Burwash map-area in Broder and Tilton Townships to the eastern part of Eden and Bevin Townships; the southern limit of the mass is unmapped, but the intrusion appears to be contiguous with other rocks of the Killarney batholithic complex. Part of the northeastern end of the mass lies within the Grenville Province, and small bodies of cataclastic to mylonitic quartz monzonite in northern Dill and southern Neelon Townships, just northeast of the main intrusion, could be genetically related to the batholith. Spaven (1966), Henderson (1967a), and Card *et al.* (1971) mapped portions of the batholith within and west of the map-area and showed that the intrusion was emplaced into previously deformed, and regionally metamorphosed metasediments and Nipissing diabase of the Southern Province by a passive stoping mechanism. The batholith was emplaced mainly within quartz-rich metasandstones, and an embayment of these metasediments in the batholith along the southeastern side of Wavy Lake in Eden Township is injected and brecciated by numerous dikes and sills of granitic rocks which increase in abundance towards the main contact of the batholith, which is marked by abundant inclusions of quartz-rich metasandstone. In the map-area, a similar zone of injection migmatite marks the southwestern contact of the batholith in Tilton Township, but all the rocks here are cataclastic and mylonitic. Southwest of the map-area, the northwestern border of the batholith is in fault contact with metasediments of the Huronian Supergroup, but within the map-area and for about 2 miles (3 km) southwest, the batholith is bordered to the northwest by metagabbro, and the contact is marked by intrusion breccias formed by injection of granitic magma into the metagabbro. Within about 2 miles (3 km) of the northwestern margin, the batholith contains abundant, elongate to slab-like inclusions and roof pendants of metagabbro and quartz-rich metasandstone, ranging in length from a few inches (5 cm) to nearly 1 mile (1.6 km) (see Henderson 1967a). These inclusions and roof pendants are particularly abundant in the map-area, and the larger ones contain numerous dikes and sills of granitic rocks.

In the map-area, the batholith consists mainly of quartz monzonite and minor granodiorite, locally with contaminated phases of trondhjemite and rare tonalite along the northern border and in the northeastern end where the granitic rocks intruded metagabbro. Elsewhere, according to data by Henderson (1967a), the batholith appears to be richer in granodiorite than in the map-area, and granodiorite and trondhjemite are abundant in the inclusion-rich zone near the northwestern border of the mass. Most of the granitic rocks are porphyritic, with coarse-grained phenocrysts of perthitic potassic feldspar predominating in quartz monzonite, and of plagioclase predominating in granodiorite and trondhjemite. Nevertheless, equigranular phases are present, particularly in the western, northern, and central parts of the batholith. Superimposed cataclasis and mylonitization, dominant in rocks of the batholith in the map-area, gradually decrease

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in intensity to the west of the area, and near the western margin, only a few narrow zones of cataclasis are evident. Aplite dikes are common locally within the batholith (see Photo 18), but pegmatite dikes appear to be rare, except locally in the embayment of metasediments southeast of Wavy Lake (Eden Township).

Textural, structural, and mineralogic features of the batholith suggest that it may be a relatively high level intrusion, possibly emplaced within the epizone as defined by Buddington (1959). Features of the batholith particularly suggestive of epizonal emplacement are: 1) the discordant nature of the contacts, 2) incorporation in place of country rocks, 3) abundant inclusions and roof pendants of country rocks, 4) porphyritic character of the granitic rocks, 5) the apparent scarcity of well developed pegmatite dikes, 6) sharp contacts with the country rocks, 7) rare presence of granophyre, 8) the presence of a fine-grained matrix in some porphyritic phases, and 9) the presence of breccias near the margins of the batholith.

Halifax Pluton

The Halifax pluton in northern Halifax and southern Tilton Townships is in the Grenville Province, just east of the Grenville Front Boundary Fault. It consists of migmatitic and gneissic quartz monzonite and minor granodiorite locally with numerous concordant inclusions of quartz-rich metasediments and arkosic metasediments, particularly in the southern half of the body. Dikes and apophyses of the mass locally cut across the host metasedimentary gneisses, and the northern end of the pluton in Tilton Township intruded and brecciated an older metagabbro body. The gneissic granitic rocks of the Halifax pluton were originally porphyritic and locally contain relict late stage dikes of gneissic aplite, but gneissic granite pegmatite dikes appear to be absent. As pointed out by Henderson (1967a), the pluton has many features in common with the Chief Lake batholith and may be genetically related to this intrusion. Although relict primary igneous features are poorly preserved, the Halifax pluton may be an epizonal intrusion.

Wanup and Estaire Plutons

The Wanup and Estaire plutons, near the common corner of Secord, Dill, Cleland, and Burwash Townships about 6 miles (10 km) southeast of the Grenville Front Boundary Fault, are composed mainly of migmatitic and gneissic quartz monzonite. The southern part of the Estaire pluton locally contains abundant migmatitic and gneissic hornblende-bearing quartz monzonite and minor granodiorite. Although intensely deformed, both plutons appear to have discordant contacts with the host metasedimentary gneisses, and both contain concordant inclusions of metasediments near their margins. The Estaire pluton contains inclusions of metagabbro and shows intrusive relationships with metagabbro bodies near the margins of the mass; intrusion breccias formed by injection of the granitic rocks into metagabbro are well developed at the contacts of the metagabbro body at the northeastern end of this pluton. Most of the gneissic granitic rocks of the two plutons were originally porphyritic, and gneissic late stage pegmatite dikes appear to be absent; the Estaire pluton contains a few, fine-grained amphibolite dikes no more than a few inches (5 cm) wide.

Broker Pluton

The Broker pluton at the western boundary of the area in Attlee Township north of Broker Lake differs markedly from the preceding plutons, in that it is composed of migmatitic and gneissic hornblende-bearing quartz monzonite, abundant pink to grey gneissic granodiorite, and minor gneissic trondhjemite. Locally, the quartz content of the hornblende-bearing quartz monzonite is as low as 12 percent, and a few late stage, gneissic granite pegmatite dikes are present. Frarey and Cannon (1969) mapped the extension of the pluton to the west of the map-area.

Frances Lake Batholith

The Frances Lake batholith in the southwestern corner of the map-area in Travers, Kilpatrick, and Struthers Townships, extends west and south of the map-area to Georgian Bay (see Frarey and Cannon 1969) and contains several varieties of granitic rocks and numerous inclusions and concordant layers of metasediments, which in the map-area, consist mainly of meta-arkose. Migmatitic and gneissic quartz monzonite and hornblende-bearing quartz monzonite are the most abundant rocks of the batholith in the map-area, but grey, gneissic to locally massive trondhjemite and gneissic, grey granodiorite form large mappable units in the mass near the western boundary of the map-area and are present sparingly elsewhere in association with the quartz monzonite. West of the map-area, trondhjemite and granodiorite dominate the southern part of the batholith (Frarey and Cannon 1969). Although many of the granitic rocks contain relict feldspar phenocrysts, much of the trondhjemite and granodiorite was originally equigranular, and massive to slightly foliated phases contain a relict hypidiomorphic-granular texture. Late stage dikes of gneissic aplite and granite pegmatite, generally only a few inches wide, are present locally in all of the granitic rocks. The batholith appears to be a complex intrusion, but further work is necessary to determine relative age relationships among the various granitic rocks.

Emma Lake Pluton

The Emma Lake pluton largely underlies the northeastern part of Allen Township, near the core of a regionally developed, complex synform. The pluton is intensely deformed and markedly migmatitic. Migmatitic and gneissic quartz monzonite is the dominant rock in the pluton, but migmatitic and gneissic hornblende-bearing quartz monzonite is locally present and is relatively common in the northern part of the pluton. Metasedimentary inclusions and narrow concordant layers of metasediments are common near Emma Lake and near the borders of the pluton. A few sills and dikes of granitic rocks are present locally in the metasediments bordering the pluton. Narrow dikelets of gneissic aplite, emplaced at a late stage in the intrusive history of the pluton, are present in the granitic rocks in many places, but pegmatitic bodies appear to be rare.

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Pine Cove Pluton

The Pine Cove pluton is a complexly deformed, elongate body of predominantly migmatitic and gneissic quartz monzonite extending northwestward from Wolseley Bay in eastern Scollard Township into southeastern Martland Township. Migmatitic and gneissic hornblende-bearing quartz monzonite is common locally, particularly in the northwestern part of the pluton, and small concordant layers and irregularly shaped inclusions of metasediments are present in many places and are particularly abundant in the southeastern part of the body. Small dikelets of gneissic aplite and granite pegmatite, generally no more than a few inches wide and probably late stage phases of the pluton, are present locally in the granitic rocks, and a few gneissic pegmatite dikes are present in the metasedimentary gneisses bordering the pluton. Near the southern margin of the pluton, in Martland Township, a narrow dike of gneissic gabbroic anorthosite appears to have intruded the granitic rocks.

West Bay Batholith

The West Bay batholith, centred on West Bay of Lake Nipissing, underlies about one-third of the eastern half of the map-area and is among the largest granitic rock bodies known in the northwestern part of the Grenville Province in Ontario (see Ayres *et al.* 1971b). A narrow zone of metasediments trending through Northwest Bay into Lake Nipissing, south of the Hardwood Islands, separates the West Bay and Sturgeon Falls batholiths. The close spatial association of these batholiths, plus the similarities in composition and structural features suggest that they are genetically related. For similar reasons, the Pine Cove pluton may also be genetically related to the West Bay batholith.

Like the Sturgeon Falls batholith, the West Bay body is complexly deformed and contains widespread metasedimentary inclusions and numerous concordant layers of metasediments. Where exposed, contacts of the batholith with the inclusions and with surrounding metasediments are commonly sharp. Although structural trends within the batholith and in the surrounding metasediments are generally concordant, local discordant contacts with the metasediments are common at the margins of the batholith, in addition to locally developed zones of intrusion breccia, formed by the injection of granitic rocks into the metasediments. Dikes and sills of migmatitic and gneissic quartz monzonite are common in the metasediments near the batholith and up to 4 miles (6.5 km) west of the batholith in Jennings and northern Cherriman Townships.

The batholith is composed mainly of migmatitic and gneissic quartz monzonite and subordinate hornblende-bearing quartz monzonite, but locally, the hornblende-bearing quartz monzonite grades into granodiorite and predominates over the quartz monzonite, particularly where metasedimentary layers and inclusions are relatively scarce. Inclusions of metagabbro are present in many places within the batholith, and particularly large metagabbro bodies, intruded and partly granitized by the granitic rocks, are present in the northwestern part in Jennings and Casimir Townships. Near the metagabbro bodies and inclusions, the granitic rocks are commonly more mafic than elsewhere, probably due to contamination of the original granitic magma by the metagabbro, and range in composition from hornblende-bearing quartz monzonite to (rarely) tonalite. Narrow dikes, generally less than 1 foot (30 cm) wide, of gneissic aplite and granite pegmatite are found throughout the batholith and were probably formed during the latter stages

of emplacement of the batholith. In places, amphibolite dikes cut across the granitic rocks, and in Falconer, Casimir, and northwestern MacPherson Townships, bodies of anorthosite suite intrusive rocks intrude the batholith (see the section on "Anorthosite Suite Intrusive Rocks"). Conformable structural trends within the batholith and the surrounding metasediments suggest that all of these rocks were folded after emplacement of the batholith to form the complex dome and basin structure shown on the map (Map 2271, back pocket). This structural pattern reflects a complex deformational history possibly involving two or more events, and together with the intensely recrystallized nature of the intrusive rocks, suggests that the batholith was most likely emplaced at an early stage in the plutonic history of the area, before the emplacement of the anorthosite suite intrusive rocks.

Sturgeon Falls Batholith

The Sturgeon Falls batholith lies mainly in the northwestern part of the North Bay map-area (Lumbers 1971a), but the numerous folded sheets of migmatitic and gneissic quartz monzonite and minor hornblende-bearing quartz monzonite in Field, Springer, Caldwell, southern Kirkpatrick, and northern MacPherson Townships form the westernmost extension of the batholith. Small metagabbro bodies intruded rocks of the batholith in Springer and southwestern Caldwell Townships, and many of the folded granitic sheets show local crosscutting relations with the surrounding metasediments. Metasediments in MacPherson and Caldwell Townships near the folded sheets and the West Bay batholith contain several sills and dikes of migmatitic and gneissic quartz monzonite and a few small dikes of gneissic granite pegmatite, all of which are probably genetically related to the two batholiths.

AGE OF THE GRANITIC ROCKS

Field relationships show that the granitic rocks are younger than the Nipissing diabase intrusions, but older than at least some of the anorthosite suite intrusive rocks. Their intense deformation and metamorphism in the Grenville Province suggest that they were emplaced early in the tectonic history of the area. These rocks are being investigated isotopically by Krogh (see Davis *et al.* 1967; 1970; Krogh *et al.* 1968; Krogh and Davis 1969a; 1969b), using uranium-lead systems in zircons and the rubidium-strontium whole-rock technique. Results obtained to date suggest that they are $1,700 \pm 150$ million years old, and were therefore emplaced prior to the culmination of the Late Precambrian high rank metamorphism.

Early Pegmatite

Gneissic, recrystallized granite pegmatite dikes are common in the metasediments and early metagabbro bodies within the Grenville Front Tectonic Zone, up to 8 miles (13 km) southeast of the Grenville Front Boundary Fault. Most of the dikes are contorted and trend northeasterly, subparallel to structural trends in their host rocks. Most

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Photo 22—Large dike of gneissic granitic pegmatite locally with cataclastic foliation and a prominent rodding lineation on foliation planes; lot 6, concession V, Dill Township.

are small bodies with widths and strike lengths rarely exceeding a few feet. Nevertheless, a few large dikes, up to a few hundred feet wide and a few thousand feet long (Photo 22), are present in Dill Township either within or bordering metagabbro bodies intruded by the Middle Precambrian granitic rocks. The dikes have sharp contacts with their host rocks and are locally cataclastic and mylonitic, with a prominent rodding lineation consisting of streaks and parallel columns rich in quartz. No internal mineralogic zoning was observed in any of the dikes, which are composed mainly of quartz and alkalic feldspar with minor muscovite, biotite, rare amphibole, and accessory zircon, garnet, and iron-titanium oxide minerals. Only the largest dikes are shown separately on the accompanying map (Map 2271, back pocket), but biotite gneiss sequences containing small dikes of these rocks are given a separate symbol on the map (map units 6c, 6d), thereby showing the general distribution of the dikes. Most of the small dikes are similar in appearance to gneissic pegmatite dikes formed during the latter stages of emplacement of the Middle Precambrian plutons. Zircons from one of the large early pegmatite dikes in Dill Township yield an age between 1,600 and 1,700 million years according to Krogh (see Davis *et al.* 1970, p.309-311), but a rubidium-strontium whole-rock analysis of material from the same dike indicates an age of 1,880 million years.

The origin of the early pegmatite remains an unresolved problem. Middle Precambrian granitic bodies are common within the zone of early pegmatite dikes, suggesting that the dikes and the granitic rocks could be genetically related. Nevertheless, no dikes

of early pegmatite were found within the granitic bodies, although the bodies do contain dikes of the Late Precambrian, zoned, massive granite pegmatite that is developed regionally throughout the Grenville Province (see the section on "Late Pegmatite"). Work by the author (Lumbers 1971b) shows that between the present map-area and Lake Timiskaming, these early pegmatite dikes are developed regionally throughout the Grenville Front Tectonic Zone south of the Boundary Fault, within the possible trough of eugeosynclinal metasediments, and that large areas containing these dikes are devoid of Middle Precambrian or younger granitic rocks. Therefore, although the early pegmatite may be similar in age to the Middle Precambrian granitic rocks, it is not necessarily genetically related to these rocks.

Regional development of the early pegmatite throughout the Grenville Front Tectonic Zone within the trough of eugeosynclinal metasediments suggests the important possibility that the trough metasediments may have undergone relatively high rank regional metamorphism prior to the Late Precambrian high rank regional metamorphism, and that the early pegmatite was generated during this earlier metamorphism (see the section on "Metamorphism of the Grenville Province"). Thus, like the granitic rocks, the early pegmatite may also reflect early tectonism within the trough of eugeosynclinal metasediments, preceding the development of the Grenville Front Tectonic Zone.

MIDDLE TO LATE PRECAMBRIAN

Early Mafic Intrusive Rocks

Intensely deformed and metamorphosed mafic intrusive rocks forming small rounded to elongate stocks, deformed tabular bodies, and dikes and sills, are relatively abundant within the Grenville Front Tectonic Zone within a few miles southeast of the Boundary Fault, but are scarce in most other parts of the area. Present data show that many of the mafic intrusive rocks are older than the Middle Precambrian granitic rocks, but some are younger than these plutonic rocks and could be Late Precambrian in age. Many of the tabular bodies and dikes and sills in the Grenville Front Tectonic Zone are intruded by the Middle Precambrian granitic rocks and are most likely high metamorphic rank equivalents of the Nipissing diabase bodies in the nearby Southern Province, but some dikes and sills elsewhere in the area are intrusive into the granitic plutonic rocks, so that multiple ages are represented. Some of the mafic stocks contain minor granitic phases and are intrusive into the granitic plutonic rocks, but many of the stocks were emplaced only within the metasedimentary gneisses so that their age relative to other intrusive rocks is unknown. Primary igneous textures are only poorly preserved locally within the larger bodies. Near the Grenville Front Boundary Fault, the metagabbro contains narrow zones of cataclasis and mylonitization, generally no more than a few feet (1 m) wide.

Most of the mafic intrusions consist of medium- to coarse-grained, dark green to black, gneissic metagabbro with alternating mafic-rich and plagioclase-rich layers. Most commonly, the metagabbro consists of about equal proportions of hornblende and plagioclase with minor garnet and biotite and accessory quartz, apatite, sphene, epidote, scapolite, carbonate, and iron-titanium oxide minerals. Near the Boundary Fault within

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the Grenville Front Tectonic Zone, the metagabbro contains minor clinopyroxene. Some stocks locally contain phases of metagabbro with as much as 65 percent plagioclase and minor phases of metadiorite and metatonalite containing higher proportions of quartz and biotite than metagabbro. Metamorphosed ultramafic rocks, consisting mainly of a medium- to coarse-grained aggregate of hornblende with accessory apatite and less than 10 percent plagioclase, are present sparingly in a few stocks. Locally in many of the larger bodies, metagabbro contains abundant, coarse-grained porphyroblasts of garnet, up to 1 inch or so (2 or 3 cm) in size. In all the mafic rocks, plagioclase ranges in composition from oligoclase to andesine, except in some metagabbro within the Grenville Front Tectonic Zone, where plagioclase as calcic as An₆₀ is common. In many of the mafic stocks containing minor granitic phases, plagioclase in the mafic rocks commonly is slightly antiperthitic, and some metatonalite contains minor, fine-grained potassic feldspar interstitial to quartz and plagioclase. Hornblende, which commonly has a sieve texture with plagioclase and minor quartz, is dark green to brown parallel to the slow vibration direction.

MAFIC BODIES POSSIBLY EQUIVALENT TO NIPISSING DIABASE

Most of the large deformed tabular bodies of metagabbro southeast of the Grenville Front Boundary Fault in Halifax, Tilton, Secord, western Burwash, Dill, western Cleland, Neelon, and Dryden Townships are probably high-rank metamorphic equivalents of the Nipissing diabase bodies in the Southern Province and are designated by a separate symbol (map unit 14b) on Map 2271 (back pocket). Moreover, dikes and sills of metagabbro, too small to be mappable, are abundant in biotite gneiss sequences near these larger mappable bodies of metagabbro and could also be equivalent in age to the Nipissing diabase bodies. The distribution of these smaller bodies is shown on Map 2271 (back pocket) by giving the biotite gneiss sequences containing them a separate symbol (map units 6c, 6d). Equivalence in age between these mafic intrusions and the Nipissing diabase is indicated mainly by three facts: 1) between Alice and Baby Lakes in southeastern Neelon Township, the Grenville Front Boundary Fault cuts through an intrusion of Nipissing diabase; on the southeastern side of the fault, the intrusion consists of metagabbro similar in mineralogy and texture to most of the metagabbro bodies southeast of the fault; 2) like the Nipissing diabase intrusions, most of the mafic bodies, including the small dikes and sills in the metasediments, are intruded by Middle Precambrian granitic rocks; and 3) the mafic bodies consist essentially of metagabbro, as do the Nipissing diabase bodies. Moreover, the mafic bodies become scarce in the metasediments of the Grenville Province at about the same latitude as Nipissing diabase intrusions become scarce in rocks of the Huronian Supergroup in the adjacent Southern Province (see Ayres *et al.* 1971b).

If the small intrusions (included in map units 6c and 6d) are taken into account, then these probable equivalents of the Nipissing diabase intrusions in the Grenville Province appear to be distinctly more abundant than are their counterparts in the

adjacent Southern Province, in the region between northern Halifax and northern Dryden Townships. This localized concentration of mafic hypabyssal intrusions, regardless of whether or not they are equivalent to the Nipissing diabase, could be a reflection of early tectonic activity near the margin of the probable trough of eugeosynclinal metasediments. The tectonic activity preceded the emplacement of the Middle Precambrian granitic rocks, the early pegmatite, and the development of the Grenville Front Tectonic Zone.

OTHER MAFIC DIKES AND SILLS

Fine- to medium-grained metamorphosed amphibolite dikes and sills of Middle to Late Precambrian age are locally present in the granitic intrusive rocks, in the anorthosite suite intrusive rocks, and in the metasediments, particularly in the eastern half of the area. The amphibolite is mainly gneissic and is similar in mineralogy to the metagabbro described above, but a few of the dikes and sills in granitic intrusive rocks locally have primary texture and relict marginal chilled zones. The metamorphosed dikes and sills probably represent hypabyssal intrusions emplaced at relatively shallow crustal levels. Although relatively few mafic dikes and sills are indicated on the map (Map 2271, back pocket), they appear to be widespread, and more detailed work would most likely reveal many others.

The presence of mafic dikes with relict chilled margins in the granitic intrusive rocks may indicate that the plutonic rocks were deformed and uplifted prior to the onset of the Late Precambrian high-rank regional metamorphism and deformation that affected most of the rocks of the Grenville Province. The relict chilled margins of some of these dikes show that the granitic intrusive rocks were relatively cool and able to fracture at the time of mafic dike emplacement, and the general features of the granitic plutons suggest that they were emplaced at lower levels than the mafic dikes.

MAFIC STOCKS

The mafic stocks consist mainly of metagabbro and minor metadiorite, but a few, such as the one at Bird Lake in western Struthers Township and the one straddling the boundary between Cleland and Dill Townships, contain dikes and irregularly shaped bodies of gneissic tonalite, trondhjemite, granodiorite, and quartz monzonite. The Cleland stock is intensely deformed and contains abundant migmatitic and gneissic quartz monzonite and granodiorite dikes, particularly near the margins of the body. Contacts of the stock are poorly exposed, but in a few places the stock appears to be intrusive into mafic dikes and sills in the surrounding metasediments. The small stock in western Springer Township north of Lake Nipissing contains minor disseminated sulphide minerals (see the section on Economic Geology), but sulphide mineralization appears to be scarce to absent in the other stocks.

LATE PRECAMBRIAN

Anorthosite Suite Intrusive Rocks

As indicated previously by the author (Lumbers 1971a; Ayres *et al.* 1971a), Late Precambrian intrusive rocks of the anorthosite suite are widespread in the northwestern part of the Grenville Province of Ontario and probably form most of the Late Precambrian plutons intrusive into Middle Precambrian metasediments underlying this region. Nevertheless, only a few intrusions of felsic members of the suite have been described (Lumbers 1971a), but several other intrusions composed of both mafic and felsic members of the suite have been mapped (Lumbers 1971c; 1971d; 1971e). In the Burwash area, almost the complete anorthosite suite is represented in several relatively small plutons widely scattered throughout the area, so that for the first time, the major features of the suite in the Ontario Grenville Province can be documented. Near the Grenville Front Boundary Fault and in the prominent synform dominating the southwestern quarter of the area, most of the anorthosite suite intrusive rocks were intensively deformed during Late Precambrian evolution of the Grenville Front Tectonic Zone. Elsewhere in the area these rocks are generally less deformed and less recrystallized than the Middle Precambrian granitic rocks they locally intrude. These relationships along with preliminary geochronologic studies (see below), suggest that the anorthosite suite rocks are Late Precambrian in age.

ROCK TERMINOLOGY AND GENERAL CHARACTER OF THE ANORTHOSITE SUITE

World-wide studies of the anorthosite suite show that nearly all members of the suite are characterized by orthopyroxene as a major mafic constituent, but as pointed out by de Waard (1968), among others, there is no general agreement concerning rock terminology of the suite, particularly of the felsic members. This rock terminology dilemma is further compounded for the known anorthosite suite rocks in the map-area and elsewhere in the Ontario Grenville Province because, even though the rocks are chemically similar to anorthosite suite rocks from other regions, amphiboles, not orthopyroxene, are the dominant mafic minerals. This scarcity of orthopyroxene could be due to recrystallization under only moderately high grade regional metamorphic conditions, or to a relatively high initial water content in the anorthosite suite magmas, or to both factors.

The anorthosite suite in the map-area consists of minor gabbro and ultramafic rocks, anorthositic gabbro, gabbroic anorthosite, anorthosite, diorite, tonalite, and a variety of more felsic rocks ranging in modal composition from syenite to quartz monzonite. All the rocks are at least partly recrystallized by regional metamorphism and most are gneissic; migmatitic varieties are rare and are developed only in some of the intensely deformed felsic rocks relatively rich in quartz. The anorthositic rocks are composed largely of andesine and sodic labradorite and are locally very coarse-grained, whereas the felsic rocks are composed mainly of sodic plagioclase, micropertthite, quartz, biotite, ferrohastingsite, garnet, magnetite and ilmenite, and are commonly porphyritic with coarse-grained feldspar phenocrysts. One variety of the felsic rocks contains clinopyroxene

and sparse orthopyroxene, and all the rocks except the gabbros and ultramafic varieties contain relatively abundant accessory zircon, a major characteristic of the suite.

The suite is subdivided into two major groups for mapping purposes: 1) anorthositic and related mafic rocks, and 2) monzonitic to granitic rocks. Both modally and normatively, all gradations exist between anorthosite and quartz monzonite (see Figures 4, 5A and 5B, and Tables 5 and 6), and abundant field and petrologic evidence shows that tonalite, diorite and the felsic rocks are genetically related to the anorthosites.

Except for the anorthositic rocks, mafic members of the suite can be classified modally according to commonly used mafic intrusive rock terminology and most of these rocks are diorite and tonalite. If amphibole is substituted for pyroxene, then the anorthositic rocks can be subdivided according to Buddington's (1939) scheme for the Adirondack anorthosite region into: 1) anorthosite which contains less than 10 percent amphibole, 2) gabbroic anorthosite which contains 10 to 22.5 percent amphibole, and 3) anorthositic gabbro which contains 22.5 to 35 percent amphibole.

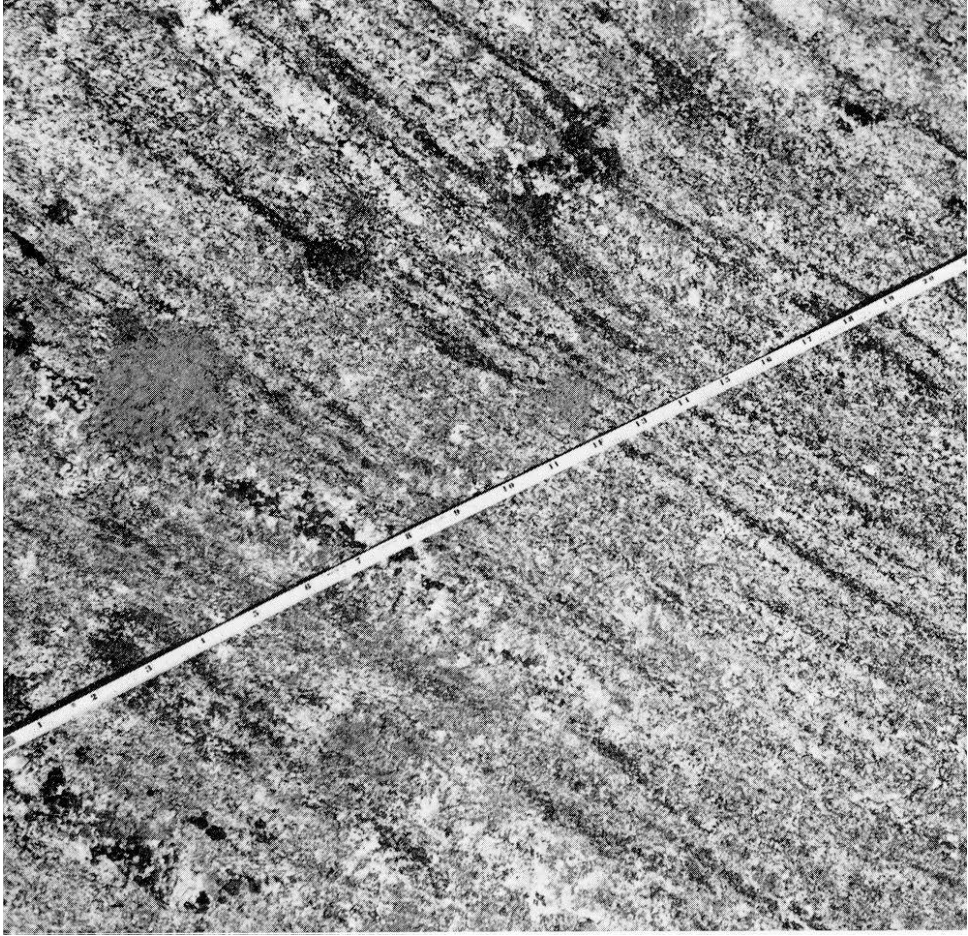
Felsic members of the suite correspond chemically to pyroxene syenite, quartz mangerite, charnockite, and quartz monzonite described by various workers as being associated with andesine-type anorthosite massifs (Isachsen 1969). Syenitic varieties contain less than 10 percent quartz and are mainly sodic, containing much more sodic plagioclase than perthitic potassic feldspar. Most of the felsic rocks contain between 10 and 20 percent quartz and are intermediate in both modal and chemical composition between potassic syenite and alkalic monzonite on the one hand, and quartz-poor potassic granite and quartz monzonite on the other. To emphasize their relatively low quartz and silica contents and to avoid introduction of new rock names, these rocks are subdivided into quartz syenite and monzonitic varieties. The monzonitic rocks are richer in perthitic potassic feldspar and are garnetiferous, in contrast to quartz syenite which rarely contains garnet; some varieties of the monzonitic rocks are green and contain clinopyroxene and rare orthopyroxene. Quartz monzonite, the most common siliceous rock type of the suite, is similar to hornblende-bearing quartz monzonite described above in connection with the granitic rocks, but is generally richer in perthitic potassic feldspar. Quartz-rich potassic granite and peculiar garnetiferous, plagioclase-quartz rocks, containing calcic oligoclase-andesine and up to 50 percent quartz, occur as minor late dike phases in some intrusions.

The general distribution of the rock types is shown on the accompanying map (Map 2271, back pocket), but because of the reconnaissance nature of the mapping, the boundaries of the various bodies shown are necessarily generalized and the detailed distribution of lithologies within a given body could not be determined. Some bodies consist mainly of anorthositic rocks, others are complex intrusions consisting mainly of either diorite and tonalite, or of the felsic members of the suite. In the map-area and elsewhere in the Grenville Province of Ontario, felsic members of the suite form the largest plutons (see Ayres *et al.* 1971a), which is in marked contrast to most other anorthosite regions where anorthositic rocks form the largest plutons (Isachsen 1969).

ANORTHOSITIC AND RELATED MAFIC ROCKS

For the most part, the anorthositic rocks are metamorphosed medium- to coarse-grained gneisses, containing abundant white to grey, granular plagioclase and streaks and discontinuous lenses of hornblende and biotite that define a prominent gneissosity (Photo

Burwash Area

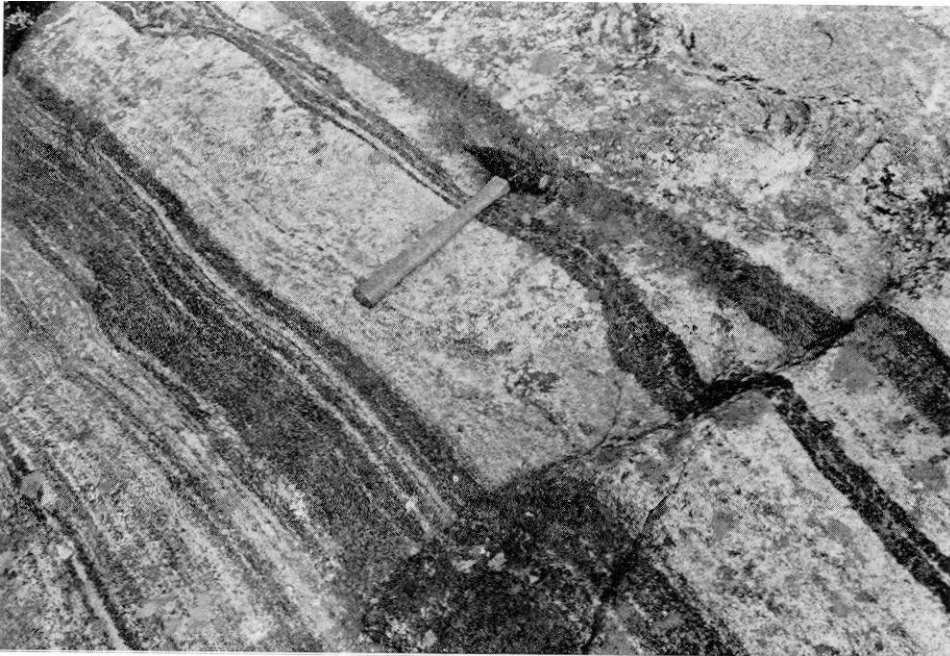


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Photo 23—Typical gneissic gabbroic anorthosite (scale is in inches); St. Charles anorthosite; lot 10, concession VI, Casimir Township.

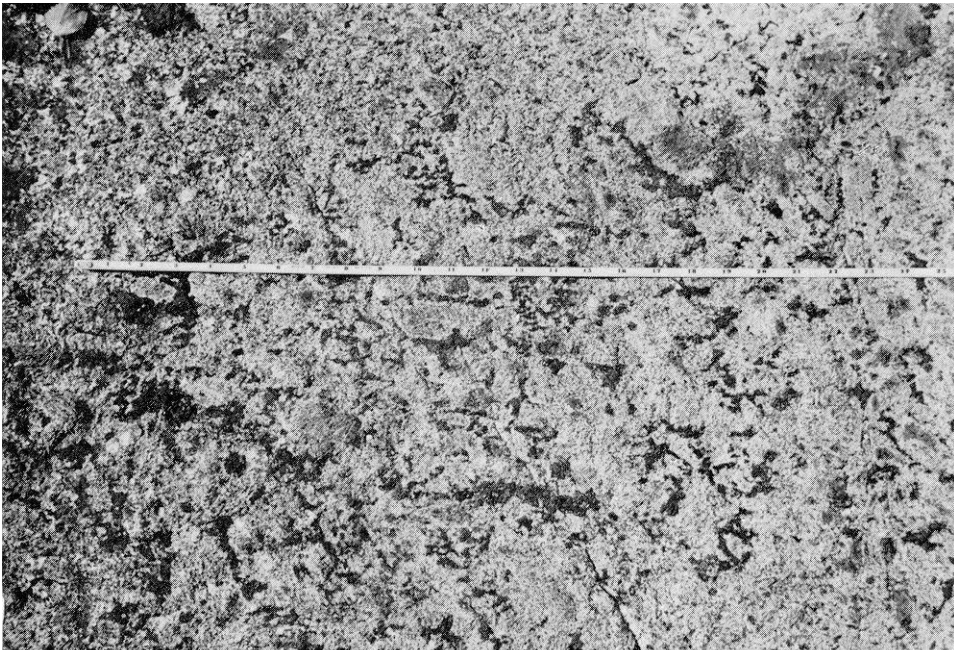
23). Fine- to medium-grained garnet is commonly disseminated throughout the rocks, discontinuous garnet-rich layers are generally present, and some hornblende grains and aggregates are surrounded by incomplete envelopes of garnet. The proportion of hornblende varies greatly within individual anorthositic units, but is most abundant near the borders of units where well defined compositional layering is common (Photo 24), and is least abundant in the central parts of the units. Gabbroic and ultramafic layers, generally no more than a few feet thick, are common in well layered portions of the units and occur sparingly elsewhere in some units. The mafic layers are contorted and stretched, but are generally continuous along strike for several hundred feet and probably reflect relict primary igneous layering.

Locally within the interior of some anorthositic plutons, the anorthositic rocks are massive with relict primary igneous textures and mineralogy (Photos 25 and 26). Hornblende in the massive phases appears to be pseudomorphous after pyroxene and



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Photo 24—Primary, igneous compositional layering in gneissic anorthositic rocks of the Mercer anorthosite; lot 9, concession VI, Falconer Township.



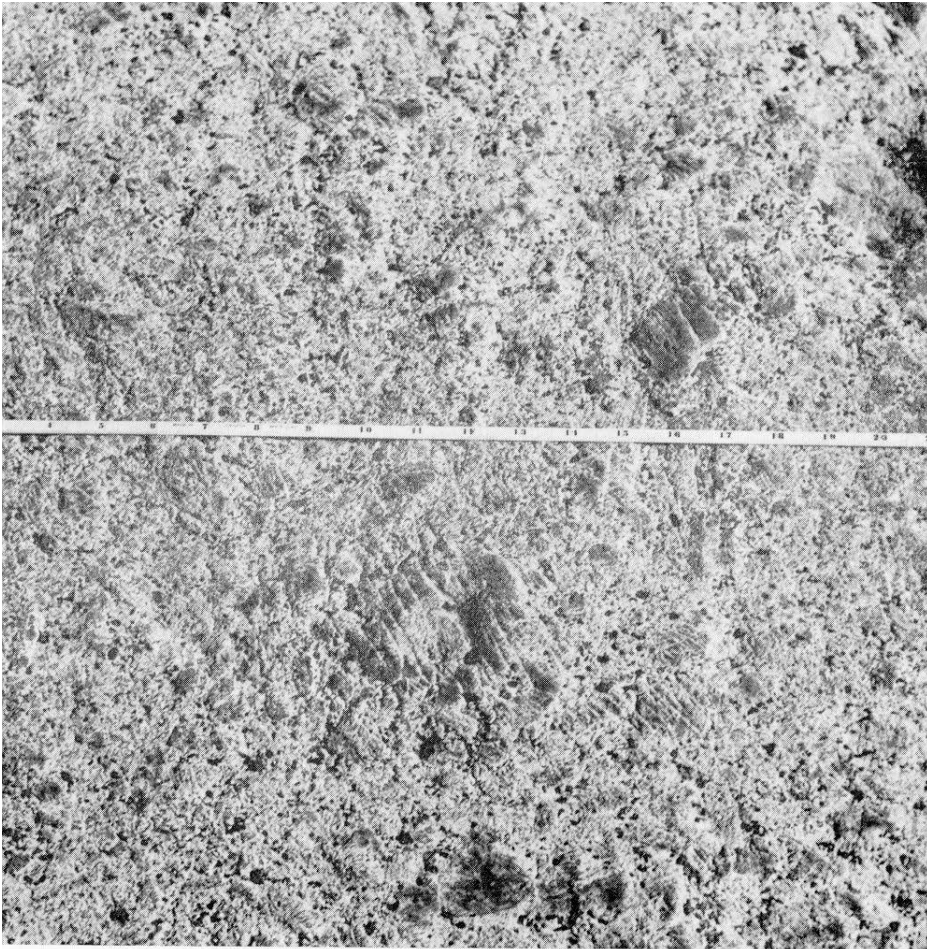
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Photo 25—Massive anorthosite from the St. Charles anorthosite containing interstitial aggregates of recrystallized pyroxene subophitically intergrown with plagioclase (scale is in inches); lot 10, concession VI, Casimir Township.

Table 5 | **AVERAGE MODES (VOLUME PERCENT) OF ANORTHOSITIC AND RELATED
MAFIC ROCKS IN THE BURWASH AREA**

ROCK TYPE	ANORTHOSITIC GABBRO		GABBROIC ANORTHOSITE		ANORTHOSITE		DIORITE		TONALITE	
	Average of 5 modes	Estimated range	Average of 4 modes	Estimated range	Average of 7 modes	Estimated range	Average of 5 modes	Estimated range	Average of 8 modes	Estimated range
Quartz	1.2	0-4	1.0	trace-3	1.8	0-5	6.9	2-9	11.7	7-16
Plagioclase	63.9	58-67	75.4	67-81	80.0	69-85	59.8	50-77	51.0	43-58
percent An	52	50-55	52	50-55	50	45-55	31	30-45	31	27-35
K-feldspar	0.4	0-1	0.3	trace-1	1.4	0.2-7	7.2	2-13	8.3	3-12
Biotite	3.6	0-6	1.5	0-4	5.1	2-11	8.5	4-13	11.2	7-16
Hornblende	25.0	22-29	13.5	10-17	7.5	4-10	12.4	5-19	14.5	4-19
Clinopyroxene	0.2	0-1	.....	.....	.....	.....	.....	.....	.....	.....
Garnet	3.2	0-12	1.9	0-6	1.4	0-5	1.4	0-6	0.8	0-3
Opaque minerals	1.1	trace-3	0.4	0-2	0.2	.....	0.7	0.1-2	0.8	0.2-2
Apatite	0.4	trace-1	0.4	0-1	0.3	.....	0.5	0.2-1	0.7	0.4-2
Zircon	trace	.....	trace	.....	0.1	.....	0.5	0-2	0.4	trace-1
Others*	1.0	.....	5.6	.....	2.2	.....	2.1	.....	0.6	.....
Totals	100.0		100.0		100.0		100.0		100.0	

*Spheue, epidote, allanite, scapolite, carbonate



ODM8917

Photo 26—Massive anorthosite from the St. Charles anorthosite containing megacrysts of plagioclase (scale is in inches); lot 10, concession VI, Casimir Township.

is partly rimmed by granular garnet containing some intergrown biotite and epidote; in a few rocks, relict clinopyroxene is preserved in the cores of hornblende grains. The original pyroxene formed interstitial aggregates subophitically intergrown with plagioclase (Photo 25), and all gradations can be found between this primary igneous texture and the metamorphic gneissic texture shown in Photo 23. Primary euhedral plagioclase phenocrysts, up to 8 inches (20 cm) in size (Photo 26), are common in massive anorthosite and gabbroic anorthosite; these grains are dark grey to purplish, due to minute inclusions of iron-titanium oxide minerals.

Gneissic diorite and tonalite, the other common mafic rock types of the suite, are dark grey to pinkish-grey medium-grained rocks relatively rich in hornblende and biotite. Some of these rocks are similar in texture and colour to Middle Precambrian, grey, gneissic granodiorite and trondhjemite, but because of lower quartz and higher mafic mineral contents in the diorite and tonalite these rocks are easily distinguished.

Burwash Area

Although tonalite contains more quartz and generally more biotite than diorite, not all of the tonalite can be distinguished from diorite macroscopically, because in some tonalites the quartz is too fine-grained to be identified in the field. Unlike the anorthositic rocks, which commonly contain coarse phenocrysts of plagioclase, diorite and tonalite are generally equigranular, with only rare relict phenocrysts of plagioclase. Where intensely deformed, plagioclase in diorite and tonalite is commonly concentrated in discontinuous, subparallel layers generally only a few millimetres wide and a few centimetres long, or in elongate augen no more than 1 cm long.

Average modes based on typical specimens of the three varieties of anorthositic rocks and of diorite and tonalite are given in Table 5, together with estimated ranges of each constituent. Quartz in anorthositic gabbro and gabbroic anorthosite is commonly intergrown with the mafic minerals and may be largely secondary in origin. Most of the quartz in anorthosite occurs either as small inclusions in plagioclase, or as fine-grained anhedral grains interstitial to plagioclase, and is probably primary. Plagioclase in all of the rocks is unzoned and slightly antiperthitic. In the anorthositic rocks, most potassic feldspar occurs as exsolution films and blebs in plagioclase, although some is interstitial to plagioclase in gabbroic anorthosite and anorthosite. In these rocks, potassic feldspar is non-perthitic and is rarely twinned. In diorite and tonalite, potassic feldspar shows grid twinning and is commonly perthitic, with coarse blebs and patches of sodic plagioclase. Although most of the rocks contain common hornblende, ferrohastingsite is rarely present in anorthosite and gabbroic anorthosite, but is relatively common in tonalite containing oligoclase.

MONZONITIC TO GRANITIC ROCKS

Most of the monzonitic to granitic rocks of the anorthosite suite are medium- to coarse-grained and gneissic, with a pronounced augen structure. They are texturally similar to the Middle Precambrian granitic rocks. In contrast to the older granitic rocks, migmatitic facies are rare; only quartz monzonite and some quartz syenite are locally migmatitic, in intensely deformed plutons in the southwestern quarter of the area. Massive phases with relict primary igneous textures are more common in felsic rocks associated with the anorthosite suite than in the older granitic rocks. The massive rocks are characterized by numerous coarse-grained, euhedral phenocrysts of partly recrystallized feldspar in a fine- to medium-grained recrystallized, granular groundmass of quartz, feldspar, and mafic minerals (Photo 27).

Some monzonitic rocks contain medium- to coarse-grained ferrohastingsite and garnet porphyroblasts and porphyroblastic aggregates in a medium-grained equigranular, feldspathic matrix. Locally, the monzonitic rocks show relict primary igneous layering due to variations in texture and mineralogy (Photo 27). Mafic layers range in composition from mafic-rich monzonitic rocks to tonalite and diorite, and alternate with felsic layers of monzonitic rocks and quartz syenite. Near the borders of some plutons of syenitic and monzonitic rocks, inclusions of surrounding metasedimentary gneisses are locally abundant and show various degrees of assimilation by the igneous rocks (Photo 28). Hornblende-bearing quartz monzonite is a minor phase in many of those plutons relatively rich in syenitic and monzonitic rocks. It is most common near contacts with metasediments, and as dikes and irregularly-shaped bodies intrusive into syenitic and monzonitic rocks.



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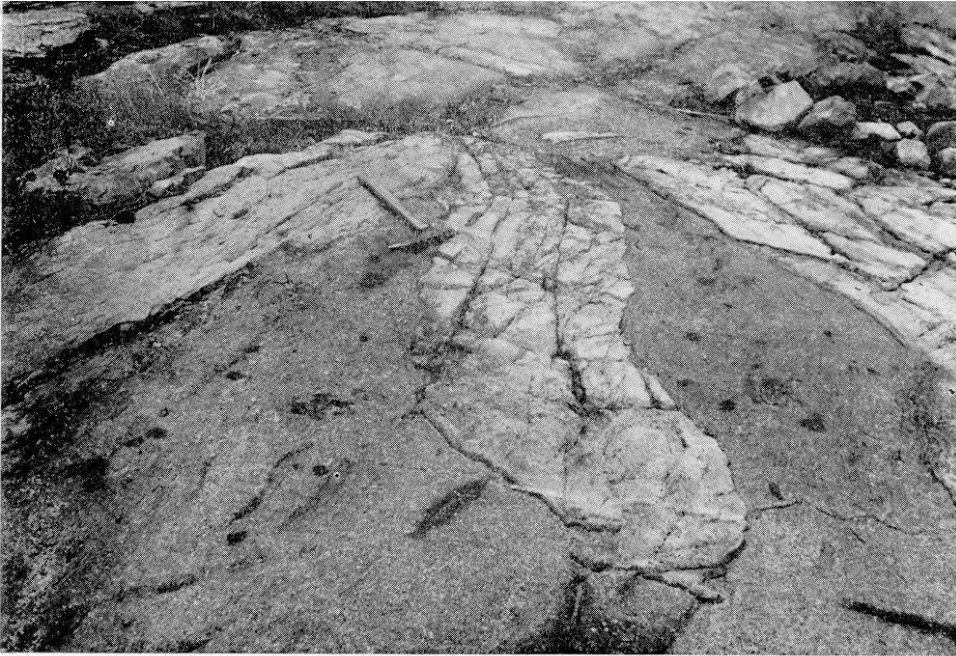
Photo 27—Massive, porphyritic monzonitic rock containing numerous coarse-grained euhedral phenocrysts of partly recrystallized perthitic potassic feldspar and showing relict, primary igneous layering; Cosby batholith, Cosby Township, north of Highway 64 at Ouellette.

Average modes based on typical specimens of the monzonitic to granitic rocks are given in Table 6, together with estimated ranges of each constituent for sodic syenite, pink to grey monzonitic rocks and quartz syenite. Sodic syenite rarely contains visible quartz and garnet and is generally pink, whereas syenite contains some visible quartz, generally no garnet, and is grey to pink. Both varieties of syenite contain more visible plagioclase than the monzonitic rocks. The monzonitic rocks, characterized macroscopically by garnet, minor quartz, and generally ferrohastingsite, show all the petrologic features described for these rocks in the North Bay area (Lumbers 1971a). Monzonitic rocks containing pyroxene are invariably light green to dark green on unweathered surfaces and grey to rusty on weathered surfaces; the green colour is due to greenish micaceous films on quartz and feldspar grains. Monzonitic rocks essentially free of pyroxene lack the greenish micaceous films and are grey to pinkish on unweathered surfaces and pink on weathered surfaces. Quartz monzonite differs from the other rocks chiefly in containing abundant visible quartz and shows about the same range in modal composition as quartz monzonites of the granitic plutons (see Figure 3), although some is richer in perthite.

Table 6 | AVERAGE MODES (VOLUME PERCENT) OF ANORTHOSSITE SUITE, MONZONITIC, SYENITIC AND GRANITIC ROCKS IN THE BURWASH AREA

ROCK TYPE	SODIC SYENITE		QUARTZ SYENITE		GREEN MONZONITIC ROCKS		PINK AND GREY MONZONITIC ROCKS		QUARTZ MONZONITE	
	Average of 6 modes	Estimated range	Average of 8 modes	Estimated range	Average of 3 modes	Estimated range	Average of 9 modes	Estimated range	Average of 3 modes	Estimated range
Quartz	4.6	0-10	14.2	11-16	9.3	3-19	13.5	3-19	27.0	
Plagioclase percent An	53.1	38-69	41.6	31-52	30.2	19-45	30.0	19-45	31.5	
Perthitic K-feldspar	10	5-28	14	8-25	15	8-20	14	8-20	10	
Biotite	28.9	13-44	23.9	16-35	45.3	24-51	37.3	24-51	34.7	
Ferrohastingsite	2.6	1-6	7.7	2-15	1.7	1-11	5.4	1-11	2.5	
Clinopyroxene	7.0	2-17	8.7	5-19	4.7	2-17	9.8	2-17	3.1	
Orthopyroxene	0.3	0-2	0-2	.....	3.4	.....	.....	.....	.....
Garnet	.....	.....	.....	.....	0.3	.....	.....	.....	.....
Opaque Minerals	0.5	0-1	trace	.....	2.1	trace-5	1.2	trace-5	.....
Apatite	1.2	trace-4	2.0	trace-5	1.9	1-2	1.4	1-2	0.5	
Zircon	0.5	trace-1	0.8	0.2-1	0.6	0.1-1	0.5	0.1-1	0.2	
Others*	0.5	0.1-2	0.4	trace-1	0.4	0.1-1	0.4	0.1-1	0.3	
	0.8	.....	0.5	.....	0.1	.....	0.5	.....	0.2	
Totals	100.0		100.0		100.0		100.0		100.0	

*Sphene, epidote, allanite, carbonate



ODM8919

Photo 28—Large blocks and slabs of quartzose metasandstone (light grey) and smaller xenoliths of other metasediments in slightly foliated quartz syenite; near the north-eastern margin of the Cosby batholith at Trout Lake, Cherriman Township.

From optical determinations, clinopyroxene in the green monzonitic rocks is a member of the diopside-hedenbergite series, and the orthopyroxene is relatively iron-rich. In a few rocks, orthopyroxene rarely partly rims clinopyroxene grains, and in one thin section of a massive green monzonitic rock, clinopyroxene shows poorly developed exsolution lamellae of orthopyroxene parallel to the (100) plane, and orthopyroxene grains rarely contain relatively coarse exsolved plates and blebs of clinopyroxene parallel to the (001) plane. This exsolution in the orthopyroxene is indicative of inverted pigeonite and of igneous temperatures, so that at least some of the pyroxene could be primary in these rocks.

Plagioclase in all the rock types is antiperthitic, and is commonly close to albite in composition in the syenitic rocks and quartz monzonite, and slightly more calcic in the monzonitic rocks. Massive phases of all the rocks commonly contain relict, euhedral, primary phenocrysts of mesoperthite with recrystallized grain boundaries; the phenocrysts contain about 50 percent exsolved sodic plagioclase as blebs and fine films. In gneissic phases, potassic feldspar is generally completely recrystallized to form anhedral grains, with coarse patches and blebs of sodic plagioclase comprising less than 50 percent of the grains. One variety of quartz syenite from the Rutter pluton in Bigwood Township is uncommonly sodic (Table 9, column 15) and is essentially a perthite-quartz-albite rock. Primary igneous zircon grains, showing simple subhedral to euhedral forms with sharp dipyramidal terminations, are relatively abundant in all the rock types, but in gneissic varieties, the zircons show corroded grain boundaries and are more discoloured near their margins than in massive varieties, probably because of superimposed metamorphism.

Burwash Area

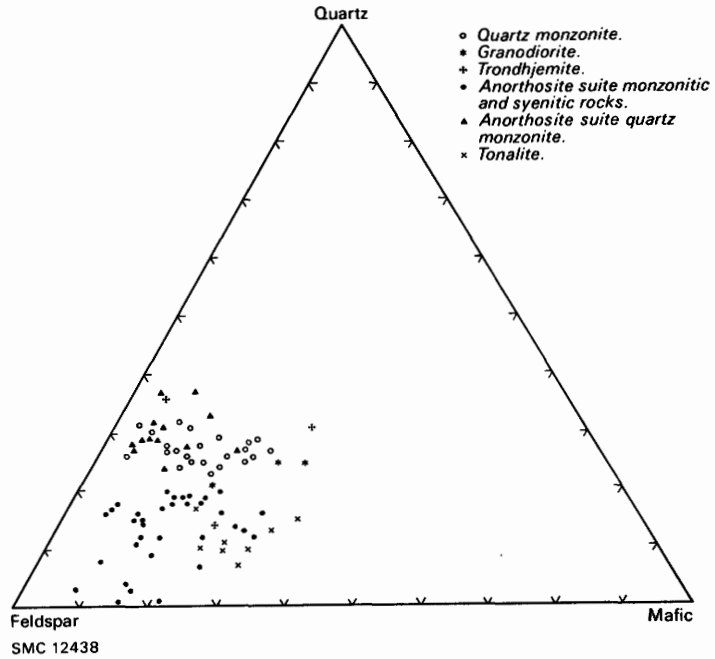


Figure 4—Modal quartz, feldspar, and mafic minerals from 52 thin sections of felsic anorthosite suite rocks and 35 thin sections of granitic rocks from the Burwash and North Bay areas.

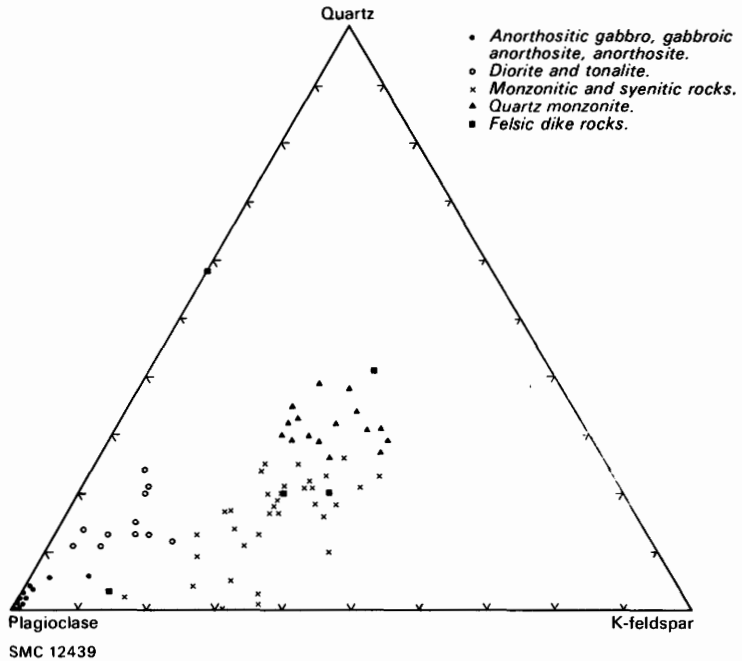


Figure 5A—Modal quartz, plagioclase, and potassic feldspar from 75 thin sections of anorthosite suite rocks from the Burwash and North Bay areas.

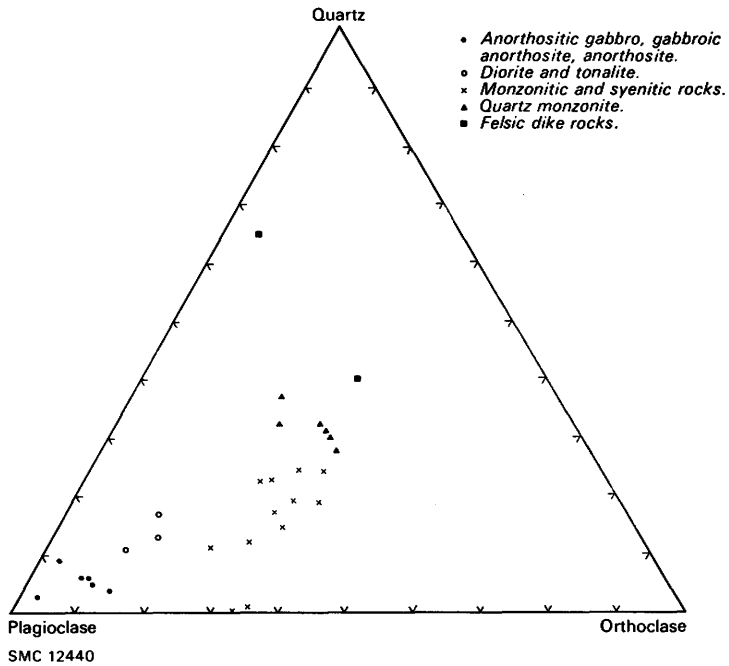


Figure 5B—Distribution of the normative quartz, plagioclase, and orthoclase of 29 analysed anorthosite suite rocks from the Burwash and North Bay areas.

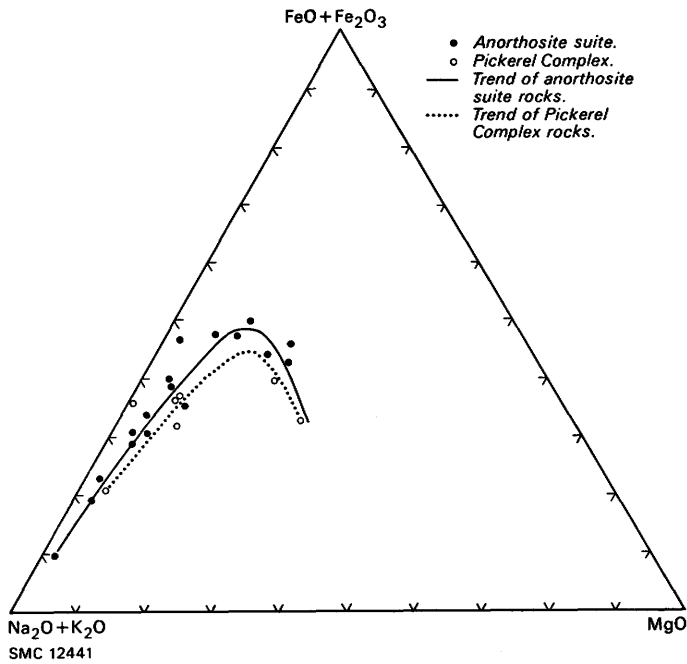


Figure 6A—MgO-FeO+Fe₂O₃-Na₂O+K₂O variation diagram for analysed rocks of the anorthosite suite from the Burwash and North Bay areas.

Burwash Area

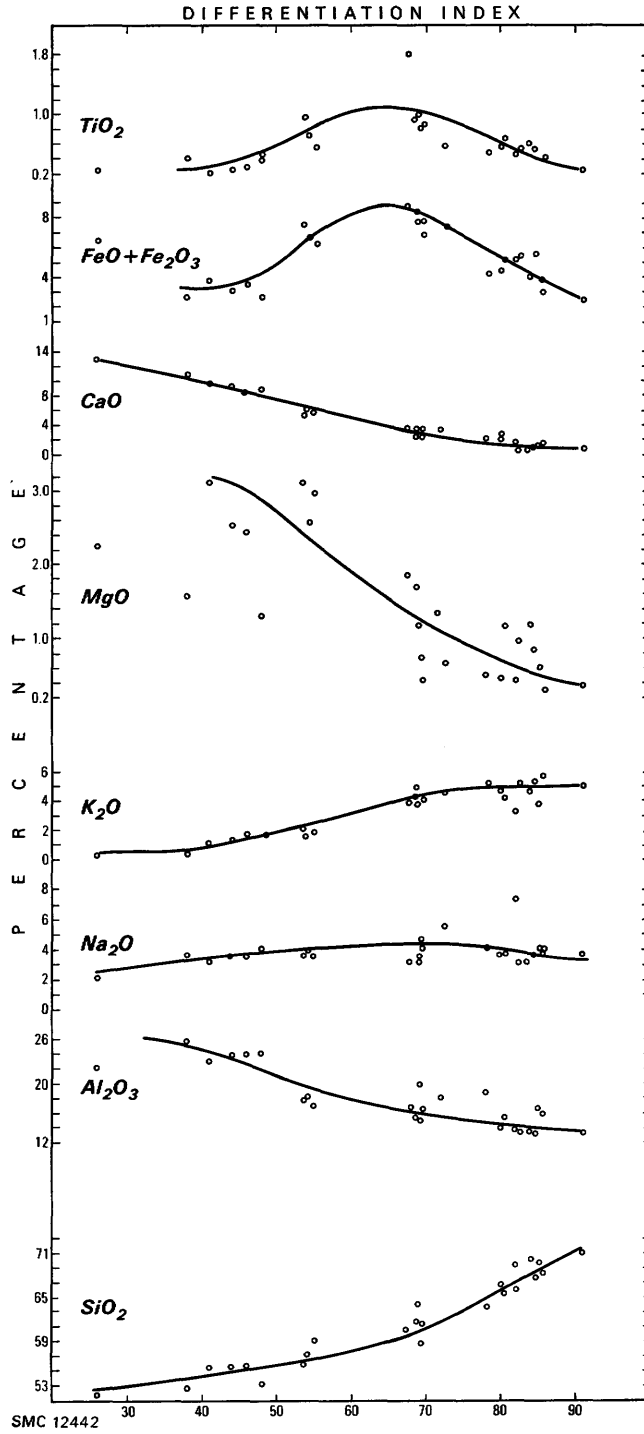


Figure 6B—Differentiation index diagram for analysed rocks of the anorthosite suite from the Burwash and North Bay areas.

Table 7

MODAL ANALYSES (VOLUME PERCENT) OF LATE DIKE ROCKS ASSOCIATED WITH THE ANORTHOSITE SUITE ROCKS IN THE BURWASH AREA IN COMPARISON TO ENDERBITE (TILLEY 1936)

SPECIMEN NO.	68-L-45	69-L-187	68-L-43	67-L-71	ENDERBITE (Tilley 1936)
Quartz	17.2	18.9	36.8	47.7	42.5
Plagioclase	15.3	32.4	15.8	34.6	48.5
percent An	16	12	20	48	36
Perthitic K-feldspar	56.8	45.2	38.1	....	4.5
Biotite	0.8	2.7	....	2.2	....
Hornblende	5.7	....	....	1.7	....
Garnet	....	0.4	5.9	9.0	....
Orthopyroxene	....	....	....	....	3.0
Opaque Minerals	2.6	0.4	1.6	1.5	1.0
Apatite	0.4	....	trace	0.3	....
Zircon	0.9	trace	1.5	0.5	present
Others*	0.3	trace	0.3	2.5	....
Totals	100.0	100.0	100.0	100.0	99.5

*Spene, allanite

Modally, the felsic members of the anorthosite suite show all gradations from tonalite and sodic syenite to quartz monzonite as shown in Figure 5A, where 75 modes of anorthosite suite rocks from the Burwash and North Bay areas are plotted in terms of volume percent quartz, plagioclase and potassic feldspar, recalculated to 100 percent. In Figure 4, 52 modes of monzonitic to granitic rocks and tonalite of the anorthosite suite in the Burwash and North Bay areas are plotted, together with 35 modes of Middle Precambrian granitic rocks from both areas in terms of volume percent quartz, feldspar, and mafic minerals, recalculated to 100 percent. Tonalite, and monzonitic to syenitic rocks of the anorthosite suite are sharply divided from the Middle Precambrian granitic rocks and anorthosite suite quartz monzonites at 20 percent quartz. Very few of the rocks of both suites contain more than 30 percent mafic minerals, and most of the anorthosite suite quartz monzonites are more leucocratic than quartz monzonites of the Middle Precambrian granitic rocks.

FELSIC DIKE ROCKS ASSOCIATED WITH THE ANORTHOSITE SUITE

Most plutons of the anorthosite suite rocks contain minor felsic dikes, generally no more than 1 foot (30 cm) in width (and thus too small to be shown on Map 2271, back pocket), which cut across the major phases of the plutons and which were presumably formed during the latter stages of emplacement of the plutons. The dike rocks are mainly fine- to medium-grained, equigranular, and pink to grey with only a slight foliation; rarely, some pinkish varieties are coarse-grained to pegmatitic. Where the dikes occur in intensely deformed host rocks, they are also deformed, but where they occur in massive host rocks, they show no evidence of deformation.

The pinkish dikes are comprised of leucocratic quartz syenite and potassic granite composed mainly of quartz, perthitic potassic feldspar, sodic plagioclase, and less than 10 percent mafic minerals. These dikes are most common in plutons containing abundant felsic anorthosite suite rocks and are relatively rare in plutons composed mainly of

Burwash Area

Table 8

**CHEMICAL ANALYSES AND NORMS OF LATE DIKE ROCKS
ASSOCIATED WITH THE ANORTHOSITE SUITE ROCKS IN THE
BURWASH AREA IN COMPARISON TO ENDERBITE (TILLEY 1936)**

SPECIMEN NO.	68-L-43	67-L-71	ENDERBITE (Tilley 1936)
Chemical Analyses (Weight Percent)			
SiO ₂	74.7	77.8	75.50
Al ₂ O ₃	12.0	9.55	13.92
Fe ₂ O ₃	0.97	1.38	0.48
FeO	2.71	3.71	1.17
MgO	0.20	1.00	0.52
CaO	0.83	2.90	3.54
Na ₂ O	2.15	1.31	3.64
K ₂ O	5.32	0.72	0.74
H ₂ O ⁺	0.10	0.54	0.15
H ₂ O ⁻	0.15	0.32	0.30
CO ₂	0.09	0.11	....
TiO ₂	0.42	0.94	0.08
P ₂ O ₅	0.01	0.01	Nil
S	0.01	0.01	....
MnO	0.07	0.13	Nil
Totals	99.7	100.4	100.04
Trace Elements (p.p.m.)*			
Ag	1	....
As	3	2	
Ba	1500	150	
Co	....	10	
Cr	10	15	
Cu	20	130	
Ga	15	5	
Ni	20	20	
Pb	20	10	
Sb	1	1	
Sc	....	20	
Sr	150	250	
V	....	20	
Y	100	150	
Zn	80	20	
Zr	600	1500	
C.I.P.W. Norms			
Quartz	37.8	58.3	42.7
Orthoclase	30.9	3.9	4.5
Albite	18.2	11.0	30.5
Anorthite	8.3	14.5	17.5
Corundum	1.2	1.3	0.7
Hypersthene	1.3	6.7	3.0
Magnetite	1.4	2.1	0.7
Ilmenite	0.8	1.7	0.2
H ₂ O	0.1	0.5	0.2
Totals	100.0	100.0	100.0

*Be, Li, Mo, Sn not detected

anorthositic rocks. The grey dikes were found only in anorthositic plutons and range in modal composition from tonalite to a peculiar garnetiferous andesine-quartz rock extremely rich in quartz. Modal analyses of the common types of pink dikes and of a typical specimen (67-L-11) of the garnetiferous grey dikes are given in Table 7. Chemical analyses and norms of a typical potassic granite dike and the garnetiferous grey rock are given in Table 8.

The garnetiferous grey rock is similar to enderbite found in several anorthosite regions associated with charnockites (Tilley 1936). Modal, chemical, and normative compositions of Tilley's (1936) type enderbite are given in Tables 7 and 8. The garnetiferous grey rock differs from Tilley's type enderbite mainly in lacking hypersthene and in containing a more calcic plagioclase, but both rocks are characterized by relatively abundant zircon. (Tilley's mode of the type enderbite does not include zircon, but this mineral is mentioned as a prominent accessory constituent in his rock description). Several anorthositic plutons mapped by the author elsewhere in the Grenville Province of Ontario also contain dikes of this enderbitic rock which appears to be peculiar to the anorthosite suite. Nevertheless, except for a relatively high zirconium content, the rock differs markedly from other rocks of the anorthosite suite in the map-area (see Figures 5A and 5B), and its petrogenesis relative to the suite remains an unresolved problem.

CHEMISTRY OF THE ANORTHOSITE SUITE ROCKS

Twelve rocks representing the main rock types of the anorthosite suite found in the map-area were analysed for their major and trace elements by the Mineral Research Branch, Ontario Division of Mines. In addition, seven other analyses of rocks of the suite from the area were obtained from the literature. Additional analyses are reported in the literature, but were not located and described adequately enough to be of use in the present study. Chemical, normative, and modal analyses of the 19 rocks are given in Table 9, along with an average of 6 chemical analyses of monzonitic rocks from the North Bay area (Table 9, column 16; and Lumbers 1971a) for comparison. Five of the analyses taken from the literature either were not accompanied by modal analyses, or modes given did not total 100 percent.

In Figure 5B, the 19 analyses from Table 9, together with two dike analyses (Table 8) and eight analyses of anorthosite suite rocks from the North Bay area (Lumbers 1971a, Tables 6 and 8), are plotted in terms of normative quartz, plagioclase and orthoclase, recalculated to 100 percent. Like the modal data in Figure 5A, the normative data in Figure 5B show the gradational nature of the suite with a continuous decrease in plagioclase content and increase in orthoclase and quartz along a band from the plagioclase corner into the centre of the diagram. Because the normative data take into account the amount of solid solution in the feldspars, there is less scatter in the array of points in Figure 5B than in Figure 5A.

When the anorthosite suite rocks from both the Burwash and North Bay areas are considered as a series, a steady variation in oxides is present from anorthosite, through diorite and tonalite, to quartz monzonite. The variation in $\text{FeO} + \text{Fe}_2\text{O}_3$, $\text{Na}_2\text{O} + \text{K}_2\text{O}$, and MgO is shown in Figure 6A. The solid line represents the general trend for all the rocks of the anorthosite suite, whereas the dotted line represents the general trend for rocks from a single pluton, the Pickerel complex. Some anorthosites plot near the alkalic apex of the figure because they contain only minor amounts of magnesia and iron; these were omitted in order to simplify the plot. Both trends show only moderate

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Table 9

CHEMICAL ANALYSES, NORMS AND MODES OF THE ANORTHIC

	Chemical Analyses (Weight Percent)							
	1	2	3	4	5	6	7	
SiO ₂	51.4	53.1	52.6	55.20	55.13	55.2	56.1	
Al ₂ O ₃	22.2	24.2	25.8	23.13	23.76	23.9	17.9	
Fe ₂ O ₃	1.34	0.86	0.44	1.09	0.57	1.28	3.07	
FeO	5.16	1.93	2.13	2.69	2.46	2.25	4.53	
MgO	2.25	1.30	1.58	3.13	2.54	2.44	3.12	
CaO	13.1	9.00	10.8	9.47	9.00	8.35	5.57	
Na ₂ O	2.02	4.00	3.75	3.42	3.59	3.66	3.61	
K ₂ O	0.44	1.56	0.45	1.18	1.37	1.77	2.15	
H ₂ O ⁺	0.64	1.15	0.34	0.36	0.69	0.49	0.99	
H ₂ O ⁻	0.24	0.17	0.08	0.04	0.06	0.31	0.20	
CO ₂	0.18	0.13	0.12	0.09	0.13	0.12	0.11	
TiO ₂	0.26	0.46	0.43	0.21	0.27	0.29	0.97	
P ₂ O ₅	0.01	0.12	0.08	0.18	0.32	0.04	0.52	
S	0.01	0.08	0.02	0.15	....	0.01	0.09	
MnO	0.13	0.06	0.04	trace	....	0.05	0.17	
Totals	99.4	98.1	98.7	100.34	99.89	100.2	99.1	9
				Trace Elements (p.p.m.)*				
Ag	2	...	...			1	...	
As	2	5	<5			1	<5	
Ba	....	800	300			600	1200	
Be	....	...	...			...	...
Co	40	6	14			20	16	
Cr	150	40	10			40	10	
Cu	140	4	9			20	10	
Ga	15	20	20			20	20	
Ni	110	30	30			70	20	
Pb	10	30	<10			10	20	
Sb	1	4	<4			1	8	
Sc	30	<20	<20			...	40	
Sr	300	600	700			600	600	
V	150	50	50			20	200	
Y	...	...	...			20	30	
Zn	50	40	30			60	110	
Zr	...	...	...			100	150	
				C.I.P.W. Norms				
Quartz	6.8	4.8	2.9	4.8	5.3	4.4	10.5	
Orthoclase	2.2	9.4	2.8	7.2	8.3	10.7	12.4	1
Albite	17.0	33.8	32.4	29.0	30.4	31.0	30.8	3
Anorthite	51.1	43.0	52.8	43.8	42.4	41.6	24.2	2
Corundum	....	....	....	....	0.8	0.7	0.9	
Olivine	....	....	....	....	....	....	....
Hypersthene	8.3	5.1	6.8	10.2	9.7	8.6	12.5	1
Diopside	11.0	....	....	2.5	....	....	....
Acmite	....	....	....	....	....	....	....
Magnetite	1.9	1.4	0.7	1.6	0.9	1.9	4.5	
Hematite	....	....	....	....	....	....	....
Ilmenite	0.6	0.9	0.8	0.5	0.6	0.6	1.8	
Apatite	....	0.3	0.3	....	0.7	....	1.4	
Calcite	0.5	0.2	0.2	....	0.2	....	....
H ₂ O	0.6	1.1	0.3	0.4	0.7	0.5	1.0	
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	10

THE INTRUSIVE ROCKS IN THE BURWASH AREA

	10	11	12	13	14	15	16	17	18	19	20
	58.2	58.8	60.6	67.9	65.91	66.03	64.4	69.75	69.70	70.09	71.0
	17.8	19.6	14.6	13.4	15.45	13.88	16.0	13.57	16.85	13.58	13.4
1	1.85	Nil	4.70	2.12	2.89	2.86	1.16	0.61	2.73	1.17	0.74
)	5.35	6.93	4.24	3.44	2.19	2.34	4.77	4.88	1.10	3.02	1.80
3	0.68	0.75	1.87	0.86	1.19	0.45	0.76	0.98	0.62	1.20	0.37
5	3.26	2.84	3.40	1.18	2.08	1.96	2.63	1.13	1.20	1.08	0.83
5	5.60	4.68	3.28	3.68	3.86	7.49	3.79	3.12	4.12	3.18	3.78
4	4.60	5.00	3.98	5.25	4.19	3.29	4.60	5.09	3.66	4.52	5.12
5	0.40	0.34	0.64	0.61	0.61	}0.35	0.40	}0.58	0.20	0.89	0.37
4	0.14	0.08	0.31	0.24	0.04		0.26		0.10	0.11	0.08
)	0.11	0.10	0.10	0.12	0.24	0.28	0.32	0.04	0.15	0.15	0.14
5	0.58	0.82	1.82	0.54	0.69	0.45	0.73	0.54	Nil	0.60	0.29
1	0.05	0.23	0.20	0.02	0.34	0.38	0.22	0.18	Nil	0.26	0.04
3	0.03	0.03	0.06	0.02	0.20	....	....	0.13	....	....	0.01
3	0.20	0.23	0.20	0.12	0.04	....	0.12	0.02	trace	....	0.05
	98.8	98.8	100.0	99.5	99.92	99.76	100.0	100.62	100.43	99.85	98.0
...	...	...	1	....							....
1	5	1	2								<5
3000	4000	2000	700								1200
5	...	3	3								....
6	6	10	....								<3
10	...	10	10								....
10	<3	10	30								<3
20	20	20	20								30
20	20	20	40								10
10	20	20	10								40
1	4	1	1								4
20	50	30	20								....
300	200	300	50								100
...	...	80	....								....
100	30	150	200								100
150	130	200	160								85
800	200	1500	1500								300
....	0.6	14.5	21.4	20.3	9.4		23.8	28.9	27.7	27.3	
26.5	29.5	24.6	31.4	25.1	19.5		30.6	21.7	27.2	30.8	
46.0	39.3	28.6	31.7	35.1	53.1		28.1	34.5	29.0	32.8	
9.8	13.1	13.5	4.2	9.3	....		4.8	5.0	3.8	3.1	
....	1.7	....	....	1.3	....		1.3	4.3	2.4	0.5	
6.6	....	....	....	....	....		....	....	....	....
3.9	13.7	4.7	5.6	3.5	2.5		9.0	1.3	6.4	3.2	
1.7	....	3.1	0.7	....	4.3		....	....	....	....
....	....	....	....	....	8.3		....	....	....	....
2.4	....	6.9	3.0	3.1	....		0.6	3.5	1.2	1.0	
....	....	....	....	....	....		....	0.3	....	....
1.2	1.5	3.5	1.1	1.0	0.8		0.8	....	0.8	0.6	
1.3	0.3	....	....	0.7	1.0		0.4	....	0.6	0.3	
0.2	....	....	0.3	....	0.7		....	0.3	....	....
0.4	0.3	0.6	0.6	0.6	0.4		0.6	0.2	0.9	0.4	
	100.0	100.0	100.0	100.0	100.0	100.0		100.0	100.0	100.0	100.0

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TABLE 9 (Continued)

	Modes (Volume Percent)					
	1	2	3	6	7	
Quartz	4.3	0.3	0.4	4.9	9.2	
Plagioclase	63.4	81.8	85.1	69.3	50.0	5
percent An	50	52	54	46	30	
K-feldspar	1.5	0.6	0.6	7.0	9.8	
Perthitic K-feldspar	....	....	....	....	....
Biotite	....	9.4	1.9	11.1	9.8	1
Hornblende(Ferrohastingsite)	27.8	....	10.9	6.7	17.4	1
Garnet	....	....	trace	....	0.9	
Clinopyroxene	1.1	....	....	....	....
Orthopyroxene	....	....	....	....	....
Opaque Minerals	0.1	....	0.2	0.1	1.9	
Apatite	0.1	0.2	0.2	0.2	0.7	
Zircon	....	....	....	0.1	trace	tr
Others**	1.7	7.7	0.7	0.6	0.3	
Totals	100.0	100.0	100.0	100.0	100.0	10

**Spheue, epidote, allanite, carbonate, scapolite

TABLE 9 Footnotes

Samples

1. Gneissic anorthositic gabbro, Red Deer Anorthosite, Awrey Township
2. Gneissic anorthosite, Mercer Anorthosite, Falconer Township
3. Massive anorthosite, St. Charles Anorthosite, Casimir Township
4. Gneissic gabbroic anorthosite, Pickerel Complex, Allen Township; chemical anal from Maxwell et al (1965, p.60).
5. Gneissic anorthosite, Pickerel Complex, Allen Township; chemical analysis from Maxwell et al (1965, p.62).
6. Gneissic anorthosite transitional into diorite, Pickerel Complex, Allen Township
7. Gneissic diorite, small sheet south of Thompson Bay, French River, Struthers Township.
8. Gneissic tonalite close to diorite in composition, Servos pluton, Servos Township
9. Gneissic tonalite, Pickerel Complex, Allen Township
10. Slightly gneissic sodic syenite, Highway 69 at Southern boundary of area.
11. Massive, green monzonitic rock, Cosby batholith, Cosby Township.

E 9 (Continued)

10	11	12	13	14	15	20
....	1.0	11.6	20.5	19.9	21.2	24.0
38.4	23.0	35.9	10.8	6.9	47.3	28.2
8	12	22	8	....	8	7
....
40.1	58.7	22.3	46.6	58.2	14.2	36.6
1.4	1.1	5.9	2.6	1.3	3.5	3.0
(17.2)	(6.4)	(18.6)	(17.2)	(7.4)	(11.2)	(6.9)
....	3.1	....	....	....	....	....
....	3.7	....	....	....	....	....
....	0.7	....	....	....	....	....
0.1	1.4	5.1	1.2	5.8	1.0	0.7
0.6	0.5	0.2	0.1	....	0.6	0.2
1.7	trace	0.3	1.0	....	0.2	0.3
0.5	0.4	0.1	....	0.5	0.8	0.1
100.0	100.0	100.0	100.0	100.0	100.0	100.0

E 9 Footnotes (Continued)

2. Gneissic quartz syenite, Western Channel pluton, Struthers Township.
3. Gneissic, pink monzonitic rock, Pickerel Complex, Allen Township.
4. Gneissic quartz syenite, Western Channel pluton, Struthers Township; chemical and modal analysis from Quirke (1929).
5. Gneissic, sodic quartz syenite, Rutter pluton, Bigwood Township; chemical and modal analysis from Hewitt (1960, p.179).
5. Average of 6 chemical analyses of monzonitic rocks of the North Bay area (Lumbers, 1971a, p.38).
7. Gneissic quartz syenite, Pickerel Complex, Allen Township; chemical analysis from Maxwell (1965, p.28).
3. Gneissic quartz monzonite, Cosby batholith, Cosby Township; chemical analysis from Quirke (1929).
3. Gneissic quartz monzonite, Pickerel Complex, Allen Township; chemical analysis from Maxwell (1965, p.28).
3. Gneissic quartz monzonite, Pickerel Complex, Allen Township.

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enrichment in iron from anorthosite to quartz monzonite, and thus are intermediate trends characteristic of calc-alkalic and alkalic rock series.

Complete chemical gradation between all rock types of the anorthosite suite is illustrated by the variation diagrams in Figure 6B, which represents all the major oxides in the analysed rocks from the Burwash and North Bay areas, plotted against the differentiation index of the rocks (weight percentages of normative quartz + orthoclase + albite), in accordance with the proposal of Thornton and Tuttle (1960). Most of the plots in Figure 6B show a moderate degree of alignment, presumably reflecting a close genetic relationship between members of the suite. Chemically, the anorthosite suite in the Burwash and North Bay areas has two major trends that are characteristic of both the anorthosite-charnockite series and the tholeiitic rock series: 1) iron and titania are moderately enriched in the intermediate rocks, and 2) silica is relatively constant in the anorthositic and intermediate rocks, and enriched only in the felsic part of the suite. Rocks of the anorthosite suite in the map-area have much lower total iron contents in the mafic members of the suite than rocks of the tholeiitic series. In the magnesia plot (Figure 6B), the anorthositic rocks, which are probably cumulates (see Emslie 1973), lie well away from the average curve. The oxides of calcium, aluminum and magnesium decrease in amount in the felsic members of the suite, whereas potassia and silica increase in these rocks. Soda is nearly constant throughout the suite, with slight enrichment in the intermediate members, as would be expected of a calc-alkalic trend (Bowen 1928, p. 100).

Although the data are scanty, some trace elements, like the major elements, vary relatively smoothly in amount with composition changes from anorthositic rocks to quartz monzonite (Table 9), providing further support for a genetic relationship between the members of the suite. Cobalt, chromium, nickel and strontium generally decrease in abundance from the mafic to the felsic end of the suite. Rocks rich in amphiboles generally contain more cobalt, chromium, copper and nickel, suggesting that these elements are concentrated in the amphiboles; rocks with a high plagioclase to potassic feldspar ratio contain the most strontium, suggesting that strontium may be preferentially concentrated in plagioclase. No systematic trends are apparent in the amounts of silver, arsenic, beryllium, antimony, scandium and vanadium in the anorthosite suite rocks, although scandium is relatively abundant in pyroxene-bearing monzonitic rocks. Gallium and lead are relatively constant throughout the suite, but yttrium and zinc contents may increase slightly in the intermediate and siliceous rocks.

Barium content increases in the intermediate rocks, and barium is most abundant in those rocks that contain the most potassic feldspar. Both barium and strontium are relatively abundant in the intermediate rocks, another characteristic of the anorthosite-charnockite series (Philpotts 1966). Zirconium generally increases in amount from the mafic to the felsic end of the suite and is highest in rocks containing abundant zircon, suggesting that most zirconium is present in this mineral. Intermediate and siliceous members of the suite are particularly rich in zirconium, which may indicate enrichment of the original magma in this element. High zirconium content is also common to other anorthosite regions (Philpotts 1966) and in this respect, the anorthosite suite resembles alkalic rocks. The relatively high strontium and barium contents on the other hand, are more typical of calc-alkalic rocks, but values of 2,000 to 4,000 ppm barium, which are present in some of the syenitic and monzonitic rocks in the map-area, are rare even in the calc-alkalic rocks, although they are not uncommon in micropertthite-rich charnockitic rocks (von Engelhardt 1936).

To summarize, the anorthosite suite in the map-area has most of the major chemical characteristics of the anorthosite-charnockite series, but the suite is largely lacking in orthopyroxene and is only moderately enriched in iron in the intermediate rocks. Chemical trends in the anorthosite suite have some features in common with trends characteristic of calc-alkalic, alkalic, and tholeiitic rock series. Moderate enrichment in iron and titanium and the relatively low amounts of silica in the intermediate rocks suggest that the suite underwent differentiation similar to tholeiitic rock suites. Nevertheless, in comparison to calc-alkalic and tholeiitic rock series, mafic members of the suite are relatively low in iron, and intermediate and siliceous members appear to be richer in barium and zirconium.

DISTRIBUTION

Several plutons of the anorthosite suite rocks are present in the western half of the area, and a large batholith of felsic members of the suite underlies the south-central part. In the eastern half of the area, in Falconer, Casimir and northern MacPherson Townships, predominantly anorthositic rocks intruded metasediments and granitic rocks of the West Bay batholith, and at the northern border of the area in Badgerow and eastern Hugel Townships, a circular stock of dioritic, syenitic, and granitic rocks intruded metasediments. All the plutons have intensely deformed gneissic borders, but within the interior portions of plutons lying outside of the Grenville Front Tectonic Zone, massive phases, showing relict primary igneous textures, and mineralogy are common. Plutons within the Grenville Front Tectonic Zone, on the other hand, are more intensely deformed than those outside of the Tectonic Zone and rarely contain massive phases in their interiors. Crosscutting relationships were noted among members of the suite in most of the plutons and indicate that the more calcic rocks are intruded by the more potassic and siliceous rocks. In general, the various members of the suite were emplaced in the following order from oldest to youngest: 1) anorthositic, gabbroic, and ultramafic rocks, 2) dioritic and tonalitic rocks, 3) sodic syenite, 4) monzonitic rocks, and 5) quartz syenite and quartz monzonite. A few exceptions to this general sequence of emplacement were found. In the Pickerel complex in southern Allen Township, a small mass of anorthosite intruded monzonitic rocks; diorite and tonalite, which are common near the borders of some anorthositic plutons, locally contain numerous narrow, contorted layers of anorthosite relatively rich in quartz. Locally, in complex intrusions containing syenitic and more siliceous phases, narrow zones of diorite and tonalite grade into anorthosite and separate the anorthosite from the more felsic rocks.

Anorthositic rocks form an elongate body in southwestern Dryden Township; these are intensely deformed with well developed mafic layering locally stretched to form tectonic breccia. Locally they contain a few small pods rich in magnetite. These rocks were mapped by Grant *et al.* (1962, p. 13) as basic injection gneiss. Similar anorthositic rocks at the northern boundary of the area, in eastern Dryden and adjacent Awrey Townships, are the southernmost part of an extensive anorthositic pluton that dominates the River Valley area to the north of the Burwash area (Lumbers 1971e). This pluton is the largest anorthositic mass mapped to date in the Grenville Province of Ontario. Major features of some of the larger anorthosite suite plutons in the area are briefly described below.

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Red Deer Anorthosite

The Red Deer anorthosite is an elongate body extending northeastward from the northern part of Red Deer Lake in eastern Cleland Township into southwestern Awrey Township. The pluton consists mainly of gneissic anorthositic gabbro and gabbroic anorthosite, with some metagabbro and metadiorite units near the eastern margin and in the southern tail of the body. Relict igneous layering is common near the borders of the pluton, but is poorly developed in the interior where locally, the anorthositic rocks are massive with relict igneous textures.

Markstay Pluton

A small body of gneissic tonalite, minor gneissic diorite, and pink to grey, gneissic quartz syenite and monzonitic rocks intrudes metasediments near the town of Markstay in Hagar Township, at the northern boundary of the area. Most of the tonalite is concentrated in the southern part of the body and is locally brecciated and injected by the monzonitic rocks and quartz syenite. Monzonitic rocks in the northern part of the pluton locally grade into gneissic quartz syenite and quartz monzonite, and narrow dikes and sills of these siliceous rocks are present locally in metasediments bordering the pluton.

Servos Pluton

The Servos pluton, a small elliptical-shaped stock at the north end of Kakakiwaganda Lake in southwestern Servos Township, consists mainly of gneissic tonalite and minor gneissic diorite, with a small irregularly shaped mass of relatively leucocratic gneissic quartz syenite and minor quartz monzonite in the eastern part of the body. The felsic rocks intrude the tonalite and diorite, and several dikes of felsic rocks are present throughout the mafic portion of the pluton; these appear to increase in abundance near the small felsic mass. A few narrow sill-like bodies of gneissic tonalite, intrusive into metasediments about $\frac{1}{4}$ mile (0.4 km) west and south of the pluton, are probably related to the main body. Although most of the rocks are deformed and gneissic, massive tonalite and diorite are present locally near the centre of the pluton.

Cox Pluton

The Cox pluton, straddles the boundary between Cox and Servos Townships and is an irregularly shaped, intensely gneissic body that consists mainly of gneissic quartz syenite and sodic syenite, locally with minor gneissic pink monzonitic rocks and quartz monzonite. A border phase of gneissic tonalite along the western and southern parts of the pluton is intruded and injected by the felsic rocks and locally contains abundant inclusions of the surrounding metasediments. At the southeastern border of the pluton, the early gneissic tonalite phase is separated from the main body by a narrow screen of metasediments. A smaller, lithologically similar, elongate intrusion lies southeast of the pluton in eastern Cox Township.

Rutter Pluton

The Rutter pluton is an intensely deformed elongate body extending southeastward from southwestern Delamere Township, through Bigwood Township parallel to Highway 69, and crosses the southern boundary of the area just north of the Pickerel River. The southern extension of the pluton beyond the map-area has not been delineated in detail, but work by Quirke (1929) and the author suggests that the body extends southeast for about another 8 miles (12.8 km) (see Ayres *et al.* 1971c). In northern Bigwood Township, the western boundary of the pluton is mainly in fault contact with the alkalic complex near the French River and a prominent easterly trending fault through Rae Lake in central Bigwood Township displaces both the alkalic complex and the pluton. Where exposed, contacts of the pluton with the surrounding metasediments are sharp, and locally, inclusions of the metasediments are present in the margins of the pluton.

North of the easterly trending fault through Rae Lake, the pluton consists mainly of pink to grey and minor green, gneissic monzonitic rocks with local sodic syenite and quartz syenite phases. Metasedimentary inclusions are abundant in places within this part of the pluton and local discordant contacts with the metasediments are common. South of the fault, the pluton consists mainly of gneissic sodic syenite, quartz syenite and only minor pink to grey gneissic monzonitic rocks. Quartz monzonite appears to be rare throughout the pluton, but minor amounts are present in a few places, particularly near the large metasedimentary inclusions in the northern part of the body. Locally, about 1 mile (1.6 km) south of the town of Rutter, in the central part of the pluton, the monzonitic rocks are only slightly foliated and rarely massive.

Pickerel Complex

The Pickerel complex is exposed mainly south of the map-area with only the northern third of the body present in southeastern Allen and adjacent southwestern Bigwood Townships (see Ayres *et al.* 1971c). Quirke (1929) briefly described some of the rocks of the complex and mapped the general outline of the body south of the map-area. In the map-area, most of the complex is intensely deformed and gneissic, but massive to slightly foliated phases are locally present in the northern end of the complex, near the road to Hartley Bay. Well exposed sections across the complex occur along the Canadian National railway line, and along the French and Pickerel Rivers. Contacts between the complex and the surrounding metasediments are generally sharp and discordant in detail, with a few sills and dikes of the intrusive rocks common in the metasediments up to a few hundred feet (100 m) from the complex.

The northern third of the complex in the map-area consists of early anorthositic and minor gabbroic phases concentrated mainly in the west-central portion and intruded by felsic anorthosite suite rocks ranging in composition from sodic syenite and monzonitic rocks to quartz monzonite. Much of the early mafic material is leucocratic anorthosite, commonly containing up to 4 percent quartz, but gabbroic anorthosite and anorthositic gabbro are associated locally with the anorthosite, and just south of Ox Island in the French River, a small mass composed mainly of metagabbro is present in the anorthositic rocks.

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Gneissic, pink to grey and minor green monzonitic rocks dominate the northern end of the complex, and commonly grade into quartz syenite and quartz monzonite near the margins of the complex by a gradual increase in quartz. Elsewhere, the felsic rocks are mainly quartz syenite and minor sodic syenite with only minor associated pink to grey monzonitic rocks; quartz monzonite is common near the borders of the complex and forms most of a relatively large mass of felsic rocks intrusive into anorthositic rocks north and south of the French River, west of Ox Island. Minor diorite and tonalite are locally common at contacts between the anorthositic and syenitic and monzonitic rocks, and in a few places, anorthosite appears to grade through diorite and tonalite into the felsic rocks. Metasedimentary inclusions are locally abundant throughout the complex, and are particularly common in the eastern part. North of the road to Hartley Bay, a small body of andesine anorthosite is intrusive into the monzonitic rocks, and north and south of the French River, dikes of sodic syenite, quartz syenite, and potassic granite, generally only a few inches wide, are present locally in the anorthositic rocks.

Cosby Batholith

The Cosby batholith, dominating the south-central part of the area, is an elongate, northwesterly trending intrusion of felsic anorthosite suite rocks, up to 21 miles (34 km) long and as much as 10 miles (16 km) across. Although for the most part, margins of the batholith are intensely deformed and gneissic, particularly near the northwestern and southeastern ends of the body, much of the interior is massive to only slightly foliated, with common relict igneous textures and structures. The batholith intruded predominantly quartzose and feldspathic metasedimentary gneisses, except in the southeastern part where it intruded biotite gneisses. Along the northeastern and southwestern flanks of the batholith, contacts with the enclosing metasediments are locally well exposed and are invariably sharp and discordant in detail, commonly with numerous dikes and sills of the intrusive rocks extending up to a few hundred feet into the adjacent metasediments. Large blocks and slabs of quartzose metasediments (Photo 28) and smaller xenoliths of other types of metasediments, showing various degrees of assimilation, are common at the margins of the batholith and are particularly abundant in Mason Township, south of the North Channel of French River. The northwestern and southeastern contacts of the batholith are poorly exposed, but also appear to be sharp. At the northwestern end of the batholith in Hoskin and Servos Townships, intensely deformed sheets and irregularly shaped masses of felsic intrusive rocks locally cut across the stratigraphic layering in the metasediments.

Most of the massive intrusive rocks are medium-grained with abundant coarse, relict phenocrysts of feldspar, but locally near the margins where the intrusive rocks are in contact with quartzose and feldspathic metasedimentary gneisses, slightly foliated to massive, fine-grained phases with only scattered, medium-grained feldspar phenocrysts are abundant and could represent a finer-grained chilled border facies (Photo 28). Lithologically, the batholith shows a crude zoning, with green monzonitic rocks and minor pink to grey monzonitic rocks predominating in the interior of Cosby, Delamere, and southeastern Hoskin Townships. A crude primary igneous compositional layering is developed locally in the monzonitic rocks, with some layers close to diorite and

tonalite in composition (Photo 27). Pink to grey monzonitic rocks and quartz syenite predominate near the borders of the batholith, but where metasedimentary inclusions are abundant and near the northwestern and southeastern contacts, quartz syenite and quartz monzonite appear to predominate. A spatial association of the quartz syenite and quartz monzonite with metasediments suggests that at least some of these more siliceous rocks were formed by contamination of the monzonitic magma by the metasediments. Nevertheless, relative age relationships of the siliceous and monzonitic rocks are poorly known, but all gradations can be found in the field between the monzonitic rocks and quartz monzonite, and in a few places quartz syenite and quartz monzonite occur as dikes in the monzonitic rocks.

Compared to the large Middle Precambrian granitic bodies, the Cosby batholith is much less deformed and more discordant, and is therefore younger than the Middle Precambrian granitic rocks.

Mercer Anorthosite

The Mercer anorthosite in northwestern Falconer Township is intrusive into granitic rocks of the West Bay batholith and is an irregularly shaped body with intensely gneissic margins and a slightly foliated to gneissic interior. A small satellitic complex northwest of the main intrusion consists mainly of gneissic to slightly foliated pink to grey monzonitic rocks with minor anorthositic rocks and metagabbro. Sharp contacts of the main intrusion with the surrounding granitic rocks are well exposed in several places, and in general, the older granitic rocks are intensely altered up to a few feet (1 m) from the intrusion and locally contain minor concentrations of garnet. A few inclusions of granitic rocks are locally present in the intrusion within a few feet of the margins, and deformed dikes of metagabbro, gneissic anorthositic gabbro, and minor metadiorite and metatonalite are common in the granitic rocks near the intrusion. Most of the intrusion consists of altered, gneissic anorthosite and gabbroic anorthosite locally rich in biotite, but near the margins and in the southerly protruding arms that cross Marshall Lake, gneissic diorite and tonalite predominate and appear to grade into anorthosite. Massive to slightly foliated anorthositic rocks, present sparingly in the interior of the widest parts of the intrusion, contain relict plagioclase crystals up to 4 inches (10 cm) across, and in places, the normally greyish anorthositic rocks are pink to red, due to numerous closely spaced hematitized fractures. Dikes of enderbite rocks, tonalite and quartz syenite cut across the anorthositic rocks in a few places.

St. Charles Anorthosite

The St. Charles anorthosite, in northwestern Casimir Township, is an elongate body about 5.5 miles (8.8 km) long and as much as 0.5 miles (0.8 km) across. The eastern part of the body is intrusive into granitic rocks of the West Bay batholith, and several dikes and small elongate masses of anorthositic rocks extend into the granitic rocks east of the eastern end of the body. Except for a narrow zone of massive to slightly foliated anorthositic rocks, no more than a few hundred feet (100 m) wide in the interior, rocks of the intrusion are gneissic. Massive phases are mainly anorthosite and minor

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gabbroic anorthosite, and contain megacrysts of plagioclase up to 8 inches (20 cm) across, and minor layers of gabbroic and ultramafic rocks. There is a progressive increase in the intensity of deformation towards the margins. Near the margins, mafic layering predominates, and local gneissic diorite and tonalite phases are present. Where exposed, contacts between the intrusion and the host metasediments and granitic rocks are sharp.

In the eastern part of the intrusion, a few elongate masses of gneissic quartz syenite and minor sodic syenite are present in the anorthositic rocks and are aligned subparallel to the gneissic foliation. Dikes of sodic syenite, quartz syenite and rare enderbite rocks intrude the anorthositic rocks in a few places and appear to be most abundant in the eastern end. A small dikelet of leucocratic diorite, rich in garnet and containing up to 3 percent zircon crystals, intrudes anorthosite in the central part of the body about 3 miles (5 km) from the western end. In the central part of the body south of the Town of St. Charles, coarse-grained anorthosite phases locally contain minor concentrations of apatite.

Badgerow Complex

The Badgerow complex, at the northern boundary of the area in Badgerow and eastern Hugel Townships, contains some varieties of sodic syenite and monzonitic rocks not recognized in the other anorthosite suite intrusions. Roughly circular in plan, with a maximum diameter of about 3 miles (5 km), the complex is only moderately deformed, with a narrow gneissic margin and a massive to slightly foliated interior. Contacts between the complex and the surrounding metasediments are poorly exposed, but inclusions of partly assimilated metasediments are common near the borders of the complex.

Irregularly shaped bodies of syenitic to anorthositic rocks, concentrated mainly in the outer part of the complex, are the oldest rocks present. These older rocks are mainly dioritic to tonalitic, although some are grey sodic syenite, consisting mainly of sodic oligoclase (about An_{10} to An_{15}), minor quartz, amphibole, biotite, and rare potassic feldspar. These rocks locally grade into andesine anorthosite and into grey monzonitic rocks that lack garnet and are composed mainly of calcic oligoclase with subordinate micropertthite, and rare clinopyroxene, biotite, and hornblende. The irregularly-shaped bodies of syenitic to anorthositic rocks were intruded by pink sodic syenite, quartz syenite, and quartz monzonite. Syenitic rocks dominate the interior of the mass. Many of these younger felsic rocks are leucocratic, commonly with less than 5 percent mafic minerals. Quartz monzonite predominates along the margins of the complex, and commonly forms dikes in the mafic phases and rarely in the syenitic rocks.

AGE OF THE ANORTHOSITE SUITE INTRUSIVE ROCKS

Geologic data show that the anorthosite suite rocks are younger than the Middle-Precambrian granitic rocks and are most likely Late Precambrian in age. Geochronologic data for these rocks are scanty, but L.T. Silver (personal communication) obtained an age of about 1,420 million years for the Cosby batholith, using uranium-lead systems in zircons from monzonitic rocks. This batholith is similar lithologically to the Powassan and Bonfield batholiths in the North Bay area (Lumbers 1971a), but these bodies are

about 100 million years younger (Krogh and Davis 1969a). Zircons from a deformed, felsic anorthosite suite intrusion on the east side of Lake Muskoka near Port Carling, about 80 miles (128 km) southeast of the map-area, yield an age of about 1,440 million years (Krogh and Davis 1969a); in the Tomiko area (Lumbers 1971c; 1971d), anorthositic bodies are intrusive into granitic rocks of the Mulock batholith which is about 1,200 million years old (Lumbers 1971a, p.32,40). Thus, from combined geologic and geochronologic data, the anorthosite suite rocks within the Grenville Province of Ontario may range in age from about 1,500 million years to slightly less than 1,200 million years, and these rocks in the map-area could conceivably fall within this age span.

Alkalic Intrusive Rocks

In the western part of Bigwood Township, an elongate alkalic complex consisting of leucocratic nepheline and alkalic syenites is intrusive into metasediments and locally, anorthosite suite rocks of the Rutter pluton, and is deformed and regionally metamorphosed. The complex extends southward for about 7 miles (11 km) from the northwestern corner of Bigwood Township to Fifteen Mile Island on the south side of the French River; a few small bodies of nepheline and alkalic syenites, probably genetically related to the main intrusion, are exposed about ½ mile (0.8 km) south of the southern tip of the complex on the northern side of the Pickerel River. Hewitt (1960, p.172-177) among others (see Hewitt 1960, p.164) have mapped the complex in detail and concluded that the intrusion was emplaced as a sill-like body into previously deformed country rocks, possibly along a pre-existing northerly trending fault zone. Northerly trending faults define parts of the eastern and western margins of the complex and could represent portions of this older fault system that were subsequently reactivated.

Hewitt (1960) distinguished three major phases within the complex: 1) gneissic hastingsite nepheline syenite forming a northern lens, 2) gneissic biotite nepheline syenite forming a southern lens, and 3) gneissic pink alkalic syenite surrounding the southern nepheline syenite lens and extending northward to flank the northern and western sides of the northern nepheline syenite lens. The pink alkalic syenite intrudes and partly replaces the nepheline syenites and is a late phase of the complex. All the syenites are predominantly leucocratic, medium-grained rocks with gneissosity marked by streaks and lenses of mafic minerals. The northern nepheline syenite lens consists mainly of albite, nepheline, potassic feldspar, and hastingsite, with accessory biotite, aegirine-augite, and rare sphene, allanite, apatite, carbonate, and zircon. Mafic minerals range in amount from 5 to 30 percent, but generally comprise less than 10 percent of the rock, and nepheline generally comprises 20 to 30 percent of the rock. The southern nepheline syenite lens consists mainly of albite, nepheline, potassic feldspar, and biotite, with only rare accessory hastingsite and aegirine-augite; other minor accessory constituents are magnetite, sphene, zircon, apatite, graphite, corundum, carbonate, sodalite, and cancrinite. Mafic minerals generally form less than 10 percent of the rock, and nepheline is less abundant than in the northern lens and generally forms 10 to 20 percent of the rock. The pink alkalic syenite consists mainly of micropertthite and albite, with minor biotite, hastingsite, and magnetite and accessory aegirine-augite, zircon, apatite,

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garnet, pyrite, carbonate, fluorite, sphene, and, rarely, graphite. Locally, syenite pegmatite, rarely with coarse corundum crystals up to 0.5 inches (1 cm) across, forms dikes and nests in the alkalic syenite.

Hewitt (1960, p.185) concluded that the difference in mineralogy between the two nepheline syenite lenses suggests composite intrusion of these rocks from the same source, and that the alkalic syenite formed in part as a reaction rim around the nepheline rocks and in part as a slightly later, more siliceous, phase of the composite intrusion. Hewitt also proposed that the country rocks and the intrusion underwent regional granitization or potash metasomatism, because "microcline and microcline antiperthite are widely introduced into the pink syenite phase of the alkalic intrusive" and contacts between the country rocks and the alkalic syenite are gradational. Although the author is in essential agreement with most of Hewitt's conclusions concerning the complex, the proposed regional granitization or potash metasomatism is not supported by field or petrographic evidence. Some albite in the alkalic syenite is partly replaced by potassic feldspar, but this replacement appears to be strictly a local phenomenon, involving only a few grains in a thin section and is due to unmixing of the alkalic feldspars, either during cooling of the syenitic magma, or during regional metamorphism, or to both factors. No evidence of widespread introduction of potassic feldspar into the alkalic syenite could be found either macroscopically or microscopically. Exposed contacts between the country rocks and the alkalic syenite of the complex are rare, but a few such contacts examined by the author are sharp, and in many places, especially near the French River, inclusions of the country rock metasediments with sharply defined outlines are present in the syenites near the margins of the complex. These relationships suggest that the alkalic syenite was indeed a discrete intrusive phase and that the complex, like the country rocks, was not subjected to extensive granitization. In this connection, a crucial outcrop was found near the northern end of the complex where a small patch of rocks of the Rutter pluton outcrop west of the fault separating the two intrusions (see Map 2271, back pocket). The contact between the pluton and the complex is not exposed, but the felsic anorthosite suite rocks of the pluton contain a few dikes of alkalic syenite of the complex with sharply defined margins (see Photo 29), providing further evidence of the intrusive origin of the alkalic syenite and showing that the complex is younger than the pluton and possibly all of the nearby anorthosite suite intrusive rocks.

The alkalic rocks are similar to the renowned nepheline and alkalic syenites of the Haliburton-Bancroft region of the Grenville Province in southeastern Ontario (Hewitt 1960) and all of these alkalic rocks form relatively leucocratic, Late Precambrian, synorogenic bodies which were involved in Late Precambrian high rank regional metamorphism. In southeastern Ontario, the nepheline and alkalic syenites have been assigned both igneous and metasomatic origins, but in spite of intensive study for nearly a century, their genesis remains a problem (Gittins and Lumbers 1972). These rocks are associated in time and space with relatively leucocratic gabbroic and dioritic bodies typically containing late syenite and monzonite phases (Lumbers 1967), and from the author's experience, some are spatially associated with anorthosite suite rocks similar to those in the map-area. Because of the spatial association with rocks of the anorthosite suite and because the anorthosite suite shows some chemical features in common with alkalic rock series, perhaps petrologists should consider the possibility that the nepheline and alkalic syenites are related genetically to the anorthosite suite.



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Photo 29—Dike of gneissic alkalic syenite (beneath the hammer) in gneissic sodic syenite of the Rutter pluton; lot 12, concession VI, Bigwood Township.

Late Mafic Intrusive Rocks

Several small bodies of recrystallized, cataclastic metadiabase, showing relict primary microtextures and mineralogy, occur within the Grenville Front Tectonic Zone up to about 12 miles (19 km) southeast of the Boundary Fault. Most of the bodies are circular to elliptical in plan and are generally no more than a few hundred feet (100 m) across. Nevertheless, two closely spaced, relatively large, irregularly shaped bodies of metadiabase occur at the south end of Burnt Lake in southwestern Secord Township: a narrow sill-like body of recrystallized diabase crosses Highway 17 in southwestern Hagar Township southeast of Markstay, and a large stock of recrystallized gabbro, diorite, and minor ultramafic rocks cut by numerous granitic dikes is present just south of the Boundary Fault in Dryden and Neelon Townships. The stock, herein termed the Wanapitei complex, is a composite intrusion whereas the other bodies consist entirely of metadiabase. All of the intrusions are discordant and show sharp contacts with their host gneisses; rarely, they contain a few inclusions of the gneisses. These features, together with the cataclastic nature of the rocks and the preservation of relict primary microtextures and mineralogy, show that the bodies were emplaced relatively late in the tectonic and metamorphic history of the Grenville Province. Moreover, their restriction to the Grenville Front Tectonic Zone suggests relatively late tectonic activity within the Zone itself.

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Metadiabase

The metadiabase is a fine- to medium-grained, dark brown to dark grey, massive to slightly foliated rock, resembling the younger, post-metamorphic diabase that forms dikes throughout the Grenville Province (see the section on "Diabase Dikes"). Macroscopically, however, the rock has a distinctive knobby appearance on both weathered and unweathered surfaces, due to cataclasis and recrystallization. Relatively coarse, rounded to patchy mafic-rich material lies in a fine-grained matrix of granular, purplish plagioclase, but some relict primary laths of plagioclase up to a few millimetres long are commonly visible. Microscopically, the metadiabase consists of plagioclase, pyroxene, biotite, garnet, amphibole, epidote, iron-titanium oxide minerals, and apatite. Plagioclase occurs as fine-grained granular aggregates and as relict primary laths with 1) recrystallized margins, 2) intensely clouded cores due to minute inclusions of iron-titanium oxide minerals, 3) bent and fractured twin lamellae and 4) relict primary oscillatory zoning. Recrystallized granular plagioclase ranges in composition from calcic oligoclase to andesine, whereas relict laths range in composition from calcic andesine to calcic labradorite. Many of the rocks show relict subophitic to isogranular microtextures. Pyroxene grains, which are mainly intensely clouded by fine inclusions of iron-titanium oxide minerals and are partly unaltered, show corona-like structures of four major types: 1) cores of partly altered pyroxene with an inner rim of fine-grained biotite and an outer rim of fine-grained garnet; 2) completely altered pyroxene grains, consisting of a fine-grained granular aggregate of amphibole forming a core to an inner rim of biotite and an outer rim of garnet; 3) pyroxene grains partly rimmed by biotite and amphibole; and 4) pyroxene grains partly surrounded by a fine-grained aggregate of intergrown amphibole and garnet. Garnet is commonly disseminated throughout the rock, and amphibole is either non-pleochroic or shows a very pale green pleochroism. Most of the relict pyroxene appears to be augite, but a few of the rocks contain rare relict grains of orthopyroxene with exsolved plates of clinopyroxene. Fine- to medium-grained, primary, iron-titanium oxide grains are partly surrounded by reddish brown biotite and less commonly, by epidote and sphene.

Wanapitei Complex

The Wanapitei complex is an elliptically shaped composite intrusion of partly recrystallized gabbro, diorite, minor ultramafic rocks, and narrow dikes and small irregularly shaped bodies of relatively quartz-rich trondhjemite, granodiorite, and associated contaminated felsic rocks. About half of the complex is covered by drift, but the remainder is well exposed. Contacts between the intrusion and the surrounding country rock gneisses are poorly exposed, except locally along the southwestern margin where numerous inclusions of metasedimentary gneisses are present in the complex, and a narrow screen of metasediments extends into the intrusion for at least 1 mile (1.6 km). Along the southeastern flank, gabbroic rocks of the complex locally intrude an anorthositic body, indicating that the complex is probably younger than the anorthosite suite intrusive rocks. Near the margins the complex is commonly gneissic, but elsewhere the various rocks are mainly massive to slightly foliated and contain several zones of cataclasis and mylonitization ranging in width from a few inches to tens of feet (5 cm to

10 m). A prominent shear zone in the northwestern part of the complex contains disseminated sulphide mineralization (see Map 2271, back pocket, and the section on "Economic Geology") and smaller mineralized zones associated with mylonitized and cataclastic phases are present elsewhere in the complex. Grant *et al.* (1962, p.10-12) described the major features of the complex, but no detailed petrologic studies of the complex have been made. Major features of the complex, revealed by a reconnaissance petrologic study by the author, are described below.

Mafic rocks of the complex commonly contain relict primary microtextures and mineralogy, and locally show a crude relict igneous layering due to variation in the proportion of plagioclase and altered pyroxene. All gradations from gabbroic anorthosite to pyroxenite can be found, but most of the complex appears to consist of medium- to coarse-grained, partly recrystallized gabbro and diorite, containing about 35 to 50 percent mafic minerals. Diorite differs from gabbro mainly in containing andesine, rare quartz, and generally more visible biotite; some gabbro is similar both macroscopically and microscopically to metadiabase described above. Some of the mafic rocks are porphyritic, containing relict phenocrysts of plagioclase and pyroxene up to about 5 cm long in a medium- to coarse-grained groundmass, but other porphyritic varieties with a fine-grained groundmass are also present. Plagioclase is generally purplish due to minute inclusions of iron-titanium oxide minerals and is zoned, ranging in composition from sodic andesine to calcic labradorite. Calcic clinopyroxene appears to be the major ferromagnesian mineral and is partly altered to various mixtures of pale green amphibole, epidote, garnet, chlorite, biotite, and opaque minerals. In some rocks alteration products form corona-like structures similar to those in the metadiabase. Minor relict orthopyroxene is present in a few of the gabbros examined in thin section. Where the mafic rocks are gneissic and cataclastic, primary microtextures and mineralogy are largely destroyed and coarse-grained garnet porphyroblasts are common.

The granitic rocks are generally leucocratic and consist mainly of medium- to coarse-grained, porphyritic to equigranular trondhjemite containing up to 35 percent quartz, partly altered oligoclase, minor epidote, chlorite, biotite, sphene, amphibole, opaque minerals, and rare zircon. Potassic feldspar is present in some of the granitic rocks and is locally sufficiently abundant to form granodiorite and quartz monzonite. Locally, tonalitic and syenodioritic phases are associated with the granitic rocks; these apparently formed by contamination of the granitic magma by the mafic rocks. These phases contain abundant inclusions of mafic rocks showing all stages of assimilation, and contain only minor quartz and potassic feldspar, with abundant plagioclase, chlorite, amphibole, and biotite.

Late Pegmatite

Late dikes of massive granite pegmatite are found in all the rocks of the Grenville Province except the post-metamorphic mafic intrusions, and were emplaced after the culmination of the high-rank regional metamorphism and accompanying deformation. The dikes have sharp contacts and generally cut across the foliation in the host gneisses (see Photo 13), but a few are subparallel to the foliation. Most of the dikes are lenticular

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with considerable variation in length to width ratios, and they range in dip from sub-vertical to nearly horizontal. The largest dikes rarely exceed a few hundred feet (100 m) in length and width, and most are no more than a few feet (1 m) wide. The largest and most persistent dikes are within the Grenville Front Tectonic Zone, and near the boundary between Ratter and Hugel Townships in the northeastern part of the area, and occur in either plutonic rocks, quartz-rich metasediments, or in metasedimentary sequences rich in calc-silicate gneiss because these rocks were apparently structurally more competent during emplacement of the pegmatite. In the eastern half of the area, many of the dikes trend northeastward and are particularly abundant near northeasterly trending faults, as in the adjacent North Bay area (Lumbers 1971a, p.67); but in the western half of the area, particularly within the Grenville Front Tectonic Zone, most of the dikes trend west to northwest, parallel to the major direction of late faulting in the zone. Although most of the dikes are too small, widespread, and numerous to be shown on the accompanying map (May 2271, back pocket), the largest dikes are indicated on the map, and many of these have been quarried for mica and feldspar (see the section on "Economic Geology").

Lithologically, most of the dikes within the Grenville Front Tectonic Zone differ from those elsewhere in that they are generally distinctly zoned with a quartz-rich core and are more hematitized and radioactive due to the common presence of allanite and, rarely, traces of other radioactive minerals (see the section on "Economic Geology"). In addition to quartz and allanite, these dikes contain alkalic feldspar, muscovite, and biotite, minor amphibole, garnet, magnetite, and specularite; and rare zircon, calcite, and apatite. Some dikes that contain abundant allanite also contain relatively abundant magnetite and pyrite. Graphic intergrowths of quartz and alkalic feldspar are common and some dikes contain crystals of allanite up to several inches (5 cm) long and of feldspar and micas up to 3 feet or so (1 m) across.

Elsewhere, the dikes are similar to those in the adjacent North Bay area (Lumbers 1971a, p.42) and are simple pegmatites low in radioactivity, consisting mainly of quartz, alkalic feldspar, and minor micas. Allanite is only a rare accessory mineral and the dikes are generally only moderately hematitized. Other minerals found sparingly are zircon, apatite, molybdenite, specularite, garnet, and pyrite. A few slightly zoned dikes in the West Bay batholith in MacPherson and Lowdon Townships contain coarse pods of white to pink calcite and are relatively intensely hematitized.

The genesis of the pegmatite dikes and the significance of the compositional differences between dikes within and without the Grenville Front Tectonic Zone requires further study. Nevertheless, the pegmatite solutions were most likely generated during the advanced stages of the high rank regional metamorphism, possibly at structural levels deeper within the crust than that at which they now occur. The dikes were emplaced at their present level when the metamorphic complex was cooling and able to fracture, and when regional deformation was on the wane.

Geochronologic data on the late pegmatite dikes are scarce, but a few uranium-lead and potassium-argon ages from dikes both within the map-area and in nearby regions have been published (Shillibeer and Cumming 1956). The ages reported range from about 900 to 1,100 million years, so that the dikes appear to be similar in age to those of the southern part of the Grenville Province in the Haliburton and Bancroft areas (Silver and Lumbers 1966).

Metamorphism of the Grenville Province

Except for the Grenville Front Tectonic Zone, the main metamorphic features of the Grenville Province portion of the area are similar to those outlined previously for the adjacent North Bay area (Lumbers 1971a, p.43-44). Within the Grenville Front Tectonic Zone, rocks of the Grenville Province display a more complex tectonic history, and locally, they contain higher metamorphic rank mineral assemblages than found elsewhere in the two map-areas. The main metamorphic features revealed by the present mapping are summarized below, and some tentative conclusions are given regarding the conditions under which the various rocks were metamorphosed.

Field relationships and geochronologic data indicate that the metasediments of the Grenville Province underwent a complicated history of deformation and plutonism; and that following the major plutonism, all the rocks were subjected to a Late Precambrian high rank regional metamorphism, during the waning stages of which granite pegmatite dikes were emplaced. Geochronologic data indicate that this late metamorphism culminated between about 1,400 and 1,200 million years ago (Lumbers 1971a, p.44). The metasediments almost certainly underwent regional metamorphism during the emplacement of the Middle Precambrian granitic plutons because these masses are syntectonic (or pre-tectonic), intensely deformed bodies that are widespread throughout the metasedimentary sequence. The presence of the Middle Precambrian gneissic pegmatite dikes concentrated within the Grenville Front Tectonic Zone also probably reflects Middle Precambrian regional metamorphism, at least within the Tectonic Zone. Nevertheless, mineral assemblages in the metasediments and plutonic rocks seem to reflect only the Late Precambrian high rank regional metamorphism, and evidence concerning the intensity of Middle Precambrian regional metamorphism is largely obscured by this later metamorphic event. Some evidence of contact metamorphism and local granitization older than the Late Precambrian regional metamorphism is preserved in metasediments next to Middle Precambrian felsic plutons. Because metasedimentary inclusions in both the Middle and Late Precambrian plutonic rocks are non-migmatitic, the early regional metamorphism was possibly less intense than the late regional metamorphism, but the gneissic pegmatite dikes could indicate that the early metamorphism was relatively intense, at least within the trough of eugeosynclinal metasediments within the Grenville Front Tectonic Zone.

In the eastern half of the area, mineral associations in the various gneisses indicate that the pressure and temperature conditions during the Late Precambrian regional metamorphism were uniform. Mineral assemblages are most typical of the kyanite-almandine-muscovite subfacies of the almandine-amphibolite facies described by Turner and Verhoogen (1960) and Winkler (1967). Most of the supracrustal rocks are biotite gneisses and hornblende gneiss, relatively poor in potassic feldspar and consisting mainly of plagioclase, quartz, biotite, hornblende, and minor garnet; epidote is a common accessory mineral in all of the gneisses, and diopside is a common accessory in hornblende gneiss. Although most of the mineral assemblages are also compatible with the staurolite-almandine subfacies of the almandine-amphibolite facies, staurolite appears to be absent whereas kyanite-bearing assemblages are found sparingly, suggesting that the gneisses were metamorphosed to the higher grade kyanite-almandine-muscovite subfacies. In most of the biotite gneisses, minor muscovite and potassic feldspar are commonly developed as microscopic films and layers at contacts between biotite and plagioclase grains, which

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suggests a metamorphic reaction involving biotite and plagioclase to produce muscovite and potassic feldspar. In some rocks, the biotite involved in this reaction is partly chloritized, but in others, chloritization is absent. Moreover, microscopic veinlets of potassic feldspar, generally no more than a few millimetres long, are present in some rocks showing this reaction, which suggests local diffusion of potassium during the metamorphism.

Mineral assemblages in some metasediments and mafic intrusive rocks in the western half of the map-area, between the Grenville Front Boundary Fault and the southeastern limit of the Grenville Front Tectonic Zone (extending along the western side of the Cosby batholith and northeastward through Nepewassi Lake and the western part of Hagar Township) are indicative of higher rank metamorphism than in the area to the east of the Tectonic Zone. Quartzose metasandstone commonly contains mineral assemblages most typical of the sillimanite-almandine-orthoclase subfacies, and some of the biotite and feldspathic gneisses contain sillimanite. Epidote, a common accessory mineral in the eastern half of the area, is generally absent in these rocks within the Tectonic Zone, and metagabbroic rocks within the Zone locally contain clinopyroxene and a more calcic plagioclase than to the east of the Zone. Kyanite- and muscovite-bearing metasediments are intercalated with the sillimanite-bearing rocks, and in some muscovitic and quartzose metasediments, kyanite and sillimanite co-exist in apparent equilibrium.

Kwak (1971) made a detailed study of the metamorphism of almandine-amphibolite facies pelitic gneisses in Dill Township, up to 3.5 miles (5.6 km) southeast of the Boundary Fault, and concluded that there is a systematic increase in metamorphic grade from the staurolite-almandine subfacies near the Boundary Fault to the sillimanite-almandine-orthoclase subfacies in the southeastern part of his area. He estimated a temperature gradient of 670°C to 750°C and a pressure gradient of 6.3 to 7.3 kilobars across his study area to account for the metamorphic assemblages. Winkler (1967) estimated that the formation of the sillimanite-almandine-orthoclase subfacies requires temperatures of at least 650°C to 700°C under an operative pressure as high as 8 to 9 kilobars. Perhaps, as suggested by Kwak (1971) for the Dill Township rocks, the prevalent temperature and pressure conditions during the Late Precambrian metamorphism throughout the entire Tectonic Zone were similar to those near the kyanite-sillimanite univariant curve.

The various subfacies of the almandine-amphibolite facies recognized within the Grenville Province are considered by Winkler (1967) and others to be typical of Barrovian-type metamorphism where the geothermal gradient is relatively low, and thus temperatures necessary for the metamorphic reactions were attained only at great depth under high pressure. This model does not agree with the field evidence obtained in the present study. If experimental data are correct and pressures in the range of 6 to 9 kilobars are necessary to form the mineral assemblages observed in the rocks, then these pressures were not developed simply by deep burial. Pressures between 6 and 9 kilobars correspond to depths of burial between about 14 and 21 miles (23 to 34 km). There is no independent evidence that rocks of the Grenville Province were buried to these depths and subsequently uplifted to their present level. Indeed, stratigraphic relationships among the various Middle Precambrian metasediments within the Grenville Front Tectonic Zone, and the fact that relatively high level epizonal intrusions of various ages locally straddle the Grenville Front Boundary Fault restrict the amount of relative uplift of the Grenville Province to at most only a few miles. Moreover, Kwak's (1971) data on the temperature and pressure conditions of regional metamorphism southeast of the Boundary Fault in Dill Township suggests a relatively high geothermal gradient in this area, as would be expected if the metamorphism was accomplished at

relatively shallow crustal levels. The high pressures were apparently developed by some mechanism other than deep burial, and in view of the fact that all of the rocks in the Grenville Province are intensely deformed and suffered considerable distortion, perhaps the necessary pressures were induced tectonically.

In the North Bay area, the author concluded that the discontinuous granitic veins giving rise to migmatitic phases of the metasediments and felsic plutonic rocks were formed by partial melting, controlled in part by the bulk chemistry of the rocks (Lumbers 1971a, p.43). Although the granitic veins of the migmatitic phases in the Burwash area also appear to be controlled in part by the bulk chemistry of the rocks, additional field and petrographic data now suggest that metamorphic differentiation may have played a more important role in the formation of the veins than partial melting. Although chemical data are lacking, the available field and petrographic data indicate that the granitic veins formed in place without the introduction of material from external sources.

Among the major features of the veins described in the present report, the following appear to be particularly critical in considerations of their origin:

1. The veins are isolated in three dimensions and those in the metasediments cannot be related directly to granitic plutonic rocks; all of these plutonic rocks appear to be older than the migmatitization.
2. Modally, the veins are richer in potassic feldspar and are more leucocratic than the plutonic granitic rocks.
3. The development of the veins appears to depend largely upon the bulk chemistry of the rocks and upon the original distribution of potassic feldspar in the rocks.
4. Mafic selvages invariably present at vein boundaries appear to balance the scarcity of mafic minerals within the veins, and potassic feldspar is scarce to absent in the inter-vein gneiss.
5. *Dents du cheval*, or large crystals of perthitic potassic feldspar, are commonly associated with the veins.
6. Metasedimentary and plutonic gneisses in intensely deformed zones, such as the cores of major folds, generally contain more granitic veins than in less intensely deformed zones.

Thus, the veins formed by partial melting, by metamorphic differentiation, or by a combination of both processes. Partial melting could account for many of the observed features. Under the temperature and pressure conditions attained in the kyanite-almandine-muscovite subfacies, the apparent dominant metamorphic grade in the gneisses, quartz- and biotite-bearing gneisses containing relatively sodic plagioclase will undergo melting in the presence of water (Winkler 1967), but melting of more calcic rocks requires higher temperatures. Metamorphic differentiation involves a redistribution of material, particularly potassic feldspar and biotite, along inhomogeneities (such as beddings) originally rich in potassic feldspar and could form granitic veins at relatively low temperatures without the production of granitic magma (see White 1966). The *dents du cheval* are difficult to explain by the partial melting hypothesis, but can be explained by the metamorphic differentiation hypothesis. Veins are rare to absent in gneisses where potassic feldspar was originally evenly distributed, and potassic feldspar is rare in the inter-vein gneiss. These features, plus the fact that some intensely deformed syenitic and monzonitic rocks of the anorthosite suite in the western half of the area are locally migmatitic, favour the metamorphic differentiation hypothesis.

Southern and Grenville Provinces

LATE PRECAMBRIAN

Mafic Intrusive Rocks

Following the Late Precambrian high-rank regional metamorphism in the Grenville Province, a few mafic to ultramafic stocks were emplaced within the gneisses of the Grenville Province, and numerous diabase dikes were intruded throughout the area in both the Grenville and Southern Provinces along regional fractures trending west to west-northwest. In the Southern Province, a few northwest-trending, relatively olivine-rich diabase dikes extend into the Grenville Front Tectonic Zone, but are not present within the Grenville Province. West to west-northwest trending dikes in which olivine is scarce to absent extend across the Grenville Front Tectonic Zone to the north and west of the map-area and may be younger than the olivine-rich dikes. Relative age relationships between the stocks and the dikes are poorly known, but one stock in the southeastern corner of the area is cut by a diabase dike, and all the stocks could be older than the west to west-northwest trending dikes. Some of the diabase dikes in both provinces are in faults that underwent post-dike movements. Conceivably, some of the olivine-poor dikes could be latest Precambrian or earliest Paleozoic in age (Lumbers 1971a, p.47).

MAFIC TO ULTRAMAFIC STOCKS

The Memesagaming Lake norite stock, the only late mafic stock in the area, lies mainly within the adjacent North Bay area, and only the westernmost part is exposed in the southeast corner of the present map-area. The entire mass is described in the North Bay report (Lumbers 1971a, p.45-46). Four small, elongate stocks of ultramafic rocks are present in the area: 1) in southwestern Cleland Township, 2) on the southern side of Highway 17 in Hagar Township, 3) on the southern side of Barlow Lake in southwestern Jennings Township, and 4) on small islands in the bay on the northern side of Trout Lake in eastern Hoskin Township. The Jennings Township body is up to 2,000 feet (600 m) long and generally no more than about 100 feet (30 m) wide, whereas the other three bodies are less than 1,000 feet (300 m) long and no more than a few hundred feet (100 m) wide. Because of the small size of these bodies, more detailed work than was possible during the present study could reveal the presence of other ultramafic bodies.

All the ultramafic intrusions consist mainly of partly serpentinized peridotite with rare minor phases of mafic-rich olivine gabbro containing less than 30 percent plagioclase. The serpentinized peridotite consists mainly of olivine, orthopyroxene, some calcic clinopyroxene which generally shows oscillatory zoning, and minor phlogopite, magnetite, apatite, and green spinel. Alteration products are mainly serpentine, anthophyllite, carbonate, and very fine-grained iron-titanium oxide minerals; in some of the rocks, most of the olivine and pyroxene are completely altered to these minerals. Olivine is commonly poikilitically intergrown with pyroxene, and plagioclase is a calcic bytownite. In the Cleland and Hagar Townships bodies, plagioclase is rare to absent and clinopyroxene is much less abundant than in the other two bodies. The peridotite in Hagar Township contains coarse-grained crystals of anthophyllite, locally more than 1 cm long,

and is locally rich in olivine. The peridotites in both Hagar and Cleland Townships are deeply weathered and have been quarried for road metal (see the section on "Economic Geology"). Sulphide mineralization is rare in all of the bodies, but the Cleland Township body has been explored for sulphide minerals by two small shafts, described in the "Economic Geology" section.

The ultramafic bodies are either within or near the southeastern margin of the Grenville Front Tectonic Zone, and like the metadiabase bodies described above, they also reflect late tectonic activity within the Zone.

DIABASE DIKES

Two petrographic types of diabase dikes are present in the map-area: olivine diabase which contains more than 10 percent olivine and diabase in which olivine is either scarce or lacking. The olivine diabase dikes are confined to the Southern Province portion of the area and are part of a regional northwest-trending swarm that intrudes rocks of both the Southern and Superior Provinces but which does not extend across the Grenville Front Tectonic Zone in the Grenville Province. Grant *et al.* (1962, p.16) showed from a detailed magnetometer survey that one olivine diabase dike terminates exactly at the Grenville Front Boundary Fault and could not be found southeast of the Fault in the Grenville Province. North of the map-area numerous other olivine diabase dikes also appear to terminate near the Boundary Fault, but in the Tomiko area (Lumbers 1971c; 1971d), olivine diabase dikes do cut across rocks of the Grenville Province. Northwest-trending diabase dikes similar to the west to west-northwest diabase dikes in the map-area also extend across the Grenville Front Tectonic Zone and intrude rocks of all three provinces (see Ayres *et al.* 1971b). These relationships suggest that there are multiple generations of olivine diabase in the vicinity of the Grenville Front Tectonic Zone in Ontario. The olivine diabase dikes in the map-area occupy fracture systems which were not reactivated after the last major tectonism along the Grenville Front Tectonic Zone. The diabase dikes, on the other hand, occupy fracture systems which postdate this tectonism and are therefore probably younger than the olivine diabase dikes.

The olivine diabase dikes were not studied petrographically by the author, but their extensions in adjacent areas are described elsewhere by Card *et al.* (1971) and Card (1968), among others. They are marked by prominent, linear, positive aeromagnetic anomalies (e.g. GSC 1965d), in contrast to the diabase dikes which are marked by only weak to moderate, linear, positive aeromagnetic anomalies (GSC 1965a; 1965c). The diabase dikes in the map-area appear to be present only here and there along the west to west-northwest trending faults, instead of persisting continuously along the faults. At least some of the diabase dikes in the North Bay area also show this phenomenon (Lumbers 1971a, p.46). Although no individual diabase dike could be traced across the Grenville Front Tectonic Zone in the map-area, some are in fractures which do cut across the zone west of the map-area (see Ayres *et al.* 1971b). Where exposed, contacts of both the olivine diabase and diabase dikes are sharp, with narrow microcrystalline chilled margins. Both types of dikes range in width from less than 1 foot to nearly 300 feet (30 cm to 100 m), and some pinch and swell along strike. Locally in the Grenville Province, country rocks are brecciated and intensely hematitized adjacent to the dikes, and a few small fragments of country rocks were included in the margins of wide dikes. Narrow subsidiary dikes, generally only a few inches wide, are found near and parallel to the margins of some wide dikes.

Burwash Area

Diabase of the west to west-northwest dikes is identical petrographically to diabase in the adjacent North Bay area (Lumbers 1971a, p.46-47). The rock is grey to black on fresh surfaces, brown-weathering and massive, with prominent tabular plagioclase. Except for the microcrystalline chilled zones, the dikes are medium-grained with rare coarse grained to pegmatitic patches in the widest dikes. Texturally, most of the dike rocks are subophitic to isogranular; ophitic texture is rare. Most of the dike rocks consist of oscillatory zoned plagioclase ranging in composition from about An₄₀ to An₈₅, calcic clinopyroxene, and pigeonite, minor iron-titanium oxides and apatite, and rare interstitial quartz in granophyric intergrowth with plagioclase. Microcrystalline chilled zones locally contain a few fine-grained phenocrysts of olivine, but olivine is extremely rare elsewhere in the dikes, and where present, it is armoured by clinopyroxene. Locally some of the dikes are extensively saussuritized and uralitized, but most are only slightly altered. The chief secondary minerals are amphibole, serpentine, biotite, carbonate, and epidote.

Paleozoic

CAMBRIAN

Mafic Intrusive Rocks

Narrow dikes of lamprophyre, no more than about 1 foot (30 cm) wide, occur in three places: 1) on the south side of Highway 17 about 1.5 miles (2.5 km) east of the road to Markstay in Hagar Township, 2) on the east side of Highway 64 about 2 miles (3 km) south of Verner in northern Caldwell Township, and 3) on the north side of a concession road about 2 miles (3 km) east of Lavigne in southwestern Caldwell Township. The dikes consist of monchiquite and are similar to the Early Cambrian monchiquite dikes associated with faults of the Ottawa-Bonnechere Graben in the North Bay area (Lumbers 1971a, p.47,54). The dikes in the map-area are also probably related to the Ottawa-Bonnechere Graben which appears to lose its identity as a mappable structure in the map-area, as discussed below in the "Structural Geology" section. All of the dikes found are in roadcuts, and because the dikes are small and poorly exposed in both the Burwash and North Bay areas, a more detailed search than was possible during the present study could reveal many more dikes.

Cenozoic

QUATERNARY

Pleistocene

Most of the Cenozoic sediments in the map-area were deposited during the Pleistocene in glacial and post-glacial lakes that formed part of the prehistoric Great Lakes described in detail by Hough (1958; 1963). During the Pleistocene, continental glacial

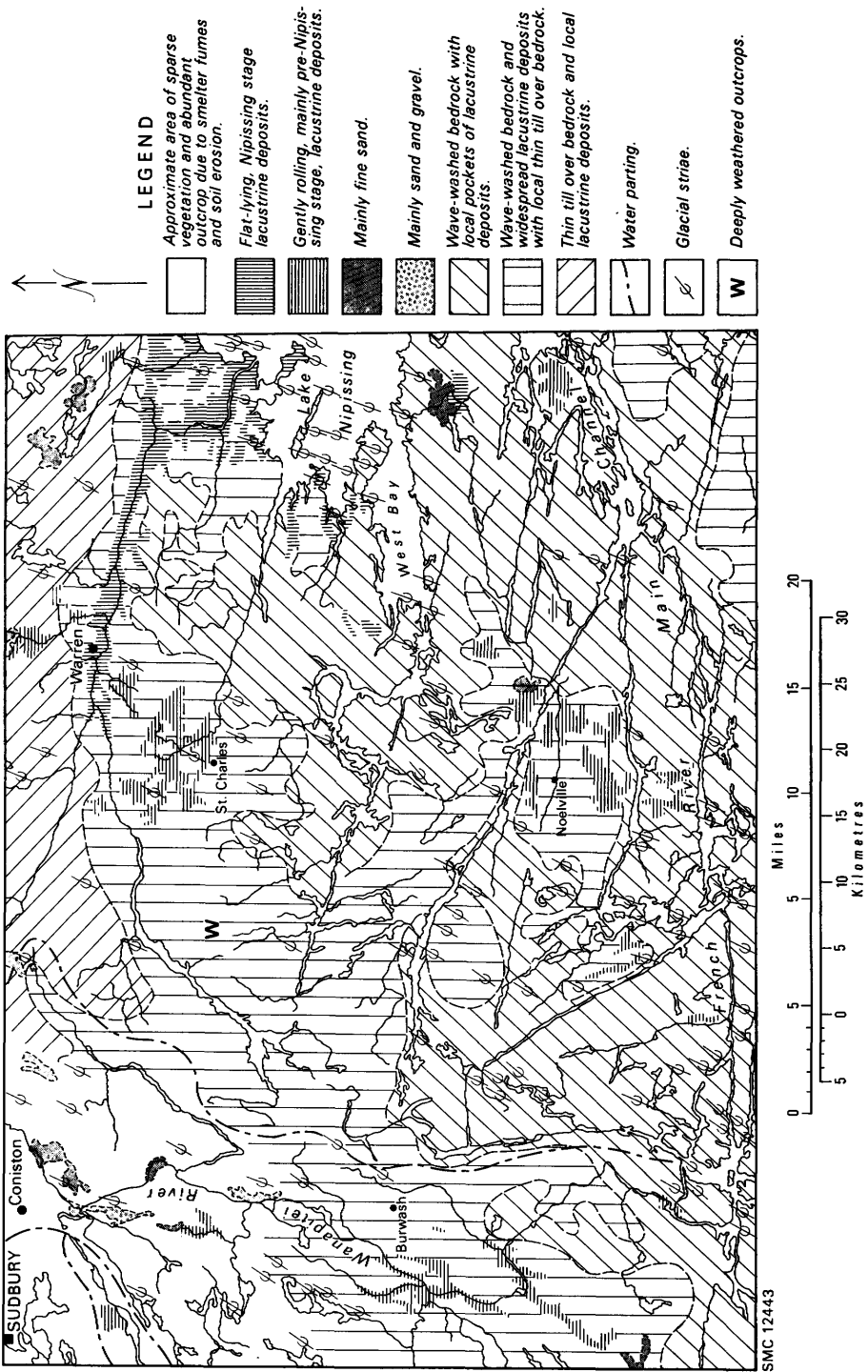


Figure 7—Some major features of the Pleistocene geology of the Burwash area.

Burwash Area

ice invaded the Great Lakes region in four major advances, but evidence of only the last glaciation, the Wisconsin, is found within the map-area. This ice-sheet retreated from the area about 9,500 to 10,000 years ago (Terasmae and Hughes 1960; Boissonneau 1968; Lowdon and Blake 1968, p.215), but as the ice margin receded northward across the area, the land initially remained depressed, despite the removal of the downward pressure of the ice, and glacial melt waters, dammed against the wasting ice front, inundated even what are now the highest parts of the area. With retreat of the ice margin north of the area, post-glacial lakes continued to inundate parts of the area, but due to post-glacial uplift of the land, these lakes decreased in size and covered successively lower parts of the area than the earlier glacial lakes; eventually these lakes drained, leaving only the small lakes in depressions that characterize the present landscape. Major features of the Pleistocene geology are summarized in Figure 7.

Direction of Ice Movement

The direction of ice movement within the Burwash area as recorded by glacial striae ranges from S5W to S50W, and these striae probably provide evidence of only the last movements of the ice mass. Striations measured during the present study within the area are plotted in Figure 7, and in general, they show a progressive change in average orientation from S15W-S25W in the eastern part to S25W-S35W in the western part. This progressive southwesterly change in striae orientation across the area from east to west was also detected in the adjacent North Bay area (Lumbers 1971a, p.58) where striae show a progressive change in orientation from south to slightly west of south in the eastern part to southwest in the western part. Interpretation of this apparent regional fan-like pattern of the striations requires further study, but the pattern may be partly the result of regional topographic control on the movements of the ice mass. From maps compiled by Boissonneau (1965; 1968) and from data collected by the author on striae north of the Burwash and North Bay areas (Lumbers 1971c; 1971d; 1971e), this pattern appears to approximately coincide with the prominent physiographic trough forming the French River-Lake Nipissing depression discussed earlier in the "Physiography" section. This topographic feature may have existed prior to the Wisconsin ice-sheet as suggested by Quirk (1936), and if so, it could have exerted local control on the movements of the ice-sheet.

Drift

Glacial drift, in the form of ground moraine, and minor kames and crag-and-tail structures, is thickest and best preserved in the northern part of the area and is largely absent in the French River-Lake Nipissing topographic depression, where wave-washed bedrock with local pockets of lacustrine deposits predominate (Figure 7). Nearly all of the drift features were modified by lake waters. Fumes from the Sudbury area smelters have destroyed most of the vegetation in the northwestern corner of the area (Figure 7), and most of the soil cover has been eroded from high areas, with the result that drift features here have been largely destroyed.

Ground moraine is the most widely distributed drift feature in the area and consists mainly of a bouldery, sandy to silty till that forms a thin, discontinuous mantle on the-



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Photo 30—Oblique air photograph of wave-washed bedrock knolls with intervening lacustrine deposits; eastern Jennings Township, west of Highway 535.

bedrock. In the northern part of the area, near Nepewassi Lake and north of Veuve River (Figure 7), the till is overlain in places by younger outwash and lacustrine deposits, and in other places was eroded by wave action of lake waters, exposing small areas of bare bedrock. Farther to the south and southwest, where elevations decrease slightly towards the French River-Lake Nipissing depression, erosion of the till from rocky uplands by lake waters is much more pronounced, and in general, the terrain is characterized by abundant wave-washed bedrock knolls with widespread lacustrine deposits in intervening low areas (see Photo 30 and Figure 7). The large area of wave-washed bedrock with local pockets of lacustrine deposits in the French River-Lake Nipissing depression (Figure 7) was repeatedly wave-washed by waters of the prehistoric Great Lakes, and little drift is present, even in valleys. Although wave action could have removed most of the drift in this area, the paucity of drift in the valleys suggests the possibility that little drift material was deposited in this region by the ice-sheet.

Coarse detritus found in the drift is largely of local derivation, but within the Grenville Province portion of the area, coarse detritus derived from rocks of the Huronian Supergroup to the north and west of the Grenville Province is common in the drift. Coarse detritus derived from the Early Precambrian Superior Province is rare. Although no Paleozoic sedimentary rocks are exposed in the area, cobbles and pebbles of these rocks (chiefly fossiliferous limestone and dolostone) are found sparingly in the till of the ground moraine and of crag-and-tail structures deposited on the lee side of rocky knolls.

Prehistoric Great Lakes and Related Deposits

Most of the lacustrine deposits shown in Figure 7 were formed during various stages in the complex history of the prehistoric Great Lakes. Published data concerning details of this history within the map-area are scarce, but from general summaries by Hough (1958; 1963) and by Boissonneau (1968) concerning the prehistoric Great Lakes and from the character of the deposits shown in Figure 7, the thickest and most extensive deposits were formed during the Nipissing post-glacial stage of the Great Lakes. Hough (1963) cites data indicating that the Nipissing stage reached its maximum altitude about 4,200 years ago, but Boissonneau (1968) summarizes some evidence suggesting that the Nipissing stage may have occurred much earlier, about 6,000 years ago. Raised beaches and other littoral features related to the prehistoric Great Lakes are rarely found in the map-area, but just north of Highway 17, east of Verner, a few strand lines, below 700 feet (210 m) in elevation and probably related to the Nipissing stage shoreline, can be followed for short distances.

In Figure 7, the flat-lying lacustrine deposits shown along the valley of Veuve River and near Lake Nipissing are below 700 feet (210 m) in elevation and are related to the Nipissing stage. These sediments, which support the best farming in the area, are characterized by a relatively flat surface and consist of varved clay, boulder clay, and minor interstratified fine sand and silt. Only the thickest and most extensive deposits of these sediments are shown in Figure 7, but local pockets are common elsewhere in depressions surrounding wave-washed bedrock knolls between Veuve River and West Bay of Lake Nipissing.

In contrast to the flat-lying Nipissing stage sediments, gently rolling lacustrine deposits characterized by an irregular surface are present in various parts of the area at elevations between 700 and 800 feet (210 to 240 m) (Figure 7). These sediments were probably deposited in glacial and post-glacial lakes older than the Nipissing stage and consist of pebbly to bouldery, massive clays with variable amounts of interstratified varved clay, sand, and gravel. Some of the massive clays contain a thin capping of varved clay, and deposits near St. Charles (Figure 7), in the north central part of the area, contain several zones of varved clay. The irregular surface expression, structural features, and general composition of these sediments suggest that most were deposited when ice was present in the region and that some represent clay tills modified by lake waters. Only the thickest and most extensive deposits of these pre-Nipissing stage sediments are shown in Figure 7, but pockets of these sediments are present in various parts of the map-area and are particularly common in a large area south of St. Charles in Jennings and western Casimir Townships, near Ouellette and Noelville in Cosby and Martland Townships, and near Burwash in Burwash Township.

Deposits of sand and gravel, fine sand, and interstratified clay, sand, and gravel are relatively abundant along the Wanapitei River and some of its tributaries (Figure 7) and appear to be related to an extensive esker and deltaic complex extending northward from just north of the map-area to Wanapitei Lake near Skead (Boissonneau 1968). This complex was terraced by wave action to form level sand deposits, and much of the fine sand and sand and gravel near the Wanapitei River in the map-area are probably a continuation of the deltaic deposits to the north, that have been spread out and smoothed by lake waters. Lacustrine deposits of clay and sand in relatively broad portions of the Wanapitei River valley in the southwestern part of the area (Figure 7)

were possibly modified by lake waters of the Nipissing stage, as suggested by Quirke (1936). Fine sand deposits are found in various places elsewhere within the map-area in association with lacustrine clays and silts, and although most of these sands are only of local extent, relatively large deposits occur south of Lake Nipissing, north of the French River near Monerville, and north of the Veuve River in the northeastern part of the area (Figure 7).

Weathering of the Bedrock

Deeply weathered bedrock is widespread in the northeastern part of the North Bay area above the ancient Nipissing stage shoreline, but below the highest glacial lake beaches and terraces (Lumbers 1971a, p.59). Such weathering is rare within the Burwash area, but a small zone of relatively deeply weathered bedrock, at an elevation of about 800 feet (240 m) is present near the southeastern corner of Hawley Township (Figure 7). These outcrops are partly mantled by modified till of the ground moraine and, like the weathered rocks in the North Bay area, are intermediate in elevation between the Nipissing shoreline and the highest glacial lake deposits. A satisfactory explanation for this weathering requires further study, but as pointed out previously (Lumbers 1971a, p.60), the weathering could be pre-glacial and preserved by a thick mantle of drift.

Recent

Recent sediments comprise swamp accumulations, beach deposits along lake shores, clay, silt, sand and gravel deposited in streams and lakes, and various types of sediments eroded from rocky uplands in range of the Sudbury area smelter fumes. The largest swamp accumulations (see Lumbers 1971f; 1971g) are near Lake Nipissing and the French River in the eastern half of the area and in the southwestern corner where relief is lowest. Recent and Pleistocene fluvial sand and gravel are essentially indistinguishable, and in places, streams have eroded Pleistocene sediments to form relatively deep V-shaped valleys. A good example of such an entrenched stream valley is that of the Veuve River.

In the northwestern corner of the area, where fumes from the Sudbury area smelters have largely destroyed vegetation, most of the soil cover on rocky ridges and hillsides has been washed by rains into adjacent depressions, leaving a desolate landscape rich in bedrock. Active soil erosion is pronounced in the depressions and abundant sand and silt are being deposited in nearby lakes and stream valleys.

STRUCTURAL GEOLOGY

A rigorous structural analysis of the Burwash area is not possible from the data collected during the present reconnaissance study, but the major sequence of structural events can be reconstructed to some extent, providing a framework for later detailed studies. Structural data obtained during the present study are summarized on Map 2271

Burwash Area

(back pocket). In the Southern Province, bedding attitudes measured in the metasediments by Grant *et al.* (1962) are generalized and shown as trend lines that outline folds, and foliation attitudes measured by the author in cataclastic rocks near the Grenville Front Boundary Fault are also generalized and shown as trend lines. Similarly in the Grenville Province, foliation attitudes measured in the gneisses are generalized and shown as trend lines that outline complex fold systems. In both provinces, only the major fold axes are indicated. Other structural elements shown are major faults and lineations produced by mineral elongation, streaking, and rodding.

DEFORMATION OF THE SOUTHERN PROVINCE

Deformation of the metasediments and intrusive rocks in the Southern Province has been discussed previously by Grant *et al.* (1962) and by Henderson (1967a; 1967b), and only a brief summary is given here. Primary sedimentary structures providing facing directions are numerous and widespread within the metasedimentary sequence and indicate that the sequence is complexly folded and faulted. Work west of the map-area by Henderson (1967a), Card (1968), and Card *et al.* (1971) among others shows that the sequence underwent early folding about easterly trending axes prior to the culmination of the Middle Precambrian low-rank regional metamorphism and the emplacement of the Middle Precambrian granitic rocks near the Grenville Province boundary. Henderson (1967a; 1967b) and Brown (1967) among others showed that near the Grenville Province, the early folds were tightened and rotated subparallel to the northeasterly trending boundary of the Grenville Province to form a complex synclinorium plunging southwestward and slightly overturned toward the northwest. The synclinorium is dismembered by numerous faults; axial planes of folds within the synclinorium strike northeast, subparallel to structural trends in the adjacent Grenville Province, are overturned slightly and dip steeply southeast. This later folding, which postdates the Middle Precambrian granitic rocks and is probably Late Precambrian in age, dominates the sequences within the map-area and appears to be related to relatively late tectonic activity along the Grenville Front Tectonic Zone. Cataclasis and mylonitization accompanied and outlasted the late folding and is most intense within a mile or so of the Grenville Front Boundary Fault, where the rocks are most tightly folded. Locally near the Boundary Fault, intensely cataclastic rocks display a prominent lineation, plunging 35 to 60 degrees southeast, produced by mineral streaking and rodding on foliation surfaces (see Photo 1), and axes of folds in the metasediments plunge steeply to the southeast parallel to the lineation. The intensity of the late folding and cataclasis gradually decreases to the northwest away from the Boundary Fault, and these late structures form the northwestern boundary of the Grenville Front Tectonic Zone (see the section "Summary of the Grenville Front Tectonic Zone").

DEFORMATION OF THE GRENVILLE PROVINCE

As discussed in the "General Geology" section, rocks of the Grenville Province reflect a complicated history of deformation, plutonism, and metamorphism, culminating in a

Late Precambrian high rank regional metamorphism with accompanying intense deformation. Major deformation along the Grenville Front Tectonic Zone outlasted the late metamorphism, so that the Tectonic Zone is superimposed upon not only Middle Precambrian metamorphism and deformation within the Southern Province, but also Late Precambrian metamorphism and deformation with the Grenville Province. A deformational history in the Grenville Province prior to these Late Precambrian events is suggested by the plutonic history and the complex fold patterns in the gneisses, but except for the relatively late (post-metamorphic) structures within the Tectonic Zone, most of the structural features appear to reflect intense deformation accompanying the late regional metamorphism. Because facing directions are not available in the metasedimentary gneisses, the terms antiform and synform refer to folds closing either in the direction of plunge (antiform) or in the opposite direction (synform).

FOLIATION AND FOLDING OF THE METASEDIMENTARY GNEISSES

Deformation of the metasedimentary gneisses is interpreted largely from the orientation of gneissosity in these rocks. As in the adjacent North Bay area (Lumbers 1971a, p.62), stratiform foliation constitutes the most important set of foliation planes, and spacing of these planes is dependent largely on the original stratification of the gneisses (see, for example, Photos 3 and 4) and is no indication of the intensity of the deformation. Between foliation planes, tabular and prismatic minerals, such as micas and amphiboles, are generally poorly aligned in gneisses derived from sandstone, but are commonly sufficiently well aligned in micaceous gneisses derived from siltstone and argillite to give the rock a schistosity (see Photos 6, 8, and 12). To the east of the Grenville Front Tectonic Zone, recrystallization of the gneisses outlasted deformation, as is common in most regionally metamorphosed terrains, and consequently recrystallized mineral grains and porphyroblasts are free of strain effects and locally cut individual gneissic folia. Within the Tectonic Zone, on the other hand, where deformation outlasted recrystallization, the recrystallized mineral grains and porphyroblasts are generally strained and fractured by late cataclasis, showing conclusively that the last major deformation within the Tectonic Zone is younger than the culmination of the late regional metamorphism. Nevertheless, a few late cataclastic and mylonitic zones, generally less than 100 feet (30 m) wide, are present locally within the metasediments east of the Tectonic Zone, particularly near major faults.

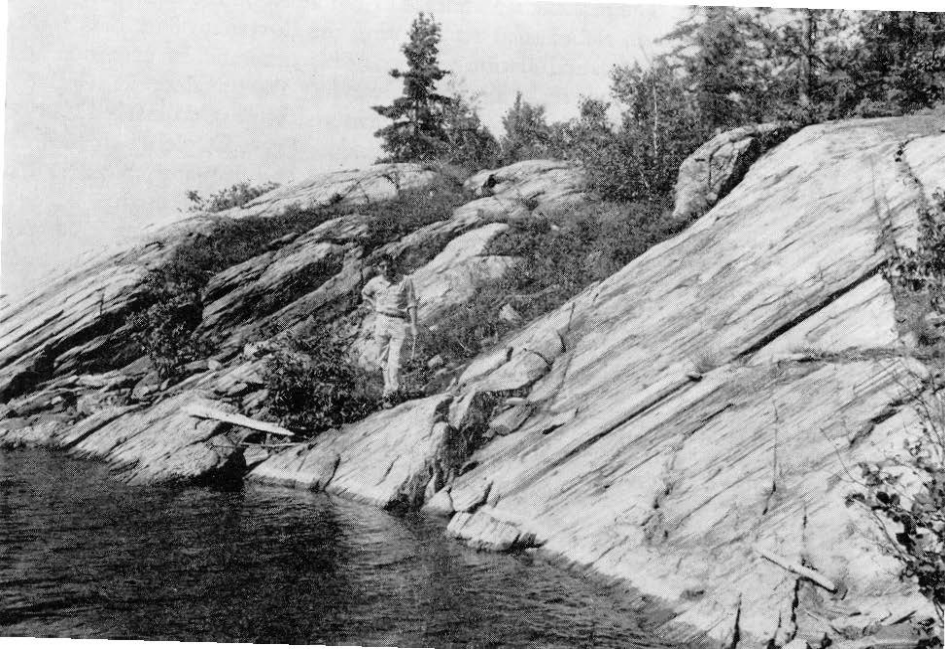
Stratigraphic marker units suitable for tracing major structures in the metasediments are rare, but in places, particularly in the western half and northeastern quarter of the area, sufficiently thick and extensive feldspathic gneiss units and folded granitic sheets intercalated with the biotite gneisses show the complexity of the folds. In general, the folds are isoclinal passive flow folds; gneissosity in the limbs of these folds is parallel to the axial surface. In the apices of the folds, gneissosity traces out the structure, and a schistosity or other foliation parallel to the axial plane is commonly present. Many of the major and minor folds are inclined to recumbent, particularly in the eastern half of the area, and areas where such folds predominate are characterized by irregular structural trends. Thickening and thinning of different lithologic units around folds and the presence of boudins show that, as in the adjacent North Bay area (Lumbers 1971a, p.63), the various metasediments had different ductilities during deformation.

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Complicated dome and basin structures, with the dominant fold axes trending westerly and northerly, characterize the eastern and central parts of the area. Nevertheless, metasediments near the larger plutonic bodies, particularly the Late Precambrian anorthosite suite intrusions, show foliation trends that conform closely to the contacts of these bodies, and locally, folds are inclined toward the youngest bodies. A few dome and basin structures contain small intrusions in their cores that could have influenced the development of the surrounding structures. Many of the mafic rocks and some anorthosite suite stocks are in basin structures, and some of these basin structures were possibly formed by the forceful emplacement of the stocks. In the western part of the area, the dome and basin structural pattern is obscured by the younger structures of the Grenville Front Tectonic Zone. Throughout a broad area extending north from the Cosby batholith in Cherriman, Jennings, Appleby, and Hagar Townships, and in adjacent parts of townships to the west, gneissosity trends and fold axes show a prominent curvature from northwest to northeast, probably because of later deformation along the Tectonic Zone. Southwest of the Cosby batholith, the western limb of a southward-plunging synclinorium that trends northward through western Bigwood, eastern Cox, and central Servos Townships into south-central Burwash Township marks the eastern boundary of the Grenville Front Tectonic Zone. The eastern limb of the synform dips more steeply than the western limb, suggesting that the structure is inclined to the west, in conformity with all other major structures within the Tectonic Zone. These relationships along the eastern side of the Tectonic Zone show that the metasedimentary gneisses are deflected around the northwestern end of the Cosby batholith, which may have acted as a buttress during the late deformation within the Tectonic Zone. Subvertical to vertical foliation attitudes and apparent stretching of stratigraphic units along the eastern limb of the synform near Murdock River suggest that the eastern limb was a zone of major displacement along which strain, caused by the buttressing effect of the batholith during the late deformation, was probably concentrated. Metasedimentary gneisses within the Tectonic Zone are dominated by north to northeast trending foliation and by relatively tight north to northeast trending isoclinal folds inclined to the west and northwest. East to southeast dipping foliation within the Zone steepens progressively toward the Grenville Front Boundary Fault from an average of about 40 degrees near the eastern margin of the Zone to about 60-70 degrees near the Boundary Fault. The Tectonic Zone is also marked by a prominent southeasterly plunging lineation (see below).

STRUCTURAL RELATIONS OF THE FELSIC PLUTONS

Foliation in the Middle Precambrian granitic sheets and batholiths is generally concordant and continuous with foliation in the surrounding metasediments, which suggests that both the granitic rocks and the metasediments have a similar tectonic history. The West Bay and Sturgeon Falls batholiths appear to be complexly folded sheets with a prominent west-northwest elongation, probably due to distortion during deformation. Other Middle Precambrian granitic bodies also appear to be elongated and distorted subparallel to the prevailing foliation trends in their host rocks. In contrast to the early batholithic sheets, the Cosby batholith, the only Late Precambrian batholithic mass in the map-area, appears to be antiformal, and isoclinal folds in the immediately surrounding metasediments are complexly contorted and generally inclined toward the batholith. Late Precambrian batholiths in the adjacent North Bay area show similar structural relations (Lumbers 1971a, p.64). Other smaller stocks of Late Precambrian felsic plutonic



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Photo 31—Typical well developed rodding lineation in a thinly bedded metagreywacke sequence; north shore of Nepewassi Lake near the southern end of Salter Island.

rocks commonly form basin structures as discussed above, and except for a few bodies within the Grenville Front Tectonic Zone, they are less distorted than the earlier granitic intrusions.

LINEATION

Lineation in the map-area is similar to that found in the North Bay area (Lumbers 1971a, p.64), and is most commonly a rodding structure, consisting of a series of parallel columns on foliation planes, about 0.5 inch to 3 inches (1.3 to 7.6 cm) in diameter and up to several feet long (see Photo 31); microscopic mineral elongation along the trend of the columns is rare. In the felsic plutonic rocks, lineation is marked in many places by stretched augen of recrystallized quartz and feldspar and by segregations of mafic minerals in foliation planes, but minerals within the augen and the segregations are generally not elongated. In migmatitic facies of the metasediments and felsic plutonic rocks, lineation is also produced by parallel irregular ellipses and columns of medium- to coarse-grained granitic material and by elongate streaks of mafic minerals.

The prominent southeasterly plunging lineation within the Grenville Front Tectonic Zone is mainly of the rodding variety, and like the dip of the foliation, the lineation steepens in plunge toward the Boundary Fault from an average of about 40 degrees near the eastern margin of the Tectonic Zone to about 60 to 70 degrees at the Boundary Fault. In the Southern Province, the plunge of the lineation in the cataclastic rocks also steepens

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toward the Boundary Fault. The tectonic significance of the lineation requires more study, but available data suggest that, rather than representing the direction of tectonic transport, the lineation and the cataclastic foliation were probably generated by extension and flattening of the Grenville Province rocks along the Boundary Fault against the relatively rigid Southern Province block. This interpretation is favoured because no marked change in structural level or lateral shift is apparent at the Boundary Fault. Dalziel *et al.* (1969) reached similar conclusions not only for these structures in the map-area, but also for similar structures in the Grenville Front region south of the Labrador Trough.

East of the Tectonic Zone, the prominent southeasterly plunging lineation gradually diminishes in intensity, and the plunge decreases to an average of about 10 to 20 degrees in the central part of the area. Within the synform in the southwestern quarter of the area, lineations also appear to decrease in intensity and in plunge, toward the south along the axis of the synform.

In the eastern half of the area, lineation attitudes vary greatly in the dome and basin structures, but in general, the lineations plunge outward from cores of domes and inward toward cores of basins. The plunge of most of the lineations is less than 30 degrees.

FAULTING

In the Grenville Province, the Late Precambrian high rank regional metamorphism obscured evidence of early faulting in the gneisses, but following the culmination of this metamorphism, the gneisses were subjected to extensive late faulting during the Late Precambrian and at least the early Paleozoic. During this tectonism, mafic to ultramafic stocks, diabase dikes, and the Cambrian lamprophyre dikes intruded the gneisses. Much of the faulting, the lamprophyre dikes, and probably most of the diabase dikes appear to be related to a westerly extension of the Ottawa-Bonnechere Graben that cuts across the central and southern parts of the North Bay area (Lumbers 1971a). The Grenville Front Boundary Fault and most of the faults in the Southern Province also were active during the Late Precambrian, but the latest deformation along many of these faults is probably older than that along most of the faults of the Grenville Province.

Most of the faults are marked by swampy depressions forming prominent lineaments readily apparent on air photographs, and outcrops are rare within individual fault zones. The faults are so numerous that only the major ones can be shown on Map 2271 (back pocket); a few of the most persistent faults are named for reference purposes.

EVIDENCE OF FAULTING

That the numerous prominent lineaments coincide with faults is shown by several structural features in rocks exposed either within or nearby the lineaments such as: 1) separation of lithologic contacts; 2) major discordancies in foliation trends; 3) prominent scarps; 4) zones of mylonitization, brecciation, and shearing; 5) locally intense hematitization; 6) quartz vein networks; and 7) diabase and lamprophyre dikes. Inspection of Map 2271 (back pocket) shows that separation of lithologic contacts and discordancies in foliation trends are common to nearly all of the faults, and narrow zones of mylonitization, brecciation, and shearing are common near many of the faults. Many

of the west to northwest trending faults contain intensely hematitized fracture surfaces, especially in the southern and eastern parts of the area. Diabase and lamprophyre dikes are confined mainly to the west to northwest trending faults.

CHARACTER AND AGE OF THE FAULTS

The character of the faults is poorly known because fault surfaces are rarely exposed. In the Grenville Province, two major systems of faulting can be recognized, as in the adjacent North Bay area (Lumbers 1971a): a northeasterly system in which strike orientations range from north-northeast to east-northeast; and a west-northwesterly system in which strike orientations range from west to northwest. The west-northwest system is the dominant direction of faulting, but faults of both systems cut across the bedrock without regard to lithology or foliation trends, and many extend for several miles. Most of the faults are probably high-angle normal faults reflecting block faulting (Lumbers 1971a, p.65), but little data is available to estimate displacement along the faults.

In the western half of the area, the northwesterly trending Murdock River fault is offset by a few westerly trending faults and has an identical trend to a north-northwest system of faults that dominate a large region of the Superior Province about 20 miles (30 km) northwest of the Grenville Province (see Ayres *et al.* 1971b). The fault follows a zone of intense deformation within the gneisses, on the eastern limb of the synform on the southwestern flank of the Cosby batholith. Late diabase is present locally within the fault in Bigwood Township. These relationships suggest that the fault represents reactivation of an older zone of deformation in the gneisses, and the fault could be part of the north-northwest system in the Superior Province, even though it appears to end within the southwestern margin of the Grenville Front Tectonic Zone.

Faulting in the Southern Province portion of the area is discussed by Grant *et al.* (1962), and in general, the west-northwest fault system in the Grenville Province appears to continue into the Southern Province. Nevertheless, some westerly and north-easterly trending faults in the Southern Province, such as the Murray and Creighton faults, appear to either merge with, or be truncated by, the Grenville Front Tectonic Zone and could be part of fault systems older than those within the Grenville Province.

The age of the faults is poorly known, but most were probably active during the Late Precambrian, following the culmination of the high rank regional metamorphism. Some were active during at least at early Paleozoic, and others could follow fracture systems that predate the high rank regional metamorphism. Of the two major fault systems in the Grenville Province, the west-northwesterly system shows most evidence of a long and complicated deformation history. Late Precambrian to possibly early Paleozoic diabase dikes and mafic to ultramafic stocks, and Cambrian lamprophyre dikes are spatially associated with this system, and evidence obtained in the North Bay area (Lumbers 1971a, p.66) suggests that this system underwent repeated deformation from the Late Precambrian to post-Middle Ordovician time. Faults of the northeasterly system are concentrated mainly south of Lake Nipissing in the southeastern quarter of the area and within a narrow zone extending from the western boundary in Attlee Township to the north-eastern end of Nepewassi Lake in Hardy and Appleby Townships. Most of these faults probably represent cross-faults that formed early in the history of the west-northwest system (Lumbers 1971a, p.67).

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Photo 32—View looking northeastward along the Grenville Front Boundary Fault from the Canadian Pacific railway, Neelon Township, with Baby Lake in the background. Cataclastic quartz monzonite of the Chief Lake batholith in the Southern Province underlies the ridge in the left foreground, whereas metasedimentary gneisses of the Grenville Province lie to the right of the rubble at the base of this ridge.

GRENVILLE FRONT BOUNDARY FAULT

The Grenville Front Boundary Fault forms the only mappable boundary for the Grenville Province and is near the northwestern margin of the Grenville Front Tectonic Zone. For the most part, outcrops within the Fault are rare, and the Fault is marked by linear swampy depressions. Nevertheless, in places such as in northern Dill and southern Neelon Townships, almost continuous exposure is present across the Fault and indicates that the Fault is a zone of extreme cataclasis and mylonitization up to 100 feet (30 m) wide (see Photo 32). Quartz vein networks and brecciated zones are found locally within and near the Fault zone, and rocks immediately adjacent to the Fault are generally more intensely cataclastic than elsewhere. That portion of the Fault extending from just east of Alice Lake in southern Neelon Township to the northern boundary of the area was considered by Grant *et al.* (1962) as an easterly continuation of the Murray fault system. Work by the author, on the other hand, suggests that the Murray fault is most likely truncated by the Grenville Front Tectonic Zone and is not continuous with the Boundary Fault. The Murray fault appears to merge with a complex system of northeasterly trending faults that extend through Richard and Daisy Lakes, northwest of the Boundary

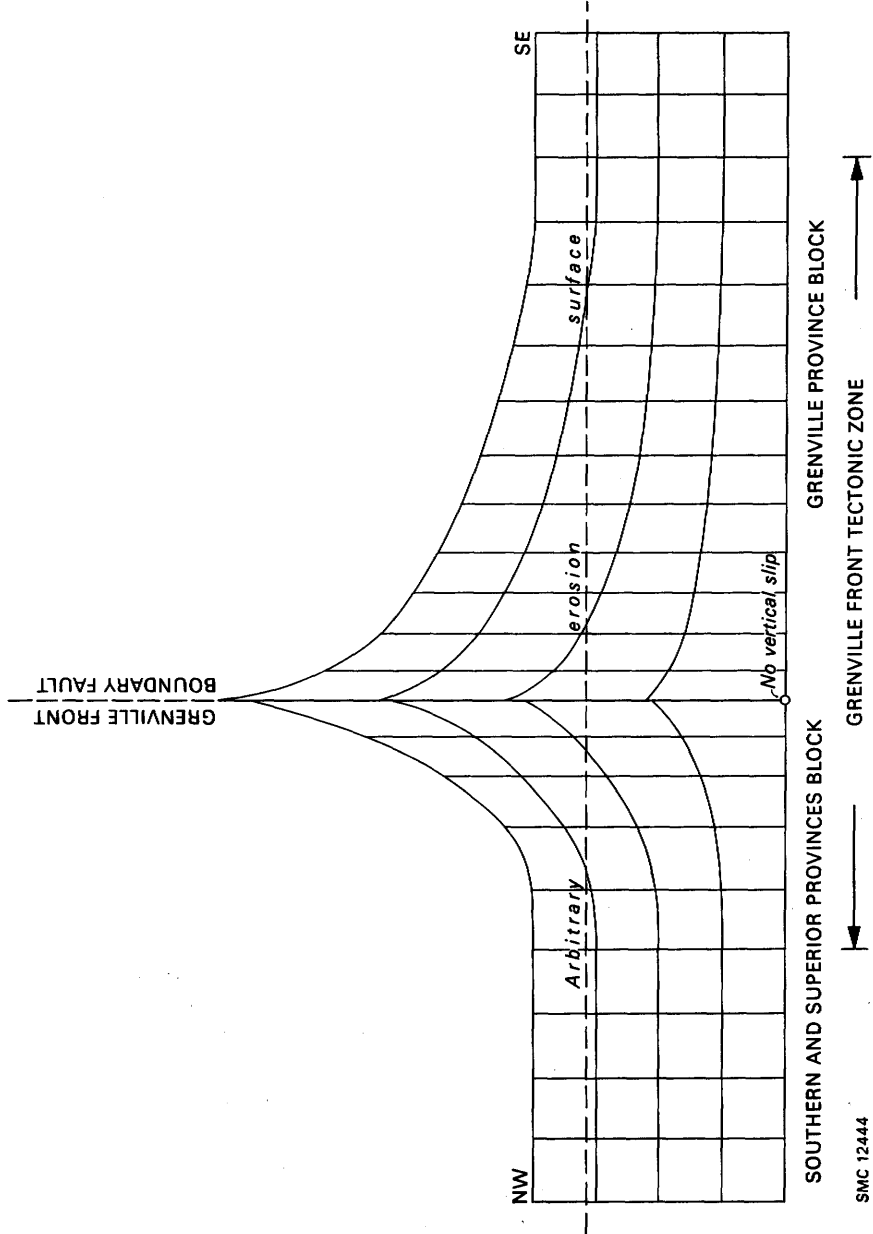


Figure 8—Hypothetical northwest-southeast cross section of the Grenville Front Tectonic Zone, showing the relative magnitude of vertical slip on the Grenville Front Boundary Fault due to differential distortion of an initially rectilinear lattice. Geological parameters used to construct the lattice are discussed in the text. Note that the magnitude of vertical slip on the Boundary Fault decreases with depth and is dependent on the relative amount of strain in rocks of the Southern and Superior Provinces block and the Grenville Province block toward the Boundary Fault.

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Fault, and cannot be traced through this myriad of faults to connect with the Boundary Fault. This northeasterly fault system also truncates the northwest trending olivine diabase dikes, but west of the map-area, these dikes are present on both sides of the Murray fault. Moreover, the Murray fault system shows a marked right-lateral separation (Grant *et al.* 1962, p.19), whereas no such offset is evident along the Boundary Fault, either within the map-area or to the northeast (Lumbers 1971e). Faults of the west-northwest system offset the Boundary Fault in numerous places so that deformation along the Boundary Fault is older than the latest faulting within the Grenville Province. Structures associated with the Grenville Front Tectonic Zone dip southeastward, suggesting that the Boundary Fault also dips in the same direction, but because lineations and the dip of cataclastic foliation steepen markedly at the Boundary Fault, the Fault could dip subvertically.

Pending further detailed structural studies of the entire Tectonic Zone, the degree of displacement along the Boundary Fault remains speculative. Present geological data suggest that the strike-slip component along the Fault may be minor, and a model can be constructed to show that the dip-slip component may also be minor. Such a model must take into account the following major features of the Tectonic Zone: 1) coarsely recrystallized gneisses of the Grenville Province are separated from moderately recrystallized rocks of the Southern and Superior Provinces by the Grenville Front Boundary Fault; 2) for considerable distance on either side of the Boundary Fault, all of the rocks are cataclastic; 3) the magnitude of strain is greater in rocks of the Grenville Province than in rocks of the Southern and Superior Provinces; and 4) the strain is distributed over a much wider zone in the Grenville Province than in the Southern and Superior Provinces.

The model that best satisfies these restrictions is given in Figure 8. The model shows the distortion of a rectilinear lattice across a hypothetical northwest-southeast cross section of the Grenville Front Tectonic Zone with the Southern and Superior Provinces block to the northwest, and the Grenville Province block to the southeast. In order to simplify the model, the Boundary Fault, which in reality probably curves southeastward with depth, is shown as vertical. The relative degree of strain in rocks of both blocks toward the Boundary Fault is shown by the distortion of the arbitrary grid lines. It is evident from the model that rocks of the Grenville Province moved upward with respect to rocks of the Southern and Superior Provinces, but because rocks of the Southern and Superior Provinces underwent considerable strain near the Boundary Fault, the magnitude of vertical slip on the Fault is relatively small. Moreover, the amount of vertical slip decreases with depth, and eventually a point is reached where there is zero vertical slip due to load pressure. An arbitrary erosion surface is also shown; this is placed at a relatively high crustal level because geological relationships in the Southern and Superior Provinces block suggest that this block is not deeply eroded. The model can be further refined and tested by obtaining detailed measurements of strain in the Tectonic Zone on both sides of the Boundary Fault, and with this data, a quantitative estimate of the vertical slip on the Fault may be possible.

The Boundary Fault most likely follows an older zone of weakness that was initiated early in the tectonic history of the area along the northwestern margin of the trough of eugeosynclinal metasediments, but present data are insufficient to speculate on the nature of early faults within the Tectonic Zone. An adequate explanation of the contrast in metamorphism across the Boundary Fault also must await further data, but perhaps this older zone of weakness was also a zone of high heat flow.

SUMMARY OF THE GRENVILLE FRONT TECTONIC ZONE

The northwestern boundary of the Grenville Province is marked by a complex tectonic zone up to 20 miles (30 km) across which is superimposed upon earlier structures in the Grenville, Southern, and Superior Provinces (Lumbers 1971b). The boundaries of the Zone are gradational, and in general, the Grenville Front Tectonic Zone is characterized by northeasterly trending cataclastic foliation and by a prominent southeasterly plunging rodding lineation. Within the Burwash area, the southeastern margin of the Tectonic Zone roughly coincides with the western limb of a synform trending north-northwest to north along the southwestern flank of the Cosby batholith to central Burwash Township, from which point the margin trends northeastward through Nepewassi Lake and western Hagar Township. Near the northwestern margin of the Tectonic Zone, high metamorphic rank gneisses of the Grenville Province are in fault contact with low metamorphic rank rocks of the Southern Province, and this fault, termed the Grenville Front Boundary Fault, provides the only mappable boundary for the Grenville Province. Macroscopic cataclasis and mylonitization extend up to 2 miles (3 km) into the Southern Province northwest of the Boundary Fault, and metasediments of the Huronian Supergroup adjacent to the Boundary Fault are intensely deformed, regionally metamorphosed to the greenschist facies, and in many places are slightly overturned toward the northwest by relatively tight folding along northeasterly trending axes. The Tectonic Zone formed as a result of major deformation that apparently culminated after the climax of the Late Precambrian high rank regional metamorphism in the Grenville Province between 1,400 and 1,200 million years ago and before the emplacement of late pegmatite dikes, about 1,000 million years ago.

Although unravelling the origin of the Tectonic Zone requires further work, data obtained during the present study and by previous workers suggest that the Zone evolved over a long period, possibly extending back into earliest Middle Precambrian time. Stratigraphic relationships of Middle Precambrian metasediments in both the Southern and Grenville Provinces within the Tectonic Zone suggest a trough, filled with eugeosynclinal greywacke and associated argillaceous and silty rocks, probably developed along what is now the northwestern margin of the Grenville Province between 2,500 and 2,150 million years ago. This trough subsequently influenced the location and development of the Tectonic Zone and may have formed in part along an ancient Early Precambrian continental margin. The trough was the locus of Middle to Late Precambrian tectonic activity, which culminated in the formation of the present Tectonic Zone during the Late Precambrian. Nipissing diabase intrusions and granitic rocks of the Killarney batholithic complex are localized near the northwestern margin of the trough, and relatively late mafic to ultramafic stocks and sheets are present throughout the Tectonic Zone within the Grenville Province; these indicate tectonism both before and after the major deformation along the Zone. During the Middle Precambrian, pegmatite dikes were emplaced within the trough metasediments and suggest that a Middle Precambrian high rank regional metamorphism and deformation may have affected the structure. Late Precambrian regional metamorphism in the Grenville Province was apparently more intense within the Tectonic Zone than elsewhere, and appears to increase in intensity immediately southeast of the Boundary Fault. Rocks of the Southern Province adjacent to the Boundary Fault were also metamorphosed during the Late Precambrian, but mineral assemblages indicate that the intensity of this metamorphism did not exceed the older Middle Precambrian greenschist facies meta-

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morphism. In spite of the contrast in metamorphic grade across the Boundary Fault, available stratigraphic and structural data suggest that rocks of the Grenville Province block were flattened against rocks of the Southern Province block with only minor relative vertical and horizontal slip along the Boundary Fault.

OTTAWA-BONNECHERE GRABEN

The Ottawa-Bonnechere Graben (Lumbers 1971a, p.67-68) is part of an extensive rift system that includes the Mattawa, Ottawa, St. Lawrence, Saguenay, and Champlain valleys and the St. Lawrence or Cabot trough. This rift system has had a long and complicated history extending back to at least the Late Precambrian, and some segments are seismically active today. The Graben extends across the central and southern parts of the North Bay area through Lake Nipissing, where Paleozoic outliers, four carbonate-alkalic rock complexes of Cambrian age, and regionally developed, Cambrian lamprophyre dikes are associated with the structure. The northern margin of the Graben is marked by the Mattawa and Crystal Falls faults, which extend northwestward to the north of the Burwash area (Lumbers 1971e), whereas the southern part of the Graben is marked by a broad zone of west-trending, *en echelon* block faults. The Playfair Lake fault and other westerly trending faults near the French River in the southern part of the map-area are a westerly continuation of this fault system which, west of the map-area, cuts across the Grenville Front Tectonic Zone and appears to merge with westerly striking faults along the North Shore of Lake Huron (see Ayres *et al.* 1971b).

Between the Ottawa River and Lake Nipissing, the throw on the various faults along the margins of the Ottawa-Bonnechere Graben decreases from east to west, and within the map-area, Paleozoic outliers and scarps with high relief appear to be absent, suggesting that the Graben loses its identity near the western boundary of the North Bay area. Nevertheless, regionally developed lamprophyre dikes associated with the Graben are present sparingly in the northeastern part of the map-area, and perhaps many of the faults of the west-northwest system are related to a relatively old segment of the Graben that has remained dormant since Late Precambrian or earliest Paleozoic time. The prominent topographic depression through Lake Nipissing and the French River area, discussed above in the "Physiography" and "Pleistocene" sections, appears to be a pre-Pleistocene feature and may be a remnant of an early structure related to the Graben.

GEOPHYSICAL DATA

Regional gravity surveys (Popelar 1971) and aeromagnetic surveys (GSC 1965a; 1965b; 1965c; 1965d) covering the area outline many of the major structural features. A positive regional gravity anomaly dominates all but the western and southeastern parts of the area and appears to reflect the distribution of the anorthosite suite intrusive rocks. Some of the major faults, such as the Murdock River fault, have a gravity expression, but others, including the Grenville Front Boundary Fault, have no apparent gravity expression.

Comparison of the aeromagnetic data to the bedrock geology shows that generalized isomagnetic contours follow regional structural trends in the gneisses of the Grenville Province but do not reflect the regional gravity anomaly. On a regional scale, the northeastern corner of the area, broad zones to the east and north of the Cosby batholith, and the northwestern part of the Grenville Front Tectonic Zone are characterized by relatively high magnetic intensities; these areas are underlain mainly by metasediments and minor granitic rocks. Some faults and diabase dikes are characterized by linear, mild positive aeromagnetic anomalies, and a few faults marked by intense hematitization are characterized by mild negative aeromagnetic anomalies. Felsic anorthosite suite rocks of the Cosby batholith locally show relatively high magnetic intensities, but many of the anorthosite and tonalite-bearing bodies show relatively low magnetic intensities. Some areas containing several small bodies of metadiabase are characterized by relatively high magnetic intensities, and mild positive aeromagnetic anomalies are centred over a few of the mafic stocks. The most intense aeromagnetic anomaly in the area is a positive anomaly with a maximum relief of about 1,200 gammas and is centred over the southern part of the Halifax pluton composed mainly of granitic rocks with inclusions of metagabbro and quartzose metasediments.

ECONOMIC GEOLOGY

The Burwash area contains a variety of metallic and non-metallic mineral deposits, but the only mineral production recorded is mainly sand and gravel from Pleistocene sediments, metamorphosed orthoquartzite and minor building stone from some of the gneisses of the Grenville Province, and several thousand tons of feldspar and a small quantity of mica from late pegmatite dikes. In 1969, mineral production was confined to sand and gravel used locally for construction purposes, and to building stone.

Metallic mineralization consists mainly of iron, copper, nickel, uranium, and rare earth minerals, but minor concentrations of pyrite and pyrrhotite are found. Most of the known concentrations of iron are associated with feldspathic and quartzose metasandstones on the southwestern flank of the Cosby batholith, but minor concentrations are present sparingly in one anorthositic intrusion and in a few late pegmatite dikes. Copper and nickel mineralization is confined to the Nipissing diabase intrusions in the Southern Province, to the Wanapitei complex just southeast of the Grenville Front Boundary Fault, and to the late mafic to ultramafic stocks within the Grenville Province. Minor uranium and rare earth mineralization is present in some of the late pegmatite dikes of the Grenville Province.

Non-metallic mineralization consists mainly of feldspar, mica, kyanite, silica (in the form of metamorphosed orthoquartzite), industrially useful rocks, sand and gravel, minor corundum and graphite, and traces of apatite and vermiculite. Feldspar and mica of commercial interest are associated with the late pegmatite dikes, and kyanite is locally abundant in some of the metasedimentary gneisses of the Grenville Province near the Boundary Fault. Corundum and most of the graphite are confined to the alkalic complex in Bigwood Township, and apatite is rarely concentrated in anorthositic rocks. Minor vermiculite is found in weathered metasedimentary gneisses in the southeastern corner of Hawley Township.

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Although only minor mineral production has been reported from the bedrock of the area, many of the gneisses of the Grenville Province are potential sources of building stone, and further exploration of some mafic intrusions, particularly within the Grenville Front Tectonic Zone, could reveal additional copper and nickel mineralization.

PROSPECTING AND MINING ACTIVITY

Recorded data concerning mineralization in the area date back to the 1800s and the initial exploratory surveys of Bigsby (1821), Murray (1849; 1857a; 1857b), Bell (1891; 1898), and Barlow (1899; 1907), but active prospecting was not initiated until the late 1800s and early 1900s, following the discovery of copper near Parry Sound and in the Sudbury area. During this period, copper mineralization was discovered in the Memesagamesing Lake stock (see Lumbers 1971a), a few workings were opened elsewhere in the area in a vain search for copper, and a few mica and feldspar deposits in late pegmatite dikes were explored. From 1909 to 1923, the Canadian Copper Company operated a quarry in metamorphosed orthoquartzite in southeastern Dill Township (number 9 on Map 2271). This material was used as a silica flux in smelting copper and nickel ores at Sudbury.

During the 1920s, several late pegmatite dikes were explored for feldspar and mica, and several thousand tons of feldspar were quarried from a few dikes. Prospecting activity declined in the 1930s, although small quantities of feldspar were produced from a few quarries established in the previous decade. Following the Second World War, interest in the area was renewed, and additional feldspar production occurred in the late 1940s. During the uranium rush of the 1950s, considerable attention was given to the late pegmatite dikes of the region, particularly the large ones that were quarried for feldspar, and minor uranium and rare earth mineralization were discovered, but not in commercial quantities.

During the 1950s and 1960s, copper and nickel mineralization in the Nipissing diabase intrusions of the Southern Province and in the Wanapitei complex in the Grenville Province were explored by surface trenching and by diamond drilling, but no mineralization of commercial interest was found. Some of the quartzose metasediments of the Grenville Province have been explored in recent times as possible sources of silica, but no commercial production has been achieved.

Recent interest in the area has focused upon copper and nickel mineralization in the Wanapitei complex and upon building stone.

METALLIC MINERALIZATION

Copper and Nickel

Copper and nickel mineralization is associated with the Nipissing diabase intrusions in the Southern Province, and is found in the Wanapitei complex and the Memesagamesing Lake stock within the Grenville Province. Several mineralized zones are present in the Memesagamesing Lake stock but all are within the North Bay map-area, and are discussed in the North Bay report (Lumbers 1971a, p.70). Traces of chalcopyrite

were found by the author in some of the metagabbroic and anorthositic intrusions of the Grenville Province and in a few of the late ultramafic bodies in the Grenville Front Tectonic Zone. According to D.H. Cross, who owns the farm on which the small ultramafic body in southwestern Cleland Township occurs, two old shafts near the northern end of the body were put down to depths of 90 (27 m) and 35 feet (11 m) in 1922, in the search for copper mineralization. Only traces of pyrite and pyrrhotite were found by the author in a few pieces of broken rock on a dump near the shafts. From available data, the various mafic and ultramafic intrusions appear to offer the only targets in the area for concentrations of copper and nickel. The greatest concentrations known are in the Nipissing diabase intrusions and in the Wanapitei complex, but exploration work recorded to date has failed to outline mineralization in economic amounts.

DESCRIPTION OF DEPOSITS

Deposits Associated with Nipissing Diabase

Two copper and nickel deposits in Nipissing diabase near the northern boundary of the map-area in Neelon Township are described by Grant *et al.* (1962, p.22) as follows:

A gossan, 250 feet by 60 feet [75 by 18 m] in surface extent, occurs in gabbro near the north boundary of lot 12, concession III, Neelon Township. The best sulphide showing is in a test pit. A grab sample, taken from the pit by J.A. Grant, assayed 2.41 percent nickel and 0.31 percent copper.

A small nickel-copper occurrence in the southeast quarter in the north half of lot 2, concession IV, Neelon Township was explored by Arcadia Nickel Corporation Limited in 1956. One short drillhole was put down and cut 10.3 feet [3.1 m] of core that averaged 0.56 percent copper and 0.54 percent nickel. A test pit in the northwest quarter of the north half of lot 1, concession III [this is marked on Map 2271] also shows a little nickel-copper mineralization.

Deposits Associated with the Wanapitei Complex

Some exploration work has been carried out in the southeastern part of the Wanapitei complex, near the contact with the anorthositic intrusion in the southwest corner of Dryden Township. Rock exposure is poor except next to the anorthositic body, and most of the work performed has been by diamond drilling and geophysical surveys. A selected sample from a small occurrence of sulphide minerals in gabbro of the complex about 2 miles (3 km) south of Wanapitei village in Dryden Township was collected by J.A. Grant (Grant *et al.* 1962, p.22) and gave upon assay 0.93 percent nickel and 0.22 percent copper. According to assessment work filed with the Resident Geologist's office, Ontario Ministry of Natural Resources, Sudbury, W.A. Perkins put down two diamond drill holes in 1952 within his claims in lots 9 to 11, concessions I and II, Dryden Township, but no data concerning mineralization are reported. In 1965, PCE Explorations Limited examined a block of 44 claims and eight optioned claims, covering the southeastern part of the complex in Dryden Township, by geophysical surveys and by diamond drilling. From logs of eight diamond drill holes submitted as assessment work, only minor disseminated pyrrhotite, pyrite, and chalcopyrite were encountered in the drill core, and assay results indicate concentrations of less than 1 percent copper and less than 1 percent nickel. In 1971, PCE Explorations held seven claims in lots 10 and 11, concession I, Dryden Township.

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Other noteworthy mineralized areas within the Wanapitei complex seen by the author are west of Highway 537 near the northeastern margin of the complex, and near the northwestern margin. Both areas are indicated as sulphide mineralization on Map 2271 (back pocket) and are gossans in sheared gabbroic rocks containing minor disseminated pyrite, pyrrhotite, and chalcopyrite. The gossan near Highway 537 is irregularly distributed over an area of a few hundred square feet and has been drilled, but data concerning this work was not available to the author. Sulphide mineralization near the northwestern margin of the complex is within a prominent northeast-trending shear zone, up to about 150 feet (45 m) wide, that can be traced intermittently along strike for about 3,600 feet (1100 m). The zone is shown on Ontario Department of Mines Map 2017 (Grant *et al.* 1962), but because the zone is a weathered gossan, subsurface sampling would be required in order to properly explore the mineralization.

As pointed out by Grant *et al.* (1962, p.10), and from the author's experience, some phases of the complex closely resemble various facies of the nickel irruptive of the south range at Sudbury. Although the Wanapitei complex is younger and more completely recrystallized and deformed than the nickel irruptive, further studies could show that it is petrologically similar. This possibility, combined with evidence of widespread copper and nickel mineralization, suggest that the intrusion is most worthy of further exploration work.

Iron

Minor concentrations of iron-titanium oxide and iron oxide minerals are present sparingly within the Grenville Province and are found in three major types of deposits: 1) metasedimentary deposits, in which thin discontinuous layers and disseminated grains of specularite and magnetite were probably derived from originally ferruginous sedimentary rocks; 2) probable magmatic segregations of iron-titanium oxide minerals in anorthositic rocks; and 3) minor concentrations of magnetite in late pegmatite dikes. Only a few of the known iron concentrations have been explored.

As mentioned previously in the discussion of feldspathic gneiss in the "General Geology" section, fine- to medium-grained, dark grey, quartz-potassic-feldspar-plagioclase gneiss, containing up to 12 percent specularite and up to 10 percent biotite, forms relatively thin units intercalated with muscovitic and quartzose gneiss at two localities near Jamot in northwestern Mason Township. These deposits constitute the largest concentrations of iron found in the area, but both are too small to be of economic interest. At one of the localities in northeastern Bigwood Township, the ferruginous gneiss occurs on the west side of an island in the North Channel of French River and forms a layer up to 10 feet (3 m) thick that contains a few massive specularite lenses up to 2 feet (0.6 m) long. At the second locality, in southeastern Delamere Township, ferruginous gneiss forms a complexly contorted layer, up to 300 feet (100 m) across and about 600 feet (200 m) long, on the southern side of a hill just north of the road junction on the northeastern side of Rangers Bay. The unit strikes northwest and dips about 70 degrees northeast. A few, thin biotite-rich meta-argillite layers are intercalated with the ferruginous gneiss. Elsewhere in the map-area, feldspathic gneiss units locally contain sparsely disseminated magnetite porphyroblasts which generally form less than 5 percent of the rock, but locally within one unit (near the northern boundary of the area in Badgerow Township) the porphyroblasts form 10 to 15 percent of the rock.

Near the northeastern corner of Hendrie Township, a shallow trench about 8 feet long, 2 feet wide, and up to 2 feet deep (2.5 by 0.6 by 0.6 m) was blasted into calc-silicate gneiss containing garnet porphyroblasts up to 6 mm across, minor disseminated magnetite, and a few minor stringers of massive magnetite associated with thin, discontinuous lenses of quartz. The trench was opened by Edward and Maurice Rivett of St. Charles who also explored the deposit by a 25 foot (7.6 m) long vertical diamond drill hole. The deposit could represent a very thin unit of iron formation intercalated with the calc-silicate gneiss.

Minor pods and lensoid masses rich in magnetite and ilmenomagnetite are present locally within the elongate anorthositic body in southwestern Dryden Township. The iron-titanium oxide masses are subparallel to the foliation in the host anorthositic rock and possibly represent primary magmatic segregations of iron-titanium oxide minerals.

Near the western boundary of Springer Township, about ¼ mile (.4 km) north of Highway 17, a late pegmatite dike in granitic rocks of the Sturgeon Falls batholith contains up to 10 percent disseminated magnetite crystals up to 1.5 cm across. The dike ranges in width from 2 to 6 inches (5 to 15 cm) and is up to 150 feet (45 m) long, and is composed mainly of perthite and quartz with inclusions of amphibolite. The mineralization has been explored by a few shallow pits. A similar magnetite-bearing late pegmatite dike, also explored by a shallow pit, is present in northeastern Servos Township near the south end of a small lake east of the road to Trout Lake.

Uranium and Rare Earth Minerals

Uranium and rare earth minerals occur as minor accessory constituents in some of the late pegmatite dikes within the Grenville Province. Most of the dikes containing these minerals are zoned with a quartz-rich core and are commonly reddish due to intense hematitization. Except for minor allanite in a few of the late pegmatite dikes in the eastern half of the area, most of the known occurrences of these minerals are in dikes within or near the eastern margin of the Grenville Front Tectonic Zone. Allanite is the most common uranium- and rare-earth-bearing mineral, but one dike on the north shore of Graham Lake in Servos Township (number 15 on map) contains relatively abundant euxenite-polycrase. Traces of euxenite, uranium-bearing pyrochlore, allanite, and ellsworthite occur in the dike worked by Wanup Feldspar Mines Limited (16 on map) in southeastern Dill Township (Traill 1970, p.207, 447; Lang *et al.* 1962, p.258), and rare earth minerals have been reported in the workings of the McMaster deposit (8 on map) in Dryden Township (Lang *et al.* 1962, p.259). All of these dikes have been worked for feldspar and are described below under "Feldspar and Mica". Toddite, a variety of uranium-bearing columbite, is reported by Traill (1970, p.161) in old feldspar workings in the northwest corner of lot 4, concession III, Dill Township. No workings were found at this locality by the author, and the closest workings are those of Elizabeth Feldspar Mines Limited, about 1 mile (1.6 km) to the east.

Minor concentrations of allanite in late pegmatite dikes were found by the author at two localities in the western half of the area: one is on the western side of Highway 69 in southeastern Dill Township, and the other is on the south side of the Main Channel of French River in southern Bigwood Township. In Dill Township, several small, irregularly shaped dikes of late pegmatite cut across gneissic granitic rocks of the Wanup pluton. Blades of allanite up to several inches long locally comprise about 15 percent of

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the dikes. In Bigwood Township, crystals and narrow seams of allanite are present in a small intensely hematitized pegmatite dike that is rich in red alkalic feldspar. The occurrence is similar to some of the allanite deposits of the Atlin-Ruffner occurrence to the south of the map-area, described by Hewitt (1960, p. 186-188).

A few shallow pits have been blasted in granitic rocks near Rae Lake in Bigwood Township in the search for uranium mineralization (Hewitt 1960, p.186). The granitic rocks exposed in the pits contain a few scattered crystals and veinlets of allanite, but pyrochlore reported to occur in the pits could not be found either by Hewitt (1960, p.186) or by the author.

According to assessment work records filed with the Resident Geologist's office, Ontario Ministry of Natural Resources, Sudbury, in 1956, C.W. Wilson examined an area of late pegmatite dikes in Scollard Township by surface trenching and 10 diamond drill holes. Most of the work reported was performed within lot 3, concession IV, Scollard Township, near the southern shore of the North Channel of French River, just south of the eastern end of the Pine Cove pluton. A shallow pit, 8 feet by 2 feet, and about 3 feet deep (2.5 by 0.6 by 1 m), blasted into a narrow late pegmatite dike on the western shore of a bay was the only workings seen by the author. A few scattered allanite crystals are present in the dike, which is composed mainly of pink alkalic feldspar and minor quartz. Details concerning the drilling were not available to the author.

Minor Sulphide Mineralization

A shallow pit has been blasted into metagabbro near the eastern margin of the small mafic stock in west-central Springer Township in the northeastern corner of the area. Minor disseminated pyrite and pyrrhotite are visible in the pit and in broken rock fragments near the pit. Rusty-weathering biotite-rich metasediments exposed on the northern shore of Millerd Lake in southwestern Secord Township contain a few quartz stringers and pyrite and pyrrhotite as sparsely disseminated grains and as minor blebs and streaks associated with the quartz stringers. A shallow pit has been blasted into the mineralized zone.

NON-METALLIC MINERALIZATION

Apatite

Minor concentrations of apatite in the St. Charles anorthosite in northwestern Casimir Township have been explored by a shallow pit blasted into coarse-grained anorthosite near the central part of the intrusion. The pit, which is about 400 feet (120 m) west of the road leading south from St. Charles village and 1 mile (1.6 km) east of Highway 535, exposes up to 10 percent coarse-grained, pale green apatite crystals and aggregates disseminated in the anorthosite. Elsewhere in the area apatite occurs only as a minor accessory mineral and is most common in the late pegmatite dikes and in anorthositic, gabbroic, and ultramafic intrusions.

Corundum

Corundum occurs in nepheline and associated alkalic syenite in lot 10, concession II, Bigwood Township, and small test pits were sunk at this locality (Hewitt 1960, p.186).

Feldspar and Mica

Several thousand tons of feldspar and small quantities of muscovite and biotite have been quarried from a few of the late pegmatite dikes. The micas occur as small books generally less than 2 feet (60 cm) in size, and the quality is poor. The pegmatite dikes explored for feldspar and mica are among the largest and most persistent found in the area; most are within or nearby the Grenville Front Tectonic Zone. They strike westerly to northwesterly, parallel to major faults of the west-northwest system, and their host rocks are either metagabbro, or metasediments containing numerous layers of hornblende gneiss or quartzose gneiss.

DESCRIPTION OF DEPOSITS

Lot 9, Concession II, Dryden Township Industrial Minerals Corporation (8)

In lot 9, concession II, Dryden Township, a large lenticular late pegmatite dike was quarried for feldspar in the 1920s. The dike is on the western side of Highway 537 about 1.5 miles (2.4 km) south of Wanapitei village, but the old workings and the extent of the dike are obscured by overburden and by relocation of the highway. The workings are known locally as the McMaster Mine and are described by Spence (1932, p. 60-61) as follows:

A large dyke is exposed on this lot, but its strike and extent are obscured by overburden. At the pit, the exposure has a width of 125 feet [38 m]. The dyke is composed of segregated masses of quartz, pink spar, and black mica, quartz predominating. These segregations in the west side of the pit exhibit the character of alternating, vertical, vein-like zones, each of which carries clean mineral. The spar zones vary from 3 to 15 feet [1 to 5 m] wide.

The deposit was first worked in 1922 by Industrial Minerals Corporation, of Toronto, and later by Mr. J. G. Anderson, of Lucknow, Ont. Work was confined to a single open-cast pit, 90 by 90 by 25 feet [27 by 27 by 8 m] deep, and shipments are stated to have totalled about 1,500 tons. The spar was conveyed to Wanapitei station, on the Canadian Pacific railway, by a tramway 1¼ miles [2 km] long. The mine has been idle since 1924 and all the plant has been dismantled.

Lots 11 and 12, Concession IV, Cleland Township Weisman Feldspar Company (17)

A late pegmatite dike straddling the boundary between lots 11 and 12, concession IV, Cleland Township, trends northerly across a metagabbro sill-like intrusion, just north of the Canadian National railway about 1 mile (1.6 km) north of St. Cloud village. The dike pinches and swells along strike and is up to 35 feet (10 m) wide and can

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be traced along strike for about 300 feet (90 m). Spence (1932, p.59) indicates that the dike was quarried for feldspar in the 1920s and describes the workings as follows:

A 35-foot [10 m] dyke of coarse granite carrying much black and white mica occurs 500 feet [150 m] east of the Canadian National railway track, one mile [1.6 km] north of St. Cloud station. The dyke carries very little clean spar. It was worked between 1922 and 1924 by the Weisman Feldspar Company, of Sudbury, and others, who ran an open-cut, 125 by 15 by 30 feet [38 by 5 by 9] deep at the inner face, along the deposit and put in a tramway and siding. It is reported that about 20 cars were shipped from the property, which has been idle since 1924.

The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lot 12, Concession III, Cleland Township

On the west side of the road leading north from Wanup, about one-tenth of a mile (200 m) north of the village in lot 12, concession III, Cleland Township, an irregularly shaped dike of late pegmatite exposed on the side of a rocky ridge has been explored by blasting a shallow pit. The dike cuts across narrow metagabbro sills in biotite gneiss and consists of quartz, pink alkalic feldspar, and accessory muscovite, biotite, and garnet. Local segregations of quartz are present, but the dike does not appear to be zoned. The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lot 12, Concession II, Cleland Township

Oscar Pelto (13)

On the east side of the Canadian Pacific railway just south of the junction with the Canadian National railway in lot 12, concession II, Cleland Township, a lensoid late pegmatite dike up to 20 feet (6 m) wide and traceable for about 50 feet (15 m) along strike has been quarried for feldspar and mica. Spence (1932, p.92) indicated that the dike was worked in 1928 when one car load of feldspar was shipped. According to J. D. Hudson, a resident of the area since 1909, 4 car loads of feldspar and some mica were shipped from the deposit between 1935 and 1936, by a Mr. Oscar Pelto.

Intrusive into metagabbro, the dike trends westerly and was worked by an open-cut about 30 feet (9 m) long, up to 15 feet (4.6 m) wide, and with a 14-foot (4.3 m) face. The dike pinches out about 10 feet (3 m) east of the open-cut, but a few smaller dikes are present in the metagabbro near the cut. Quartz, pink alkalic feldspar, and muscovite constitute most of the dike, but minor biotite and accessory hematite and apatite are present locally. The dike contains a quartz-rich core, and in the face of the open-cut, muscovite crystals up to 1 foot (30 cm) across can be seen. The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lots 1 and 2, Concessions III and IV, Dill Township

Elizabeth Feldspar Mines, Limited (7)

In lots 1 and 2, concessions III and IV, Dill Township, a relatively large lensoid body of late pegmatite was quarried for feldspar during 1925 and 1926 by Elizabeth

Feldspar Mines Limited, of Toronto. Shipments of about 6,000 tons are reported to have been made (Spence 1932, p.60). The pegmatite body trends west-northwest and is about 300 feet (90 m) long and up to 110 feet (34 m) wide. The body is intrusive into quartzose metasandstone cut by metagabbro which locally contains garnet crystals up to 2 inches (5 cm) across. Spence (1932, p.60) described the dike and the workings as follows:

The rock contains a large amount of disseminated quartz, and black and white mica in large, thin plates. There is also a little garnet present. The mixed character of the rock necessitated careful cobbing and a gasoline-driven crushing and picking plant was installed in 1926 in a building erected at the pit entry. . . . Rock was conveyed to this plant by inclined skipway, sledged and fed to a jaw crusher, from which it passed to a 20-foot [6 m] picking-belt. The spar was trammed to a loading chute at the mine siding on the Canadian Pacific railway, one fourth mile [.4 km] distant.

Work was confined to a single opening consisting of a 15-foot [5 m] inclined cut carried 150 feet [45 m] into the face of a low knoll and terminating in a large chamber 60 by 50 by 30 feet [18 by 15 by 9 m] high. The mine has been idle since 1926.

In addition to the workings described by Spence, a small open-cut is present in the low knoll about 20 feet (6 m) south of the main workings, and some material was removed from the deposit in 1966 for display purposes at Expo, the 1967 World's Fair held in Montreal.

Muscovite and biotite crystals up to 3 feet (1 m) across occur in the dike and coarse graphic intergrowths of quartz and alkalic feldspar are common, but the dike is not obviously zoned. A few apatite and zircon crystals occur in quartz-rich segregations within the dike near the entrance to the main open-cut, and some hematite and smoky quartz are present throughout the dike. Locally, the dike contains small, intensely hematitized patches which are slightly radioactive when tested with a geiger counter, but for the most part, the dike is non-radioactive.

The contact of the dike with the host quartzose metasandstone is steeply dipping and sharp, with only slight contact metamorphic effects, chiefly minor feldspathization of the metasandstone up to a few inches from the contact. A few inclusions of the metasandstone are present in the dike in the knoll above the main workings.

Lot 2, Concessions II and III, Dill Township

A narrow zone of several small northwesterly striking pegmatite dikes is present on the top of a rocky ridge underlain by garnetiferous biotite gneisses in lot 2, near the boundary between concessions II and III, Dill Township, about ¼ mile (.4 km) northeast of the deposit worked by Wanup Feldspar Mines Limited (see below). The dikes pinch and swell along strike and are generally less than 6 feet (2 m) wide, but one relatively large dike, about 15 feet (4.6 m) wide, has been explored by a pit, 8 feet (2.5 m) square and about 6 feet (2 m) deep; a few other shallow pits have been blasted into the dike near the main pit. The dikes are zoned with a quartz-rich core and are composed mainly of quartz, alkalic feldspar, and minor muscovite, biotite, and garnet. A few crystals of allanite are present in broken rock fragments near the main pit. The dikes were tested by the author with a geiger counter for radioactivity and although a few readings slightly above background were recorded, most of the dikes appear to be non-radioactive.

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Lots 2 and 3, Concession II, Dill Township

Wanup Feldspar Mines, Limited (16)

In lots 2 and 3, concession II, Dill Township, a large, irregularly shaped late pegmatite dike intrusive into metagabbro was quarried extensively for feldspar between 1925 and 1928 by Wanup Feldspar Mines, Limited. Spence (1932, p. 59-60) described the dike and the workings as follows:

The mine on this lot is the largest operation for feldspar in the Sudbury-Parry Sound region. It was opened in 1925 by Wanup Feldspar Mines, Ltd., of Lucknow, Ont., who continued work until 1928, when flooding of the pit from an adjacent swamp caused the abandoning of operations. A total of about 10,000 tons of high-grade spar is stated to have been shipped.

The deposit consists of a very large dyke that carried its best and cleanest spar in the south portion of the single pit opened on it. At the north end of this opening, the dyke exhibits predominantly graphic granite character and, in addition, carries a wide, central vein of white mica. This mica occurs as a mass of large, intergrown crystals, up to 12 inches [30 cm] across, occupying a zone that measures 25 feet [8 m] across at its widest and that would be capable of yielding a large tonnage. The crystals, however, would yield very little good sheet mica, since they are of "wedge" type, splitting into plates of unequal thickness. The mica is also spoilt for sheet purposes by "tangle-sheet" structure, which impairs splitting quality, and is rather heavily spotted. It is, therefore, only suitable for grinding scrap. Several cars are reported to have been shipped for this purpose to a grinding plant in the United States.

Only a small part of the total dyke exposure has been worked, and the deposit extends for several hundred feet across a low ridge rising to the north of the pit. This pit has been opened in the south side of the ridge and worked back from it towards the level ground at its base. It is 200 feet long by 50 feet wide and 90 feet deep [60 by 15 by 27 m] at the south end.

The dike trends northwesterly, dips subvertically, is up to 200 feet (60 m) wide, and can be traced along strike for about 800 feet (240 m). Although the dike contains local segregations and narrow veins of quartz, it lacks a quartz-rich core. In addition to quartz, alkalic feldspar, and muscovite, the dike contains minor biotite, garnet crystals up to 2 cm across, rare apatite and zircon, and traces of allanite, uranium pyrochlore, euxenite, and ellsworthite. In 1954 and 1955, Cubar Uranium Mines Limited explored the uranium and rare earth mineralization by diamond drilling, but this mineralization proved to be too erratically distributed to be of commercial interest (Hewitt 1967, p.66-67).

Lot 2, Concession II, Dill Township

Northern Feldspar Mines Limited (12)

Spence (1932, p.59) described a feldspar deposit in lot 2, concession II, Dill Township as follows:

A 25-foot [8 m] dyke of pink spar, carrying a considerable amount of both black and white mica in large crystals, as well as soda spar and garnet in the wall zones, is exposed on this lot for a distance of 350 feet [105 m]. The dyke has the same general strike as that worked one-half mile [105 m] to the northeast on lot 2 in concession III, and is probably a continuation of the latter.

Two small pits were opened at opposite ends of the outcrop in 1924-25 by Northern Feldspar Mines, Ltd., of Sudbury, and 800 tons of spar is reported to have been shipped. The property has since lain idle.

The largest pit is an open-cut, 20 by 20 by 35 feet [6 by 6 by 11 m] deep, at the mine face, carried into the side of a low knoll. Most of the muscovite mica is rather heavily spotted: it occurs in crystals up to 10 inches [25 cm] across, but these are of "wedge" type, yielding only small cuts, and would mostly only be suitable for grinding scrap.

The property lies 1½ miles [2.4 km] southwest of Wanup station, on the Canadian Pacific railway.

The deposit was not visited by the author, and the dike referred to in Spence's description as occurring in lot 2, concession III, Dill Township, is actually that worked by Wanup Feldspar Mines in lot 2, concession II, Dill Township.

Lot 1, Concession III, Burwash Township

Mount Pleasant Mine (11)

Near the southern end of Nepewassi Lake in lot 1, concession III, Burwash Township, a late pegmatite dike was quarried intermittently for feldspar between 1927 and 1949 (Spence 1932, p.57; Hewitt 1952, p.13). About 555 tons of feldspar were shipped from the deposit which is known locally as the Mount Pleasant Mine. Spence (1932, p.57, 59) described the deposit and early workings as follows:

A dyke of irregular width, ranging from 25 to 125 feet [8 to 38 m] occurs at the south end of Aiginawassi Lake and has been worked intermittently since 1927 by Mr. S. Charrette, of Burwash. The deposit is rather remote and lies 5 miles [8 km] from Burwash station, on the Canadian Pacific railway: shipment is possible only by winter road.

Two pits have been opened and are situated on opposite sides of a narrow arm of the lake. The north pit consists of a shallow stripping upon a body of mixed spar and quartz, largely of graphic granite character, and carrying considerable black mica in large, thin plates. Some of these plates are as much as 6 feet [2 m] across. The dyke cuts across a narrow neck of land 300 feet [90 m] wide and 30 feet [9 m] high, and is exposed for the entire distance, the maximum width being 125 feet [38 m].

A second pit, 60 by 12 by 15 feet [18 by 4 by 5 m] deep, has been opened across an arm of the lake from the above and 500 feet [150 m] from the water. The dyke here is of similar character but carries a larger proportion of clean spar.

About 250 tons of spar have been shipped from the property.

Because of further quarrying following his visit, the two pits referred to by Spence have been enlarged, a few other shallow pits have been opened, and more of the dike has been stripped of overburden. The dike trends westerly and intrudes only slightly migmatitic biotite gneiss containing many thin layers of calc-silicate gneiss. Several apophyses of the dike extend into the host metasediments, and many of these apophyses are prominently zoned with a quartz-rich core, although the main dike is poorly zoned, with only local concentrations of quartz in the core. Minor muscovite and a few scattered crystals of apatite up to 2 cm in size are also visible in the dike. The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lot 5, Concession I, Burwash Township

On the west side of the road to Trout Lake near the boundary between Burwash and Servos Townships in lot 5, concession I, Burwash Township, a westerly trending late pegmatite dike up to 4 feet (1.2 m) wide and traceable for about 50 feet (15 m) along strike has been explored by stripping and blasting of shallow pits. The dike intrudes

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feldspathic gneiss, is intensely hematitized, and is composed mainly of reddish alkalic feldspar, quartz, biotite, and minor muscovite and apatite. Quartz-rich segregations are locally present, and feldspar forms crystals up to about 1 foot (30 cm) in size. A few blades of allanite are present locally within the dike, but testing of the dike by the author with a geiger counter failed to show anomalous radioactivity.

Lot 6, Concession VI, Servos Township (15)

In lot 6, concession VI, Servos Township, near the eastern end of Graham Lake, a late pegmatite dike emplaced within a feldspathic gneiss sequence containing minor intercalated biotite gneiss and calc-silicate gneiss has been quarried for feldspar, but no information could be obtained concerning the workings.

The dike trends N55E and dips 80 degrees SE and is exposed in an open-cut, 75 feet long, about 18 feet wide, with a 30-foot face (23 by 5.5 by 9 m) driven into the side of a hill near the northern shore of the lake. Contacts of the dike with the host metasediments are sharp, and in places, apophyses of the dike extend into the host rocks. The dike is intensely hematitized and is composed mainly of reddish alkalic feldspar, quartz, minor muscovite, biotite, iron-titanium oxide minerals, and erratically distributed, markedly radioactive euxenite-polycrase. The euxenite-polycrase forms massive aggregates up to 6 inches (15 cm) across, concentrated mainly near the footwall of the dike near the face of the open-cut. Minor pyrite is intergrown with the euxenite-polycrase, and traces of garnet, apatite, zircon, and rutile are visible locally within the dike. Quartz is most abundant near the core and forms irregularly distributed pods throughout the dike. Although the dike contains the largest concentration of uranium and rare earth minerals noted by the author in the map-area, available data suggest that this mineralization is too small and erratically distributed to be of commercial interest.

Lot 6, Concession II, Hawley Township

Canada Flint and Spar Company (5)

In 1947 and 1948, Canada Flint and Spar Company quarried a relatively large, irregularly shaped late pegmatite dike exposed on the southwestern side of a hill near the northwestern shore of Nepewassi Lake in lot 6, concession II, Hawley Township, and 150 tons of feldspar were stockpiled (Hewitt 1952, p.13). Emplaced within biotite gneisses containing abundant intercalated layers of calc-silicate gneiss, the dike strikes northwesterly, dips subvertically, is up to 150 feet (45 m) wide, and can be traced along strike for nearly 500 feet (150 m). Several narrow subsidiary pegmatite dikes and quartz veins are present in the metasediments near the northwestern end of the dike.

Much of the dike has been stripped of overburden and explored by numerous shallow pits, but the main workings consist of an open-cut about 30 feet long, up to 10 feet wide, and with an 18-foot face (9 by 3 by 5.5 m) in the central part of the dike. A dump near the mouth of the open-cut contains mainly broken, coarse-grained feldspar crystals.

The central part of the dike near the face of the open-cut is relatively rich in quartz, but elsewhere, the dike consists mainly of coarse-grained pink, alkalic feldspar crystals up to a few feet in size with minor intergrown quartz and biotite forming books up to 1 foot (30 cm) across. Minor muscovite and sparsely distributed, partly hematitized magnetite crystals are present in the dike, and traces of apatite and zircon are visible in the open-cut. The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lot 1, Concession III, Ratter Township

J.R. Lee (10)

A late pegmatite dike in a low rocky ridge just west of Highway 539, on the farm of J.R. Lee in lot 1, concession III, Ratter Township, was quarried for feldspar in the 1950s and 1960s. Erana Mines Limited of River Valley, Ontario, used the feldspar as crushed aggregate in the production of decorative stone plaster, stucco, and precast panels.

Striking about N35E and dipping subvertically, the dike cuts across biotite gneiss containing some intercalated hornblende gneiss units, and is exposed over a width of 125 feet (38 m) and a length of about 300 feet (90 m). Workings consist of a southern open-cut about 80 feet long and 35 feet wide, with a 12-foot face (24 by 10 by 3.7 m); a northern open-cut about 15 feet long and 90 feet wide, with a face up to 10 feet high (4.6 by 27 by 3 m); and a small pit on the eastern edge of the dike about 10 feet by 5 feet, and up to 4 feet deep (3 by 1.5 by 1.2 m). The dike consists mainly of quartz and pink to pale pink alkalic feldspar, with most of the quartz concentrated near the core of the dike. A few crystals of muscovite and biotite are scattered throughout the dike, and joint surfaces coated with earthy hematite are common. The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lot 1, Concession II, Ratter Township

Consolidated Feldspar Limited (6)

In lot 1, concession II, Ratter Township, near the western bank of Deer Creek, a late pegmatite dike was quarried for feldspar by Consolidated Feldspar Limited in the 1920s. Spence (1932, p.60) described the deposits as follows:

A dyke of pink spar, in part rather heavily iron-stained, was worked on this lot in 1926-27 by Consolidated Feldspar, Ltd., of Toronto, with a production of a few hundred tons. Work was confined to a small open-cut carried into the side of a ridge for a distance of 50 feet [15 m].

The dike is largely overgrown by brush and the workings were partly flooded by waters of Deer Creek during the author's visit in June, 1969, so that the extent and attitude of the dike could not be determined. Biotite and muscovite crystals are sparsely scattered throughout the dike, and testing of the dike by the author with a geiger counter showed no anomalous radioactivity.

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Lot 4, Concession II, Ratter Township (14)

In lot 4, concession II, Ratter Township, about $\frac{1}{4}$ mile (.4 km) south of the township road that cuts across this lot, a lensoid mass of late pegmatite exposed on the southwestern side of a low ridge has been quarried for feldspar. Where exposed in an open-cut driven into the hill, the dike appears to strike westerly and to dip southward about 20 degrees, and consists mainly of pink alkalic feldspar, forming crystals up to 3 feet (1 m) across, with intergrown quartz forming pods scattered throughout the dike. Graphic intergrowths of quartz and feldspar are present locally, and books of biotite up to 1.5 feet (0.5 m) in size and minor iron-titanium oxide minerals are associated with some of the quartz pods. Minor biotite and muscovite are intergrown with the feldspar crystals, and some of the pod-forming quartz is of the smoky variety. The open-cut is up to 45 feet wide, about 30 feet long, and has a 15-foot face (14 by 9 by 4.6 m). Where the dike pinches out into the host biotite gneisses, about 60 feet (18 m) to the east of the open-cut, numerous narrow quartz veins are present in the metasediments. No information could be obtained concerning the workings, but from the size of the open-cut and the amount of material on a nearby dump, some feldspar appears to have been removed from the deposit. The dike was tested by the author with a geiger counter for radioactivity with negative results.

Lot 12, Concession II, Hugel Township

H. Carmichael (2)

On the farm of Mr. Harry Carmichael in lot 12, concession II, Hugel Township, almost due east of the Consolidated Feldspar deposit, a late pegmatite dike, forming a low ridge a few hundred feet east of Highway 539, is quarried for feldspar by Erana Mines Limited. The feldspar is trucked to Erana's mill near River Valley, about 18 miles (29 m) to the north, where it is crushed into various size fractions for use as aggregate in decorative stone plaster, stucco, and precast panels.

Workings consist of an open-cut driven 21 feet (6.4 m) into the ridge and with an 18-foot (5.5 m) face. The dike strikes N50E and is exposed over a width of about 200 feet (60 m) and a length of about 650 feet (200 m). Although contacts with the surrounding biotite gneiss are poorly exposed, the dike appears to dip subvertically, and a few inclusions of the metasediments are present rarely within the dike. In many places, the dike is intensely fractured and is composed mainly of pale pink alkalic feldspar and glassy quartz, commonly in coarse graphic intergrowths. A few coarse quartz segregations are present locally within the dike, and biotite, as elongate crystals up to 1 foot (30 cm) long and 4 inches (10 cm) across, is scattered throughout the dike. Other minerals noted sparingly in the dike are muscovite and specularite; coatings of earthy hematite are common on fracture surfaces. Testings of the dike by the author with a geiger counter failed to show anomalous radioactivity.

Lot 10, Concession VI, Delamere Township

A small, shallow pit has been blasted into a narrow late pegmatite dike about 500 feet (150 m) north of the west end of Delamere Lake in Delamere Township. The dike consists largely of pink alkalic feldspar, quartz and relatively abundant muscovite and biotite, forming books up to about 6 inches (15 cm) in size. A few tiny apatite crystals are visible in places within the dike. No information concerning the workings could be obtained, but the pit was possibly put down to explore the mica mineralization.

Graphite

Traces of graphite are present locally in some of the biotite gneisses derived from argillaceous rocks, and minor graphite occurs with corundum in nepheline and alkalic syenite in lot 10, concession II, Bigwood Township (Hewitt 1960, p.186). None of these occurrences, however, appears to be of economic interest.

Kyanite

Fine- to coarse-grained, grey to dark grey, garnet-kyanite-muscovite-biotite-plagioclase-quartz gneiss, derived from aluminous argillaceous rocks, forms several thin units intercalated with other metasedimentary gneiss within a few miles southeast of the Grenville Front Boundary Fault in Dill and Dryden Townships. Most units of the gneiss in Dryden Township are sufficiently large to be shown separately on Map 2271 (back pocket), but those in Dill Township are too small to be shown, although some units in which kyanite appears to be relatively abundant are indicated as kyanite occurrences. Although the gneiss contains up to 43 percent kyanite (see Table 2A, rock type 10), most units of the gneiss are probably unsuitable as a commercial source of kyanite either because of their small size, or because the kyanite is erratically distributed throughout the gneiss. Moreover, the kyanite is locally altered to fine-grained sericitic material and commonly contains tiny inclusions of other minerals. Nevertheless, relatively large units of the gneiss north of the map-area in Dryden Township locally contain sufficiently large concentrations of kyanite to be of economic interest (see Pearson 1962, p.36-37), but no commercial production has been achieved.

Silica

Some of the metamorphosed orthoquartzite units containing more than 95 percent quartz, intercalated with muscovitic and quartzose gneiss units in the western half of the area have been explored or utilized as a source of silica for flux. A relatively small deposit of orthoquartzite in lot 1, concession I, Dill Township, was quarried by the Canadian Copper Company (subsequently incorporated into the International Nickel Company of Canada Limited) from 1909 to 1923 (Hewitt 1963, p.15). The large unit of muscovitic and quartzose gneiss on the southwestern flank of the Cosby batholith

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in Cosby and Delamere Townships appears to contain the largest and most extensive units of metamorphosed orthoquartzite in the map-area, but smaller units in Secord Townships are also potential sources of silica flux. Nevertheless, in most of these deposits, the orthoquartzite is complexly intercalated with less pure quartz-rich metasandstones, necessitating selective quarrying in order to achieve large tonnages of high grade material competitive with that produced by Industrial Minerals of Canada Limited at Badgely Point near Killarney (see Hewitt 1963, p.11-12).

Two small test quarries have been opened in orthoquartzite-rich sequences southwest of the Cosby batholith, one in lot 3, concession II, Delamere Township, and the other near the boundary between Delamere and Cosby Townships in lot 12, concession I, Cosby Township. Hewitt (1963, p.14) obtained chemical analyses of a few sampled sections of orthoquartzite in Cosby Township, as shown in Table 10.

Table 10 | CHEMICAL ANALYSES OF METAMORPHOSED ORTHO-QUARTZITE, COSBY TOWNSHIP

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	TiO ₂	Na ₂ O	K ₂ O
42	98.07	1.00	0.40	0.05	0.06	0.06	0.06	0.50
44	96.98	1.76	0.75	0.05	0.03	0.09	0.04	0.50
45	98.09	0.37	1.09	0.01	0.02	0.08	0.04	0.50

Sample 42 is a composite chip sample taken over a 350-foot width across the strike of the quartzite just north of the Noelville road in the southern part of Cosby Township.

Sample 44 is a composite chip sample taken over a 700-foot width across-structure on a quartzite, immediately north of the schoolhouse in Cosby Township on the Noelville road.

Sample 45 is a composite grab sample from the small quartzite quarry, ½ mile north of the main road, Cosby Township.

According to assessment work filed with the Resident Geologist's office, Ontario Ministry of Natural Resources, Sudbury, two units of quartz-rich metasandstone in lots 6 and 7, concession IV, Secord Township, have been explored as a possible source of silica flux by Isaac Burns, D.L. McKinnon, and Primary Gold Mines Limited, but details concerning the work are scanty. Hewitt (1963, p.15) gives chemical analyses of two chip samples collected 80 feet (24 m) apart by Mr. Burns across a 300-foot wide (90 m) unit of orthoquartzite in lot 7, concession IV, Secord Township, and concludes that the rock is suitable for silica flux.

Vermiculite

In lot 1, concession I, Hawley Township, a small zone of deeply weathered bedrock, discussed above in the "Pleistocene" section, consists of intercalated calc-silicate gneiss and biotite gneiss. Minor vermiculite is present locally in the calc-silicate gneiss and can be seen in weathered debris at the point where the road along the boundary between Hawley and Hendrie Townships turns northward into Hawley Township. According to

assessment work filed with the Resident Geologist's office, Ontario Ministry of Natural Resources, Sudbury, S. Bjelajac examined this occurrence in 1962, but the mineralization appears to be too small to be of economic interest.

Industrially Useful Rocks

Migmatitic biotite gneiss is quarried for crushed stone at the Burwash Industrial Farm in Laura Township (property 1 on map), and Maurice Ouellette operates a small quarry in granitic rocks of the West Bay batholith in Casimir Township, about 1 mile (1.6 km) north of Maskinonge Island (property 3 on map). The Ouellette quarry was opened in 1967, and a small crushing plant is used to produce crushed stone. Small tonnages of crushed stone used for local road construction have been quarried from granitic rocks of both the Cosby batholith, south of Ouellette in Mason Township, and the West Bay batholith, south of Lavigne in McPherson Township. Two of the late ultramafic bodies within and near the Grenville Front Tectonic Zone have been quarried for road metal. The small ultramafic stock in southwestern Cleland Township is no longer used for this purpose, but some material is removed periodically from the stock on the southern side of Highway 17 in Hagar Township, which is known locally as the Black Fox quarry. Peridotite in these stocks is deeply weathered in places and can thus be easily removed without blasting.

The economic potential of the nepheline syenite in Bigwood Township has been discussed by Hewitt (1960, p.186). Although this syenite is petrographically similar to that being quarried by Industrial Minerals of Canada Limited near Nephton, in Peterborough County, it lacks the high purity of the Nephton deposits and thus could not compete economically.

Because of the geographical position of the area, with its major railway and highway routes giving direct access to the main North American markets, some rocks of the Grenville Province portion of the area should be considered as possible sources of building stone. Among the various rocks, those that appear to be particularly well suited for this purpose are the massive anorthositic rocks such as found in the central part of the St. Charles anorthosite; massive pink to grey monzonitic rocks of the Cosby batholith; many of the quartz-rich metasandstones, cataclastic metasediments and granitic rocks within the Grenville Front Tectonic Zone; migmatite biotite gneiss; biotite-rich, silty facies of the biotite gneiss; gneissic syenitic rocks of the anorthosite suite and Middle Precambrian granitic rocks containing coarse feldspar augen.

Sand and Gravel

As described in the section on the Pleistocene, sand and gravel deposits are relatively scarce within the map-area and most are too thin to support large tonnage operations. Many of the deposits consist mainly of fine sand and are used only for local road construction. Nevertheless, in eastern Dill Township near the Wanapitei River, sand and gravel deposits related to an extensive esker and deltaic complex to the north of the map-area are locally sufficiently thick to be used extensively for local construction pur-

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poses in the Sudbury area. The largest pit (property 4 on Map 2271, back pocket) is operated by Pagnutti Brothers Sand and Gravel Limited.

SUGGESTIONS FOR FUTURE EXPLORATION

The present study of the Burwash area shows that the known mineralization can be related to the stratigraphy and to the complex plutonic, metamorphic, and deformational history, and provides basic data, heretofore lacking, for the planning and execution of future exploration work. Major conclusions concerning the mineral potential of the area are summarized below under metallic and non-metallic mineral resources.

Metallic Mineral Resources

Because the area is underlain mainly by clastic siliceous metasediments and by felsic intrusive rocks, all of which are notably scarce or lacking in sulphide mineralization, the base metal potential is necessarily limited. Copper and nickel appear to be the only base metals that may occur in economic concentrations, and about the only exploration targets available for these metals are the various mafic and ultramafic stocks and sheets. Of the various mafic to ultramafic bodies mapped, the Nipissing diabase intrusions and especially the Wanapitei complex appear to offer the best targets. Nevertheless, several small mafic and ultramafic bodies of various ages are present within the Grenville Front Tectonic Zone, and although none of these bodies appear to contain economically significant mineralization, they reflect sub-crustal faulting with associated, mantle-derived igneous activity, suggesting that the Tectonic Zone should be examined in detail, particularly by geophysical methods, for possible sub-surface base metal mineralization. Moreover, although no base metal mineralization is known to be associated with the anorthositic intrusions in the map-area, these bodies should be considered in future explorations for copper and nickel, because such mineralization is associated with a large anorthositic complex to the northeast, in the River Valley area (Lumbers 1971e).

The potential for economic deposits of iron, uranium, and the rare earths is low. The quartzose and feldspathic metasandstones in the Grenville Province contain the largest known concentrations of iron-titanium oxide minerals in the map-area, but these deposits are too small to be of economic interest. All of the known concentrations of uranium and the rare earths occur in the late pegmatite dikes, and nearly all of the dikes so mineralized are either within or near the Grenville Front Tectonic Zone. These relationships suggest that further exploration work for these commodities should be concentrated on late pegmatite dikes within the Tectonic Zone, but from the available data, it seems unlikely that economic concentrations will be found. In the Kipawa region of Quebec, uranium and thorium are known to be concentrated within quartz-rich metasandstones similar to those of the map-area (see Lumbers 1971a, p. 78). No such mineralization has been discovered within the map-area, but this association should be taken into account in future exploration work.

Non-Metallic Mineral Resources

Many of the rocks of the Grenville Province portion of the area are potential sources of building and ornamental stone, and although this resource has not been developed, it possibly constitutes the main mineral potential of the map-area. The complex metamorphic and tectonic history superimposed upon the large variety of metasedimentary and plutonic rocks of the Grenville Province produced many extraordinary rock types with interesting combinations of colours and textures that should prove to be marketable in the large urban centres of North America. Moreover, most of these rocks are well exposed and are located near major highway and railway routes leading to the potential markets.

Except for sand and gravel presently being utilized, the other non-metallic mineral deposits in the area appear to have little or no economic potential, although some of the metamorphosed orthoquartzite units could conceivably be used in the future if the nearby resources at Killarney become depleted.

As pointed out previously by the author (Lumbers 1971a, p.94), diamond-bearing kimberlite intrusions could be associated with the Ottawa-Bonnechere Graben, but monchiquite dikes of Cambrian age are the only intrusive rocks known to be associated with the Graben in the map-area.

ROCKS AND MINERALS FOR THE COLLECTOR

A variety of rocks and minerals are present in the map-area which are of interest to mineral collectors. Crystals of garnet, specularite, magnetite, uranium and rare earth minerals, biotite, muscovite, feldspar, apatite, zircon, and pyrite can be obtained from the old workings in the late pegmatite dikes. Some of these dikes also contain smoky quartz and well developed graphic intergrowths of quartz and feldspar generally termed graphic granite.

Some of the metasedimentary gneisses contain relatively good quality crystals of kyanite, sillimanite, diopside, garnet, and hornblende. The best quality kyanite is in the units of garnet-kyanite-muscovite-biotite-plagioclase-quartz gneiss near the northern boundary of the area in Dryden Township. Sillimanite crystals and aggregates can also be collected from this rock unit and from muscovitic and quartzose gneiss exposed along Highway 64 in Cosby Township. Garnet is relatively abundant in most of the micaceous metasedimentary gneisses throughout the map-area (see Table 2A), but the largest crystals observed by the author in these rocks are within the Grenville Front Tectonic Zone, in the northwestern corner of the area. Diopside and hornblende crystals are generally small and are best developed in units of marble and calc-silicate gneiss, generally in association with epidote. Marble exposed on the Canadian Pacific railway in Dill Township contains minor brucite. Some of the feldspathic gneiss units contain relatively large crystals of magnetite and partly hematitized magnetite (see "Iron" in the "Economic Geology" section).

Relatively large garnet crystals up to 2 inches (5 cm) in size are present in some of the metagabbro intrusions, and large crystals of anthophyllite can be collected in the peridotite body on the south side of Highway 17 in Hagar Township. Crystals of plagioclase up to 8 inches (20 cm) across are present in the central part of the St. Charles anorthosite, and corundum and relatively small graphite crystals can be collected in the southern part of the alkalic complex in Bigwood Township.

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