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PETROLOGICAL STUDIES IN THE SAKAMI-LAKE GREENSTONE BELT OF NORTHWESTERN QUEBEC

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Petrological Studies in the Sakami-Lake
Greenstone Belt of Northwestern Quebec

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INTRODUCTION

The Problem of Greenstone Belts

Each continent has regions of very old Precambrian rock exposures which form its shield areas. Parts of these shield areas consist of greenstone belts which are tightly folded synformal structures containing sequences of metavolcanic and metasedimentary rocks and intrusive plutonic rocks of diverse composition. Greenstone belts are of considerable geologic interest. Apart from their proven economic potential (Sharpe, 1965), these formations are among the oldest rocks known (Viljoen and Viljoen, 1970, p.28; Anhaeusser and others, 1969, p.2177).

At the present time not enough is known about the various greenstone belts collectively to construct a generally acceptable model for their development (Pettijohn, 1970, p.243). Studies involving all aspects of geologic investigation are needed to obtain a more factual appreciation of their development and indirectly, as presently available data suggests, a better understanding of crustal tectonic history and continental origins (Goodwin, 1970, p.30; Pettijohn, 1970, p.243; Gill, 1966, p.15).

The writer's objective in this report is to present the results of field and laboratory studies of rocks of the Sakami Lake greenstone belt of northwestern Quebec and correlate these results with some known aspects of greenstone belts in other parts of the Superior Province.

It is hoped that the results of this study, and others, will ultimately lead to an understanding of these portions of the ancient continental crust.

The Archean of the Canadian Shield

The various Precambrian formations of the Canadian Shield have been divided into two main groups: those formed during the Early Precambrian, or Archean, Eon and those formed during the younger Proterozoic Eon (Stockwell, 1968, p.696). The Superior Wyoming and Slave structural provinces of the Canadian Shield (Engel and Engel, 1970, p.297; Stockwell, 1968, p.695) consist predominantly of the major exposure areas of Early Precambrian in North America. The rocks concerned were severely affected most recently by the Kenoran Orogeny which occurred about 2.5 billion years ago (Engel and Engel, 1970, p.297). The Superior Province is characterized by east-west trending belts which consist of gneissic and massive granitic rocks separated by belts of greenstone. These granitic and greenstone belts generally range from a few miles to a hundred miles in width and some are several hundred miles long (Pettijohn, 1937; Goodwin, 1968).

Synthesis of data from various studies indicates that greenstone belts have several features in common:

- (1) Greenstone belts probably developed on a sialic crust.
- (2) Greenstone belts formed on a relatively thin, flexible crust although they are presently situated on the thicker, more stable parts of the continental masses.
- (3) Greenstone

belts tend to exhibit a strong regional trend.

The Significance of Granite in the
Archean Crustal Rocks

Field evidence, experimental and theoretical considerations, and conclusions drawn from lunar studies (Wetherill, 1972) coincide to indicate that the earth's crust was predominantly granitic during at least a major part of its early development, including the period of time in which greenstone belts were forming. The presence of numerous granitic plutons in and near greenstone belts may be explained through this concept.

The results of lunar studies done in association with the American Apollo Program suggest that the earth was completely molten during part of its early history (Wetherill, 1972 p.17). During this period any thin crustal formation would tend to be impermanent (Anhaeusser and others 1969; Martin 1969; Wetherill, 1972). However, by about 3.5 billion years ago radioactive decay (K^{40} and U^{235}) would have diminished considerably and the resulting lower temperatures at the earth's surface would allow a thin sialic crust to develop, the base of which would be at a depth of about thirty kilometers (Wetherill, 1972, p.18). This concept of development conforms with earlier theoretical considerations suggesting that an initial granitic crust existed (Rittmann, 1962, p.272 - 274; Vening Meinesz, 1952).

Studies conducted by Patterson and Tatsumoto (1964) involving concentrations of potassium, uranium, thorium

and lead from potassium feldspars indicate that the earth experienced a period of relatively high migration of these elements from the interior to the crust about 3.0 - 3.5 billion years ago or about a billion years after the earth's formation. This phenomenon is considered to be associated with the development, through differentiation and migration, of huge volumes of granite in the earth's crustal areas during and immediately after the early greenstone belt developments (Engel, 1970, p.436).

Roering (1965) states that the geosynclinal-orogenic cycle cannot adequately explain the large volume and anorogenic aspect of so much of the granite. In addition, several authors have suggested that differentiating and degassing of the earth has been going on up to the present (Engel, 1970, p.440).

It appears, therefore, that the various greenstone belts could have developed on a relatively thin sialic crust before the final assembling and consolidation of the great thicknesses of granite which now characterize the Early Precambrian shield areas.

The suggestion of the existence of a pre-volcanic or pre-Keewatin granitic crust is substantiated by sulphur isotope studies on granitic material from Dome Stock in the Red Lake greenstone belt of western Ontario which indicate that the sulphur has been fractionated and enriched in the sulphur isotope S^{34} . This enrichment, according to

the authors (Gross and Ferguson, 1965, p.945), indicates that the granitic material was, at some previous time, exposed at the earth's surface.

Radiometric age determinations from zircon crystals taken from Archean gneisses in southwestern Minnesota show an age of about 3.5 billion years (Catanzaro, 1963; Goldich and others, 1970). This result indicates that these rocks formed before the Kenoran Orogeny occurred 2.5 billion years ago and conforms with radiometric age dates from other continents which indicate the existence of rocks up to about 3.5 billion years old in several shield areas of the world (Wetherill, 1972, p.8; Salop, 1972, p.254).

Several geologists have presented theoretical, experimental, and field evidence indicating that pre-existing granitic crustal rocks could be intruded into younger, overlying volcanic and sedimentary rock sequences under certain circumstances. The emplacement of basic volcanic material on less dense granitic rock would create an unstable situation in which the granitic rock would tend to be displaced upwards by the force of gravity (Anhaeuser and others, 1969; Thompson and others, 1968). Experimental work on models in a centrifuge conducted by Ramberg (1957) tends to substantiate this concept.

Various greenstone belts in the Archean are characterized by numerous granitic intrusive bodies which tend to show features compatible with this concept. These bodies show (Pettijohn, 1970, p.243): (1) regionally conformable

boundaries with local cross-cutting or injection features; (2) cataclastic features, often distinguishable along the border areas; (3) greenstone dipping away from the contact areas and suggesting the upward movement of the granitic material; (4) anticlinal regional structure and clustered occurrence; (5) low grade metamorphic effects confined to the greenschist facies.

Some Similarities of Greenstone Belts
and Recent Island Arc Structures

Greenstone belts generally show rock successions similar to modern island arc orogenic areas. The Swaziland System in the Barberton area of South Africa consists of low volcanic sequences followed by a predominantly sedimentary succession (Engel, 1970, p.437). This system is very similar to the succession found in parts of the Phillipine Islands. The lower part of the Swaziland System (the Onverwacht Series) is very similar to rocks in parts of the Kurile Islands and the Aleutian Islands.

Since the recent island arc structures such as the Aleutian Islands are associated with crustal thicknesses ranging from about twelve to fifteen kilometers, there is a distinct suggestion that the old greenstone belts of North America and other areas developed in crustal material much thinner than that in which they presently exist (Engel, 1970, p.439).

In addition, Engel (1966, p.439) suggests that the telescoped nature of the metamorphic aureoles where

granites are in contact with greenstone, the bimodal nature of the mineral facies, and the absence of blueschists are indicative of a thin-crust, low pressure environment.

Investigations by Jakes and White (1972) of the chemical composition of volcanic rocks in island arc areas show a distinct trend in K_2O content in relation to position in the sequence and also in relation to depth to the Benioff zone. Oceanic tholeiitic basalt tends to be the first manifestation of island arc evolution (Baker, 1968). However, the K_2O content tends to increase with successively higher levels. This variation was also noted by Baragar (1968) in studies of greenstones in the Abitibi greenstone belt of the Superior Province. In addition, according to Jakes and White (1972, p.30), studies by Dickinson (1968) and Gill (1970) show that the K_2O content of the volcanic rocks relative to the SiO_2 content increases across an island arc toward the continental side, and is expressed by a progressive change from tholeiitic basalt, through rocks of the calc-alkaline series, to shoshonite on the continental side of the arc structure.

Research conducted by Wilson and others (1965) involving analysis of 261 samples from ten greenstone belts in the southern part of the Superior Province indicates that the metavolcanic rocks all belong to the basalt-andesite-rhyolite (or calc-alkaline) suite (Barth, 1962, p.170) which is considered to be typical of continental and island arc orogenic regions. The authors conclude that there must have

been a continental nucleus in existence during Archean time.

Although the analyses of Wilson and others (1965) show volcanics of the calc-alkaline suite over a wide area of greenstone-belt structures in the Superior Province, the more detailed studies of Baragar (1968) show the presence of oceanic tholeiitic metabasalts in the Abitibi greenstone belt. Baragar also states that his analyses are very similar to analyses from the Yellowknife area in the Slave Province. These variations in analysis suggest that the Superior Province greenstone belts may yield a wider variety of data as more detailed studies are undertaken in various regions.

Progressive Changes in Rock-Type Properties

The exact nature of the earlier crustal rocks is still very much an open question. Comparison of geological provinces of North America shows a gradual but distinct change in rock types with time. Sedimentary rock zones of the Superior Province contain about 70 percent of high rank graywacke and are relatively poor in the more mature sedimentary rocks (carbonates and quartzites) whereas progressively younger provinces show a much higher relative content of sedimentary rocks such as sandstone, quartzite, and carbonate rocks (Engel and Engel, 1970, p.300). Engel and Engel (1970) state that it is impossible for the metabasalt-graywacke suites of the Superior-Wyoming Province to have formed on a well defined continent of the present day type.

Some Aspects of Archean Stratigraphic Studies

The construction of a stratigraphic column for the Archean of the Canadian Shield has been continuing since the last century. Although stratigraphic successions have been described for local areas using local names, the question of major divisions within the Archean is still an unsettled question.

In the early part of this century Archean or Early Precambrian volcanic rocks were considered to be extrusives onto a pre-existing granitic crust (the Laurentian granites). Lawson's work (Lawson, 1913) in the Rainy Lake region of western Ontario indicated that the basement or Laurentian granites were actually intrusive into the volcanics. In addition, Lawson found that the volcanics conformably overlay micaceous schists and gneisses of sedimentary origin.

Lawson compiled a stratigraphic chart for the Archean in western Ontario which showed five major rock types (Lawson, 1913) which were, from oldest to youngest: (1) the Couthiching Mica Schists; (2) the Keewatin Lavas; (3) the Laurentian Granites; (4) the Seine Series or Timiskaming Conglomerates; and (5) the Algoman Granites.

Pettijohn (1970, p.240) points out that the term Algoman Granites was used in referring to those granites which cut across all other Archean rocks and marked an orogeny which closed out the Archean Era. In this sense the orogeny referred to would be equivalent to what is now called the

Kenoran Orogeny (Stockwell, 1970, p.49-50).

Subsequent studies by numerous geologists showed a striking lithological unity in the various green-stone belts across the Canadian Shield and a tendency developed to place formations into simple groups (King, 1951, p.8). Volcanic zones were called Keewatin type volcanic rocks and sedimentary rocks above volcanic rocks were called Timiskaming or Knife Lake type. Granites intruding volcanics were called Laurentian type and granites intruding higher sediments were called Algoman type. A major unconformity was thought to have developed after the emplacement of the Laurentian granites and was referred to as the epi-Laurentian interval (King, 1951, p.8). Stratigraphic succession charts for the Precambrian in North America were based on rock properties and show divisions within the Archean (King, 1951, p.7).

The application of radiometric methods of age determination and the realization that the Archean, and Precambrian as a whole, were much longer eons than previously thought gradually led to much revision of correlation techniques in Precambrian rocks (James, 1960; Pettijohn, 1970). Some geologists could not uphold the distinction made between Laurentian and Algoman granites (Bass, 1961; Thompson, 1936; Stockwell, 1968). The Archean came to be regarded as a single volcanic-sedimentological rock group on the assumption that the Laurentian and Algoman granites were essentially the same, or could not be distinguished and that the conglomerates

associated with the Timiskaming group were only of local significance and did not represent a widespread erosional episode.

However, some investigators continued to distinguish a Laurentian orogeny in the Archean in compiling a stratigraphic succession and time classification for the Precambrian (Goldich, 1968, p.721) and more recent work has led to some reservations about the indivisibility of the Archean. Apparently, great thicknesses of conglomerate and associated graywacke which lie unconformably on greenstone in the Yellowknife area contain significant quantities of material derived from granite (Henderson and Brown, 1966; Pettijohn, 1970, p.24). In addition, areas in western Ontario have sediment accumulations containing enough quartz and granitic fragments to indicate the presence of granitic source materials in major proportions (Donaldson and Jackson, 1965; Walker and Pettijohn, 1971). These observations suggest that a major granitic intrusive episode may have occurred prior to the development of the Seine Series or Timiskaming conglomeratic series (Pettijohn, 1970, p.242).

The foregoing summary of several contributions to the knowledge of early crustal development indicates that more studies are necessary for the realization of Pettijohn's concept of an acceptable model for greenstone-belt development and, consequently, enhancement of our knowledge concerning early crustal development. Although contributions have been

made from such areas as lunar studies it is apparent that more investigations are required in the areas of stratigraphy, structure, petrology of the volcanic rocks, and the provenance of rocks of sedimentary origin.

REGIONAL RELATIONS

The southern part of the Superior Province has been the subject of numerous studies beginning in the last century and parts of some belts have been studied in considerable detail. However, the northern part of the Superior Province, in northern and northwestern Quebec, has received relatively little attention although it has been known for several decades that greenstone belts of considerable dimensions exist in the Eastmain River and Sakami Lake regions (Shaw, 1942).

Accessibility and Location

The region concerned in this research is part of the Superior Province in the Precambrian Shield, in west-central Quebec east of James Bay (Figure 1). Accessibility to the region is most easily achieved by float plane from Fort George, or from Matagami which is located about 610 kilometers (380 miles) south of Sakami Lake. Matagami is accessible by highway from the Montreal region and both Matagami and Fort George are serviced regularly by commercial airline from Montreal. A highway from Matagami to Fort George is under construction and will pass a few kilometers to the west of the mapped area; however, the road is not expected to be open to the public until the summer of 1975.

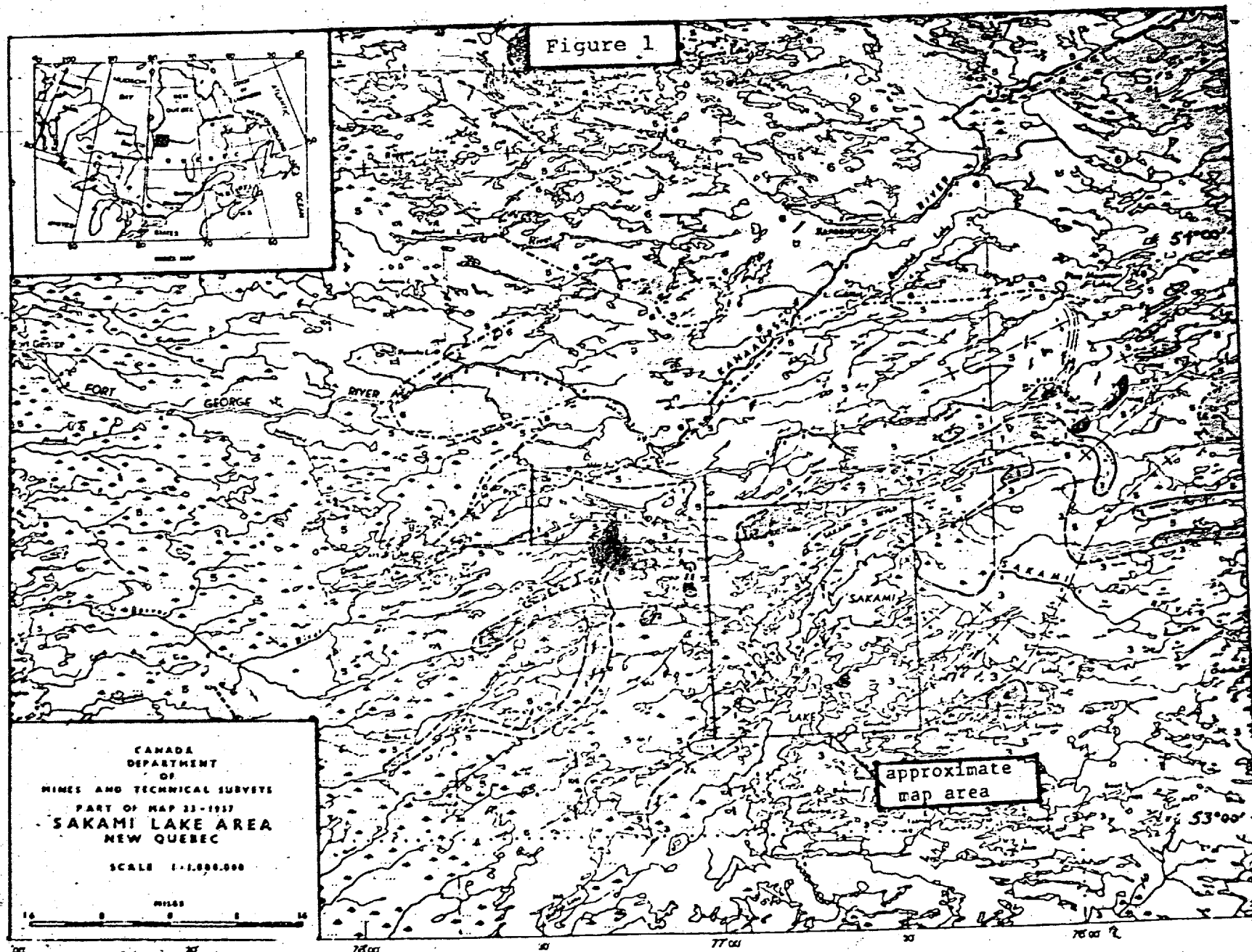


Figure 1: Location and Regional Geology of the
Sakami Lake Area.
(Archean and Proterozoic according to Alcock, 1934)

LEGEND

PROTEROZOIC	10	Gabbro dykes, in part with diabasic texture
	9	MANITOUNUK GROUP (8,9)
	9	Chiefly andesite; some basalt and/or gabbro sills
	8	Limestone, sandstone, quartzite, siltstone, arkose; includes some 9
ARCHEAN	7	Quartzite; minor pebble conglomerate and conglomerate
	6	Granite to granodiorite, massive to poorly foliated; includes minor granite gneiss
	5	Granite gneiss, porphyritic in part; varies to banded gneiss and paragneiss; includes minor amounts of 2 and 6
	4	White to grey granite and pegmatitic granite
	3	Gneiss and schist derived primarily from sedimentary material, interlayered with white to grey granite and pegmatitic granite (4)
	2	Gneiss and schist derived from sedimentary (S) and volcanic (V) rocks, commonly with minor granitic material; in part derived from 1
	1	Andesite, dacite, rhyolite, and pyroclastic rocks, varying to greenstone and amphibolite; minor quartzite, conglomerate, greywacke, and quartz-magnetite iron-formation

Geological boundary (defined, approximate, gradational)	
Bedding, tops known (inclined)	
Gneissosity, schistosity (inclined, vertical, dip unknown)	
Lination (inclined, plunge known)	
Trend lines (from air photographs)	
Fault (approximate, assumed)	
Anticline (trace of crest plane)	
Syncline (trace of trough plane)	
Mineral occurrence	Cu

SYMBOLS FOR METALS OR MINERALS

Copper (stain)	Cu
Iron oxide (rusty zones)	Fe
Magnetite-rich sands	mag
Pyrite	py
Quartz-magnetite iron-formation	if

Trading post	
Wireless station	
Sand or mud	
Marsh	
Falls and rapids	
Height in feet above mean sea-level	550

Geology by K.E. Eade, W.W. Haywood, and H.A. Lee, 1957

Approximate magnetic declination, 21° 40' West

Surficial Geology

This part of the Superior Province has been glaciated and exhibits many of the features considered typical of continental glaciation (Cotton, 1958, p.292, 338-347; von Bandat, 1962, p.306-312). Drainage in the region is westward to Hudson and James Bay and the major rivers, including the Fort George and the Eastmain, appear to be part of the superposed system to which all of the major streams in northern Quebec belong. Some of the tributary streams and streams flowing into some of the lakes appear to be controlled by bedrock structure.

Regional Structure and Petrology

Early publications of the last century (Low, 1889, 1900a, 1900b; Leith, 1910) are mainly concerned with regional surveys along the east coasts of Hudson Bay and James Bay with relatively more attention given to a few areas such as the Nastapoka Islands in southeast Hudson Bay (Leith, 1910).

Regional reconnaissance surveys were done over a large area (about 140,000 square miles or 360,000 square kilometers) of central and western New Quebec during the late 1950's (Eade, 1966, 1971). The coordinates of the surveyed area are: longitude $68^{\circ}00'$ - $80^{\circ}00'$ W., latitude $52^{\circ}00'$ - $56^{\circ}00'$ N. As a result of this survey, which includes the Sakami Lake region, a large part of the shield area was divided into fifteen major rock groups. Nine of these groups

were considered to be Early Precambrian or Archean (Eade, 1966, p.10-11). Four of the bedrock groups were delineated in the Sakami Lake area.

The areas of the various rock groups are indicated on map 1155A which accompanies Eade's report (Eade, 1966) and are also shown on map 23 - 1957. This preliminary map with notes on part of this region, concerns the area with coordinates of longitude $74^{\circ}30'$ - $80^{\circ}00'$ W., and latitude $52^{\circ}50'$ - $56^{\circ}00'$ N. (Eade and others, 1957). Eade considered the several greenstone zones in the region to be the oldest rocks in this part of the Superior Province and described them as remnants in a younger granitic terrain (Eade, 1966, p.17). The major compositional features of the greenstone units and the other rock groups delineated by Eade are indicated in the legend accompanying Figure 1.

Contacts between the major rock groups appear to be gradational and conformable (Eade, 1966, p.10). However, the various exposures of the Proterozoic Sakami Formation, which consists of quartzitic sandstone, are considered to be bound by fault planes, and owe their preservation to down faulting (Eade, 1966, p.49).

Folding

Folds through the region are generally broad and open with minor folds superimposed on the major structures. The axial trends of major folds are generally about 090° ranging to about 045° (Figure 1).

A relationship appears to exist between fold patterns and the distribution of massive granite (Unit 7, Figure 1) and foliated granitic rocks (Unit 5, Figure 1). Massive granite tends to be concentrated in anticlinal structures and more foliated rocks tend to be concentrated in synclinal structures (Eade, 1966, p.65).

In some parts of the western region of Eade's survey the contact of massive and foliated rocks follows a sinuous course coinciding with the noses of plunging, major folds (Eade, 1966, p.67).

Faulting

Faulting among the metasedimentary and metavolcanic rock units is indicated by slickinsiding and fault gouge or breccia in many areas. A major fault zone of regional extent appears to occupy a topographic low which extends through the Lake Duncan area striking about 070° . The zone is 20 to 25 kilometers wide and consists of a series of short enechelon faults with some east-west trending cross-faults (Eade, 1966, p.68).

Many of the lakes in the mapped area, such as Lake Cataseau and Long Lake, are in basins controlled by bedrock structure. Investigation of topographic maps (Sakami Lake map sheet 33-F) and satellite photographs indicate that many of these structurally controlled lakes and rivers are parts of larger networks of fault and/or joint systems which extend over thousands of square miles. At least four linear

patterns are apparent, which, with slight variations trend 010° , 050° , 100° and 130° .

Metamorphism

Two distinct grades of regional metamorphism are observed in this part of the Superior Province (Eade, 1966, p.62). The western two-thirds of the area, which includes the Sakami Lake region, is predominantly in the amphibolite facies. The eastern third of the region contains large areas which are considered to be in the granulite facies.

Radiometric Age Determinations

Radiometric age determinations have been made on biotite and muscovite from parts of the reconnaissance survey region (Eade, 1966, p.61). The analyses were made by the Geological Survey of Canada Laboratories in Ottawa. The average age obtained for the oldest rocks in the region is about 2.3 billion to 2.5 billion years with a suggested error of about +125 million years (Lowden, 1960, p.2, as quoted by Eade, 1966, p.62). Eade (1966, p.2) suggested that the last orogeny to affect the area was the Kenoran. He assumed, therefore, that the rocks affected are Early Precambrian or Archean. None of the locations listed in the table of results (Eade 1966, p.61) are in the immediate map area concerned in this report.

Chemical Analysis

Chemical analyses were done on specimens collected by Eade. In compiling the results the New Quebec region was divided into unit areas and the Sakami Lake region

was included in unit area number 14. Results for each of the various rock groups have been tabulated (Eade and Fahrig, 1971, p.34) and the average chemical composition for the unit areas and for the Archean of New Quebec as a whole area also listed (Eade and Fahrig, 1971, p.41).

The average chemical composition of unit area number 14, which includes the Sakami Lake region, is based on specimens from rock groups 1, 5, 6, 7, 9 and 10. Table 1 lists the average composition for unit area number 14 and for the Archean of New Quebec.

TABLE 1

OXIDE	AVERAGE UNIT AREA 14	AVERAGE ARCHEAN OF NEW QUEBEC
SiO ₂	65.8	64.9
Al ₂ O ₃	15.7	16.2
Fe ₂ O ₃	1.1	1.5
FeO	2.8	3.0
MgO	2.5	2.3
CaO	3.0	3.3
Na ₂ O	4.3	4.1
K ₂ O	2.7	2.8
TiO ₂	0.42	0.49
P ₂ O ₅	0.16	0.16
MnO	0.08	0.08
CO ₂	0.30	0.20
H ₂ O ()	1.0	0.80
(FROM: Eade and Fahrig 1971, P.41)		

REGIONAL GEOMORPHOLOGY, STRUCTURE,
AND PETROLOGY OF THE SAKAMI LAKE AREA

The mapped area consists of approximately 1826 square kilometers (705 square miles) in the Sakami Lake region of north western Quebec (Longitude: $76^{\circ}45'$ W., Latitude: $53^{\circ}20'$ N.) which is about 137 kilometers (85 miles) east of Fort George, on the east coast of James Bay (Figure 1).

Surficial Geology

The Sakami Lake area is part of the regional slope down to sea level at James Bay from the Kaniapiscau Highland area about 645 kilometers (400 miles) to the east at the headwaters of the Fort George and Kaniapiscau Rivers. The mapped area is drained by the Sakami-Fort George River system (Figure 1).

Maximum relief in the area is about 153 meters (500 feet). The higher elevations are about 260 - 275 meters (850 feet - 900 feet) above sea level and are located in the hill regions along the east side of Sakami Lake. The lower elevations are about 122 - 137 meters (400 feet - 500 feet) above sea level and are located in the Long Lake and Alder Lake areas in the northwest part of the mapped area.

Features of glaciation in the area include undeveloped drainage, numerous swamps and lakes, ground moraine, sand and gravel ridges, glacial striae and grooving of bedrock. Many of the lakes are bound by morainal deposits. Some till deposits are irregular: others however, are elongate, having a consistent north-northwest strike, and

are fairly evenly spaced thereby resembling the washboard moraines characteristic of the Chapais area to the south. Glacial striae were observed in several locations and indicate a general southwest direction of ice movement. This direction of ice movement is also suggested by the general northeasterly elongation of eskers which, in some areas, intersect the washboard moraines at about 90° thereby forming a rough square-like pattern of ridges.

Bedrock Exposure

Bedrock exposures in this region are predominantly isolated hills and low rises, but there are some large exposures which are more than about two hundred meters across. Exposures are separated by swamps or wooded areas and exposed rock surfaces are generally weathered to some extent. In some places the weathered surface enhances observation of rock texture and structure, but other exposed surfaces are covered by a dense mat of lichen which obscures rock texture, structure, and color. At many outcrops it was necessary to strip back moss and shrubbery to increase bedrock exposure and to obtain moist surfaces free of moss and lichen. Such freshly exposed surfaces often show rock texture and structure which could not be found otherwise.

As a result of the isolated pattern of outcrops, contacts between major rock groups are generally unexposed and could only be inferred after the plotting of field data. Foliation and layering are usually parallel within the major rock groups, and boundaries between rock groups tend to be

parallel to foliation and layering in the vicinity. Diabase dikes strike approximately northwest.

Fracture Patterns

Several of the linear patterns discussed in the section on faulting appear to have formed at least three zones of intersection within the mapped area. Each of the zones involves two or more of the linear patterns. The zones of intersection are: (1) the area between Long Lake, Lake Dacey and Hook Lake which involves the intersection of possible fracture zones striking at about 110° - 120° and 045° - 060° ; (2) the west end of Lake Cataseau appears to be an area of intersection of two fracture zones striking at 120° and 060° ; (3) the central region of Sakami Lake seems to be a zone of intersection of lineaments striking at about 135° , 020° and 050° . The lineament striking at 060° mentioned in (2) above, passes through and is parallel to Lake Cataseau and the lineament striking at about 120° is a continuation of the zone which passes through Lake Dacey and Long Lake. Interrelationships of the linear patterns through the Sakami Lake region suggests that both right and left lateral apparent movement has occurred.

Petrology and Structure

Two main rock groups were delineated in the mapped region by Shaw (1942). These groups were: (1) pre-granites which included the Metasedimentary and Metavolcanic rocks; and (2) undifferentiated granites. Detailed stratigraphic studies were not attempted.

Four of the rock groups delineated by Eade (1966) exist in the mapped region (Figure, 1). However, none of the locations from which samples were taken for radiometric age determinations done in connection with Eade's regional survey are within the mapped area.

Results of the writer's work indicate that the mapped area consists of steeply inclined metavolcanic and metasedimentary rocks with associated granitic plutonic bodies, diabase dikes and metabasaltic intrusives.

Major Rock Units

Five major rock units have been delineated in the mapped area:

Unit (1): in the northwest and central parts of the area are two elongate belts, striking at approximately 090° and 045° respectively, which converge towards the northeast. These bands, which constitute Unit (1), consist primarily of interlayered metasedimentary and metavolcanic rocks and contain the major greenstone units in the mapped area.

Unit (2): granitic rocks of several varieties constitute Unit (2), which separates the two belts mentioned in Unit (1) above. Minor zones of metasedimentary and metavolcanic rock and metabasaltic dike rock also occur in this zone.

Unit (3): consists of an interlayered sequence of light colored metasedimentary and darker metavolcanic rock which is exposed in the area immediately north of the east-west

striking belt mentioned in Unit (1) above. This sequence grades northward into a zone consisting predominantly of granitic rock.

Unit (4): Consists of a complexly folded, interlayered sequence of fine to medium grained gneiss and granitic rock and composes the region southeast of the mapped area. This sequence appears to grade conformably into the north-easterly striking metavolcanic-metasedimentary rock unit mentioned in (1) above.

Unit (5): the area directly north of Lake Cataseau, in the north-central part of the mapped area, consists of a distinctive hill region underlain by cross-bedded quartz arenite which, at lower elevations, contains bands and lenses of partly brecciated reddish mudstone. This relatively undisturbed unit is part of the Proterozoic Sakami Formation which crops out at several locations in this part of the Superior Province, and constitutes Unit (5).

Petrology

The metavolcanic rocks comprising part of Unit (1) mentioned above are composed of three major varieties: (1)a: mafic to felsic extrusive flows and fine grained massive to foliated greenstone which has conformable and disconformable relationships with associated rocks; (1)b: poorly sorted fragmental rock; and (1)c: well foliated rock which may be partly water-laid volcanic ash.

The mafic to felsic extrusive flows of unit

(1)a contain pillowed lavas; porphyritic and amygdaloidal rock; laminated rock which contains what may be compressed or sheared fragments; and pinkish weathering felsic flow rock which contains rounded fragments of rhyolitic material and rounded fragments of highly quartzitic, granular rock (Plate 1, Figure 1).

Metavolcanic rocks of unit (1)b include:

massive greenish-gray weathering rock which contains angular to rounded fragments of various rock types including granite; banded fragmental rock in which the fragments appear to consist of the same material as the matrix; and medium to dark greenish-gray weathering rock which contains light olive green weathering, round fragments which may be highly altered fragments of mafic rock origin.

The well foliated rock of possible volcanic ash origin (unit (1)c) forms light grayish-pink weathering exposures. In some places the rock is well banded and extremely hard and tough. In other places the material is crenulated, relatively soft and apparently highly sheared. Metasedimentary rocks of Unit (1) are of several varieties which are mainly: (1)d: medium-gray weathering, banded, impure sandstone; (1)e: light gray weathering, micaceous sandstone; (1)f: very fine grained, banded, garnetiferous, medium gray weathering rock; (1)g: garnetiferous banded quartz iron formation, which is usually highly crenulated and folded (Plate 1, Figure 2); and (1)h: medium gray, fine

grained, laminated rock which contains clots and veins of reddish iron carbonate. These rocks are discussed in more detail in subsequent sections of the report.

The granitic rocks of Unit (2) consist of three main groups or varieties: (2)a: light gray weathering, foliated, biotite granites which are usually porphyritic, contain conspicuous quartz, and are often gneissic (possibly due to a high degree of shearing or cataclasis); (2)b: sheared, light to medium grayish-green quartz porphyry rock in association with contorted metabasaltic or greenstone dikes; (2)c: massive granite which has variable quartz content, cross-cutting relationship with fine grained banded tuffs, (Plate 2, Figure 1), numerous dark inclusions of amphibole-rich material, and partly digested fragments of fine grained, medium to dark gray rock (Plate 2, Figure 1).

As mentioned earlier, Unit (3) consists of an interlayered, steeply inclined sequence in which felsic layers of foliated feldspathic metawacke are intercalated with darker greenish-gray weathering layers of mafic composition.

In the eastern part of the area underlain by Unit (4), the banded rocks consist of granitic gneiss and also fine-grained, dark feldspar-biotite schists. The coarse-grained more massive granitic rocks have both conformable and disconformable relationships with the foliated banded units. Some of the rocks are garnetiferous

and contain conspicuous well formed tourmaline. The western outcrops of Unit (4) consist predominantly of medium gray, slightly brownish metasandstone and metasiltstone which has what appear to be pre-consolidation slump structures in several exposures (Plate 2, Figure 2).

Unit (5), as mentioned earlier, consists of cross-bedded, reddish weathering, quartz arenite. The lower parts of the sequence contain units of zones or brecciated very fine-grained massive, reddish weathering mudstone. Also, observable in some zones are occasional thin lines of well rounded gravel and pebbles.

In addition to the various rock types discussed above, greenstone dikes and, to a lesser extent, granitic dikes are common features in a large part of the mapped area. In some locations the greenstone dikes have been contorted or folded and faulted (Plate 3, Figure 1), whereas in other places, they are massive with no indication of involvement in deformation.

The various rock groups mentioned above will be discussed further in subsequent sections of the report.

PETROLOGY

Petrology discussed in this section concerns major points of field and microscope work together with some results of chemical analysis. More detailed petrography and additional chemical calculations are in Appendix 1.

Metavolcanic Rocks

This section is a discussion of the several metavolcanic rock types mentioned in the previous section which are essentially extrusive flows now consisting of fine, massive, foliated, and porphyritic greenstone; amygdaloidal and pillowed lavas; and fragmental and banded greenstone tuffs. Felsic metavolcanic flow and fragmental rocks are also included.

Greenstone; Massive, Foliated, Porphyritic

Massive greenstone units are not confined to any particular part of the mapped area. However, they appear to be more conspicuous in certain places such as: the area around the east end of Long Lake and to the northeast of the lake; the region immediately south of Lake Cataseau; the southwestern part of the mapped area; and a zone paralleling the west side of the northeasterly trending metavolcanic-metasedimentary rock band at Sakami Lake. Massive greenstone is found as dikes in granite rock and as conformable units within banded greenstone zones. In some places the massive greenstone is porphyritic.

In the region around the mouth of the Sakami

River at Lake Cataseau, massive to sheared porphyritic granite appears to be intruded by greenstone. At some contacts the greenstone has distinct foliation adjacent to the apparently more massive granite (Plate 3, Figure 1).

The region bordering the west side of the zone of the metavolcanic-metasedimentary rocks at Sakami Lake contains an interbanded and interlensing sequence of granite and greenstone. Some of the greenstone contains phenocrysts of highly altered, light gray feldspar which form up to 25 percent or more of the rock in some places and ranges in size from a few millimeters to two or three centimeters in diameter. These phenocrysts are randomly distributed in most cases, but in some exposures feldspar concentrations change abruptly suggesting some internal segregating process operating at the time of emplacement. Most of the phenocrysts are anhedral; however, some have well formed euhedral outlines observable in exposure surfaces. There is no apparent orientation of the phenocrysts and foliation has not developed around them.

Considerable epidote in the highly altered phenocrysts suggests that these features were primary plagioclase crystals with a high calcium content which would be expected in a mafic rock.

The greenstone units tend to parallel the regional foliation and appear to be less numerous westward from the main metavolcanic-metasedimentary rock band. Only

the narrower units appear to have a high phenocryst content whereas occasional phenocrysts are observable in the thicker bands to the east.

Inclusions of greenstone were found in the associated granite in some places and foliation within the greenstone fragments has been crosscut by the surrounding granite. More continuous units of greenstone have also been intruded by granitic rock. A folded sequence of meta-sedimentary rocks, probably greenstone tuffs, pillowed lavas, and massive intrusive greenstone occurs in the southwest part of the mapped area.

Banded quartzitic iron formation and garnetiferous-amphibolite schist constitute the metasedimentary layers with conformable units of finely banded greenish-gray rock which may be banded tuffs. Pillowed lavas occur in the vicinity which show upper surfaces facing north-northwest. Greenish-gray weathering metabasalt shows intrusive cross-cutting relationships with the folded metasedimentary units in several outcrops. In some places inclusions of light gray quartzite, which have alteration zones around the edges indicated by a distinctive change to lighter gray color, occur in the massive greenstone.

The presence of a reddish garnet assumed to be almandine, green amphibole, minor amounts of sillimanite, and some white mica in the area suggests that metamorphism had reached the almandine-amphibolite facies, probably the

sillimanite-almandine-muscovite subfacies (Turner and Verhoogen, 1960, p.544).

The apparent interbanded nature of the greenstone and granite, the interpenetration of the two rocks in some places, and the cataclastic features observed in several exposures provides some information relative to emplacement; specifically the following are observed:

- (1) granitic units, as well as much of the greenstone, have elongate forms paralleling regional foliation;
- (2) some of the granitic rock, as indicated by features of cataclasis, was tectonically disturbed or possibly emplaced while in the solid or semi-solid state; however, the penetration by granite into greenstone and the occurrence of greenstone fragments in granite indicates that the granite was fluid or highly mobile in some places;
- (3) the occurrence of massive greenstone crosscutting folded metasedimentary layers (Plate 1, Figure 2) indicates that basaltic rock was emplaced in the region after the phase of tectonic activity represented by the folded units.

The occurrence of basaltic intrusive rock into folded metasedimentary rock suggests that sedimentation had occurred before basaltic intrusive activity in at least some parts of the region. In addition, the interlayered aspect of granitic rock and greenstone and the occurrence of what appear to be greenstone dikes in granite in nearby areas suggests that granite in some parts of the mapped

area predates metavolcanic rocks. However, the presence of finely banded rock, probably tuffs, conformable with the folded metasediments indicates earlier volcanism occurred and contributed material to the metasedimentary sequences.

Greenstone; Amygdaloidal, Pillowed Lavas

Amygdaloidal rock of basaltic to intermediate composition is exposed in the Sakami Lake and Long Lake regions. Exposures observed in the Sakami Lake area are dark greenish-gray weathering units with distinct ovoidal features observable. Some of these structures are empty and some are partly to completely filled with a feldspathic mineral. These features, which suggest a vesicular structure in the original rock, range from several millimeters to about two centimeters across and have a direction of elongation highly inclined to the exposure surface.

Similar features characterize a light green weathering rock in the Long Lake region where weathered surfaces show well defined ovoid quartz bodies. Thin-section studies show numerous ovoidal to irregular quartz-filled amygdules randomly distributed through the rock. (Plate 4, Figure 1). The greenish color on weathered surface appears to be due to a high epidote content in the matrix.

Pillowed lavas are exposed at several locations within the mapped region; these include the Long Lake area, the central and northern regions of Sakami Lake, and the southwest part of the mapped area. Pillowed lavas

also form several outcrops in the westward extension of the greenstone belt, to the west of the mapped area in the region around Lake Duncan and north of the lake. The pillowed structures were useful as top indicators in four of the regions within the mapped area. Rinds are not well delineated at all of the outcrops, but where they are thick and distinctive, they are darker than the central parts of the pillow and consist of tough, slightly flakey rock which weathers more easily resulting in a slight hollow between the pillow structures. Thin-section studies of some of the pillow rock show that it is fined grained, highly altered with considerable epidote content, and contains minor scattered, irregular amygdules consisting of calcite and quartz.

Greenstone; Fragmental, Banded Tuffs

Banded greenstone in the Sakami Lake region is conformably associated with more felsic metavolcanic and metasedimentary rock including banded-quartzitic iron formation. The east-west trending zone around Long Lake continues to the west of the mapped area and divides into two distinct belts, one trending northwest and the other southwest toward Lake Duncan. These belts contain banded, fragmental greenstone as a major component. The metavolcanic-metasedimentary rock zone trending northeast in the Sakami Lake region also contains banded fragmental greenstone as a major component.

Several zones of greenstone are finely banded, suggesting an ash of fine fragmental origin. In some places the rock consists of light to dark greenish-gray crenulated bands. At one outcrop, observed west of the mapped area, the crenulated, finely laminated greenstone has been intruded by light gray aplitic rock. The random orientation of tuff fragments in the aplitic dike indicate the fluid nature of the intrusive rock (Plate 3, Figure 2). Thin lense-like structures, forming part of the finely banded sequence suggest that flattened fragments or bodies make up part of the banded sequence.

Well layered greenstone has been found to grade into complexly folded zones which contain minor conspicuous light gray bands which serve to delineate folds, the highly contorted nature of which suggests preconsolidation movement or slumping.

The Long Lake area contains several exposures showing the close, gradational relationship of banded greenstone tuffs and coarser fragmental greenstone in which fragments are up to several centimeters across and sometimes angular. Fragments appear to be of the same composition as the surrounding greenstone with the exception of some reddish fragments. The reddish color may be due to a higher degree of oxidation of the iron content or the fragments may be from a different parent rock.

An extrusive subaqueous environment is indicated by the several occurrences of pillowed lavas and also by the various exposures of extrusive flows and

probable tuffs which contain bands of felsic metasedimentary rock. Some topographic relief is also suggested by the various occurrences of apparent slump structure in layered sequences. The occurrence of interbanded felsic metasedimentary rocks and units of volcanic origin coincides with the suggestion made previously that volcanism probably was a recurring phenomenon.

Post-deformational intrusion of granitic rock is indicated by intrusion of aplite into banded greenstone tuffs (Plate 3, Figure 2) and also by intrusion of massive granite into banded tuffs in other regions (Plate 2, Figure 1).

Part of the area south of Long Lake consists of massive granite in contact with fragmental rock of volcanic origin. Several exposures of the metavolcanic rock indicates that the zone extends for more than a kilometer and is more than twenty meters wide.

The fragmental rock consists of angular to rounded mineral and rock fragments some of which are granite (Plate 4, Figure 2). The fragments are randomly distributed in a greenish-gray matrix rich in epidote, chlorite, and felsic minerals, which suggests that this zone is in the greenschist facies, probably the quartz-albite-muscovite-chlorite subfacies (Turner and Verhoogen 1960, p.534). The contact zone is gradational over a zone about ten meters wide consisting of fractured granite, the fractures containing greenish-gray material like that

forming the matrix in the fragmental rock. The intensity of fracturing is gradational from thin irregular fractures to partings several centimeters wide in which blocks of granitic material are apparently separated from the main granitic mass and surrounded by the greenish matrix material. The west contact of the fragmental zone was not observed; however, available exposure indicates that the zone is over twenty meters thick.

At least four possible explanations can be considered from the observed metavolcanic-granitic rock sequence: (1) the fragmental rock was emplaced on pre-existing granitic rock the surface of which was broken up by weathering processes; (2) the fragmental rock represents fluidization processes; (3) the fragmental rock is not volcanic but glacial in origin, and represents a till deposit on pre-existing granite, the surface of which was prepared by frost action in a subaerial environment; (4) the granitic rock is intrusive into the fragmental rock. Lack of detailed information in the area makes definite conclusions about origin unwarranted; however, in each case mentioned the common factor is the presence of crustal rocks of several types prior to the event concerned.

Felsic Metavolcanic Rocks

Felsic metavolcanic rock is exposed in several places in the region. Varieties consist of rhyolitic flows; quartz-feldspar-porphyry rock; fragmental flows; and

a very fine grained, well banded, felsic rock which may be water-laid tuffs.

Exposures generally weather light gray to slightly pinkish and are foliated to massive. In the Long Lake region exposures of rhyolitic flow rock contain rounded fragments consisting entirely of highly sutured quartz. Collectively, these fragments give the exposure a conglomeratic appearance on weathered surface (Plate 1, Figure 1). A distinctive wavy crenulation is observable on some exposures of very fine grained, finely banded and sheared felsic rock which may consist of water-laid tuffs.

Felsic Metavolcanic Rocks; Porphyritic

Exposures of felsic, porphyritic, metavolcanic rock contain phenocrysts of quartz which are usually resorbed to some extent. Albite phenocrysts are more numerous than potassium feldspar phenocrysts and also are more commonly observed than quartz phenocrysts. The matrix is felsic with minor brown biotite and calcite observable. Minor amounts of epidote occur in some places.

In some exposures quartz consists of elongate to ovoid units which contrast in shape with the euhedral feldspar crystals. These quartz units may be vesicle fillings or amygdules.

Although some exposures contain fresh looking feldspar phenocrysts, other exposures contain phenocrysts which are highly altered so that they are only vaguely

distinguishable in thin section. In other cases the phenocrysts have been granulated through cataclasis so that they appear as round structures with ill-defined boundaries randomly distributed through the rock.

Some exposures in the Sakami Lake region consist of randomly distributed feldspar phenocrysts in a foliated felsophyric groundmass which also contains elongate clots and lenses of brown biotite and quartz-feldspar aggregates. Some feldspar grains are well formed, others are altered and partially disintegrated appearing as ovoid to round clots with indefinite boundaries.

Several examples suggest that there is a gradation between the porphyritic rock and slightly banded rock which contains some coarser feldspar units and also stringers and clots of biotite and chlorite. This slightly banded and foliated rock may be of sedimentary origin.

Exposures in some parts of the Long Lake region consist of porphyritic rock in which zoned plagioclase phenocrysts are surrounded by distinct flow or compaction features. The zoning in the plagioclase is delineated by a high degree of alteration which is more extensive in the central portions of the grains. Flow lines around the grains are made more conspicuous by orientation of greenish amphibole which is a common constituent of the granular groundmass in addition to minor amounts of brown biotite.

Felsic Metavolcanic Rocks; Fragmental

Felsic metavolcanic rocks of pyroclastic origin are exposed at several locations in the Long Lake region. The rock and mineral fragments are highly saussuritized and some units appear to consist of alteration products in the form of fine granular aggregates. The finer fraction consists of felsic minerals and minor amounts of chlorite, epidote, opaque mineral grains, occasional grains of amphibole and calcite. This assemblage suggests that metamorphism is in the greenschist facies, probably the quartz-albite-muscovite-chlorite subfacies (Turner and Verhoogen, 1960, p.535).

Flow or compaction features are common textural elements and in some cases give the rock a definite foliation. Other exposures contain more massive, less altered rock in which partially resorbed or embayed quartz grains are common constituents (Plate 4, Figure 3) and the finer fraction consists of felsic minerals with minor calcite, biotite and opaque grains.

The variety of felsic metavolcanic rocks observed indicates that rhyolitic flows and possibly fragmental ash flows occurred in the region. These felsic rock units accumulated in the vicinity of greenstone units of extrusive origin and have similar attitudes suggesting that the two rock types may belong to the same volcanic episode.

Subaerial and subaqueous environments within

the volcanic zone are indicated by the close association of banded sedimentary units and more massive fragmental metavolcanic rocks and the felsic flows. This situation also suggests that the sediments may be of volcanic origin.

Chemical Analyses

Chemical analyses of mafic and felsic metavolcanics from different parts of the mapped area, the tabulation of which is given in Appendix 3, were analysed according to the alkali-lime index or Peacock diagram (Peacock, 1931, p.54) and the Rittmann suite index or sigma value calculation (Rittmann, 1962, p.110). Results support one another in indicating that metavolcanic rocks in the mapped area belong to the calc-alkaline or Pacific suite of Rittmann (Rittmann, 1962, p.110). Graphs indicating the alkali-lime index are shown in Figure 2. The results indicate a continental orogenic environment of volcanism.

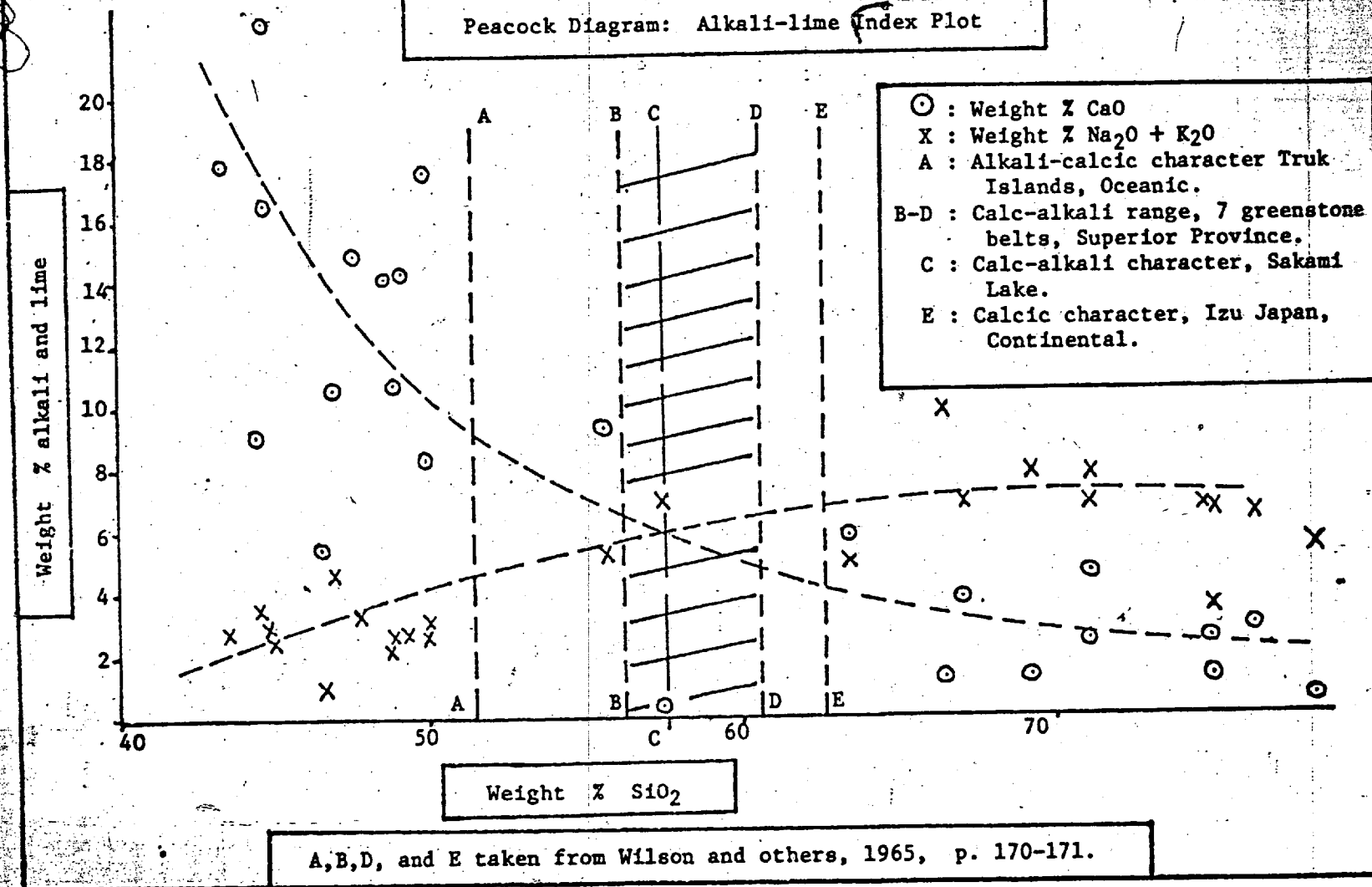
Calculation of the Rittmann sigma value, or suite index, for the various results shows a range of values from one to five with a distinct concentration in the range of 1.2 to 2.5. These values place the volcanism in the strong to average portion of the calc-alkaline group (Rittmann, 1962, p.110). The sigma value is arrived at by the following formula^m in which the oxides are in weight percent:

$$(Na_2O - K_2O)^2 / SiO_2 - 43.$$

The plotting of alkali-lime indexes (Figure 2) in accordance with the Peacock diagram gives an index of

FIGURE 2

Peacock Diagram: Alkali-lime Index Plot



about 57.8. In this calculation the $\text{Na}_2\text{O} + \text{K}_2\text{O}$ values are plotted against the corresponding SiO_2 value in each analysis. Similarly, the CaO values are plotted against SiO_2 in each analysis. Curves drawn through the alkali and calcic plots intersect at some intermediate point between the extremes of SiO_2 content. This point of intersection is related to the suite type of volcanic rock. Volcanic rock from the Truk islands, considered to be typically oceanic, has an alkali-lime index of 51.5 and is of the alkali-calcic suite or character (Wilson and others, 1965, p.170). The Izu group from Japan is calcic in nature with a lime-alkali index value of 62.5 on the Peacock diagram (Wilson and others, 1965, p.170).

The results discussed above indicate that metavolcanic rocks in the Sakami Lake region, with a alkali-lime index of about 57.8 belong to the same suite as metavolcanic rocks from seven different greenstone belts in the northern Ontario area of the Superior Province in which alkali-lime indexes range from 56.1 to 60.6 (Wilson and others, 1965, p.171). The Sakami Lake results are particularly close to the results for Timmins and Longlac areas which are 58.0 and 58.6 respectively (Wilson and others, 1965, p.171)...

Goodwin (1967, p.90) has averaged the chemical composition of volcanic rock types from the Birch-Uchi Lakes area in northwestern Ontario resulting in average values for

basalt, andesite, dacite, rhyodacite, and rhyolite. The alkali-lime index value for these averaged values is in the range of 57.5 - 60.0 and the Rittmann sigma value averages 1.2 with extremes of 0.9 and 1.5. These values strongly suggest that volcanism in this part of the Superior Province also belongs to the same suite as the Sakami Lake region as well as the several other greenstone belts mentioned.

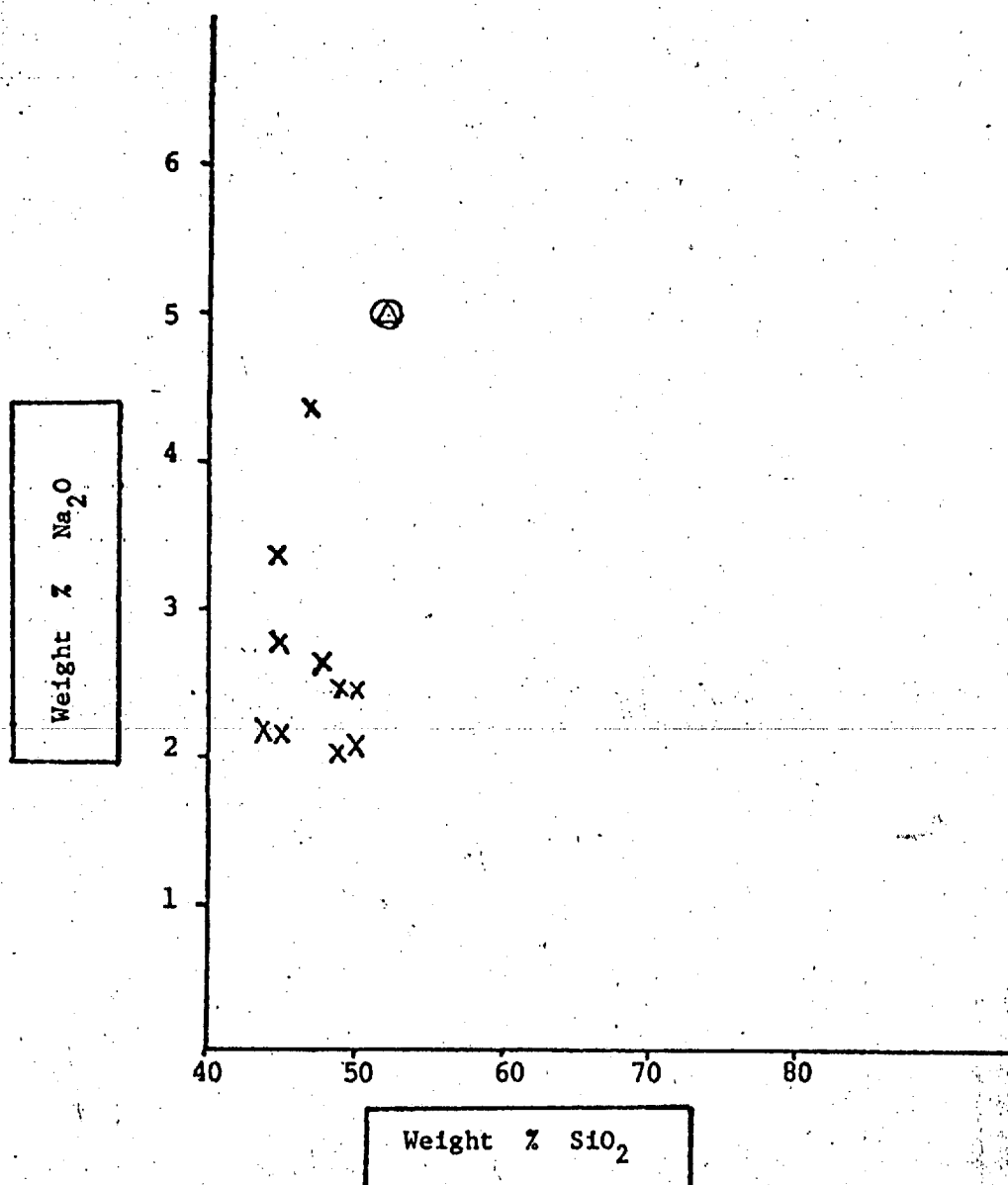
Plotting of Na_2O values against SiO_2 values indicates that the volcanic rocks are not spilitic (Figure 3). This result coincides with the tendency for greenstone belts of the Superior Province not to be spilitic (Wilson and others, 1965, p.174). The value for the average spilite is considerably higher than any Na_2O values found in these analyses.

The significance of these results is discussed further under conclusions and discussions.

Metasedimentary Rocks

Metasedimentary rocks associated mainly with the major metavolcanic zones in the mapped area consist of several varieties: (1) banded quartz-iron formation, most of which is strongly magnetic; (2) massive to finely layered feldspathic wacke with gradations to arkosic wacke and feldspathic arenite; (3) banded quartz arenite; (4) banded quartzitic, limonitic rock; (5) banded amphibolite schists and lithic wacke of both mafic and felsic varieties.

FIGURE 3



⊙ : Average Spillite

X :

Weight % Na_2O , Metabasalt analyses, Sakami Lake

Iron Formation

Banded quartz-iron formation crops out in several parts of the mapped area and also forms part of the westward extension of the greenstone belt around Lake Duncan and to the north of the lake. In all exposure areas observed the iron formation units are associated with, or are in the near vicinity of, metavolcanic and metasedimentary units.

Pronounced banding is observable in all exposures which consists of interlayered bands and lenses of light gray weathering quartz-rich units (Plate 4, Figure 4), bluish-gray weathering magnetite-rich lenses, and dark greenish-gray weathering amphibole-rich layers. These units occur in different proportions in the various exposures and in different parts of the same outcrop. The layers are generally folded and, in some places, highly contorted. Reddish-brown-weathering garnetiferous bands are most conspicuous in exposures in the southwest part of the area (Plate 1, Figure 2).

Thin-section studies indicate that the light gray weathering bands consist mainly of granular quartz with minor magnetite and greenish amphibole. Magnetite-rich bands consist predominantly of magnetite in association with quartz and amphibole. In some instances the three minerals form interlensing units in which one or the other mineral predominates. In some exposures the magnetite grades from granular aggregates with quartz to massive

magnetite in which grain boundaries are indistinguishable.

Exposures of banded iron formation along the south shore of Long Lake contain highly magnetic, bluish-gray, iron-rich layers associated with light gray siliceous bands. The layering is discontinuous in some zones where it is slightly disturbed or disrupted. The iron formation units in this region are associated with light grayish-green, hard felsic rock of possible volcanic origin. To the south of the lake the iron formation is finely banded, crenulated, highly magnetic, and associated with greenstone.

The westward continuation of the Long Lake greenstone belt north of Lake Duncan, contains extensive units of banded iron formation which are highly magnetic in part. The iron formation is associated with layered greenstone which includes pillowed lavas and is complexly folded in some areas. In one area the banded iron formation has been intruded by gabbro which occurs as a lense-shaped unit in the iron formation. Some of the banding adjacent to the gabbro is highly contorted suggesting that the layered material was in a relatively incompetent, pliable state adjacent to the gabbro intrusive. The garnetiferous iron formation in the southwest region is also folded and intruded by massive greenstone.

The conformable association of the iron formation with metasedimentary units lacking magnetite-rich layers and with mafic metavolcanic rocks suggests that the

iron formation was deposited in favorable environments in volcanic regions and that volcanism may have supplied at least some of the iron represented by the magnetic rich layers. This association of metavolcanic and metasedimentary rocks with layered magnetic quartz-iron formation in which layers of magnetite are interlayered with quartzitic units (Place 4, Figure 4), some of which are entirely quartz, is a commonly observed relationship in greenstone belts of the Superior Province (Goodwin, 1952) and has been called the Algoma type iron formation (Douglas, 1970, p.174).

The intrusion of iron formation by massive mafic rocks (Plate 1, Figure 2) indicates, as mentioned previously, that sedimentation and tectonic activity predated some of the volcanism or at least emplacement of massive basaltic units. The slump structures occurring in some of the iron formation units suggests unstable conditions and some topographic relief in the region. This condition is also indicated by texture and composition of some of the metasedimentary rock units discussed in the following sections.

Metasedimentary Rocks; Arkosic and Feldspathic
Metawackes, Quartz and Feldspathic Meta-Arenites

Metamorphosed impure sandstones, ranging in maturity from arkosic metawacke to quartz meta-arenites, are major components in the metavolcanic-metasedimentary rock belt in the Sakami Lake area. There appears to be a conformable gradation from this zone into the predominantly

Metavolcanic zone to the west and into the granite-gneissic zone to the east.

Arkosic and feldspathic metawackes are exposed along the west shore of Sakami Lake (north) in a northeasterly trending zone. Exposures weather medium gray and show banding in some places. Exposures are more varied along the east side of the lake as metawackes grade into a sequence containing feldspathic arenite and coarse granite units.

Some exposures in this easterly region contain well developed dark tourmaline crystals in a diablastic habit. Exposures of arkosic metawacke, in which minor bands of lighter gray rock show well developed boudinage structure, also occur.

Exposures consisting of fine grained, dark gray and buff weathering metasedimentary rock units occur in the central part of the metasedimentary-metavolcanic rock belt at Sakami Lake. Some of the layers are disrupted and have a rolled structure (Plate 2, Figure 2). The occurrence of the disturbed units immediately adjacent to more continuous layering suggests that the disturbance may be due to preconsolidation slumping.

Banded brownish-gray weathering metasedimentary units are exposed in the northwest part of the lake. Some of the bands have been fragmented and the fragments have random orientation. Contacts with neighboring layers vary from

sharp and straight to slightly gradational and disturbed. This structure also suggests preconsolidation slumping.

A common associate of banded greenstone, greenstone flows, and massive greenstone, is a medium to light gray weathering metasedimentary rock in which coarse diablastic green amphibole, probably actinolite-tremolite, occurs as a major constituent. Thin-section studies indicate that the rock is a fine grained felsic metawacke in which greenish chlorite forms part of the fine fraction. Amphibole forms up to 10 percent or more of the rock and has a conspicuous sieve texture suggesting a secondary origin. The rock has conformable and disconformable relationships with the associated greenstone indicating intrusion by basaltic rock.

Chemical analysis of this rock shows that it is chemically similar to some graywackes, particularly to a variety from the Miocene of Papua (Pettijohn, 1975, p.306). A comparison is given in Rows F and G of Table 2. Pettijohn (1957, p.303) suggests that such rock is derived from, or is contaminated by, basaltic tuffs. This view coincides with the metavolcanic association observed in the field at Sakami Lake mentioned in previous paragraphs.

Arkosic and feldspathic metawacke units inter-layered with greenish-gray weathering garnetiferrous-amphibolite bands occur in the southwest area. Bands of light gray, soft, sericite schist and, to a lesser extent,

TABLE 2

Comparison of Chemical Compositions
of Some Metasedimentary Rocks

	↓		↓		↓		↓	↓
Oxide	A	B	C	D	E	F	G	H
SiO ₂	64.7	63.14	62.40	63.9	72.3	53.30	55.8	50.4
Al ₂ O ₃	14.8	15.54	15.20	14.9	15.2	18.33	13.9	14.2
Fe ₂ O ₃	1.5	}	0.57	}	}	2.41	}	}
FeO	3.9		4.61			2.36		
MgO	2.2	3.62	3.52	3.7	0.3	2.62	5.0	6.5
CaO	3.1	5.84	4.59	4.7	5.3	5.88	10.7	9.9
Na ₂ O	3.1	3.80	2.68	3.5	4.4	2.18	3.6	2.9
K ₂ O	1.9	1.11	2.57	2.1	0.9	1.72	0.9	0.1
TiO ₂	0.5	0.35	0.50	0.5	0.3	0.84	0.7	1.3
MnO	0.1	0.06	-	-	-	0.08	0.01	0.1

- (A) Average of 23 graywackes (Pettijohn, 1957, P. 307).
- (B) Average of 6 feldspathic-arkosic wackes, Sakami Lake area.
- (C) Average of 3 graywackes from the Archean of Minnesota (included in (A) above).
- (D) Typical looking feldspathic wacke, Sakami Lake area.
- (E) Average of 2 arkosic wackes, Sakami Lake area.
- (F) Graywacke from the Miocene of Papua (included in (A) above).
- (G) Average of 2 probable volcanic graywackes from the Sakami Lake area.
- (H) Average of 2 basaltic, lithic wackes from the Sakami Lake area.

bands of highly quartzitic schist also occur in this region. The banded sequence grades northward into banded iron formation and greenstone and into a granitic region southward.

Metasedimentary rock units in the distinctly banded zone between Long Lake and Alder Lake in the northwest part of the map area contain light gray weathering layers of feldspathic metawacke interbanded with fine greenish-gray weathering greenstone. At one location, the south-facing side of one of the light gray bands is slightly disturbed and fragments of light gray rock occur within the greenstone. The fragments are randomly oriented and consist of very fine-grained, light gray feldspathic metawacke to feldspathic meta-arenite in which foliation had developed prior to disruption.

Metasedimentary rocks comprising the arkosic and feldspathic metawackes and meta-arenites contain ferromagnesian minerals and opaque minerals to varying degrees in addition to the predominant felsic mineral content. Chlorite, biotite and amphibole are the most common ferromagnesian minerals. Garnet and tourmaline, usually exhibiting well developed sieve texture, occur in some zones. Opaque minerals form minor constituents. Those observable are magnetite, hematite, pyrite, ilmenite and leucoxene. The leucoxene is found in association with opaque mineral which is dark in reflected light and is probably ilmenite. The felsic minerals are predominantly quartz and altered albitic feldspar. Color-

less mica or sericite is observable in most zones to some extent and microcline also occurs as a minor constituent in some places.

Metamorphism among the various metawackes in the central part of the region appears to be in several subfacies of the greenschist facies. Zones containing chlorite and white mica in association with quartz and albite are indicative of the quartz-albite-muscovite-chlorite subfacies. In addition the chlorite-actinolite association found in many zones of metawacke derived in part at least, from mafic volcanics (Table 2) is also indicative of this facies. The presence of brown biotite in places suggests that parts of the region had been in the quartz-albite-epidote-biotite subfacies; however, many of the biotite grains contain chlorite suggesting prograde or retrograde transitions to the quartz-albite-muscovite-chlorite subfacies. Some zones contain the almandine-biotite assemblage which indicates the occurrence of the quartz-albite-epidote-almandine subfacies.

The occurrence of tourmaline at several locations suggests that it may be a minor, but commonly occurring, constituent among the metawackes and also indicates that boron was a constituent in the original sediments.

Zircon is a common constituent in biotite in which pleochroic halos are also observable. Sillimanite occurs as a very minor constituent in the very fine, impure

sandstones in the southwest part of the region.

Banded Quartz Arenite

Banded quartz arenite, in which brecciated mudstone and lenses of rounded gravel and pebbles occur in the lower members, forms a distinctive hill region immediately north of Lake Cataseau, in the north part of the mapped area.

In addition to quartz, feldspar (including microcline) and calcite are minor constituents. The grains are moderately to well sorted and rounded to subrounded. Recrystallization and suturing has resulted in a tight, interlocking fabric in some places. In other places intergranular zones occur and are occupied by finer felsic mineral grains.

This sequence of quartz arenite is part of the Proterozoic rock assemblage discussed earlier in the section on regional relations. It contrasts with the Archean units in being distinctly cross bedded in many places. Moreover, bedding in these units is only slightly inclined whereas the Archean units in the vicinity are steeply inclined and consist of a variety of rocks.

Quartz arenite is also exposed as conformable units in the Archean metasedimentary-rock sequence of Sakami Lake (north). Sericite, biotite, chlorite and amphibole form minor constituents in varying proportions. Some of the sericite has well developed sieve texture. Disruption

of primary layering is indicated in some places by thin curved layers of amphibole in an otherwise massive fabric of interlocking quartz grains.

The zone of predominantly metamorphosed impure sandstones at Sakami Lake represents a continuous unit of clastic metasedimentary rocks adjacent to a metavolcanic-metasedimentary zone which consistently forms the rock sequence to the west and northwest. The banded units in the southwest, including the iron formation, are on strike with these clastic rock units and may be a facies in an essentially contemporaneous sequence of wide lateral extent across the mapped area.

Rows A, B, C, and D of Table 2 indicate that the feldspathic-arkosic metawackes, representing the major part of the impure metasandstone zone, have the chemical composition of graywackes. The metawackes from the Sakami Lake area are similar in chemical composition to graywackes from Archean areas of the Shield as well as graywackes of more recent development (Table 2).

The presence of banding within the unit suggests variation in conditions and composition. This is shown by the presence of conformable bands of arkosic arenite (Table 2, Row E) and metawacke units of more mafic composition (Table 2, Row G).

Foliated Felsite

The northwest part of the Sakami Lake area contains several exposures of a very fine grained, highly

sheared, crenulated felsic rock which consists mainly of alternating zones of very fine granular, felsic layers and layers rich in micaceous mineral which appears to be sericite. Layers of an opaque mineral constitute about 15 to 20 percent of the rock and are more commonly observed in the micaceous zones. The opaque mineral is whitish gray in reflected light, suggesting that it is leucoxene. Chlorite, occurring as clots and lenses, forms about 5 percent of the rock.

Some exposures in the region contain a similar appearing rock which is a fine-grained quartz metawacke. It is highly sheared with slip surfaces intersecting at low angles. A micaceous mineral forms about 25 percent of the rock.

Banded Quartzitic, Limonitic Rock

Fine grained light gray to rusty weathering quartzitic sandstone is exposed in several places in the Sakami Lake region. Limonite content in the rock causes the rusty appearance of the weathered rock, and much of this limonite appears to be due to pyrite alteration. Some bands contain a higher concentration of limonite and weather to a slightly darker brown.

Several exposures are quartzite units with streaks and lenses of dark gray, very fine shaley material. The sugary or saccharoidal texture of the almost clear quartz suggests that it may be recrystallized chert and the dark lenses may be original argillaceous material.

Several exposures of quartz-limonite rock also occur in the metavolcanic-metasedimentary zone north of Long Lake.

Many of the exposures, particularly in the Sakami Lake region, occur on strike with each other and these rocks may represent a particular facies of considerable lateral extent in the mapped area.

Banded Amphibolitic Schist and Gneiss

Banded amphibolitic schist and gneiss are exposed at several locations in the metavolcanic-metasedimentary rock bands and in adjacent zones. Fine grained, foliated, amphibole-gneiss units consist of interlensing of felsic minerals and greenish amphibole in which sieve texture is often observable. The fine grained units of felsic minerals have altered felsic grains which appear to be feldspar. Amphibole, epidote, and opaque grains in small clots and stringers are minor constituents. An opaque mineral often forms the core area of bead-like aggregates of sphene; these relationships suggest that the opaque mineral is ilmenite and that the sphene is derived from the ilmenite.

Amphibole-quartz gneiss consists of inter-layered units of felsic minerals, mostly quartz, and amphibolite units which are garnetiferous in part. Units range from a few millimeters to several centimeters in thickness and are associated with the banded magnetic-iron

formation zones. Zircon, usually distinguished by pleochroic halos, is a common constituent of the amphibolitic layers. The zircon tends to be concentrated in elongate lenses; however, these concentrations are not related to amphibole-grain boundaries. These lenses may represent relict bedding in an otherwise recrystallized rock.

Quartz-rich layers appear to be disrupted zones of more finely banded rock, as thin, elongate and curved stringers of amphibole outline fold patterns. This feature is observable in the amphibolitic units also, in which case folds are outlined by contacts between colorless and greenish amphibole units.

It appears that amphibolitic gneisses, in some cases at least, represent disturbed and recrystallized bodies of rock which were originally more finely banded. This phenomenon is further exemplified in exposures in the northwest part of Sakami Lake where medium to coarse grained amphibole-chlorite layers, which are intercalated with quartz-calcite layers, contain parallel stringers of fine opaque mineral which transect the grain boundaries of the much coarser amphibole and chlorite (Plate 5, Figure 2).

Another variety of amphibole-rich rock consists of amphibolitic schist in which in which layers of poikiloblastic amphibole are interlayered with felsic units consisting mainly of quartz, colorless epidote, and brown biotite as a minor constituent in some zones. Some

of the felsic layers have a distinctive boudinage structure with quartz being the major mineral in the fracture areas between the boudins.

Minor, fine granular opaque grains form discontinuous stringers in some layers. However, in the coarser amphibolite-rich units the opaque grains constitute clots and minor scattered stringers. As in the instances mentioned above it appears that the stringers of opaque mineral may be relicts of primary bedding which has been disturbed to varying degrees.

In some zones greenish chlorite-rich layers are intercalated with felsic units consisting mainly of quartz and feldspar with calcite and epidote as minor constituents. Occasionally opaque grains form elongate lenses adjacent to the felsic units. There appears to be a gradual variation in the frequency of the felsic and opaque-mineral bands relative to the chlorite-rich units which suggests a rhythmic variation in the original depositional conditions.

Lithic Metawacke

Units of lithic metawacke consist of rock which has lithic fragments of predominantly mafic composition and varieties in which rock fragments are felsic, mainly of granular quartz.

The units which are more mafic contain poorly sorted aggregates of amphibole grains, amphibole-felsic rock fragments, quartz grains in minor amounts,

patches of chlorite, opaque grains, and clots of massive, fine, brown alteration products which contain flecks and patches of an opaque mineral. Calcite also forms scattered patches. Other varieties contain clots and irregular curved lenses of fine granular felsic minerals which appear to be remnants of disrupted layers (Plate 5, Figure 3).

Units of felsic, lithic metawacke are exposed in the Sakami Lake region which contain rounded fragments composed of sutured quartz grains. Quartz, feldspar, sericite and biotite form the finer fraction. There appears to be a gradation between this rock and rock in which there is a more continuous gradation of grain size between the coarser lithic fragments and the finer fraction.

Some exposures in the Long Lake area consist of disrupted sedimentary units in association with masses of chlorite, calcite and quartz. The fragments of sedimentary rock consist of layers of highly sutured quartz interbedded with relatively thin layers of granular magnetite. The chlorite-calcite-quartz matrix also contains well formed, randomly distributed pyrite grains.

Thin-section studies of mafic, lithic metawacke indicate that these rocks probably are derived from mafic volcanics. In addition, chemical analysis (Table 2, Row H) show that some of these rocks are similar to basalts chemically.

Massive units of amphibole-rich rock, in

which the amphibole appears to be largely secondary as indicated by pronounced sieve texture and comb-like texture between mafic and felsic minerals, may also be basaltic in origin. However, the various exposures of amphibolitic schist and gneiss in which relict banding occurs indicates that finely banded sediments with mafic mineral-rich units were forming in the vicinity of volcanic activity. The present coarser, gneissic structure of these rocks is due to recrystallization.

Plutonic Rocks

Medium to coarse-grained rocks of possible plutonic origin consist of granites, pegmatites, diabase and gabbro. The gabbroic rocks are closely associated with greenstone units and the term is used in the field to indicate a medium grain size. Fine to coarse grained rocks of ultra-mafic igneous origin, or possibly of sedimentary origin, are exposed in several places.

The granitic rocks consist of massive amphibole granite (Plate 5, Figure 4) and porphyritic granite in which mafic minerals consist of biotite, chlorite, epidote and amphibole in varying proportions. Phenocrysts consist of feldspar and, to a lesser extent, quartz. Feldspar is commonly highly altered; however, numerous occurrences of zoning and relict twinning indicates that plagioclase is the predominant feldspar in the granitic rocks. Analysis of albite twinning shows that the plagio-

clase is in large part albite with some andesine observable, and the common occurrence of zoned plagioclase suggests the igneous origin of the granite.

Cataclastic texture is commonly observed in most granite units and gneissic structure is due to cataclasis in many places.

Some exposures, particularly around the Sakami Lake metavolcanic-metasedimentary rock belt, show granite and greenstone units interlayered or interlensing and interpenetration between these rocks has resulted in exposures where greenstone and dark schists occur as fragments in granitic rock.

Diabase occurs as dikes and rock of ultramafic igneous origin is suggested by several exposures of amphibole-pyroxene bearing rock and, in other places, tremolite-anthophyllite rich units. Thin-section studies of some of these rocks are discussed in Appendix 1.

Amphibole Granite

The mapped region south of Long Lake contains areas underlain by amphibole granite (Plate 5, Figure 4) which has a variable quartz content. The granite is medium grained, massive, and weathers pinkish gray; mafic inclusions are common features.

The pinkish-gray weathering is due to a high degree of alteration in the feldspar much of which is zoned plagioclase (Plate 5, Figure 4). In addition, iron-oxide

staining is a common feature and some exposures contain reddish veins of very fine material some of which appears to be highly altered constituents of the host rock.

Several regions contain banded greenstone units which have been disconformably injected by the amphibole granite (Plate 2, Figure 1) and many of the contact areas contain inclusions of the greenstone in various stages of incorporation in the massive granite (Plate 2, Figure 1).

Some inclusions have a conspicuous development of secondary light gray feldspar and some of these feldspar grains transect the contact of the granite and the inclusion. Inclusions are also observable which contain inclusions of pre-existing rock, well defined and darker than the host material. Many of the inclusions in the granite and some contact zones with the banded greenstone have reaction zones several millimeters thick which appear to consist of dark green amphibole.

Scattered dark green mineral clots which are commonly ovoid are observable in the amphibole granite in some areas. These clots range from two to three centimeters up to ten and twelve centimeters across and all appear to consist of green amphibole which often shows a radiating habit in the smaller structures. Larger units tend to have an outer rim one to two centimeters thick in which the fibrous crystals are perpendicular to the surface.

The interior of these features consists of a cluster of randomly oriented crystals of amphibole which appears to be the same type, but of slightly finer grain size.

Only one analysis of the amphibole granite is available (Table 3). The analysis shows a close similarity to Daly's average diorite and a little less acidity than Daly's average tonalite. To what extent

Table 3

Comparison: Intermediate Plutonic Rocks

↓

Oxide	A	B	C
SiO ₂	58.5	59.7	62.4
Al ₂ O ₃	14.6	16.9	16.4
Fe _x O _y	6.8	7.2	6.4
MgO	3.5	3.6	2.8
CaO	10.1	6.2	5.5
Na ₂ O	4.8	3.5	3.4
K ₂ O	1.1	2.1	2.1
TiO ₂	0.6	0.4	0.7
MnO	0.0	0.0	0.0

- (A) Analysis of one sample of amphibole granite rock, Sakami Lake area.
- (B) Daly's average diorite (Hatch, Wells and Wells, 1949, p.267).
- (C) Daly's average tonalite (Hatch, Wells and Wells, 1949, p.267).

contamination has affected the composition of the rock type is uncertain. The scattered occurrences of amphibole clots, zoned plagioclase, and observable variation in quartz content in many exposures suggest that the rock may vary from dioritic to granitic composition.

Granite; Porphyritic, Sheared

The region west of Sakami Lake has numerous exposures of medium-grained, medium gray to slightly pinkish-weathering granite which is predominantly porphyritic and has a variable quartz content.

The phenocrysts are mainly plagioclase and, to a lesser extent, quartz. Ferromagnesian minerals consist of chlorite, biotite, amphibole, and epidote in varying proportions with chlorite, biotite, and epidote being consistent components. Massive units of greenstone, some of which are fragmental, are exposed among granite units and some exposures are observable in which greenstone fragments are included in granite and in some cases greenstone fragments have been penetrated by the granite. In addition, exposures occur in which the granite contains dike-like structures, stringers and lenses of lighter, more quartz-rich granitic rock. These penetration features suggest that granitic rock has incorporated more mafic rocks during its emplacement or, as suggested in the section on metavolcanic rocks, granite and greenstone, particularly granite, has been remobilized to some extent during tectonic activity. This action could

result in granite penetrating and fracturing units of greenstone which were associated with the granite previously.

Stringers and lenses of lighter quartz-rich granite could have originated from late stage fluids within the granite body.

The randomly distributed phenocrysts in the granite vary from light gray to slightly pinkish and the associated matrix commonly has a light greenish color similar to a variety of porphyritic granite mentioned in subsequent paragraphs.

This northeast-trending zone immediately west of the metavolcanic-metasedimentary rock belt at Sakami Lake contains units of granite interlayered with and cross-cutting greenstone units some of which are porphyritic and discussed under metavolcanic rocks.

This region around Sakami Lake also contains exposures of porphyritic granite in which phenocrysts of zoned plagioclase and microcline are commonly observed. Larger grains are well formed and mafic-mineral inclusions give some of the phenocrysts a sieve texture. Brownish-green biotite, minor greenish amphibole, and epidote are the mafic constituents and form about 10 percent of the rock. Quartz forms about 15 percent and tends to form clots or clusters of grains.

The region south of Lake Cataseau and immediately west of the Sakami River contains exposures of

highly sheared quartz-porphyry granite in association with contorted and folded dike-like units of greenstone which are discussed in the section on metavolcanic rocks.

Phenocrysts in the granite, which are predominantly quartz, appear on weathered surfaces as light colored coarse knots which, in association with the highly sheared greenish matrix, give the rock a fragmental appearance. The greenish color appears to be due to the fine texture and a consistent chlorite and epidote content. Some feldspar phenocrysts are observable which are highly altered and granulated through cataclasis.

Granitic zones in the Sakami Lake and Long Lake areas appear to be elongate units interlensing with greenstone bands, some of which are dike-like features and others fragmental. The amphibole granite discussed earlier is a more massive unit with a more irregular shape.

The massive structure of the amphibole granite which is also apparent in thin section, where signs of cataclasis were not observed, is in marked contrast to the highly cataclastic texture observed in much of the predominantly porphyritic granite. It appears that the massive amphibole granite postdates any severe tectonic activity in the region and was definitely emplaced in the fluid state whereas the highly sheared granite was involved in severe tectonic activity or was emplaced in a semisolid or solid state for the most part.

Granitic Rock, Gneissic Pegmatitic

The map area east of Sakami Lake consists of a folded, interlayered sequence with granitic intrusives which have conformable and disconformable relationships with the layered rocks. The layered rocks consist of fine grained, dark, feldspar-biotite schists and coarser, granitic gneisses.

Medium-grained, light gray, foliated, granitic gneiss composes a large part of the central region east of the lake. The material is often friable and is fairly equigranular. Biotite forms about 3 percent of the rock. It is evenly disseminated and alignment of the grains forms a distinct foliation. Minor amounts of garnet and muscovite are also present.

Some dike rocks in this foliated rock have foliation conformable to that in the host rock. Foliation is indicated by aligned biotite grains some of which transect the contact between the dike material and the host rock. Coarse, pinkish-gray, massive, granitic dikes intrude the finer granitic gneiss in several areas and these dikes have various attitudes and constitute the greater part of many outcrops.

Feldspar-biotite schist interlayered with medium to fine-grained granite is exposed in most areas east of Sakami Lake. In addition to interlayering there are disconformable contacts between the two rocks and inclusions of schist exist in the granitic rock. Ptygmatic structures

involving irregular granitic veins in the schist are common occurrences.

The feldspar-biotite schist is fine grained, medium to dark gray and contains variations to a more gneissic structure. The biotite content is variable but most often appears to be about 20 to 25 percent of the rock. The schist often has granitic bodies associated with it which vary from bands conformable to foliation to irregular ptigmatic-like features. In some instances, these structures are observed to connect with more conformable granitic units and appear to represent mobilized or injected materials derived from the larger masses of granite.

The feldspar-biotite schist often occurs as large inclusions within the gray granitic rock units. These inclusions vary from irregular, folded or contorted features to relatively undisturbed structures with alignment and foliation parallel to that of other schist exposures in the vicinity.

Thin quartz lenses occur in the schist in some areas. In some cases straight, thin, quartz stringers or veins form a distinct crosscutting pattern over the exposure and give the impression of quartz-filled joints.

The interlayered schist and granitic rock contain coarse, gray to pinkish granitic dikes which in some places occur as irregular blobs and pods in the finer host rock. The dike rock contains occurrences of euhedral

tourmaline crystals which, in some zones, have a common attitude expressing a mineral lineation. Apparently the tourmaline crystals occur on planes coincident with foliation planes in the granitic host rock. This phenomenon suggests that the tourmaline is of metamorphic origin and developed under directioned stresses in the area.

Coarse, massive light gray to pinkish pegmatitic units form massive exposures in some regions east of the lake. These units vary from dikes a few centimeters wide to large ridges and cliffs. Light gray to pinkish feldspar, often euhedral and subhedral, forms the greater part of the rock. Quartz blebs, traces of biotite, and occasional clusters of dark tourmaline form the remainder. Graphic granite is a minor feature in some exposures.

The distribution of minerals in the smaller pegmatitic units varies considerably in some regions. In some places the distribution is uniform, but, in others quartz, or sometimes biotite, is concentrated in blebs or lenses in the central portions of the dikes. Tourmaline is a major accessory in some exposures and in some places the tourmaline crystals have their long axes normal to the contact zone or in a slight radiating pattern centered near the contact wall.

Some of the large pegmatitic bodies which form distinct ridges have units of feldspar-biotite schist associated in the lower protected areas of the steeper,

cliff-forming slopes. It appears that the massive pegmatite is conformably interlayered with the feldspar-biotite schist in such instances.

Several exposures of distinctly reddish-pink granitic rock occur in the area east of Sakami Lake. These form a minor part of the exposed rock. Some of these units have light pinkish-gray feldspar similar to that in the coarse pegmatitic rock but with a distinct reddish staining on the exposed surfaces of the feldspar grains which appears to be iron oxide.

Diabase

Large exposures of diabase are not numerous in the map area. In most instances exposures do not show contact relationships and regional trend is, therefore, not often decipherable. One large diabase dike, situated in the west part of the central Sakami Lake area, cuts across banded material and also cuts across aplitic dikes associated with the banded rock. Contacts are sharp and there is no apparent contact-alternation zone. Some parts of the dike, which strikes 335° are weakly magnetic. The diabase weathers brownish-gray and exhibits a medium-grained diabasic or ophitic texture. A large diabase dike of regional extent occurs in the northeast part of the area trending across the north part of Sakami Lake at approximately 315° . This feature cuts across the steeply inclined northeast trending metavolcanics and metasedimentary rocks and forms several

small islands in the lake. At one location in the meta-volcanic-metasedimentary sequence the dike has been faulted and offset by several hundred feet showing an apparent right-lateral movement.

Only one analysis of the diabase is available (Table 4); however, this analysis suggests that diabase in the Sakami Lake region is alkalic rather than tholeiitic. This feature and the high K_2O value relative to typical tholeiitic flood basalts is very suggestive in considering the time of intrusion of the Sakami Lake diabasic rock.

Both tholeiitic and alkalic basalts form diabase dike swarms in the Canadian Shield (Stockwell and others, 1970, p.131). Analyses of various dike swarms indicate that the tholeiitic dikes generally are pre-Neohelikian (late Proterozoic) in age and the alkalic dikes are younger. In addition, Leich (1966) has suggested, on the basis of radiometric age determinations based on the potassium-argon method, that the increasing K_2O content coincides with younger age.

The relative alkalic nature of the Sakami Lake analysis (Table 4) and the relatively high K_2O content in relation to tholeiitic flood basalts (Table 4) would suggest that the diabase dikes at Sakami Lake are not Archean in age but Proterozoic or younger. This suggestion is compatible with field features which show that diabase has cut across other rock units and postdates folding in the region.

Table 4Chemical Analysis of Diabasic Rocks

Oxide	A	B	C	D
SiO ₂	47.6	46.8	50.6	51.9
Al ₂ O ₃	13.1	14.6	13.6	15.1
Fe _x O _y	10.8	11.6	13.1	10.3
MgO	8.7	6.8	5.5	6.6
CaO	14.7	12.4	9.5	10.0
Na ₂ O	2.4	2.6	2.6	2.1
K ₂ O	2.3	1.1	0.7	0.9
TiO ₂	0.4	3.0	1.9	1.3
MnO	0.01	0.2	0.2	0.2

- (A) Analysis of diabase sample, Sakami Lake area.
- (B) Average effusive alkali basalt (Barth, 1962, p.59, after Nockolds, 1954).
- (C) Average of 11 Deccan basalts (Turner and Verhoogen, 1960, p.208, after Washington, 1922).
- (D) Average of diabase from 4 different parts of the world (Turner and Verhoogen, 1960, p.215).

Rocks of Probable Ultramafic Origin

Rocks of possible ultramafic origin in the region consist of dark gray, massive pyroxene-amphibole-garnet-bearing rock, massive anthophyllite-tremolite-talc,

and talc-carbonate schist.

The north part of the mapped area in the Sakami Lake region contains several exposures of massive, medium to coarse grained rock which weathers dark gray to slightly reddish in some places. Major constituents appear to be pyroxene, amphibole and to a lesser extent garnet. These rocks are exposed in the vicinity of greenstone; granitic rock; and banded, rusty weathering, quartzitic rock.

Massive anthophyllite-tremolite-bearing rock occurs on several islands in Sakami Lake. Randomly distributed dark gray blebs show distinctively on the medium-gray weathering surface. Thin-section studies indicate that the rock is mainly massive anthophyllite and tremolite with talc and minor pale-brown mica. The darker gray blebs appear to be pseudomorphs after olivine consisting of tremolite, a colorless fibrous serpentine mineral and opaque grains some of which are pyrite.

To the east of these exposures an outcrop of fine, massive rock with a distinct diablastic texture is exposed in association with feldspar-biotite-schist. The rock consists of anthophyllite, tremolite and a pale brown micaceous mineral. Contact zones with the feldspar-biotite schist are highly foliated and irregular suggesting a possible intrusive origin for the rock.

Calcareous talc schist is exposed in the southwest part of the mapped area. The rock is highly

crenulated and foliated. Talc forms about 80 percent of the rock and carbonate mineral forms most of the remainder in the form of thin lenses. Dilute hydrochloric acid does not react with the carbonate mineral which suggests that it is dolomite or possibly magnesite. About 1 to 3 percent of the rock consists of pyrite grains.

The mineral assemblage contained in these rocks in addition to the relict olivine structures mentioned is highly suggestive of regional metamorphism of ultrabasic rocks (Harker, 1939, p.275 - 278; Williams, Turner and Gilbert, 1953, p.223 - 225). The most essential aspect of this alteration procedure is the presence of an aqueous solution containing SiO_2 and CO_2 which can enter into reactions; correspondingly, magnesian and ferrous carbonate may migrate away from the area or collect in distinctive units.

Winkler has indicated (1967, p.27 - 29) that the talc-dolomite and/or magnesite mineral assemblage may result from the alteration of siliceous, magnesite bearing, dolomites in the albite-epidote-hornfels facies of contact metamorphism or in the greenschist facies of regional metamorphism. In addition, the talc-tremolite-anthophyllite assemblage may occur as a result of reactions in siliceous, carbonate rocks in the hornblende-hornfels facies (Winkler, 1967, p.37 - 39).

CONCLUSIONS AND DISCUSSIONS

The evaluation and correlation of results from this study indicate that the Sakami Lake greenstone belt has similarities in several respects with other greenstone belts of the Superior Province, mainly in the petrology of the metavolcanic and metasedimentary rocks, and in the evidence that felsic plutonic rocks were sources for some of the sediment. It seems likely that the greenstone belt at Sakami Lake developed in the same way as the other greenstone belts of the Superior Province and it is also probable that the Sakami Lake belt is an integral part of the Superior Province complex of greenstone belts and can be subjected to the same model of development.

As a result of the studies done in the Sakami Lake area appropriate boundaries of several rock groups have been delineated (see accompanying maps). In this section conclusions are presented concerning four distinct aspects of the region which are listed below and will be discussed in that order. Following this discussion a sequence of events will be presented in tabular form.

Conclusions

1. Pre-volcanic Terrane

Rocks of mixed composition including felsic plutonic rocks constituted an exposed hinterland of low relief at the time of the volcanism from which the metavolcanic rocks at Sakami Lake are derived.

2. Rock Assemblage at Sakami Lake

The rock assemblage at Sakami Lake is similar to that occurring in many other greenstone belts in the Superior Province which have, according to Pettijohn (1943), assemblages typical of the eugeosynclinal environment. Subaerial conditions appear to have prevailed in some regions.

3. Regional variations in the Rock Assemblage of Greenstone Belts

The greenstone belt assemblage appears to be a conformable phase of a more extensive metasedimentary-metavolcanic rock group. Some granitic rock units in the greenstone belt region may be the result of reconstitution and recrystallization of pre-existing layered rocks.

4. Tensional Origin of the Sakami Lake Greenstone Belt

The Sakami Lake greenstone belt appears to be part of a regional network of belts which originated through fracturing in the earth's crust.

Discussions

1. Pre-volcanic Terrane

Felsic plutonic rocks and/or gneissic rocks constituted at least part of an exposed hinterland of low relief at the time of the volcanism which formed the precursors of the metavolcanic rock units at Sakami Lake.

The various metawackes constituting the elongate section along the east side of the main metavolcanic-metasedimentary rock sequence fall within the graywacke range

in chemical composition (Table 2.).

Thin section studies indicate that the felsic grains are fairly equidimensional and the quartz contains few impurities or inclusions although trains of dust-like particles are common. Undulant extinction was not noticeably strong among the quartz grains. Rock fragments were not observed among the wackes. Although some of the mafic mineral grains could be reconstituted mafic rock fragments the grains observed appear to be clastic mineral fragments. These features coincide with Pettijohn's view (Pettijohn, 1957, p. 303) that the average graywacke is mainly quartz and feldspar, approximately two-thirds of the total, and is therefore derived mainly from felsic plutonic rocks. A probable granular, felsic-rock origin is also suggested by the very close similarity in chemical composition between Daly's average diorite (Table 3, Row B) and the typical feldspathic wacke of Table 2, Row D, in the previous section.

Lithic units in the felsic-lithic metawackes which form part of the metasedimentary rock sequence consist of relatively coarse polycrystalline quartz fragments (Plate 5, Figure 1). These fragments are very similar to quartz fragments noted by Walker and Pettijohn in graywackes associated with greenstones in western Ontario and considered indicative of a felsic-plutonic source area (Walker and Pettijohn, 1971, p. 2122). Severely strained quartz with undulant extinction suggests that the grains could have come from granular units which had suffered some directional pressure.

Fragments of granitic rock are visible in outcrop in association with fine-grained greenish gray and reddish metavolcanic fragments in the metavolcanic band south of Long Lake. Various components have also been described in thin-section studies. The rock and mineral association found in this unit substantiates the other evidence for a source area containing granular felsic rocks.

Grains larger than granules (2-4 millimeters) were not observed in the metasedimentary rock sequence suggesting that the proposed source area was in low relief. In addition, the occurrence of arenaceous units in several areas indicates that periods of less rapid deposition occurred and conditions may have been similar to a stable shelf environment particularly in the eastern zone of the mapped area.

It appears that a hinterland area of low relief and consisting, in large part at least, of felsic plutonic rocks existed at this time and was supplying sediments to an elongate trough area at the time of volcanism.

This concept is further substantiated by the chemical analysis of the metavolcanic rocks which belong to the calc-alkaline suite (Figure 2) which is indicative of a continental orogenic or island arc environment.

2. Rock Assemblage at Sakami Lake

The greenstone-belt assemblage at Sakami Lake consists of the following main rock types: (1) metamorphosed

clastic sediments of graywacke chemical composition interlayered with minor bands of arenaceous metasedimentary rocks; (2) banded quartzitic iron formation closely associated with metavolcanic rocks and more mafic fragmental units, and tuffs; (4) rhyolitic fragmental zones and finely banded felsic metasediments of probable felsic volcanic origin; (5) metavolcanic units interlayered with metawackes of probable mafic volcanic origin. Preconsolidation fold and slump features exist at several locations within the banded metasediments (Plate 2, Figure 2) and in the banded iron formation.

This assemblage is similar to that found in many of the greenstone belts in the Superior Province (Pettijohn, 1943). The greenstone belts are considered by some authors (i.e. Pettijohn, 1943) to represent eugeosynclinal conditions. One exception or difference in the assemblage at Sakami Lake appears to be the lack of conglomeratic zones; however, such zones may be found in the future.

A subaqueous environment is indicated by the several assemblages mentioned previously. However, subaerial conditions are suggested in some places by the occurrence of fragmental felsic units in association with porphyritic felsic zones. Research done by Cook (1966) and Ross and Smith (1961) strongly suggests that bodies of rock often referred to as rhyolite flow are actually³ fragmental ash flows, or ignimbrites, which are erupted subaerially. The apparent close association and/or variation from subaerial to subaqueous environments in

parts of the area, possibly indicating the existence of a group of islands, is suggested by the close association of felsic, fragmental units and finely banded units which may be water-laid equivalents of the fragmental extrusives erupted subaerially.

Several authors have stated that rhyolitic volcanism, and especially the extrusion of ignimbrites, occurs towards the end of the tectonic episode or in the later stages of the geosynclinal cycle (i.e. Cook, 1966, p.15). Although this concept would suggest that the felsic extrusive zones in the Sakami Lake belt represent the last phases of volcanism as well as subaerial conditions, it has been established that a consistent pattern or sequence does not prevail in the greenstone belts of the Superior Province.

Research conducted by Moorehouse (1965, p.947-948) indicates that the stratigraphic succession within documented greenstone belts in the Canadian Shield does not conform to an overall consistent pattern. In the majority of cases volcanic rocks are succeeded by sedimentary rock units. However, in at least 15 percent of the cases recorded volcanic rocks supersede sedimentary rock units. In some cases volcanic rocks are interlayered with sedimentary rocks forming a repeated succession. In still other instances the sedimentary rocks form a unit between volcanic sequences. Within the volcanic rock sequence mafic units underlie felsic units in the majority of cases. In about 15 percent of the

cases the succession is repeated more than once, beginning with mafic materials. Volcanism recurs at the end of the cycle in about 20 percent of the cases. Moorehouse suggests that this variation is what should be expected in the vicinity of volcanic activity and quite different sequences may be contemporaneous.

3. Regional variations in the Rock Assemblage of Greenstone Belts

Several features suggest that the metavolcanic and metasedimentary rock units at Sakami Lake may be a conformable part of a more extensive metasedimentary rock complex in which metavolcanic rocks form some units.

The quartz-feldspar-biotite schist units east of Sakami Lake appear to be conformable and grade into the metawackes at Sakami Lake. Similarly, the region immediately to the west of the Sakami Lake greenstone belt appears to be a conformable continuation of the belt units although much of the mineral content has recrystallized (Plate 5, Figure 2).

Reconnaissance work done by the writer in the region north of Lake Duhcan, to the west of the mapped area, indicates that gradations occur from well-banded, felsic, and mafic sequences to zones in which the mafic units are crosscut or injected by a felsic fraction, giving the appearance of mafic inclusions in granitic material. These layered sequences were also found to contain some zones of mafic rocks and minor, banded, magnetic, iron-formation units. In the same region large areas consist of granodioritic rocks

which are often elongate in form parallel to the regional strike of foliation and have zones containing mafic inclusions. The occurrence of mafic inclusions in felsic plutonic rocks was also a commonly observed phenomenon within the mapped area. These observations tend to substantiate Eade's view (Eade, 1966, p.63) that the felsic units in this part of the Canadian Shield are predominantly of sedimentary origin. A further development of these observations suggests that large bodies of massive, felsic plutonic rocks in the region could be remobilized units which had previously consisted of interlayered felsic and mafic metavolcanic and metasedimentary rocks.

The incorporation and digestion of mafic units by more mobile felsic material could result in massive plutonic bodies of intermediate to granitic composition such as the amphibole granite (Table 3). A possible mechanism for such a phenomenon has been suggested by Henderson and Brown (1966), and Boyle (1961) in their interpretation of field and laboratory studies done in the Slave Province of northwestern Canada, where features occur which are similar in many respects to those observed by the writer.

Henderson and Brown (1966, p.46) observed that mineral and structural variations occur in granitic rocks near greenstone contact areas in the Slave Province. The sodium to potassium ratio is high near the contact, whereas the ratio is much lower away from the contact. These chemical

qualities coincide with the occurrence of granodiorite in the contact zones and granite farther from the contact. In addition, near the contact, there are zones of greenstone inclusions which form up to 30 percent of the rock volume. Areas of assimilation contain inclusions partially transformed into clots of hornblende and some are entirely transformed. This hybrid rock is cut by normal granodioritic rock. Boyle (1961, p.74) suggests that the transformation of sediments below the volcanic assemblage had resulted in granitic material which in turn was basified near the greenstone contacts resulting in granodiorite..

In addition to these granodioritic modifications irregular shaped bodies of dioritic composition exist which contain varying proportions of hornblende and feldspar and a few small quartz eyes. Some of these units contain undisturbed tuff beds. These "islands" are on strike with the main tuff bands, and form up to about 40 percent of the rock volume in some areas. The authors suggest that these bodies represent dioritization of greenstone by refusion, recrystallization or by replacement (metasomatism).

4. Tensional Origin of the Sakami Lake Greenstone Belt

The greenstone belt at Sakami Lake represents a trough or depositional basin in which volcanism occurred. However, the cause of this crustal feature can only be suggested here.

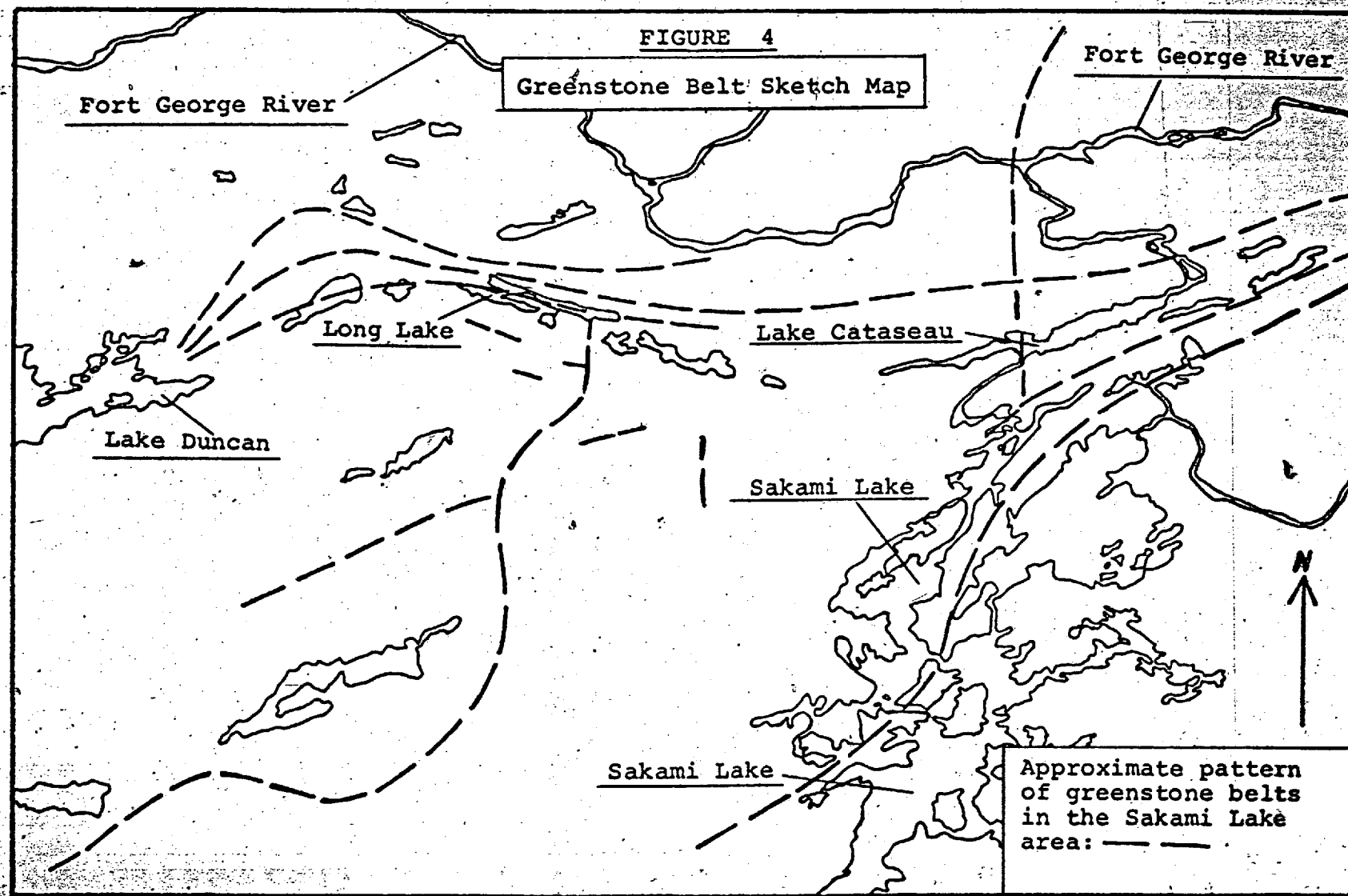
Reconnaissance work done by the writer west of



the mapped area together with interpretations of pre-existing maps and aeromagnetic survey maps (Geological Survey of Canada, 1971) indicates that the belt at Sakami Lake is part of a network of greenstone belts containing several branches or forks. It is suggested here that this network may represent rifting in the continental mass. The several belts in the region come together at angles of up to 45° and more in some places (Figure 4). Some bands show an approximate parallelism. This pattern would seem more compatible with fracturing under tension than regional compressive forces which would tend to result in parallel and semi-parallel troughs.

It is possible that the metavolcanic rock concentrations represent extrusion along the fractures and the associated metawackes represent sediments derived from adjacent areas of higher elevation, although some are derived from the volcanic extrusions. In this sense the metasediments in the greenstone belt are essentially contemporaneous with the volcanism.

This concept is compatible with the previously made statement that the greenstone belt at Sakami Lake has some similarities to the eugeosynclinal environment as visualized by Pettijohn (1943). However, eugeosynclinal zones are often forced down to considerable depths as a prelude to upheaval and mountain building. Anhaeusser has stated (1969, p.2187) that greenstone is not likely to be



part of geosynclinal zones which were taken down to the environment of anatexis for they still maintain a low metamorphic facies. Volcanism through rifting does not necessarily involve the geosynclinal sequence of events although the trough-like structure involved could result in an accumulation with similarities to geosynclinal deposits.

The following paragraphs briefly outline major features and resulting conclusions drawn from several studies of greenstone belts in the Superior Province and the Slave Province. In each case fracturing of a pre-existing crust is stipulated.

Work in greenstone areas of the Slave Province (McGlynn and Henderson, 1970) indicates that the volcanic sequences there are essentially a marginal facies in a sedimentary accumulation. Conglomeratic units associated with the sediments and volcanics contain rounded granitic fragments in contrast to minor, angular volcanic fragments. The authors suggest that the conglomerates are derived from an essentially granitic hinterland. The trough is considered to be the result of crustal tension and normal faulting during which fracturing occurred along the trough margins allowing extrusive activity. Three locations are referred to in which possible exposures of pre-volcanic crust may exist. In each case the rock type is considered to be highly altered granitic material (McGlynn and Henderson, 1970, p. 34-35).

The synthesis of field work done in the Abitibi greenstone belt of western Quebec and eastern Ontario (Goodwin and Ridler, 1970) suggests that the belt developed through the separation of two tectonic units or plates. The widening structure appears to have had two major fracture zones along an east-west axis and along which extrusive activity led to the formation of several volcanic piles. Sediments associated with the south part of the trough region indicate that a sialic material composed the hinterland to the south and southeast. In addition, gravity surveys show average readings for the area surrounding the trough in contrast to distinct high negative and low negative readings associated with granitic and mafic units respectively within the trough.

This pattern is interpreted by the authors as indicating the existence of mixed rock units around the trough whereas distinctive granitic batholiths and basaltic-rich volcanic piles form large parts of the trough structure.

These interpretations suggesting the occurrence of exposed rock units prior to the emplacement of the volcanics and sediments which compose the greenstone belts also apply to the Sakami Lake belt and coincide essentially with conclusions made by Anhaeusser based largely on studies done in South Africa in which he suggests that greenstone bands were initiated by parallel downwarps or fault-bound troughs on a thin, unstable sialic crust (Anhaeusser and others, 1969, p.2179).

TABLE 5

Suggested sequence of the main geological events in the Sakami Lake region.

RECENT	1. Recent glaciation, erosion, development of swamps and bogs, river and lake deposits.
POST ARCHEAN	1. Various events, including normal and transverse faulting and Paleozoic sedimentation.
	2. Intrusion of diabase dikes.
	3. Proterozoic sedimentation on eroded surfaces.
UNCONFORMITY	
ARCHEAN	1. Disconformable intrusion of plutonic amphibole granite of variable composition, inclusion of mafic units and banded tuffs.
	2. Regional folding; formation of isoclinal folds in the trough areas and development of regional foliation trends; development of regional metamorphism corresponding to the greenschist and almandine-amphibolite facies; probable intrusion of felsic plutonic units, in the semi-solid state, during folding.
	1. Intrusion of basaltic dikes into surrounding regions in association with eruptions in the trough areas.
	2. Slumping of sedimentary units within the trough, possibly triggered by volcanic eruptions and earthquakes.
	3. Occurrence of islands during the volcanic eruptions from which subaerial extrusion of felsic volcanic materials occurred.
ARCHEAN	4. Volcanic extrusion along the fractures; formation of wackes, arenites, and banded iron formation.
	5. Submergence of part of the continental mass and the formation of fractures; probably through tensional forces.
	UNCONFORMITY
ARCHEAN	1. The formation of a continental nucleus of low relief with exposed felsic, plutonic rocks.

PLATE 1

Figure 1

Rhyolitic extrusive flow rock, Long Lake area. Light gray-pink rounded structures (A) occurring in a slightly darker pinkish gray matrix (B). Scale = 15.2 centimeters long or 6 inches.

Figure 2

Banded, magnetic, quartz-iron formation, Sakami Lake area. The folded iron formation (A) is garnetiferous and contains medium to dark gray magnetite in thin discontinuous bands. The sequence has been cross-cut by a massive greenstone dike (B). Scale = the hammer which is about 35.5 centimeters long or 14 inches.

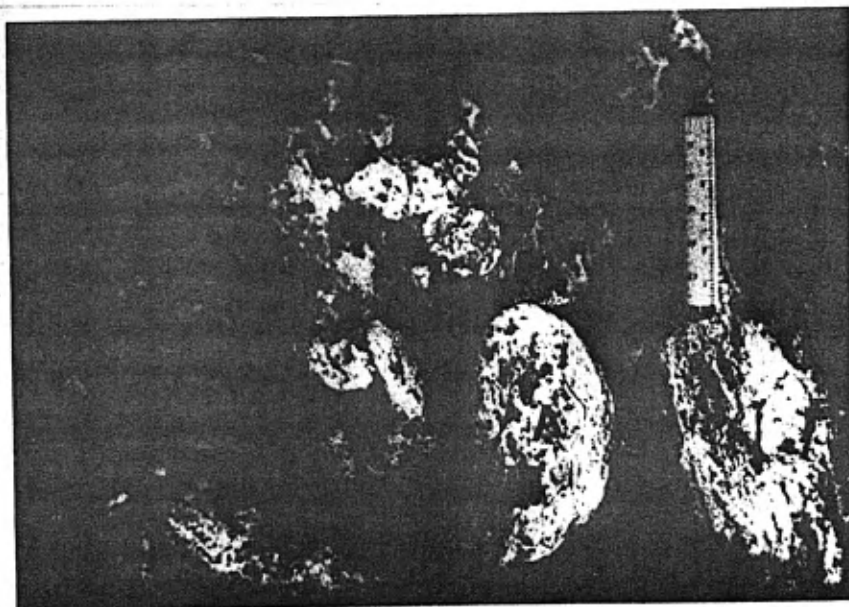
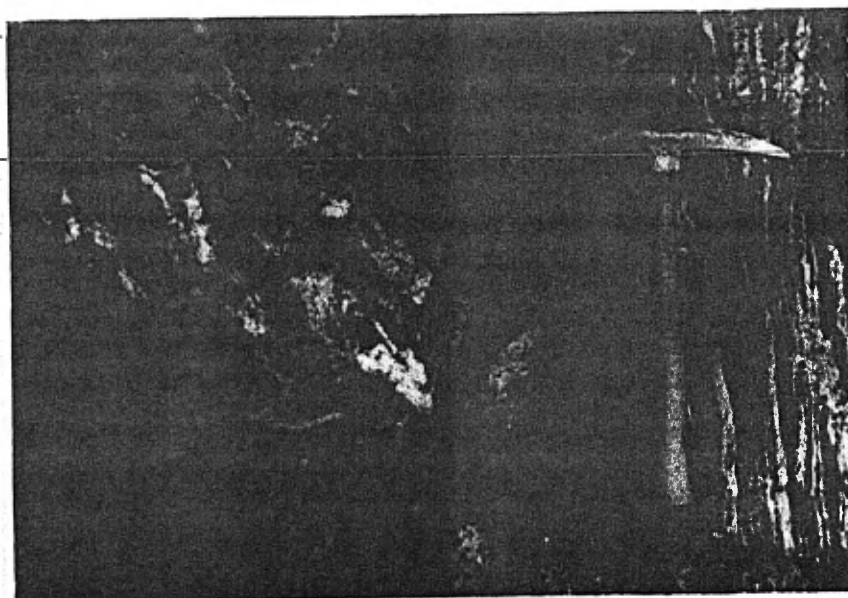
PLATE 1Figure 1Figure 2

PLATE 2

Figure 1

Greenish gray banded tuffs (A) disconformably intruded by medium grained, massive amphibole granite (B), Long Lake area. Banded tuff fragment (C) and a zone of inclusions in the granite at various stages of incorporation (D). Scale = 15.2 centimeters or 6 inches.

Figure 2

Banded metasedimentary rock, Sakami Lake area. The light bands have been fragmented and have a rolled structure (A) which suggests pre-consolidation slump movement. Scale = 15.2 centimeters or 6 inches.

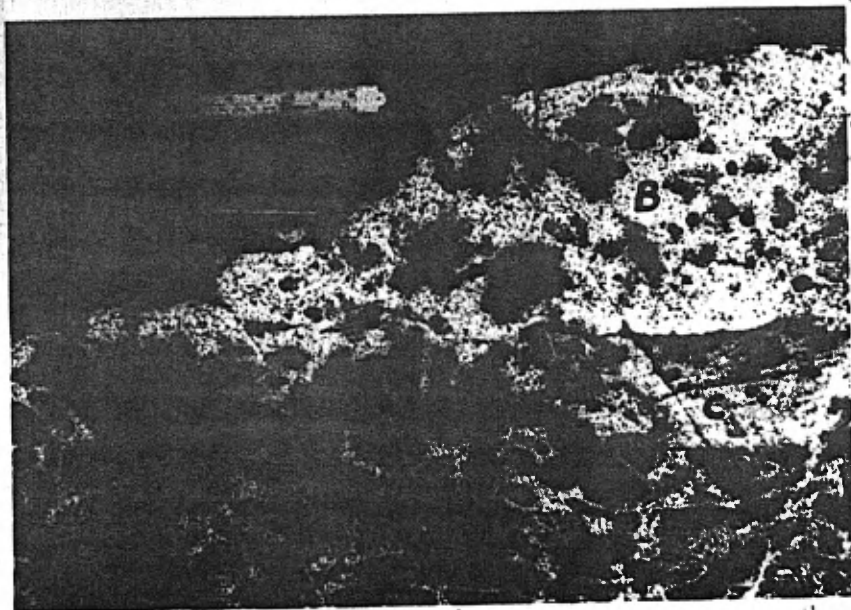
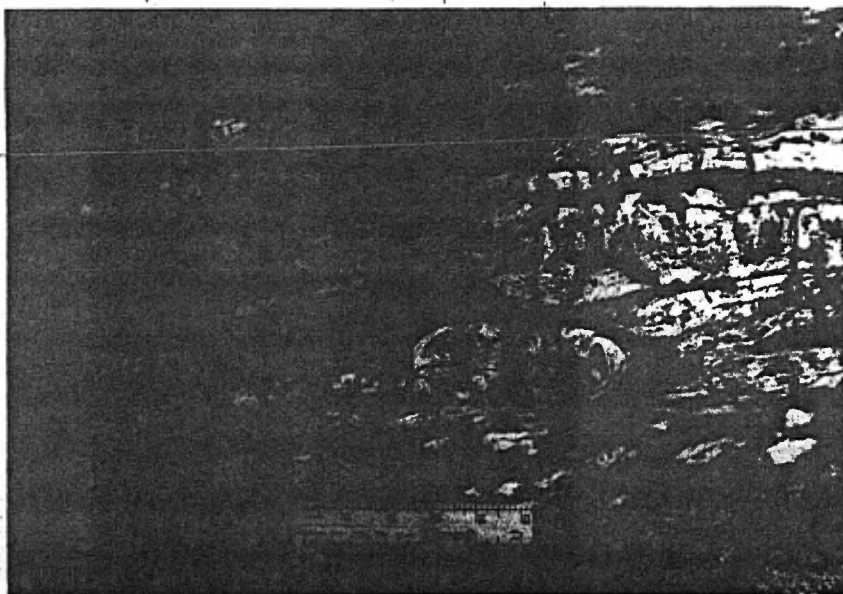
PLATE 2Figure 1Figure 2

PLATE 3

Figure 1

Massive granitic rock (A) in contact with greenstone dike rock (B), Lake Cataseau area. Note the foliated nature of the greenstone along the contact zone (C). Scale = the hammer which is about 35.5 centimeters long or 14 inches.

Figure 2

Intruded greenstone tuffs, north of Lake Duncan, west of Long Lake. Finely banded, steeply inclined, and crenulated greenstone tuffs (A) have been disconformably intruded by aplitic rock. The fluid state of the intrusion is indicated by the disconformable attitude of the larger inclusions which were rotated. The discontinuous lense-like habit of some bands (B) suggests that compressed fragments may have contributed to the banded sequence. Scale = the sunglasses which are about 12 centimeters long or 5 inches.

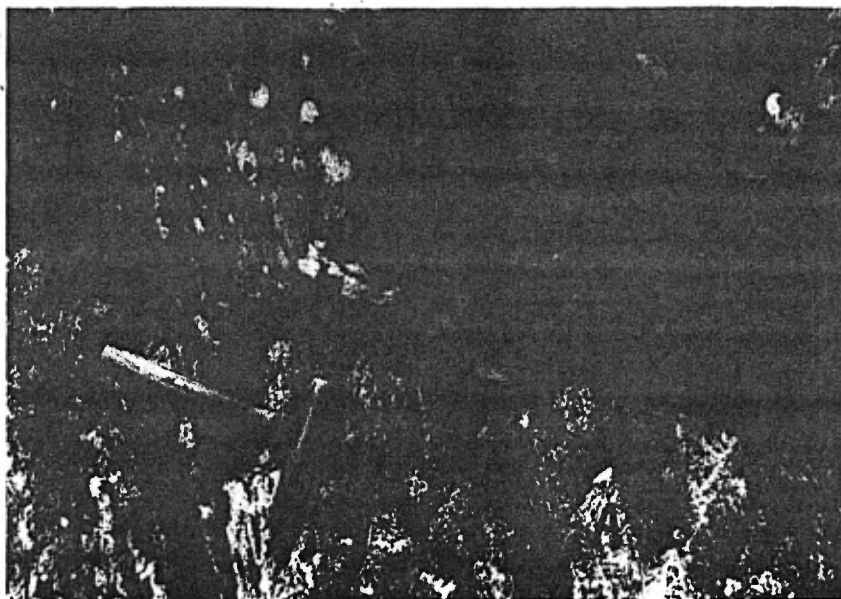
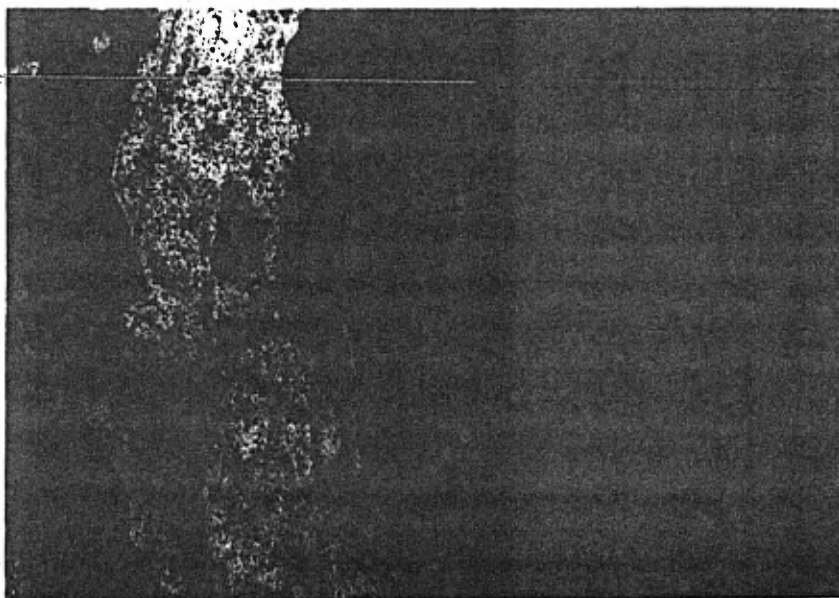
PLATE 3Figure 1Figure 2

PLATE 4

Figure 1

Amygdaloidal basaltic flow rock Long Lake area. Note the well formed plagioclase phenocrysts (A) and the ovoid to irregular amygdules (B). The finer groundmass (C) consists of epidote, felsic minerals, chlorite, and relatively small round amygdules. The groundmass is a medium brown-gray in plain light. Cross nicols, 5.9 millimeters.

Figure 2

Metavolcanic rock of fragmental origin, Long Lake area. The rock contains fragments of foliated granite (A), altered plagioclase (B), angular quartz fragments (C), fragments (D) containing about 50 per cent chlorite and amphibole in addition to felsic minerals, traces of sphene, calcite and epidote. Grains of chlorite (E) are randomly distributed. The finer fraction (F) consists of quartz, chlorite, amphibole, felsic minerals and epidote. Plain light, 5.9 millimeters.

Figure 3

Felsic metavolcanic rock of fragmental origin, Long Lake area. Altered plagioclase of albitic composition (A), embayed quartz (B) occur in a felsic groundmass which contains minor amounts of calcite, biotite, and opaque mineral grains. Crossed nicols, 5.9 millimeters.

Figure 4

Banded magnetic iron formation, Sakami Lake region. Relatively coarse, magnetite-rich bands (A) are interlayered with amphibole-felsic bands (B) and zones (C) containing intertonguing lenses of amphibole grains and felsic mineral grains which seem to be mainly quartz. Some lenses contain all of these minerals in varying proportions. Plain light, 5.9 millimeters.

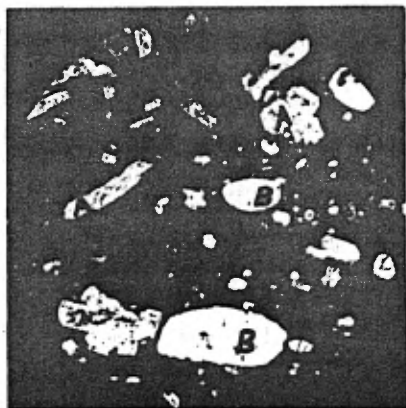
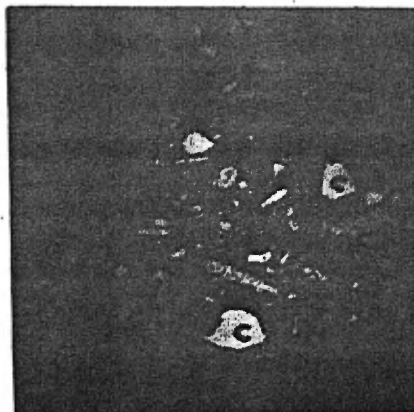
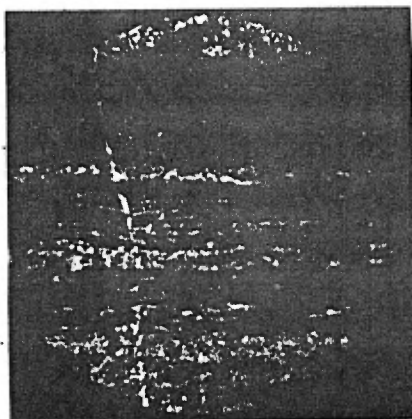
PLATE 4Figure 1Figure 2Figure 3Figure 4

PLATE 5

Figure 1

Felsic lithic wacke, Sakami Lake region. Rounded to subrounded fragments of polycrystalline quartz (A) randomly distributed in a finer grained felsic matrix (B) which contains minor amounts of biotite and sericite. Crossed nicols, 5.9 millimeters.

Figure 2

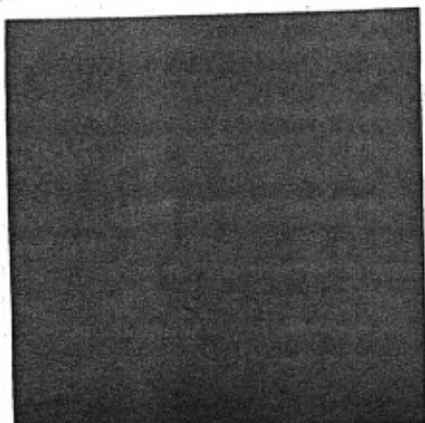
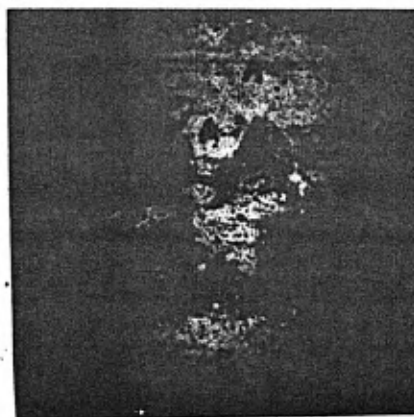
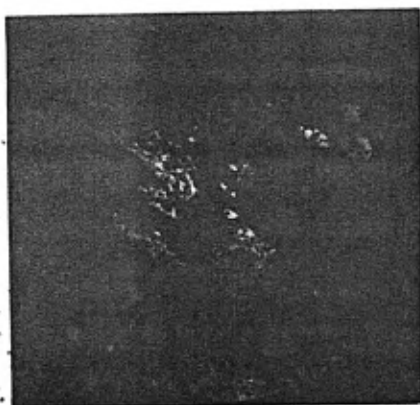
Amphibole-quartz gneiss, Sakami Lake region. Bands consisting of amphibole and chlorite (A) and containing thin discontinuous stringers of opaque minerals (B) are interlayered with felsic layers composed of granular quartz and carbonate (C). Plain light, 5.9 millimeters.

Figure 3

Lithic wacke, Lake Cataseau region. Fragments of disrupted very fine grained, granular feldspathic wacke (A) and other fragments consisting of amphibole, quartz, quartz-feldspar rock with some chlorite, clots of chlorite and fragments of granular quartz. The finer fraction consists of quartz, feldspar chlorite and biotite. Plain light, 5.9 millimeters.

Figure 4

Massive amphibole granite, Long Lake area, composed of altered, zoned plagioclase (A), green amphibole (B), and quartz (C). Crossed nicols, 5.9 millimeters.

PLATE 5Figure 1Figure 2Figure 3Figure 4

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REFERENCES

- Abbey, S., 1968, Analysis of rocks and minerals by atomic absorption - part 2; determination of total iron, magnesium, calcium, sodium potassium: Geol. Surv. Canada Paper 68-20.
- Alcock, F.J., 1934, Report to the national committee on stratigraphic nomenclature: Trans. Roy. Soc. Canada, V.28, Sec. 4.
- Anhaeusser, C.R., Mason, R., Viljoen, M.J., and Viljoen, R.P., 1969, Reappraisal of some aspects of Precambrian Shield geology: Geol. Soc. America Bull., V.80, No.11, p. 2175-2200.
- Baker, P.E. 1968, Comparative volcanology and petrology of the Atlantic island-arcs: Bull. Volcanology, V.32, p. 189-206.
- Baragar, W.R.A., 1968, Major-element geochemistry of the Noranda volcanic belt, Quebec-Ontario: Canadian Jour. Earth Sci., V.5, No.4, p. 773-790.
- Bass, M.N., 1961, Regional tectonics of part of the southern Canadian Shield: Jour. Geol. V.69, p. 668-702.
- Barth, T.F.W., 1962, Theoretical petrology: John Wiley and Sons, Inc. New York, 416 p.
- Boyle, R.W., 1961, The geology, geochemistry, and origin of the gold deposits of the Yellowknife District: Geol. Surv. Canada, Memoir 310.
- Cook, E.F., 1966, Tuff lavas and ignimbrites: American Elsevier Publishing Company, Inc., New York, 212 p.
- Catanzaro, E.J., 1963, Zircon ages in southwestern Minnesota: Jour. Geophys. Research, V.68, p. 2045-2048.
- Cotton, C.A., 1958, Geomorphology: Whitcombe and Tombs Ltd., Christchurch, London, 505 p.

Dickinson, W.R., 1968, Circum-Pacific andesite types:
 Jour. Geophys. Research, V.73, p. 2261-2269.

Donaldson, J.A., and Jackson, G.D., 1965, Archean
 sedimentary rocks of North Spirit Lake area,
 northwestern Ontario: Canadian Jour. Earth
 Sci., V.2, No.6, p. 622-647.

Eade, K.E., 1966, Fort George and Kaniapiskan River
 (West half) map areas, New Quebec: Geol. Surv.
 Canada Memoir 339, 82 p.

Eade, K.E., and Fahrig, W.F., 1971, Geochemical
 evolutionary trends of continental plates;
 a preliminary study of the Canadian Shield:
 Geol. Surv. Canada Bull. 179, 51 p.

Engel, A.E.J., 1966, The Barberton Mountain Land;
 clues to the differentiation of the earth:
 Univ. Witwatersrand Econ. Geol. Research Unit,
 Inf. Circular 27.

Engel, A.E.J., and Engel, C.G., 1964, Continental
 accretion and the evolution of North America,
 in: A.P. Subramaniam and S. Balakrishna, eds.,
 Advancing frontiers in geology and geophysics;
 a volume in honor of M.S. Krishnan: Hyderabad,
 Indian Geophysical Union, p. 17-37.

Flanagan, F.J., 1969, United States Geological Survey
 Standards - II, First compilation of data for the
 new United States Geological Survey rocks:
 Geochim. et Cosmochim. Acta, V.33, p. 81-120.

Gill, J.E., 1966, Principles and limitations of
 Precambrian stratigraphy, in: The relationship
 of mineralization to Precambrian stratigraphy
 in certain mining areas of Ontario and Quebec:
 Geol. Assoc. Canada, Spec. Paper, No.3, p. 9-19.

Gill, J.B., 1970, Geochemistry of Viti Levu, Fiji, and its evolution as an island arc: Contr. Mineralogy and Petrology, V.27, p. 179-203.

Goldich, S.S., 1968, Geochronology in the Lake Superior region: Canadian Jour. Earth Sci., V.5, No.3, p. 715-724.

Goldich, S.S., Hedge, C.E., and Stern, T.W., 1970, Age of the Morton and Montevideo gneisses and related rocks southwestern Minnesota: Geol. Soc. America Bull., V.81, p. 3671-3696.

Goodwin, A.M. 1952, Structure, stratigraphy, and origin of iron formations, Michipicotin area, Algoma District, Ontario, Canada: Geol. Soc. America Bull., V.73, p. 561-586.

——— 1967, Volcanic studies in the Birch-Uchi Lakes area of Ontario: Ontario Dept. of Mines, Miscellaneous Paper No.6, 96 p.

——— 1968, Evolution of the Canadian Shield: Proc. Geol. Assoc. Canada, V.19, p. 1-14.

Goodwin, A.M., and Ridler, R.H., 1970, The Abitibi orogenic belt, in: Symposium on Basins and Geosynclines of the Canadian Shield: Geol. Surv. Canada, Paper 70-40, p. 1-30.

Gross, W.H., and Ferguson, S.A., 1965, The anatomy of an Archean greenstone belt: Canadian Mining and Metallurgical Bull., V.58, No.641, p. 940-946.

Hatch, F.H., Wells, A.K., and Wells, M.K., 1949, The petrology of the igneous rocks: Thomas Murby and Company, London, 469 p.

Harker, A., 1939, Metamorphism: A study of the transformations of rock masses: Methuen and Company Ltd., London, 362 p.

Henderson, J.F., and Brown, I.C., 1966, Geology and structure of the Yellowknife greenstone belt, District of Mackenzie: Geol. Surv. Canada Bull. 141, 87 p.

Jakes, P., and White, A.J.R., 1972, Major and trace element abundances in volcanic rocks of orogenic areas: Geol. Soc. America Bull. V.83, No.1, p. 29-40.

James, H.L., 1960, Problems of stratigraphy and correlation of Precambrian rocks with particular references to the Lake Superior region: American Jour. Sci., V.258-A, (Bradley volume), p. 104-114.

King, P.B., 1951, The tectonics of middle North America: Princeton University Press, Princeton, New Jersey, 203 p.

Lawson, A.C., 1913, The Archean geology of Rainy Lake re-studied: Geol. Surv. Canada Memoir 40, 115 p.

Leich, A.P., 1966, Potash-argon dates of basic intrusive rocks of the District of Mackenzie, N.W.T.: Canadian Jour. Earth Sci., V.3, p. 389-412.

Leith, C.K., 1910, An Algonkian basin in Hudson Bay; a comparison with the Lake Superior Basin: Econ. Geol., V.5, pt.4, p. 227-246.

Low, A.P., 1889, Report on exploration in James Bay and country east of Hudson Bay: Geol. Surv. Canada Ann. Rept. 1887-88, V.3, Pt. J. 94 p.

— 1900a, On an exploration of the east coast of Hudson Bay from Cape Wolstenholme to the south end of James Bay: Geol. Surv. Canada Ann. Rept., V.12, 97 p.

Low, A.P., 1900b, On the geology and physical character of the Nastapaka Islands, Hudson Bay: Geol. Surv. Canada Ann. Rept., V.13, Report DD, 30 p.

Martin, H., 1969, Problems of the age relations and structure in some metamorphic belts of southern Africa: Geol. Assoc. Canada, Spec. Paper, No.5, p. 17-26.

Moorhouse, W.W., 1965, Stratigraphic position of sulphides in the Archean: The Canadian Mining and Metallurgical Bull., V.58, No.631, p. 947-950.

McGlynn, J.C., and Henderson, J.B., 1970, Archean volcanism and sedimentation in the Slave Structural Province, in: Basins and geosynclines of the Canadian Shield, Geol. Surv. Canada Paper 70-40, p. 31-44.

Patterson, C., and Tatsumoto, M., 1964, The significance of lead isotopes in detrital feldspar with respect to chemical differentiation within the earth's mantle: Geochim. and Cosmochim. Acta, V.28, p. 1-22.

Peacock, M.A., 1931, Classification of igneous rock series: Jour. Geol., V.39, p. 54.

Pettijohn, F.J., 1937, Early Precambrian geology and correlation problems of the northern subprovince of the Lake Superior region: Geol. Soc. America Bull., V.48, p. 153-202.

——— 1943, Archean sedimentation: Geol. Soc. America Bull., V.54, p. 941-943.

——— 1957, Sedimentary rocks: Harper Brothers, New York, 718 p.

——— 1970, The Canadian Shield, A status report, in: Symposium on basins and geosynclines of the Canadian Shield: Geol. Surv. Canada Paper 70-40, p. 239-265.

Roubault, M., de La Roche, H., Govindaragu, K., 1970, Etat actuel (1970) des études cooperatives sur les standards geochemique du Centre des Recherches Petrographique et Geochemique: Science de la Terre, Tome XV, No.4, p. 351-393, Nancy, France.

Ramberg, H., 1957, Gravity, deformation and the earth's crust: Academic Press, New York, 214 p.

Rittmann, A., 1962, Volcanoes and their activity (translated from the second German edition by E.A. Vincent): Interscience Publishers, New York, 305 p.

Roering, C., 1965, The tectonics of the main gold producing area of the Barberton Mountain Land: Geol. Soc. South Africa Trans., V.68, annexure.

Ross, C.S. and Smith R.L., 1961, Ash-flow tuffs: their origin, geologic relations, and identification: United States Geol. Surv. Prof. Paper 366, 81 p.

Salop, L.I., 1972, A unified stratigraphic scale of the Precambrian: International Geological Congress, 24th Session, Section 1, p. 253-259.

Sharpe, J.I., 1965, Field relations of Matagami sulphide masses bearing on their disposition in time and space, in: Canadian Mining and Metallurgical Bull., V.58, No.641, p. 951-964.

Shaw, G., 1942, Preliminary map Eastmain, Quebec: Geol. Surv. Canada Paper 42-10.

Stockwell, C.H., 1968, Geochronology of stratified rocks of the Canadian Shield: Canadian Jour. Earth Sci., V.5, No.3, p. 693-698.

Stockwell, C.H., McGlynn, J.C., Emslie, R.F., Sandord, B.V., Norris, A.W., Donaldson, J.A., Fahrig, W.F., and Currie, K.L., 1970, Geology of the Canadian Shield in: Douglas, R.J.W., ed., Geology and Economic Minerals of Canada: Geol. Surv. Canada, Econ. Geol. Report No.1, 838 p.

Thompson, J.E., 1936, Gold deposits of the belt extending from Manitou Lake to Lake of the Woods: Proc. Canadian Inst. Mining and Metallurgy, p. 686-701.

Thompson, J.B. Jr., Robinson, P., Clifford, T.N., and Trask, N.J. Jr., 1968, Nappes and gneiss domes in west-central New England, in: Zen, E-An, White, W.S., Hadley, J.B., and Thompson, J.B. Jr., eds., Studies of Appalachian geology, northern and maritime: Interscience Publishers, New York, 475 p.

Turner, F.J., and Verhoogen, J., 1960, Igneous and metamorphic petrology: McGraw-Hill Book Company Inc., New York, 964 p.

Vening Meinesz, F.A., 1952, The origins of continents and oceans: Geol. Mijnbouw, n.s., V.14, p. 373-384.

Viljoen, M.J., and Viljoen, R.P., 1970, Archean volcanicity and continental evolution in the Barberton region, Transvaal: African Magmatism and Tectonics, p. 27-49.

Von Bandat, H.F., 1962, Aerogeology: Gulf Publishing Co., Houston, Texas, 350 p.

Walker, R.G., and Pettijohn, F.J., 1971, Archean sedimentation: Analysis of the Minnitaki Basin, northwestern Ontario, Canada: Geol. Soc. America Bull., V.82, No.8, p. 2099-2130.

Wetherill, G.W., 1972, The beginnings of continental evolution: Tectonophysics, V.13.

Williams, H., Turner, F.J., Gilbert, C.M., 1955,
Petrography; an introduction to the study of
rocks in thin sections: W.H. Freeman and
Company, San Francisco, 406 p.

Wilson, H.D.B., Andrews, P., Moxham, R.L., and Ramlit, K.,
1965, Archean volcanism in the Canadian Shield:
Canadian Jour. Earth Sci., V.2, No.3, p. 161-174.

Winkler, H.G.F., 1967, Petrogenesis of metamorphic
rocks: Springer-Verlag, Inc., New York, 237 p.

APPENDICES

APPENDIX I

Thin section petrography of: mafic and felsic metavolcanic rocks; metasedimentary rocks; rocks of plutonic origin; and rock of probable ultramafic origin.

Metavolcanic RocksGreenstone; Massive, Fine to Coarse

Fine, medium, and coarse-grained rocks of mafic composition consist of about equal amounts of ferromagnesian minerals and felsic minerals. Epidote, sphene, calcite, and opaque minerals are minor rock components.

In the massive to foliated fine grained rock the feldspar is commonly xenoblastic and occupies space between xenoblastic greenish amphibole grains. Some of the felsic minerals grains are clear or colorless and contain distinct grains of epidote and fine, elongate amphibole grains. Other grains contain alteration products in the form of fine, fibrous material. Vague relict twinning exists in some grains indicating plagioclase. Distinct quartz grains are occasionally seen in some zones as minor constituents. Epidote forms up to about 12 percent of the rock in some places.

Some of the coarser material consists of xenoblastic amphibole and minor chlorite together with xenoblastic plagioclase. The amphibole is slightly pleochroic in pale, yellowish, olive green to medium-light green, whereas the chlorite has similar pleochroism but distinctive purplish-blue interference colors. Sieve texture is common through the

amphibole in the form of small round grains of felsic minerals, probably feldspar.

The amphibole mineral has an intergranular to subophitic textural relationship with the plagioclase. However, the plagioclase, which is xenoblastic, often shows a common optical orientation with several other plagioclase grains in the vicinity. Relict twinning exists in most of the plagioclase which suggests an igneous origin for the rock.

Epidote forms about 7 percent of the rock and is randomly disseminated. Sphene forms about 3 percent of the rock as scattered clots of bead-like grains. In some zones cataclasis is indicated by deformed twinning in plagioclase and granularity between some grains.

Greenstone; Porphyritic

Porphyritic metabasalt in the region consists mostly of rocks in which highly altered plagioclase phenocrysts form the coarse fraction; in other cases augite forms phenocrysts. Coarse clots of calcite, some of which is associated with minor quartz, also forms coarse, felsic structures in some of the metabasalt.

The plagioclase phenocrysts are subhedral to anhedral, colorless, and form up to 20 percent or more of the rock volume. The phenocrysts have been altered to epidote, a fine fibrous mineral, and minor chlorite which has purplish-blue interference colors. Some of the pseudomorphs after plagioclase contain some brownish biotite and a fine, opaque

mineral in the grain margins.

In those outcrops where augite phenocrysts occur they form about 5 - 7 percent of the rock and are randomly distributed. They are colorless to very faint bluish-gray in plain light, optically positive with a $2v$ of about 45° , and tend to have an ovoid to stubby bipyramidal form. The crystals also commonly display curved fractures.

The groundmass of the metabasalt is similar in the various sections. It is subophitic with amphibole being slightly predominant and composing about half the rock volume. Amphibole grains are randomly oriented with jagged or comb-like grain boundaries and have a prominent sieve texture. The plagioclase laths making up part of the groundmass are randomly oriented and have a subhedral to anhedral outline although the crystals are highly altered to a fine, fibrous, felted mineral.

Some of the augite-porphyry rock contains random clots of what appears to be fine, fibrous alteration products including some epidote; in addition, epidote forms part of the matrix in all sections observed. In some places the mineral forms grayish blotches or clots some of which partially enclose plagioclase laths. Sphene forms bead-like aggregates of high relief in some zones and an opaque mineral occasionally forms irregular units around plagioclase grains; some grains are bounded by straight lines giving the plagioclase an angular outline.

Greenstone; Amygdaloidal

Amygdaloidal metabasalt consists of randomly distributed plagioclase phenocrysts and ovoid to irregular amygdules in a fine, massive groundmass which is medium to dark grayish brown in plain, transmitted light.

Plagioclase phenocrysts are predominantly euhedral, partially altered, and usually show some sieve texture, enclosing epidote and patches of alteration products. Several examples of albite twinning indicate a maximum extinction angle of about 18° . Euhedral phenocrysts, showing vague pericline twinning show an angle of about 0° between twin planes and the grain edge. These twinning properties suggest that the plagioclase is andesine in the $An_{36} - An_{40}$ range of composition.

Amygdules are ovoid to irregular and show a range of sizes from coarse to fine. Several of the ovoid amygdules show flow structure around their borders. Most of the amygdules consist of highly sutured quartz with distinct undulant extinction. Some of the smaller amygdules consist of a fine granular mass which is brownish-gray in plain transmitted light and seems to be a mixture of epidote, chlorite and a felsic mineral.

The groundmass consists of epidote, fine, partly altered plagioclase laths, and chlorite. It appears that the medium to light greenish color of the thin sections, when handheld in reflected light, is largely due to well disseminated epidote and chlorite in the groundmass.

Greenstone; Fragmental

Exposures of massive, fragmental metavolcanic rocks which contain unsorted, angular to subrounded mineral and rock fragments of various compositions are observable in the Long Lake region.

The finer faction consists of felsic material, epidote, and a ferromagnesian mineral which appears to be amphibole. Among the coarser components are: quartz, massive and foliated granite fragments, amphibole, sphene, plagioclase, metabasaltic fragments, and fragments of highly altered fine grained material.

The quartz consists of angular fragments, rounded fragments, highly sutured granular quartz, and some fragments which are rounded and show slight embayments which suggest partial resorption. Some of the angular fragments of quartz show fine conchoidal-like cusped features suggesting that the grains may have been chipped. Some granitic fragments are massive and consist of plagioclase, quartz and amphibole and minor calcite. Other granitic fragments are foliated, medium to fine grained; consist of quartz, altered feldspar, calcite and chlorite; and display signs of cataclasis. Occasional fragments of quartz-feldspar rock are observable in which the feldspar contains myrmekite.

Amphibole grains are randomly spaced through the rock. These grains are in various shades of green in plain light and some are pleochroic in light olive green to medium

green; all tend to be elongate, but rounded and show a low extinction angle. Chlorite exists as small irregular patches and as parts of grains and tends to show parallel extinction with purplish-brown interference colors. Fragments of metabasalt consist of massive amphibole, plagioclase laths, chlorite and minor epidote and sphene.

Some fragmental material of mafic composition has been discussed in the appendix section on metasedimentary rocks under lithic wackes.

Felsic Metavolcanic Rocks; Porphyritic

Phenocrysts of either, or both, quartz and feldspar form up to about 30 percent of these rocks. Quartz phenocrysts are usually embayed or partly resorbed and feldspar phenocrysts are altered to some extent. Many of the grains are fractured and broken. The presence of albite plagioclase is indicated by the analysis of relict albite twinning on some of the grains.

The felsophyric groundmass consists of quartz, feldspar, minor amounts of brown biotite, and about 20 percent of a colorless, micaceous mineral. Traces of an opaque mineral and chlorite exist together forming stringers which are parallel to flow or compaction structure around some of the phenocrysts. Some of the opaque mineral is whitish gray in reflected light which suggests that leucoxene has formed as an alteration product of ilmenite.

Some varieties of felsic, extrusive porphyritic

rock contain about 10 percent of quartz phenocrysts. Flow structure is delineated by fine, semi-opaque stringers which appear to contain considerable epidote and scattered clots of green chlorite with minor epidote. The matrix consists of green chlorite and a colorless, micaceous mineral.

In some instances the quartz bodies are irregular in shape and consist of interlocking quartz grains. The matrix consists of green chlorite and a colorless micaceous mineral in association with granular quartz and feldspar. Scattered pyrite forms about 2 percent of the rock.

Feldspar-quartz porphyry rock, in which the feldspar is almost unaltered and the quartz occurs in the form of elongate, ovoid structures composed of highly sutured, interlocking grains occurs in some parts of the Sakami Lake area. The feldspar phenocrysts form up to about 50 percent of the rock and are predominantly euhedral. The ovoid quartz units form less than 7 percent of the rock and may be amygdules. Flow or compaction structure occurs around some grains.

In some samples brown biotite forms about 3 percent of the rock and contains traces of zircon with associated pleochroic halos.

The matrix is felsophyric consisting of granular quartz and feldspar and 7 to 10 percent of brown biotite. In some portions of the rock chlorite and epidote form part of the matrix. In addition epidote and micaceous

minerals also occur as alteration products of the feldspar phenocrysts.

Some of the porphyritic rock contains phenocrysts which have been granulated and fractured through cataclasis. Granulation has resulted in some round grains with ill-defined margins whose fractures contain finer, secondary, feldspar and quartz.

Feldspar porphyry rock exhibiting distinct flow or compaction structure is exposed in some areas east of Long Lake. Phenocrysts form about 25 to 30 percent of the rock. They are commonly zoned and highly saussuritized with the central regions of the grains being more altered. The saussuritization products include epidote and sericite. Relict twinning is vaguely distinguishable in some grains. Granophyric rims are observable around some of the phenocrysts.

The matrix consists of quartz and feldspar with about 25 percent amphibole and minor amounts of brown biotite. Elongate, green amphibole grains delineate flow or compaction texture around many of the phenocrysts.

Some of the amphibole grains have a well developed sieve texture suggesting that some of the crystals are of secondary origin. The zoned structure of the phenocrysts suggests that the rock is of igneous origin.

Some units in the Sakami Lake region consist of randomly distributed feldspar in a foliated, felsophyric

matrix which contains elongate lenses and clots of biotite and quartz-feldspar units. There is a distinct gap in the grain size of the matrix and the coarser, randomly distributed feldspar. This rock variety shows a complete gradation to the quartz-feldspar porphyry extrusive rock discussed above. Feldspar units are altered but some show relict twinning and euhedral outlines are occasionally observed. Other feldspar units occur as clots of vaguely defined feldspar grains which seem to be the result of the break-up or dissociation of pre-existing larger feldspar grains.

The matrix consists predominantly of granular quartz and feldspar with traces of biotite, chlorite and calcite. In some places biotite forms up to 25 to 30 percent of the matrix and calcite is a major component in some cases constituting about 10 percent. Minor amounts of epidote occur in the matrix in some zones.

Ovoid to lense-like clots of calcite with minor quartz are randomly distributed and constitute about 15 to 20 percent of the rock in some areas. These structures do not form layers and seem to be independent units resulting from mineral replacement or the filling of voids.

Felsic Metavolcanic Rocks; Fragmental

Extrusive rocks consisting of fragments and phenocrysts in a felsophyric groundmass are exposed in the Long Lake region (Plate 4, Figure 3). Phenocrysts and some fragments consist of partially resorbed quartz, highly

saussuritized feldspar, including albite, and minor amphibole. Other fragments observable consist of pre-existing rock and mineral grains which are partially amphibole and partially chlorite.

In some places the coarse fraction consists almost entirely of saussuritization products as pseudomorphs after feldspar, many of which are well defined rectangular forms. Calcite forms up to about 5 percent of the rock as scattered grains and aggregates.

The matrix consists of very fine, highly sutured quartz and feldspar with light greenish chlorite, traces of epidote and opaque grains, and occasional traces of amphibole and calcite. Flow or compaction structure is a common feature around fragments and phenocrysts.

Metasedimentary Rocks

This section concerns supplementary information, based mainly on thin section studies, on the metasedimentary rocks which are essentially: (1) banded iron formation; (2) arkosic and feldspathic wacke; (3) foliated felsite; (4) quartz arenite; (5) amphibole schist and gneiss; and (6) mafic and felsic lithic metawackes.

Banded Iron Formation

Banded magnetic iron formation in the mapped area consists mainly of ferromagnesian rich layers inter-banded with units consisting predominantly of quartz and magnetite.

Cyclic variation is observable in some zones. One of these locations shows three phases, (Plate 4, Figure 4): (A) a zone of granular ferromagnesian mineral and felsic mineral with minor magnetite which grades into (B) which is an interlayered sequence of relatively thin bands of felsic mineral and magnetite with units of ferromagnesian mineral and minor magnetite. This zone is followed by (C) which is a relatively thick unit of granular magnetite and felsic mineral with magnetite predominating. Contacts with the neighbouring cycle vary from gradational to sharp.

The magnetite is fine grained but slightly variable in grain size and is euhedral to anhedral. Felsic minerals are fine grained and appear to be entirely quartz. They occur as layers with disseminated magnetite and as fine quartz-rich stringers interlayered with magnetite-rich units. The ferromagnesian mineral appears to be all amphibole. It is green to almost colorless and pleochroic from pale olive green to medium green with a slight bluish tint. Elongation is positive and extinction is inclined at an angle of about 18° . Banded magnetic-iron formation in the region north of Lake Duncan, to the west of the mapped area, also consists of interlayered amphibole and quartz-magnetite-rich units; contacts between these layers are shown to be slightly gradational in thin-section studies.

The quartz-magnetite units are fine grained

and contain minor scattered amphibole grains. Amphibole-rich units consist of massive, randomly oriented, colorless grains with minor scattered grains of quartz and magnetite. Sieve texture is observable in the amphibole as a result of included quartz grains. Rust staining is commonly observed through the amphibole and often consists of patches or stains on individual grains.

The Long Lake region contains exposures of iron formation which consist of interlayered quartz and magnetite. Some of the quartz units contain scattered magnetite grains near band margins. However, some magnetite units are massive and completely opaque which results in large opaque masses forming parts of some layers. The layers are commonly disturbed and, in some places, the layers have been folded over one another and sheared, and some layers have a distinct rolled-up structure. These structural features suggest preconsolidation movement.

Arkosic and Feldspathic Metawackes

Several varieties of feldspathic metawacke exist in the area. The region north of Long Lake contains layers of feldspathic metawacke interlayered with dark green-weathering mafic units. The wacke is fine grained, foliated and contains about 10 percent greenish chlorite and about 1 to 3 percent epidote. Layering within the bands is formed by variation in the amount of quartz and also in the grain size of quartz. The feldspar is made conspicuous through

fine alteration products which give the grains a cloudy-gray color relative to quartz in plain transmitted light. Some of the layers have been fragmented in part resulting in the random distribution of angular fragments in a matrix of fine, felsic grains and greenish chlorite which is purplish brown in polarized light.

A prominent variety of feldspathic metawacke in the Sakami Lake region is a slightly to well foliated, medium to fine grained type, in which biotite is usually the main ferromagnesian mineral. The biotite is brown to reddish brown and forms up to about 25 percent of the rock in some zones. Traces of zircon and associated pleochroic halos are a common feature in the biotite. Occasionally, the biotite has greenish patches, particularly around the edges of grains, which suggests a partial transition to chlorite through retrograde metamorphism. Traces of amphibole exist in some zones. It is pleochroic in pale to medium green, has inclined extinction, and positive elongation. Basal sections show extinction parallel to the long diagonal which also has positive elongation. Traces of olive green tourmaline and scattered, coarse, quartz grains are often present. The feldspar has some fine alteration products associated with it which gives the grains a cloudy gray color in plain light. Also, relict twinning is present in some grains which indicate a plagioclase content.

In the southwest region at Sakami Lake, feldspathic metawacke is exposed which has coarse brown biotite with well developed sieve texture forming about 30 percent of the rock. The sieve texture is formed by inclusions of felsic grains and occasional greenish tourmaline grains. Coarser tourmaline with well developed sieve texture forms about 15 percent of the rock, and also is olive green. Coarse garnet forms 3 to 5 percent of the rock and also has conspicuous sieve texture formed by the inclusion of tourmaline and felsic mineral grains.

* Secondary amphibole with conspicuous sieve texture is the major ferromagnesian mineral in some zones of feldspathic metawacke in the Sakami Lake region. The rock is fine to occasionally coarse grained and massive. Traces of green chlorite and brown biotite are observable throughout the rock.

Feldspathic meta-arenite forms part of the metasedimentary sequence in the Sakami Lake area. It is a medium to coarse grained rock in which some recrystallization has formed a tight fabric of interlocking grains. Light greenish-brown biotite forms up to about 10 percent of the rock and contains occasional grains of zircon and associated pleochroic halos.

Cataclasis has formed shearing planes and granulation around some grain boundaries. Boehme lamellae, developed at oblique angles to the foliation trend, are

observable in some zones.

Arkosic metawacke exists in the region in several variations. Some of the material is very similar to the biotite-rich feldspathic metawackes except for the greater feldspar content. Other varieties have a relatively high epidote content and some zones contain a high quantity of amphibole which has well developed sieve texture.

One variety of arkosic metawacke appears to have originated from porphyritic granite. The rock is coarse to fine grained and is slightly foliated. Sericite and light to medium green biotite form about 10 to 12 percent of the rock and epidote forms about 1 to 3 percent. Cataclastic effects have resulted in coarse plagioclase grains being granulated and broken and many have bent twinning. Quartz has formed lenses of interlocking grains with strong undulant extinction.

Fine grained, foliated arkosic metawacke which contains about 7 to 10 percent epidote is exposed in the Long Lake area. The epidote exists as grains and lense-like clots. Chlorite forms about 10 to 12 percent of the rock. It is greenish in plain light and purplish brown in polarized light. Most of the chlorite has fine stringers of very fine, semi-opaque, granular mineral which appears to be epidote. Feldspar is altered and appears as cloudy-gray grains in plain light.

In many parts of the mapped area fine to very

fine grained arkosic metawacke with coarse, secondary amphibole development is a commonly observed rock. The amphibole has well developed sieve texture. Some grains are elongate in needle-like form and others have jagged terminations or comb-like texture commonly associated with secondary growth. Chlorite forms about 7 to 10 percent of the rock. It is fine grained and randomly distributed through the granular felsic matrix. Variations of this rock have coarse amphibole forming up to about 35 percent of the material. Opaque minerals, which exist in minor amounts, varies from dark in reflected light to whitish gray which suggests ilmenite with associated leucoxene.

Foliated Felsite

Several exposures were observed in the northwest part of Sakami Lake which consist of very fine grained, highly sheared, and crenulated felsic rock. The rock contains about 15 to 20 percent of opaque minerals and has alternating zones of very fine granular, felsic units, and micaceous mineral units which appear to be predominantly sericite. Opaque minerals are observable in both the granular felsic units and the micaceous units, but is more concentrated in the micaceous zones. It is whitish gray in reflected light suggesting that it is leucoxene. Chlorite forms about 5 percent of the rock as clots and lenses. In addition to being crenulated, thin-section studies in reflected light indicate that layers have been folded and

contorted suggesting preconsolidation movement.

Some exposures contain a similar appearing rock which is a fine quartz metawacke. The rock is very fine grained and highly sheared with sericite and chlorite common constituents in shear zones. Slip surfaces intersect at low angles resulting in a structure which may give an initial false impression of crossbedding. The micaceous mineral forms about 20 to 25 percent of the rock. Gradations to more feldspathic minerals are observable in which the opaque mineral forms distinct elongate units and clusters which are whitish gray in reflected light.

Minor amounts of epidote and traces of apatite occur in most of the sections studied. Opaque minerals exist to some extent in all of the metawackes. Much of the opaque mineral is yellowish in reflected light which suggests a pyrite content. However, some sections show many of the opaque grains as whitish gray in reflected light (in some cases only part of the grain). This phenomenon suggests that leucoxene has developed through alteration of ilmenite. In some areas, the opaque mineral is associated with gold-brown rims which do not appear to change color in transferring from plain to polarized light. This mineral appears to be limonite or goethite.

Quartz Arenite

Thin-section studies of rock from the reddish weathering sandstones in areas around the north side of Lake

Cataseau indicate that these rocks are medium to coarse grained quartz arenites with minor amounts of calcite and feldspar including some microcline. The rock is moderately to well sorted and grains are rounded to subrounded.

In some zones, recrystallization and suturing has formed a tight fabric of interlocking grains. Other zones have the areas between larger grains filled with finer, felsic mineral. Many grains have a fine opaque dust around their boundaries which appears to be the iron oxide which gives the rock a marked reddish color in surface exposures.

Other regions around Sakami Lake contain layers of massive quartz arenite which is fine grained and has a tight fabric composed of interlocking grains. Some zones have been fragmented and angular fragments of the quartz arenite occur randomly oriented in a matrix of very fine felsic grains and pale green chlorite.

Poorly sorted quartz arenite which is very fine to fine grained with randomly distributed coarse fragments occurs in some areas. The grains are rounded to recrystallized resulting in a fabric of interlocking grains. Many of the grains contain trains or stringers of very small inclusions. Minor amounts of sericite are observable which have a distinct sieve texture. Also minor amounts of brown biotite and greenish chlorite are observable.

Some zones of quartz arenite are, in part at least, folded or disrupted with relict layering now delineated by thin, curved bands of amphibole in a coarser

grained, massive fabric of interlocking quartz grains. Minor amounts of greenish to brown biotite are present in which scattered zircon grains and associated pleochroic halos occur. Sieve texture is a common feature among the ferromagnesian minerals suggesting that they are secondary developments.

Banded Amphibolitic Schist and Gneiss

Finer grained amphibolite schists tend to show distinctive foliation in thin section and consists of interlensing stringers and lenses of greenish amphibole and granular felsic minerals.

The amphibole is pleochroic in light olive green to medium green with a slight bluish tinge. Elongation is positive and extinction is inclined and irregular, crystal terminations showing a comb-like texture are a common feature and sieve texture exists in some places.

The felsic zones consist of clear, granular material with sieve texture in the form of epidote, amphibole and some opaque grains as inclusions. The opaque minerals are observable as individual grains and as small clots and stringers. Some of the opaque grains are yellow in reflected light suggesting pyrite. Opaque units are often observed as core areas of bead-like aggregates of sphene which suggests that the opaque mineral is ilmenite and the sphene has formed through alteration of ilmenite.

Some of the fine amphibole-rich units contain

stringers and lenses of felsic minerals some of which is altered to a very fine fibrous mineral which suggests that the stringers contain altered feldspar as a major component.

Chlorite rather than amphibole is the predominant ferromagnesian mineral in some of the green-schist. The fine grained, well foliated rock owes its layering to variation in felsic, ferromagnesian, and opaque mineral concentration.

The ferromagnesian mineral is chlorite which has distinctive purplish blue interference colors and forms the foliation. Chlorite forms about 40 percent of the rock. Felsic mineral content appears to be quartz with some feldspar, including albite, suggested by occasional grains showing some twinning. Epidote forms about 15 percent of the rock and is observable as scattered grains and clots which appear as grayish blotches in plain light.

Opaque grains are observed as individual grains and elongate concentrations adjacent to felsic layers. Some of the opaque grains are yellow in reflected light indicating pyrite. In other zones a blood-red color is associated with the margins of some opaque units indicating a hematite content.

Slight irregular lense-like partings perpendicular to foliation are observable in some sections. These partings or fractures are filled with calcite which forms about 7 to 10 percent of the rock in some places.

Minor amounts of calcite are also observable as scattered grains through the main mass of the rock.

A rhythmic variation in environmental conditions is suggested by the gradual increase in the opaque mineral content in association with more felsic mineral-rich units followed by a reversal of the sequence.

Amphibole-quartz-gneiss in which amphibole-rich layers are interbanded with felsic layers rich in quartz is exposed in the southwest part of the map area. The layering varies from a few millimeters to several centimeters and xenoblastic amphibole is a commonly observed feature.

Amphibole-quartz-gneiss associated with banded magnetic iron formation consists of contorted, granular, quartz-rich layers interlayered with units consisting of xenoblastic green or colorless amphibole and xenoblastic garnet which has a distinctive sieve texture.

The individual quartz units consist of fine layers which have been crenulated without, apparently, affecting the adjacent amphibolite-rich layers in each case. Minor amounts of colorless amphibole is randomly distributed through the quartz-rich layers and individual quartz layers are delineated by relatively thin concentrations of the colorless amphibole. Limonite occurs as small clots scattered through the quartz and particularly in association with thin amphibole bands. It also exists on

thin veining which transgresses layering suggesting that the limonite is a postconsolidation development.

Amphibole, observable as a colorless to green mineral has positive elongation, low extinction angle, and low order interference colors. The greenish variety is pleochroic in light olive green to medium green with a slight bluish tinge. Grains are elongate and randomly oriented. The greenish variety of amphibole is generally predominant; however, the colorless variety is predominant along contact areas with the quartz-rich units and also is the type occurring as grains in the xenoblastic garnet which forms up to 20 percent of the amphibole-rich units. Amphibole grains which are partly colorless and partly green also occur.

Some amphibole units have a conspicuous zircon content and associated pleochroic halos. The zircon has no apparent relationship to the amphibole grains, but tends to concentrate in elongate clusters or lenses. This phenomenon suggests that the zircon represents original bedding in a fine grained sediment which subsequently suffered recrystallization resulting in the coarser amphibole.

Some exposures of layered rock in the greenstone zone immediately north of Long Lake contain well developed tourmaline grains in a matrix of fine amphibole and minor calcite.

The tourmaline is commonly well formed, has

a common orientation, and has a well developed sieve texture formed by numerous inclusions of amphibole. The amphibole grains are colorless, have positive elongation, a low extinction angle of about 18° , and a 2V of about 75° to 80° . The grains are optically negative and basal sections show the typical amphibole cleavage. These optical qualities suggest that the amphibole is tremolite.

Minor amounts of light brown biotite and, to a lesser extent, pale green chlorite are randomly distributed through the amphibole. Calcite forms about 1 to 3 percent of the rock in the form of slightly irregular fracture fillings.

Exposures in the northwest part of Sakami Lake contain amphibole-quartz gneiss which consists of calcareous quartz bands interlayered with amphibole-chlorite units in which stringers of opaque minerals are commonly observed.

Amphibole and chlorite form a coarse grained, massive texture within the individual mafic units. However, the stringers of relatively fine opaque grains form parallel and semi-parallel layers which extend across the boundaries of the amphibole and chlorite grains (Plate 5, Figure 2). The amphibole and chlorite are greenish and show pleochroism in pale olive green to medium green; however, the chlorite shows distinctly bluish interference colors.

Units of amphibole schist occur in the north

part of the region; in these amphibole-rich units are inter-layered felsic units which, in some places, show a boudinage structure. The fine to medium-grained amphibole forms about 60 percent of the rock. The amphibole has some preferred orientation and has sieve texture formed by the inclusions of clear, rounded felsic grains. The amphibole grains have positive elongation, inclined extinction of about 18° and pleochroism is in pale olive green to medium green.

The felsic units consist of quartz and colorless epidote and, in some places, minor amounts of brown biotite and feldspar. In the instances of boudinage development the tension release fractures in the felsic units contain quartz concentrations. Epidote and amphibole form inclusions in some of the felsic grains which appear to be feldspar.

Opaque grains form stringers parallel to foliation in some of the relatively thin bands; however, in zones of thicker more massive amphibole units, the opaque grains are randomly distributed or in clots with occasional slightly irregular stringers observable.

Lithic Metawacke

Lithic metawacke similar in some respects to some of the feldspathic metawacke mentioned above is exposed in the Sakami Lake region (Plate 5, Figure 1). Coarse to very coarse quartz fragments form about 10 percent of the rock. These fragments consist of sutured, interlocking

quartz grains. The fragments are rounded to subrounded and are randomly distributed, some of the fragments show compression features around them in the apparent pushing aside of micaceous mineral grains. Biotite, sericite and chlorite are observable in varying amounts and total about 10 to 12 percent of the rock with sericite often showing sieve texture.

Lithic metawacke derived from mafic sources is exposed in some regions in the vicinity of metavolcanic rocks. It consists of highly altered, fine grained to very coarse grained fragments randomly oriented in a matrix of greenish chlorite. The fragments are angular to subrounded and consist of very fine, granular, dark gray masses of minerals which seem to be alteration products consisting of felsic minerals and epidote. Some fragments have a brownish gray iron-oxide content; other fragments consist of amphibole fragments and units of granulated felsic minerals which contain clots of chlorite showing purplish blue interference colors. Occasional scattered quartz grains and fragments of granular quartz rock are also observable. The finer fraction consists of greenish chlorite and felsic minerals. Calcite forms about 7 to 10 percent of the rock in the form of randomly distributed grains and clots.

Lithic metawacke derived in part from mafic rocks and in part from disrupted feldspathic metawacke occurs in the Lake Cataseau area. The rock consists of fine

to coarse grained amphibole, quartz, and felsic fragments containing some chlorite. Also fragments of altered mafic minerals, including chlorite, and fragments of granular quartz rock, are observable in a matrix of chlorite, biotite, quartz, and felsic minerals. Scattered through this rock are aligned lenses of fine to very fine grained feldspathic metawacke some of which have been distorted (Plate 5, Figure 3).

Fine fragmental rock of possible mafic composition forms massive, poorly sorted units and also foliated rock in which there is some layering due to variation in mineral concentration. The massive, poorly sorted rock consists of amphibole, amphibole-felsic fragments, patches of chlorite, scattered quartz grains, opaque grains, and patches of brownish alteration products which contain minor opaque flecks and clots.

The greenish amphibole grains are slightly elongate and often appear to be bent. Green chlorite is commonly associated with the amphibole and has a distinctive purplish blue interference color. Fragments of amphibole-felsic rock contain minor amounts of calcite. Pyrite forms part of the opaque mineral content as indicated by a distinct yellow color in reflected light. The matrix consists of epidote, felsic minerals and greenish chlorite which also has purplish blue interference colors.

Plutonic Rocks

Amphibole Granite

The amphibole granite exposed in several areas west of Sakami Lake and south of Long Lake is a massive, medium grained reddish-gray weathering rock with amphibole-rich inclusions in some zones.

The feldspar content consists of zoned plagioclase, some albite-oligoclase (An_{10}) and microcline. Green amphibole is the predominant mafic mineral and greenish chlorite is present in minor amounts. Fine epidote is observable as part of the saussuritization products produced through plagioclase alteration. Sphene and opaque mineral grains are observable in minor amounts.

Plagioclase is commonly zoned with the central part of the grains being more conspicuously altered and with epidote forming part of the alteration. Relict albite twinning is observable on some grains, the analysis of which indicates albite-oligoclase (An_{10}). Microcline is less abundant than the plagioclase and exhibits a well developed cross-hatched twinning.

Fine to medium grained amphibole-rich units are observable in some sections. Felsic minerals in these units consist of plagioclase, microcline and quartz. Plagioclase consists of scattered, coarse, altered grains containing some epidote. Microcline forms large coarse grains which have inclusions of amphibole in the form of

individual crystals and clots of crystals. About 30 to 40 percent of the units consist of amphibole.

Granite; Foliated, Porphyritic

Porphyritic granite which has suffered cataclasis to varying degrees is exposed in many parts of the Sakami Lake and Lake Cataseau areas and to the west. It is predominantly medium grained and is massive to foliated. Biotite, epidote, feldspar, and quartz form the finer fraction in addition to occasional clots of highly sutured quartz grains.

Quartz and feldspar form phenocrysts and chlorite also forms coarse units. Feldspar is altered with many grains broken and bent, indicated in part by curved and displaced albite twinning planes. Analysis of several thin sections indicates that plagioclase is albite-oligoclase in the range of $An_4 - An_{10}$ with a predominance in the area of An_7 . Some of the coarser feldspar grains are highly granulated and some are fractured with finer grained, reconstituted feldspar in the fracture zones. Quartz grains are highly sutured and exhibit undulant extinction. Some quartz grains show slight embayments which may be due to resorption. In some places the rock fabric has a fragmental appearance; however, this texture may be due to the high degree of cataclasis suffered by the rock.

In some sectors the granite is predominantly medium grained and only slightly porphyritic. Feldspar

consists predominantly of albite, minor amounts of microcline and a few scattered grains showing myrmekitic texture. Ferromagnesian minerals consist of about 3 percent chlorite and minor amounts of epidote. Some zones contain brown biotite with zircon. Cataclasis is indicated by granulation of coarser grains and reddish iron-oxide staining is commonly observed. Some sections show up to about 3 percent epidote and minor amounts of calcite.

One variation of the granite mentioned above contains distinctive chlorite units in which quartz forms elongate lenses parallel to the cleavage in the host chlorite which is readily observed by its purplish blue interference colors. The quartz has a fibrous-like structure (perpendicular to the chlorite-quartz contacts) which is indicated by the extinction pattern of the quartz during stage rotation under crossed nicols. The chlorite grains also have a fine epidote content in the form of semi-opaque stringers parallel to cleavage in the host mineral.

Exposures of granitic rock occur in the area between Sakami Lake and Long Lake in which mafic minerals consist of amphibole and brown biotite and form about 10 percent of the rock. Some of the amphibole has a well developed sieve texture. Plagioclase consists, in part at least, of aligoclase (An_{20}). Minor amounts of sphene are observable and epidote forms up to about 10 percent of some zones.

Some exposures consist of medium to coarse grained massive granite in which a graphic intergrowth of quartz and feldspar can be observed. Albite and minor amounts of chlorite are also observable.

Diabase

Diabase in the region has an observable ophitic to subophitic texture in the form of euhedral plagioclase crystals partially to completely enclosed by a ferromagnesian mineral, probably altered clinopyroxene. The plagioclase shows relict twinning and is also highly altered by the formation of a colorless, fine, fibrous-mineral. Some of the plagioclase crystals are well developed lath-shaped grains and albite twinning indicates a compositional range of about $An_{45} - An_{52}$. Calcite forms scattered irregular clots and constitutes about 15 percent or more of the rock in some places.

Rocks of Probable Ultramafic Origin

Exposures on some islands in the central Sakami Lake region consist of tremolite-anthophyllite-talc schists. Some of the rock contain what appear to be pseudomorphs after olivine which consist of tremolite, serpentine and opaque minerals.

The pseudomorphs after olivine have curved fractures delineated by very fine, fibrous, colorless serpentine. Central zones of these fractures contain lenses and clots of a very fine, opaque mineral which is black in

of talc consists of box-like structures composed of a fine, very pale buff, micaceous mineral.

Some areas of the altered ultramafic rock contain zoning which is indicated by variation in the relative amounts of tremolite, anthophyllite and talc. One example of this zoning displayed in a thin section consists of fine, fibrous tremolite (which has been crenulated prior to the development of the coarser anthophyllite) adjacent to a zone of massive, fine tremolite. Adjacent to the tremolite is a zone of fine, felted, pale brown talc containing coarser, randomly oriented anthophyllite in minor quantities.

Calcareous-Talc-Schist

Highly crenulated and foliated calcareous-talc-schist is exposed in the southwest part of the mapped area. Talc content consists of fine, fibrous, colorless to pale green grains which exhibit high order interference colors. The carbonate mineral is concentrated in thin lenses which form about 15 percent of the rock. It is colorless, granular, and does not react with dilute hydrochloric acid. Some grains show a well developed rhombic outline which suggests that at least some of the carbonate recrystallized after the crenulation and foliation development in the talc. The lack of acid reaction suggests that the carbonate may be dolomite or possibly magnesite.

About 1 to 3 percent of the rock consists of randomly distributed pyrite grains which, in thin section,

are yellow in reflected light. These grains, some of which show a well developed cubic outline in thin section, are yellow in reflected light.

APPENDIX 2

Investigation ProceduresField Procedures

Field work was accomplished over three field seasons by a field party of the basic type used by the Quebec Department of Natural Resources for semi-reconnaissance work. The party consisted of seven members: the writer, a senior assistant, two junior assistants, a cook, and two field guides or bushmen.

All work was conducted from tent camps and field equipment consisted of the basic necessities for mapping. Plane tabling or similar surveying practices were not attempted. Transportation was done by canoe or on foot. Camp moves, however, were usually done by float plane which always necessitated camping on lakes of a certain minimum size.

Base maps were made by the cartography section of the Quebec Department of Natural Resources from aerial photographs. The base maps were transparencies from which ordinary print-off maps could be made. The base maps show the location of streams, lakes, swamps and the centers of some aerial photographs with the photo and flight-line numbers. Both the base maps and aerial photographs have a scale of 2 inches = 1 mile or 1/31,680.

In the course of field work traverses were planned so that the regions concerned were traversed at

about half mile or 0.8 kilometer intervals. Aerial photographs were used in planning traverses and were used in the field for recording the locations of outcrops. In addition to note taking and sampling photographs were often taken of outcrop features. Data taken in the field was later transferred to base maps which eventually resulted in an outcrop map in which colors were used to delineate the various rock types. Traverses and station numbers were also recorded on separate base maps.

Several hundred standard thin sections were made from selected rocks and about 35 hand specimens were later chosen for chemical analyses. The method of chemical analysis is discussed in subsequent paragraphs. Thin-section studies were done through the use of a Leitz research polarizing microscope. Photographs of selected features were made through the use of a rolleiflex twinlense-reflex camera mounted on the microscope. Some plagioclase analysis were done with a Zeiss four-axis universal stage mounted on a Zeiss polarizing microscope.

Chemical Analysis

Atomic absorption analyses were done with the Perkin-Elmer 403 spectrophotometer. Samples were prepared according to the technique outlined by Trent and Slavin (1964) in which an accurately weighed portion of sample, about one gram, is dissolved in HF and H_2SO_4 acids then diluted to 250 millimeters with about 9 percent HCL.

Five rock standards from two sources were used in the analysis: the United States Geological Survey preparations G-2, BCR-1, and PCC-1 which are granite, basalt, and peridotite respectively; the University of Nancy preparations DR-N, and BR which are diorite and basalt respectively. These powder preparations were prepared in the same manner as the unknown samples. The results of analyses for the United States Geological Survey preparations are listed in a publication by F.J. Flanagan, (1969). Results for the Nancy preparations are listed in a publication by De La Roche and Govindaraju (1971).

Stock solutions were prepared for each element required and these were used as standards during the analysis of unknown samples. The known rock standards from the institutions mentioned were analysed at the same time as the unknowns and served as an indication of accurate preparation of the unknown specimens.

Absorption values for each test were recorded on graphs by a recorder (Perkin-Elmer model 53). Each graph represents a total of about ten readings each of which represented a machine signal average of ten readings. The concentrations were then calculated according to the formula proposed by Abbey (1968) which has been computerized:

$$Ca = \frac{CL + Aa - AL}{AH - AL} - CH - CL$$

where

- Ca = concentration in the sample
- CL = concentration in the lower standard
- Aa = absorbance of the sample
- AL = absorbance of the low standard
- AH = absorbance of the high standard
- CH = concentration in the higher standard

For each determination the readings were taken in the sequence:

L - a - H - a - L

where:

- L = Low standard
- H = High standard
- a = sample

The atomic absorption technique was used to determine the concentration, in parts per million, in each sample for each of the following elements: aluminum, total iron, magnesium, calcium, sodium, potassium, titanium, and manganese. From the concentrations the percent composition by weight of the corresponding oxide was calculated. The approximate silica content was calculated by subtracting the total of all the other oxides from one hundred.

In order to obtain a meaningful analysis by the computer, the value for total iron had to be divided into oxidized and reduced states (Fe_2O_3 and FeO). The amount of total iron allotted to each of these categories

was decided on by comparing the percentages of the other components with analysis of various igneous rocks listed in Barth (1962, p.58) and Hatch, Wells, and Wells (1949).

The results obtained for the samples of igneous origin were subjected to a computerized program for the CIPW norm calculation. These results, and also the weight percentages of the various metal oxides resulting from atomic absorption analyses, have been listed in Appendix 3.

APPENDIX 3

Appendix 3 consists of the results of CIPW norm calculations from chemical data obtained by atomic absorption analyses. The CIPW norm calculations consist of five separate figures listed as P, PM, Q, C and PC. In each case:

- (1) $P = \text{weight percent of oxide} / 100$
- (2) $PM = \text{molecular weight of the oxide}$
- (3) $Q = P / \text{molecular weight of the oxide}$
- (4) $C = Q \times 1000 \times D$ where D = a calculation factor concerned in the computer programming technique
- (5) $PC = C \times 100 / \sum C$

The reference for the computer program used is: The University of Quebec at Montreal, Canada, geology

program: CDC 6400; FTM V30 - P288 OPT = 1

24/02/72.

WEIGHT PERCENT OF THE OXIDES

1 SI02 = 71.025
 2 AL2O3 = 14.9
 3 FE2O3 = 0.79
 4 FE0 = 0.39
 5 MG0 = 0.32
 6 CA0 = 4.53
 7 NA2O = 4.94
 8 K2O = 2.89
 9 TI02 = 0.194
 10 P2O5 = 0.00
 11 MNO = 0.02
 12 CO2 = 0.00

Specimen: 5-H-8

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SI02	.7102	60.0848	.011821	11.8208	65.6032
2	AL2O3	.1490	101.9612	.001461	2.9227	16.2203
3	FE2O3	.0079	159.6922	.000049	.0989	.5491
4	FE0	.0039	71.8484	.000054	.0543	.3012
5	MG0	.0032	40.3114	.000079	.0794	.4406
6	CA0	.0453	56.0794	.000808	.8078	4.4830
7	NA2O	.0494	61.9790	.000797	1.5941	8.8469
8	K2O	.0289	94.2034	.000307	.6136	3.4052
9	TI02	.0019	79.8988	.000024	.0243	.1348
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MNO	.0002	70.9374	.000003	.0028	.0156
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 5-H-8

QUARTZ	= 23.75
ORTHOSE	= 17.08
PLAGIOCLASE	= 51.75
(ANORTHITE = 9.95)	
(ALBITE = 41.80)	
NEPHELINE	= 0.00
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 0.00
WOLLASTONITE	= 4.31
DIOPSIDE SS	= 1.72
(DIOPSIDE = 1.72)	
(HEDENBERGITE = 0.00)	
HYPERSTHENE	= 0.00
(ENSTATITE = 0.00)	
(FERROSILITE = 0.00)	
OLIVINE	= 0.00
(FORSTERITE = 0.00)	
(FAYALITE = 0.00)	
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= .76
HEMATITE	= .27
ILMENITE	= .37
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 99.999245

WEIGHT PERCENT OF THE OXIDES

1 SI02 = 7 69.09
 2 AL2O3 = 7 18.00
 3 FE2O3 = 7 1.6
 4 FEO = 7 1.5
 5 MGO = 7 0.61
 6 CAO = 7 1.18
 7 NA2O = 7 5.32
 8 K2O = 7 2.62
 9 TI02 = 7 0.05
 10 P2O5 = 7 0.00
 11 MNO = 7 0.01
 12 CO2 = 7 0.00

Specimen: 17-H-2A

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SI02	.6909	60.0848	.011499	11.4987	63.5957
2	AL2O3	.1800	101.9612	.001765	3.5308	19.5274
3	FE2O3	.0160	159.6922	.000100	.2004	1.1083
4	FEO	.0150	71.8484	.000209	.2088	1.1547
5	MGO	.0061	40.3114	.000151	.1513	.8369
6	CAO	.0118	56.0794	.000210	.2104	1.1637
7	NA2O	.0532	61.9790	.000858	1.7167	9.4945
8	K2O	.0262	94.2034	.000278	.5562	3.0764
9	TI02	.0005	79.8988	.000006	.0063	.0346
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MNO	.0001	70.9374	.000001	.0014	.0078
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
	TOTAL	.9998				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 17-H-2A

QUARTZ	= 24.06
ORTHOSE	= 15.48
PLAGIOCLASE	= 50.87
(ANORTHITE = 5.85)	
(ALBITE = 45.02)	
NEPHELINE	= 0.00
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 4.27
WOLLASTONITE	= 0.00
DIOPSIDE SS	= 0.00
(DIOPSIDE = 0.00)	
(HEDENBERGITE = 0.00)	
HYPERSTHENE	= 2.89
(ENSTATITE = 1.52)	
(FERROSILITE = 1.37)	
OLIVINE	= 0.00
(FORSTERITE = 0.00)	
(FAYALITE = 0.00)	
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= 2.32
HEMATITE	= 0.00
ILMENITE	= .09
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 99.980086

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ? 74.976
2	Al2O3	= ? 13.4
3	Fe2O3	= ? 3.34
4	FeO	= ? 1.76
5	MgO	= ? 0.23
6	CaO	= ? 2.48
7	Na2O	= ? 1-2.12
8	K2O	= ? 1.48
9	TiO2	= ? 0.21
10	P2O5	= ? 0.00
11	MnO	= ? 0.004
12	CO2	= ? 0.00

Specimen: 20-H+1A

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SiO2	.7498	60.0848	.012478	12.4784	72.1521
2	Al2O3	.1340	101.9612	.001314	2.6285	15.1982
3	Fe2O3	.0334	159.6922	.000209	.4183	2.4187
4	FeO	.0176	71.8484	.000245	.2450	1.4164
5	MgO	.0023	40.3114	.000057	.0571	.3299
6	CaO	.0248	56.0794	.000442	.4422	2.5571
7	Na2O	.0212	61.9790	.000342	.6841	3.9556
8	K2O	.0148	94.2034	.000157	.3142	1.8168
9	TiO2	.0021	79.8988	.000026	.0263	.1520
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0000	70.9374	.000001	.0006	.0033
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 20-H-1A

QUARTZ	= 51.26
ORTHOSE	= 8.75
PLAGIOCLASE	= 30.24
(ANORTHITE = 12.30)	
(ALBITE = 17.94)	
NEPHELINE	= 0.00
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 3.80
WOLLASTONITE	= 0.00
DIOPSIDE SS	= 0.00
(DIOPSIDE = 0.00)	
(HEDENBERGITE = 0.00)	
HYPERSTHENE	= .71
(ENSTATITE = .57)	
(FERROSILITE = .13)	
OLIVINE	= 0.00
(FORSTERITE = 0.00)	
(FAYALITE = 0.00)	
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= 4.84
HEMATITE	= 0.00
ILMENITE	= .40
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 100.000002

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ?	57.68
2	Al2O3	= ?	19.70
3	Fe2O3	= ?	4.70
4	FeO	= ?	7.50
5	MgO	= ?	1.57
6	CaO	= ?	0.13
7	Na2O	= ?	3.03
8	K2O	= ?	3.81
9	TiO2	= ?	1.86
10	P2O5	= ?	0.00
11	MnO	= ?	0.02
12	CO2	= ?	0.00

Specimen: 24-H-6B

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SiO2	.5768	60.0848	.009600	9.5998	54.7576
2	Al2O3	.1970	101.9612	.001932	3.8642	22.0417
3	Fe2O3	.0470	159.6922	.000294	.5886	3.3576
4	FeO	.0750	71.8484	.001044	1.0439	5.9543
5	MgO	.0157	40.3114	.000389	.3895	2.2215
6	CaO	.0013	56.0794	.000023	.0232	.1322
7	Na2O	.0303	61.9790	.000489	.9778	5.5771
8	K2O	.0381	94.2034	.000404	.8089	4.6139
9	TiO2	.0186	79.8988	.000233	.2328	1.3279
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0002	70.9374	.000003	.0028	.0161
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
	TOTAL	1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 24-H-6B

QUARTZ	= 19.73
ORTHOSE	= 22.51
PLAGIOCLASE	= 26.28
(ANORTHITE =	.64)
(ALBITE = 25.64)	
NEPHELINE	= 0.00
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 10.36
WOLLASTONITE	= 0.00
DIOPSIDE SS	= 0.00
(DIOPSIDE =	0.00)
(HEDENBERGITE =	0.00)
HYPERSTHENE	= 10.76
(ENSTATITE =	3.91
(FERROSILITE =	6.85)
OLIVINE	= 0.00
(FORSTERITE =	0.00)
(FAYALITE =	0.00)
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= 6.81
HEMATITE	= 0.00
ILMENITE	= 3.53
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 100.000048

WEIGHT PERCENT OF THE OXIDES

1 SiO2 = 48.522
 2 Al2O3 = 12.0
 3 Fe2O3 = 4.0
 4 FeO = 12.0
 5 MgO = 5.6
 6 CaO = 14.0
 7 Na2O = 2.02
 8 K2O = 0.12
 9 TiO2 = 1.72
 10 P2O5 = 0.00
 11 MnO = 0.018
 12 CO2 = 0.00

Specimen: 26-H-1A

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SiO2	.4852	60.0848	.008076	8.0756	46.4613
2	Al2O3	.1200	101.9612	.001177	2.3538	13.5423
3	Fe2O3	.0400	159.6922	.000250	.5010	2.8822
4	FeO	.1200	71.8484	.001670	1.6702	9.6091
5	MgO	.0560	40.3114	.001389	1.3892	7.9924
6	CaO	.1400	56.0794	.002496	2.4965	14.3629
7	Na2O	.0202	61.9790	.000326	.6518	3.7502
8	K2O	.0012	94.2034	.000013	.0255	.1466
9	TiO2	.0172	79.8988	.000215	.2153	1.2385
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0002	70.9374	.000003	.0025	.0146
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
	TOTAL	1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

QUARTZ	=	.68
ORTHOSE	=	.71
PLAGIOCLASE	=	40.41
(ANORTHITE = 23.32)		
(ALBITE = 17.09)		
NEPHELINE	=	0.00
LEUCITE	=	0.00
KALIOPHILLITE	=	0.00
ACMITE	=	0.00
METASILICATE DE NA	=	0.00
METASILICATE DE K	=	0.00
CORINDON	=	0.00
WOLLASTONITE	=	0.00
DIOPSIDE SS	=	38.34
(DIOPSIDE = 19.22)		
(HEDENBERGITE = 19.13)		
HYPERSTHENE	=	10.79
(ENSTATITE = 5.04)		
(FERROSILITE = 5.75)		
OLIVINE	=	0.00
(FORSTERITE = 0.00)		
(FAYALITE = 0.00)		
ORTHOSILICATE DE CA	=	0.00
MAGNETITE	=	5.80
HEMATITE	=	0.00
ILMENITE	=	3.27
SPHENE	=	0.00
PEROWSKITE	=	0.00
RUTILE	=	0.00
CHROMITE	=	0.00
APATITE	=	0.00
FLUORINE	=	0.00
PYRITE	=	0.00
CARBONATE DE NA	=	0.00
CALCITE	=	0.00
THENARDITE	=	0.00
HALITE	=	0.00
ZIRCON	=	0.00
H2O+	=	0.00
H2O-	=	0.00

Specimen: 26-H-1A

 TOTAL = 99.999897

WEIGHT PERCENT OF THE OXIDES

1 SI02 = 78.11
 2 AL2O3 = 11.70
 3 FE2O3 = 2.3
 4 FE0 = 1.8
 5 MG0 = 0.69
 6 CA0 = 0.32
 7 NA2O = 3.42
 8 K2O = 2.12
 9 TI02 = 0.50
 10 P2O5 = 0.00
 11 MNO = 0.04
 12 CO2 = 0.00

Specimen: 3-F-4B

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SI02	.7811	60.0848	.013000	13.0000	73.5139
2	AL2O3	.1170	101.9612	.001147	2.2950	12.9780
3	FE2O3	.0230	159.6922	.000144	.2881	1.6289
4	FE0	.0180	71.8484	.000251	.2505	1.4167
5	MG0	.0069	40.3114	.000171	.1712	.9679
6	CA0	.0032	56.0794	.000057	.0571	.3227
7	NA2O	.0342	61.9790	.000552	1.1036	6.2408
8	K2O	.0212	94.2034	.000225	.4501	2.5452
9	TI02	.0050	79.8988	.000063	.0626	.3539
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MNO	.0004	70.9374	.000006	.0056	.0319
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
	TOTAL	1.0100				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 3-F-4B

QUARTZ	= 48.09
ORTHOSE	= 12.53
PLAGIOCLASE	= 30.53
(ANORTHITE = 1.59)	
(ALBITE = 28.94)	
NEPHELINE	= 0.00
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 3.20
WOLLASTONITE	= 0.00
DIOPSIDE SS	= 0.00
(DIOPSIDE = 0.00)	
(HEDENBERGITE = 0.00)	
HYPERSTHENE	= 2.37
(ENSTATITE = 1.72)	
(FERROSILITE = .65)	
OLIVINE	= 0.00
(FORSTERITE = 0.00)	
(FAYALITE = 0.00)	
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= 3.33
HEMATITE	= 0.00
ILMENITE	= .95
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 101.000462

WEIGHT PERCENT OF THE OXIDES

1 SI02 = ? 44.63
 2 AL2O3 = ? 13.8
 3 FE2O3 = ? 4.58
 4 FEO = ? 9.12
 5 MGO = ? 7.58
 6 CAO = ? 16.30
 7 NA2O = ? 2.77
 8 K2O = ? 0.21
 9 TI02 = ? 0.99
 10 P2O5 = ? 0.0
 11 MNO = ? 0.02
 12 CO2 = ? 0.0

Specimen: 7-F-9A

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SI02	.4463	60.0848	.007428	7.4278	41.6597
2	AL2O3	.1380	101.9612	.001353	2.7069	15.1819
3	FE2O3	.0458	159.6922	.000287	.5736	3.2171
4	FEO	.0912	71.8484	.001269	1.2693	7.1192
5	MGO	.0758	40.3114	.001880	1.8804	10.5462
6	CAO	.1630	56.0794	.002907	2.9066	16.3019
7	NA2O	.0277	61.9790	.000447	.8939	5.0132
8	K2O	.0021	94.2034	.000022	.0446	.2501
9	TI02	.0099	79.8988	.000124	.1239	.6949
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MNO	.0002	70.9374	.000003	.0028	.0158
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 7-P-9A

QUARTZ	= 0.00
ORTHOSE	= 1.24
PLAGIOCLASE	= 27.58
(ANORTHITE = 24.60)	
(ALBITE = 2.98)	
NEPHELINE	= 11.08
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 0.00
WOLLASTONITE	= 0.00
DIOPSIDE SS	= 45.80
(DIOPSIDE = 30.04)	
(HEDENBERGITE = 15.76)	
HYPERSTHENE	= 0.00
(ENSTATITE = 0.00)	
(FERROSILITE = 0.00)	
OLIVINE	= 5.77
(FORSTERITE = 3.47)	
(FAYALITE = 2.30)	
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= 6.64
HEMATITE	= 0.00
ILMENITE	= 1.88
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 100.000002

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ? 47.778
2	Al2O3	= ? 13.0
3	Fe2O3	= ? 3.6
4	FeO	= ? 10.8
5	MgO	= ? 6.72
6	CaO	= ? 14.8
7	Na2O	= ? 2.63
8	K2O	= ? 0.66
9	TiO2	= ? 1.21
10	P2O5	= ? 0.00
11	MnO	= ? 0.012
12	CO2	= ? 0.00

Specimen: 29-F-3A

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	Q	C	PC
1	SiO2	.4778	60.0848	.007952	7.9518	44.4137
2	Al2O3	.1300	101.9612	.001275	2.5500	14.2427
3	Fe2O3	.0360	159.6922	.000225	.4509	2.5183
4	FeO	.1080	71.8484	.001503	1.5032	8.3958
5	MgO	.0672	40.3114	.001667	1.6670	9.3110
6	CaO	.1480	56.0794	.002639	2.6391	14.7405
7	Na2O	.0263	61.9790	.000424	.8487	4.7402
8	K2O	.0066	94.2034	.000070	.1401	.7826
9	TiO2	.0121	79.8988	.000151	.1514	.8459
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0001	70.9374	.000002	.0017	.0094
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000

TOTAL 1.0121

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: 29-F-3A

QUARTZ	=	0.00
ORTHOSE	=	3.90
PLAGIOCLASE	=	33.99
(ANORTHITE	=	21.72)
(ALBITE	=	12.28)
NEPHELINE	=	5.41
LEUCITE	=	0.00
KALIOPHILLITE	=	0.00
ACMITE	=	0.00
METASILICATE DE NA	=	0.00
METASILICATE DE K	=	0.00
CORINDON	=	0.00
WOLLASTONITE	=	0.00
DIOPSIDE SS	=	42.61
(DIOPSIDE	=	24.01)
(HEDENBERGITE	=	18.61)
HYPERSTHENE	=	0.00
(ENSTATITE	=	0.00
(FERROSILITE	=	0.00)
OLIVINE	=	7.78
(FORSTERITE	=	3.93)
(FAYALITE	=	3.85)
ORTHOSILICATE DE CA	=	0.00
MAGNETITE	=	5.22
HEMATITE	=	0.00
ILMENITE	=	2.30
SPHENE	=	0.00
PEROWSKITE	=	0.00
RUTILE	=	0.00
CHROMITE	=	0.00
APATITE	=	0.00
FLUORINE	=	0.00
PYRITE	=	0.00
CARBONATE DE NA	=	0.00
CALCITE	=	0.00
THENARDITE	=	0.00
HALITE	=	0.00
ZIRCON	=	0.00
H2O+	=	0.00
H2O-	=	0.00

TOTAL = 101.209853

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ?	58.45
2	Al2O3	= ?	14.60
3	Fe2O3	= ?	2.80
4	FeO	= ?	4.00
5	MgO	= ?	3.53
6	CaO	= ?	10.10
7	Na2O	= ?	4.82
8	K2O	= ?	1.12
9	TiO2	= ?	0.61
10	P2O5	= ?	0.00
11	MnO	= ?	0.01
12	CO2	= ?	0.00

Specimen: 41-F-16

CIPW NORM CALCULATIONS

I	OXYDE	P	PM	O	C	PC
1	SiO2	.5845	60.0848	.009728	9.7279	53.9040
2	Al2O3	.1460	101.9612	.001432	2.8638	15.8690
3	Fe2O3	.0280	159.6922	.000175	.3507	1.9431
4	FeO	.0400	71.8484	.000557	.5567	3.0849
5	MgO	.0353	40.3114	.000876	.8757	4.8523
6	CaO	.1010	56.0794	.001801	1.8010	9.9797
7	Na2O	.0482	61.9790	.000778	1.5554	8.6185
8	K2O	.0112	94.2034	.000119	.2378	1.3176
9	TiO2	.0061	79.8988	.000076	.0763	.4230
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0001	70.9374	.000001	.0014	.0078
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0004				

WEIGHT PERCENT OF THE OXIDES

1	SiO ₂	= ?	49.945
2	Al ₂ O ₃	= ?	12.9
3	Fe ₂ O ₃	= ?	3.66
4	FeO	= ?	8.54
5	MgO	= ?	7.13
6	CaO	= ?	17.7
7	Na ₂ O	= ?	2.01
8	K ₂ O	= ?	0.91
9	TiO ₂	= ?	0.79
10	P ₂ O ₅	= ?	0.00
11	MnO	= ?	0.015
12	CO ₂	= ?	0.00

Specimen: 44-M-57

CIPW NORM CALCULATIONS

	OXYDE	P	PM	Q	C	PC
1	SiO ₂	.4994	60.0848	.008312	8.3124	45.2806
2	Al ₂ O ₃	.1290	101.9612	.001265	2.5304	13.7838
3	Fe ₂ O ₃	.0366	159.6922	.000229	.4584	2.4970
4	FeO	.0854	71.8484	.001189	1.1886	6.4748
5	MgO	.0713	40.3114	.001769	1.7687	9.6349
6	CaO	.1770	56.0794	.003156	3.1562	17.1931
7	Na ₂ O	.0201	61.9790	.000324	.6486	3.5332
8	K ₂ O	.0091	94.2034	.000097	.1932	1.0524
9	TiO ₂	.0079	79.8988	.000099	.0989	.5386
10	P ₂ O ₅	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0001	70.9374	.000002	.0021	.0115
12	CO ₂	0.0000	44.0099	0.000000	0.0000	0.0000
	H ₂ O ⁺	0.0000	17.007		0.0000	0.0000
	H ₂ O ⁻	0.0000	17.007		0.0000	0.0000
TOTAL		1.0360				

CIPW MINERAL CONTENT IN VOLUME PERCENT

QUARTZ	=	0.00	Specimen: 44-M-5
ORTHOSE	=	5.38	
PLAGIOCLASE	=	31.51	
(ANORTHITE	=	23.49)	
(ALBITE	=	8.02)	
NEPHELINE	=	4.87	
LEUCITE	=	0.00	
KALIOPHILLITE	=	0.00	
ACMITE	=	0.00	
METASILICATE DE NA	=	0.00	
METASILICATE DE K	=	0.00	
CORINDON	=	0.00	
WOLLASTONITE	=	0.00	
DIOPSIDE SS	=	52.46	
(DIOPSIDE	=	33.65)	
(HEDENBERGITE	=	18.80)	
HYPERSTHENE	=	0.00	
(ENSTATITE	=	0.00	
(FERROSILITE	=	0.00)	
OLIVINE	=	2.58	
(FORSTERITE	=	1.51)	
(FAYALITE	=	1.07)	
ORTHOSILICATE DE CA	=	0.00	
MAGNETITE	=	5.31	
HEMATITE	=	0.00	
ILMENITE	=	1.50	
SPHENE	=	0.00	
PEROWSKITE	=	0.00	
RUTILE	=	0.00	
CHROMITE	=	0.00	
APATITE	=	0.00	
FLUORINE	=	0.00	
PYRITE	=	0.00	
CARBONATE DE NA	=	0.00	
CALCITE	=	0.00	
THENARDITE	=	0.00	
HALITE	=	0.00	
ZIRCON	=	0.00	
H2O+	=	0.00	
H2O-	=	0.00	

TOTAL = 103.599954

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ? 67.02
2	Al2O3	= ? 16.60
3	Fe2O3	= ? 1.5
4	FeO	= ? 2.5
5	MgO	= ? 1.66
6	CaO	= ? 3.3-84
7	Na2O	= ? 6.03
8	K2O	= ? 0.86
9	TiO2	= ? 0.50
10	P2O5	= ? 0.00
11	MnO	= ? 0.02
12	CO2	= ? 0.00

Specimen: B-27-4B

CIPW NORM CALCULATIONS

I	OXIDE	P	PM	Q	C	PC
1	SiO2	.6702	60.0848	.011154	11.1542	61.1642
2	Al2O3	.1660	101.9612	.001628	3.2561	17.8550
3	Fe2O3	.0150	159.6922	.000094	.1879	1.0301
4	FeO	.0250	71.8484	.000348	.3480	1.9080
5	MgO	.0166	40.3114	.000412	.4118	2.2581
6	CaO	.0384	56.0794	.000685	.6847	3.7548
7	Na2O	.0603	61.9790	.000973	1.9458	10.6699
8	K2O	.0086	94.2034	.000091	.1826	1.0012
9	TiO2	.0050	79.8988	.000063	.0626	.3432
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0002	70.9374	.000003	.0028	.0155
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0053				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: B-27-4B

QUARTZ	= 17.51
ORTHOSE	= 5.08
PLAGIOCLASE	= 66.71
(ANORTHITE = 15.69)	
(ALBITE = 51.02)	
NEPHELINE	= 0.00
LEUCITE	= 0.00
KALIOPHILLITE	= 0.00
ACMITE	= 0.00
METASILICATE DE NA	= 0.00
METASILICATE DE K	= 0.00
CORINDON	= 0.00
WOLLASTONITE	= 0.00
DIOPSIDE SS	= 2.74
(DIOPSIDE = 1.78)	
(HEDENBERGITE = .96)	
HYPERSTHENE	= 5.36
(ENSTATITE = 3.31)	
(FERROSILITE = 2.05)	
OLIVINE	= 0.00
(FORSTERITE = 0.00)	
(FAYALITE = 0.00)	
ORTHOSILICATE DE CA	= 0.00
MAGNETITE	= 2.17
HEMATITE	= 0.00
ILMENITE	= .95
SPHENE	= 0.00
PEROWSKITE	= 0.00
RUTILE	= 0.00
CHROMITE	= 0.00
APATITE	= 0.00
FLUORINE	= 0.00
PYRITE	= 0.00
CARBONATE DE NA	= 0.00
CALCITE	= 0.00
THENARDITE	= 0.00
HALITE	= 0.00
ZIRCON	= 0.00
H2O+	= 0.00
H2O-	= 0.00

TOTAL = 100.530187

WEIGHT PERCENT OF THE OXIDES

Specimen: M-25-14

1	SiO2	= ?	46.40
2	Al2O3	= ?	3.98
3	Fe2O3	= ?	3.40
4	FeO	= ?	5.90
5	MgO	= ?	33.00
6	CaO	= ?	5.55
7	Na2O	= ?	0.07
8	K2O	= ?	0.82
9	TiO2	= ?	0.05
10	P2O5	= ?	0.00
11	MnO	= ?	0.13
12	CO2	= ?	0.00

CIPW NORM CALCULATIONS

I	OXIDE	P	PM	Q	C	PC
1	SiO2	.4640	60.0848	.007722	7.7224	40.3316
2	Al2O3	.0398	101.9612	.000390	.7807	4.0773
3	Fe2O3	.0340	159.6922	.000213	.4258	2.2239
4	FeO	.0590	71.8484	.000821	.8212	4.2887
5	MgO	.3300	40.3114	.008186	8.1863	42.7542
6	CaO	.0555	56.0794	.000990	.9897	5.1687
7	Na2O	.0007	61.9790	.000011	.0226	.1180
8	K2O	.0082	94.2034	.000087	.1741	.9092
9	TiO2	.0005	79.8988	.000006	.0063	.0327
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0013	70.9374	.000018	.0183	.0957
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		.9930				

CIPW MINERAL CONTENT IN VOLUME PERCENT

QUARTZ	=	0.00
ORTHOSE	=	4.85
PLAGIOCLASE	=	8.72
(ANORTHITE = 8.12)		
(ALBITE = .59)		
NEPHELINE	=	0.00
LEUCITE	=	0.00
KALIOPHILLITE	=	0.00
ACMITE	=	0.00
METASILICATE DE NA	=	0.00
METASILICATE DE K	=	0.00
CORINDON	=	0.00
WOLLASTONITE	=	0.00
DIOPSIDE SS	=	15.26
(DIOPSIDE = 14.04)		
(HEDENBERGITE = 1.22)		
HYPERSTHENE	=	22.55
(ENSTATITE = 20.50)		
(FERROSILITE = 2.04)		
OLIVINE	=	42.90
(FORSTERITE = 38.66)		
(FAYALITE = 4.24)		
ORTHOSILICATE DE CA	=	0.00
MAGNETITE	=	4.93
HEMATITE	=	0.00
ILMENITE	=	.09
SPHENE	=	0.00
PEROWSKITE	=	0.00
RUTILE	=	0.00
CHROMITE	=	0.00
APATITE	=	0.00
FLUORINE	=	0.00
• PYRITE	=	0.00
CARBONATE DE NA	=	0.00
CALCITE	=	0.00
THENARDITE	=	0.00
HALITE	=	0.00
ZIRCON	=	0.00
H2O+	=	0.00
H2O-	=	0.00

Specimen: M-25-14

 TOTAL = 99.301502

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ? 43.568
2	Al2O3	= ? 13.7
3	Fe2O3	= ? 4.7
4	FeO	= ? 9.3
5	MgO	= ? 7.26
6	CaO	= ? 17.9
7	Na2O	= ? 2.19
8	K2O	= ? 0.26
9	TiO2	= ? 1.104
10	P2O5	= ? 0.00
11	MnO	= ? 0.018
12	CO2	= ? 0.00

Specimen: M-28-9

CIPW NORM CALCULATIONS

	OXYDE	P	PM	Q	C	PC
1	SiO2	.4357	60.0848	.007251	7.2511	40.9275
2	Al2O3	.1370	101.9612	.001344	2.6873	15.1680
3	Fe2O3	.0470	159.6922	.000294	.5886	3.3224
4	FeO	.0930	71.8484	.001294	1.2944	7.3060
5	MgO	.0726	40.3114	.001801	1.8010	10.1653
6	CaO	.1790	56.0794	.003192	3.1919	18.0162
7	Na2O	.0219	61.9790	.000353	.7067	3.9888
8	K2O	.0026	94.2034	.000028	.0552	.3116
9	TiO2	.0110	79.8988	.000138	.1382	.7799
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0002	70.9374	.000003	.0025	.0143
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

QUARTZ	=	0.00
ORTHOSE	=	0.00
PLAGIOCLASE	=	26.78
(ANORTHITE = 26.78)		
(ALBITE = 0.00)		
NEPHELINE	=	10.04
LEUCITE	=	1.20
KALIOPHILLITE	=	0.00
ACMITE	=	0.00
METASILICATE DE NA	=	0.00
METASILICATE DE K	=	0.00
CORINDON	=	0.00
WOLLASTONITE	=	0.00
DIOPSIDE SS	=	46.75
(DIOPSIDE = 30.16)		
(HEDENBERGITE = 16.59)		
HYPERSTHENE	=	0.00
(ENSTATITE = 0.00)		
(FERROSILITE = 0.00)		
OLIVINE	=	4.87
(FORSTERITE = 2.87)		
(FAYALITE = 2.00)		
ORTHOSILICATE DE CA	=	1.45
MAGNETITE	=	6.81
HEMATITE	=	0.00
ILMENITE	=	2.10
SPHENE	=	0.00
PEROWSKITE	=	0.00
RUTILE	=	0.00
CHROMITE	=	0.00
APATITE	=	0.00
FLUORINE	=	0.00
PYRITE	=	0.00
CARBONATE DE NA	=	0.00
CALCITE	=	0.00
THENARDITE	=	0.00
HALITE	=	0.00
ZIRCON	=	0.00
H2O+	=	0.00
H2O-	=	0.00

Specimen: M-28-9

TOTAL = 99.999972

WEIGHT PERCENT OF THE OXIDES

1	SiO2	= ? 46.85
2	Al2O3	= ? 16.60
3	Fe2O3	= ? 5.20
4	FeO	= ? 9.20
5	MgO	= ? 6.10
6	CaO	= ? 10.40
7	Na2O	= ? 4.35
8	K2O	= ? 0.51
9	TiO2	= ? 0.63
10	P2O5	= ? 0.00
11	MnO	= ? 0.16
12	CO2	= ? 0.00

Specimen: M-30-3

CIPW NORM CALCULATIONS

I	OXIDE	P	PM	Q	C	PC
1	SiO2	.4685	60.0848	.007797	7.7973	43.3997
2	Al2O3	.1660	101.9612	.001628	3.2561	18.1236
3	Fe2O3	.0520	159.6922	.000326	.6513	3.6249
4	FeO	.0920	71.8484	.001280	1.2805	7.1271
5	MgO	.0610	40.3114	.001513	1.5132	8.4225
6	CaO	.1040	56.0794	.001855	1.8545	10.3222
7	Na2O	.0435	61.9790	.000702	1.4037	7.8130
8	K2O	.0051	94.2034	.000054	.1083	.6027
9	TiO2	.0063	79.8988	.000079	.0788	.4389
10	P2O5	0.0000	141.9446	0.000000	0.0000	0.0000
11	MnO	.0016	70.9374	.000023	.0226	.1255
12	CO2	0.0000	44.0099	0.000000	0.0000	0.0000
	H2O+	0.0000	17.007		0.0000	0.0000
	H2O-	0.0000	17.007		0.0000	0.0000
TOTAL		1.0000				

CIPW MINERAL CONTENT IN VOLUME PERCENT

Specimen: M-30-3

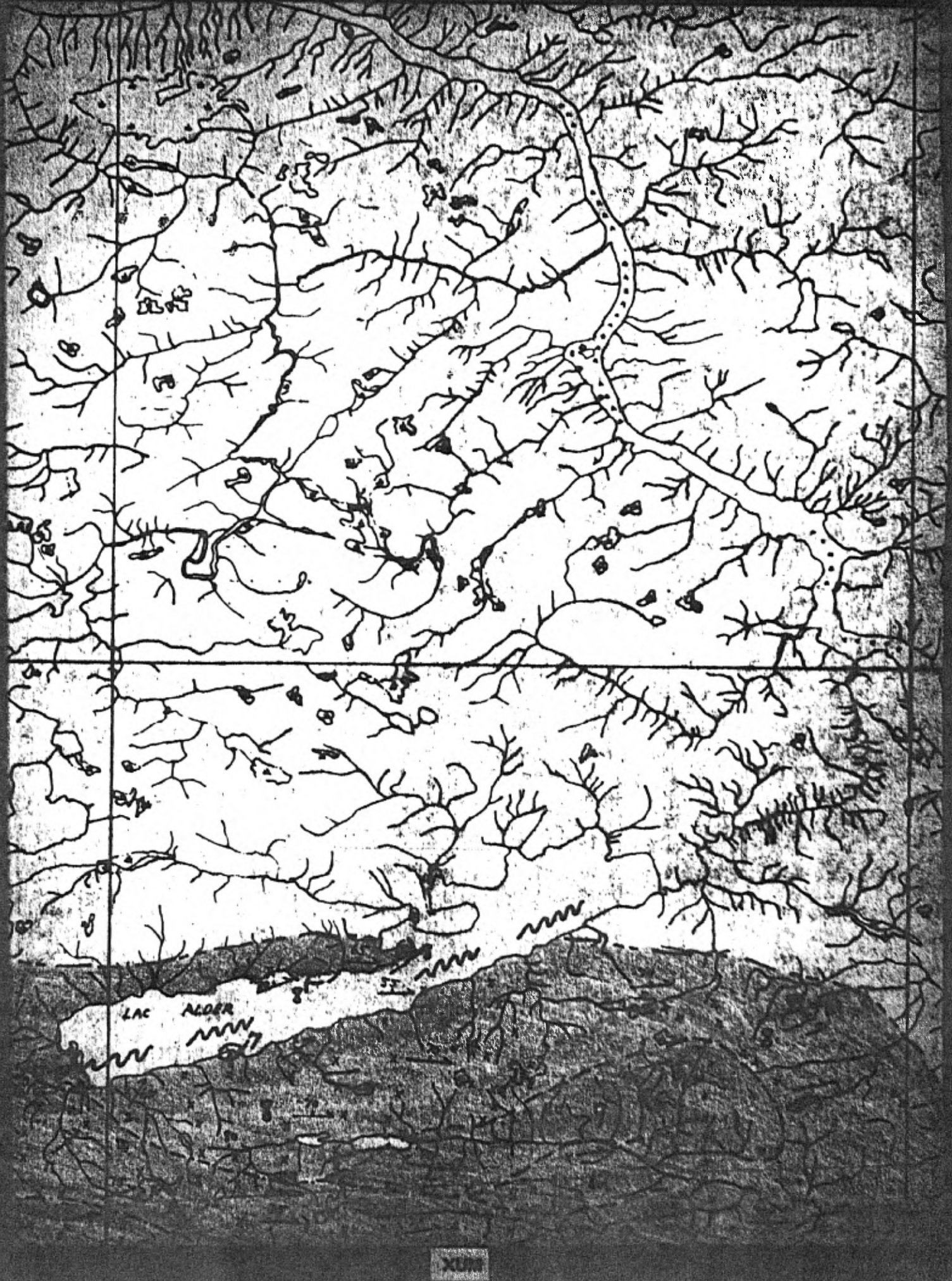
QUARTZ	=	0.00
ORTHOSE	=	3.01
PLAGIOCLASE	=	45.83
(ANORTHITE = 24.26)		
(ALBITE = 21.57)		
NEPHELINE	=	8.26
LEUCITE	=	0.00
KALIOPHILLITE	=	0.00
ACMITE	=	0.00
METASILICATE DE NA	=	0.00
METASILICATE DE K	=	0.00
CORINDON	=	0.00
WOLLASTONITE	=	0.00
DIOPSIDE SS	=	22.43
(DIOPSIDE = 13.35)		
(HEDENBERGITE = 9.08)		
HYPERSTHENE	=	0.00
(ENSTATITE = 0.00)		
(FERROSILITE = 0.00)		
OLIVINE	=	11.74
(FORSTERITE = 6.31)		
(FAYALITE = 5.43)		
ORTHOSILICATE DE CA	=	0.00
MAGNETITE	=	7.54
HEMATITE	=	0.00
ILMENITE	=	1.20
SPHENE	=	0.00
PEROWSKITE	=	0.00
RUTILE	=	0.00
CHROMITE	=	0.00
APATITE	=	0.00
FLUORINE	=	0.00
PYRITE	=	0.00
CARBONATE DE NA	=	0.00
CALCITE	=	0.00
THENARDITE	=	0.00
HALITE	=	0.00
ZIRCON	=	0.00
H2O+	=	0.00
H2O-	=	0.00

TOTAL = 100.001794

140'



140'







LEGEND: Long Lake Region

- 10 Extensive regolith areas lacking bedrock exposures.
- Amphibole granite, occasional mafic and banded tuff inclusions
- Granite, massive to gneissic occasional mafic inclusions
- Granite, cataclastic, porphyritic, weathering light greenish gray, quartz phenocrysts common, often associated with greenstone
- Interbanded greenstone and light gray weathering, fine grained arenite and metabasite
- Gabbroic rock medium grained massive to slightly foliated
- Banded quartzitic iron-formation, associated with greenstone tuffs in some areas.
- Felsic fragmental flow rock porphyritic in some areas
- Felsic volcanic rock contain quartz phenocrysts
- Greenstone or metabasalt, banded fragmental to massive, pillowed lavas
- ARCHEAN

MAP SYMBOLS

	Approximate rock unit boundary		Foliation, vertical
	Limits of mapped area		Foliation inclined, plunge on foliation plane
	Regolith areas		Jointing, inclined
	Gradational boundary		

53°35'

53°30'

77°30'

BASE MAP CARTOGRAPHY PREPARED BY
THE QUEBEC DEPARTMENT OF NATURAL
RESOURCES FROM AERIAL PHOTOGRAPHS
TAKEN IN 1959-60



7729

7710

**GEOLOGY
LONG LAKE AREA
NORTHWESTERN QUEBEC CANADA**

SCALE 1:63,360

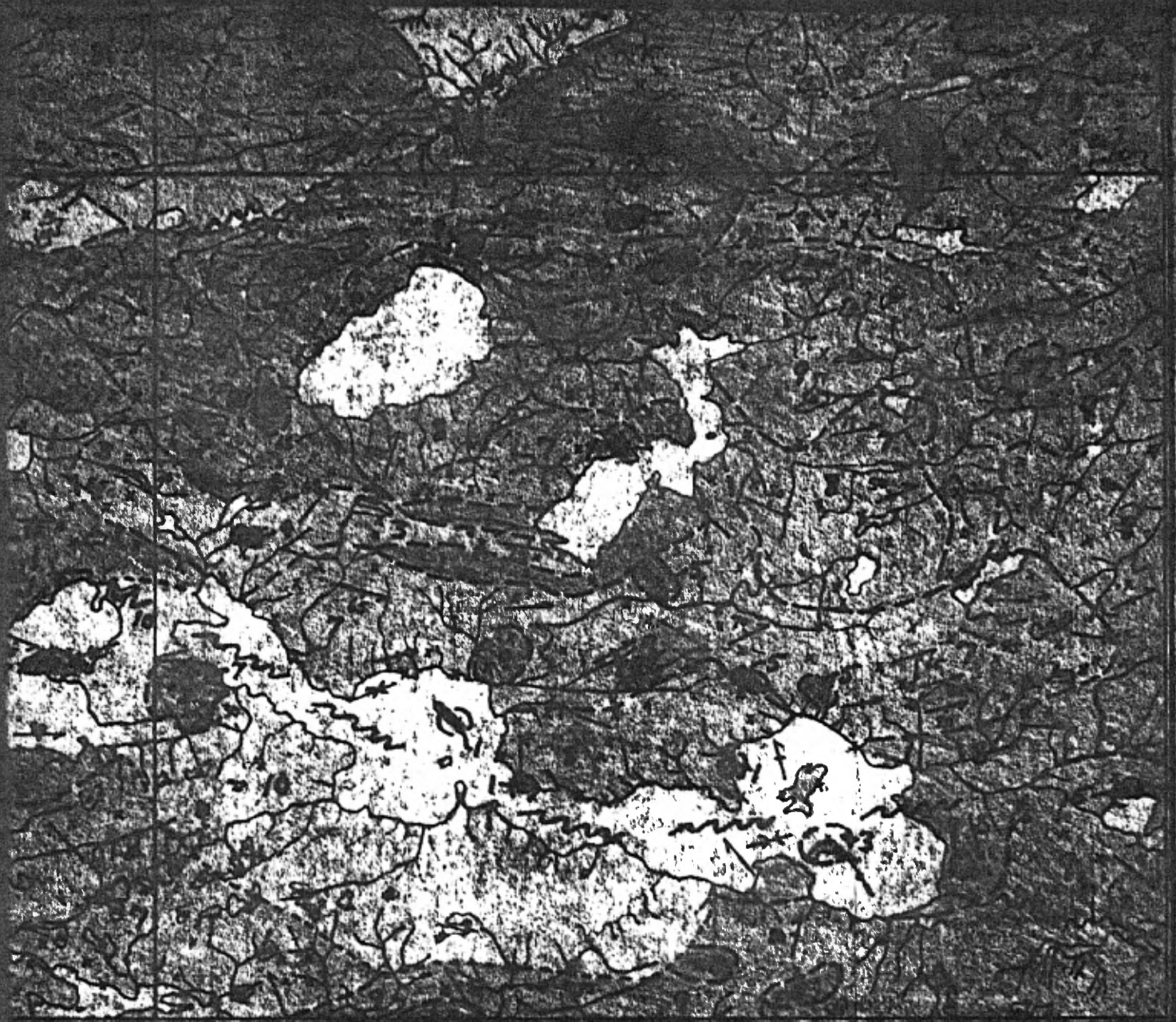
MILES



KILOMETERS



MAGNETIC DECLINATION 10 WEST



7710

DA



5338

-  : Possible bedrock fracture zone
-  : Synform, overturned
-  : Antiform axis area
-  : Synform axis area
-  : Glacial striae
-  : Bedrock exposure areas
-  : Swamp or bog
-  : Slickensiding
-  : Dragfold axis, plunge of lineation
-  : Foliation, dip unknown
-  : Foliation, inclined

-  : Jointing, vertical
-  : Pillowed lavas, trend inclined
-  : Pillowed lavas, trend vertical
-  : Pillowed lavas, unknown and elongation plunge
-  : Pillowed lavas, overturned, plunge elongation
-  : Mineralization
-  : Magnetic iron formation
-  : Diabase

5339

1700



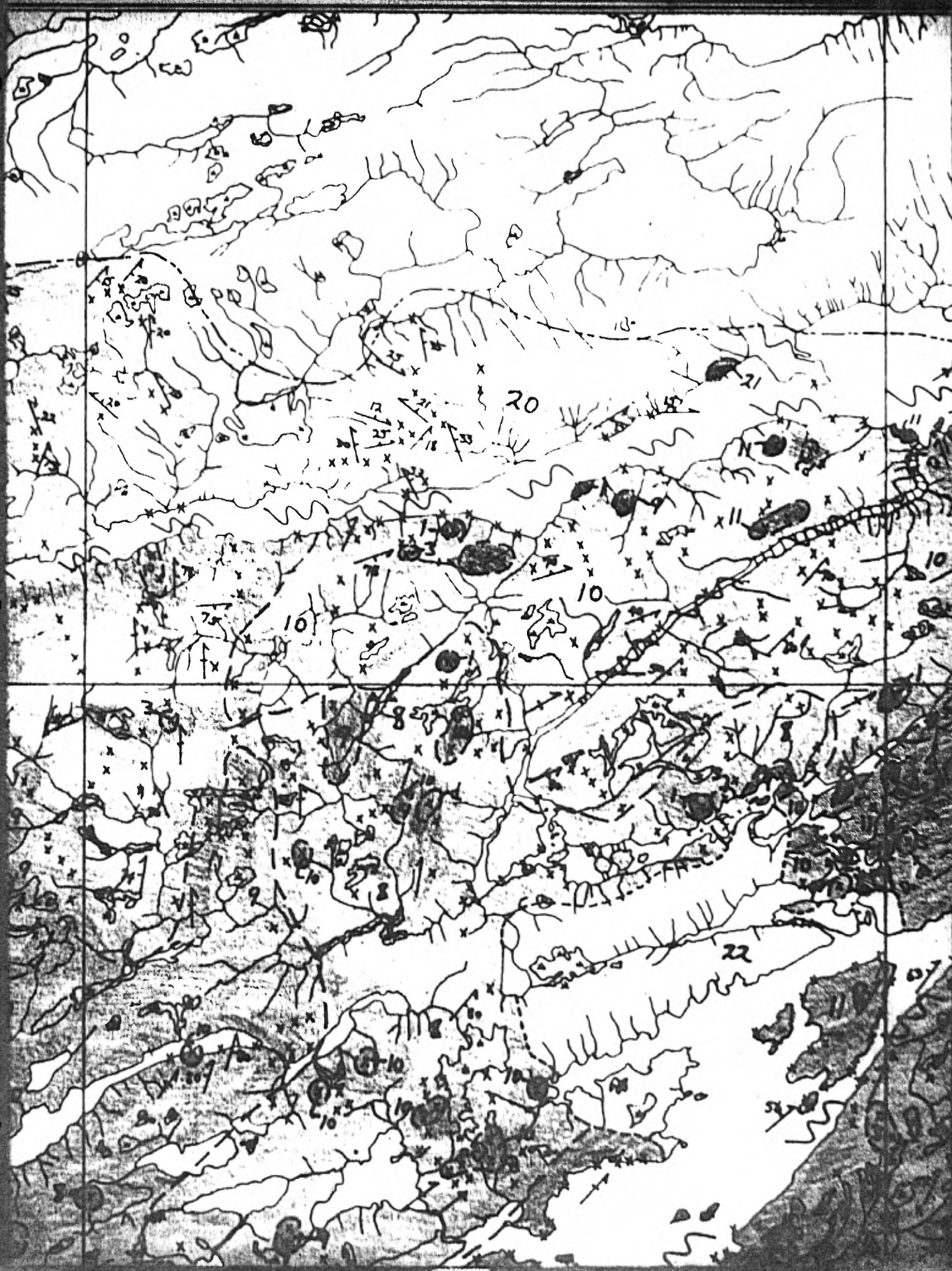
	: Possible bedrock fracture zone		: Pillowed lavas, trend inclined
	: Synform, overturned		: Pillowed lavas, trend vertical
	: Antiform axis area		: Pillowed lavas, tops unknown and elongation plunge
	: Synform axis area		: Pillowed lavas overturned, plunge of elongation
	: Glacial striae		: Mineralization
	: Bedrock exposure areas		: Magnetic iron formation
	: Swamp or bog		: Diabase
	: Slickensiding		
	: Dragfold axis, plunge of lineation		
	: Foliation, dip unknown		
	: Foliation, inclined		

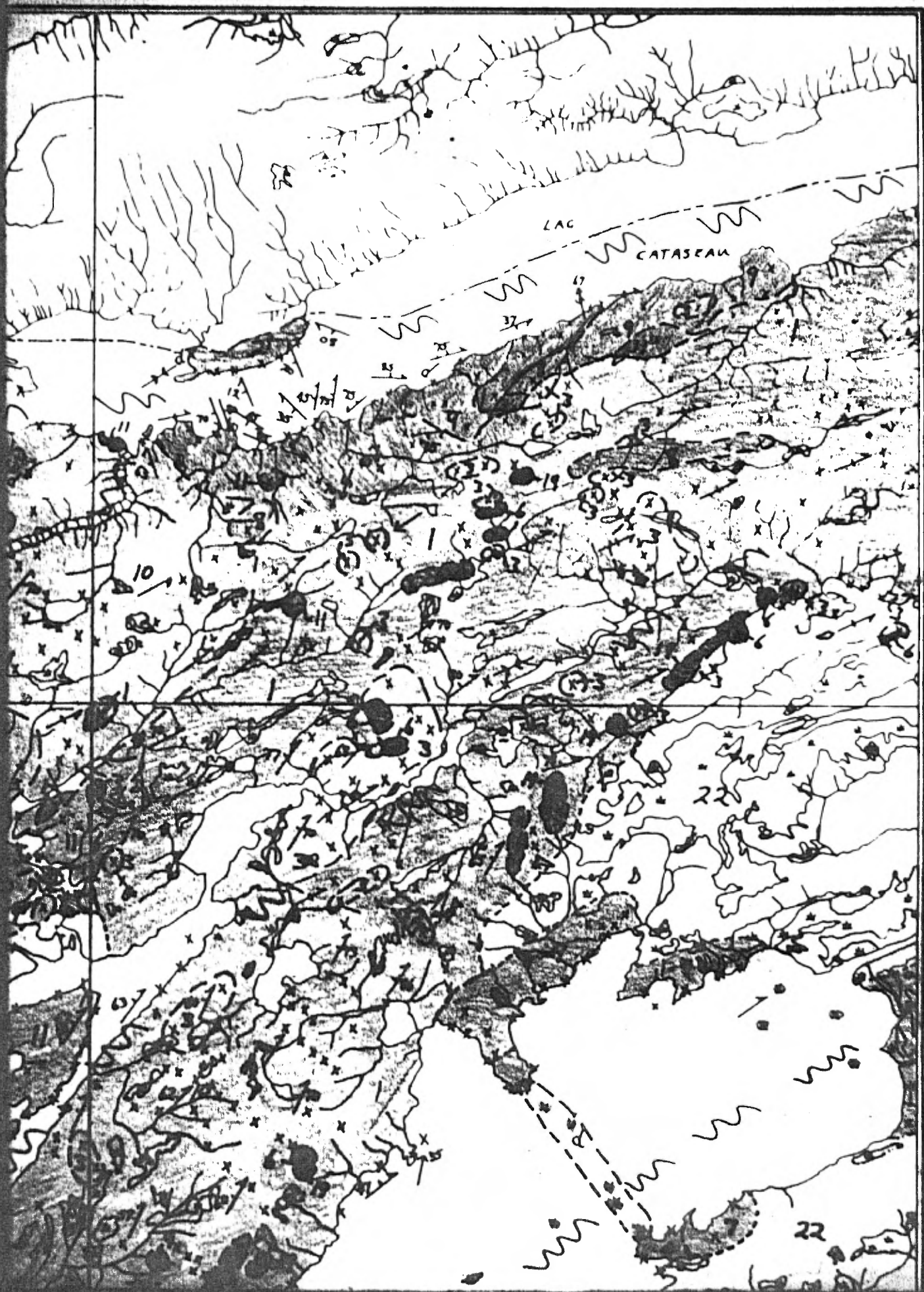


53°55'

53°30'







PROTEROZOIC

22

Large irregular areas lacking bedrock exposure

20

Interbedded quartz arenite and reddish mudstone conglomerate, brecciated in part

Quartz arenite, banded, light brown to slightly reddish, medium to fine grained, occasionally cross bedded

Amphibole-pyroxene rock medium to coarse grained, dark gray to greenish, occasionally garnetiferous

Massive tremolite-anthophyllite rock with probable ultra basic derivative

17

Medium gray granitic rock, variable quartz content, occasional inclusion of mafic material

Porphyritic granite, massive, prominent zoned plagioclase, medium to light gray weathering

15

Medium grained granitic gneiss, weathering friable, foliated

14

Coarse grained pinkish granite occasional tourmaline content

13

Arkosic to feldspathic meta-sandstone and arkosic arenite interlayered with granitic rock

12

Interbedded grayish granite and biotite-feldspar schist

11

Interlayered amphibole schist greenstone and granite zones

10

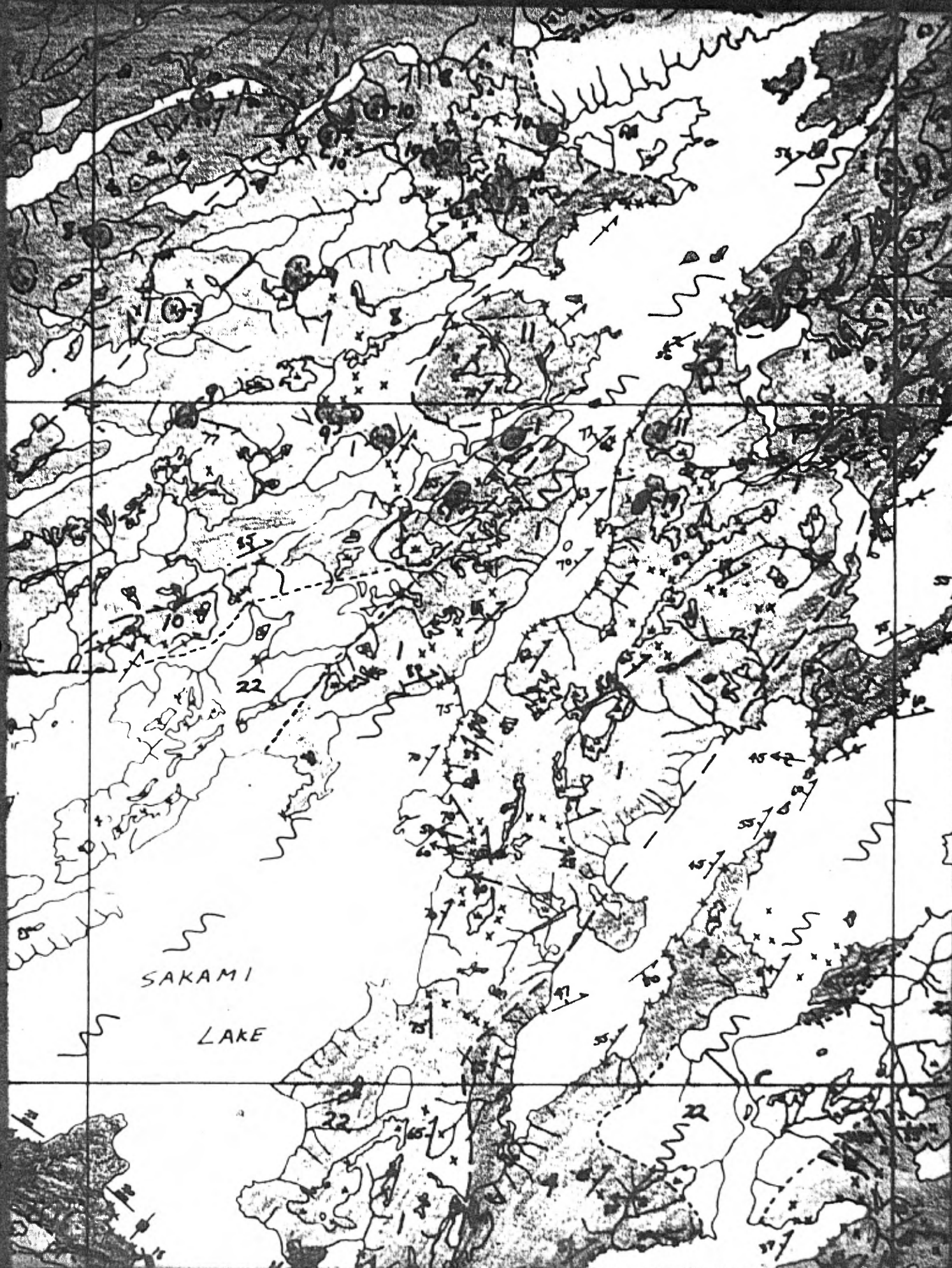
Porphyritic granite, cataclastic, light to medium gray to greenish in part, zones of massive and banded greenstone

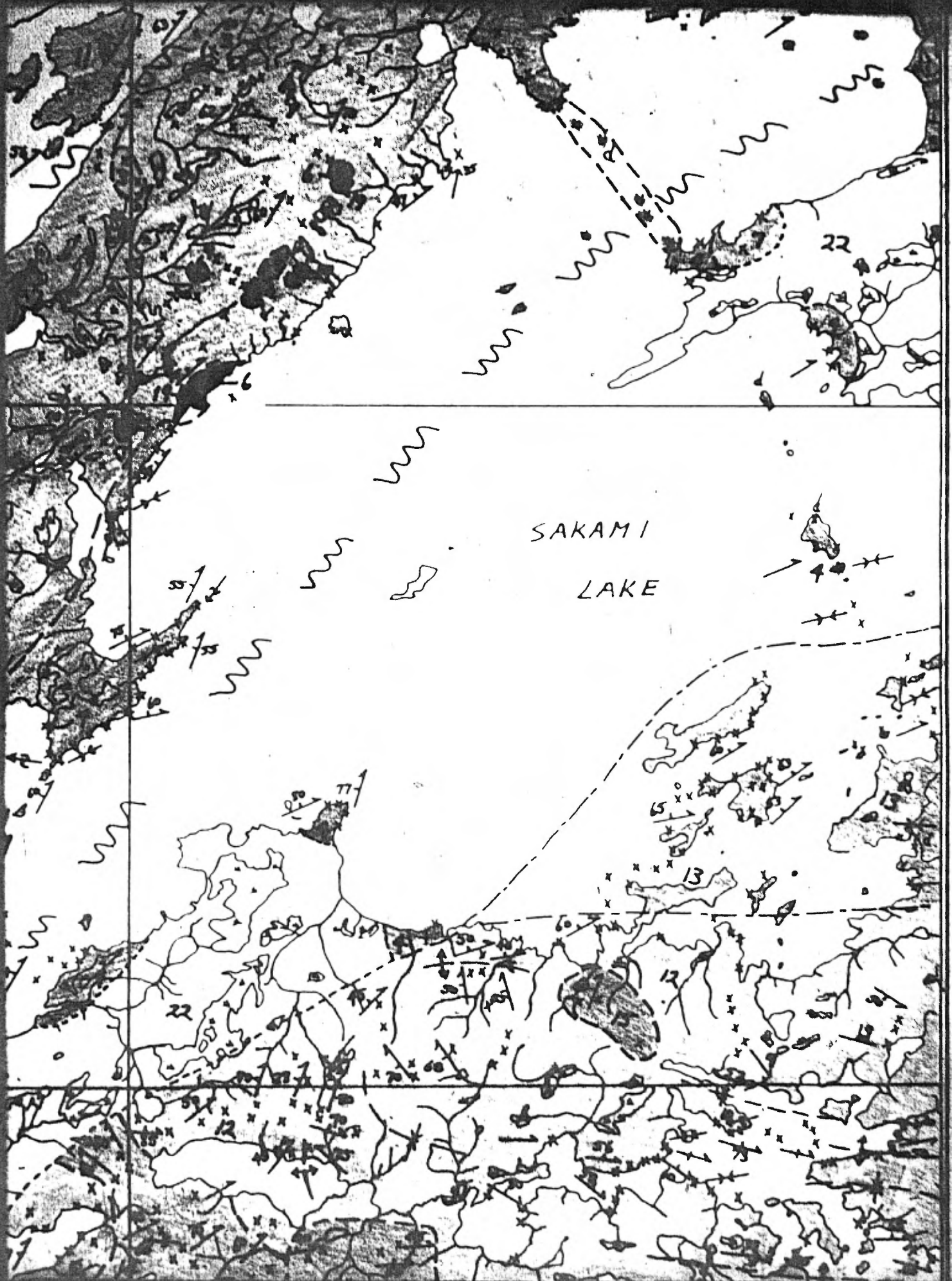
Amphibole granite, variable quartz content,

53°25'

53°20'

XUM





ARCHEAN

5325'



Arkosic to feldspathic metawacke and arkosic arenite interlayered with granitic rock



Interbanded grayish granite and biotite-feldspar schist



Interlayered amphibole schist greenstone and granite zones



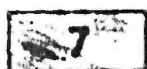
Porphyritic granite, cataclastic, light to medium gray to greenish in part, zones of massive and banded greenstone



Amphibole granite, variable quartz content, medium to coarse grained, porphyritic in part, gradations to porphyritic granite containing fine greenish matrix



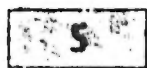
Granite, medium to coarse grained, porphyritic in part. Minor greenstone zones and gradations to slightly greenish matrix



Quartz arenite, light gray, interlayered with darker feldspathic metawacke and arkosic metawacke



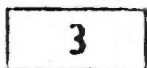
Banded quartzitic rock, light gray, fine grained, rust weathering



Arkosic and feldspathic metawacke, felsic-lithic metawacke, amphibolite schist, quartz-schist, talc carbonate schist, granitic units



Feldspathic to arkosic metawacke with zones of feldspathic and quartz arenite



Felsic volcanic rock, light gray-pinkish, grayish green, discontinuous color banding, foliated zones of greenstone and metawacke



Greenstone, banded to massive, pillowed lavas, quartzitic and sericite schist zones, banded quartzitic and garnetiferous iron-formation zones, amphibole schist and gneisses



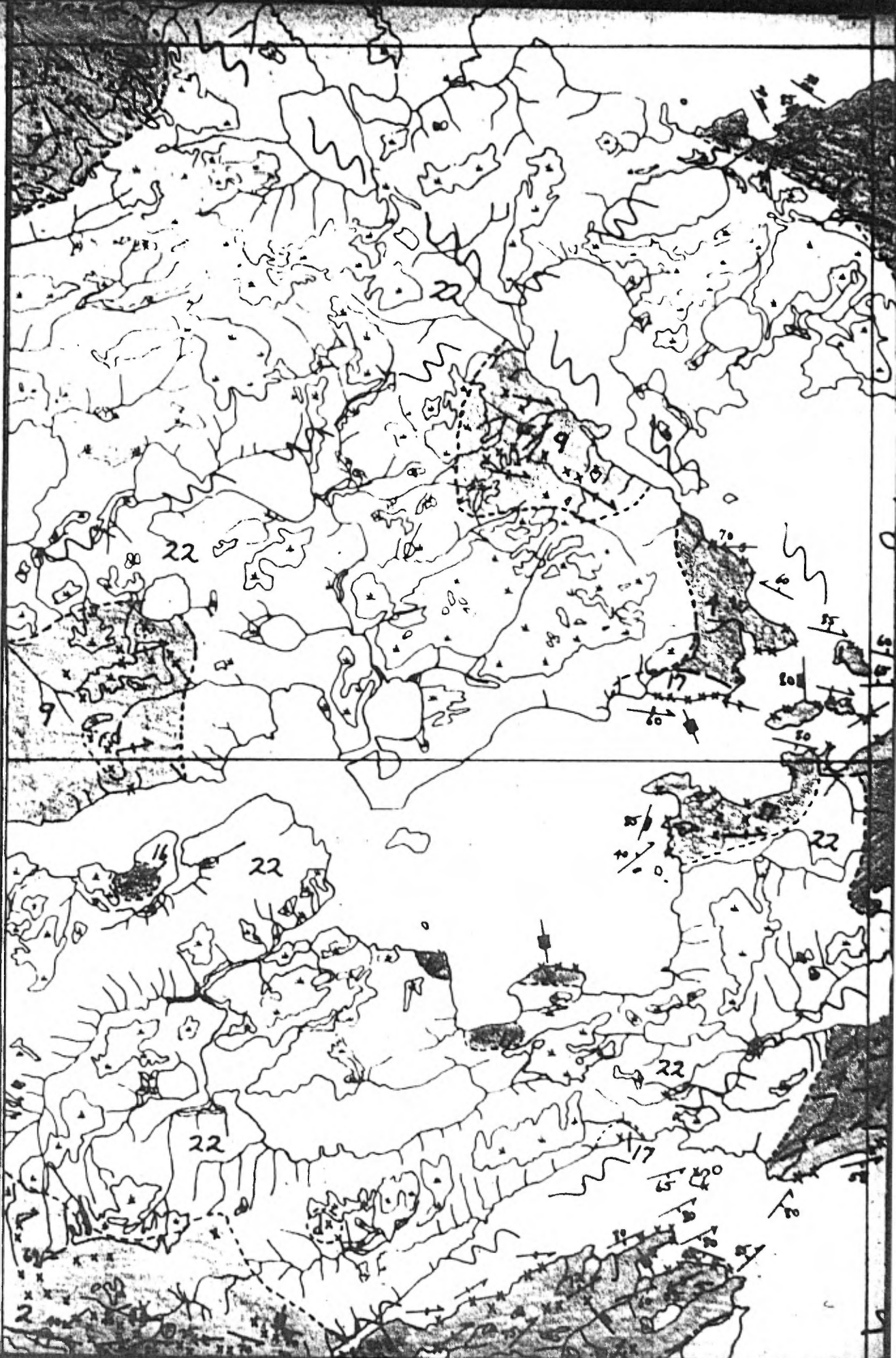
Banded to massive greenstone, pillowed lavas, gabbroic zones, metawackes of volcanic origin

5320'

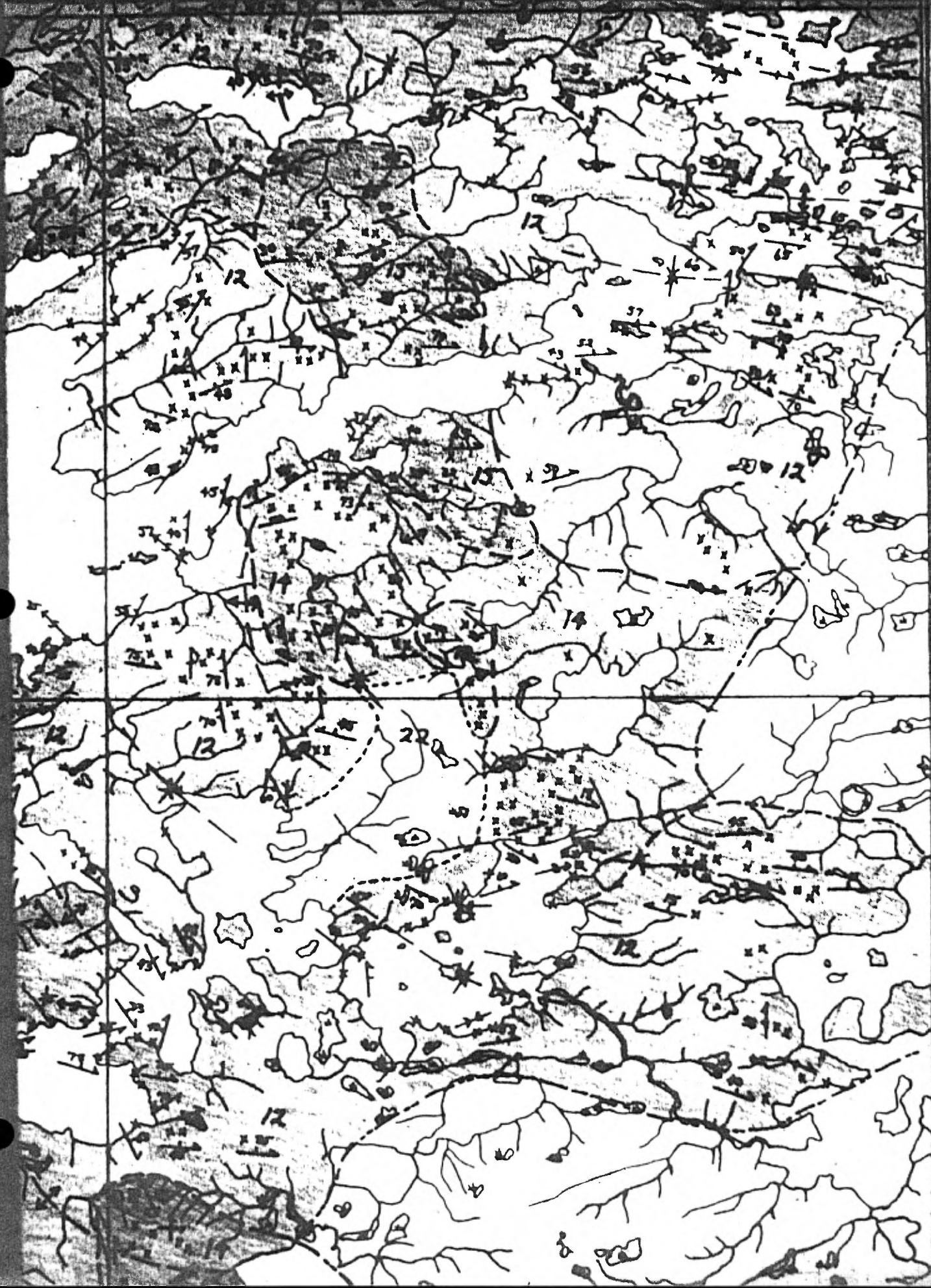
MAP SYMBOLS

53°20'

53°15'







MAP SYMBOLS

 : Approximate rock unit boundary

 : Limits of mapped area

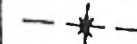
 : Regolith areas

 : Gradational boundary

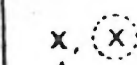
 : Possible bedrock fracture zone

 : Synform, overturned

 : Antiform axis area

 : Synform axis area

 : Glacial striae

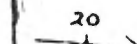
 : Bedrock exposure areas

 : Swamp or bog

 : Slickensiding

 : Dragfold axis, plunge of lineation

 : Foliation, dip unknown

 : Foliation, inclined

 : Foliation, vertical

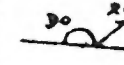
 : Foliation inclined, plunge on foliation plane

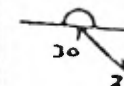
 : Jointing, inclined

 : Jointing, vertical

 : Pillowed lavas, trend inclined

 : Pillowed lavas, trend vertical

 : Pillowed lavas, tops unknown and elongation plunge

 : Pillowed lavas overturned, plunge of elongation

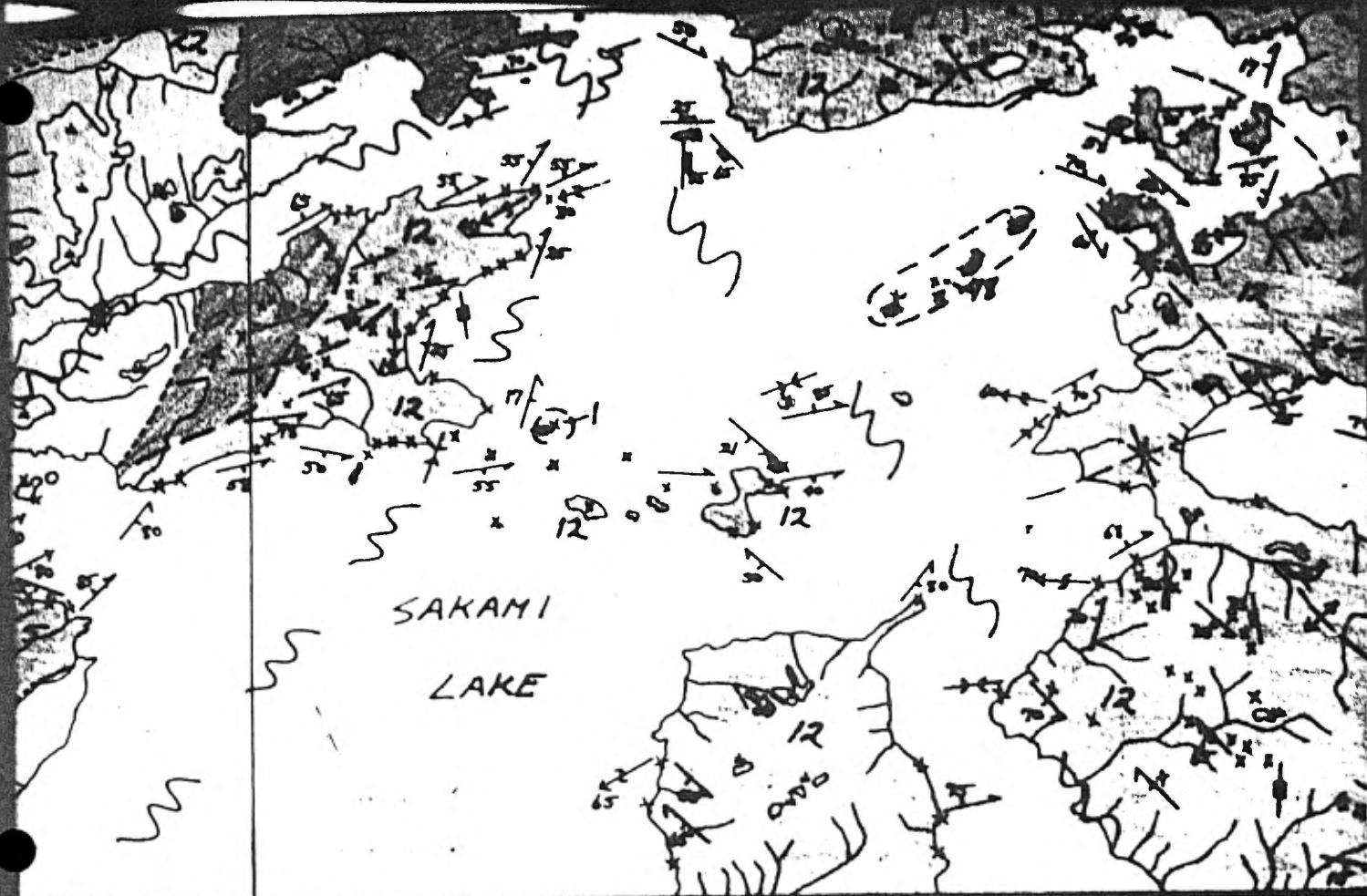
 : Mineralization

 : Magnetic iron formation

 : Diabase

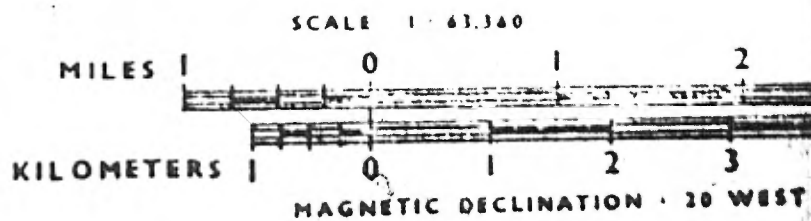


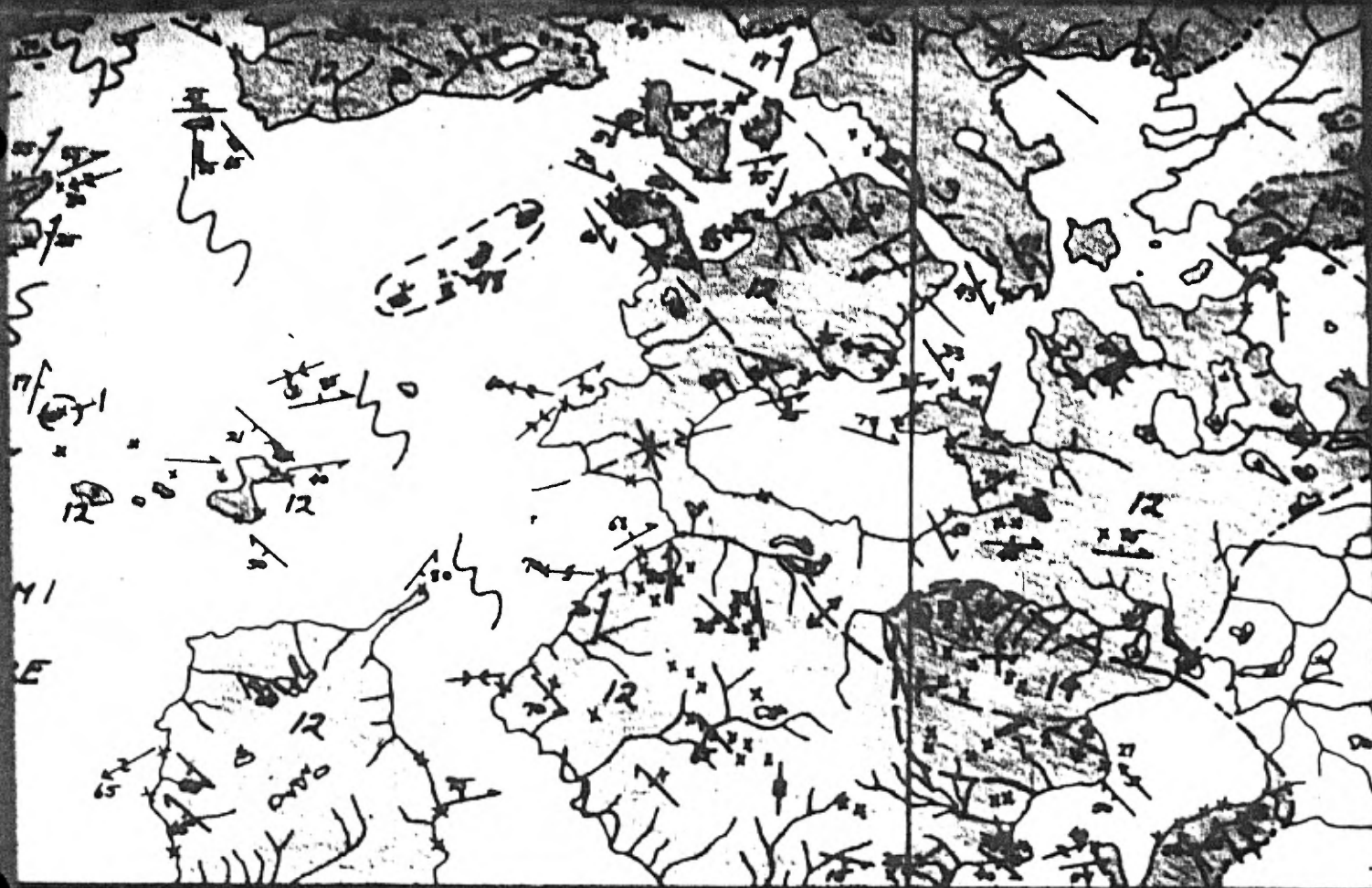
BASE MAP CARTOGRAPHY PREPARED BY
THE QUEBEC DEPARTMENT OF NATURAL
RESOURCES FROM AERIAL PHOTOGRAPHS
TAKEN IN 1959-60



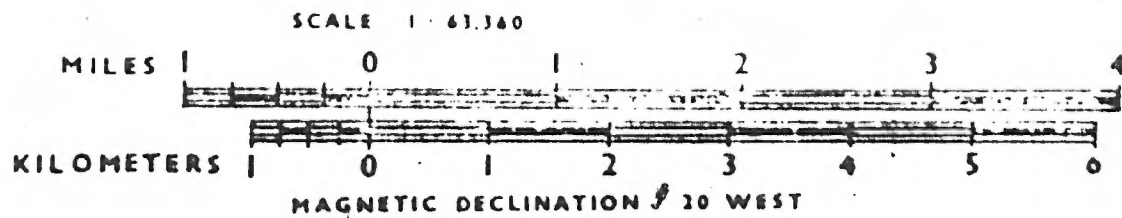
76°50'

GEOLOGY SAKAMI LAKE AREA NORTHWESTERN QUEBEC CANADA





GEOLOGY SAKAMI LAKE AREA NORTHWESTERN QUEBEC CANADA

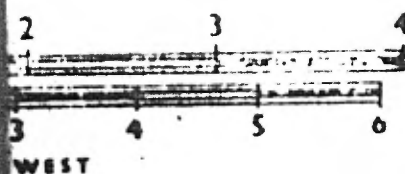
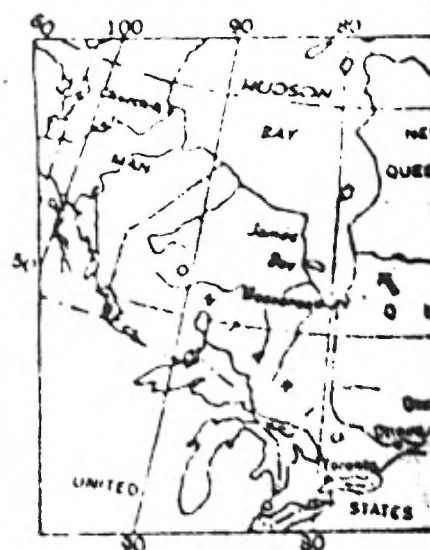




76°40'

76°30'

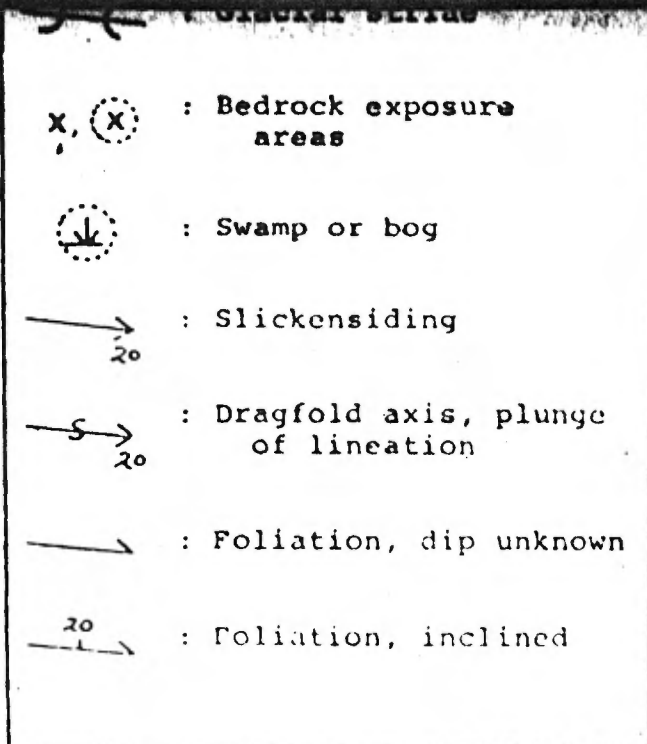
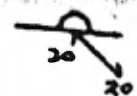
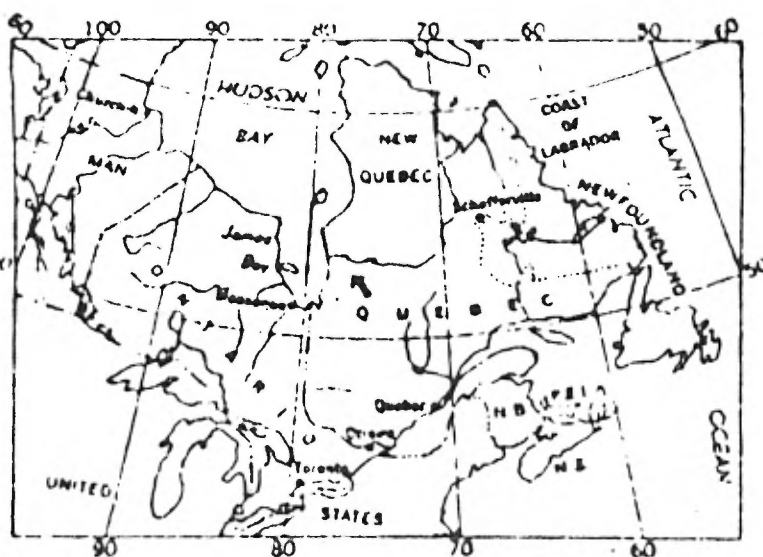
NADA



INDEX



53°10'
78°30'



INDEX MAP

x, (x)

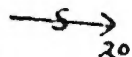
1. Bedrock exposure areas



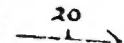
: Swamp or bog



1. Slickensiding

: Dragfold axis, plunge
of lineation

: Foliation, dip unknown



: Foliation, inclined



turned, plunge of
elongation



: Mineralization



: Magnetic iron
formation



: Diabase .

