

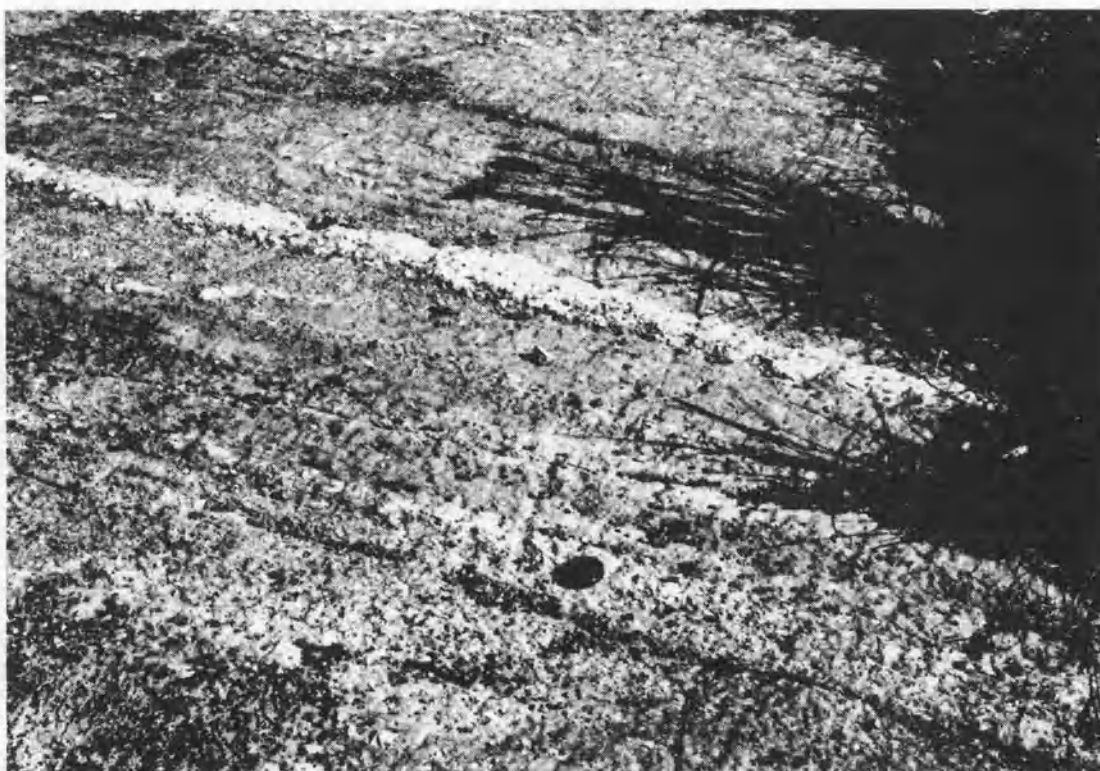
Twenty Third Annual Meeting

Thunder Bay, Ontario

Institute on Lake



Superior Geology



MATTABI TRIP

Archean Metallogeny and Stratigraphy

of the

South Sturgeon Lake Area

by

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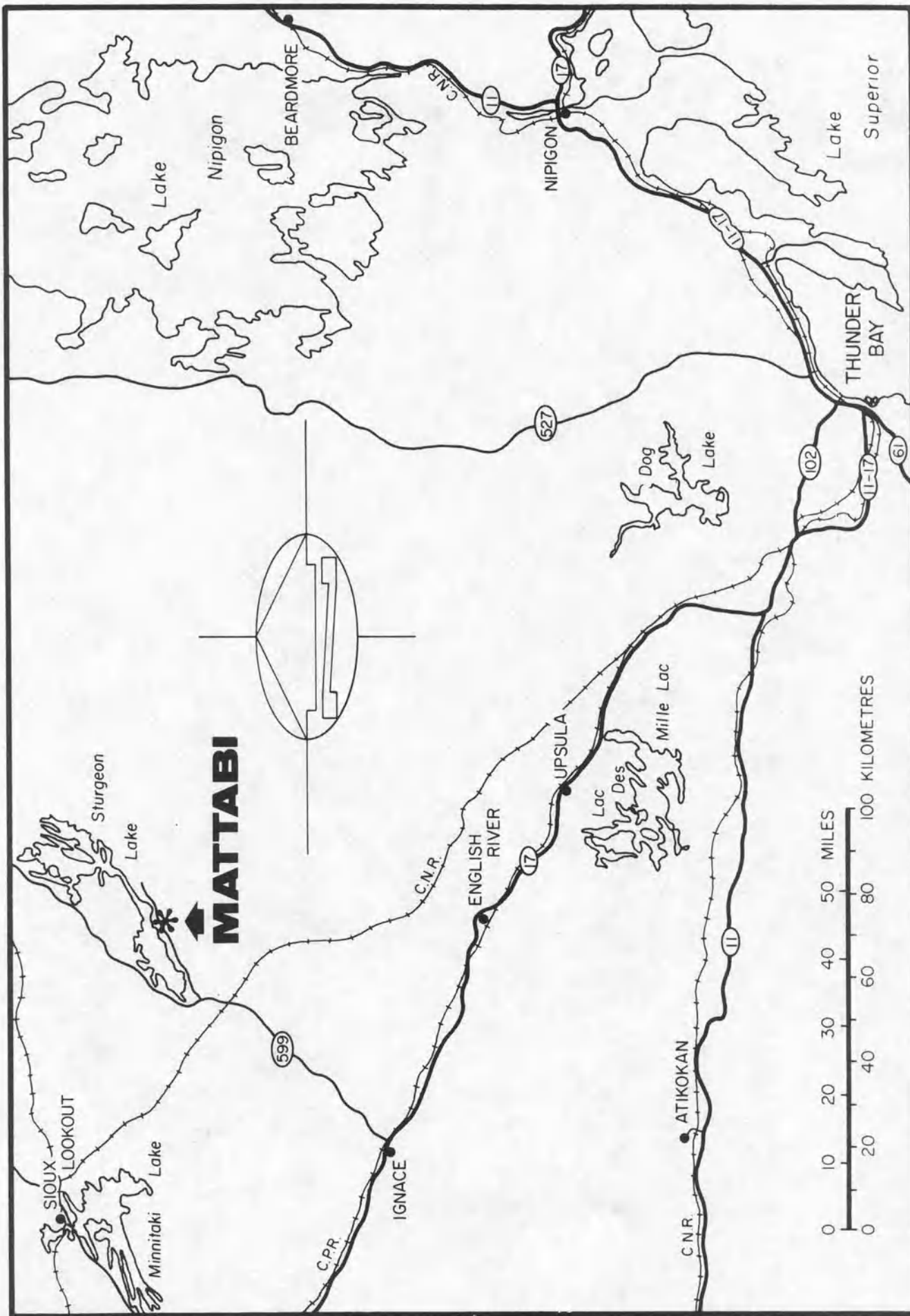
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Cover Photo: Lapilli Tuff Unit

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Archean Metallogeny and Stratigraphy of the South Sturgeon Lake Area

Introduction

Exploration in the Sturgeon Lake area started in 1898, but the only economically significant deposits developed before 1969 were the Darkwater Gold Mine (1935-37) and the St. Anthony's Gold Mine. In 1969 discovery of a massive sulphide orebody by Mattagami Lake Mines Ltd. sparked an exploration rush. Mattabi Mines Ltd. was incorporated in 1970 to develop and mine this orebody, on Abitibi Paper Co. Ltd.'s Block 7 land tract. Mattabi is owned 60% by Mattagami Lake Mines Ltd., and 40% by Abitibi Paper Co.

The Mattabi deposit was first located by ground geophysical followup to an anomaly indicated on an airborne Input Survey. Subsequent diamond drilling outlined a massive sulphide deposit with a length of 1800 feet and a maximum width of 300 feet. The deposit has a distinctive EM and magnetic anomaly. The pre-production ore reserves were 13,665,800 tons with an average grade of 7.5% zinc, 0.8% copper, 0.77% lead and 3.10 oz./ton silver. Since 1972 the deposit has been mined from an open pit. Underground development work began in 1975.

In 1970, Falconbridge Nickel Mines Ltd., testing an induced polarization anomaly, discovered a massive sulphide orebody on claims optioned from New Brunswick Uranium Metals and Mining Ltd. Sturgeon Lake Mines Ltd. is a joint venture company involving Falconbridge Copper Ltd., N.B.U. Mines Ltd. and Sturgeon Lake Mines Ltd.

Pre-production ore reserves were 2,110,584 tons grading 2.98% Cu, 10.64% Zn, 1.47% Pb, 6.14 oz/ton Ag and 0.021 oz/ton Au.

The mine (open pit) started production in March, 1974 and production was stockpiled near the crusher until milling commenced in September 1974. The mill is currently operating at a rate of 1200 tons per day. During 1971 and 1972, the Lyon Lake and Creek Zone deposits, containing 4,029,500 tons of ore with grade 6.66% zinc, 1.15% copper, 0.63% lead, and 3.30% per ton of silver, were discovered. These deposits have a poor geophysical expression, and were located by drilling after determining regional stratigraphic controls.

PREVIOUS GEOLOGICAL WORK

The most recent mapping is by N.F. Trowell (1970, 1972, 1974a, 1974b, 1974c) who has comprehensively studied the Sturgeon Lake area. In addition to his excellent maps and reports he has recently undertaken a synoptic study of the entire region (1976).

Earlier mapping by Rodgers (1964) Tanton (1940 and Horwood (1937b) provided a general geologic framework.

Unpublished theses completed in the area include Beggs (1975), Covello (1971), Friske (1974), Gordanier (1975), Hiscott (1974), Kasarda (1973) and Nielsen (1974). In addition, Shegelski (1975, 1976) has undertaken a study of the sedimentary rocks, including iron formation, of the Sturgeon-Savant Lakes region.

REGIONAL GEOLOGY

The Sturgeon Lake-Savant Lake region (Figure 1) is composed of Archean volcanic and minor sedimentary strata which are deformed about two sets of fold axes (Figure 2). The synclines are relatively tight, whereas the anticlines are broad. The two fold sets were probably developed during the Kenoran orogeny, due to the emplacement of large granitoid

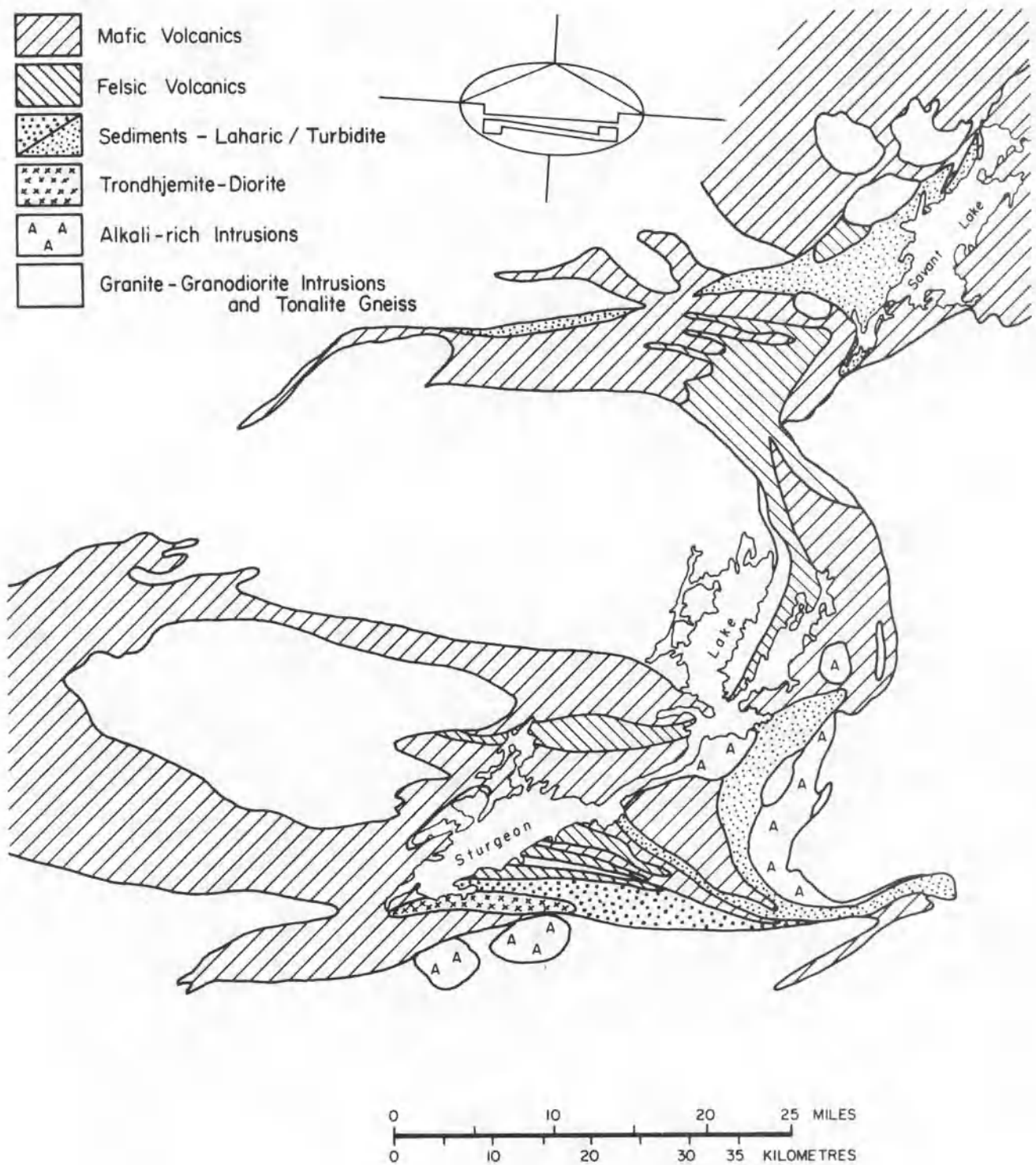


Fig.1. Geology of the Sturgeon-Savant Lakes Area.
(after Trowell 1970, 1972, a, b, 1974, 1975)

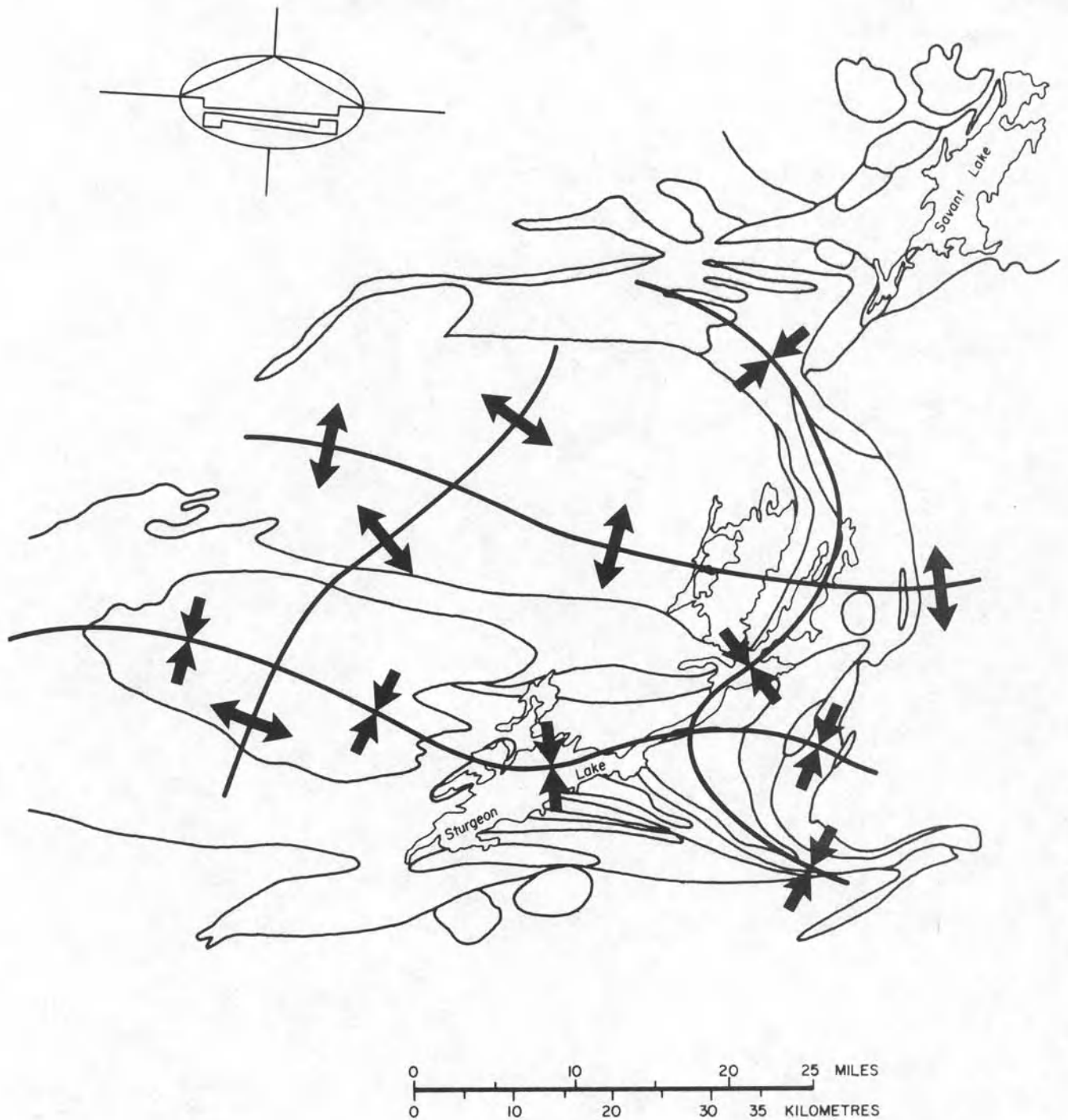


Fig.2. Major Axial Traces of Folds, Sturgeon-Savant Lakes Area.

diapirs or domes which bound the supracrustal rocks.

In the Sturgeon Lake area (south half of Figures 1 and 2), the supracrustal rocks may be divided into two domains. The northern domain of predominantly basaltic rocks contains less than 5% felsic strata, and which is approximately 45,000 feet thick. The southern domain includes approximately 30,000 feet of approximately equal amounts of felsic and mafic volcanic strata, and approximately 15% sedimentary rocks.

The southern domain contains the massive sulphide deposits to be visited during the trip, and is described in detail below.

SOUTH STURGEON LAKE GEOLOGY

This volcanic edifice is a north facing sequence with a generally steep northerly dip which forms the southern limb of a syncline with a shallow easterly plunge (Figure 2). The strata are not tightly folded locally and major faulting is absent.

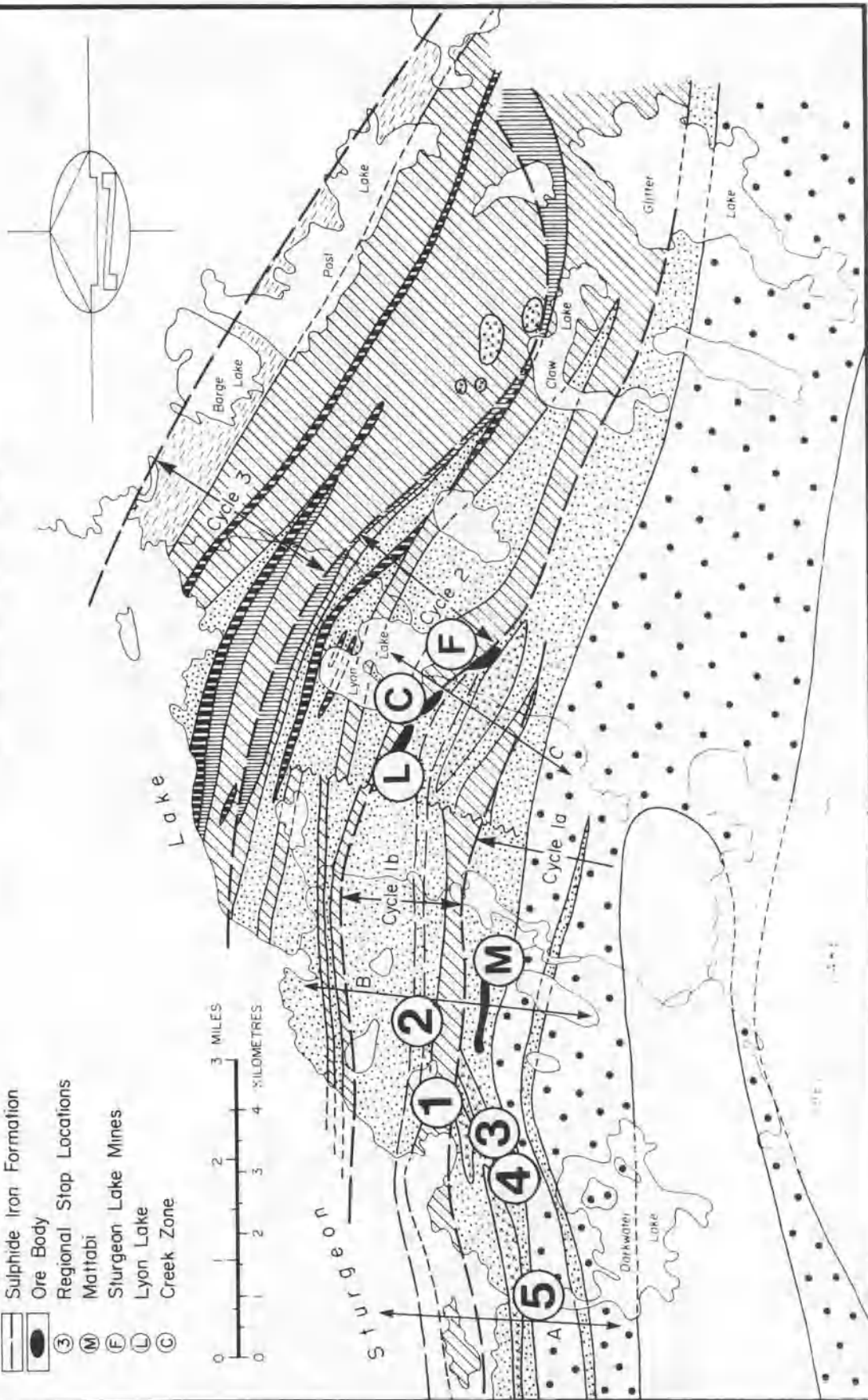
The strata are divided into three cycles. Each cycle represents a major period of volcanism, normally with a mafic base and felsic top. These cycles are separated by either a disconformity or a sedimentary unit, indicating a distinct break in volcanism.

The lowermost cycle (1) may conveniently be divided into lower and upper members (A and B). The lower member contains the Mattabi deposit, the upper member the Lyon Lake and Falconbridge deposits.

PETROLOGY AND CHEMISTRY

A mafic unit, only a few hundred feet thick forms the base of the pile (Figure 1). This unit thickens westward, and southwest of Sturgeon Lake, is composed of pillowed and massive basaltic and

Fig. 3.
GEOLOGY OF THE
SOUTHERN STURGEON LAKE
VOLCANIC BELT



andesitic flows, of low-K tholeiite affinity. The upper part of this unit (Hiscott, 1974) is more andesitic.

Above the thin easterly edge of this mafic base, a major unit of epiclastic breccia (indicated as sediment on Figure 1, and lapilli tuff on Figure 3) the "footwall lapilli tuff" member, is laterally extensive and at the eastern edge of the pile rests directly on possible basement. This member is overlain by volcanic strata which contain the Mattabi deposit.

The composition of the volcanic rocks is distinctly bimodal (Figure 4). Contoured variation diagrams, as described by Ridler (1973) further illustrate this bimodality (Figure 5). The two groups are (a) a mafic to intermediate group, with SiO_2 ranging from 45% to 64%, and (b) a felsic group with SiO_2 ranging from 68% to 79%. This distinct bimodality is further illustrated by various major elements (Figure 6) and 'fractionation' indexes, such as the Rittman and Larsen indexes (Figure 7).

Within each group, the elements appear to be distributed as a continuum. Data for the "mafic" group extends over a relatively wide range (e.g. CaO, Figure 6a, ranges from 3 to 12%, SiO_2 from 45 to 63%), which may be the result of either fractionation or contamination of a basaltic magma. Chemical variation within the felsic group is more limited, possibly indicating a more limited degree of fractionation or contamination.

Classification of the volcanic rocks into 'series' and lithotype is possible by examining plots of both major and minor elements, as well as by more sophisticated discriminant function analysis (Pearce 1976)

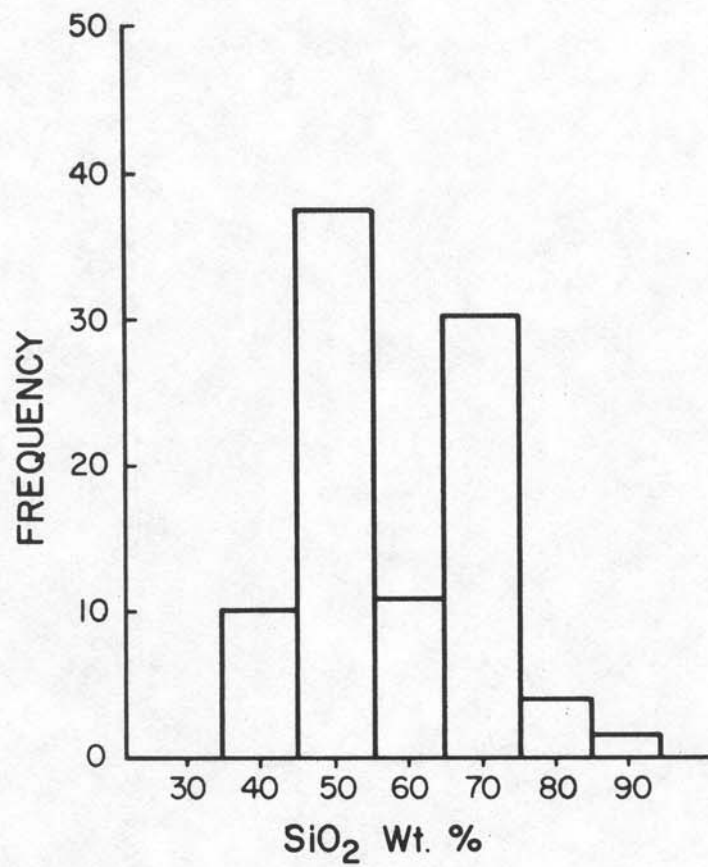


Fig.4. Frequency distribution of SiO₂, South Sturgeon Lake Volcanic Rocks.

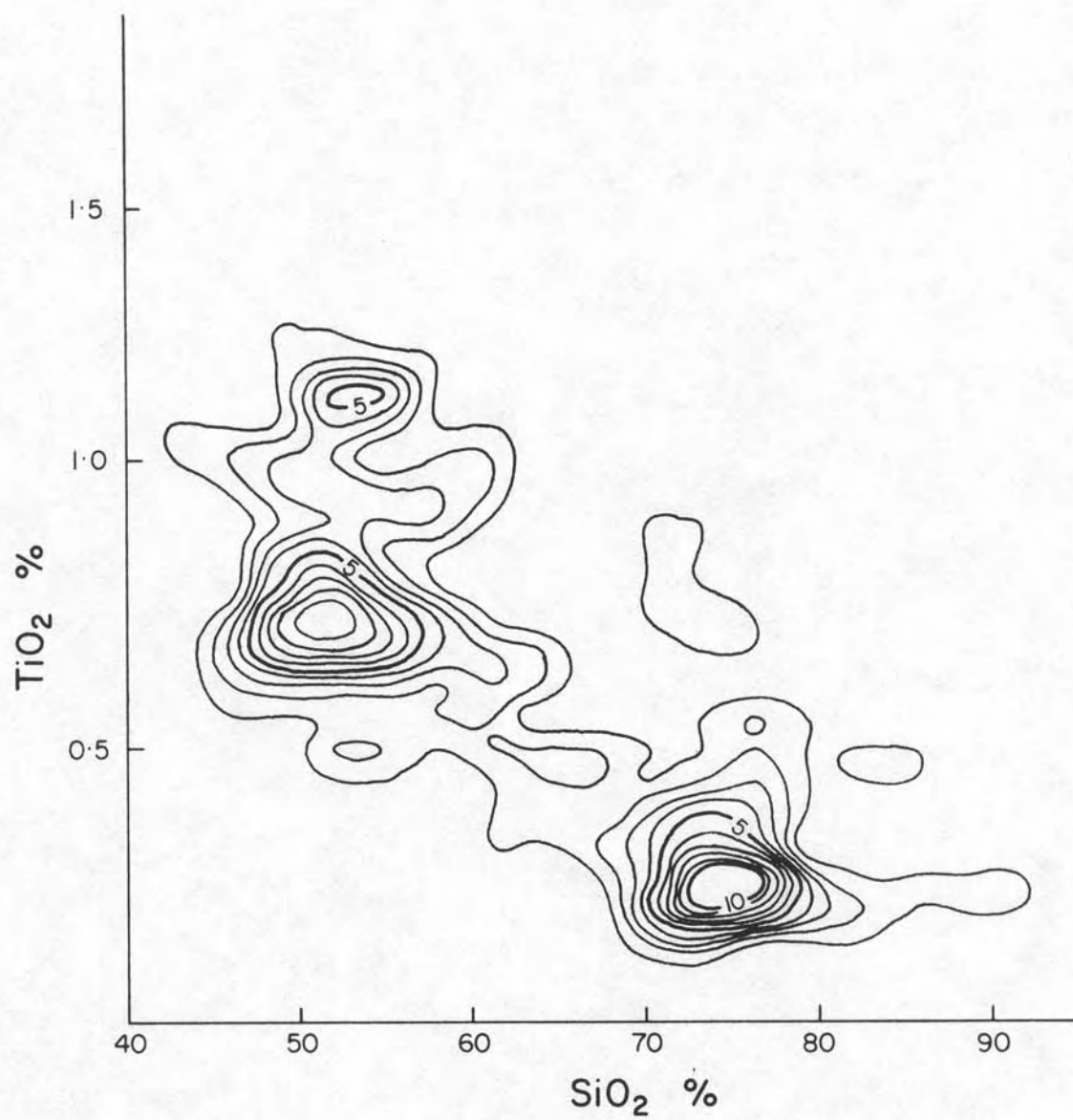
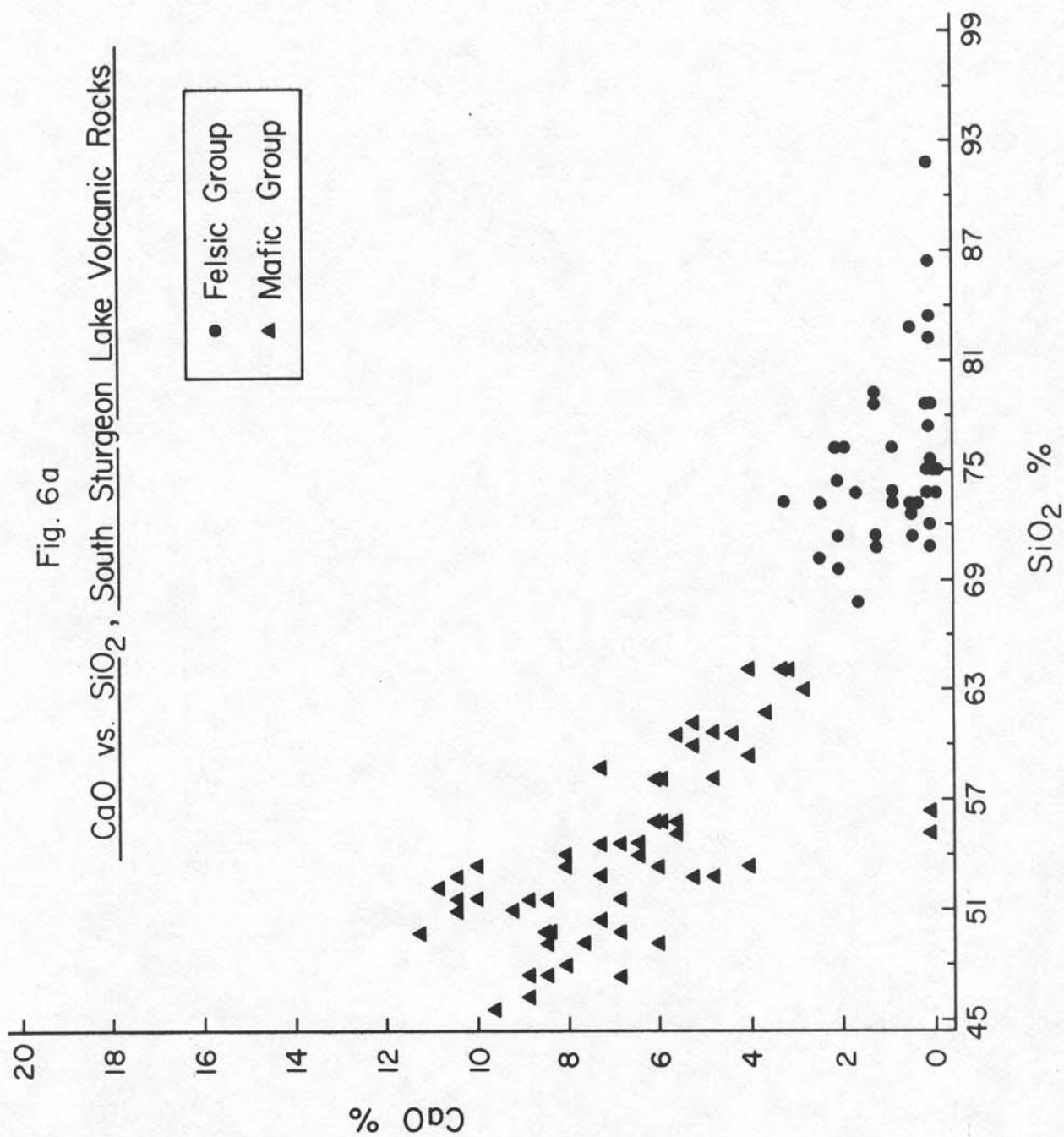
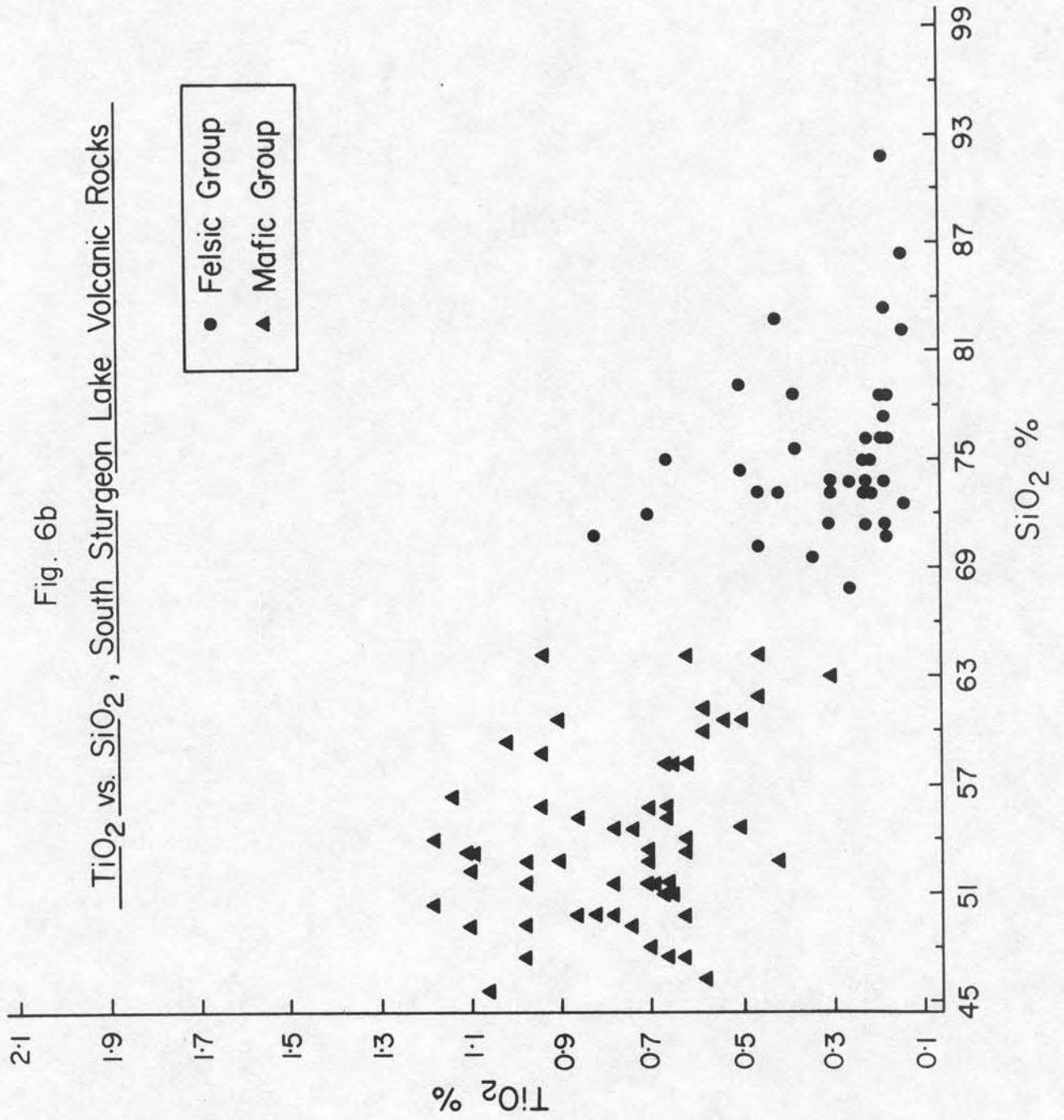
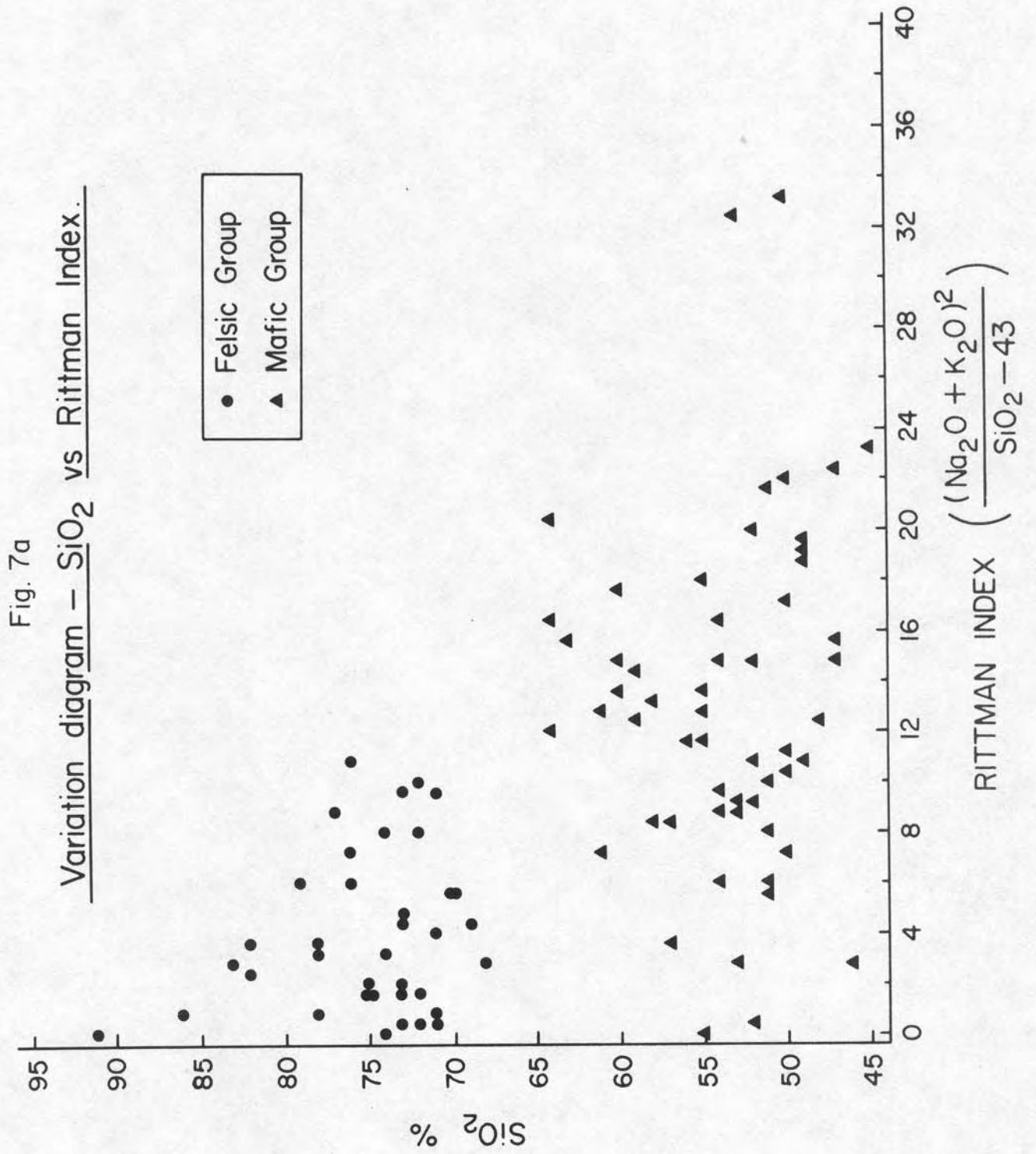
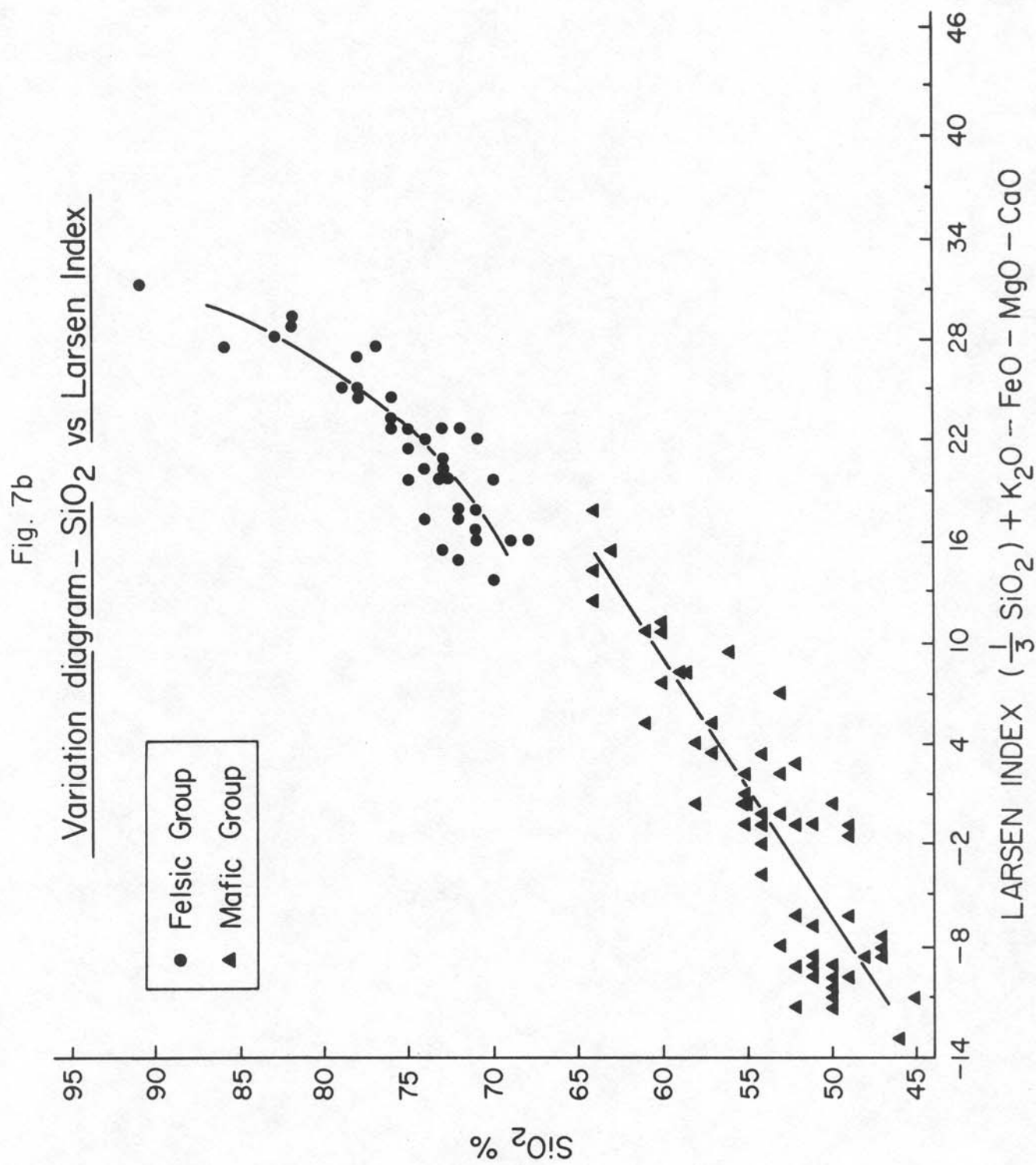


Fig. 5. Contoured variation diagram, TiO_2 vs SiO_2 , illustrating strong chemical bimodality.









and normative-based calculations (Irvine & Baragar 1971).

Taylor (1969) uses K_2O vs SiO_2 to assign series and lithotypes. Although K_2O is commonly added during submarine weathering (Pearce, 1976) and SiO_2 subtracted, thus reducing the reliability of Taylor's method, application of his method does produce results which may be usefully compared to other discrimination methods.

In cycle 1, 55% of the rocks belong to the tholeiitic group, 45% to the calc-alkaline group (Figure 8). Rocks within the felsic subgroup of this cycle show a distinct change upwards through the cycle, moving from 63% tholeiitic in cycle 1A to 60% calc-alkaline in cycle 1B.

Cycle 2 mafic rocks are 50% calc-alkaline, 50% tholeiitic. Cycle 2 felsic rocks are 93% calc-alkaline, 7% tholeiitic. Cycle 3 mafic rocks are 80% tholeiitic.

The distribution of data in Figure 8 illustrates the compositional bimodality, with a paucity of dacite. The mafic group contains 37% basalt, 35% basaltic andesite and 28% andesite. The volume of basaltic andesite and andesite increases with stratigraphic height, possibly as a result of fractionation. Over 64% of the rhyolite in cycle 1A is of the low-K variety, whereas virtually all of the rhyolite of cycle 1B is of 'normal' composition. Cycle 2 mafic rocks are dominantly andesitic, and its felsic rocks are more K-rich rhyolites. Cycle 3 mafic rocks are basaltic andesites.

Thus either fractionation or contamination has affected in parallel both rhyolite and basalt-andesite magmas of cycles 1 through 2. Cycle 3 appears to represent a return to more primitive composition, but its felsic component is too inadequately represented to draw further conclusions.

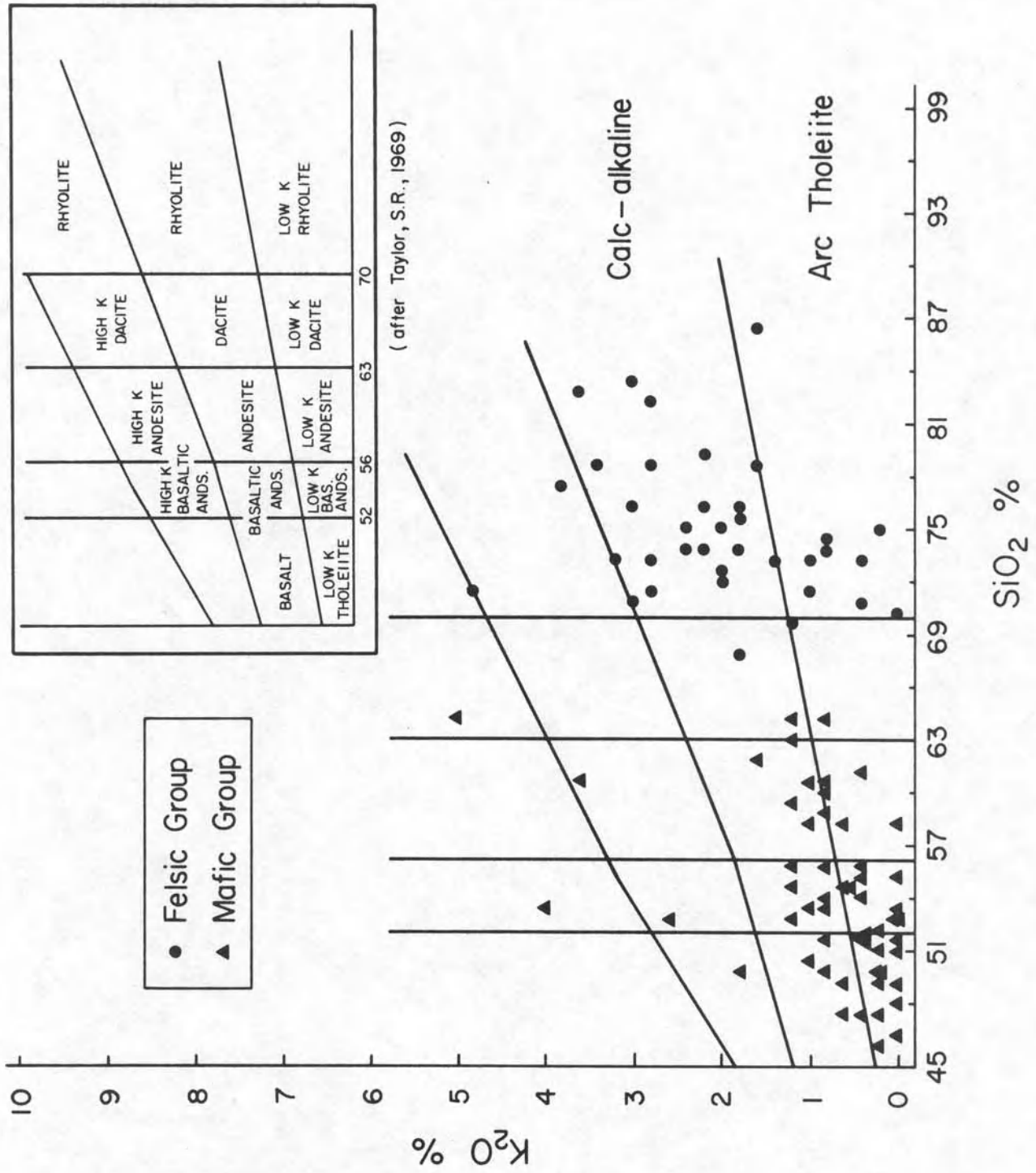


Fig.8. K_2O vs. SiO_2 , with classification fields (after Taylor, S.R., 1969).

An additional method of series classification proposed by Pearce and Cann (1973) and reviewed by Smith and Smith (1976) uses the distribution of relatively immobile elements Y, Zr, Ti and more mobile Sr in basaltic rocks. Only the mafic rocks of cycle 1B and higher have been analyzed (Figure 9) and the data indicate that according to this system, classification cycle 1B is 65% calc-alkaline, and 35% ocean floor basalt, whereas cycle 2 is over 90% calc-alkaline. Cycle 3 is 50% calc-alkaline, marking a return to more "primitive" mafic compositions. This data thus generally corresponds to the SiO_2 - K_2O data.

In summary, rocks of the "mafic" and "felsic" groups are probably derived from separate melts, and each group has progressive fractionation or contamination with stratigraphic height through two-thirds of the pile. The upper cycle appears to have a more primitive composition, not related to these lower cycles.

Several stratigraphic members have important distinguishing chemical and petrographic features, discussed individually below. Stratigraphic sections, from west to east, which illustrate in some detail the lithology and chemistry of the pile are shown in Figure 10. TiO_2 and Larsen index are chosen to represent the chemical variation. The former is immobile and generally accepted as a reasonably good 'discriminator' of rock types, and the latter accounts for most of the 'fractionated' elements, and is a useful petrochemical index. The relationship of the latter index to SiO_2 is shown in Figure 7.

Although many of the litho-stratigraphic members shown in the sections (Figure 10) are laterally extensive, 'facies' changes or pinch-outs necessitate treating each area separately. Attention will be

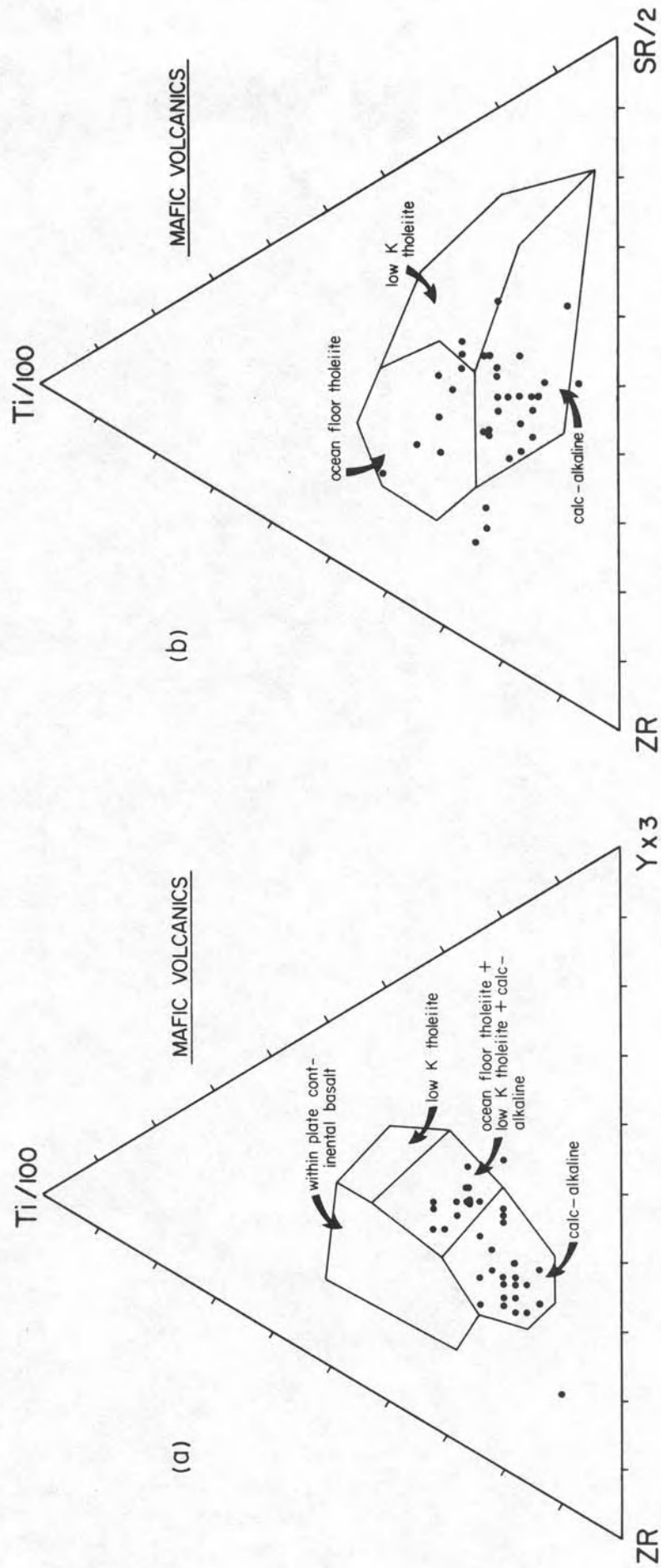


Fig. 9. Ti-Zr-Y-Sr Diagrams With Classification Fields (after Pearce and Cann, 1973).

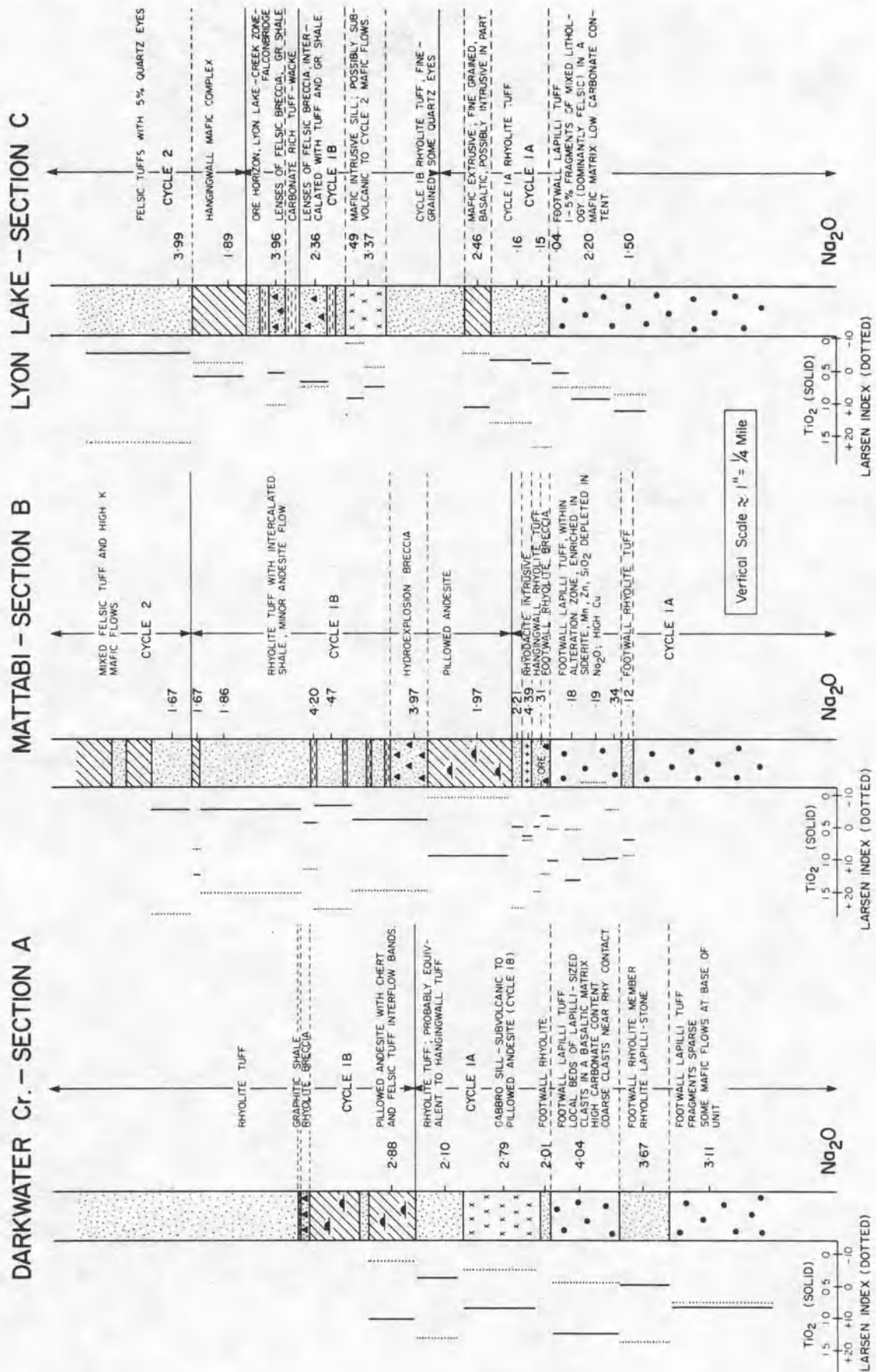


Fig. 10. Stratigraphic sections (see fig. 3 for location of sections).

drawn principally to the Mattabi area (section 2, Figure 10) with more abbreviated notes on the adjoining areas.

(A) Mattabi-F-zone area (Figure 10, sections A and B).

1) Footwall Lapilli Tuff (cycle 1A):

This unit is laterally the most extensive within the South Sturgeon Lake edifice and forms the base, over 3000 feet thick (Figure 3). It consists of up to 50% (commonly 3 to 5%) subangular felsic lapilli (0.8 to 3 cm in diameter) distributed through and supported by a mafic matrix. Bedding is evident only near the top of the unit. Extensive chemical and petrographic data (Franklin 1976) indicate that the unit is composed of submarine laharic breccia, derived through submarine erosion of an adjacent mafic pile. A thin but laterally extensive rhyolite tuff bed occurs approximately 1000 feet below the top. This felsic component may have been derived from either more local felsic volcanic activity, or as transported clasts from an adjacent pile.

The chemical composition of the unit is highly variable, dependent on clast frequency. The rock is typically andesitic (Table 1), marked by high carbonate and TiO_2 contents. Concentrations of the latter element are higher than in any rock found within the South Sturgeon pile, suggesting either derivation from a more primitive ocean floor tholeiite source, or less likely, unusual mechanical concentration of Ti-bearing minerals. The carbonate may represent a very early precipitate, either as a diagenetic or syngenetic product. It probably predates the formation of the Mattabi deposit (Franklin et al. 1975).

TABEL 1

Composition of rocks in cycles 1 and 2, South Sturgeon Lake

	Lapilli mafic portion FRSL 2	Cycle 1a rhyolite FRSL 29	Cycle 1b andesite FRSL 57	Cycle 1b rhyolite F71-43	Cycle 2 rhyolite FRSL 68	Intrusion sill FRSL 35	Cycle 2 andesite FRSL 77	Mattabi Rhyodacite Sill AT 59
SiO ₂	51.90	74.18	51.80	79.36	76.18	47.37	52.78	57.90
Al ₂ O ₃	13.53	13.66	12.30	12.68	12.86	15.36	14.79	14.78
TiO ₂	1.15	0.52	0.99	.51	.23	.85	1.02	0.65
Fe ₂ O ₃ (T)	9.50	2.42	13.17	1.59	1.70	10.20	9.23	9.24
MgO	4.26	1.08	5.33	.90	1.72	4.37	4.00	3.23
MnO	.13	0.03	0.16	.05	.02	.14	.12	0.12
CaO	6.67	2.34	8.56	1.45	.87	8.11	5.15	5.05
K ₂ O	.79	1.00	.10	2.39	3.04	.57	2.75	0.63
Na ₂ O	1.77	2.08	2.88	2.21	1.46	2.79	1.60	1.71
P ₂ O ₅	n.d.	n.d.	0.11	.12	.03	n.d.	.20	0.18
Co ₂	9.00	0.81	0.70	1.06	1.76	6.55	8.65	4.06
H ₂ O (T)	2.15	1.16	2.88	1.26	.81	3.49	2.07	2.82
Total	100.55	99.28	98.97	103.58	100.68	99.80	102.36	100.37

2) Mine rhyolite horizon (cycle 1A): This horizon consists of two rhyolitic units, each texturally distinctive, the hanging wall rhyolite tuff and the footwall rhyolite agglomerate.

The footwall rhyolite unit has a maximum thickness of approximately 200 feet, and immediately below the Mattabi deposit is composed of tightly packed rhyolite agglomerate bombs with approximately 10% rhyolitic tuff matrix. The fragments and matrix are compositionally similar, and thus difficult to separate in outcrop. Away from the deposit, the number of agglomerate fragments diminishes, and westward along the ore horizon, sulphide-bearing fragments are common. Within the Mattabi Mine, a thin unit divides the upper and lower orebodies. It ranges to 10 feet in thickness and is composed of discontinuous chert lenses, geometrically similar to those described above, and of rhyolite tuff. Quartz eyes are sparsely distributed through the unit. This band represents a short resumption of volcanic activity and may be a final representation of the event which produced the footwall rhyolite agglomerate.

The upper 150 feet of this horizon forms the hanging wall to the deposit. It is composed of minor rhyolite agglomerate, more prevalent massive rhyolite tuff, and near the ore deposit, some chert bands. Quartz phenocrysts are rare in this unit and in general it is petrographically similar to the underlying rhyolite agglomerate.

A representative analysis of the mine rhyolitic rocks (Table 1) illustrates the generally low-K characteristic.

3) Cycle 1B Mafic unit

The andesite unit which overlies the hanging wall rhyolite is approximately 2000 feet thick, and contains pillowed, brecciated, and massive units. Thin chert and graphitic shale members are intercalated with the flows. The lower 1000 feet includes feldspar porphyry flows and feldspar crystal tuff members; these are typically biotite-rich with the assemblage albite-biotite-(chlorite)-quartz-dolomite dominating. Near the base, rhyolite tuff beds are intercalated with mafic tuff and flow units.

Upper members of the unit are ophitic-textured medium-grained flows, with albite-epidote-chlorite-dolomite as the dominant mineral assemblage. Remnant, partially chloritized amphibole phenocrysts are common in some upper flows. Feldspar is typically saussuritized. Dolomite ranges from 3 to 10 per cent throughout the unit.

4) Cycle 1B Felsic rocks

Two members comprise this unit above the Mattabi deposit.

(a) Breccia member: This is approximately 500 feet thick, and is composed of highly angular blocks of rhyolite, ranging to 75 cm. in diameter, with less than 10% aquagene tuff matrix. Some fragments may be pumiceous. Fragments of such extreme angularity and large size are obviously derived from a proximal felsic volcanic centre, and are probably the product of steam explosion. Some of the fragments are composite, indicating that initial brecciation occurred before total solidification of the magma; the solidified product eventually underwent further brecciation (probably by explosion) and the fragments were transported ballistically, to form a rubble bed.

From examination of drill core, this unit appears to be crudely bedded, and several episodes of explosive volcanism were followed by settling of coarse to fine fragments.

(b) Rhyolite tuffs: The breccia unit is overlain by fine massive rhyolite tuff. Unfortunately this unit is poorly exposed, but in drill core is a poorly bedded, probably submarine ash flow sequence. At least four distinct, laterally extensive graphitic shale beds occur in the lower 1600 feet.

These tuffs are chemically very similar to the underlying rhyolite breccia. Both units are slightly more potassic than the rhyolite of unit 1A.

Thin sections reveal that the rocks are locally quartz-porphyritic, fine grained, and fiammé-like tuff fragments are locally distinct.

5) Intrusive Rocks: In addition to the felsic Beidleman Bay complex (described below), two intrusive bodies are prominent. The largest, a mafic dyke-sill complex, transects the footwall strata approximately 2000 feet west of Mattabi, and forms a sill within the hanging wall rhyolite (cycle 1A) to the west of the dyke (Figure 3). This dyke extends up to, but does not cross-cut, the prominent pillowed andesite unit at the base of cycle 1B. The dyke and sill are chemically similar to these flows (Table 1) and probably represent a subvolcanic feeder system. This section is composed of gabbro, and has high magnetic relief.

The second intrusive body is an intermediate-composition dyke-sill complex. The dyke cuts the eastern end of the Mattabi orebody, and forms a sill in the hanging wall rhyolite (cycle 1A), approximately 10 metres above the ore (Figure 15). This rock is porphyritic, not highly

sheared, easily distinguished by its homogeneous character, tan colour and evenly distributed elongate chlorite grains. It contains approximately 20% dolomite, and is andesitic to dacitic (or rhyodacitic) in composition (Table 1).

(B) Lyon Lake area

The Lyon Lake deposits occur at the top of cycle 1B. In addition to local lithologic changes, some units, notably the major pillowed andesite at the base of cycle 1B, pinch out to the west of the Lyon Lake area. The major differences in the litho-stratigraphy are as follows:

(1) Footwall Lapilli tuff: This unit continues to form the base of the sequence in this area, and has a more mixed fragment lithology. Fragments constitute less than 10% of the rock, and include a mixture of mafic and felsic volcanic-derived clasts.

(2) Rhyolite (cycles 1 & 2).

Due to the absence of the pillowed andesite, accurate stratigraphic positioning is difficult in this unit. Rhyolite of the lower half is similar to the mine-area rhyolite (i.e. low K, fine grained, tuffaceous). The distinctive graphitic shale beds noted above Mattabi terminate below the Lyon Lake deposits, possibly cut off by an unconformity. Rocks above these beds form a dome several thousand feet in diameter, and include several distinct lenses of rhyolite breccia, and a tuff bed with abundant dolomite and pyrrhotite. Thin, discontinuous graphitic shale lenses are intercalated with both the carbonate-rich tuff and the breccia zones. The abundance of breccia within the Lyon Lake dome probably indicates the presence of a local volcanic centre.

The rhyolite unit at the Lyon Lake and Creek Zone deposits is capped by a thin massive lens of tuff-wacke, probably derived by fragmentation of adjacent felsic volcanic rocks. This lens pinches out before reaching the more easterly Falconbridge deposit.

(3) Intrusive rocks: A large lensoid body of fine to medium grained gabbro lies within the footwall rhyolite below the Falconbridge-Lyon Lake deposits. This rock has the chemical composition of gabbro (basaltic andesite), similar to those hanging wall mafic volcanics which overlie the Falconbridge-Lyon Lake deposits and forms the base of cycle 2, and also has high magnetic relief. It is very similar to the dyke-sill complex west of Mattabi, and possibly is also a subvolcanic sill, representing part of the feeder system to the cycle 2 basal mafic unit.

(4) Cycle 2: The hanging wall of the deposits is a composite unit of flows and subvolcanic sills of basaltic andesite composition. Within the Lyon Lake-Falconbridge area, it lies with possible unconformity on the Cycle 1B rhyolite and tuff-wacke. It pinches out to the west of the Lyon Lake deposit.

STRUCTURE

The area has undergone pervasive, yet mild deformation. On a regional scale, the strata have undergone two ductile deformations. Initially they were folded about an east-west axis located near the north shore of Sturgeon Lake (Figure 2) which produced the steep northerly dips; a second phase of folding about a steeply plunging north-south axis was relatively gentle, producing a change in strike from 90° in the Mattabi-Beidelman Bay area to 120° to the west of Lyon & Swamp Lakes.

At Mattabi the entire north-facing sequence of volcanic rocks including the ore body dips to the north at 80° , and forms the southern limb of a major syncline. The rocks are pervasively foliated with more intense shearing near the orebody. Only the distinctly bedded footwall lapilli tuff affords an opportunity to examine bedding-cleavage relationships. Bedding immediately south of the ore body strikes at 285° to 290° , cleavage strikes 250° to 265° . Both bedding and cleavage dip steeply north. Lapilli fragments are rotated by the stress which produced the local shearing near the mine, but little stretching is evident. Minor folds are virtually absent in the mine area. Local faulting has displaced the western end of the orebody by 10 to 20 feet.

Deformation in the area of the Falconbridge Copper deposit is more intense than at Mattabi, as the footwall is highly foliated. The orebody is displaced by numerous minor faults (each with a few feet of displacement) that transect the strike of the strata and are at a high angle. In addition, thrustlike movement of the hanging wall basaltic andesite unit has caused intense deformation and possible folding of the upper part of the orebody.

The relatively gentle dip of the Falconbridge deposit is probably a product of the sulphides having been deposited on the flanks of a locally discordant felsic dome.

THE BEIDELMAN BAY INTRUSION

The Beidelman Bay intrusion (Figure 11) outcrops for a length of 12 miles and an average width of 1.5 miles, and has been mapped by Graham (1931), Rodgers (1964) and most recently by Trowell (1974a). A possible westerly extension of the intrusion has been mapped by Trowell (1970) in the Shanty Lake area, 4 miles west of Sturgeon Lake.



FIGURE 11a, GEOLOGY

Scale: 1" = 2 miles

(after Trowell, 1969 (O.D.M. 2268, 2269))

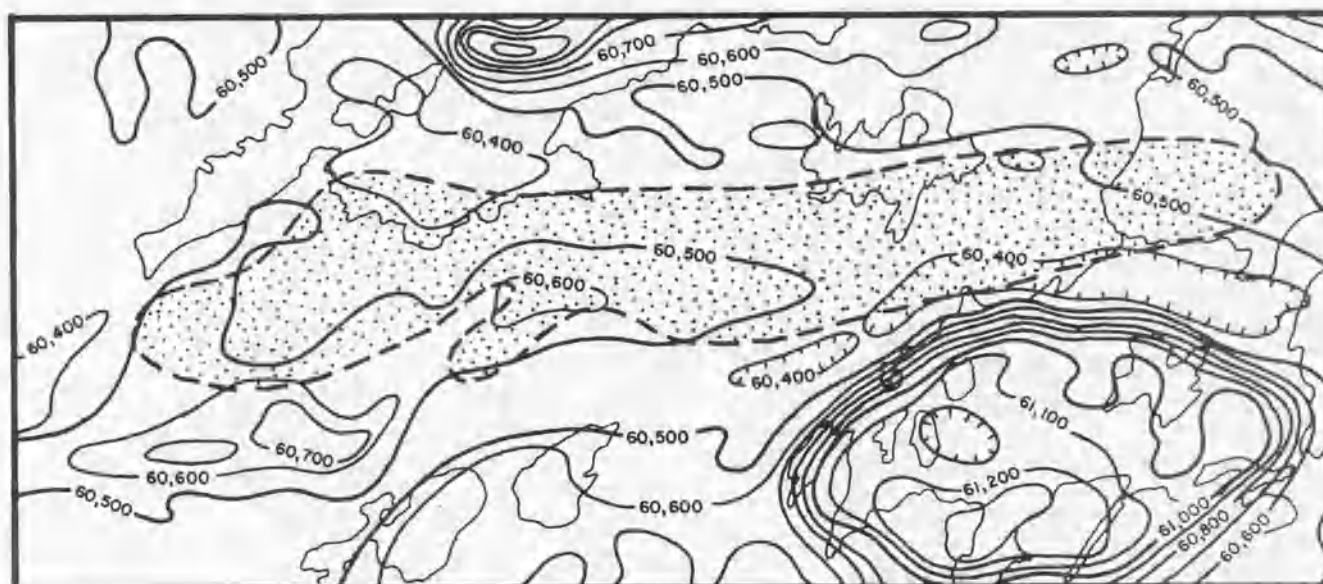


FIGURE 11b, AEROMAGNETIC

Contour Interval: 100 gammas

(after G.S.C. Aeromagnetic Maps 1117G & 1127G, 1961)

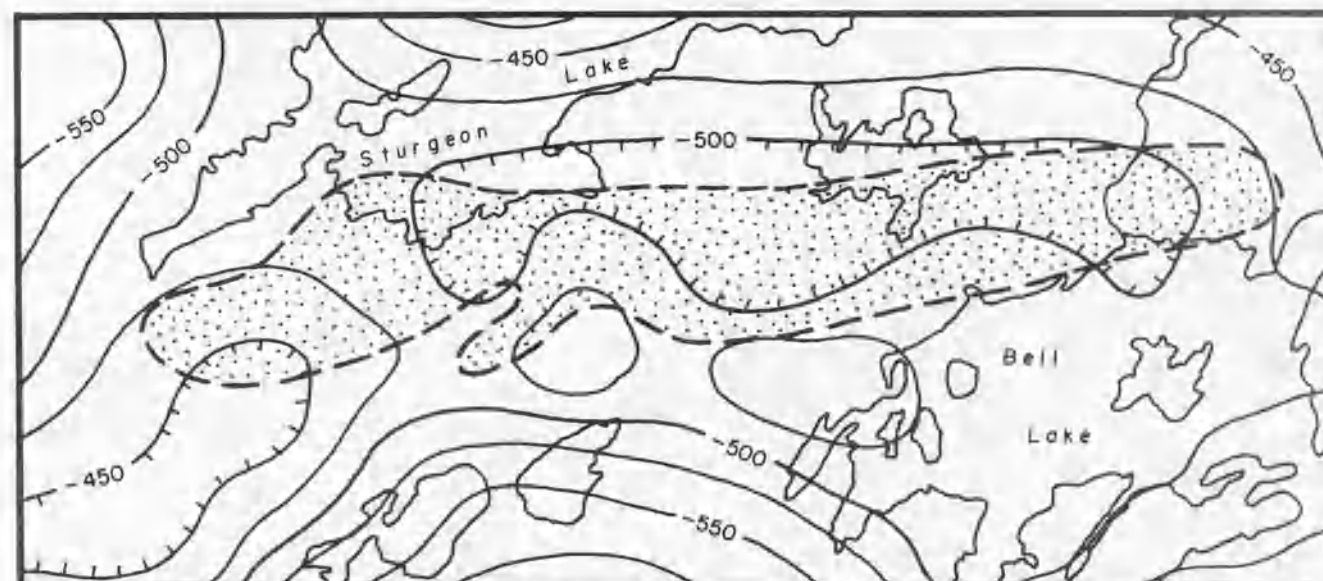


FIGURE 11c, GRAVITY

Contour Interval: 2.5 mg.

(after Barlow et al, 1975 (O.D.M. P1050))

The intrusion is composed of homogeneous trondhjemite with minor quartz diorite, feldspar porphyry and granodiorite. Since it is foliated in a manner similar to the adjacent volcanic rocks, the intrusion is considered to be part of relatively early igneous activity in the region.

GEOPHYSICAL EXPRESSION

The Beidelman Bay Intrusion is characterized by weak geophysical expression. The aeromagnetic response over the intrusion is reproduced in figure 11b. The lack of good magnetic delineation for the intrusion contrasts with the sharp anomalies attributed to the younger elliptical quartz monzonite stock to the south.

A regional gravity survey for the Sturgeon Lake area was completed in 1974 (Barlow, et al., 1975). A portion of the resulting Bouguer anomaly map is reproduced in figure 11c. A local gravity response coincides quite well with the boundaries of the intrusion. An interpretation of the regional aspects of the gravity data for the South Sturgeon Lake area (Dusanowskyj and West, 1976) produced a cross-sectional model of a roughly wedge-shaped volcanic belt of no greater than 4 km depth extent. Since the Beidelman Bay intrusion occurs near the flank of this wedge it is difficult to resolve the geometry of the intrusion from the granite-migmatite terrain to the south using the gravity data.

LITHOLOGY AND PETROCHEMISTRY

Nomenclature for the equigranular phases of the intrusion is consistent with that of Streckeisen (1973) and is useful for both macroscopic and microscopic classification, provided that alkali feldspar staining is used. The major equigranular lithologies are as follows:

(a) Trondhjemite: According to Streckeisen (1973), this is a leucocratic, equigranular medium grained rock rich in quartz and plagioclase. The modal quartz to quartz plus plagioclase ratio is between 0.4 and 0.6, and the alkali feldspar to total feldspar rate is less than 0.1.

Trondhjemite is the most commonly encountered lithology, comprising at least 90% of the area of the intrusion? Hand samples are normally grey to pink in colour, with abundant quartz. The plagioclase is albitic and quartz-plagioclase intergrowths are locally common. Ferromagnesian minerals are present in small quantities. Two modal analyses for trondhjemitic samples are presented in Table 2. No modal difference is evident between those samples with quartz-plagioclase intergrowth and those without intergrowths.

(b) Quartz diorite, according to Streckeisen (1973), contains biotite and/or amphibole, and is medium grained and equigranular. Feldspar ratios are similar to trondhjemite, and the quartz to quartz plus plagioclase ratios are greater than 0.2, but less than 0.4.

The rocks of quartz diorite composition comprise less than 5% of the intrusion and are commonly located near its margins. Macroscopically, these rocks are rich in biotite and hornblende with colour indices greater than 10. Quartz is normally visible. Microscopic examination reveals abundant plagioclase exhibiting varying degrees of alteration. Large (3 to 4 mm) plagioclase grains exhibiting oscillatory zoning are commonly found in contact with smaller (1 to 2 mm) plagioclase and quartz grains. The larger grains often have albitic rims and cores of anorthite composition ranging from 33 to 63% (analysis by Univ. Western Ontario microprobe, R. Hodder pers. comm.). A mineralogical composition

TABLE 2

Mineralogical Compositions, Beidelman Bay Intrusion

	Trondhjemite (Quartz-plagioclase intergrowths)	Trondhjemite (no intergrowths)	Quartz Diorite
Quartz	42.5	40.5	16.1
Plagioclase	53.6	53.8	49.7
Alkali Feldspar	tr.	-	-
Biotite	2.8	4.2	5.0
Hornblende	-	-	23.5
Opakes	1.1	1.5	5.7
Total number of points:	1229	906	298

for a typical quartz diorite sample has been included with the modal analyses in Table 2.

(c) Granodiorite, according to Streckeisen (1973) is medium grained, equigranular, and has a quartz content similar to quartz diorite and trondhjemite.

Rocks of granodiorite composition are rare in the intrusion, as staining revealed only a few samples with sufficient alkali. Macroscopically the granodiorite is indistinguishable from trondhjemite, but microscopic examination reveals the presence of microcline. Small granodiorite zones are evenly distributed throughout the trondhjemitic body.

In addition to the equigranular phases described above, the intrusion hosts a volumetrically minor porphyritic phase. Typically this rock is composed of a grey to green aphanitic groundmass containing plagioclase (commonly with some quartz and less common amphibole) phenocrysts up to 1 cm in diameter. Later deformation has rendered contact relationships between this and other phases ambiguous as the local patches can variously be interpreted as dyke remnants or rafted blocks of an early crystallized phase.

Near the contact between the intrusion and the surrounding volcanic rocks, intrusive breccias are locally present. In addition, large xenoliths of volcanic rock occur in the intrusion in the vicinity of the porphyry copper showing (Fig. 11a).

Deformation subsequent to solidification of the intrusion has produced a number of rock types which appear to be foliated equivalents of each of the above rock types. Microscopic examination of a number of samples with varying degrees of foliation suggests that the intrusion behaved in a brittle manner under stress. Deformation proceeded with the granulation of feldspars accompanied by the rotation and fracture of

quartz grains. The result is a well developed cataclastic texture of augens and aggregates of quartz set in a fine grained sericitic matrix which commonly appears to have partly recrystallized to biotite. The resulting bimodal grain size distribution is the reason for the term "quartz porphyry" applied to the intrusion by earlier investigators.

Average chemical composition of the three major rock types of the Beidelman Bay intrusion are listed in Table 3. The CIPW norms for the composition (Table 4) were calculated on a calcite-free basis.

TABLE 3
Whole rock analyses, Beidelman Bay Intrusion

	Trondhjemite	Quartz Diorite	Feldspar Porphyry
SiO ₂	75.73	58.23	66.76
Al ₂ O ₃	12.40	16.49	15.60
*Fe ₂ O ₃	.72	1.81	.72
*FeO	1.93	4.89	1.94
MgO	.25	2.59	.87
CaO	1.05	4.90	3.06
Na ₂ O	5.15	4.82	4.76
K ₂ O	1.25	1.19	1.77
MnO	.05	.11	.04
TiO ₂	.29	.90	.35
P ₂ O ₅	.03	.12	.05
CO ₂	.84	1.50	1.35
H ₂ O	.44	1.62	.99
Total	100.13	99.17	98.26
No. Samples	6	4	3

* Estimated from Fe₂O₃ total by only a few determinations. Analyses by XRF technique.

TABLE 4
Normative compositions for data in Table 3

	Trondhjemite	Quartz Diorite	Feldspar Porphyry
Quartz	37.3	9.4	23.5
Orthoclase	7.4	7.0	10.5
Albite	43.6	40.8	40.3
Anorthite	5.0	19.9	14.9
Diopside	-	3.1	-
Hypersthene	3.2	11.1	4.6
Magnetite	1.0	2.6	1.0
Ilmenite	.6	1.7	.7
Corundum	.7	-	.4
Normative An%	10.4	32.8	27.0

Trace element analyses were carried out by x-ray fluorescence for the elements Rb, Sr, Y, Zr, Nb, Ba on pellets pressed from powdered rock samples. The analyses are generally reproducible within 10 ppm at the 100 ppm concentration level for each of the elements. The trace element data are plotted against Larsen Index in figure 12. A summary of the trace element compositions and ratios for the entire intrusion, based on a trondhjemitic bulk composition is given in Table 5. In addition, comparable data from Arth and Hanson (1972) and the south Sturgeon Lake volcanic rocks are also presented.

For ease of discussion, normative data for the major rock types have been plotted on a ternary projection, the Q-Ab-Or face, of the four-component system Q-Ab-Or-An (Figure 13). The position of the cotectic line at 5 k bar H₂O (Winkler, 1976) is shown for reference. Where comparisons between modal and normative data are possible, little

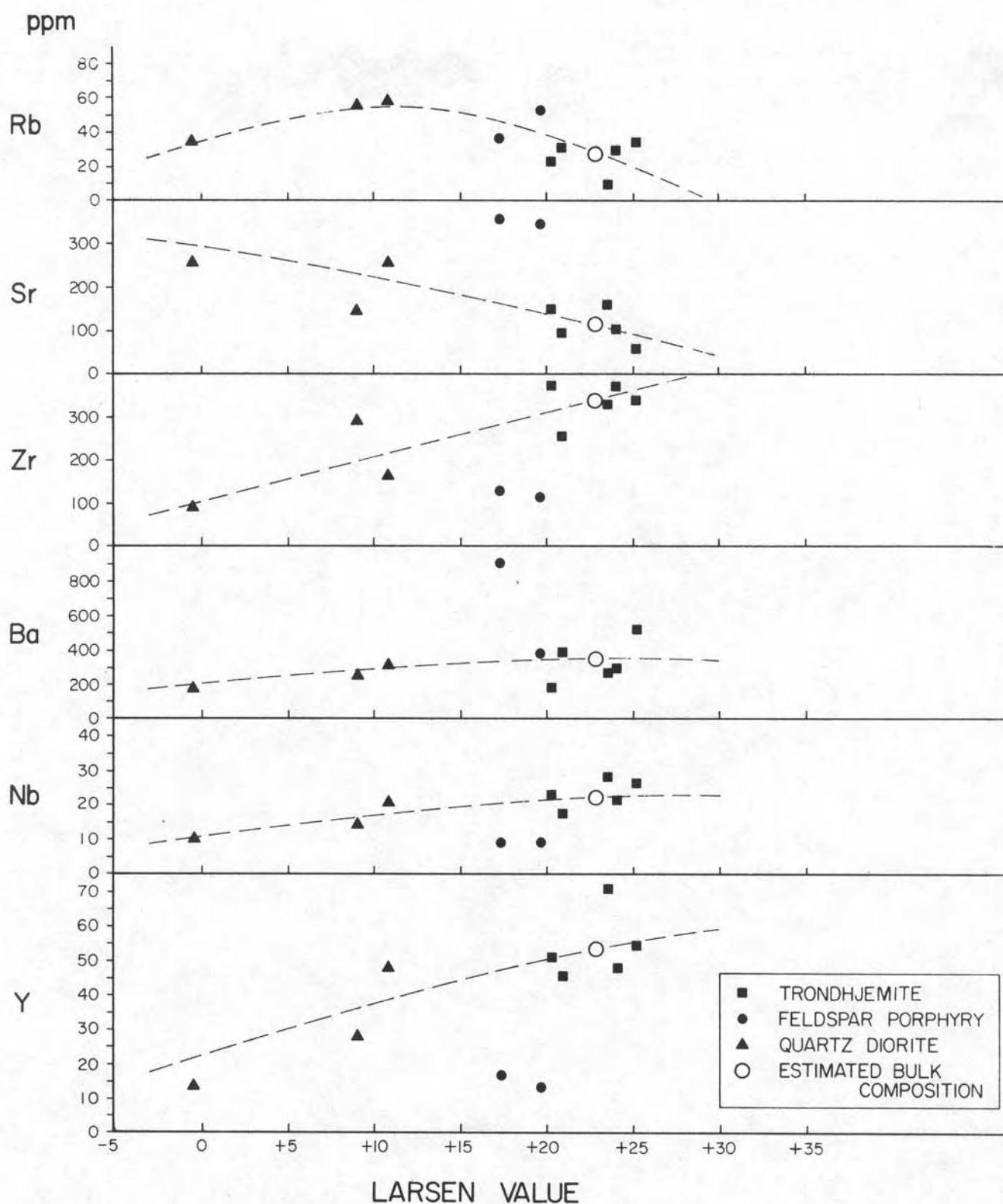


Fig. 12. Variation diagrams — minor elements vs Larsen Index, Beidelman Bay Intrusion.

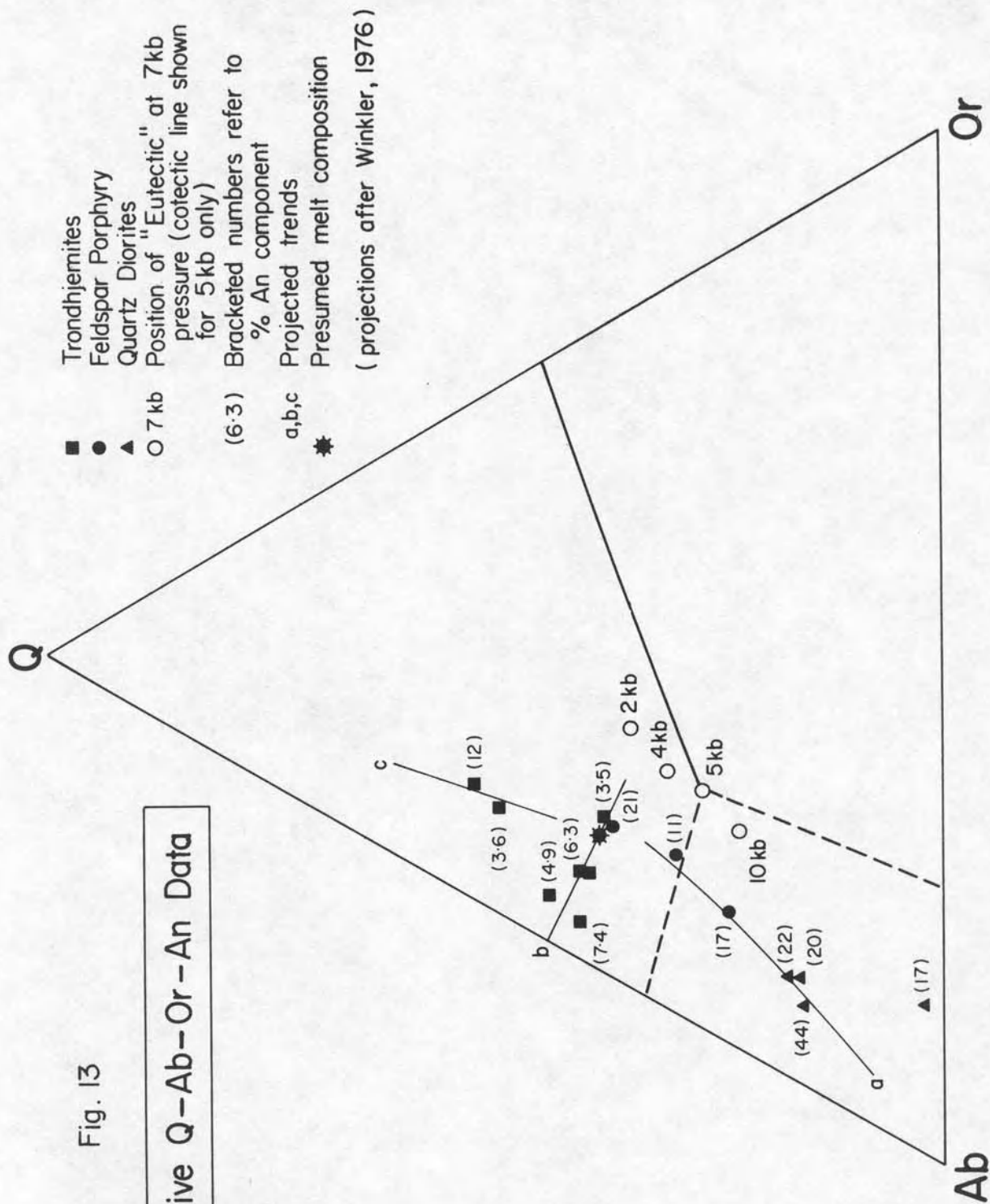
Table 5

Trace Elements, Beidelman Bay Intrusion and Felsic
Volcanic Rocks South Sturgeon Lake Area.

	Rb	Sr	Y	Zr	Nb	Ba	K	K/Rb	Rb/Sr	Sr/Ba
Beidelman Bay Trondhjemite	25	110	53	340	23	350	1.2×10^4	480	0.23	0.32
Beidelman Bay Feldspar Porphyry	46	346	14	126	9	673	1.4×10^4	317	0.13	0.55
Beidelman Quartz Diorite	49	217	31	184	16	253	0.9×10^4	202	0.23	0.86
Cycle 2 Felsic Rocks	58	76	53	330	27	540	2.3×10^4	390	0.76	0.14
Cycle 1B Felsic Rocks	53	170	21	160	12	276	1.8×10^4	354	0.31	0.62
Cycle 1A Felsic Rocks	30	90	45	280	20	190	1.2×10^4	400	0.33	0.47
Arth and Hanson 1972 table 1 samples 6, 7, 8	7.8 to 30.3	557 to 661				343 to 503	0.4 to 2.0×10^4	254 to 551	0.13 to 0.35	1.08 to 1.68

Fig. 13

Normative Q-Ab-Or-An Data



difference in the position of the composition was evident in this quarternary system, except that modal data is slightly poorer in orthoclase, due to presence of biotite. In spite of the small number of data points, it is apparent that the data occupy one of three trends (a, b, and c) originating roughly at a common point which has a bulk composition approximately equal to that of the average trondhjemite of this body (Table 3). This bulk composition lies slightly above the quartz-plagioclase cotectic surface regardless of pressure.

Within the aforementioned quaternary system (Winkler 1976) fractional crystallization of a melt of this composition will begin with crystallization of plagioclase until the melt composition to the quartz-plagioclase cotectic surface at which time this pair will co-crystallize. Continuous fractionation will then drive the composition to the cotectic line at which time alkali feldspar will join as a crystallizing phase.

The crystallization path described above is essentially consistent with the trends (a) and (b) in figure 13. Trend (a) probably results from mixing of early fractionally crystallized plagioclase plus ferromagnesian phases with the trondhjemitic bulk composition. Mixing of early-formed plagioclase along with the trondhjemitic melt formed the feldspar prophyry. Rapid cooling near the intrusion margins aided this process. As noted earlier these early formed feldspars in the quartz diorite and porphyritic phases have normal oscillatory zoning formed as a result of local disequilibrium (rapid cooling) near the margins of the body. The albite rich rims formed on feldspars in the quartz-diorite, and porphyry phases would 'trap' an excess amount of Sr, due to increased uptake of Sr by An poor feldspars (Phillpotts and Schnetzler

1970, Berlin and Henderson 1968). This accounts for the abnormally high Sr content of these phases. Thus from the major and minor element data, it is evident that the quartz diorite and porphyritic phases are early formed disequilibrium products that formed near the margins of the intrusion. Subsequent stoping of blocks of porphyry into the trondhjemite melt produced discontinuous block and fragmented dyke structures.

From the trace element data, it is evident that most of the variability in distribution of these elements is due to the volumetrically minor quartz diorite and feldspar porphyry phases. The data for trondhjemite forms a relatively tight cluster (Figure 12) with no linear trend relative to the Larsen fractionation index. This suggests a lack of strong fractionation of the trondhjemitic melt.

Comparison of both major and minor elements between the felsic volcanic rocks and trondhjemite of the Beidelman Bay Intrusion (Table 1 cf. Table 3, and Table 5, respectively) illustrates the close compositional similarity between these two units. The Na_2O content of the Beidelman Bay intrusion is significantly higher than that of the felsic volcanics, possibly due to sea-floor leaching of the latter. The close chemical similarity is probably indicative of co-magmatic parentage. The Beidelman Bay intrusion may thus be a syn-volcanic "magma pool".

MINERAL DEPOSITS

The Beidelman Bay intrusion hosts two types of mineral deposit. The Darkwater gold mine, which operated in the mid-1930's, exploited quartz-carbonate veins occurring in the intrusion near its northern margins (figure 11). No detailed examination of this deposit has been undertaken, but a complete description has been made by Horwood (1937a). A porphyry copper-type occurrence hosted by the intrusion (Figure 11)

has been investigated by Friske (1974). This work was expanded upon and reported by Franklin (1975).

The sulphide mineralogy encountered in the showings includes in decreasing order of abundance; pyrrhotite, chalcopyrite, sphalerite and molybdenite. The mineralization occurs as disseminations, on foliation planes, and locally as "cement" to an intrusive breccia. Copper grades range up to 0.6% and average 0.2% in the main "mineralized" area. Local mineralogical alteration includes the development of quartz and sericite veins and the growth of a secondary light brown biotite in mineralized specimens. On a larger scale, the copper occurrences appear to be roughly centred in a zone of alteration characterized by an increased sericitization of feldspars. This zone also displays microscopic evidence of the cataclastic deformation discussed earlier. Trace element analysis of a number of regionally disposed samples revealed a zonal distribution of copper and zinc within the intrusion which mirrors the alteration mineralogy.

The problem of the localization of the copper-zinc, molybdenum mineralization is much more difficult to resolve. The solid conclusions are that the strongest copper mineralization:

- a) is located central to a broad halo of copper-zinc enrichment,
- b) is associated with local and regional alteration and deformational patterns,
- c) is spatially related to a large "block" (roof pendant?) of volcanic wall rock,
- d) does not appear to be related to any one intrusive rock type,
- e) is locally associated with an intrusive breccia.

Although no single model of sulphide localization is preferred, consideration should be given to the possible spatial relationships between the mineralization and the "roof" of the intrusion in the third dimension. Such a relationship might resolve the zonal haloes, deformational intensity and the abundant volcanic blocks. In such a model hydrothermal mineralizing solutions could be generated in the wall-rocks adjacent to the intrusion.

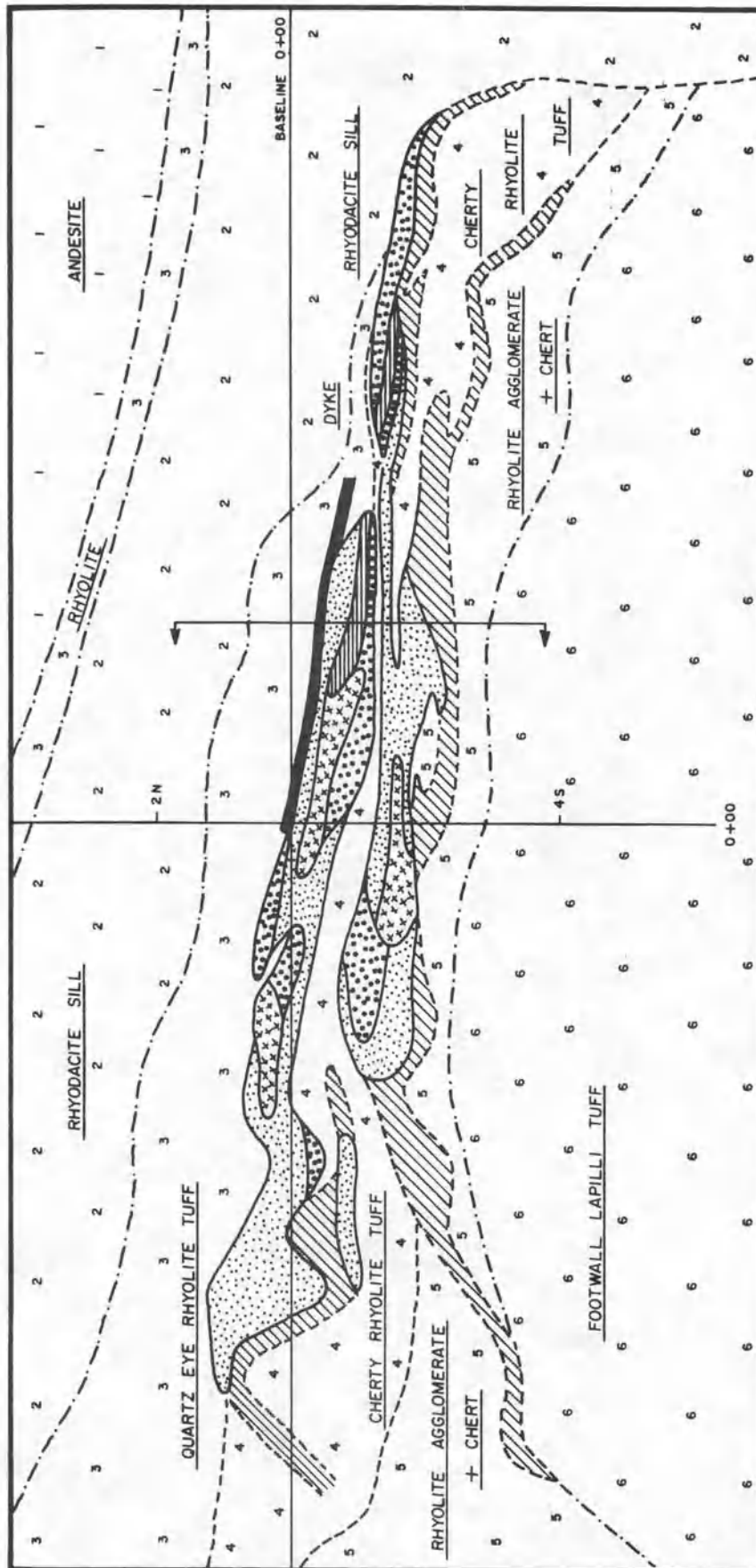
MATTABI OREBODY

The Mattabi ore body (Fig. 14) is grossly similar to the typical body described by Roscoe (1965) and Sangster (1972) in that it is a conformable stratabound zoned accumulation of massive to semi-massive sulphide in a volcanic or volcanoclastic terrain. It is a proximal-type deposit, as defined by Sangster (1972). In detail many of its attributes differ from those of the typical Noranda massive sulphide deposits.

ORE ZONE

The ore body may be conveniently divided into two conformable beds, the upper and lower zones (Figs. 14, 15). These are divided by a unit of cherty rhyolite tuffs, described previously (unit 1A, page 19). This unit thins rapidly upwards and to the east.

Each ore zone may be considered as a separate geologic entity, although for mining purposes both must be considered as constituting a single ore body. The Mattabi deposit is thus a sequence of two stacked or "en echelon" ore zones. Each ore zone has been subdivided on mineralogical, assay, and textural bases into five "facies". These are (1) high sphalerite ore, (2) high pyrite, low sphalerite ore, (3) massive chalcopryrite ore, (4) high galena ore, (5) stringer ore and



PLAN OF THE MATTABI DEPOSIT - BENCH 5

STURGEON LAKE AREA

MINERALOGICAL ZONING

- HIGH SPINELITE
- LOW SPINELITE - HIGH PYRITE
- HIGH CHALCOPYRITE
- HIGH GALENA CONTENT ZINC ORE
- STRINGER ORE

ROCK TYPES

- ANDESITE
- RHYODACITE DYKE - SILL
- QUARTZ EYE RHYOLITE TUFF
- CHERTY RHYOLITE TUFF
- RHYOLITE AGGLOMERATE + CHERT
- FOOTWALL LAPILLI TUFF
- DYKE

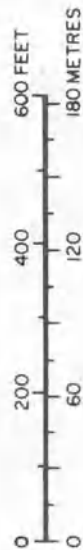
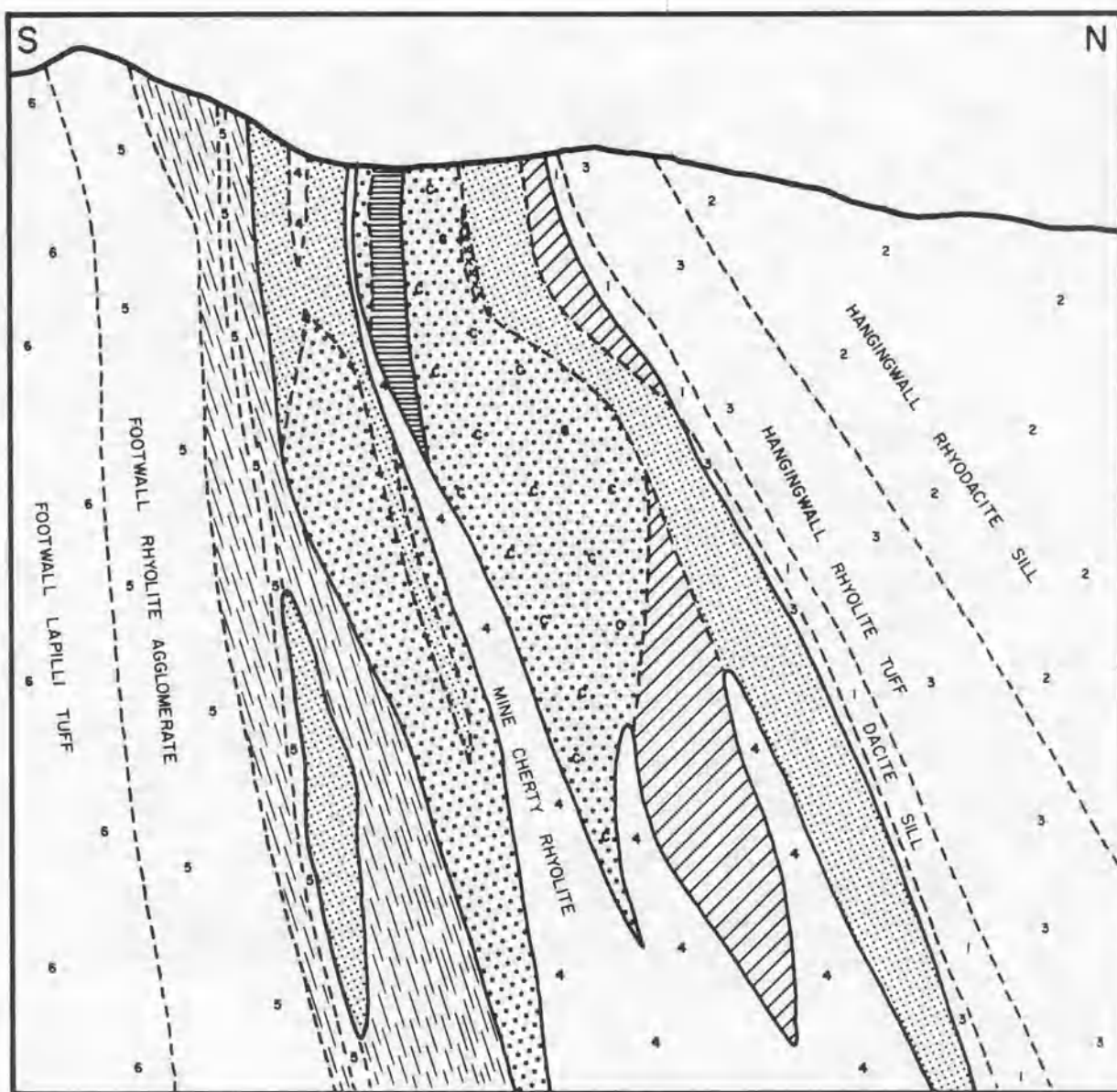


Fig. 14



CROSS SECTION 3+00E – MATLABI DEPOSIT

STURGEON LAKE AREA

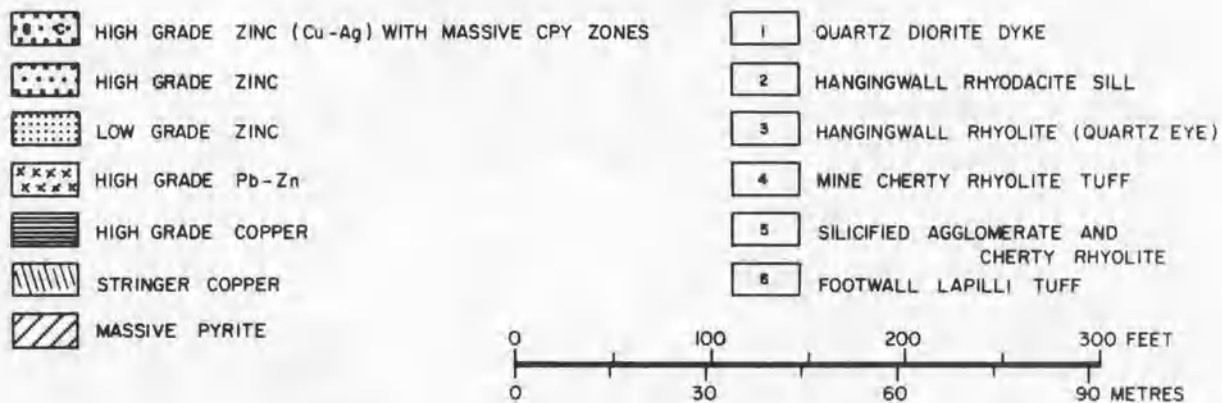


Fig. 15

alteration pipe. Facies (1) to (4) all form part of the conformable massive sulphide portions of the ore, and grade into each other. The fifth portion is more disseminated and locally disconformable; the alteration pipe, of which zone 5 is the only mineable portion, is definitely discordant to the strata and regional structure. This zone is described in more detail below. The "facies" are arranged in a similar distribution pattern for each zone. Essentially, each massive zone is underlain by a stringer zone. The stratigraphic top layer of each zone is pyritic (facies 2). These pyritic facies extend conformably westward to form the extremity of the massive ore. The massive ore contains a high galena bearing (facies 4) core area (two areas in the north). These galena rich zones grade laterally in both directions into massive sphalerite ore. The north zone contains a massive chalcopyrite band which strikes eastward from the galena rich zones; this massive chalcopyrite zone is contained within the sphalerite and massive pyrite ore. Unpublished data (Table 6) from a comprehensive study done by Dr. A.E. Johnson of CANMET outline some of the important compositional aspects of the mineralogy.

The individual facies are as follows:

(1) HIGH SPHALERITE ORE

The massive sphalerite ore typically is composed of 50 to 75% sphalerite, 20 to 45% pyrite, 2-5% gangue, and accessory to 5% chalcopyrite. The ore contains discontinuous pyrite bands, 0.5 to 3 cm in width. These bands are generally conformable to the ore body but are locally contorted, slumped, or brecciated. Bands can be traced over 1 to 3 meters in strike length. It is of significant interest that the bands are oriented in the plane of schistosity (approximately 260°) and

Ore Mineralogy of the Mattabi Orebody

Mineral	Analysis	Formula
Pyrite		FeS_2
Pyrrhotite		$\text{Fe}_{(1-x)}\text{S}$
Chalcopyrite		CuFeS_2
Sphalerite	Zn=58.11 Fe= 7.37 Mn= 0.19 Cd= 0.09 Hg= 0.41 S=32.89	$(\text{Cu}_{.001} \text{Hg}_{.002} \text{Mn}_{.003} \text{Fe}_{.129} \text{Zn}_{.866})_{1.001} \text{S}_{1.00}$
Galena	Pb=81.99 Ag= 0.67 Bi= 1.52 S=11.75 Se= 4.48	$(\text{Pb}_{0.936} \text{Bi}_{0.017} \text{Ag}_{0.014})_{.967} (\text{Se}_{.135} \text{S}_{.865})_{1.00}$
Tetrahedrite	Cu=15.08 Fe= 4.86 Ag=32.42 Zn= 1.02 Sb=26.42 As= 0.13 S=20.85	$(\text{Ag}_{1.445} \text{Cu}_{1.138})_{2.583} (\text{Fe}_{0.418} \text{Zn}_{0.077})_{.495}$ $(\text{Sb}_{1.042} \text{As}_{.010})_{1.052} \text{S}_{3.121}$
Bournonite	Pb=42.17 Sb=29.24 Cu=12.60 S=19.11	$\text{Cu}_{0.984} \text{Pb}_{1.02} \text{Sb}_{.995} \text{S}_{3.00}$
Cubanite	Cu=23.41 Fe=40.72 S=35.26	$\text{Cu}_{1.01} \text{Fe}_{1.99} \text{S}_{3.00}$
Gudmundite	Fe=27.00 Sb=56.91 S=14.58	$\text{Fe}_{1.03} \text{Sb}_{1.00} \text{S}_{0.97}$
Pyrargyrite	Cu= 0.11 Fe= 0.36 Zn= 0.12 Ag=61.82 As= 0.38 Sb=20.81 S=16.16	$\text{Ag}_{3.21} \text{Sb}_{0.96} \text{S}_{2.83}$
Dyscrasite	Sb=25.21 Ag=70.95 As= 5.67	$\text{Ag}_{3.03} (\text{As}_{.25} \text{Sb}_{.75})_{1.00}$
Amalagram	Ag=58.15 Hg=37.2	Approx. Ag_3Hg
Electrum	Ag=56.16 Au=36.88 Hg= 5.57 Sb= 0.55	

Minerals Analyzed by Microprobe techniques for Dr. A.E. Johnson, CANMET

thus have possibly been transformed due to the deformational event.

Sphalerite in this facies is massive with minor exsolved blebs of galena (near high galena zones) and chalcopyrite. Grain size is variable and exsolution is common only in the coarse portions of the ore.

(2) PYRITIC ORE

Massive pyrite zones are composed of fine to coarse pyrite with up to 10% sphalerite forming a matrix. Coarse pyrite is commonly euhedral (cubes), whereas, the fine pyrite occurs as reticulate and dendritic felted masses enclosing sphalerite. The pyritic ore is typically very low in copper content, but does contain recoverable silver in addition to zinc. No silver-bearing mineral in this facies has been recognized in this preliminary investigation. The pyritic band at the bottom of the south zone contains up to 50% pyrrhotite, surrounding large cubes of pyrite.

(3) MASSIVE CHALCOPYRITE

This ore has not been microscopically examined in detail. In the pit it is composed of 75 to 90% chalcopyrite with sphalerite forming conformable streaks through it. The ore is coarse grained and contains accessory arsenopyrite. The latter mineral occurs as euhedral crystals commonly 2 to 3 mm in length. In addition, members of the tetrahedrite-tennantite series and pyrite occur as minor constituents.

(4) GALENA ORE

This ore might better be characterized as lead-zinc ore as it commonly contains 25% galena, 50% sphalerite, 10% pyrite, 1 to 2% tetrahedrite-tennantite, and 2 to 3% arsenopyrite. On the edges of this facies, galena occurs as exsolved blebs in sphalerite and outlines sphalerite grain boundaries and twin planes. In the central portion of

a galena-rich area, galena completely surrounds sphalerite blebs. Tetrahedrite is a common accessory and contains rare bournonite inclusions. Dr. A.E. Johnson (personal communication 1972) reports accessory boulangerite also. Arsenopyrite occurs as fine-grained dusty aggregates, intermixed with pyrite.

(5) CHALCOPYRITE STRINGER ORE

The chalcopryite stringer zones are essentially conformable with the structure of the ore body and are more laterally extensive than the massive sulphide zones. They form the top of the alteration pipe and appear to have formed in the zone immediately below the surface on which the massive sulphides were precipitated. This ore is formed of veins and blebs of sulphide which crosscut both the footwall rhyolite and the mine cherty rhyolite. The latter unit divides the two ore zones and its upper portion forms a second stringer ore zone. The veins are commonly 10 to 20 cm, ranging to one meter, in length, and rarely exceed two centimeters in width. The ore is composed of coarse grained chalcopryite with minor pyrite, pyrrhotite and accessory arsenopyrite. Magnetite is present in a few veins. Pyrrhotite is more pervasive relative to pyrite in the footwall stringer zone.

GENERAL

The sulphides are variably recrystallized. The central top portion of the south zone has retained many primary textural relations; concentric growth zoning and fine reticulate textures indicate that recrystallization has been minor. The remainder of the ore has been recrystallized. Grain size is coarsest at the top of the north ore zone. Generally grain size increases towards the south as well as the

north edges of the ore body.

Preliminary examination of the gangue mineralogy by thin section and x-ray methods indicates that quartz is the most abundant gangue followed in abundance by chlorite, sericite, garnet, amphibole, biotite, kyanite, anthophyllite, and gahnite. Kyanite and garnet are best developed at the bottom edge of the two ore zones. Gahnite, a zinc spinel, is generally formed only in those deposits which have been metamorphosed to amphibolite facies. Its occurrence along with that of garnet and kyanite, suggests that at least local relatively high-grade metamorphism has affected the ore body.

The massive sulphide portions of the ore contain local large blocks of rhyolite and chert. These blocks apparently have been stoped into the ore and have been emplaced due to slumping. Within the upper portion of the alteration pipe, a thin trachytic rhyodacite dyke cuts the sequence subparallel to the orebody (Fig. 14).

MATTABI ALTERATION PIPE

Alteration pipes are thought to be 'hot spring' or fumerolic channelways, and are found underlying almost all massive sulphide deposits. They are useful guides to ore and may also give information regarding stratigraphic top. Pipes are well documented in the Noranda area where the "dalmatianite" alteration pattern is accepted as typical.

Alteration is confined to the rocks underlying the Mattabi deposit, is extensive and in many ways different from that of the Noranda camp. The detailed mineralogy and petrochemistry at Mattabi have been outlined elsewhere (Franklin et al. 1975) and will only be briefly reviewed here. Alteration studies at the Lyon Lake and Falconbridge deposits are the subject of current research by J. Hinzer

(Mattagami Lake Mines Ltd.) and P. Friske (Univ. New Brunswick).

At Mattabi, alteration occurs on two scales. On a local scale (Fig. 16) a 'cone' of alteration descends below the deposit, and is a zone of addition of metals and profound mineralogical change. More subtle alteration on a more regional scale includes a large zone of possible Na_2O depletion, marked by breakdown of feldspar and a consequent increase in aluminous mineral content.

The important mineralogical and chemical alteration features are shown in Figure 16. The following are the more notable mineralogic features:

(a) Siderite is distinctly developed below the deposit in a cone-shaped zone, and essentially defines the 'proximal' alteration zone. Within the footwall lapilli tuff, carbonate is ubiquitous (as dolomite), but below the deposit, although the CO_2 content remains essentially the same, dolomite is replaced by siderite. Within the footwall rhyolite breccia, siderite occupies fractures and possibly has partially replaced silicate matrix and clasts.

(b) Chloritoid is developed throughout the footwall zone, and although it occurs beyond the siderite zone, it is more abundant in this zone. It forms up to 15% of the rock, is evenly disseminated through both footwall lithologies, and is easily distinguished in rhyolite.

(c) Sericite occurs as irregular pods or patches in the footwalls. These pods range to over 100' in thickness and diameter. It locally forms up to 50% of the footwall lapilli tuff, as fine grained, fibrous patches, and up to 30% in the rhyolite.

(d) Andalusite is ubiquitous in the footwall rocks, and extends for at least 2000' away from the deposit. It constitutes approximately 5% of

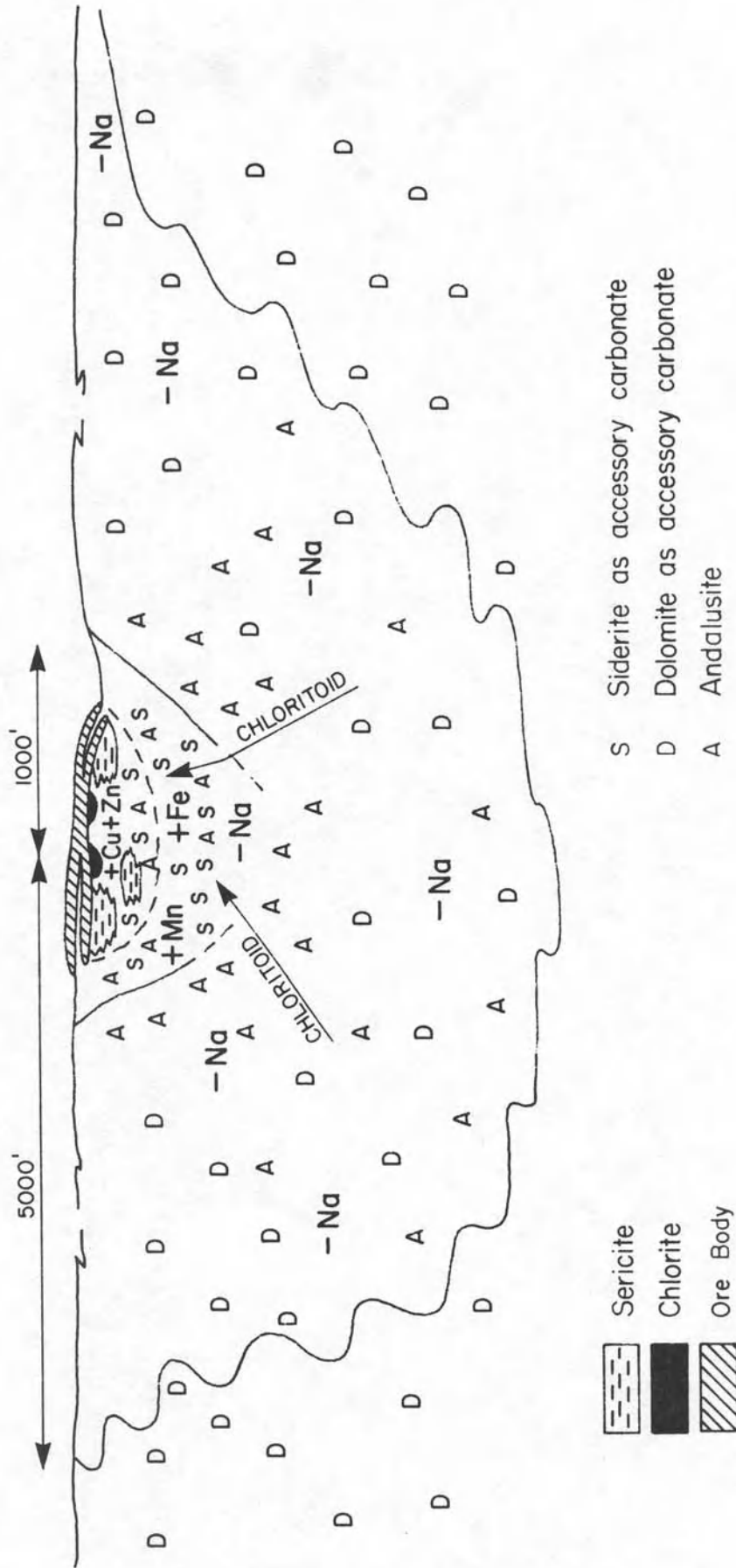


Fig. 16. Schematic plan of alteration assemblages; chemical changes indicated by + or - (e.g. +Cu, -Na), alteration minerals shown in legend. Dolomite is not an alteration product.

the rock, and occurs as ragged porphyroblasts.

(e) Quartz is enriched in a stratiform zone which underlies the deposit, and occurs both as a product of silicification of rhyolite, and as chert.

(f) Chlorite (magnesian ripidolite) is remarkably rare in the alteration zone, unlike many other deposits. Pods of massive chlorite ranging to 30' in diameter have formed at the base of the massive ore, however.

(g) Sulphide minerals: Pyrite, pyrrhotite, chalcopyrite and minor sphalerite occur in veins and as disseminations through the alteration zone. Except for a 50-foot zone immediately below the ore, where they commonly constitute 2-5% of the rock, sulphides rarely exceeds 0.5%

(h) Other minerals: Kyanite and anthophyllite occur as minor constituents in and immediately below the ore. Kyanite occurs principally in veins. Magnetite occurs with chalcopyrite in the stringer ore. Almandine garnets occur in the chlorite pods, along with minor biotite.

The more important chemical features of the alteration are:

(a) Copper and zinc are anomalously enriched in a remarkably small area below the deposit;

(b) Manganese is distinctly enriched within the entire siderite zone. Factor analysis of quantitative mineralogic data indicates that manganese is present in both siderite and chloritoid.

(c) Iron is distinctly enriched in the siderite zone.

(d) Silica is enriched below the deposit, as both rhyolite-replacement and chert.

(e) Sodium is very distinctly depleted through a footwall zone of at least 5000 feet radius below the deposit.

(f) Carbonate is increased only immediately below the deposit, where it forms irregular patches, 2 to 5 cm in diameter.

The major element alteration characteristics are further demonstrated in Table 7 and the stratigraphic columns of the Mattabi area (Section B, Figure 10). The Na_2O distribution given on the stratigraphic column documents the low Na_2O content of the footwall rocks, compared with the hanging wall. This depletion represents a breakdown of feldspar, and is reflected by the increased abundance of andalusite. Breakdown of feldspars would possibly release trace metals, thus providing one possible source of metal for the deposit.

Both the Na_2O depletion and Mn enrichment are characteristics useful as an exploration tool. Although Na_2O depletion has been documented at many proximal massive sulphide deposits, Mn enrichment is present only where carbonate was an essential part of the ore-forming solution, or was present in the footwall rocks prior to alteration.

Lyon Lake-Creek Zone Deposits

The Lyon Lake and Creek Zone deposits have been examined only in drill core, and detailed description should be postponed until underground access is available. The deposits are stratiform and form thin, continuous sheets, conforming to the rhyolite (cycle 1B) - andesite (cycle 2) contact.

STURGEON LAKE MINE (FALCONBRIDGE COPPER)

Regional Geology

The Sturgeon Lake Orebody is located at a contact between overlying andesitic flows and tuffs and underlying porphyritic rhyolite to rhyodacitic fragmental flows and tuffaceous phases (Fig.3). In the vicinity of the orebody the strike of the units vary from north-south in the

TABLE 7

Composition of rocks near Mattabi Mine

	Na ₂ O depleted Lapilli with Mn enrichment SL21 B	Altered Rhyolite SL86 A	Mine Rhyodacite intrusion F71-27
SiO ₂	52.80	72.15	55.56
Al ₂ O ₃	14.40	12.21	13.98
TiO ₂	1.34	.73	.64
Fe ₂ O ₃ (T)	16.00	5.06	8.38
MgO	4.69	4.24	3.44
MnO	.52	.15	.13
CaO	.34	.30	6.70
K ₂ O	1.48	2.09	.88
Na ₂ O	.22	.20	1.78
P ₂ O ₅	.26	.14	.18
CO ₂	5.87	1.08	6.40
H ₂ O (T)	3.16	2.11	2.44
	101.08	100.46	100.51

northern portion to slightly south of east in the eastern portion. The dip of the orebody varies from vertical near surface to 40° to the northeast with depth. There is much to be learned about the structural geology in the vicinity of this deposit. The marked changes in strike and dip of the deposit as well as a geologically complex northern extremity indicate deformation due to folding and possibly locally intense faulting.

OREBODY

The orebody consists predominantly of pyrite, sphalerite and chalcopryrite with lesser amounts of galena, tennantite-tetrahedrite, and pyrrhotite. Minor arsenopyrite is generally associated with the chalcopryrite (Meyer 1971). The zonal distribution of the sulphides is as follows: a) the main or central portion of the lens is essentially composed of pyrite and sphalerite with the lower portion being relatively chalcopryrite rich, and containing minor pyrrhotite; b) the eastern and northern limbs (extremities) are composed of sphalerite-pyrite; and c) the stringer zone consists of chalcopryrite and pyrite with minor sphalerite and pyrrhotite. Galena is generally associated with the sphalerite rich areas of the central and northern zones of massive sulphides and occurs as disseminated subhedral specks. Local areas of the sulphides are well banded.

The hanging wall contact has been intruded by a semiconformable dioritic to lamprophyric dyke (up to 20 ft. wide). This dyke cross-cuts the massive sulphides towards the extremities of the deposit and "horse-tails" and becomes "inter-banded" with the massive sulphides as a multiple intrusion. Strong shearing of this dyke(s), in the fringe areas, (possibly a result of folding) has resulted in strong

alteration of the dyke in these areas and has provided a channel-way for groundwater circulation. The resultant altered ore, further affected by superficial oxidation, is more difficult to treat metallurgically.

FOOTWALL ROCKS

The massive sulphides are underlain by a quartz porphyritic to fragmental rhyolite unit. The porphyritic phase is generally restricted to the upper 40 feet of this unit and grades into the underlying non-porphyritic phase. The footwall rhyolites are medium grey in hand specimen with the porphyritic phase containing up to 10% bluish grey quartz phenocrysts up to 2 mm in diameter. Where the footwall rocks have been affected by metal-bearing hydrothermal solutions, they are described as white cherty "bleached" zones. The "bleached" zone is composed of very fine grained granular quartz - feldspar with interstitial sericite and a few coarse subhedral phenocrysts of quartz. Development of muscovite occurs in areas of streaky sericite. There is no evidence of fragmentation (Buchan 1971). The alteration zone also contains narrow zones of chlorite that contain occasional garnet porphyroblasts and local disseminated subhedral magnetite. Carbonate and tourmaline have also been reported in the alteration pipe. Further detailed mapping and geochemical analysis are required to help delineate the various alteration facies. The "bleached" zone extends approximately 80 feet below the massive sulphides but extends further into the footwall below the stringer pipe.

Chemical analyses of the wall rocks, including altered footwall strata, are shown in Table 8. The "Footwall Rhyolite" and "Altered Footwall Rhyolite" are both distinguished by very low Na_2O contents. This may indicate the presence of a very large alteration zone, similar

TABLE 8 - COMPOSITION OF ROCKS IN THE STURGEON LAKE MINES AREA*

	FOOTWALL RHYOLITE (26 Samples)	ALTERED FOOTWALL RHYOLITE (3 Samples)	FOOTWALL ANDESITE (9 Samples)	HANGING WALL ANDESITE (20 Samples)
SiO ₂	69.3	72.4	51.68	54.60
Al ₂ O ₃	13.95	13.18	13.96	14.49
Fe ₂ O ₃	3.84	4.05	12.89	9.02
CaO	1.64	1.03	8.89	7.31
MgO	1.24	2.30	2.93	3.75
K ₂ O	3.81	2.54	0.78	1.54
Na ₂ O	0.60	0.47	2.06	3.00
TiO ₂	0.44	0.39	1.05	0.87
Cu	17	27	43	50
Zn	81	527	96	98
Pb	4	287	3	3
Ni	2	2	36	79
Co	19	22	41	36
Ag	5	14	17	15
Mn	383	235	2068	1253

* These are partial 'rapid' analyses completed by J.W. McConnell (1976) at Queens University.

to the "regional-scale" alteration observed at Mattabi (Friske, pers. comm. 1976). Thus this deposit appears to a proximal deposit, as further borne out by the metal zoning in the deposit.

The Lyon Lake and Creek zone deposits are stratiform deposits with a considerably different alteration pattern. (Hinzer, pers. comm. 1975). Sodium depletion is essentially absent, and 'alteration' is confined to an increased amount of carbonate in the footwall, accompanied by some enrichment in manganese, particularly towards the Falconbridge deposit.

From the distribution of alteration and metal zoning at Falconbridge Copper, it appears that the latter proximal deposit was also the source of metal-rich brine which spilled out along the paleosurface, and accumulated in adjacent shallow basins developed on the volcanic dome. Metals then precipitated in these basins to form 'distal-type' Lyon Lake and Creek Zone deposits.

MINING - MILLING

Overburden stripping of the deposit commenced during July 1973. Completion date was August 1974, after removal of 2.8 million cubic yards of material.

ULTIMATE OPEN PIT SIZE:	Length 1500 ft.
	Width 1300 ft.
	Depth 390 ft.
MINING RATE:	2500 Tons/day Ore
	6000 Tons/day Waste
BENCH HEIGHT:	35 feet
BERM WIDTH:	40 feet-every second bench
OVERALL DESIGN PIT SLOPE:	59 Degrees

ROAD GRADE:	11.2% (Maximum)
DRILLING:	Ore - 4½" diameter hole
	- 9' x 9' square pattern
	Waste - 4½" diameter hole
	- 8' x 12' square pattern
LOADING	4 Caterpillar 988 FE Loaders
HAULING:	6 Caterpillar 769B - 35 Ton Trucks

The blast hole cuttings from each blast are collected for metallurgical testing. Ore types requiring different metallurgical procedures are stored on separate stockpiles allowing a controlled mill feed.

Construction of the mill commenced in July 1973 with production starting in September 1974 at a rated capacity of 1200 TPD. The ore is treated to produce three final concentrates of: 1) Copper-Silver Concentrate, 2) Zinc Concentrate, and 3) Lead-Silver Concentrate. The ore that is treated can be categorized as follows: 1) high copper, high zinc, and medium lead content, 2) high copper, low zinc, and low lead content and 3) low copper, high zinc, and high lead content. Whenever possible types 1 and 2 are blended.

STOP DESCRIPTIONS

OPEN PIT EXAMINATION, MATLABI MINE

The areas to be examined in the pit are difficult to fix precisely due to the continual nature of mining. An attempt will be made to see representative types of alteration, to examine various types of massive ore, and to examine the immediate footwall and hanging wall rocks.

STOP M1: FOOTWALL LAPILLI TUFF, FOOTWALL RHYOLITE

This unit is a submarine laharic breccia composed of discontinuous beds of subangular rhyolite lapilli fragments in a matrix of more mafic composition. Different azimuths of cleavage and bedding are evident, and rotated fragments are common. The rock is thoroughly altered, with pits and brownish rust colour caused by weathering of siderite alteration. The matrix is somewhat silicified in this area, giving it a grey rather than more typically greenish colour. Silicified cross fractures stand up on the weathered surface, and minor pyrite is present.

Walking towards the pit, several small outcrops of lapilli tuff, with a decreased number of fragments, are evident. Near the pit edge, the footwall rhyolite breccia is exposed. Fragments are difficult to distinguish, due to relatively tight packing, lack of compositional variation between fragment and matrix, and pervasive silicification.

Most of these exposures were present before discovery of the mine. Although their chemistry (Table 9) distinctively points to the presence of nearby ore (high Mn, low Na_2O), their outcrop appearance gives little obvious clue.

STOP M2: HANGING WALL 'RHYODACITE' DYKE-SILL COMPLEX

The 'rhyodacite' dyke-sill complex occupies much of the east end and north sides of the pit. It is a grey, massive, 'quartz-eye' rock which cuts the east end of the orebody. The rock is carbonate rich, and its darker colour, relative to rhyolite, is due to higher chlorite content.

A thin dyke of similar rock cuts the footwall stringer ore.

STOP M3: ALTERATION PIPE AND STRINGER ORE

The types of alteration to be examined will be as follows:

(1) Carbonate alteration consists of siderite, as spots and as massive zones, and is pervasive throughout the alteration pipe. Irregular areas of disseminated pyrite with minor pyrrhotite generally accompany the carbonate within the alteration pipe. Chloritoid is commonly disseminated through these zones. (2) Stringer ore is formed of thin discontinuous chalcopyrite veins commonly associated with local chlorite and chloritoid alteration, but occurs also through both silicified and carbonate rich zones. These veins are normally well defined, and strike approximately at right angles to the regional structure. (3) Chloritic alteration, in some areas is massive, and is commonly associated with large sub-hedral garnets.

Much of the alteration contains andalusite generally evident only in thin section.

STOP M4: HANGING WALL RHYOLITE

Little of the hanging wall rhyolite is evident in the pit. It is exposed on the main ramp leading to the pit bottom, and consists of moderately foliated, light grey tuff. Quartz eyes (1-2%) are disseminated.

STOP M5 MASSIVE SULPHIDES

The types of ore to be examined will be (a) massive chalcopyrite ore (east end of pit) (b) high sphalerite and high galena ore in the central portion of the pit and (c) pyritic ore and cherty rhyolite unit in the west end of the pit.

FALCONBRIDGE COPPER PIT

Exact stop locations cannot be fixed at the time of writing of this guide. Stops will include an examination of footwall and hanging wall rocks, and a selection of ore types.

REGIONAL OUTCROP EXAMINATION (FIG. 3)

The following outcrops are typical of cycle 1 volcanic and volcanoclastic rocks, and are chosen to illustrate the variety and lateral extent of various members. Outcrops of cycle 2 and 3 are not accessible by road, and are best examined in shoreline outcrops on Sturgeon Lake.

STOP R1: HANGING WALL PILLOW LAVA (CYCLE 1B)

This stop is located near the water tower to the east of the mine office. A second portion of the outcrop is exposed immediately across the road from the mine office. At the water tower, extremely good examples of andesite bombs caught up in andesite matrix are exposed. In addition, on the north edge of the outcrop, some pillows are exposed. These are clearly well developed andesitic pillows with thick selvages and highly vesicular tops and bottoms. More conclusive pillow facings are evident in the outcrop opposite the mine office. The chemical composition is noted in Table 9.

STOP R2: FELSIC HYDROEXPLOSION BRECCIA (CYCLE 1B)

This stop is located approximately 1000 feet east of the Mattabi mine office, just off the road to Falconbridge Copper Mines Limited near the intersection of the old and new roads to Lyon Lake. This outcrop is composed of the unit which immediately overlies the hanging wall andesite. The outcrop is composed of highly angular bomb-sized rhyolite fragments which comprise approximately 75% of the rock. These fragments are cemented in a matrix of fine rhyolitic ash. The ash is altered in

TABLE 9

Composition of volcanic rocks at Field Trip Stops

	Lapilli (FW) at Mine SL 35	HW pillow lava R1 FRSL 18	Mine agglom- erate R3 SL 83A	intrusive dyke R4 AT 8C	Breccia from cycle 1B R2 C 47	F zone lapilli R5 F zone	F zone fragment 9W 82N
SiO ₂	60.70	51.31	72.95	48.30	73.41	54.6	72.95
Al ₂ O ₃	11.73	14.74	10.02	12.71	12.66	16.9	10.56
TiO ₂	1.02	.73	.33	1.07	.43	1.10	.47
Fe ₂ O ₃ (T)	15.49	9.62	8.60	12.00	2.32	8.63	2.95
MgO	3.34	3.11	1.69	3.95	.57	7.0	2.33
MnO	0.53	.34	.03	.21	.08	.08	.09
CaO	0.15	6.96	.68	8.80	3.36	1.79	2.75
K ₂ O	0.79	.85	.54	.70	1.15	2.09	1.17
Na ₂ O	0.12	3.37	.31	2.16	3.97	2.5	3.67
P ₂ O ₅	0.36	n.d.	.12	.30	.05	.24	.14
CO ₂	3.81	6.84	.12	6.88	1.43	2.3	4.00
H ₂ O (T)	2.74	2.41	2.01(2.46) ¹	3.76	.72	4.3	.81
	100.78	100.28	99.74	100.85	100.17	101.52	101.89

¹Sulphur.

part to chlorite. The fragments are angular to subrounded and contain feldspar and rare quartz phenocrysts. Fragments range in size to 2 feet in diameter, and the long axes are generally aligned parallel to strike. This outcrop represents one of the coarsest fragmental units in the south Sturgeon Lake belt. The coarse nature is best developed in this immediate area indicating proximity to a volcanic source. An analysis of a fragment from this outcrop is in Table 8.

STOP R3: MATLABI RHYOLITE AGGLOMERATE

This unit is directly on strike with the ore body and is approximately 1500 feet to the west of it. It is composed of agglomerate and lapilli-sized bombs of rhyolite composition, which are moderately well packed. The matrix material which forms 5-10% of the rock is composed of rhyolitic ash. Some of the bombs are rich in sulphide (pyrite) which rusts to give a conspicuous spotted gossan surface. This unit is approximately 200 feet thick at this point. In thin section, the rock is composed of quartz, feldspar and sericite with minor chlorite. An analysis of this rock is given in Table 8.

STOP R4: INTRUSIVE DYKE

This outcrop is located immediately west of Stop R3. The Matlabi sequence is cut by a prominent north-trending dyke which extends through the footwall lapilli tuff, mine rhyolite agglomerate and hanging wall rhyolite. It does not cut the hanging wall andesite and thus appears to be a feeder dyke to this unit. (Stop R1).

The dyke is composed of chlorite, altered feldspar and locally contains up to 10% accessory magnetite. To the west a thick semi-concordant sill intrudes the felsic sequence. This sill is of variable granularity, and locally has a well developed ophitic texture. It may

by the product of multiple injection. Joints in the dyke are generally developed perpendicular to strike. An analyses is given in Table 4.

STOP R5: FOOTWALL LAPILLI TUFF, DARKWATER CREEK AREA:

This outcrop is on a small access road north of the mine road 500 feet east of Darkwater Creek bridge.

These outcrops are within the same unit examined (Stop M1) on the south side of the Mattabi pit. This outcrop illustrates the bedded nature of the felsic lapilli, and the distinct compositional difference between felsic fragments and mafic matrix. Bedding is common only near the top of this unit. To the south, on Darkwater Lake, fragments attain a maximum size within the unit of 5 to 7 cm. Analyses of both the total rock (predominantly matrix) and a fragment are given in Table 4.

STOP R6: BEIDELMAN BAY INTRUSION:
MATTABI MINE ROAD, 4.85 MILES EAST OF HWY 599

At this outcrop the foliated equivalent of trondhjemite is exposed. Blue quartz "eyes" are set in a biotite-rich fine grained matrix. Analyses of samples from the immediate area are very similar to those for the "average" trondhjemite discussed in the text.

STOP R7: BEIDELMAN BAY INTRUSION:
MATTABI MINE ROAD, 2.15 MILES EAST OF HWY. 599

Exposed here is the equigranular trondhjemite phase which typifies the intrusion. In contact with the trondhjemite are blocks (or dykes?) of feldspar porphyry which comprise saussuritized plagioclase phenocrysts in a fine grained quartz-carbonate-sericite groundmass. These porphyries are chemically characterized by trace element compositions which are deviant from the "trend" displayed by quartz diorite and trondhjemite samples (see text). A major element analysis of a

porphyry sample from this locality yielded 66% SiO_2 , 4.9% Na_2O and 1.8% K_2O . The high Sr concentration in the porphyry samples (approx. 350 ppm, may be explained by a concentration of approximately 600 ppm. In the phenocrysts. A consideration of distribution coefficients suggests that such values are possible in a disequilibrium situation with a melt composition of 120 ppm.

STOP R8: (a) Footwall Lapilli tuff

(b) Cycle 1 rhyolite

(c) Cycle 3 sedimentary unit (conglomerate)

These outcrops are located on the southeast side of Elbow Creek (c) and southwest of Elbow Creek along a small access road leading to Elva Lake ((a) and (b))(Fig. 17).

(a) Footwall lapilli tuff: Outcrops on the road (west of hill south of Elbow Creek) and west along access road (excellent glacial polish) afford an excellent opportunity to examine the western portion of this unit. Here it is composed of 80% mafic fragments, 10% felsic fragments, set in a mafic matrix. A vesicular mafic dyke, one meter in width, cuts this outcrop.

(b) Cycle 1 rhyolite: Small outcrops of rhyolite are located along the shore, north of the large outcrop at (A). The rhyolite is grey, massive, and probably tuffaceous.

(c) Cycle 3 sedimentary unit: These outcrops of polymictic conglomerate belong to a unit which lies unconformably on the volcanic pile, and extends from the top of cycle 4, where it outcrops on islands south of Sturgeon Narrows, southward to this location. Clasts are subangular to rounded and composed of several volcanic lithologies. This unit is overlain by shale and iron formation (not exposed). Note that some

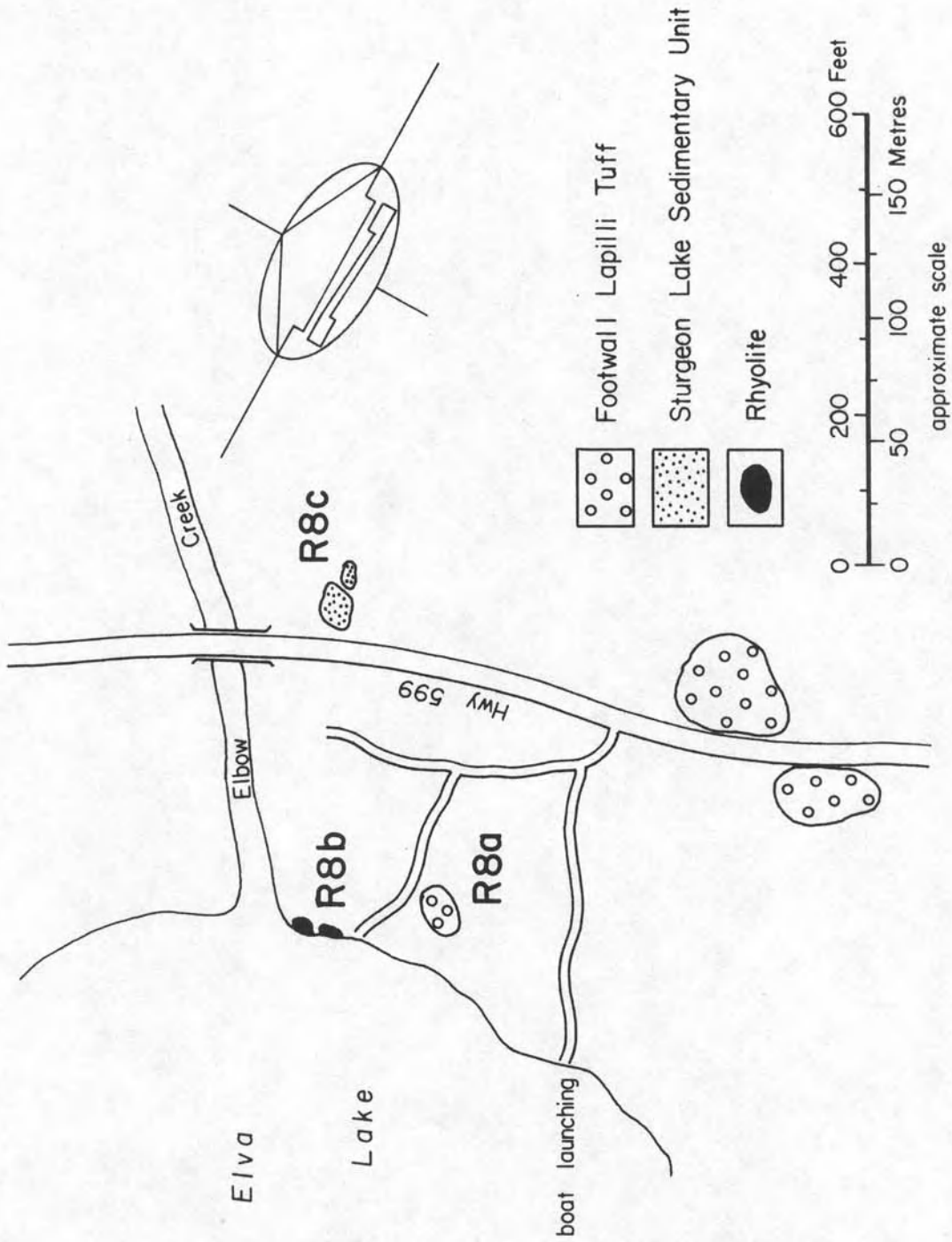


Fig. 17. Geology of Stop R8, Highway 599 at Elbow Creek.

fragments are carbonate-rich (similar to carbonate-rich strata near Mattabi and Lyon Lake) and the matrix is locally carbonate-bearing.

Acknowledgements

This guidebook was prepared with the co-operation of the geological staffs at Mattabi Mine Ltd., Falconbridge Copper Ltd. and Mattagami Lake Mines Ltd. J.M. Franklin was responsible for the regional descriptions, P. Severin for the Falconbridge Copper descriptions, W.Gibb and A. Tammam for the Mattabi data, and K.H. Poulsen for the Beidelman Bay description. S. Spivak, Lakehead University, provided exemplary draughting services.

Much of the petrochemical research and alteration study was supported by grants from the Geological Survey of Canada and National Research Council to J.M. Franklin. Mattagami Lake Mines Ltd. (Exploration Division) provided considerable encouragement, and access to drill data.

R.H. Ridler, Geological Survey of Canada, provided many useful critical comments, as well as his RIDLERPLOT program to construct the contoured variation diagram.

Murray Duke and Roger Eckstrand also contributed useful criticisms of the manuscript.

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