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DEPARTMENT OF ENERGY AND MINES
MINERAL RESOURCES DIVISION

ECONOMIC GEOLOGY REPORT
ER79-4

PORPHYRITIC INTRUSIONS AND RELATED MINERALIZATION IN THE FLIN FLON VOLCANIC BELT

by
D.A. BALDWIN

1980

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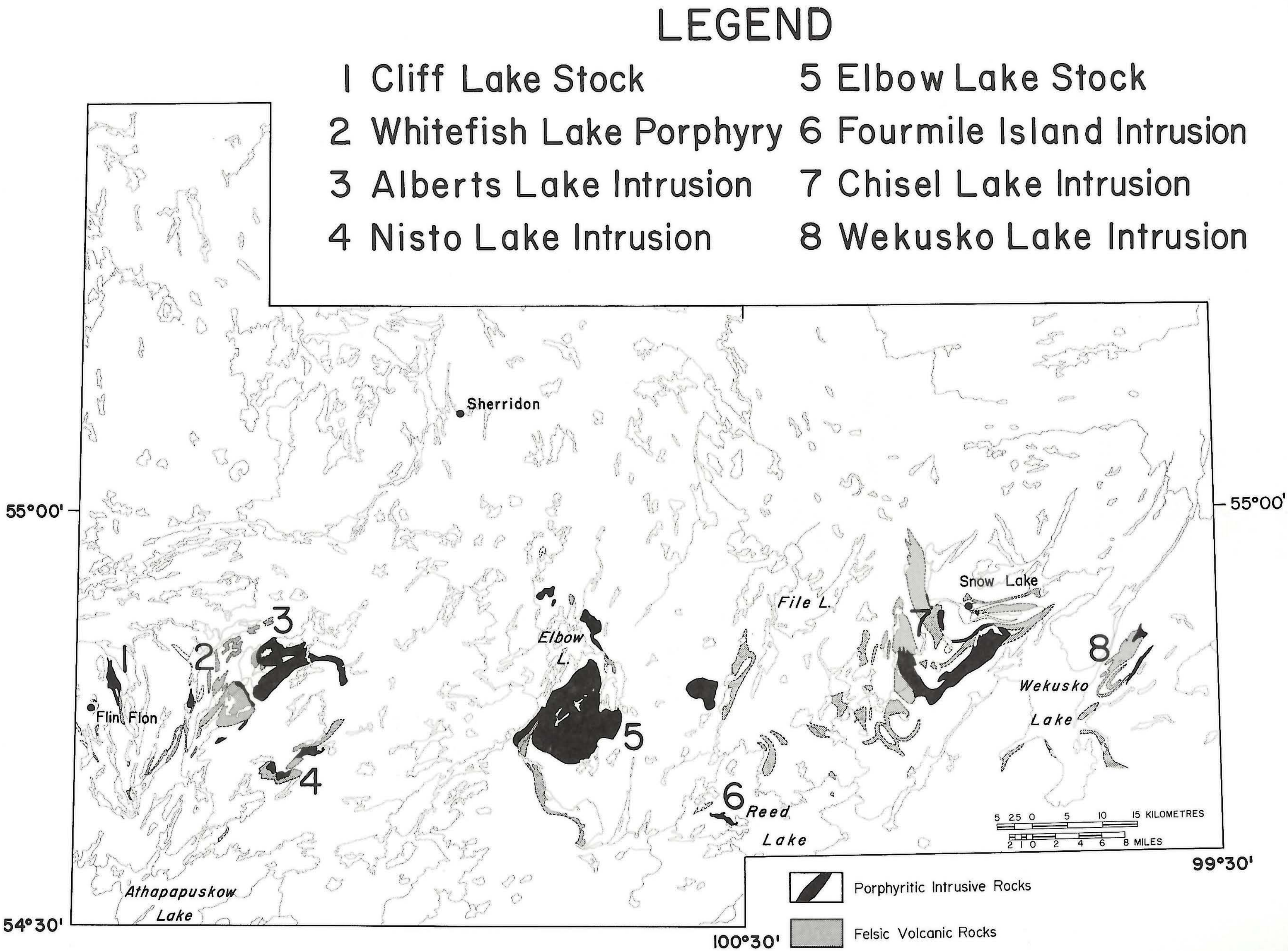

FIGURE 1: Distribution of porphyritic intrusive and felsic volcanic rocks in the Flin Flon volcanic belt.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Potassium-deficient, felsic, sub-volcanic porphyritic intrusions are present in the Flin Flon volcanic belt. These intrusions have geological and chemical characteristics of plutonic rocks that elsewhere host porphyry copper-molybdenum deposits. The Flin Flon volcanic belt is also intruded by large batholithic complexes that are interpreted to be representative of its root zones.

Detailed descriptions of rock types, contact relationships, xenoliths, alteration, faulting, veins and mineralization are presented. Chemical data for four plutons are discussed.

The porphyritic intrusions have an aeromagnetic signature similar to that of their host rocks, with the exception of one pluton which could be outlined on the basis of its different aeromagnetic response.

The porphyritic intrusions in the Flin Flon volcanic belt have some of the features of Mesozoic and younger island arc intrusions that host porphyry copper-molybdenum deposits. These features include tectonic setting, host rocks, texture, composition, contact relationships, intrusion-mechanism and in a few cases mode and type of mineralization. It is possible that economic porphyry-type copper and/or molybdenum deposits might occur in these intrusions in the Flin Flon volcanic belt.

INTRODUCTION

An evaluation of porphyritic intrusions in the Flin Flon volcanic belt as possible hosts for base metal mineralization was undertaken as a subproject of an evaluation of disseminated base metal environments in Manitoba. This evaluation was conducted under the Federal-Provincial Non-Renewable Resources Evaluation Program. (NREP).

Objectives of the subproject were to investigate porphyritic intrusive rocks and the enclosing volcanic rocks to:

(a) determine the presence or absence of geological environments favourable for porphyry-type mineralization;
(b) determine whether favourable environments are mineralized;
(c) determine the factors controlling the observed mineralization;
(d) determine genetic and spatial relationships between volcanism, plutonism and mineralization;
(e) discriminate between geologically favourable and non-favourable environments for porphyry-type mineralization in the Flin Flon and Snow Lake area;
(f) determine the potential for large-tonnage, low-grade porphyry-type mineral deposits in the Flin Flon volcanic belt.

Porphyry-type Cu-Mo occurrences are present in various places in the Canadian Shield (Kirkham 1972b). Some of these deposits have been mined (e.g. McIntyre Mine, Timmins, Ontario) and others approach economic grade. In Manitoba, this type of mineralization has been reported from the Superior Province (Elbers, 1976; Haskins and Stephenson, 1974; Sopuck, 1971), however, to date exploration efforts have indicated only subeconomic quantities of copper and molybdenum (Haskins and Stephenson, 1974).

In the southern part of the Churchill Province, widespread vein-replacement pyrite and chalcopyrite mineralization occurs in chloritic, sericitic and siliceous altered rocks adjacent to the main Flin Flon massive sulphide deposit. Extensive pyritic altered zones containing copper, molybdenum, and gold occur on and near Missi Island in the Amisk Lake area, Saskatchewan. Kirkham (1974) suggests that these occurrences have some characteristics of porphyry-type mineralization. With the above exceptions the author was unable to find any documentation of, or records of, exploration for porphyry-type mineralization in the Churchill Province.

Field work for this project was carried out in the summer of 1976. One mineralized pluton was identified and several other intrusions with a similar tectonic history were delineated. This study focused on the Flin Flon and Snow Lake area because:

i) it is an active mineral producing area,
ii) published descriptions of "quartz-eye" granite intrusions indicated that they are similar to mineralized porphyry intrusions elsewhere,
iii) disseminated sulphide mineralization had been reported to occur in and around the intrusive bodies,
iv) these intrusions outcrop extensively, and
v) most of the area is easily accessible by road and/or river systems.

This project was terminated after the first year when it was felt that enough preliminary information had been acquired to outline the general characteristics of possible porphyry-type environments in the Flin Flon and Snow Lake region.

The dimensions and distribution of the intrusions investigated during this study, and their spatial relationship to felsic volcanic rocks are shown in Figure 1. All of the rocks mentioned in this paper have been metamorphosed to some degree but for convenience the prefix "meta" has been dropped. The plutonic rocks have been classified according to Streckeisen's scheme (1975).

Data presently available for the porphyritic intrusions in the Flin Flon volcanic belt are minimal and incomplete due to sparce sample density and the short duration of the project. The following discussion is based upon limited field observations, twenty thin sections, ten whole rock analyses and interpretations based in part on data and descriptions of previous workers.

ACKNOWLEDGEMENTS

The author was assisted in the field by P. Plaza and L. Solkoski. Analyses, thin sections and stained slabs, and figures were prepared by the staff of the Manitoba Mineral Resources Division Analytical Laboratory, Rock Preparation Laboratory and Drafting Section respectively.

Dr. R.V. Kirkham of the Geological Survey of Canada, Economic Geology Section, acted in the capacity of Federal Advisor to this project. His assistance and guidance during the development and execution of the project were invaluable to the author.

Discussion with colleagues on the Mineral Resources Division staff, in particular Drs. J.W. Stewart and G.H. Gale helped to improve the final product.

Drs. R.V. Kirkham and D.C. Findlay of the Geological Survey of Canada and Drs. W.D. McRitchie, G.H. Gale and A.H. Bailes reviewed the manuscript. The author is grateful for their comments.

Special thanks are due to Ms. D. Navitka who patiently and meticulously typed the numerous drafts and the final manuscript.

GENERAL GEOLOGY

Basaltic flows and pyroclastic rocks with minor andesite, dacite, rhyolite and derived sedimentary rocks belonging to the Aphebian (?) Amisk Group, and granitic intrusive rocks are the dominant rock types in the Flin Flon volcanic belt. Stauffer et al. (1975) have suggested that the rocks may have been deposited in an island arc tectonic environment. They are overlain unconformably by

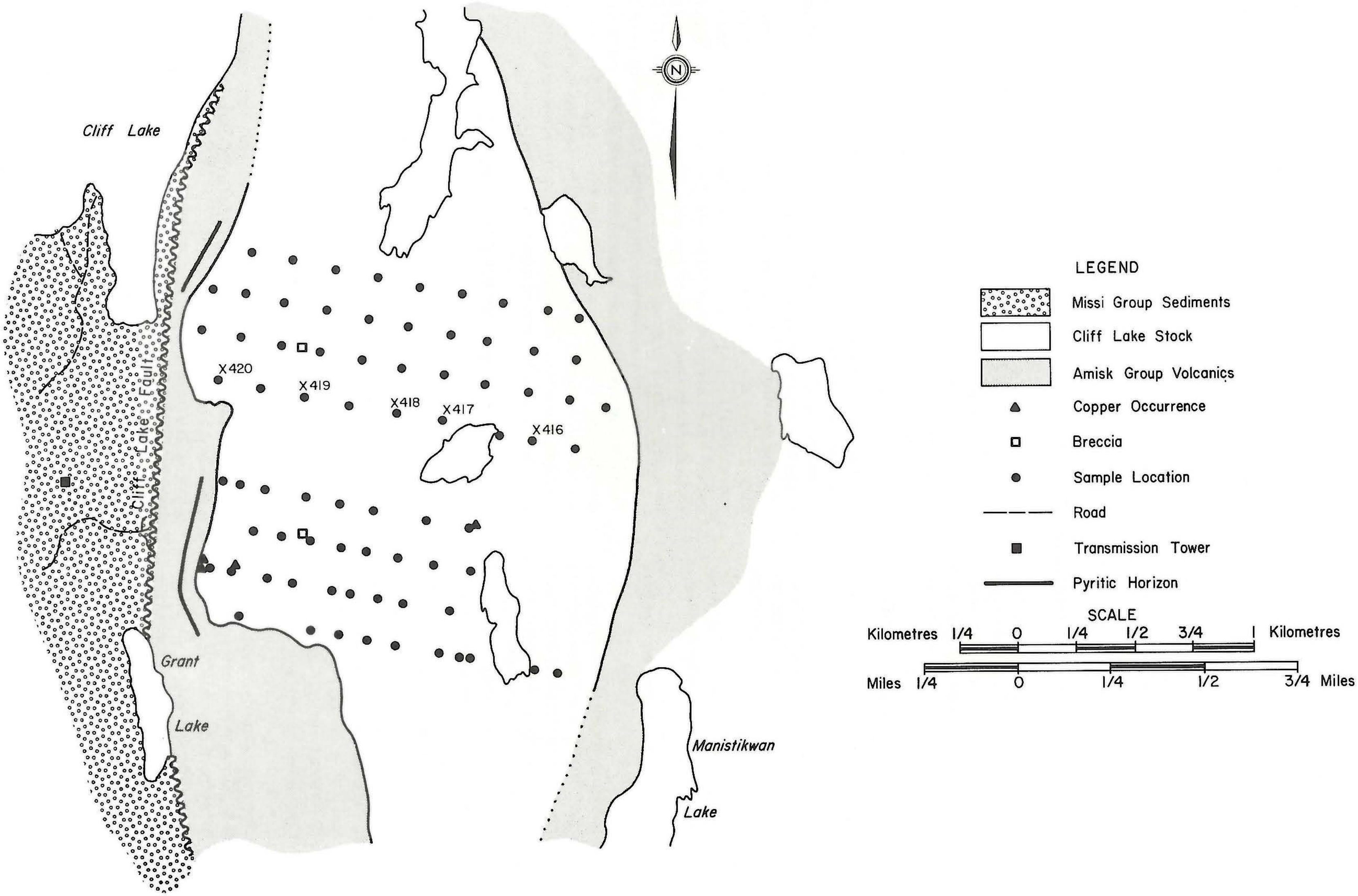

FIGURE 2: General Geology of the Cliff Lake Stock. Numbered sample locations refer to analyses in Table II.

sandstones and conglomerates belonging to the Missi Group, and are intruded by numerous dykes and stocks of peridotite to granite composition. Batholithic bodies of granodiorite to granite intruded the volcanic belt during the Hudsonian Orogeny.

Numerous geological maps and reports of the area, dating from 1917 to the present, have been published. Geological work carried out prior to 1971 has been reinterpreted and compiled by Bailes (1971).

INTRUSIVE BODIES

1. CLIFF LAKE STOCK

The 5 km^2 Cliff Lake Stock (Fig. 1, 2) which intrudes Amisk Group volcanic rocks, is a composite body consisting of porphyritic tonalite and younger granitic quartz porphyry phases. The porphyritic tonalite contains numerous xenoliths and roof pendants of greenstone, and has contacts with the volcanic rocks that are sharp and discordant, and in places the contacts may be faulted. The porphyritic tonalite contains chloritic and propylitic alteration. The granitic quartz porphyry is relatively unaltered. Foliation in the host volcanic rocks passes through the volcanic-plutonic contact but is only weakly developed in the intrusion.

Minor disseminated pyrite and chalcopyrite occur locally in the porphyritic tonalite, and traces of gold occur in poorly developed stockworks and veinlets. A well developed pyritic zone in the host volcanic rocks is parallel to the west contact of the intrusion.

The Intrusion has been brecciated locally. The breccias consist of angular fragments of porphyritic tonalite and granitic quartz porphyry in a fine grained aphanitic tourmaline-rich matrix. The breccia zones are pipe-like, elliptical to circular and less than 20 m^2. They have sharp contacts with the host rocks and are not mineralized.

The western contact of the intrusion has a hornblende hornfels metamorphic aureole up to 50 m wide in the volcanic rocks, and locally there is a 50 to 70 m wide chilled marginal phase of porphyritic tonalite. The eastern contact is marked by a deep topographic depression which probably represents a fault.

PORPHYRITIC TONALITE

The porphyritic tonalite constitutes 90 per cent of the Cliff Lake Stock. It is medium grained and weathers pale buff-red to pale cream. It is pale green where it is contaminated by the assimilation of xenoliths. It is composed of subhedral to anhedral crystals of pale blue quartz (< 4 mm) and crystals of plagioclase (2-3 mm) that are set in a chloritic matrix. Potassium feldspar rarely exceeds five per cent. Hornblende and biotite are almost totally altered to irregular masses or clots of chlorite. Feldspar is generally euhedral, quartz forms anhedral eyes and mafic minerals are less altered in the fine grained (1 mm to 2 mm) chilled marginal phase of the porphyritic tonalite than they are in the medium grained phase.

The porphyritic tonalite contains a weak foliation which is parallel to the long dimension of the intrusion. It also contains thin fractures spaced 6 to 13 mm apart, that are filled with epidote or quartz.

GRANITIC QUARTZ PORPHYRY

The granitic quartz porphyry intrudes the porphyritic tonalite from which it is readily distinguished by the microcrystalline matrix, the roundness of the quartz phenocrysts and the very high ratio of matrix to phenocrysts. The granitic quartz porphyry is buff-cream, fine grained and contains rounded pale blue quartz phenocrysts. The matrix is a fine grained mixture of microcrysts of quartz, plagioclase and potassium feldspar, and comprises 95 per cent of the rock.

The granitic quartz porphyry occurs as elliptical to irregularly-shaped intrusions up to 100 m diameter and as dykes. The dykes are generally restricted to the main intrusion but locally occur as off-shoots within the host volcanic rocks. The cross-cutting contacts of the dykes are well exposed.

DIABASE DYKES

Two sets of diabase dykes, approximately perpendicular to one another, occur in the Cliff Lake Stock. The youngest set strikes north and has a near vertical dip, the other strikes east and dips slightly to the south. The dykes are generally less than one metre wide, have chilled contacts and, although locally displaced by faults, can be traced continuously for distances up to 400 m. Similar dykes are present in the volcanic rocks but none could be traced continuously across the contact between the Cliff Lake Stock and the host volcanic rocks.

BRECCIAS

Tourmaline-filled breccias occur at two localities in the Cliff Lake Stock (Fig. 2). At the northern locality, which is hosted by porphyritic tonalite, fragments of porphyritic tonalite and broken crystals of quartz and plagioclase (Fig. 3) occur over an area 1 m wide by 10 m long. The long dimension of the breccia zone is parallel to a very weak foliation in the host porphyritic tonalite. The fragments are set in a fine grained aphanitic matrix composed of up to 45 per cent black tourmaline. Plagioclase in inclusions at the margin of the breccia zone and in the adjacent host porphyritic tonalite, is altered to potassium feldspar. At the southern breccia locality, which is hosted by granitic quartz porphyry, breccia fragments are angular, irregularly shaped, 10 to 15 cm in diameter and are separated by 1 to 2 mm fractures that are filled with fine grained aphanitic tourmaline. The breccia occurs over a roughly circular area of 20 m^2. The breccia fragments are free of alteration except at the outer margins of the structure, where there is minor quartz-sericite alteration.

Similar breccia zones have been described from Tertiary granitic bodies in the Andean porphyry copper province (Sillitoe and Sawkins, 1971; Ambrus, 1977), Copper Basin, Arizona (Johnson and Lowell, 1961), and Copper Creek, Arizona (Kuhn, 1941; Simons, 1964). Other examples are documented from Mexico (Perry, 1961; Sillitoe, 1976) and Utah (Butler, 1913). Many examples of tourmaline-filled breccias are known from porphyry copper deposits in British Columbia, e.g. Shaft Creek, Highmount, Bethlehem, Mt. Nansen and Glacier Gulch (Drummond and Godwin, 1976).

The tourmaline breccia structures in the Cliff Lake Stock are interpreted as pipes and are thought to be of the hydrothermal collapse type described by Sillitoe and Sawkins (1971) and Sillitoe (1976). Breccia pipes of this kind typically occur in high level intrusions.

XENOLITHS

Numerous xenoliths of volcanic rocks and local xenoliths of hornblende gabbro occur near the margin of the Cliff Lake Stock. Their distribution is irregular and patchy. They locally form up to 80 per cent of the intrusion at its margin. The number of xenoliths decreases uniformly toward the centre of the intrusion but even here they are still present. Volcanic rocks outcrop over areas of 330 to 500 m^2 in the intrusion. They are interpreted to be roof pendants. Xenolith lithologies commonly reflect the stratigraphy of the nearby volcanic rocks and in this manner lithologies of the country rocks can be traced across the volcanic and plutonic contact into the intrusion. Xenoliths in the outer 200 m of the intrusion vary in size, shape and degree of assimilation. They are generally less than one metre in diameter, but 3 to 4 m and 5 to 10 cm diameter xenoliths are also abundant. They are rounded to angular, but are typically sub-

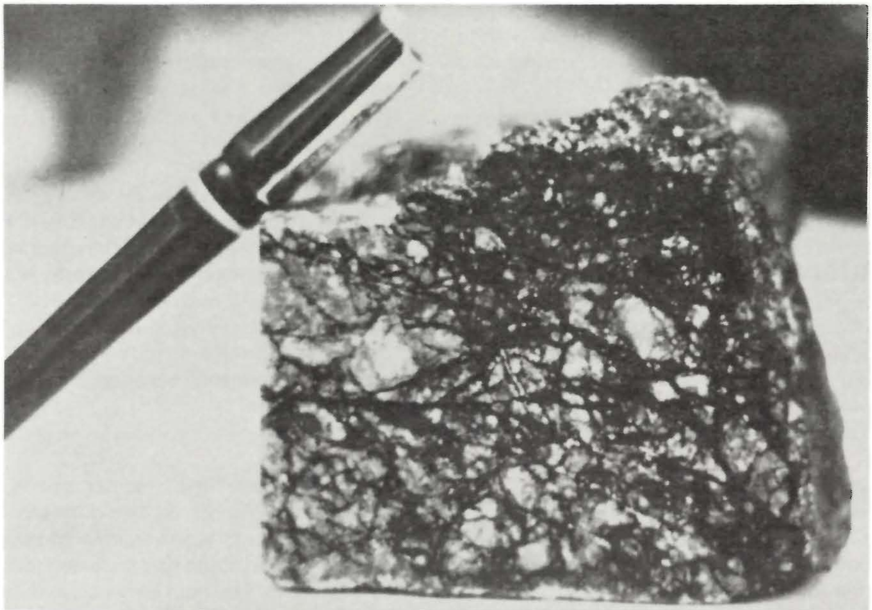

FIGURE 3: Tourmaline-filled breccia in porphyritic tonalite; Cliff Lake Stock.

angular with two angular corners (Fig. 4). The degree of assimilation of the xenoliths varies from a slight alteration around the periphery to a near total obliteration of the original rock (Fig. 5, 7 and 8).

The xenoliths appear to have resulted from incipient brecciation. This is best displayed where tonalitic magma has invaded pillow basalt along pillow selvages resulting in complete separation of the selvage (Fig. 6). At many localities numerous small xenoliths can be visually pieced together to form what was originally a single large xenolith.

Recrystallization (porphyroblastesis) of quartz to 1 mm metacrysts and of plagioclase up to 1.5 mm metacrysts has occurred in most xenoliths. In the larger xenoliths this recrystallization is confined to their margins.

Veinlets of epidote, chlorite, sericite and carbonate that terminate abruptly at the periphery of xenoliths are probably alteration veinlets that formed prior to the emplacement of the porphyritic tonalite.

QUARTZ VEINS

Tourmaline-bearing quartz veins postdate all other geological features in the Cliff Lake Stock. The veins vary in width from a few centimetres to a metre, strike at 060° azimuth, have vertical dips and can be traced for hundreds of metres. Fine grained coatings of tourmaline along vein walls are present in all of the observed veins, and fine grained aggregates containing a few well developed crystals of tourmaline occur locally within the veins.

ALTERATION

Alteration mineral assemblages in the Cliff Lake Stock have somewhat overlapping parageneses marked mainly by an increase in K_2O toward the centre of the stock and a concomitant loss of CaO.

In the least altered rocks, quartz is unaffected and plagioclase is partially dusted with sericite and minor pinhead grains of epidote, carbonate and/or chlorite. Mafic minerals are completely destroyed and replaced by mosaics of chlorite crystals and/or chlorite and epidote and leucoxene. Microfractures are filled with carbonate and quartz; the minor potassium feldspar (probably primary) in the rock is unaltered.

Toward the centre of the Cliff Lake Stock, plagioclase becomes more altered, many crystals are completely replaced by sericite, epidote and chlorite, and carbonate often forms a thin coating on relict plagioclase grains. Original quartz is overgrown by secondary quartz and the groundmass is altered to chlorite, epidote, carbonate and leucoxene. Finely-disseminated minor pyrite and magnetite are present in the groundmass and quartz and carbonate fill veinlets.

Potassic alteration has been recognized in the central part of the intrusion, however it is not widely distributed nor well developed. Plagioclase is dusted with sericite and potassium feldspar replaced outer margins of plagioclase crystals. The groundmass is completely chloritized, secondary biotite is weakly developed and quartz, carbonate and minor chlorite fill microfractures.

The extent to which the observed mineral assemblages have resulted from, or been affected by, metamorphism is unknown. However, the zoned distribution of the assemblages, as reflected by the overlapping parageneses, is probably a primary feature in the intrusion.

MINERALIZATION

Minor disseminated pyrite is ubiquitous in the stock and locally (Fig. 2) minor chalcopyrite occurs as disseminated grains or in fractures.

In porphyritic tonalite, pyrite occurs as tiny crystals in the groundmass but rarely exceeds two per cent of the rock. Chalcopyrite occurs rarely as 1 mm grains and although specimens and outcrops were examined in detail it was rarely observed. In the granitic quartz porphyry, chalcopyrite occurs as numerous tiny grains in 4 to 5 mm patches and in fractures with very minor molybdenite. Pyrite has the same habit as the chalcopyrite but it forms patches that are larger (4 to 10 mm).

A zone of disseminated pyrite, less than two metres wide, crosscuts the stratigraphy in the volcanic rocks and is locally parallel to the west margin of the Cliff Lake Stock. It was traced for a distance of approximately 800 metres (Fig. 2) and coincides approximately with the observable limits of the contact metamorphic aureole. Within this pyritic zone the volcanic rocks are locally heavily gossaned and chloritic alteration is associated with the pyrite. This mineralized zone appears to be metasomatic in origin and to be contemporaneous with the contact metamorphism of the volcanic rocks.

FIGURE 4: Xenoliths of volcanic rock in porphyritic tonalite; Cliff Lake Stock.

FIGURE 5: Partially assimilated xenolith in the Cliff Lake Stock.

FIGURE 6: Intrusion of porphyritic tonalite along pillow selvages in xenoliths of pillowed basalt; Cliff Lake Stock.

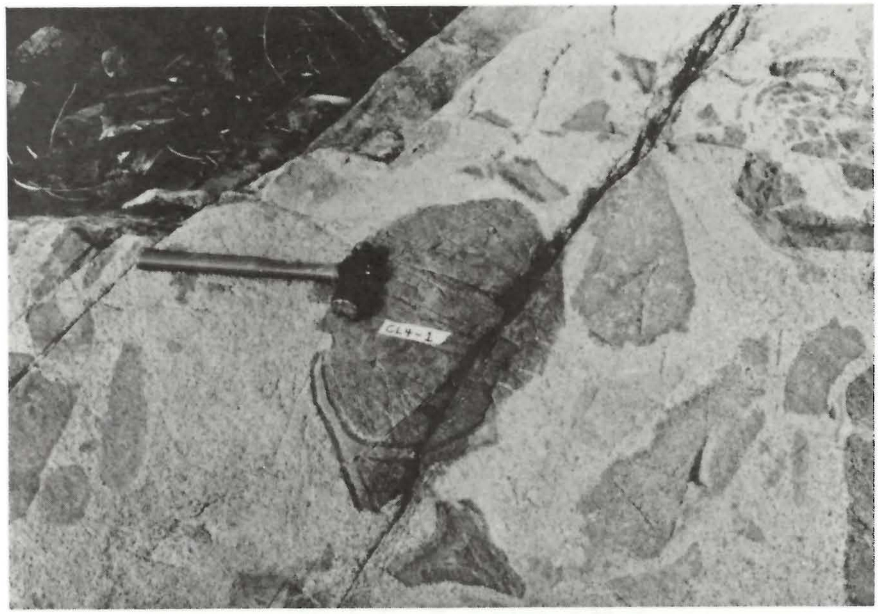

FIGURE 7: Xenoliths of volcanic rock formed by incipient brecciation; at the margin of the Cliff Lake Stock.

FIGURE 8: Xenoliths formed by incipient brecciation; Cliff Lake Stock.

2. WHITEFISH LAKE PORPHYRY

The Whitefish Lake Porphyry (Fig. 1) is a single phase, quartz monzodiorite body which intrudes volcanic rocks of the Amisk Group (Fig. 9). It is approximately 2900 m long and 300 to 600 m wide. Its contacts are sharp and xenoliths of country rock are numerous near its margins. The rock also forms small dykes in the volcanic rocks up to 250 m from the main intrusion. Sulphide mineralization (Cu-Mo) is concentrated as films, patches and disseminations on fractures. Hydrothermal alteration that has formed propylitic assemblages is common, however, where copper and molybdenum mineralization is present minor potassic alteration occurs locally. Disseminated sulphides in the matrix of the rock are rare. Sample locations and sample numbers for this intrusion are shown on Figure 10.

QUARTZ MONZODIORITE

The quartz monzodiorite is pale greenish pink and is homogeneous. It contains 5 mm phenocrysts of plagioclase and hornblende that are set in a fine grained matrix of interstitial plagioclase, hornblende, minor quartz and potassium feldspar, sericite, chlorite, epidote and minor carbonate. Magnetite globules ($\leq$ 1 mm) are ubiquitous and are commonly surrounded by leucoxene. Plagioclase, the dominant mineral, occurs as well developed laths, and locally as well formed equidimensional crystals. Larger crystals commonly have oscillatory zoning. Hornblende, which is subordinate to plagioclase, has a prismatic habit. Potassium feldspar occurs as interstitial grains and in veinlets. Quartz occurs only as microscopic interstitial grains.

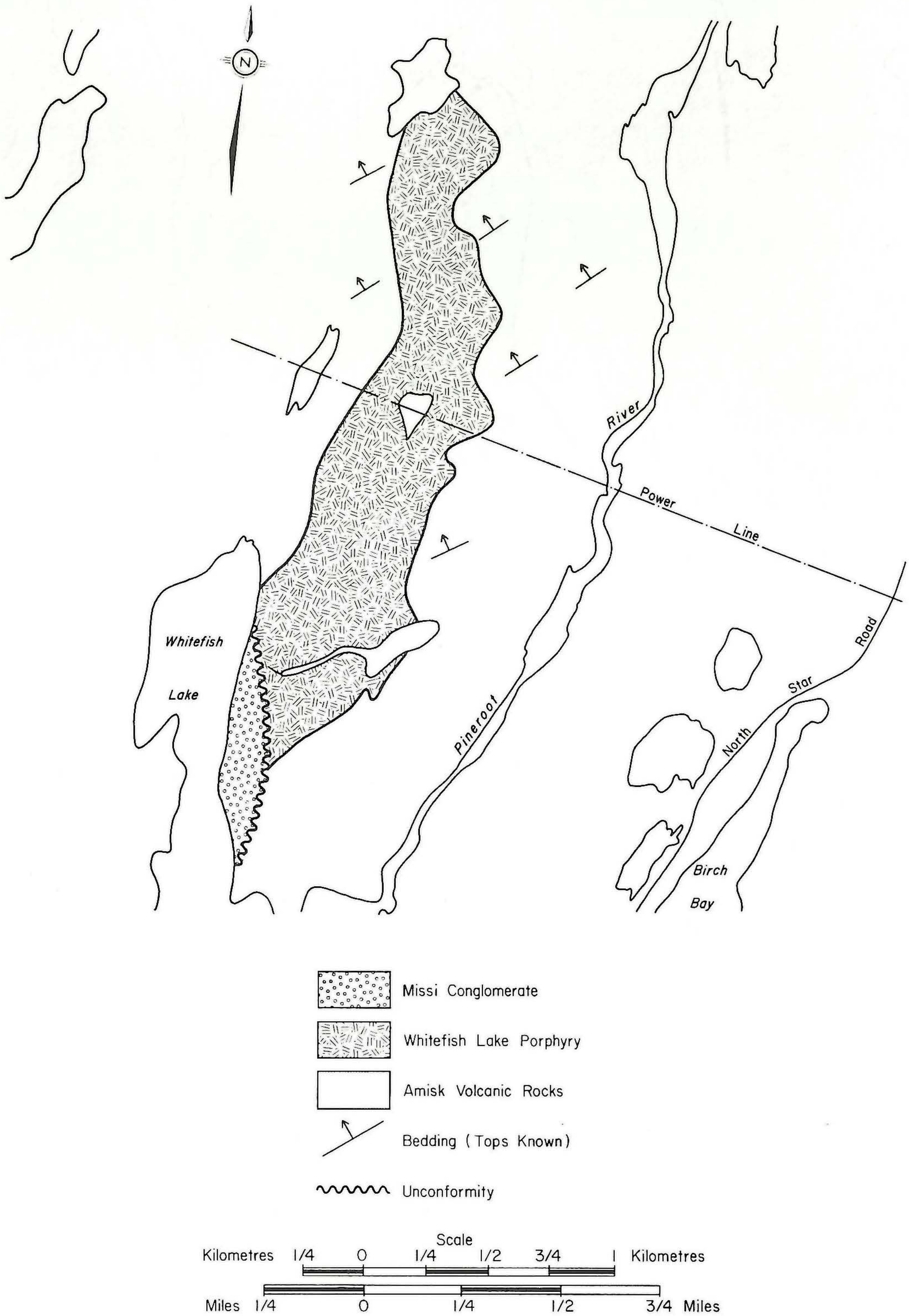

FIGURE 9: Generalized geological map of Whitefish Lake Porphyry.

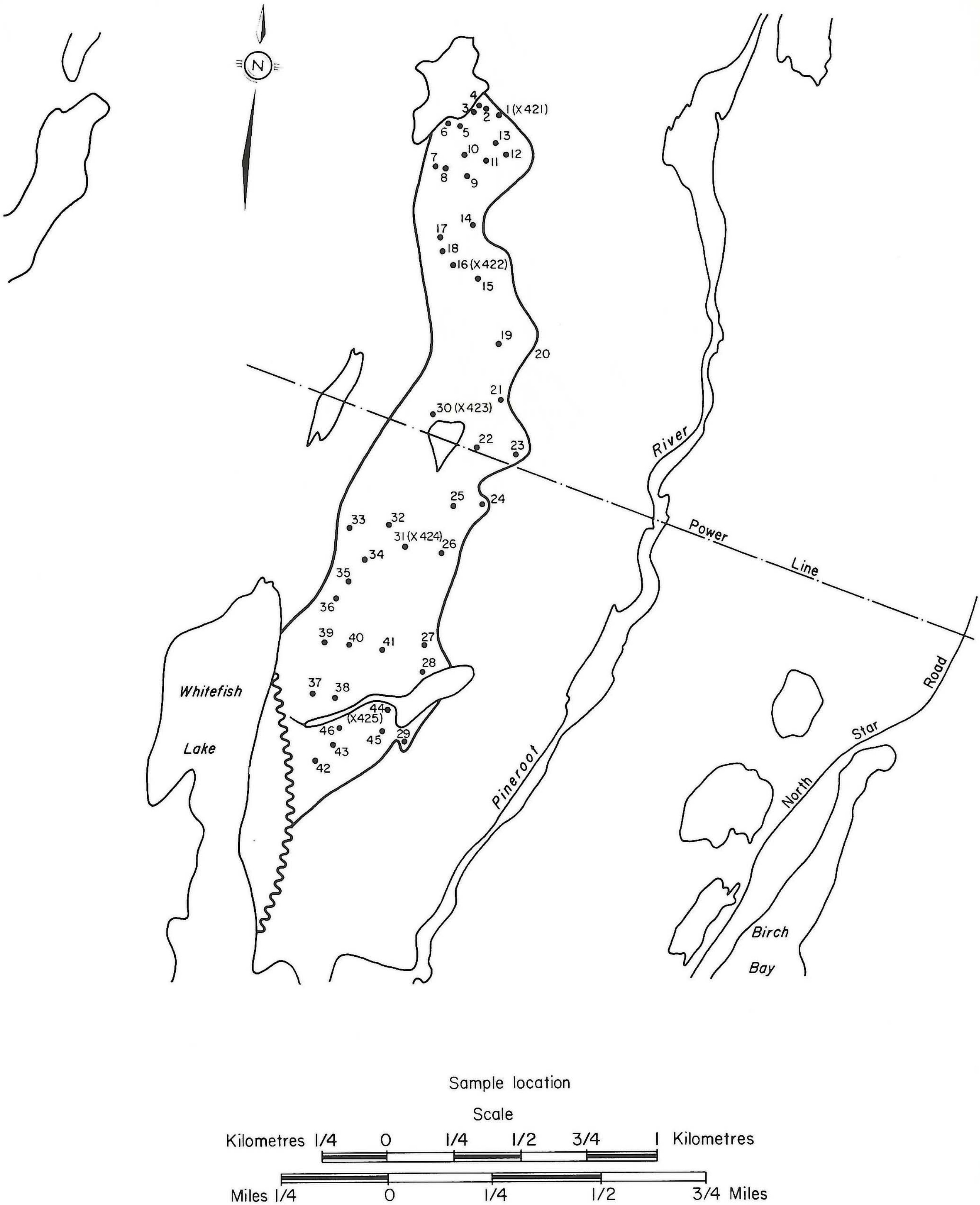

FIGURE 10: Sample locations and sample numbers Whitefish Lake Porphyry. All sample numbers are prefixed by WFL. Numbers in parentheses refer to analyses in Table II.

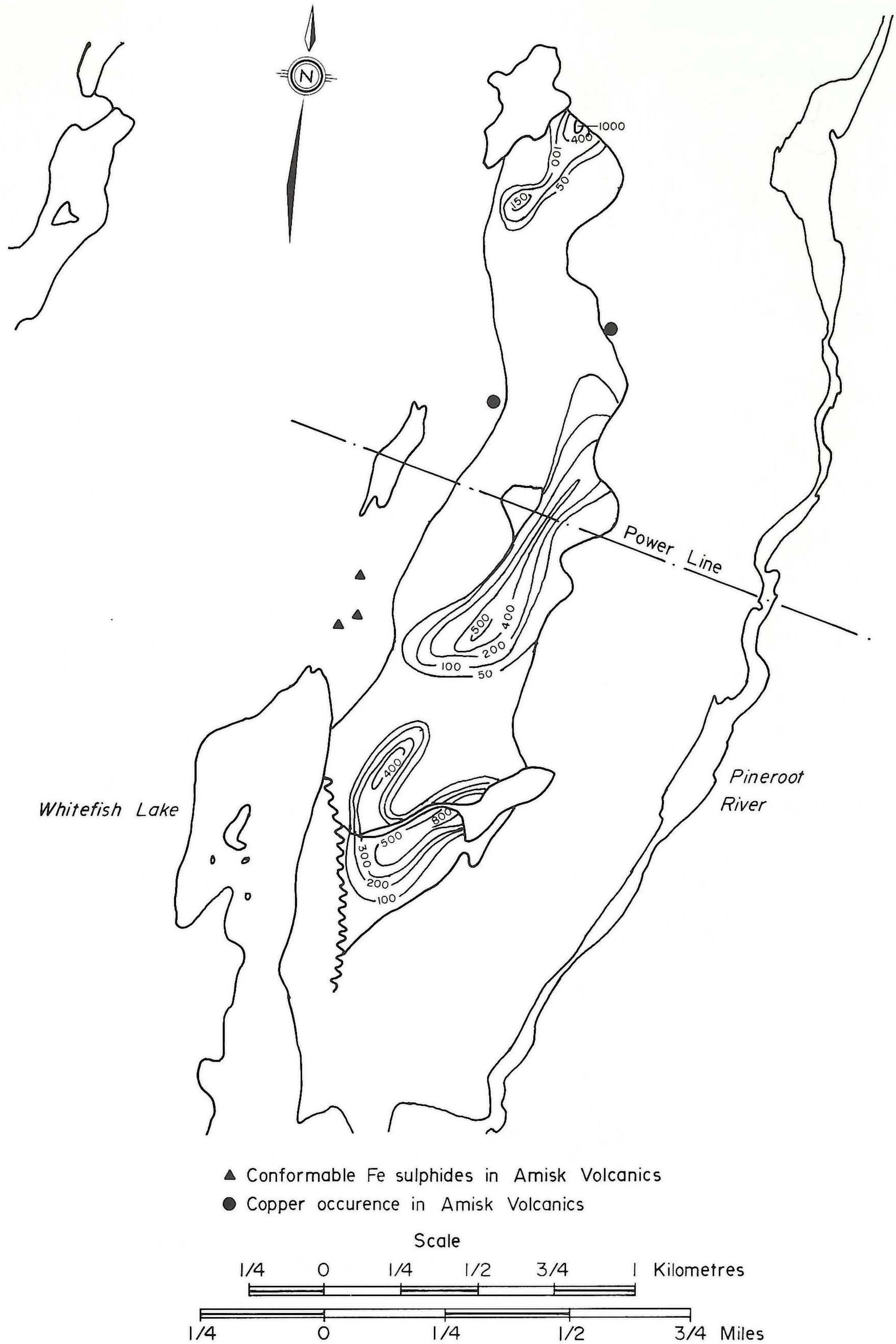

FIGURE 11: Distribution of Cu (ppm) in the Whitefish Lake Porphyry, conformable massive sulphide in volcanic rocks (▲) and chalcopyrite in quartz veins in volcanic rocks (●).

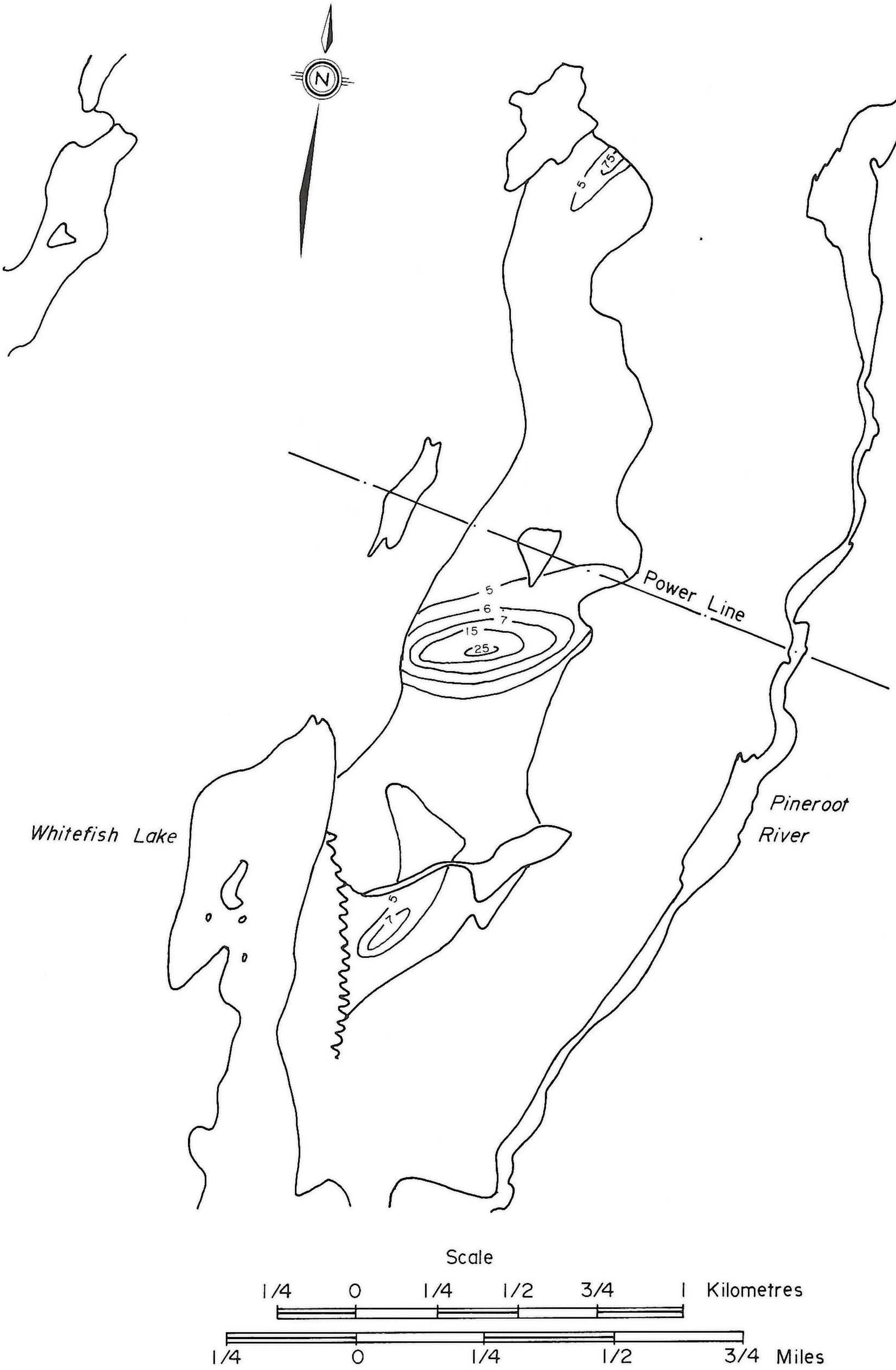

FIGURE 12: Distribution of Mo (ppm) in the Whitefish Lake Porphyry.

Dykes of quartz monzodiorite in the host volcanic rocks have chilled contacts and their matrix is finer grained than that in the main intrusion. Dykes range in thickness from 50 cm to 10 m. Sets of parallel dykes 5 to 10 m apart are common.

COUNTRY ROCKS

Basic lavas and volcanic-derived sediments comprise the country rock. The lavas are fine grained, basaltic and include both pillowed and massive flows. The volcaniclastic sediments commonly have graded bedding and are locally interbedded with volcanic flows. Laminated argillite and chert commonly cap the beds of volcaniclastic sediments.

XENOLITHS

Xenoliths of country rock occur throughout the intrusion but are most abundant near the outer margins. They are angular, square to rectangular and rarely exceed one metre across. Their contacts are sharp and they show little evidence of assimilation.

CONTACT RELATIONSHIPS

The contacts of the intrusion with the host volcanic rocks are not exposed, but have been delineated to within 10 to 15 m. Volcanic rocks up to 30 m from the intrusion are recrystallized and are characterized by 1 to 2 mm metacrysts of hornblende. At its margin the intrusion locally has a fine grained groundmass containing less than 25 per cent phenocrysts of plagioclase and hornblende; this rock is probably a chilled contact phase.

FAULTS

Only a few faults were observed in the Whitefish Lake Porphyry. None could be traced for more than 20 m. Minor shear zones filled with potassium feldspar and quartz, occur locally. They may have formed contemporaneously with alteration of the intrusion.

ALTERATION

Hydrothermal alteration in the Whitefish Lake Porphyry is variable. At the very outer margin of the intrusion alteration is limited to slight dustings of sericite on plagioclase. Toward the centre of the intrusion alteration of plagioclase increases and consists of sericite, epidote, and chlorite, with epidote occurring as globules within the sericite. Hornblende is replaced locally by chlorite, epidote and carbonate. Veinlets are filled with epidote and quartz. The most intense alteration is characterized by the replacement of plagioclase by potassium feldspar or by masses of epidote and chlorite. Carbonate adhering to skeletal outlines of altered plagioclase is common, as is replacement of hornblende by chlorite and carbonate. Microveinlets and fractures filled with potassium feldspar, quartz, chlorite, pyrite, chalcopyrite and molybdenite, are common.

The host volcanic rocks are altered locally. This alteration comprises green chlorite associated with stockworks of pyrite veinlets.

MINERALIZATION

Sulphides in the intrusion are confined to fractures. Pyrite is ubiquitous. Chalcopyrite and molybdenite are concentrated in three areas (Figs. 11, 12). The chalcopyrite and molybdenite are associated with the most intensely altered portions of the Whitefish Lake Porphyry. Three vertically dipping fracture sets striking at 045°, 065°, and 170°, and one sub-horizontal set contain the sulphides.

TABLE 1 — ANALYTICAL RESULTS — WHITEFISH LAKE PORPHYRY

Sample	Cu (ppm)	Mo (ppm)	Sample	Cu (ppm)	Mo (ppm)
WFL- 1	440	76	WFL-27	91	4
2	980	5	28	182	4
3	23	6	29	83	4
4	94	3	30	11	3
5	32	2	31	800	6
6	13	3	32	59	24
7	96	4	33	74	15
8	148	7	34	218	5
9	10	3	35	70	2
10	50	5	36	ND	ND
11	29	3	37	350	4
12	8	2	38	78	5
13	10	3	39	122	5
14	39	2	40	85	3
15	28	4	41	19	2
16	22	2	42	196	7
17	12	3	43	480	7
18	8	2	44	800	3
19	74	3	45	22	3
20	50	3	46	340	5
21	330	5			
22	102	4			
23	83	5			
24	13	5			
25	204	7			
26	108	4			

ND Not determined. Analyses done by the staff of the Analytical Lab., Man. Min. Res. Division.

Molybdenite occurs preferentially in the 045° and sub-horizontal fracture sets. Spacing of the fractures varies from 4 to 30 cm.

Pyrite and chalcopyrite occur as fine grained disseminated patches up to 2 cm across. Molybdenite occurs as rosettes up to 4 mm across and as thin films together with chalcopyrite. Analytical results for copper and molybdenum from grab samples are given in Table 1.

The host volcanic rocks contain concordant bodies of massive pyrite. They also contain chalcopyrite-bearing quartz veins (Fig. 11). A stockwork of pyrite mineralization was observed at one locality in the volcanic rocks between parallel porphyry dykes that are themselves barren of sulphides.

3. ALBERTS LAKE INTRUSION

Granitic rocks in the Alberts Lake area (Fig. 1) are equigranular, medium grained, massive to weakly foliated, grey to pink granodiorite. The rocks do not appear to be altered, however, adjacent to quartz veins and fractures, feldspar has been epidotized in many localities.

The granitic rocks consist of plagioclase, potassium feldspar, quartz, biotite and hornblende. Texturally, they are phaneritic, hypidiomorphic granular.

Xenoliths of country rock are not common, but where present, they have been recrystallized and have a weak porphyritic texture. Primary features in them have been destroyed during recrystallization but no evidence exists of extensive xenolith assimilation.

Narrow veins of milky white quartz, less than 6 cm wide are numerous and some contain abundant pyrite. Locally, the granitic rocks contain traces of pyrite.

The granitic rocks at Alberts Lake are interpreted to be deep seated orogenic batholiths.

4. NISTO LAKE INTRUSION

Three small irregularly shaped bodies of quartz monzodiorite crop out south and east of Nisto Lake (Fig. 1). Because of limited rock exposure these bodies cannot be outlined in detail. The quartz monzodiorite is porphyritic, with 2 to 6 mm phenocrysts of plagioclase and 3 mm long phenocrysts of hornblende set in a fine grained groundmass. Texturally it is strikingly similar to the Whitefish Lake Porphyry. Contact relationships were not observed and fracturing does not appear to be well developed in these intrusions.

The quartz monzodiorite contains ubiquitous disseminated magnetite and minor amounts of disseminated pyrrhotite and/or pyrite. Disseminated and stringer chalcopyrite in altered volcanic rocks, in the vicinity of the Nisto Lake Intrusion, are possibly genetically related to this pluton.

5. ELBOW LAKE STOCK

The Elbow Lake Stock (Fig. 1) is a pear-shaped "quartz-eye" granite body (Stockwell, 1935; Quaraishi, 1967; Hunt, 1970) that underlies an area of approximately 75 km^2, and is tonalite to granite in composition (Fig. 13, 14). It intrudes Amisk Group volcanic rocks. An intrusive origin is indicated by zoned plagioclase, massive texture, abundance of xenoliths, a chilled border phase with sharp contacts and a narrow metamorphic aureole (Hunt, 1970). Numerous small dykes extend from the pluton into the country rock.

The Elbow Lake Stock has two prominent sets of well developed joints that strike at right angles to one another. Pink to rose coloured pegmatite dykes and milky white quartz veins, that are locally sulphide bearing, fill the joints and fractures.

Sparse, finely-disseminated pyrite occurs locally within the pluton. Numerous gold occurrences are reported in the Elbow Lake area (McGlynn, 1959). Many of these are associated with quartz veins and porphyry dykes in volcanic rocks close to the contact of the pluton.

PLUTONIC ROCKS

The Elbow Lake Stock consists of massive, grey to pink, equigranular granite, granodiorite and tonalite. These rocks are characterized by grain sizes less than 3 mm and are strikingly similar to the porphyritic tonalite in the Cliff Lake Stock. They contain euhedral plagioclase and subhedral quartz, biotite and hornblende. The overall texture of the rock is hypidiomorphic granular. Bluish "quartz-eyes", consisting of slightly strained quartz aggregates, are prominent and weather in relief. Alkali feldspars occur as anhedral crystals that are interstitial to plagioclase. Mafic minerals tend to be fine grained and to form clusters or clots.

The quartz, plagioclase and alkali feldspar contents of the rocks are graphically displayed in Figure 15. The average mafic mineral content is approximately 12 per cent but higher concentrations at the contact result from the assimilation of xenoliths of country rock.

The pluton is characterized by a gradational, roughly concentric, compositional zoning (Fig. 13) (Hunt, 1970). The outer zone is tonalite passing through a zone of granodiorite to granite. This change is reflected by an increase from margin to core in alkali feldspar and by an accompanying change in the composition of plagioclase from An_{38} to An_6 (Fig. 14) (Hunt, 1970).

The narrow contact metamorphic aureole in the volcanic rocks around the pluton reported by Hunt (1970) was not observed by the present author.

XENOLITHS

Xenoliths of country rock are present throughout the intrusive body but are most abundant near its margin. They vary in size from about 6 cm to over 75 cm in diameter. They are largest and most angular near the margin of the stock. Ten to fifteen metres away from the contact, the xenoliths lose their angular shape and decrease in size. Although pillow lava, bedded volcaniclastic rocks and volcanogenic sediments have been recognized, the majority of the xenoliths are now hornblende gneiss or schist.

DYKES AND VEINS

Dykes 3 to 4 m thick and containing phenocrysts of feldspar and pale blue quartz are common in the volcanic rocks surrounding the stock. Similar dykes have been reported to be abundant adjacent to small bodies of "quartz-eye" granite north of Elbow Lake and just west of Sewell Lake (Stockwell, 1935). Finer grained equivalents, called porphyry and rhyolite dykes by Stockwell (1935), crosscut both the country rocks and the "quartz-eye" granite. The southeast trending dykes are abundant in the volcanic rocks close to bodies of "quartz-eye" granite.

Pegmatite, aplite and quartz veins are locally abundant. The pegmatite and aplite occur in irregular patches, pods and dykes from one metre to tens of metres across. Stockwell (1935) reported that pegmatites were not found in or near bodies of "quartz-eye" granite, but Quaraishi (1967), Hunt (1970) and the present author have observed many occurrences near these bodies that can be traced for up to 100 m. Quartz veins, 1 to 30 cm wide, occur in both the volcanic rocks and in the stock. Where they cut xenoliths the veins carry sulphides. Gold is reported to occur in quartz veins close to or at the contact of the stock and the volcanic rocks (Stockwell, 1935; Hunt, 1970).

CONTACT RELATIONSHIPS

Contacts are sharp and discordant. At the western contact, the tonalite cuts the bedding, foliation and cleavage in the host volcanic rocks. Intense warping and vertically plunging drag folds in the country rock are present along the northwestern contact but were not observed elsewhere. The southern contact is steeply dipping to the southwest and is extremely sharp (Hunt, 1970). Numerous dykes extend from the pluton and younger dykes intrude its western and northern margins.

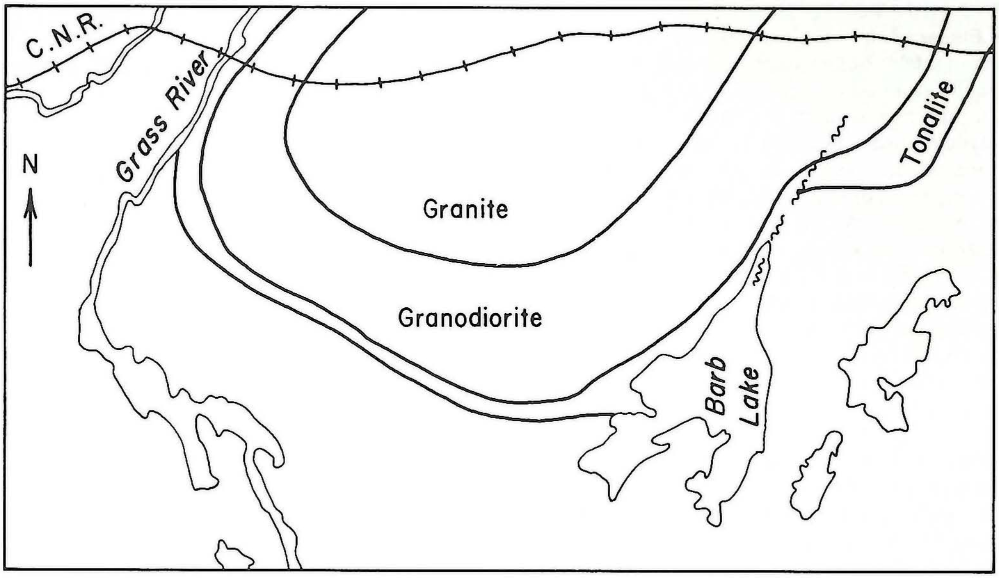

FIGURE 13: Schematic interpretation of compositional zoning in the southern part of the Elbow Lake Stock (modified after Hunt, 1970).

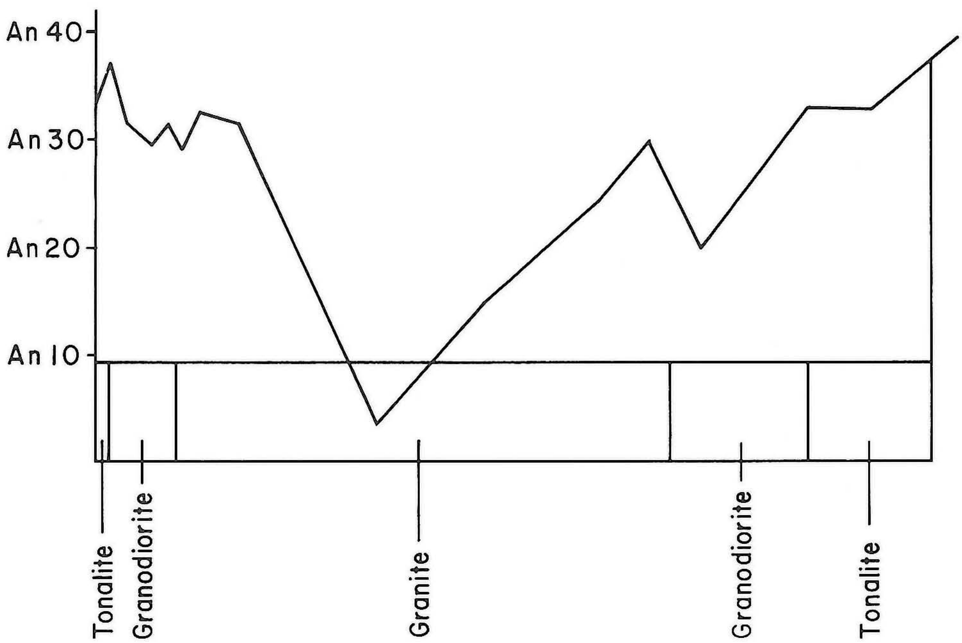

FIGURE 14: Variation in plagioclase composition in the Elbow Lake Stock in a section taken along the C.N. Railway (modified after Hunt, 1970).

DEFORMATION AND METAMORPHISM

The rocks in the Elbow Lake Stock are relatively undeformed, however, they do contain a faint but widespread foliation. Quartz at the margin of the stock is strained and slightly granulated.

Quaraishi (1967), concluded that the stock was intruded following the regional metamorphism of the country rocks because the stock did not appear to have been affected by regional metamorphism. However, the contact relationships, the faint but widespread foliation in the stock, the narrow but pronounced metamorphic aureole around the stock, the absence of cleavage or well developed foliation in the xenoliths and the major fold axial traces that parallel plutonic contacts (Hunt, 1970) all suggest that intrusion of the stock predated deformation and metamorphism and that the pluton acted as a buttress against which the volcanic rocks were more highly deformed.

ALTERATION

Three distinct zones of alteration are recognized within the pluton. In the outer zone plagioclase is dusted with sericite whereas the mafic constituents are virtually unaltered. In the middle zone the amount of sericite in plagioclase is greater than in the outer zone, and, in addition, chlorite replaces the edges of biotite and hornblende crystals and sphene is rimmed by ilmenite. In the core zone, the euhedral crystal shapes of the plagioclase, observed in the other two zones, are partially destroyed and there is extensive replacement by sericite, epidote, and carbonate. The mafic minerals are replaced by chlorite or chlorite and epidote. A high potash feldspar to plagioclase ratio in the core zone is probably a primary feature of the pluton. Microcline and antiperthite are unaltered and generally interstitial to plagioclase and quartz.

Quaraishi (1967) attributed the increase in intensity of the alteration from the margin to core of the stock to be due to late magmatic hydrothermal alteration. He suggested that the hydrothermal fluids came from within the stock itself. It is suggested here that the concentric composition zonation of the stock noted by Hunt (1970) is also a consequence of this hydrothermal alteration, which resulted in an increase of potassium feldspar and albitic plagioclase in the core of the stock.

MINERALIZATION

Minor disseminated pyrite occurs in the outer margins of the pluton, and is particularly abundant in the southwestern appendage. Disseminated magnetite is ubiquitous but is more prevalent in the outer margins.

Disseminated pyrite and minor chalcopyrite are present in volcanic rocks cut by dykes and quartz veins spatially related to the pluton.

6. FOURMILE ISLAND INTRUSION

Porphyritic tonalite, the "quartz-eye" granite of Stanton (1947) and Harrison (1949), occurs in an area 5 km in length and 600 m maximum width, at the south end of Reed Lake on Fourmile Island (Fig. 1). It intrudes Amisk Group basic volcanic rocks, pillowed andesite and chlorite schist (Stanton, 1947; Harrison, 1949; and Rousell, 1970). Contacts are not well exposed but appear to be fairly sharp and to be conformable to bedding in the host volcanics. Enclaves of country rock are numerous and are partially assimilated. The quartz diorite is locally sheared and silicified. Chloritic alteration is pervasive. Gold mineralization accompanied by minor chalcopyrite is present in quartz veins filling shears in weakly mineralized shatter zones and weak siliceous stockworks (Stewart, 1977).

PORPHYRITIC TONALITE

The porphyritic tonalite is pink to grey and locally greenish, medium grained, porphyritic and generally massive, has a schistose texture near the contacts and resembles the porphyritic tonalite in the Cliff Lake Stock.. Phenocrysts of sodic andesine (4 mm) averaging An_{36} comprise approximately 45 per cent of the rock and 5 mm white to pale blue quartz aggregates constitute 40 per cent of the rock. Chlorite, the main mafic mineral, generally comprises 5 per cent of the rock but locally forms up to 15 per cent. Accessory carbonate, magnetite, biotite and allanite (Russell, 1970) are present in minor amounts. At the east end of the island, the rock matrix is fine grained and the rock could be classified as "quartz porphyry".

Chlorite is abundant in local shear zones. Many of these shear zones are quartz-filled and their wall rocks are silicified.

COUNTRY ROCKS

The country rocks are pillowed basalts and andesite that have been metamorphosed to the greenschist facies. They contain elliptical quartz and carbonate filled cavities 3 to 4 mm in diameter, that are considered to be deformed amygdules. Andesites are generally massive, but are locally pillowed. Rocks interpreted to be volcaniclastic sediments contain octahedra of magnetite.

XENOLITHS

Xenoliths of country rocks occur throughout the intrusion. They are narrow, and some have strike lengths up to tens of metres. The long direction of the xenoliths trends parallel to the bedding and foliation in the country rocks. The xenoliths have been altered to chlorite schist and the attitude of the strong schistose fabric in them is the same as that of the country rocks and the intrusion. All of the xenoliths have been silicified and chloritized.

CONTACT RELATIONSHIPS

Contacts are poorly exposed. Where observed, they are concordant with bedding and foliation in the country rock and the intrusive rock is sheared and schistose. Cross-cutting relationships were not observed. The intrusion is interpreted to be a sill.

ALTERATION

Silicification and chloritization were the most prominent alteration processes in the intrusion. The silicification may have been synchronous with or even postdated the deformation that produced the shearing in the intrusion.

Microscopically, plagioclase is partially altered to sericite, and chlorite; biotite and hornblende are altered to epidote. Locally, chlorite is abundant and this may be related to the assimilation of xenoliths of the country rocks.

It is not known whether the alteration was hydrothermal or metamorphic in origin.

MINERALIZATION

Numerous gold occurrences have been reported to occur at Fourmile Island (Stanton, 1947; Harrison, 1949; Rousell, 1970; Stewart, 1977). All these occurrences are similar and consist of quartz veins and stringers concentrated in sheared, fractured and silicified zones in the porphyritic intrusion. Chalcopyrite, as disseminated grains and as coarsely crystalline stringers, is reported to occur at the eastern end of Fourmile Island by Harrison (1949) and Stewart (pers. comm., 1977) but was not observed by the author. Pyrite, locally disseminated in the porphyritic tonalite, occurs in stringers associated with "shattered" zones and as discrete cubes in quartz veins and silicified rocks. Sphalerite, although reported by Harrison (1949) was not observed by the author nor by Stewart (pers. comm., 1977).

7. CHISEL LAKE INTRUSION

Porphyritic tonalite outcrops in a large U-shaped body and as two smaller concordant bodies (Harrison, 1949) in the Chisel Lake and Snow Lake area (Fig. 1). They generally have conformable contacts but locally cut the host volcanic rocks (Harrison, 1949; Williams, 1966). Xenoliths of country rock are numerous in the contact zones of the intrusions and are also present locally within the intrusive bodies. A weakly developed foliation and/or lineation is common. Where they occur together, the lineation is located within the plane of the foliation. These imposed fabrics persist across contacts and are parallel to fabrics in the surrounding country rocks (Williams, 1966).

The origin of this rock is controversial. Harrison (1949) regarded it as intrusive; Russell (1957) favoured a sedimentary origin and Williams (1966) suggested that it is metamorphosed crystal tuff. On the basis of field relationships and similarities with the Cliff Lake and Elbow Lake Stocks the present writer supports Harrison's (1949) interpretation of an intrusive origin.

PORPHYRITIC TONALITE

Euhedral plagioclase (oligoclase) and grey or blue quartz "eyes" which together account for approximately 80 per cent of the rock are set in a fine grained grey to pink matrix. Mafic constituents are biotite and hornblende and accessory pyrite and pyrrhotite are present locally.

The quartz "eyes" consist of one or more large crystals that are generally elliptical and display undulose extinction. In the groundmass plagioclase forms a mosaic with quartz. Textures are variable and depend upon the degree of development of the imposed foliation. Schistose to gneissic textures with porphyritic metacrysts prevail in the contact zone however, away from the contacts, the rock is massive.

COUNTRY ROCKS

Country rocks include pillowed and amygdaloidal mafic volcanic rocks, amphibolite, felsic volcanics, sedimentary rocks and staurolite-garnet schists.

At the extreme western contact of the intrusion, the country rock is a fine grained, grey, massive, very siliceous, garnet-bearing rock (Unit A of Harrison, 1949). Elsewhere in the File Lake area (Harrison, 1949) and particularly in the vicinity of Ghost Lake and Chisel Lake, these rocks are recognized as siliceous flows and pyroclastic rocks with reworked sedimentary equivalents at the stratigraphic top of the unit (Williams, 1966; Gale and Koo, 1977).

At the eastern contact of the body, just west of Tent Lake, the country rocks are pillowed basalt, staurolite-garnet schists, and amphibolites (metavolcanic rocks) (Williams, 1966).

East of the axial planar trace of the Threehouse Lake syncline, the countryrocks on both the northwest and southeast of the intrusions are dominantly pillowed and massive mafic volcanic rocks with local occurrences of silicic volcanic rocks (Gale and Koo, 1977). The intrusion is considered to occupy the core of a major antiformal structure in the Anderson Lake area and also was probably folded along with the volcanic rocks in this early structure (G. Gale, pers. comm., 1977).

XENOLITHS

Numerous concordant enclaves of country rock are present in the contact zone. Gradational contacts of amphibolitic xenoliths within the enclosing porphyritic tonalite are probably due to xenolith assimilation. Within the main mass of porphyritic tonalite conformable intercalations of amphibolite, varying from 5 to 150 m^2 and from square to rectangular are abundant locally. In places, a biotite-rich zone rims the xenoliths at their contact with the porphyritic tonalite.

CONTACT RELATIONSHIPS

Harrison (1949) recognized that the intrusion had metasomatized the country rocks and therefore, in many places he arbitrarily defined the contacts between the intrusion and country rocks. Williams (1966) described the contacts as being conformable and sheeted, and where he observed definite disconformable relationships, the contact zone was reported to be several metres wide.

Where the U-shaped intrusion terminates on the eastern and northwestern ends, contact relationships are unclear, although interfingering and gradational relationships prevail. West of Chisel Lake, along the C.N. Railway, at the extreme western contact of the intrusion, dykes of the porphyritic tonalite cut silicic volcanic rocks.

ALTERATION

Alteration products are sericite, epidote, chlorite and minor potassium feldspar. Regional metamorphism to almandine amphibolite facies resulted in the recrystallization of the matrix and has obscured primary relationships. Secondary mineral assemblages in the porphyritic tonalite are considered to be a metamorphic rather than hydrothermal alteration products.

MINERALIZATION

Disseminated pyrite and pyrrhotite are the only sulphides that were observed in the intrusion; however, several volcanogenic massive sulphide deposits hosted in mafic and siliceous volcanic rocks occur within 500 metres of the porphyritic tonalite (Harrison, 1949; Gale and Koo, 1977).

8. WEKUSKO LAKE INTRUSION

Outcrops of the porphyritic intrusive bodies in this area (Fig. 1) are small and lichen covered.

The rocks are similar in composition, mineralogy and texture to the porphyritic tonalite in the Cliff Lake and Elbow Lake Stocks. Contact relationships were not observed, nor was any mineralization. Stockwell (1937) gives good descriptions of these intrusive bodies.

Sill-like bodies of this rock less than 10 m across, were observed in association with gold-bearing quartz veins at the McCafferty, Molly and Bachelor properties.

AGE OF INTRUSION

Prior to 1971, the Amisk Group was thought to be of Archean age and was deformed by both the Kenoran (2560 Ma) and Hudsonian (1800 Ma) orogenies (Leech et al., 1963; Anhaeusser et al., 1969). Mukherjee et al. (1971) concluded, on the basis of Rb-Sr isotopic data and structural studies, that the Amisk Group is Aphebian and was therefore subjected to only the Hudsonian orogeny. They placed the beginning of volcanism at 1865 Ma and the end of the Hudsonian orogeny at 1800 Ma.Sangster (1972b), from single stage model lead ages for the Flin Flon (1950 ± 44 Ma) and Schist Lake (1800 ± 44 Ma) mines supported these views and concluded that the ore bodies are coeval with their host rocks. Recently MacQuarrie (pers. comm., 1977) obtained an 1880 Ma zircon (U/Pb) age for a sample of tonalite collected from the southwestern margin of the Cliff Lake Stock.

Secondary fabrics (schistosity) in the porphyritic intrusions of the Flin Flon volcanic belt persist across contacts and are parallel to the schistosity in the country rocks. Bruce (1918), Stockwell (1946) and Burwash et al. (1964) reported that pebbles of the Cliff Lake Stock, or a rock identical to it, are contained in Missi conglomerate. The present author observed several pebbles in Missi conglomerate that look identical in hand specimen to the porphyritic tonalite of the Cliff Lake Stock. Near Creighton Creek, east of the Hanson Lake Road, approximately 2 km northwest of Flin Flon, granitic boulders suspiciously similar to parts of the Annabel Lake Pluton, in Saskatchewan, occur in Missi conglomerate which unconformably overlies the Amisk Group (Kirkham, 1974).

From field evidence and isotope data it can be suggested that the porphyritic intrusions in the Flin Flon greenstone belt are probably of Aphebian age, predate the Missi Group and were deformed and metamorphosed during the Hudsonian orogeny.

GRANITIC ROCK CHEMISTRY

The composition fields for the porphyritic intrusions studied are graphically presented in Figure 15. Chemical analyses are presented in Table II.

The most mafic intrusion studied is the Whitefish Lake Porphyry. No chemical analyses were obtained from the three small intrusions at Nisto Lake, however they are mineralogically and texturally similar to the Whitefish Lake Porphyry and are therefore assumed to be quartz monzodiorite in composition. The Cliff Lake Stock and the Chisel Lake intrusions are tonalite and although data are not available for the intrusions at Fourmile Island and Wekusko Lake, similarities in mineralogy indicate that they are also tonalite. The Elbow Lake Stock is compositionally zoned from tonalite to granite as reflected by the variation in plagioclase composition (Fig. 14).

Whole rock geochemical data (Table II) for four of the intrusions is presented as a plot of major elements versus silica (Fig. 16). The sample population is small and much more data is required before positive statements about petrologic relationships can be made. However, the available data indicated that in each intrusion Al_2O_3, CaO, MgO and total Fe decrease, and that K_2O and Na_2O increases as the SiO_2 content increases. These variations could have resulted from differentiating magmas, magma contamination, and/or a superimposed deuteric hydrothermal alteration.

AEROMAGNETIC INTERPRETATION

With the exception of the Elbow Lake Stock, the aeromagnetic signatures of the porphyritic intrusions are similar to those of their host rocks. At Elbow Lake, the 2500 gamma contour (flight altitude of 1000 feet above ground level) parallels the shape of the stock. However the size of most intrusive bodies is small or narrow compared to the Elbow Lake Stock and regional magnetic effects probably mask any local variations around the smaller plutons.

Removal of the regional magnetic effects could result in a residual in which the intrusive bodies could be outlined (I. Hosain, pers. comm., 1979).

MODE OF EMPLACEMENT

The Cliff Lake Stock, Whitefish Lake Porphyry and the Elbow Lake Stock are characterized by sharp crosscutting contacts with the volcanic rocks, limited emplacement related structural disturbances, stoping, assimilation of xenoliths and, in the Cliff Lake Stock, breccia and "shattered" zones. These features have been interpreted by Stringham (1966), Lowell and Gilbert (1970) and Sillitoe (1973) to indicate passive emplacement of plutons.

Concordant sheeted contact zones with schistose and gneissic features, such as those seen in the Chisel Lake and Fourmile Island intrusions, are interpreted as evidence of forceful emplacement (Stringham, 1966).

The sparse outcrop in the areas of the Nisto Lake and Wekusko Lake intrusions preclude conclusions as to their mode of emplacement.

ORIGIN

Sharp contacts, oscillatory zoned plagioclase, abundance of xenoliths, contact metamorphic aureoles in country rock and chilled border zones in the plutons support a magmatic intrusive origin for the porphyritic intrusions in the Flin Flon volcanic belt.

With more analytical data it may be possible to establish the nature of the magma and perhaps establish a genetic relationship between the volcanism and plutonism in the Flin Flon volcanic belt.

DISCUSSION

Although presently accepted genetic models for porphyry deposits (Sillitoe, 1973) have been developed for deposits in continental margin environments, the island arc porphyry deposits are probably similar except for the absence of a thick pre-volcanic basement and the tendency for the intrusive host rock to the mineralization to be generally K_2O deficient and more mafic as compared to the continental margin intrusions (Kesler, et al. 1975; Gustafson, 1978; Maron and McDonald, 1978).

Porphyry-type mineralization associated with high-level felsic intrusions has been described from several localities in the Canadian Shield (Davies, 1965; Kirkham, 1972b, 1973; Cimon, 1973; Ayres et al., 1973; Ayres and Averill, 1974; Findlay, 1976; Riley et al., 1971). These intrusions are sub-volcanic in nature, pre-tectonic and are thought to be associated with felsic volcanism.

The porphyritic intrusions in the Flin Flon volcanic belt are spatially associated with felsic volcanic rocks (Fig. 1), however it has not yet been documented that the two are genetically related.

The porphyritic intrusions in the Flin Flon volcanic belt and those that host porphyry mineralization in island arc terranes lie in the same compositional fields (Fig. 15). Also the Rb-Sr values for the Cliff Lake Stock and Whitefish Lake Porphyry are less than 0.2 (Table II), whereas the average for continental deposits is 0.3 to 0.4 (Kesler et al., 1975).

Probably the most diagnostic feature of all porphyry deposits is their extensive hydrothermal alteration which is arranged in zonal shells decreasing in intensity outward and upward from a deep central potassium silicate core (Lowell and Gilbert, 1970).

Weak potassium silicate alteration is present locally in the Cliff Lake Porphyry, Whitefish Lake Porphyry and the Elbow Lake Stock. Propylitic alteration, accompanied by stockworks of quartz and potàssium feldspar grades outwards from the potassium silicate alteration zone. In the propylitic alteration zone biotite and hornblende are largely replaced by chlorite, plagioclase is partially altered to sericite, and minor pyrite and ubiquitous magnetite occur as disseminations in the rocks. The alteration mineral assemblages in the plutons are interpreted to be hydrothermal and to have formed by processes similar to those operating in porphyry Cu-Mo deposits.

The association of gold and porphyry Cu-Mo deposits is well documented. Examples of this association occur in the Upper Triassic Intrusions at Copper Mountain in British Columbia, and in Precambrian strata in the McIntyre Mine, in Ontario. Deposits in the southwest Pacific are probably the best known examples of this association (Kesler, 1973; and Gustofson, 1978). In the Flin Flon volcanic belt, the association of gold and porphyritic intrusive rocks has been established (Stockwell, 1937; Tanton, 1941; Harrison, 1949; McGlynn, 1959; and Stewart, 1977).

If there is a temporal, spatial and genetic relationship between the porphyritic intrusions and volcanism, there may also be similar relationships between porphyry-type mineralization, precious metal deposits and volcanogenic massive sulphide deposits in the sense that the subvolcanic intrusions may bridge the gap between volcanism and plutonism (Fig. 17).

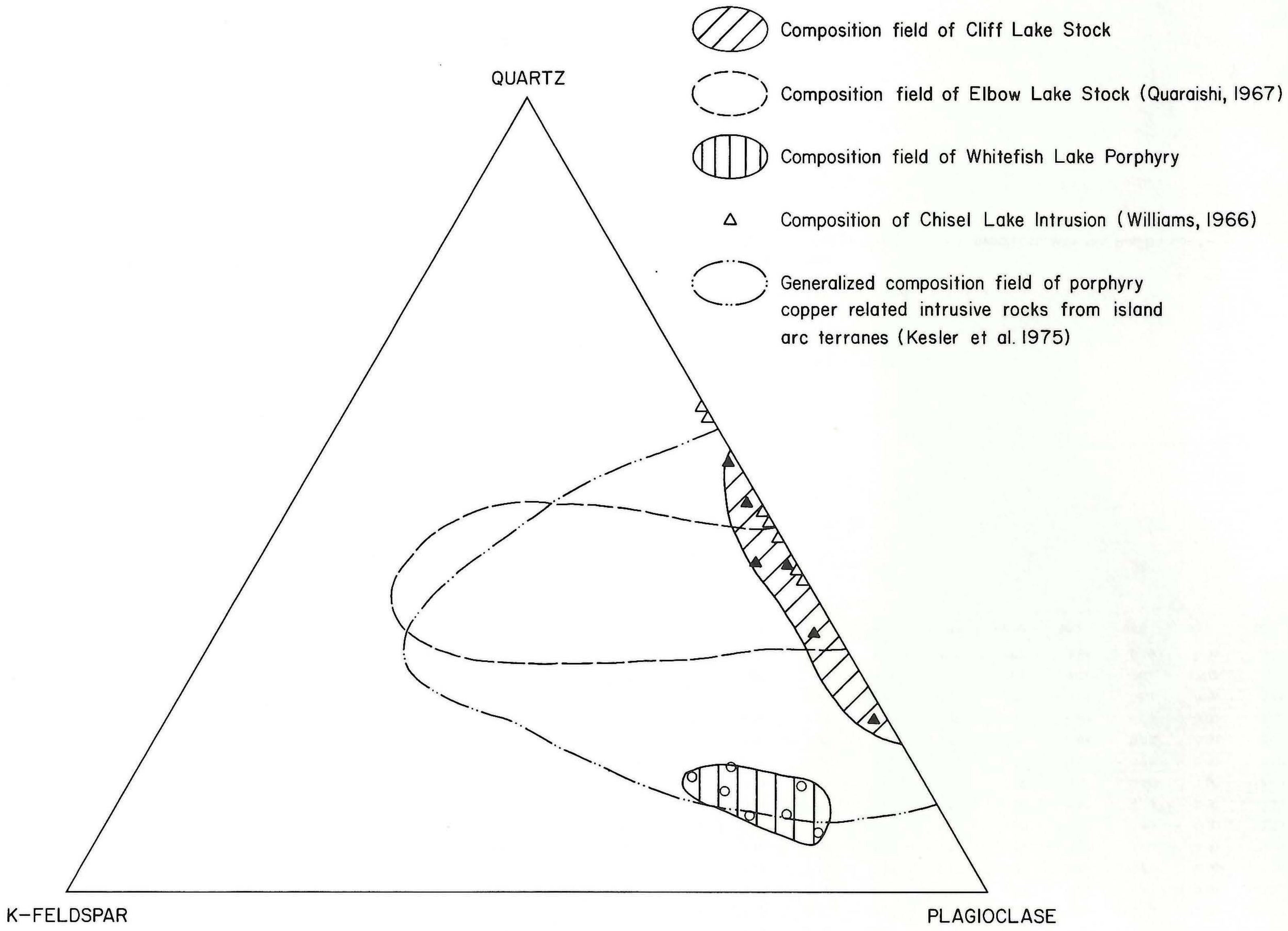

FIGURE 15: Modal analyses of porphyritic intrusions in the Flin Flon volcanic belt compared to that for porphyry copper related intrusive rocks from island arc terranes (Data points for this study: O — Whitefish Lake Porphyry, ▲ — Cliff Lake Stock).

TABLE II — CHEMICAL ANALYSES OF PORPHYRITIC INTRUSIONS

OXIDE WT. %	CLIFF LAKE PORPHYRY++ X416	X417	X418	X419	X420	WHITEFISH LAKE PORPHYRY++ X421	X422	X423	X424	X425
SiO_2	72.35	76.00	69.15	69.05	71.55	63.30	60.25	58.75	57.10	51.30
Al_2O_3	12.33	11.38	13.58	13.89	12.66	14.71	16.00	16.62	16.81	15.56
Fe_2O_3	1.27	0.71	1.12	1.94	0.79	ND	ND	ND	ND	ND
FeO	3.45	2.39	4.16	3.37	3.43	ND	ND	ND	ND	ND
CaO	2.72	1.21	2.80	2.80	1.26	4.38	4.26	4.60	4.61	4.51
MgO	0.62	0.77	1.47	1.17	1.90	2.99	3.23	3.17	3.49	6.48
Na_2O	3.98	4.55	3.79	3.66	3.78	4.60	4.05	3.77	3.46	4.06
K_2O	0.83	0.79	0.72	1.09	1.10	2.18	3.25	3.60	3.46	0.95
TiO_2	0.27	0.22	0.31	0.30	0.30	0.53	0.49	0.49	0.57	0.73
P_2O_5	0.06	0.04	0.06	0.06	0.06	0.22	0.19	0.21	0.24	0.36
MnO	0.07	0.03	0.10	0.08	0.02	0.07	0.09	0.10	0.11	0.14
H_2O	1.30	1.23	2.03	1.92	2.00	1.57	2.01	1.99	2.49	3.91
S	Nil	0.03	Nil	0.05	0.05	0.13	0.02	0.02	0.05	0.19
CO_2	1.03	1.08	0.67	0.20	1.51	0.33	0.48	0.86	0.72	1.62
TOTAL	100.28	100.43	99.96	99.58	100.41	ND	ND	ND	ND	ND
PPM										
Cu	10	19	24	20	15	440	22	11	800	800
Mo	5	5	5	10	5	76	2	3	6	3
Pb	<1	<1	<1	<1	<1	<1	<14	<1	<1	<1
Zn	46	51	67	61	67	40	60	58	69	106
Ni	<1	<1	<1	<1	<1	ND	ND	ND	ND	ND
Cr	<10	<10	<10	<10	<10	ND	ND	ND	ND	ND
Rb	15	18	11	20	21	50	87	106	113	19
Sr	173	141	145	200	126	800	860	710	800	440

OXIDE WT. %	ELBOW LAKE STOCK+ A-5-65	A-6-65	A-11-65	A-19-65	A-23-65	A-24-65	CHISEL LAKE° Wf 1655	Wf 1656	Wf 1657	Wf 1658	Wf 1659
SiO_2	66.20	67.80	62.80	66.40	65.70	63.00	74.40	77.30	77.30	77.00	72.50
Al_2O_3	15.50	15.50	15.75	16.20	15.85	16.80	11.80	10.70	10.90	11.60	10.90
Fe_2O_3	3.43	2.24	3.10	2.13	1.67	2.79	0.70	0.40	0.60	0.20	0.40
FeO	1.14	1.24	2.54	1.68	2.12	2.24	1.35	3.21	2.98	2.36	5.36
CaO	4.03	3.17	5.45	4.10	3.85	5.40	2.80	1.20	0.60	0.80	2.40
MgO	3.00	2.10	3.25	2.50	2.35	2.55	0.50	0.80	0.90	0.30	1.00
Na_2O	2.77	3.19	2.70	3.06	3.40	3.06	4.60	4.10	3.60	3.80	2.20
K_2O	2.04	2.64	2.64	2.55	2.32	1.72	0.60	0.40	1.90	2.30	2.10
TiO_2	0.29	0.19	0.26	0.15	0.35	0.26	0.20	0.20	0.10	0.10	0.20
P_2O_5	0.12	012	0.25	0.16	0.44	0.32	0.00	0.00	0.00	0.00	0.00
MnO	0.17	0.06	0.12	0.09	0.08	0.12	0.00	0.00	0.00	0.00	0.10
H_2O	0.95	0.83	0.84	0.48	0.81	0.76	0.38	0.53	0.64	0.44	0.98
S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CO_2	0.28	ND	ND	ND	ND	ND	1.34	0.19	0.31	0.03	0.51
TOTAL	99.92	99.08	99.70	99.50	98.94	99.02	98.7	99.0	99.8	98.9	98.7

*Analytical methods
Colour Spectrometer — SiO_2, Al_2O_3, Fe_2O_3, FeO, TiO_2, P_2O_5
Atomic Absorption — CaO, MgO, Na_2O, K_2O, MnO, Cu, Mo, Pb, Zn, Ni, Cr, Rb, Sr
Penfield Moisture — H_2O
Leco Induction Furnace — CO_2, S

ND Not determined or not reported.
+ From Quaraishi (1967).
° From Williams (1966).
++ This study. Analyses by the staff of the Analytical Lab. Man. Min. Res. Division.*

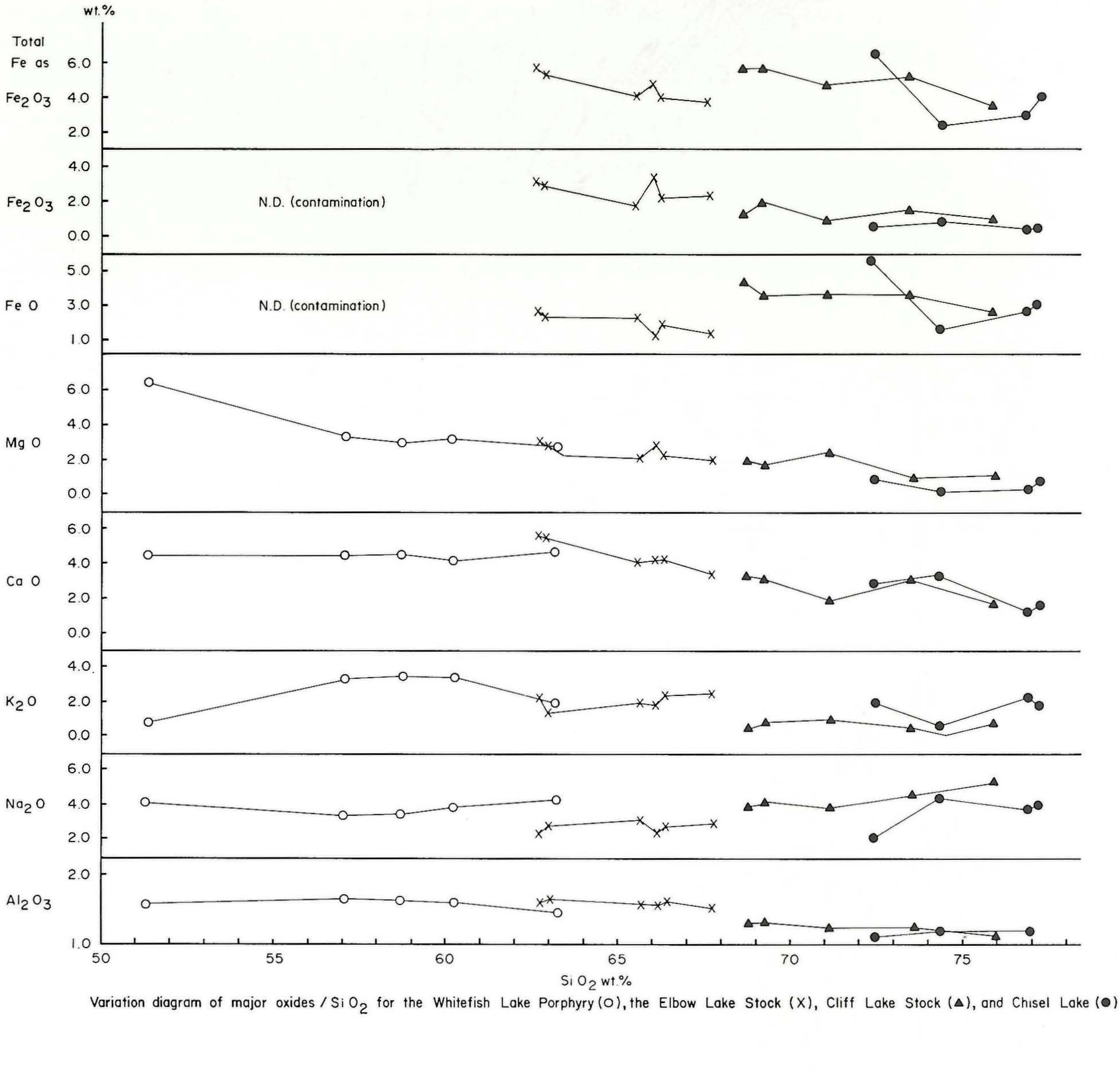

FIGURE 16: Variation diagram of oxides vs SiO_2 for the Whitefish Lake Porphyry (O), the Elbow Lake Stock (X), Cliff Lake Stock (▲) and Chisel Lake Intrusion (●). Data from Quaraishi (1967), Williams (1966), Baldwin (this study).

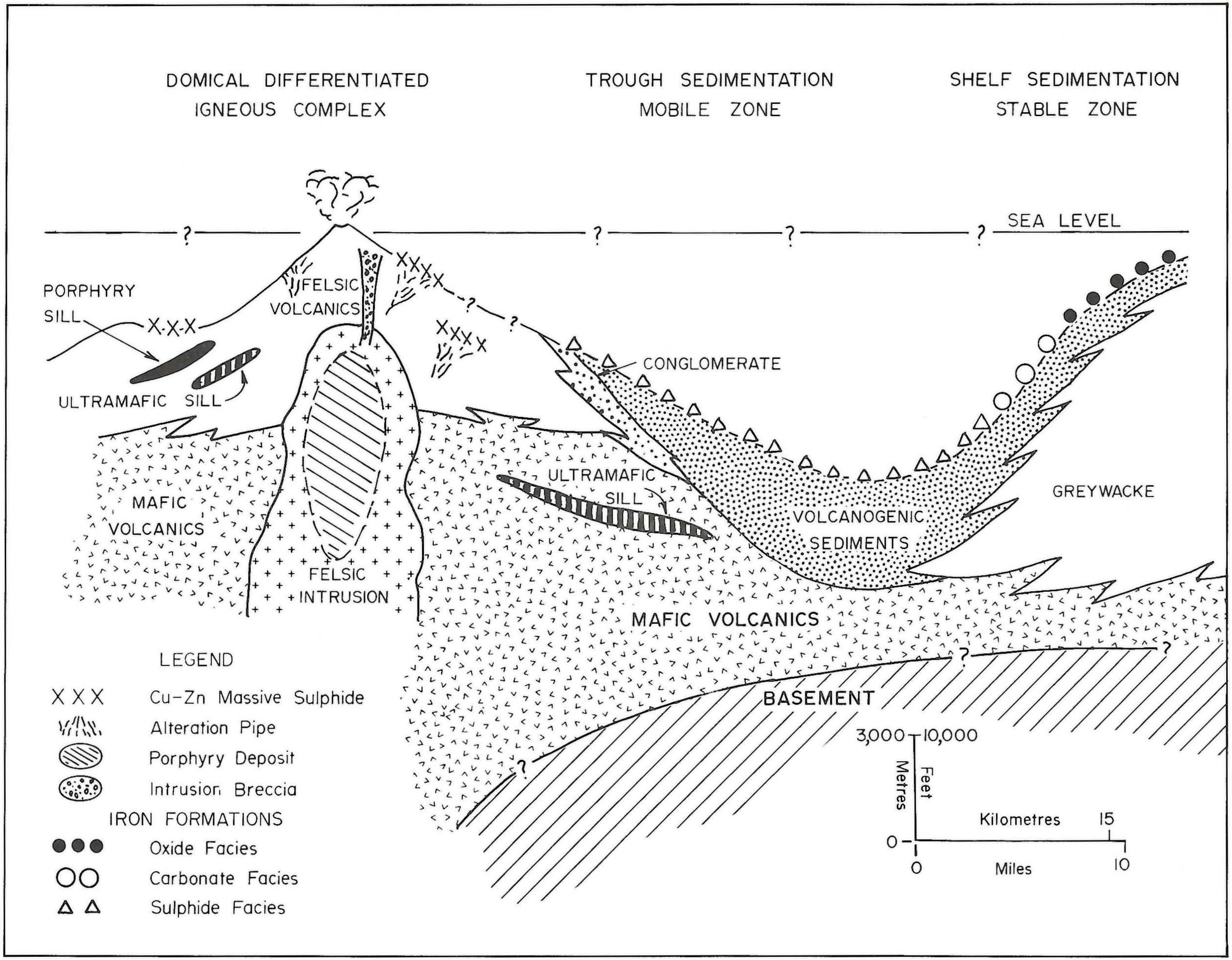

FIGURE 17: Schematic tectonic, stratigraphic and mineral deposit relations in a submarine volcano-sedimentary complex. (Modified from Hutchinson et al. 1971; Ridler, 1973; Sangster and Scott, 1976).

CONCLUSIONS

The small sized (less than 75 km^2) stock-like or sill-like porphyritic intrusions in the Flin Flon volcanic belt may be sub-volcanic intrusions that were possibly coeval with Amisk felsic volcanism. The composition of these intrusions, their contact relationships with the host rocks, their internal structures, and their alteration and mineralization are similar to those of Mesozoic and younger porphyritic intrusions in island arc terranes. Some of the latter intrusions host large, low grade porphyry copper and molybdenum deposits with gold as an important by product. Based on the information available, there appears to be some similarity between some of the porphyritic intrusions in the Flin Flon volcanic belt and those that contain porphyry-type copper and molybdenum deposits elsewhere in the world.

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