GEOLOGIC SETTING OF PRECIOUS METAL MINERALIZATION IN THE SILVER CREEK TO ISLAND LAKE AREA, MARQUETTE COUNTY, MICHIGAN

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by

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ABSTRACT

A 10 mi.^{2} (25.9 km.^{2}) area northwest of Marquette, Michigan was geologically mapped at a scale of 1:6,000. The mapped area includes sections 3, 10, 11, 12, 13, 14, 15, 23, 24, and 25 of T. 49 N., R. 28 W. The Silver Creek Prospect and many old exploration trenches are located within the area.

The Silver Creek to Island Lake area is dominated by metamorphosed and variably deformed Archean volcanic and intrusive rocks. The oldest rocks are Archean pillowed basalts with minor felsic pyroclastic deposits which have been intruded by Archean gabbro and diabase. These mafic rocks have been intruded by multiple stocks of Archean granodiorite. Rhyolite intrusives cross-cut the basalts and gabbros and may have been contemporaneous with the granodiorite intrusions. The Archean granodiorite has been cross-cut by Lower Proterozoic metadiabase. There are a few small isolated outcrops of Lower Proterozoic slates and metagraywackes to the south and west of the Archean rocks in the Mulligan Plains and to the northeast in the Clark Creek Basin. All Archean rocks are cut by reversely polarized Keweenawan diabase.

The Archean basalts, rhyolites, and granodiorites are subdivided into highly foliated and (relatively) nonfoliated varieties. In addition, the basalts and gabbros are subdivided into a highly altered variety. The basalts are generally amphibole-chlorite-plagioclase metabasalts and chloritic schists. The highly altered basalts are chlorite-sericite-carbonate-quartz metabasalts. The gabbros are medium- to coarse-grained amphibole metagabbros. The rhyolite intrusives are dominantly quartz-sericite schists. The granodiorites include granodiorite, tonalite, quartz monzodiorite and quartz diorite and are interpreted as syntectonic.

The stratigraphic orientation of the basalts is uncertain due to lack of recognizable pillows and bedding and to the high degree of deformation in the area. Pillows give a top direction to the south in the southern sections and to the north in the northern sections.

The major structure in the area is a large steeply plunging synformal anticline. The fold symmetry is outlined by a gabbro sill and the Hill's Lakes Pyroclastic Member. The granodiorites intrude the fold hinge in sections 13 and 14. The typical Archean axial planar foliation in the area strikes N 68° W and dips 86° N. The typical Lower Proterozoic cleavage strikes N 74° W and dips 51° S. The rhyolite dikes typically strike N 70° W to N 60° W, that is, subparallel to the Archean foliation in the area. They appear to intrude the axial planar foliation and are also syntectonic, if they are contemporaneous with the granodiorites. Faults in the area are of two general ages: older ones trending roughly E-W that are truncated by younger H-S trending ones. Shear zones are common and are most prevalent in the basalts, but many are too small to be shown on the map. The shear zones are of both brittle-ductile and ductile types. Displacement is probably greatest in the vertical sense, but horizontal displacement is evident in deformed pillows.

The pillowed basalts are metamorphosed from lower greenschist to upper amphibolite facies. The increase in metamorphic grade appears to be associated with contact metamorphism related to the emplacement of the granodiorite plutons. The lower greenschist metabasalts are characterized by chlorite-actinolite-albite-clinozoisite/epidote with minor carbonate and sericite and have relict magmatic textures. The upper amphibolite facies metabasalts are characterized by hornblende-calcic plagioclase-hypersthene and are schistose. The retrograde nature of the basalt mineral

assemblages indicate that the mineralization postdates the Archean metamorphism. Altered basalts are associated with faults and shear zones and consist of chlorite-albite-carbonate-epidote-sericite-quartz.

Quartz veins are found in all rock types, are of multiple generations, and are locally abundant. For example, in section 24 a quartz vein is approximately 110 ft. (33 m.) thick. The epigenetic quartz veins are commonly hosted in highly sheared, chloritized and sericitized basalts and gabbros and highly sheared and sericitized granodiorite and rhyolite intrusives.

Anomalous concentrations of gold are associated with pyrite, chalcopyrite, pyrrhotite, and arsenopyrite and occasionally galena and sphalerite in quartz veins. At the Silver Creek Prospect quartz veins with galena, sphalerite, chalcopyrite, pyrite, and minor arsenopyrite and pyrrhotite are cross-cut by siderite veins. The structure, alteration, rock types, and numerous quartz veins make the Silver Creek to Island Lake Area favorable for precious metals.

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INTRODUCTION

The purpose of this project was to provide a geological map of an area north of the Dead River Storage Basin in Marquette County (Fig. 1) which encloses several old precious metal prospects. The major rock units and structures were mapped at a scale of 1:6,000 (Plate I). Special attention was given to the evidence for and the nature of mineralization. This report presents a field description of the area supplemented by petrographlc and whole rock geochemical data.

ACKNOWLEDGEMENTS

This study has been funded by the Geological Survey Division of the Michigan Department of Natural Resources and the Department of Geology and Geological Engineering at Michigan Technological University. The field assistance of Roger Bond, Bill Swenor, Jennifer Daniels and Jennifer Huffman was greatly appreciated. We would like to extend our appreciation to Drs. Kalliokoski, Gregg and Johnson who read and commented on the thesis (Johnson, 1987) on which this report is based.

LOCATION

The field area is located northwest of Marquette, Michigan in Marquette County (latitude 37° 45' and longitude 46° 40') at the northwest end of the Dead River Storage Basin (Fig. 1). It is within the Champion and Negaunee quadrangles and includes sections 3, 10, 11, 12, 13, 14, 15, 23, 24, and 25 of T. 49 N., R. 28 W.

ACCESSIBILITY AND GEOGRAPHIC FEATURES

Access by car is good along either County Road 573 (Dear Lake Road), a paved road out of Ishpeming, and along the North Dead River Road (gravel) or County Road 510, a partially paved road out of Marquette, and along the Red Road (gravel) (Fig, 1). Access by foot is hampered by the 100 to 250 ft. cliff of Mulligan Creek which extends south along Mulligan Creek and southeast through sections 23, 24, and 25. This cliff is almost continuous except for a few breaks due to small creeks.

The Mulligan Plains are flat lying to gently rolling, sand-covered, and locally forested with jack pine. The highlands northeast of the cliff of Mulligan Creek are forested with mature stands of hardwood and smaller stands of red and white pine. Clark Creek Basin is a gently rolling sand plain forested with jack pine. The northeast corner of section 3 has been harvested for hemlock recently, and has produced a very thick secondary growth of hardwood 'whips'.

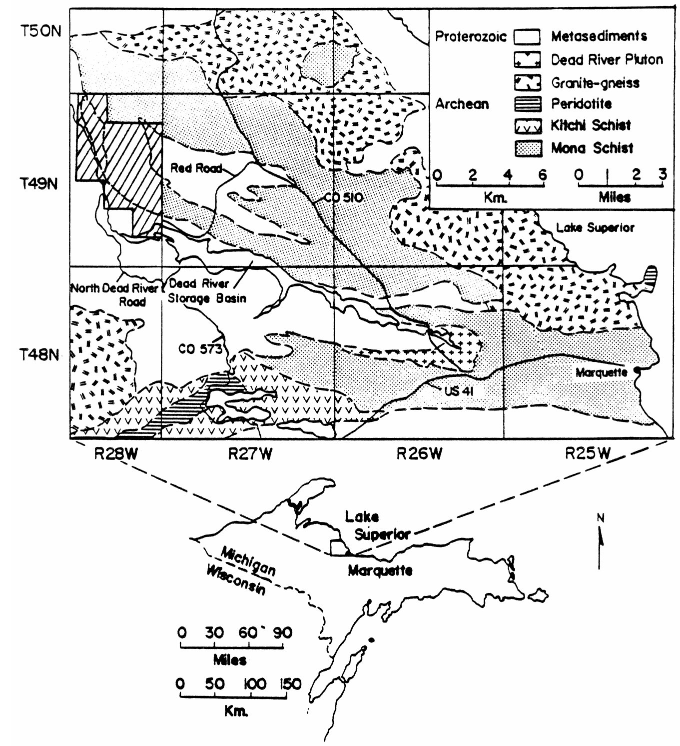


FIGURE 1.--Regional geology and location (diagonal ruling) of the Silver Creek to Island Lake Area (Modified from Morgan and DeCristoforo, 1980).

FIELD MAPPING

Field mapping was conducted during the summers of 1985 and 1986 at a scale of 1:6,000 by the compass and pace method from taped base lines. Traverses were spaced as necessary to allow reasonable lithologic correlations between them. In areas of particularly rugged relief traverses were abandoned and mapping was done directly on enlargements of the 1:25,000 topographic map. Where possible, contacts and major structures were walked out to assure geological accuracy. In areas of abundant ouctcrop (>70%), outcrops were mapped to a distance of approximately 250 ft. from the traverse line. Consequently some large outcrops were not mapped in their entirety and are shown open on the map.

LABORATORY PROCEDURES

Whole rock geochemistry was determined by X-ray fluorescence analyses on an automated Phillips wavelength dispersive spectrometer by T. J. Bornhorst at Michigan Technological University using the technique described by Rose and others (1986). FeO was determined by colorimetry (Fritz and Popp, 1986) and Fe_2O_3 was calculated by subtraction from the total Fe_2O_3 determined by XRF. H_2O- was determined by drying at 110° C overnight and H_2O+ by heating to 1000° C for two hours. CIPW norms were determined and are shown with petrographic descriptions. Whole rock geochemical components were determined for representative samples collected during the 1985 field season from sections 10, 15, 23, 24, 25 and the southern part of section 14. The location of samples for whole rock geochemistry, gold and silver assay, and petrographic description are shown in Appendix A. Gold was determined by combined neutron activation and fire assay and silver by inductively coupled plasma by Nuclear Activation Services Limited, Hamilton, Ontario, Canada.

Plagioclase compositions were determined by the Michel Levy technique when albite twinning was present and if twinning was absent by the relief relative to that of the mounting medium (n=1.54); albite, <1.54; calcic plagioclase, >1.54. The distinction between actinolite and hornblende was determined on the basis of color and ZAC (Winchell, 1961).

PREVIOUS WORK

Host of this area is not covered by geological maps at a scale of less than 1:62,500. The 7 1/2 minute geological maps of Gair and Thaden (1968), Puffet (1974), and Clark et.al. (1975) cover the Sands and Negaunee Quadrangles immediately east of this study area. The bedrock geologic map of the Negaunee southwest quadrangle (Clark et.al., 1975) includes the east half of section 25 and the southeast corner of section 24, T. 49 N., R. 28 W. The area is included in the 1:62,500 compiled bedrock geology of the Northern Complex by Bodwell (1972). The Morgan Gold Mining Company studied the area in the 1930's as part of a regional exploration program (unpublished maps and reports; Kelly, 1936) and Morgan and DeCristoforo (1980) provided a regional geologic description of the area.

GEOLOGIC SETTING

REGIONAL GEOLOGIC SETTING

The Silver Creek to Island Lake Area is located at the northwest end of the Dead River Basin on the north-vest trending limb of the Archean aged Ishpeming Greenstone Belt (see Fig. 1). On the south limb of the Ishpeming Greenstone Belt are the Kitchi Schist, dacitic, andesitic, and basaltic volcanoes, the Dear Lake Peridotite, a serpentinized peridotite, and the Mona Schist, a succession of mafic flows. This report covers the geology of a portion of the north limb.

The Ishpeming Greenstone Belt is bound to the north and west by Archean granitoid intrusions. Archean rock units have been metamorphosed to greenschist facies or higher. Lower Proterozoic metasediments in the Dead River and the Marquette troughs are in fault contact with the Archean rock units. Lower Proterozoic rock units in the Dead River trough have been metamorphosed to greenschist facies. Lower Proterozoic and Archean rock units are cut by east-west trending Keweenawan diabase dikes.

STRATIGRAPHY AND STRATIGRAPHIC NOMENCLATURE

The stratigraphic nomenclature used in this report is informal. The mapping of the Silver Creek to Island Lake Area is part of a cooperative systematic precious metals mapping program by the Geological Survey Division of the Michigan Department of Natural Resources and the Department of Geology and Geological Engineering of Michigan Technological University. It is anticipated that after further mapping, rock unit names will be formalized.

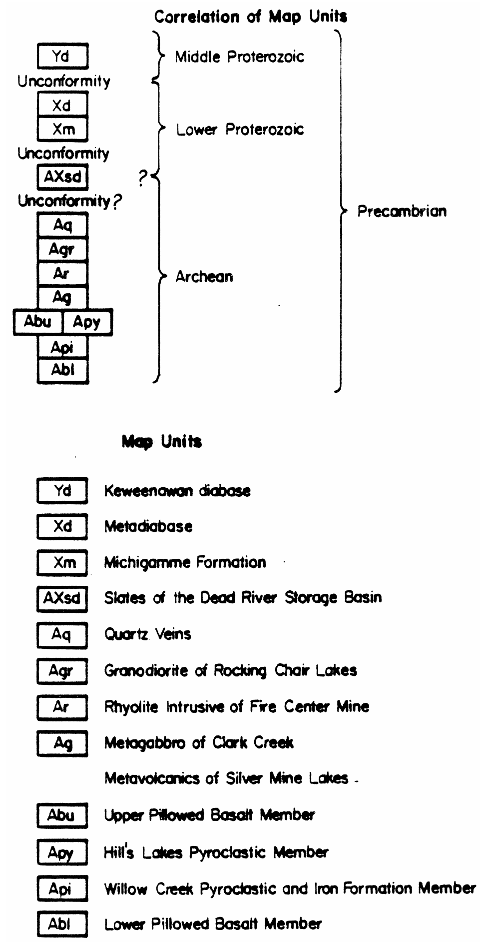


FIGURE 2.--Correlation diagram of map units north of the Dead River Basin. Compiled from Owens and Bornhorst (1985), Baxter et.al. (1987) and this study (see Plate I).

The Silver Creek to Island Lake Area is dominated by metamorphosed and variably deformed Archean volcanic and intrusive rocks (Fig. 2, Fig. 3). The oldest rocks are pillowed basalts (Metavolcanics of Silver Mine Lake) which have been intruded by gabbro and diabase (Metagab-bro of Clark Creek), and these in turn, have been intruded by multiple plutons of granodiorite (Granodior-ite of Rocking Chair Lakes). Rhyolite dikes and sills (Rhyolite Intrusive of Fire Center Mine) in the basalts and gabbros may be coeval with the granodiorite intrusions.

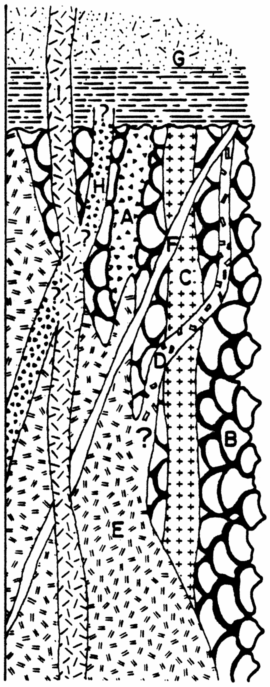


FIGURE 3.--Stratigraphic column cartoon of the Archean and Proterozoic units in the Silver Creek to Island Lake Area.

The Archean rocks have been intruded by Lower Proterozoic diabase (Metadiabase). There are a few small isolated outcrops of Lower Proterozoic slates and metagraywackes (Michigamme Formation) which are in fault contact with the Archean rocks in the Mulligan Plains and to the northeast in the Clark Creek Basin. The Archean and Lower Proterozoic rocks have been crosscut by Keweenawan diabase dikes.

MAJOR STRUCTURES

The major structure in the Silver Creek to Island Lake Area is a large scale steeply plunging synformal anticline (see Fig. 40). The symmetry of this fold is outlined by a gabbro sill and by the Hill's Lakes Pyroclastic Member.

Several generations of faults are evident in the Silver Creek to Island Lake Area (see Fig. 41). The oldest are Archean faults which are frequently subparallel to the strike of gabbro and rhyolite intrusions whose contacts in this area are generally faulted and/or highly sheared. The character of faulted contacts ranges from major faults along the large gabbro in section 23 to thin, shear zones along rhyolite intrusives. These older faults are truncated by faults which trend generally north-south. The faults which are reflected in the north-south to northwest trend of the cliff of Mulligan Creek may be contemporaneous with the north-south faults which cut the Archean rocks elsewhere. These are possibly Late Archean faults and the fault along the cliff of Mulligan Creek may have been reactivated in the Early Proterozoic.

The dominant Archean foliation in the area strikes N 68° W and dips 86° N (see Fig. 43), and the majority of rhyolite intrusives and many of the faults parallel this strike. The Lower Proterozoic metasedimentary rocks exhibit a well developed slaty cleavage which typically strikes N 74° W and dips 51° S (see Fig. 44).

ROCK UNITS

INTRODUCTION

The map area is dominated by Archean pillowed basalt lava flows which have been intruded by Archean gabbro and diabase dikes and sills. This mafic succession has been intruded by Archean rhyolite dikes and sills and granodiorite plutons. The stratigraphic orientation and thickness of the lava flows is difficult to clearly ascertain due to the degree of ductile and brittle-ductile shearing, multi-generation faulting, and lack of Archean interflow sediments and identifiable pillows. Rock units in the area have been subdivided into foliated and (relatively) nonfoliated varieties. In addition, another variety, highly altered, has been added for the basalts and gabbros.

METAVOLCANICS OF SILVER MINE LAKES

The Metavolcanics of Silver Nine Lakes are a thick sequence of Archean pillowed basalt lava flows originally defined by Owens and Bornhorst (1985) in the Fire Center Area and are the dominant lithology cropping-out in sections 3, 11, 12, 13, 14, 23, 24, and 25, T. 49 N., R. 28 W. In the Clark Creek Area an Upper Pillowed Basalt Member was recognized in the Metavolcanics of Silver Mine Lakes (Baxter et.al., 1987). In this area these basalts were first defined as the Metavolcanics of Silver Creek (Johnson et.al., 1986), but now are correlated with the Upper Pillowed Basalt Member. The accumulated thickness of these pillowed basalts probably exceeds 3,000 ft. The basalts are in fault contact with Lower Proterozoic sediments to the south along the cliff of Mulligan Creek in sections 23 and 24. Stratigraphic tops are difficult to determine due to the deformation in the area, but a few pillows in section 24 indicate that the stratigraphic top is to the south while top determinations in section 11 indicate tops to the north. This divergence of younging directions is confirmed by the large scale fold in the area. Outcrops occur most frequently as gently sloped knobs and ridges, but commonly have vertical, glacially plucked north faces. In this study, the unit has been subdivided into three varieties: Nonfoliated, Foliated, and Highly Altered Basalt.

Upper Pillowed Basalt Member

The Upper Pillowed Basalt Member is composed of relatively nonfoliated pillowed basalt lava flows and rare mafic tuffs are the dominant lithologies in sections 3, 11, 12, 13, 14, 23 and 24. This variety is commonly dark green, but ranges from black to medium grayish green, aphanitic to very fine-grained with distinct pillow and probable, highly deformed, pillow structures. Pillow structures are common, but are most often deformed.

The deformation of the pillows ranges from flattening which obliterates pillow cusps to shearing which causes pillows to develop amoeboid shapes with feathered margins. Recognizable vesicles are rare. Pillow breccias have been recognized and are most conspicuous in altered areas where alteration exaggerates the contrast between matrix and fragments. Mafic tuffs are difficult to identify in the field. They are gray to dark gray and aphanitic.

FIGURE 4.--Photomicrograph of lower greenschist facies metabasalt. Light areas are albite; light gray areas are epidote/clinozoisite; gray areas are actinolite. Sample from N center of section 24. Width of field is approximately 1.1 mm. Plane polarized light.

DESCRIPTION--Sample 24E24. Blasto-intergranular to blasto-intersertal; pale green to bluish green, 0.04 mm, subidioblastic, actinolite (Z^C 15); colorless, 0.02mm, xenoblastic, albite, pseudomorphously replacing magmatlc plagioclase; colorless to light yellow, .04mm, xenoblastic, clinozoisite/epidote, frequently occurs as aggregates with sphene; brown, 0.02 mm, xenoblastic sphene, frequently occurs as extremely fine-grained aggregates; 0.01mm, xenoblastic magnetite; trace white mica; trace carbonate.

MODAL MINERALOGY	CIPW NORM
Actinolite...50.4	Anorthite....24.5
Albite.......36.4	Diopside.....22.2
Clino/Ep..... 6.4	Albite.......16.8
Sphene....... 4.0	Hypersthene..10.2
Magnetite.... 1.6	Magnetite.... 7.8
Carbonate.... tr	Orthoclase... 5.2
Sericite..... tr	Quartz....... 3.0
(500 points)	Ilmenite..... 2.7
	Apatite...... 0.3

Black colored basalts are common along the contact with the granodiorites and to the north in sections 11 and 3. The lightest colored basalts of the Pillowed Basalt Member are usually slightly foliated and contain relatively more carbonate as disseminations and as fine, cross-cutting veinlets; these basalts commonly effervesce with HCl.

The basalts have been metamorphosed from lower greenschist to upper amphibolite facies. Lower greenschist facies is characterized by chlorite, pale green pleochroic actinolite, clinozoisite/epidote, with minor sericite, carbonate, and fine-grained disseminated pyrite, with relict magmatic textures (Fig. 4). Upper greenschist facies is characterized by pale green pleochroic actinolite, light green hornblende, albite and clinozoisite/epidote with metamorphic textures (Fig. 5, Fig. 6). Lower amphibolite facies is characterized by hornblende, calcic plagioclase, clinozoisite/epidote (Fig. 7) and, in the mafic tuffs, by garnet and biotite with well developed metamorphic textures. Upper amphibolite facies is characterized by green to light brown hornblende, calcic plagioclase, hypersthene and diopside with well developed schistosity (Fig. 8).

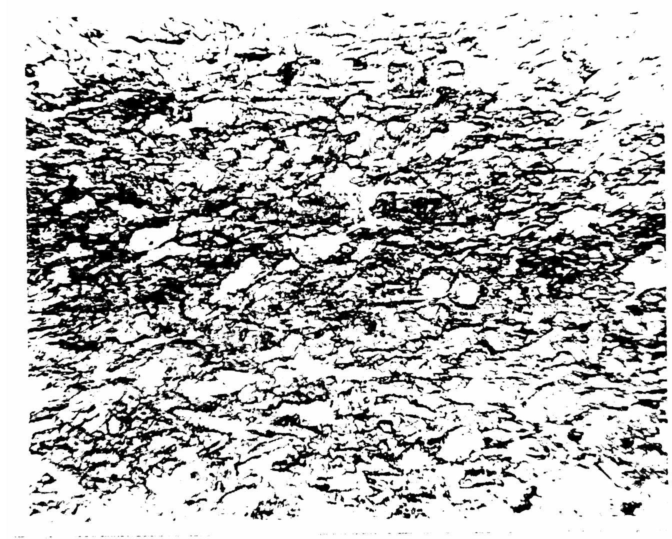


FIGURE 5.--Photomicrograph of upper greenschist facies metabasalt. Light areas are albite; gray areas are hornblende. Note foliation trends ENE. Sample from SW 1/4 of section 14. Width of field is approximately 1.1 mm. Plane polarized light.

DESCRIPTION--Sample 14E6. Schistose; pale yellow to bluish green, 0.08 mm, subidioblastic, nematoblas-tic, hornblende (Z^C 16), altering to chlorite and epidote-sphene; clouded, 0.02 mm, xenoblastic, albite, altering to sericite; colorless, 0.01 mm, subidioblastic, sericite, replacing albite; light green, 0.01 mm, xenoblastic, chlorite; 0.01 mm, subidioblastic, poikiloblastic, pyrite; colorless to pale yellow, 0.05 mm, xenoblastic and idioblastic, clinozoisite/epidote, idioblastic epidote rimmed by xenoblastic clinozoisite; brown, <0.01 mm, idioblastic sphene.

MODAL MINERALOGY	CIPW NORM
Hornblende...70.5	Anorthite....23.9
Albite....... 9.7	Diopside.....21.3
Sericite..... 7.0	Orthoclase...16.0
Chlorite..... 5.0	Albite.......11.8
Pyrite....... 3.5	Hypersthene..11.3
Clino/Ep..... 2.2	Magnetite.... 5.0
Sphene....... 1.3	Olivine...... 3.9
(600 points)	Ilmenite..... 1.4
	Apatite...... 0.2

The distinction between basalts and gabbros within the amphibolite facies is difficult in the field. The northern area of section 3 is upper amphibolite facies. In this area both gabbros and basalts are fine- to medium-grained, frequently banded, and schistose. Where the distinction between gabbro and basalt is not clear the map rock unit symbol has been queried (Plate 1).

The basalts of the Upper Pillowed Basalt Member are magnesian to iron rich tholeiites (Table 1 and Fig. 9). The chemical composition of these metabasalts are markedly similar to those of the Fire Center Mine Area (Owens, 19S6) suggesting little systematic differentiation from Lower to Upper Pillowed Basalt Member.

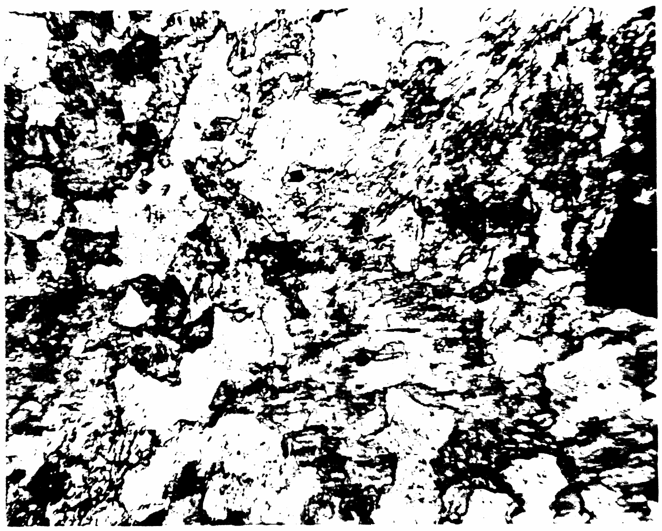


FIGURE 6.--Photomicrograph of upper greenschist facies metabasalt. Light areas are albite; gray areas are actinolite; dark gray areas are epidote/clinozoisite; black areas are pyrite. Sample from SE 1/4 of section 10 near granodiorite-basalt contact. Width of field is approximately 1.1 mm. Plane polarized light.

DESCRIPTION--Sample 10D4. Granoblastic; pale yellow to light green, 0.1 mm, subidioblastic, actinolite (Z^C 14); colorless, 0.1 mm, xenoblastic, albite, slightly corroded with alteration to sericite; yellow to colorless, 0.07 mm, xenoblasitc to idioblas-tic, epidote/clinozoisite; brown, xenoblastic, 0.04 mm, sphene; idioblastic, porphyroblastic, 0.2 mm, pyrite.

MODAL MINERALOGY		CIPW NORM	
Actinolite	48.1	Albite	26.9
Albite	30.1	Anorthite	18.7
Ep/Clino	19.3	Hypersthene	17.5
Sphene	1.9	Diopside	14.4
Pyrite	0.6	Magnetite	9.8
(700 points)		Orthoclase	4.8
		Ilmenite	2.1
		Apatite	0.3
		Quartz	0.2

Foliated Basalt Variety

The Foliated Basalt Variety occurs along faults, sheared contacts, and shear zones throughout the area and is largely unmapped. This variety has two macros-copically distinct end members: 1) dull black to dull brown, aphanitic, friable, and generally limonite-rich, schistose mylonite; and 2) medium green phyllonite.

The black end-member is composed dominantly of chlorite and albite, but frequently contains abundant disseminated pyrite (estimated up to 15%) (Fig. 10). The green phyllonite end-member is composed dominantly of chlorite and albite with minor quartz and commonly contains lenses of porphyroblastic carbonate with quartz (Fig. 11). In the green phyllonite, pyrite is found as fine disseminations and is commonly concentrated in the chloritic groundmass which surrounds the carbonate-quartz lenses.

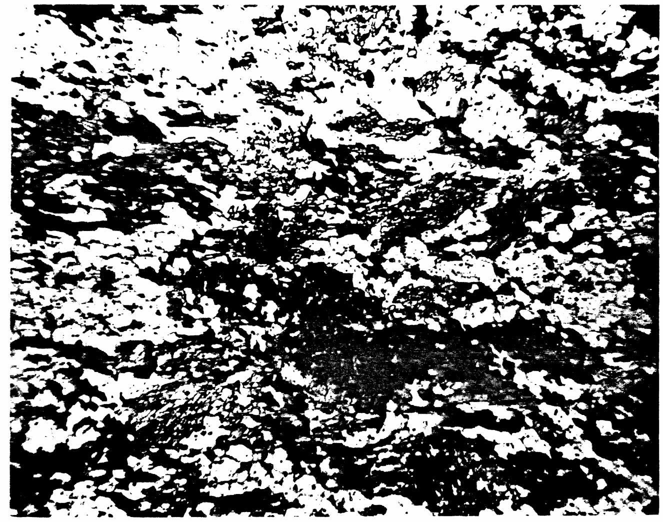


FIGURE 7.--Photomicrograph of lower amphibolite facies basalt. Light areas are calcic plagioclase; dark gray areas are hornblende. Sample from NW 1/4 of section 11. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 11C14. Granoblastic with poorly developed foliation; light to dark green, 0.1 mm, idioblastic, nematoblastic, hornblende (Z^C 17), outlines poorly developed sigmoidal foliation; colorless, 0.1 mm, xenoblastic, calcic plagioclase, slight marginal alteration to sericite; light brown, <0.1 mm, xenoblastic, ‘ratty’, biotite, ‘ratty’ margins lined with sphene(?); colorless, <0.1 mm, xenoblastic, sericite; brown, <.01 mm, xenoblastic, sphene; .03 mm, xenoblastic, magnetite.

MODAL MINERALOGY	
Hornblende	54.2
Calcic Plag.	43.2
Biotite	1.6
Sericite	tr
Sphene	tr
Magnetite	tr
(500 points)	

Analyses of the Foliated Variety show basaltic komatiite compositions (Table 2, Fig. 12). The Foliated Variety does show enrichment of Mg and Fe and depletions in K relative to the Nonfoliated Variety. These enrichments and depletions are reflected in the high chlorite content of these rocks.

Highly Altered Basalt Variety

The Highly Altered Basalt Variety is found scattered throughout the Silver Creek to Island Lake Area (Fig. 13), commonly associated with sheared rocks or adjacent to faults. This variety can be distinguished from the Nonfoliated Variety by a lighter gray color (weathered surfaces exhibit various shades of light green and yellow). The altered basalts are aphanitic to fine grained, generally massive or poorly foliated and are composed of varied assemblages of chlorite, albite, sericite, clinozoisite/epidote, carbonate and quartz.

a)

FIGURE 8.--Description on following page.

b)

FIGURE 8.--Photomicrographs of upper amphibolite facies basalt: a) black bands in amphibolite schist; light gray to dark gray areas are hornblende; irregular light areas are calcic plagioclase; equant light areas are apatite, b) light band in amphibolite schist; irregular light areas are calcic plagioclase; prismatic light areas are epidote/clino-zoisite; gray areas are hornblende; dark gray (high relief) areas are sphene. Sample from near center of section 3. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 3D9. a) Schistose; light brown to blue green, 0.4 mm, nematoblastic, idioblastic, hornblende (Z^C 18), occasionally replaced by diop-side, calcite and plagioclase; colorless, 0.15 mm, xenoblastic, calcic plagioclase; colorless, 0.2 mm, xenoblastic, hypersthene; light green, 0.2 mm, xenoblastic, diopside, frequently replacing hornblende; colorless, 0.4 mm, idioblastic, mm, apatite; green, 0.4 mm, subidioblastic, chlorite, replacing biotite. b) Schistose; colorless, 0.15 mm, granoblastic, xenoblastic, calcic plagioclase; light brown to blue green, 0.04 mm, subidioblastic, hornblende (Z^C 18); colorless, 1.0 mm, porphyroblastic, idioblastic, epidote/clinozoisite; brown, 0.02 mm, xenoblastic, sphene; colorless, <0.01 mm, xenoblasitic, sericite, replacing plagioclase.

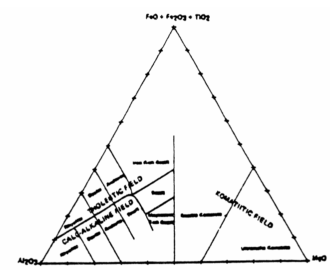
MODAL MINERALOGY a)	
Hornblende...	93.0
Calcic Plag..	4.7
Hypersthene..	tr
Diopside.....	tr
Ep/Clino.....	tr
Apatite......	tr
Chlorite.....	tr
Carbonate....	tr
(estimated)	

MODAL MINERALOGY b)	
Calcic Plag..	64.7
Ep/Clino.....	14.0
Hornblende...	13.7
Sericite.....	4.7
Sphene.......	2.7
Apatite......	tr
(estimated)	

Table 1.--Chemical analyses of metabasalts.

	1	2	3	4
SIO2	48.47	48.11	48.37	45.98
TIO2	0.92	1.00	0.71	1.30
AL2O3	12.66	11.57	13.09	12.10
FE2O3	4.08	6.02	3.21	4.93
FEO	7.77	7.97	7.33	10.13
MNO	0.19	0.23	0.22	0.27
MGO	6.68	9.64	8.74	5.88
CAO	11.10	6.50	9.25	9.55
NA2O	1.25	2.84	1.31	1.82
K2O	1.26	0.72	2.53	0.81
H2O+	2.57	3.13	3.31	3.11
H2O-	0.05	0.20	0.10	0.13
P2O5	0.10	0.11	0.07	0.14
S	0.06	0.10	0.18	0.11
TOTAL	97.16	98.14	98.42	96.26
V	226	241	178	305
CR	293	353	400	262
NI	171	161	149	116
CU	62	37	31	55
ZN	77	104	87	95
RB	24	8	57	7
SR	182	266	181	199
Y	17	17	19	22
ZR	48	57	41	67
NB	5	5	6	6
BA	16	21	26	19
LA	4	9	2	6

1. 10B11-basalt
2. 10D4-basalt
3. 14E6-basalt
4. 24E24-basalt



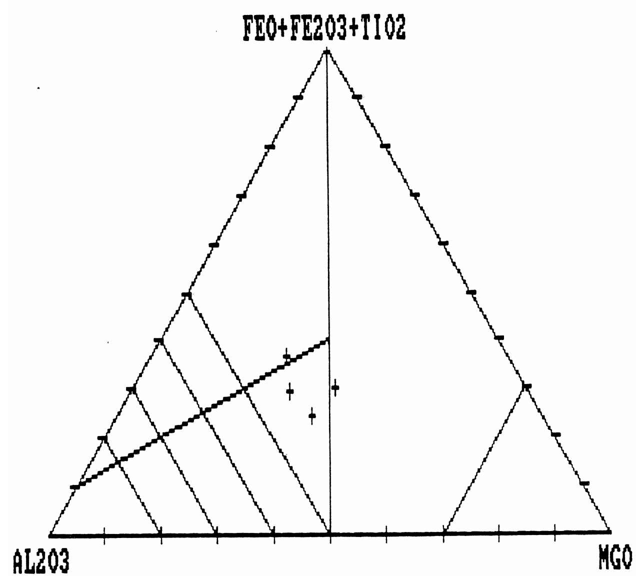


FIGURE 9.--Jensen Cation Plot (Jensen, 1976; Grunsky, 1981) of Upper Pillowed Basalt.

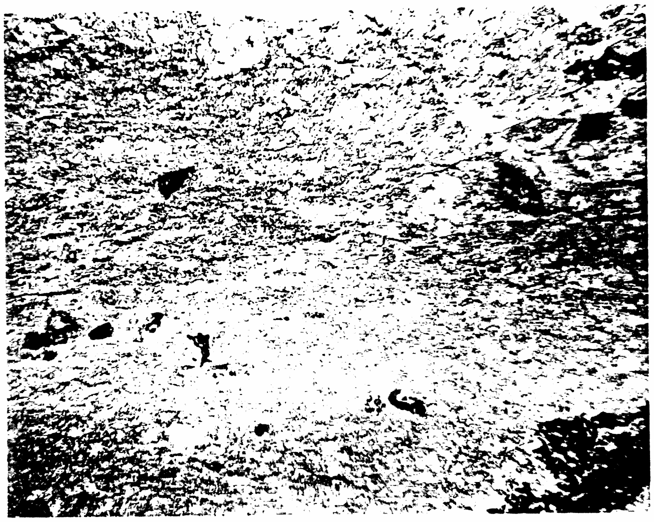


FIGURE 10.--Photomicrograph of black chloritic type of Foliated Basalt Variety. Light areas are albite, quartz and carbonate; gray areas are chlorite; dark areas are pyrite. Mote foliation trends E-W. Sample from SW 1/4 of section 15. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 15A4. Schistose blastomylonite, with flaser structures; light green, 0.03 mm, lepidoblastic, xenoblastic, chlorite; colorless, 0.06 mm, xenoblastic, albite, as small scale flaser structures and mortar textured aggregates; colorless, 0.05 mm, xenoblastic, carbonate; colorless, undulose, 0.04 mm, xenoblastic, quartz, in flasers and in mortar textured aggregates; 0.05 mm, idioblastic to xenoblastic, pyrite; colorless, 0.04 mm, subidioblastic, apatite.

MODAL MINERALOGY		CIPW NORM	
Chlorite	50.0	Hypersthene	29.6
Albite	29.5	Anorthite	18.6
Carbonate	9.5	Corundum	12.1
Pyrite	6.0	Magnetite	10.9
Quartz	4.0	Albite	9.7
Apatite	tr	Orthoclase	3.7
(estimated)		Ilmenite	2.7
		Olivine	1.9
		Apatite	0.2

The largest occurrence of Highly Altered Basalt is found in a few fault-bound areas in sections 24 and 25. Brecciated rhyolite dikes are commonly associated with the Highly Altered Basalt Variety in this area. Here, the variety is medium to light gray, aphanitic to very fine-grained metabasalt and poorly developed schists composed of chlorite, albite, sericite, carbonate and quartz (Fig. 14, Fig. 15). The modal composition is quite variable, for example, it is common in a single outcrop to find specimens that are composed dominantly of either sericite or chlorite. The mineral abundance and the overall distribution of this variety indicates that a major Archean hydrothermal system may have been focused in this area.

A large irregular interconnected altered area, strongly associated with faults, is found in the southern part of section 11 and along a fault that extends into the northern part of section 14. In this area the basalt has been altered to variable amounts of chlorite, epidote and albite with minor sericite and carbonate (Fig. 16). The associated sulfides are pyrrhotite and minor chalcopyrite. A large quartz vein is found associated with this altered area in the southwest corner of section 11.

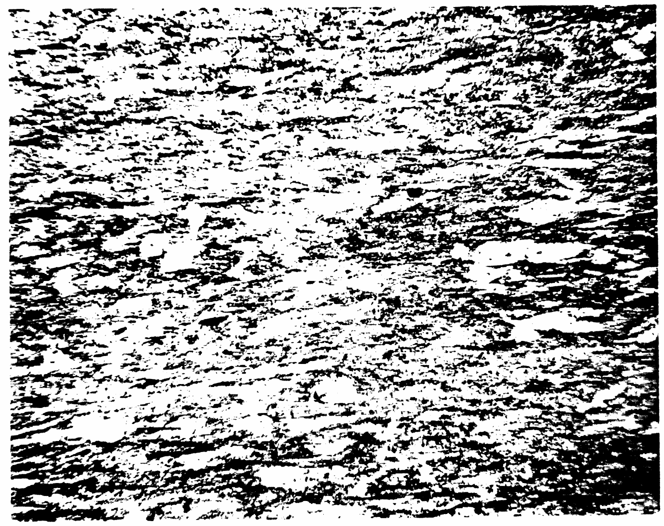


FIGURE 11.--Photomicrograph of phyllonite type of Foliated Basalt Variety. Light areas are dominantly carbonate with minor albite; gray areas are chlorite. Sample from near center of section 24. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 24E18. Phyllonite; colorless, 0.5 mm, idioblastic, carbonate; light green, <0.01 mm, lepidoblastic, xenoblastic, chlorite; colorless, <0.01 mm, xenoblastic, albite; colorless, <0.01 mm, xenoblastic, quartz; brown, <0.01 mm, xenoblastic, sphene; <0.01 mm, xenoblastic, pyrite.

MODAL MINERALOGY		CIPW NORM	
Carbonate	10.0	Anorthite	25.4
Groundmass	90.0	Albite	14.8
		Diopside	14.7
		Olivine	13.2
		Hypersthene	10.7
		Magnetite	6.7
		Orthoclase	3.0
		Ilmenite	1.9
		Apatite	0.2

(estimated: groundmass = chlorite+albite+quartz+sphene+pyrite)

Another altered area is located in the northwest corner of section 13 and the southwest corner of section 12. The basalts consist of variable amounts of carbonate, chlorite, epidote, albite, sericite and quartz. The most common sulfide is pyrite which commonly occurs along thin shears as fine- to medium-grained, euhedral masses and as fine-grained disseminations. A large quartz vein also occurs in this area.

The mineral assemblage in the altered basalts is commonly retrograde. However, the retrograde nature of the assemblages is not readily evident in the section 24 and 25 area since this area is lower greenschist facies. The distinction can be made because the regional facies commonly contains abundant actinolite, whereas the more local altered basalts contain chlorite as the dominant ferromagnesian mineral. To the north, retrograde chlorite-epidote zones are found within the upper amphibolite facies assemblage.

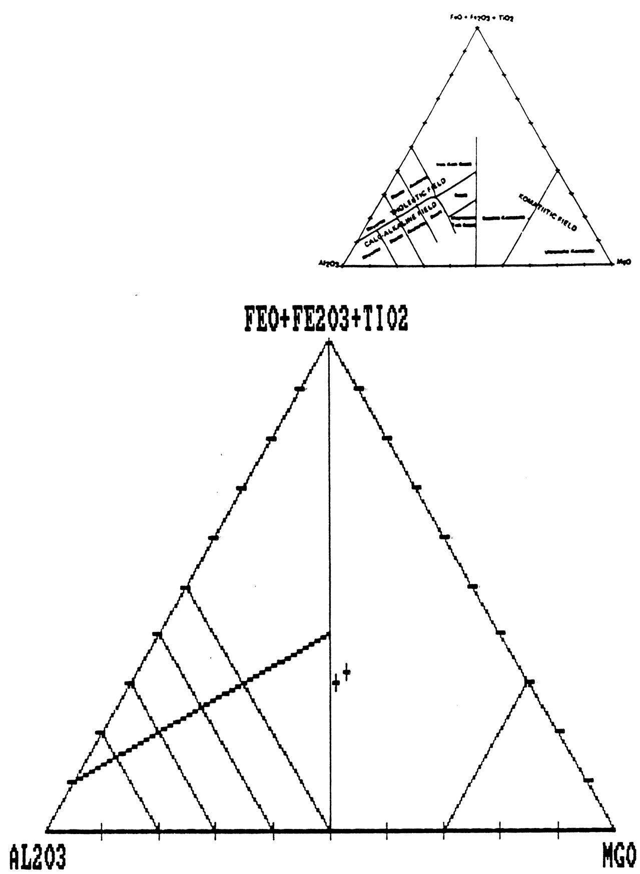
Table 2.--Chemical analyses of foliated basalts.

	5	6
SIO2	39.34	42.55
TIO2	1.21	0.95
AL2O3	13.00	11.97
FE2O3	6.30	4.34
FEO	12.37	10.14
MNO	0.22	0.23
MGO	12.18	10.10
CAO	3.28	8.17
NA2O	0.97	1.64
K2O	0.53	0.48
H2O+	9.50	9.14
H2O-	0.10	0.09
P2O5	0.09	0.08
S	0.01	0.01
TOTAL	99.10	99.89
V	329	238
CR	473	589
NI	206	332
CU	19	108
ZN	120	96
RB	12	3
SR	114	100
Y	16	16
ZR	66	35
NB	7	9
BA	14	13
LA	nd	nd

nd-not detected

5. 15A4-foliated basalt
6. 24E18-foliated basalt

FIGURE 12.--Jensen Cation Plot (Jensen, 1976; Grunsky, 1981) of Foliated Basalt Variety.



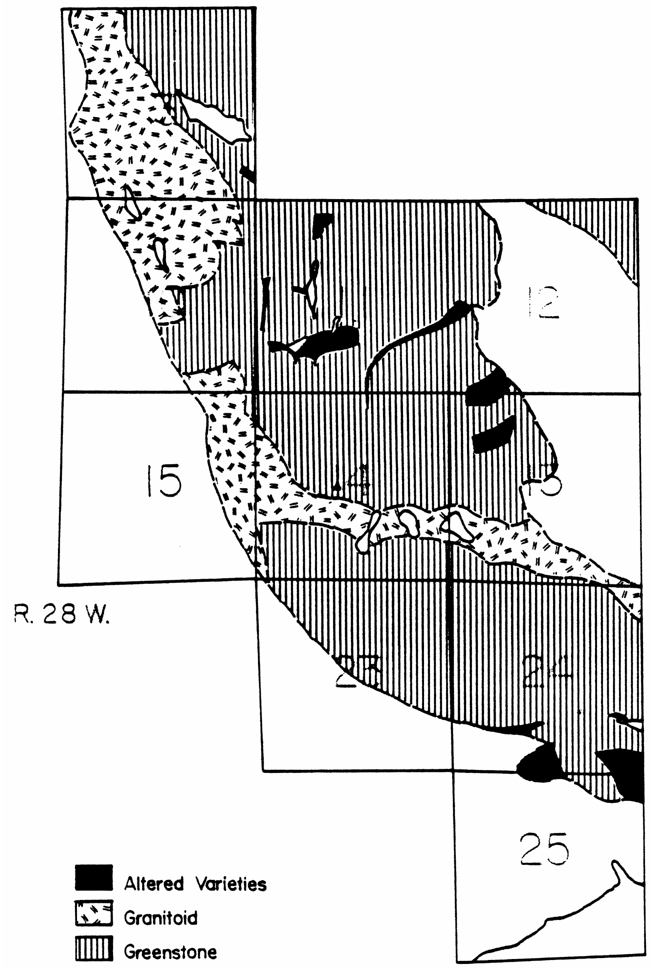


FIGURE 13.--Location map of altered basalt and gabbro varieties in the Silver Creek to Island Lake Area.

FIGURE 14.--Photomicrograph of Altered Basalt Variety. Light areas are albite; gray areas are chlorite. Note relict magmatic texture. Sample from SE 1/4 of section 24. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 24H1. Blasto-intergranular to blasto-intersertal; light green, 0.2 mm, xenoblastic, mm, chlorite, pseudomorphously replacing pyroxene; colorless, 0.04 mm, xenoblastic, albite, as aggregates pseudomorphously replacing magmatic pla-gioclasej 0.1 mm, xenoblastic, sulfide (pyrite ?); colorless, 0. 1 mm, porphyroblastic, xenoblastic, carbonate.

MODAL MINERALOGY	CIPW NORM
Albite.......50.0	Hypersthene..21.4
Chlorite.....46.5	Albite.......20.7
Sulfide...... 2.5	Corundum.....17.2
Carbonate.....0.7	Magnetite....14.5
(600 points)	Orthoclase... 5.9
	Anorthite.... 4.6
	Quartz....... 3.2
	Ilmenite..... 2.9
	Apatite...... 0.3

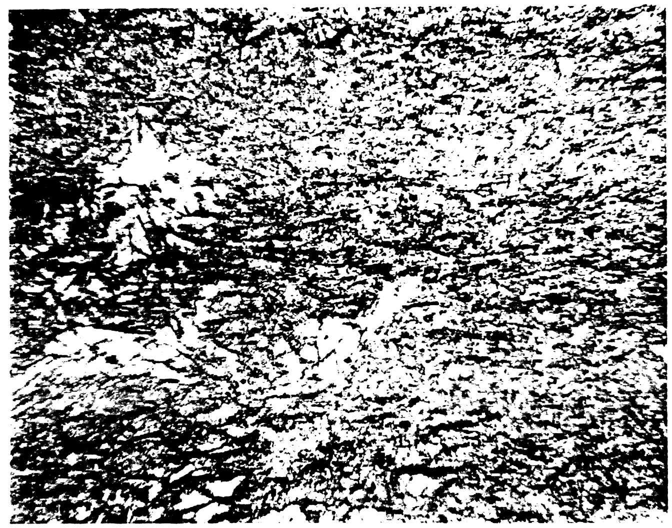


FIGURE 15.--Photomicrograph of Altered Basalt Variety. Large light areas are quartz aggregates; light areas are albite; gray areas are chlorite. Note dispersed foliation trending ENE. Sample from SE 1/4 of section 24. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 24H4. Blasto-intergranular to blasto-intersertal with schistose zones; light green, 0.04 mm, xenoblastic, chlorite, regular masses are pseudomorphous replacement of pyroxene; colorless, 0.03 mm, xenoblastic, albite, aggregates pseudomorphously replacing magmatic plagioclase frequently altering to sericite; colorless, 0.05 mm, xenoblastic, quartz, as <1.9 mm 'pods' and as dispersed xenoblastic grains; colorless, <0.01 mm, xenoblastic, sericite, replacing albite; 0.1 mm, xenoblastic, sulfide (pyrite ?); colorless, 0.03 mm, xenoblastic, carbonate.

MODAL MINERALOGY	CIPW NORM
Chlorite.....51.2	Anorthite....24.0
Albite.......30.8	Diopside.....19.6
Quartz....... 8.6	Hypersthene..15.5
Sericite..... 5.8	Albite.......15.2
Sulfide...... 2.2	Magnetite.... 6.4
Carbonate.... 1.4	Orthoclase... 6.2
(500 points)	Ilmenite..... 2.0
	Quartz....... 1.1
	Apatite...... 0.2

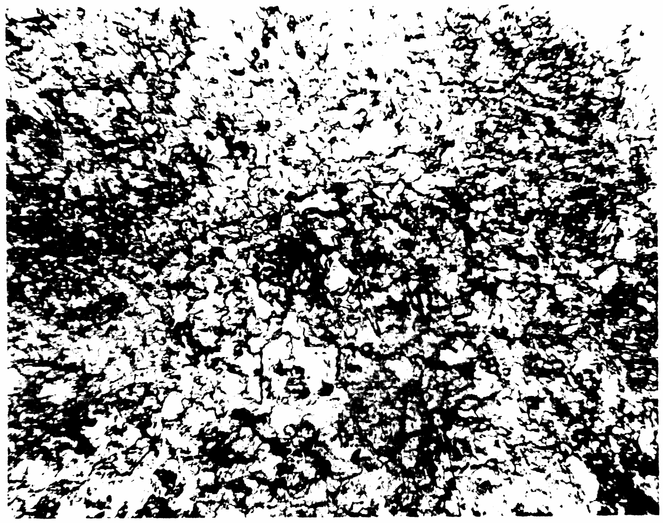


FIGURE 16.--Photomicrograph of Altered Basalt Variety. Clear light areas are quartz; clouded light areas are clinozoisite/epidote; gray areas are chlorite; dark gray areas are sphene. Sample from S center of section 11. Width of field is approximately 1.1 mm. Plane polarized light.

DESCRIPTION--Sample 11G1. Granoblastic; colorless to light yellow, 0.08 mm, subidioblastic to xenoblastic, clinozoisite/epidote; colorless, 0.04 mm, xenoblastic, quartz; pale green, <0.01 mm, xenoblas-tic chlorite; pale green, 0.03 mm, subidioblastic, actinolite; brown, 0.01 mm, xenoblastic, sphene; colorless, 0.1 mm, xenoblastic, carbonate; 0.01 mm, xenoblastic pyrrhotite.

MODAL MINERALOGY

Clino/Ep.....	63.5
Quartz.......	16.5
Chlorite.....	12.5
Actinolite...	5.5
Sphene.......	2.0
Carbonate....	tr
Pyrrhotite...	tr

(estimated)

Chemical analyses characterize the Highly Altered Basalts as magnesian to iron-rich tholeiites (Table 3, Fig. 17). The alteration in section 23 and 24 shows consistent depletions in Mn, Ca and P and enrichments in Mg relative to the Nonfoliated Variety. Elements such as Si and Na are not as consistent, but this could reflect chemical zonation within the altered area and/or an inadequate sampling.

Hill's Lakes Pyroclastic Member

The Hill's Lakes Pyroclastic Member is located in section 11 east of the northern lake of Hill's Lakes. This unit strikes to the northeast and has a thickness of at least 160 ft. It is composed of white to tan pumiceous lapilli in a black schistose matrix (Fig. 18). The lapilli are extremely deformed giving vertical surfaces a banded appearance.

The matrix is composed of hornblende, calcic plagioclase, biotite and garnet with minor sericite, chlorite, tourmaline and clinozoisite/epidote. The lapilli are composed of calcic plagioclase and quartz with minor hornblende, sericite and clinozoisite/epidote.

Table 3.--Chemical analyses of altered basalts.

	7	8	9
SIO2	40.48	45.54	48.39
TIO2	1.38	0.93	1.02
AL2O3	14.08	11.59	13.77
FE2O3	9.14	3.93	4.92
FEO	12.17	7.61	9.30
MNO	0.07	0.19	0.07
MGO	9.02	9.07	9.04
CAO	1.00	8.60	0.32
NA2O	2.24	1.61	2.52
K2O	0.92	0.94	1.64
H2O+	6.21	5.78	5.16
H2O-	0.05	0.14	0.05
P2O5	0.11	0.10	0.07
S	0.14	0.03	0.08
TOTAL	97.01	96.06	96.35
V	359	202	261
CR	524	490	663
NI	220	96	227
CU	109	80	62
ZN	118	71	87
RB	6	8	28
SR	46	281	43
Y	11	17	13
ZR	55	86	30
NB	7	9	8
BA	15	27	18
LA	nd	14	nd

nd-not detected

7. 24H1-altered basalt.
8. 24H4-altered basalt
9. 25AA-altered basalt

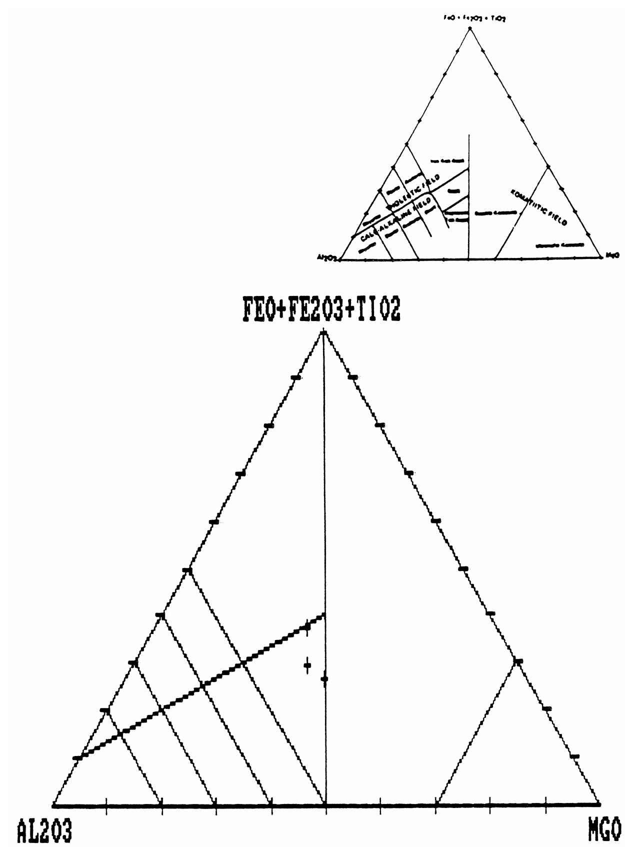


FIGURE 17.--Jensen Cation Plot (Jensen, 1976; Grunsky, 1981) of Altered Basalt Variety.

FIGURE 18.--Photograph of sample from Hill's Lakes Pyroclastic Member. Note pumiceous character of the lapilli. Sample from east of Hill's Lakes.

Age and Origin of the Metavolcanics of Silver Mine Lakes

The Upper Pillowed Basalt Member of the Metavolcanics of Silver Mine Lakes is the oldest rock unit in the map area. They are undoubtedly Archean in age by their association with the Mona Schist (Gair and Thaden, 1968; Puffet, 1974; Clark et.al., 1975). The age of the Mona Schist is about 2,700.m.y. (Trow, 1979). The Upper Pillowed Basalt Member is a thick succession of sub-aqueously emplaced tholeiitic basalts with minor breccia and tuff horizons. The intermediate composition of the Hill's Lakes Pyroclastic Member is distinct from the basalts and represents the emplacement of a subaqueous ash-flow during a hiatus in basaltic volcanism. The basalts were deformed and metamorphosed by a Late Archean tectonic event and subsequently altered and mineralized probably during the Late Archean.

METAGABBRO OF CLARK CREEK

The Metagabbro of Clark Creek was named by Owens and Bornhorst (1985) for exposures in section 35, T. 49 N., R. 27 W. about 5 miles east of this area. In this area, the Metagabbro of Clark Creek consists of medium-to coarse-grained metamorphosed Archean gabbro dikes and concordant sills. Foliated gabbro was not mapped as a separate unit because it occurs generally either as very thin margins on or thin zones within the gabbro bodies. Outcrops of this unit are rounded knobs and tend to lack the vertical and glacially plucked north facing slopes found in the Metavolcanics of Silver Mine Lakes. In the field, the Lower Proterozoic Meta-gabbros are almost indistinguishable from the Archean metagabbros of the lover metamorphic facies and consequently have been included in the Metagabbro of Clark Creek in areas of greenschist facies metamorphism.

In the study area the Metagabbro of Clark Creek is typically medium greenish-gray and dark bluish-green in color and medium- to coarse-grained. It is composed of hornblende or actinolite and plagioclase with minor sericite, clinozoisite/epidote, sphene. The opaques can be either magnetite or pyrite, pyrrhotite and cubanite. The amphibole is typically bluish green hornblende pseudomorphously replacing ophitic pyroxenes (Fig. 19). The plagioclase form aggregates of two types: those retaining their magmatic texture and those having a mosaic texture. The composition of the plagioclase reflects the grade of metamorphism: albite in greenschist facies and calcic plagioclase in the amphibolite facies.

Foliated gabbros (not distinguished) are much less common than the Foliated Basalt Variety and are found in very sharp, thin, shear zones within gabbro bodies and along faulted margins. The foliated gabbros are locally light green, aphanitic, and occasionally phyllonitic and are composed of chlorite and plagioclase with minor sericite and quartz.

FIGURE 19.--Photomicrograph of Metagabbro of Clark Creek. Light areas are albite and sericite; light gray areas (high relief) are clinozoisite/epidote; gray and dark gray areas are hornblende. Sample from near center of section 23. Width of field is approximately 4.4 mm. Crossed polars.

DESCRIPTION--Sample 23Agn. Blasto-ophititc to blasto-subophititc; green to bluish green, 2.0 mm, blas-to-ophitic, subidioblastic, hornblende (Z^C 19), pseudomorphously replacing ophitic pyroxenes; colorless to clouded, 0.1 mm, xenoblastic, albite, aggregates pseudomorphously replacing magmatic plagio-clase; colorless, 0.1 mm, idioblastic to xenoblastic, clinozoisite/epidote, as idioblastic grains and as xenoblastic aggregates; colorless, <0.01 mm, xenoblastic, sericite, as alteration of albite; brown, <0.01 mm, xenoblastic, sphene, frequently in clinozoisite/epidote aggregates; 0.1 mm, xenoblastic, pyrrhotite, chalcopyrite and cubanite.

MODAL MINERALOGY		CIPW NORM	
Hornblende...	56.7	Anorthite.......	25.6
Albite.......	17.8	Diopside........	21.8
Clino/Ep.....	11.0	Albite..........	13.9
Sericite.....	9.0	Hypersthene.....	10.8
Sphene.......	3.0	Olivine.........	8.9
Sulfide......	2.5	Orthoclase......	4.9
(600 points)		Magnetite.......	4.1
		Ilmenite........	2.0
		Apatite.........	0.3

Chemically the gabbros are very similar to the basalts (Table 4, Fig. 20). They are magnesian tholeiites. Sample number 12 is compositionally different, but this sample of gabbro was taken very near the contact where the gabbro is intruded by the granodiorite.

Highly Altered Gabbro Variety

Highly Altered Gabbros are a minor unit in the map area and typically occur adjacent to faults and shears. Fresh surfaces are light gray to light green and those that are highly epidotized are a distinct pistachio green. They may be well foliated or have a massive appearance. Common alteration assemblages include chlorite, albite, epidote, quartz, sericite and carbonate (Fig. 21) with chalcopyrite, pyrrhotite and pyrite.

Age and Origin of the Metagabbro of Clark Creek

The Metagabbro of Clark Creek is considered to be Archean in age (Owens and Bornhorst, 1985). The gabbros cross-cut the Metavolcanics of Silver Mine Lakes and are cross-cut by the Rhyolite Intrusive of Fire Center Mine. The gabbros are intrusive and may be related to the late stages of magmatism which produced the Metavolcanics of Silver Mine Lakes. If so, their composition on the tholeiite trend (Fig. 22) does not suggest any appreciable differentiation. Alteration and mineralization are probably Late Archean.

Table 4.--Chemical analyses of metagabbros.

	10	11	12	13	14
SIO2	45.34	44.98	50.70	54.61	44.42
TIO2	0.84	0.97	1.40	1.07	1.21
AL2O3	13.18	12.06	10.46	8.27	13.68
FE2O3	2.94	2.65	5.37	6.87	4.12
FEO	9.46	10.22	9.30	5.62	7.68
MNO	0.19	0.20	0.23	0.13	0.13
MGO	9.01	9.04	7.32	5.92	16.59
CAO	9.54	9.73	9.85	12.80	2.15
NA2O	1.56	1.53	1.92	0.26	0.72
K2O	0.62	0.77	0.77	0.43	1.33
H2O+	2.52	3.07	2.91	1.92	7.01
H2O-	0.10	0.09	0.00	0.14	0.19
P2O5	0.12	0.12	0.14	0.24	0.07
S	0.10	0.08	0.23	0.04	0.00
TOTAL	95.52	95.51	100.60	98.32	99.30
V	198	228	326	241	300
CR	337	293	161	44	471
NI	190	203	48	29	195
CU	49	97	131	119	4
ZN	81	82	78	47	43
RB	8	10	8	1	19
SR	133	133	144	1425	44
Y	17	17	20	18	18
ZR	49	49	62	249	40
NB	6	7	6	nd	11
BA	9	13	20	13	37
LA	8	6	nd	9	nd

nd-not detected

10. 23AGC-gabbro
11. 23AGN-gabbro
12. 24K28-gabbro
13. 23K1-altered gabbro
14. 241D10-foliated gabbro

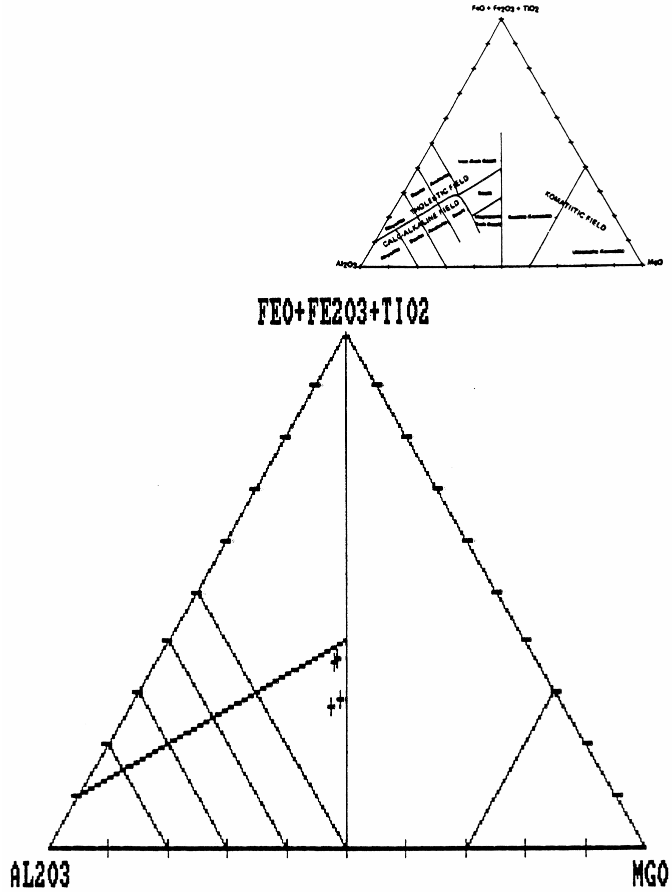


FIGURE 20.--Jensen Cation Plot (Jensen, 1976; Grunsky, 1981) of the Metagabbro of Clark Creek.

RHYOLITE INTRUSIVE OF FIRE CENTER MINE

The Rhyolite Intrusive of Fire Center Mine is named for numerous, thin, felsic intrusive dikes and sills. This name is a modification of Rhyolite Porphyry of Fire Center Mine (Owens and Bornhorst, 198S) and was modified to incorporate the diverse textural variety observed in the rhyolite intrusives in this area. The range of textures observed include: porphyritic, aphanitic and granular. Porphyritic rhyolites are the most common, aphanitic rhyalites are next, and granular rhyolites are the least common. An attempt to distinguish individual rhyolite intrusive bodies by their textures was not successful since apparently distinct textures are often gradational laterally into each other. Most of the rhyolite intrusives are less than 20 ft. wide and the width is slightly exaggerated on the map. There are many intrusives which are less than 10 ft. thick and none of these are shown on the map. The intrusives strike generally N 60° to N 70° W, dip near vertical and are generally well foliated with a similar orientation. Less commonly, intrusives are found that strike approximately north-south along faults. This suggests that the north-south trending faults were pre-rhyolite and thus, Archean in age. The outcrops of this unit are generally topographically negative relative to the surrounding mafic volcanic and intrusive rocks, although a rhyolite intrusive in section 24 forms a south facing vertical cliff. The rhyolites typically break into regular angular blocks.

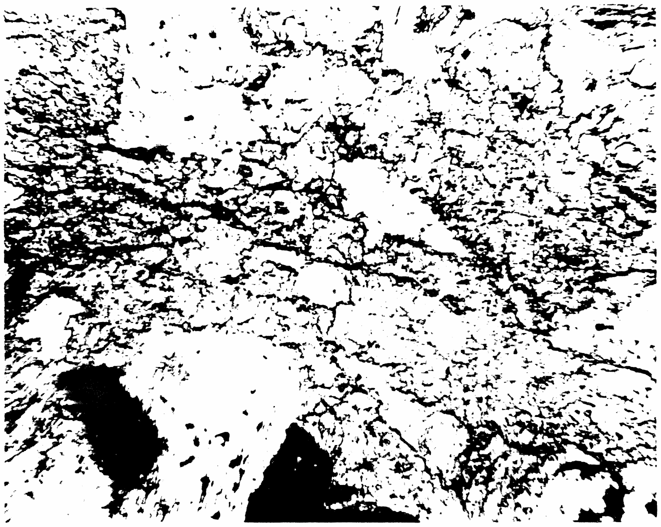


FIGURE 21.--Photomicrograph of Highly Altered Gabbro. Light areas are albite; gray areas are actinolite; dark gray areas are epidote. Sample from E center section 23. Width of field is approximately 1.1 mm. Plane polarized light.

DESCRIPTION—Sample 23K1. Blasto-hypidiomorphic granular; yellow green, 0.10 mm, xenoblastic, epidote, pseudomorphously replacing plagioclase; pale green to green, 0.80 mm, subidioblastic, actinolite (Z^C 13) mm, pseudomorphously replacing pyroxene; clouded, 0.10 mm, xenoblastic, albite; brown, 0.80 mm, subidioblastic, hematite, pseudomorphously replacing magnetite; light green, 0.03 mm, xenoblastic, chlorite; 0.03 mm, xenoblastic, chalcopyrite.

MODAL MINERALOGY	
Epidote......	45.0
Actinolite...	26.0
Albite.......	24.6
Hematite.....	3.2
Chlorite.....	tr
Chalcopyrite.	tr
(500 points)	

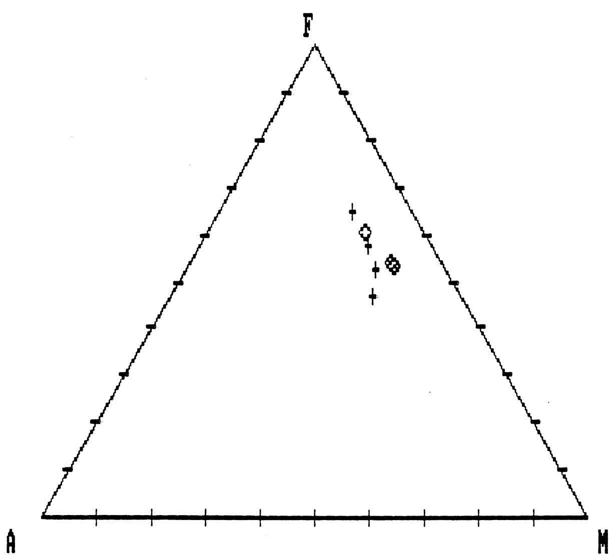


FIGURE 22.--AFM Plot of the Upper Pillowed Basalt Member (+) and the Metagabbro of Clark Creek (o).

Porphyritic rhyolite intrusives are commonly light gray to tan schists, composed of quartz, sericite and albite. Quartz porphyries are the most common, but quartz-feldspar porphyries are also found. Quartz phenocrysts are typically embayed (Fig. 23) and feldspar phenocrysts are commonly albite (Fig. 24). The ground-mass is typically composed of granoblastic quartz and albite and lepidoblaetic sericite. Minor pyrite is common as disseminated euhedral grains.

Aphanitic rhyolite intrusives exhibit a range of colors from uniform to mottled pink, orange, red, tan, and white and in hand specimen they strongly resemble cherts. They contain very minor disseminated euhedral pyrite. The aphanitic rhyolites are typically composed of fine-grained sutured quartz and albite (Fig. 25).

Granular rhyolites are gray to dull pink, fine-grained and allotriomorphlc, similar in texture to granite. They are composed of albite, quartz, microcline and minor muscovite, epidote, chlorite, apatite and pyrite (Fig. 26).

Chemically the rhyolites are calc-alkalic rhyolites (Table 5, Fig. 27). They have a small amount of chemical variation.

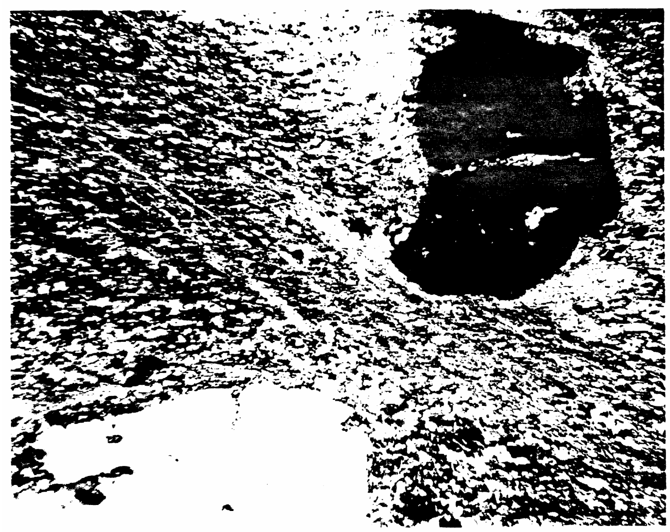


FIGURE 23.--Photomicrograph of quartz porphyry type of the Rhyolite Intrusive of Fire Center Mine. Large grains are quartz; groundmass is composed of quartz and sericite. Sample from SE 1/4 of section 24. Width of field is approximately 4.4 mm. Crossed polars.

DESCRIPTION--Sample 24G7A. Schistose; colorless, 2.0 mm, embayed, quartz phenocrysts; colorless, 0.04 mm, granoblastic, mosaic, quartz; colorless, 0.05 mm, lepidoblastic, xenoblastic, sericite.

MODAL MINERALOGY	
Quartz.......	62.0
Muscovite....	37.0
Pyrite.......	tr
(estimated)	

CIPW NORM	
Quartz.......	41.3
Orthoclase...	29.4
Corundum.....	21.7
Albite.......	2.2
Hypersthene..	1.9
Ilmenite.....	0.4
Magnetite....	0.3
Apatite......	0.1

FIGURE 24.--Photomicrograph of quartz-feldspar porphyry type of Rhyolite Intrusive of Fire Center Mine. Grain in lower right hand is quartz; grains at right center and upper left are albite; matrix is quartz, albite and sericite. Sample from near center of section 23. Width of field is approximately 4.4 mm. Crossed polars.

DESCRIPTI0N--Sample 23Ap. Porphyritic; clouded, 0.40 mm, corroded, subhedral, albite phenocrysts; clouded, 0.10 mm, granoblastic, xenoblastic, albite, commonly altering to sericite and rarely clinozo-site; colorless, 0.60 mm, embayed, anhedral, quartz phenocrysts; colorless, 0.05 mm, granoblastic, xenoblastic, quartz; colorless, 0.10 mm, anhedral, muscovite phenocrysts; colorless, <0.01 mm, xenoblastic, sericite; colorless, 0.05 mm, xenoblastic, colinozoisite; .04 mm, idioblastic, pyrite.

MODAL MINERALOGY	CIPW NORM
Albite.......48.0	Albite.......40.4
Quartz.......38.5	Quartz.......24.7
Musc/Ser.....11.0	Orthoclase...17.0
Clinozoisite. 1.5	Corundum..... 7.9
Pyrite....... tr	Anorthite.... 1.7
(estimated)	Hypersthene.. 1.5
	Magnetite.... 0.4
	Ilmenite..... 0.4
	Apatite...... 0.1

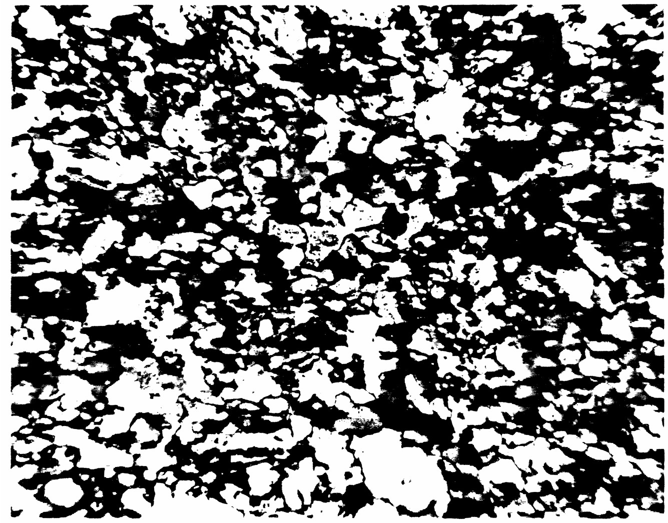


FIGURE 25.--Photomicrograph of aphanitic type of Rhyolite Intrusive of Fire Center Mine. Clear grains are quartz; clouded grains are albite. Sample from NE 1/4 of section 23. Width of field is approximately 1.1 mm. Crossed polars.

DESCRIPTION--Sample 23L1S. Granoblastic; clouded, 0.04 mm, xenoblastic, sutured, albite; colorless, 0.04 mm, xenoblastic, sutured, quartz; light green, <.01 mm, lepidoblasitc, xenoblastic, chlorite, foliated along thin shears.

MODAL MINERALOGY	CIPW NORM
Albite.......52.0	Albite.......63.7
Quartz.......48.0	Quartz.......27.1
Chlorite..... tr	Orthoclase... 3.8
(estimated)	Hypersthene.. 0.9
	Diopside..... 0.2
	Acmite....... 0.2
	Ilmenite..... 0.1

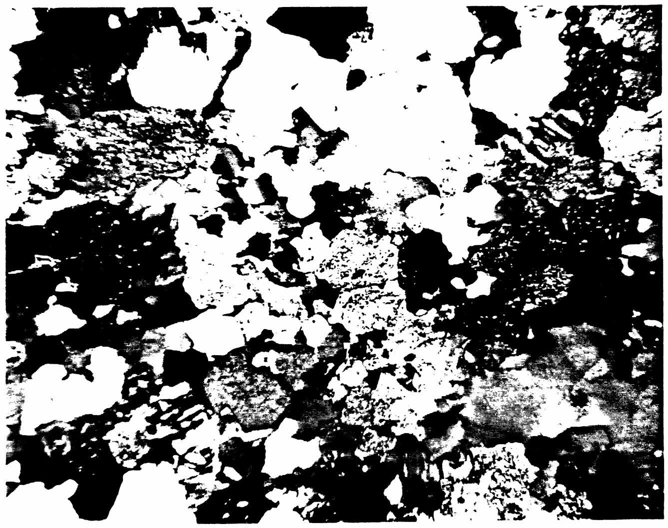


FIGURE 26.--Photomicrograph of granular (granitic) type of Rhyolite Intrusive of Fire Center Mine. Clear grains are quartz; clouded grains are albite; twinned grains are microcline. Sample from near center of section 3. Width of field is approximat-ley 4.4 mm. Crossed polars.

DESCRIPTION--Sample 3D8. Allotriomorphic granular; colorless to clouded, 0.75 mm, anhedral, corroded, albite, rimmed and cross-cut with clear albite, altered to sericite and locally altered to clinozoisite/epidote, colorless, 0.29 mm, undulose, anhedral, quartz; colorless to clouded, 0.29 mm, anhedral, microcline; light green, <0.01 mm, xenoblastic, chlorite, psuedomorphously replacing biotite; colorless, 0.10 mm, anhedral, muscovite; colorless, <0.01 mm, xenoblastic, sericite, alteration of albite; colorless, 0.10 mm, subidioblastic to xenoblastic, clinozoisite/epidote, alteration of albite along fractures in albite; colorless, 0.05 mm, subhedral, apatite.

MODAL MINERALOGY	
Albite.......	40.0
Quartz.......	31.8
Microcline...	22.8
Chlorite.....	2.0
Muscovite....	1.5
Epidote......	1.5
Apatite......	tr
Magnetite....	tr

Table 5.--Chemical analyses of rhyolites.

	9	10	11	12	13
SIO2	69.43	67.59	74.33	70.45	71.75
TIO2	0.22	0.20	0.03	0.22	0.01
AL2O3	14.96	15.96	12.99	18.35	17.53
FE2O3*	1.74	1.51	0.37	1.05	0.88
FEO	0.23	na	na	na	na
MNO	0.04	0.02	0.01	0.01	0.01
MGO	0.63	0.51	0.46	1.00	0.56
CAO	1.44	0.43	0.08	0.03	0.10
NA2O	2.52	4.90	7.88	0.29	2.22
K2O	3.90	2.96	0.64	5.51	4.88
H2O+	2.43	1.44	0.40	2.18	1.61
H2O-	0.00	0.05	0.05	0.10	0.00
P2O5	0.07	0.06	0.02	0.06	0.02
S	0.34	na	na	na	na
TOTAL	97.95	95.63	97.26	99.25	99.57
V	14	14	13	15	nd
CR	4	16	19	11	9
NI	4	5	3	3	6
CU	19	20	32	23	44
ZN	40	32	8	124	47
RB	84	57	7	104	88
SR	114	270	40	19	26
Y	15	8	4	15	13
ZR	120	97	39	112	33
NB	18	8	25	21	28
BA	59	41	97	97	12
LA	44	9	10	47	nd

*Feo determined by colorimetry (Fritz and Popp, 1986), where undetermined FeO is reported as Fe2O3.

na-not available
nd-not detected

9. 14E3-rhyolite
10. 23AP-rhyolite
11. 23L18-rhyolite
12. 24G7A-rhyolite
13. 24K15-rhyolite

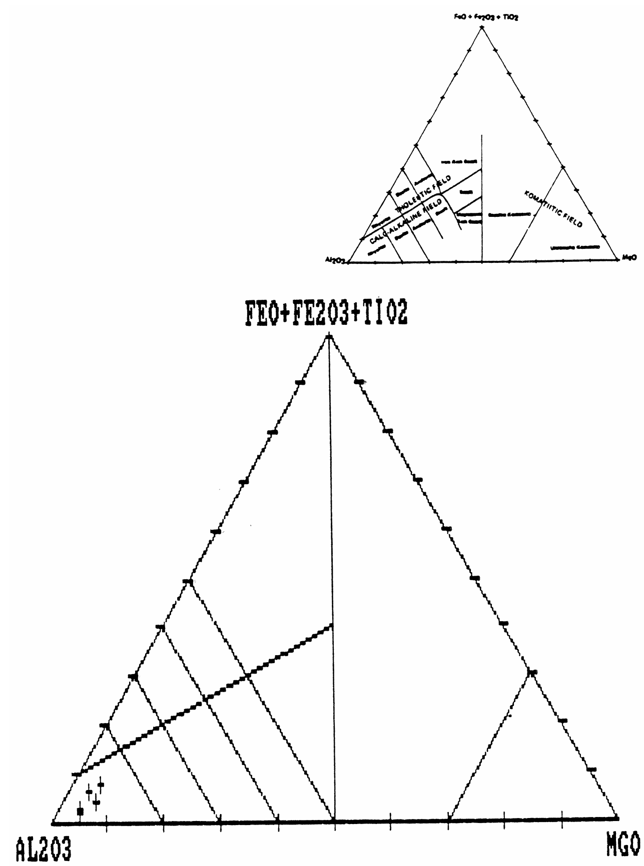


FIGURE 27.--Jensen Cation Plot (Jensen, 1976; Grunsky, 1981) of Rhyloite Intrusive of Fire Center Mine.

Foliated Rhyolite Variety

The Foliated Rhyolite Variety occur in zones of intense shearing and along the margins of rhyolite intrusives in shear contact with the surrounding rocks. They are dull gray, aphanitic, schistose mylonites. They are composed of granoblastic quartz and albite, lepidoblastic sericite and minor chlorite with fine-grained disseminated pyrite. They exhibit relict flaser structures (Fig. 28). Chemically the foliated variety are similar to the Nonfoliated Variety (Table 5).

Age and Origin of the Rhyolite Intrusive of Fire Center Mine

The rhyolites are considered to be Archean in age. The intrusive nature of the rhyolite is supported by the occurrence of several rhyolite dikes intruding the Archean Metagabbro of Clark Creek. The rhyolite dikes do not intrude the granodiorites and based on textural and geochemical arguments may be contemporaneous with, or a late stage of, the Granodiorite of Rocking Chair Lakes.

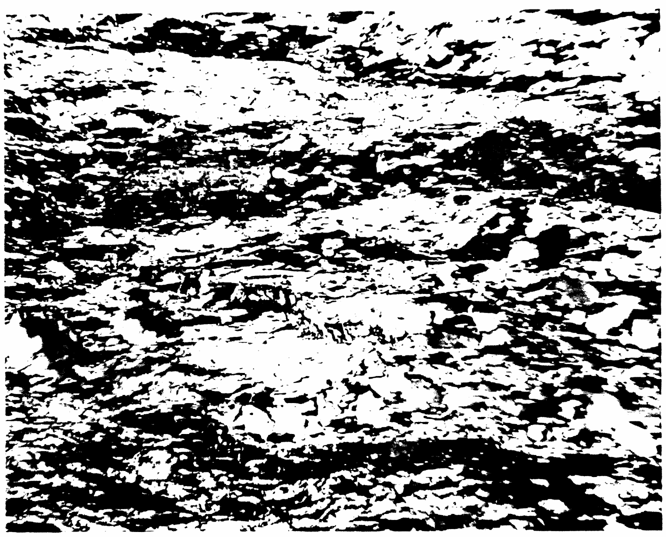


FIGURE 28.--Photomicrograph of Foliated Rhyolite Variety. Irregular clear grains are quartz; E-W foliation distinguished by sericite; groundmass quartz and sericite. Sample from E center of section 24. Field of view 1.11 mm. Crossed polars.

DESCRIPTION--Sample 24K15. Schistose blastomylonite; colorless, 0.02 mm, granoblastic, mosaic, xenoblastic, quartz; colorless, 0.06 mm, lepidoblastic, xenoblastic, sericite; clouded, 0.01 mm, granoblastic, xenoblastic, corroded, albite; 0.30 mm, idioblastic, pyrite.

MODAL MINERALOGY	CIPW NORM
Quartz.......52.0	Orthoclase...26.8
Sericite.....32.0	Albite.......17.5
Albite.......15.0	Quartz.......15.8
Pyrite....... tr	Hypersthene.. 1.3
(estimated)	Magnetite.... 0.2

GRANODIORITE OF ROCKING CHAIR LAKES

The Granodiorite of Rocking Chair Lakes is named for the dominantly granodiorite intrusions which occur around the Rocking Chair Lakes and along the cliff of Mulligan Creek in sections 10 and 15. The stock-sized intrusions are commonly in shear/fault contact with the surrounding basalts, but at least one very sharp intrusive contact has been observed in the SE 1/4 of section 10. Blocks of basalt (up to 10 ft. by 6 ft.) are common within the granodiorite in the NE 1/4 of section 10. A large basalt inlier in section 3 is interpreted as a roof pendant based on the consistency of its foliation with that in the surrounding basalts. In the Lake 3 to Lake 3 area abundant small rounded basalt xenoliths are common in the granodiorite.

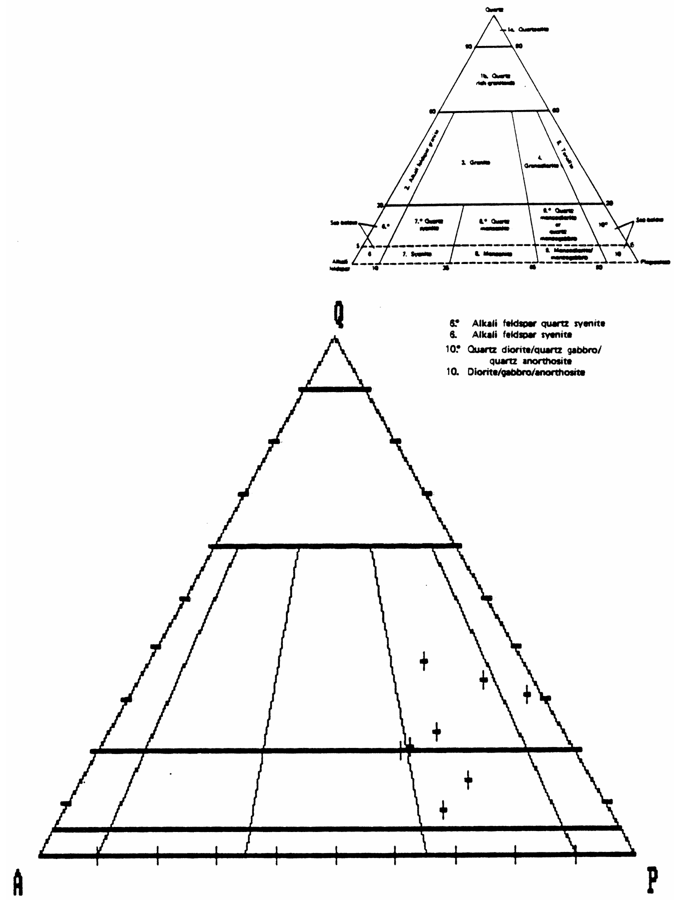


FIGURE 29.--Streckeisen (1976) Plot of Granodiorite of Rocking Chair Lakes.

The Granodiorite of Rocking Chair Lakes is found around Rocking Chair Lakes and along Mulligan Creek in sections 10 and 15, to the north along the cliff of Mulligan Creek in section 3, as a 1000 ft. wide body striking subparallel to the basalt foliation across sections 13, 14 and 24 and in a small stock (approximately 500 ft. in diameter) in the center of section 23.

The Granodiorite of Rocking Chair Lakes is medium gray to light pink, medium- to coarse-grained, hypidiomorphic to allotriomorphic granular, and has varied compositions including: granodiorite, tonalite, quartz monzonite, quartz monzodiorite and quartz diorite (Fig. 29). It can be subdivided into three phases that have the following end-members in a ternary system: massive, amphibole rich, and altered.

The massive end-member is composed of plagioclase, k-feldspar, quartz, amphibole and minor sericite, epidote, chlorite, apatite and carbonate (Fig. 30). The plagioclase is commonly oligoclase-andesine, seriate to porphyritic, corroded, with alteration to sericite and occasionally epidote. The plagioclase is commonly rimmed by albite giving the plagioclase a distinct red color in hand specimen. Quartz occurs as anhedral interstitial grains. K-feldspar, commonly microcline, is generally much finer grained than the plagioclase. Masses of epidote, chlorite and sphene pseudomorphously replace biotite. Plagioclase rimmed with albite and altered to sericite and epidote and the pseudomorphous replacement of biotite by chlorite indicate greenschist fades metamorphism.

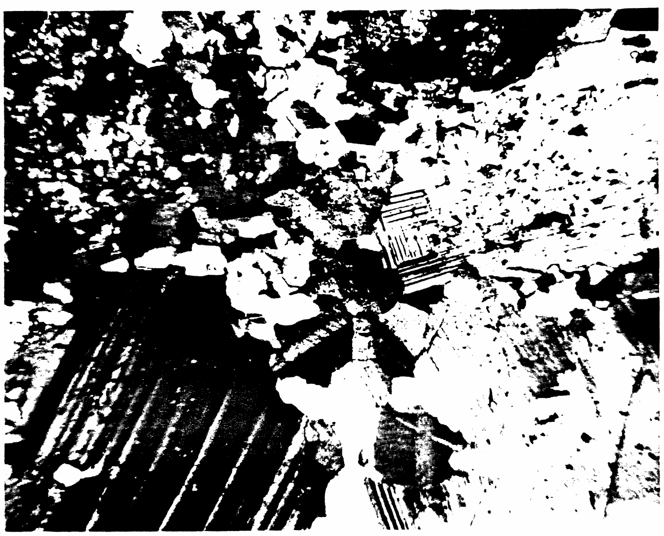


FIGURE 30.--Photomicrograph of massive type of Granodiorite of Rocking Chair Lakes. Large twinned grains are oligociase-andesine; clear grains are quartz; gray area at upper left is chlorite, epidote and sphene pseudomorphously replacing biotite. Sample from NE 1/4 of section 10. Width of field is approximately 1.1 mm. Crossed Polars.

DESCRIPTION--Sample 10A9. Quartz monzodiorite; hypidiomorphic granular; colorless, 2.25 mm, porphyroblastic to seriate, subhedral, oligociase-andesine, frequently altered to epidote; colorless, 0.60 mm, subhedral to anhedral, microcline; yellowish green, 0.1 mm, idioblastic to subidioblastic, epidote, as alteration of plagioclase and biotite; colorless, 0.1 mm, anhedral, quartz; light green, 0.04 mm, xenoblastic, chlorite, as alteration of biotite; colorless, 0.1 mm, euhedral, apatite; brown, 0. 02 mm, xenoblastic, sphene, as alteration of biotite.

MODAL MINERALOGY	
Olig/And	51.2
Microcline	22.3
Epidote	16.0
Quartz	6.8
Chlorite	3.2
Apatite	tr
Sphene	tr
(600 points)	

CIPW NORM	
Albite	50.1
Anorthite	14.6
Orthoclase	11.9
Hypersthene	8.3
Magnetite	4.4
Ilmenite	1.1
Apatite	0.8
Diopside	0.8
Olivine	0.5

The amphibole rich end-member is found near the margins of the intrusive bodies and is probably the result of assimilation of the surrounding basalt and gabbro. This type is most common in the south east corner of section 3 in a vide band along the basalt-granodiorite contact. This end-member is typically dark gray and fine- to medium-grained (Fig. 31).

The altered end-member is found in a granodiorite boss in the center of section 23. It is red to orange and fine- to medium grained (Fig. 32). This boss is cross-cut by stockwork quartz veins.

The Granodiorite of Rocking Chair Lakes show a calc-alkalic affinity (Table S, Fig. 33). It is slightly low in silica content relative to other rocks of this type due to the high amphibole content and can be classified as I-type granites (Table 7).

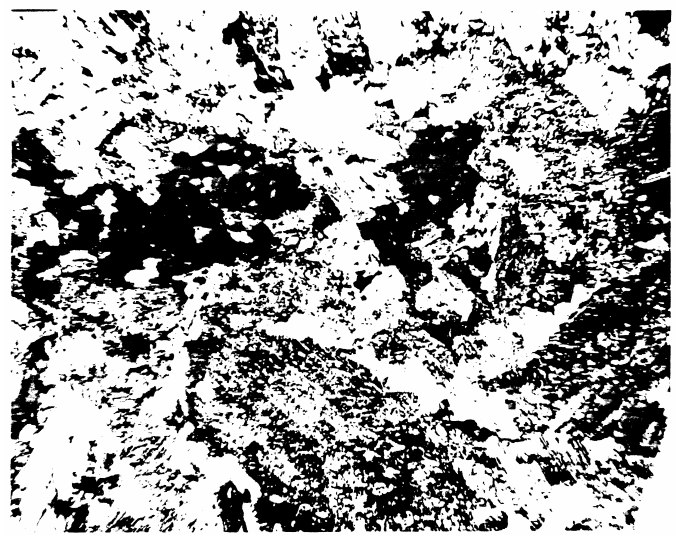


FIGURE 31.--Photomicrograph of amphibole rich type of Granodiorite of Rocking Chair Lakes. Clouded grains are andesine; clear grains are quartz; gray grains are hornblende. Sample from SE 1/4 of section 3. Width of field is approximately 4.4 mm. Crossed polars. Description on following page.

DESCRIPTION--Sample 3D3. Hypidiomorphic granular; light green to bluish green, 0.58 mm, subhedral, hornblende (Z^C 16), altering to carbonate, epidote and sphene; clouded, 0.39 mm, corroded, anhedral, andesine, altering to sericite; clear, 0.39 mm, anhedral, k-feldspar; colorless, 0.03 mm, xenoblastic, sericite; brown, 0.04 mm, xenoblastic, sphene, as alteration of hornblende, commonly in aggregates with epidote; yellow, 0.04 mm, xenoblastic, epidote; colorless, 0.13 mm, anhedral, quartz; colorless, 0,05 mm, xenoblastic, carbonate; light green, 0.40 mm, subidioblastic, chlorite, pseudomorphously replacing biotite; colorless, 0.07 mm, subhedral, apatite.

MODAL MINERALOGY	
Hornblende	55.8
Andesine	25.2
K-feldspar	6.3
Sericite	5.5
Sphene	3.2
Epidote	2.0
Quartz	1.0
Carbonate	1.0
Chlorite	tr
Apatite	tr
(400 points)	

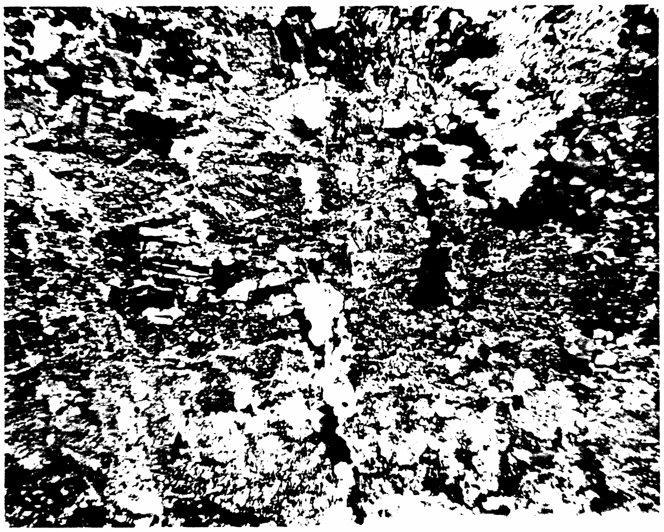


FIGURE 32.--Photomicrograph of altered type of Granodiorite of Rocking Chair Lakes. Clouded areas are intensely sericitized plagioclase; clear areas are quartz; twinned grains are microcline. Sample from center of section 23. Width of field is approximately 4.4 mm. Crossed polars.

DESCRIPTION--Sample 23Agr. Allotriomorphic granular; clouded, i.12 mm, anhedral, undulose, oligoclase/andesine, intense alteration to sericite, often in flaser structures, and occasionally in veinlets with quartz; colorless, 0.06 mm, anhedral, quartz, commonly in flaser structures, and occasionally in sutured veinlets; colorless, <0.01 mm, xenoblastic, sericite, abundant along fractures in plagioclase; clear, 0.26 mm, anhedral, microcline, in flaser structures; light brown to brown, 0.04 mm, xenoblastic, biotite, found along fractures; 0.02 mm, xenoblastic, sulfides, commonly found along fractures with sericite.

MODAL MINERALOGY		CIPW NORM	
Olig/And.....	37.5	Albite.......	31.5
Quartz.......	30.6	Orthoclase...	29.6
Sericite.....	17.0	Quartz.......	15.6
Microcline...	13.3	Corundum.....	12.3
Biotite......	1.5	Hypersthene..	2.7
Sulfide......	tr	Anorthite....	1.2
(800 points)		Magnetite....	0.6
		Ilmenite.....	0.6
		Apatite......	0.2

Table 6.--Chemical analyses of granodiorites.

	1	2	3	4	5	6	7	8
SIO2	53.27	53.95	58.63	57.88	59.62	62.21	53.10	55.15
TIO2	0.62	0.54	0.53	0.48	0.60	0.31	0.71	0.74
AL2O3	15.19	16.45	15.16	13.68	16.45	18.89	14.51	15.70
FE2O3*	2.13	2.86	1.66	3.95	3.14	2.26	6.75	6.98
FEO	4.51	2.34	3.11	na	na	na	na	na
MNO	0.13	0.11	0.09	0.06	0.05	0.03	0.13	0.08
MGO	5.88	4.83	4.80	2.06	3.75	1.06	5.27	5.69
CAO	5.43	3.44	2.69	4.12	1.45	0.36	3.61	1.80
NA2O	3.51	5.64	3.98	3.36	4.08	3.88	2.52	3.26
K2O	2.28	1.92	3.27	3.54	4.62	5.22	2.98	2.39
H2O+	2.19	1.92	3.03	3.28	2.55	1.64	5.81	3.50
H2O-	0.05	0.00	0.05	0.05	0.05	0.00	0.00	0.05
P2O5	0.22	0.36	0.28	0.28	0.31	0.09	0.23	0.28
S	0.01	0.01	nd	na	na	na	na	na
TOTAL	95.42	94.37	97.28	92.74	96.67	95.95	95.62	95.62
V	128	94	90	79	109	36	140	147
CR	219	89	80	60	136	28	301	203
NI	102	49	47	35	98	13	127	137
CU	18	19	10	63	23	63	23	33
ZN	90	90	102	71	41	47	61	129
RB	61	27	64	72	90	99	70	70
SR	619	935	597	895	407	231	322	273
Y	17	17	17	16	16	14	18	19
ZR	127	256	195	223	151	153	135	137
NB	nd	2	5	2	7	6	6	11
BA	70	93	142	145	148	98	97	93
LA	27	72	90	55	39	39	51	56

*FeO determined by colorimetry (Fritz and Popp, 1986), where undetermined total FeO is reported as Fe2O3.

na-not available
nd-not detected

1. 10A5-tonalite
2. 10A9-quartz monzonite
3. 10A10-granodiorite
4. 10A14-granodiorite
5. 15C7-quartz monzodiorite
6. 23AGR-granodiorite
7. 24K29-tonalite
8. 10C7-foliated quartz monzodiorite

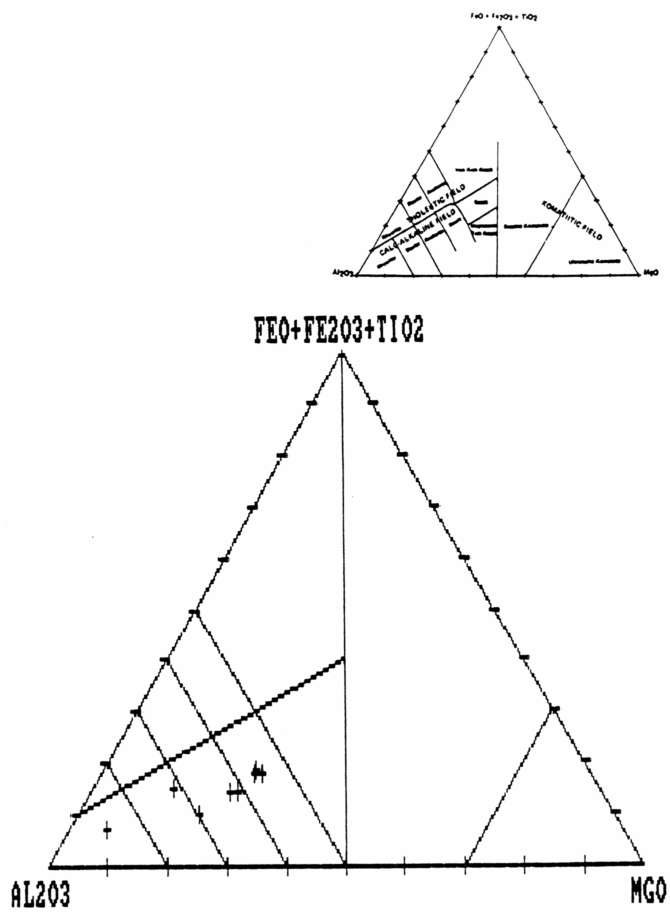


FIGURE 33.--Jensen Cation Plot (Jensen, 1976; Grunsky, 1981) of Granodiorite of Rocking Chair Lakes.

TABLE 7.--Characteristics of I-type granites (Ferguson, Chappell and Goleby, 1980) observed in the Granodiorite of Rocking Chair Lakes.

CHEMICAL CRITERIA

Na_2O > 3.2%

Mol. $Al_2O_3/Na_2O + K_2O + KaO) < 1.1$

Broad spectrum of composition from felsic to mafic.

Regular inter-element variations within plutons; linear or near-linear variation diagrams.

C. I. P. W. normative diopside or <1% normative corundum.

<65% SiO_2 most common.

MINERALOGICAL CRITERIA

Hornblende present (hornblende-bearing xenoliths common).

Cordierite, garnet, andalusite and sillimanite absent.

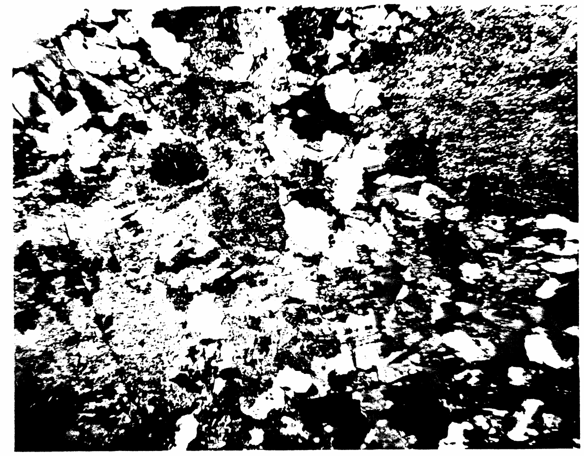
Foliated Granodiorite Variety

The Foliated Granodiorite Variety is found along intrusive contacts and faults that cross cut the granodiorite. It is gray to black, fine-grained to aphanitic, schistose mylonite with flaser structures. It is composed of plagioclase, chlorite, k-spar and quartz with minor apatite, sericite and epidote (Fig. 34). Locally, this variety hosts abundant (up to 20%), disseminated, euhedral pyrite.

Age and Origin of the Granodiorite of Rocking Chair Lakes

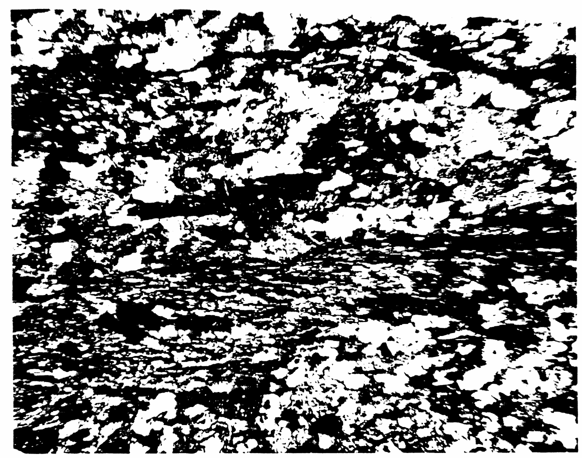
The Granodiorite of Rocking Chair Lakes is considered to be Archean in age. It intrudes the Metagabbro of Clark Creek and the Metavolcanics of Silver Mine Lakes. Mo rhyolite dikes were found cutting the Granodiorite of Rocking Chair Lakes. A well defined intrusive contact is exposed in a cliff face cliff face in the extreme southeast corner of section 10. Magmatically stoped blocks of basalt are common in the NE 1/4 of section 10. The west northwest trending granodiorite in sections 14, 13 and 24 has intruded the hinge of the major fold in the area.

The intrusion of the granodiorite has metamorphosed the basalts. The contact metamorphosed basalts are generally well foliated whereas the granodiorites are generally massive. These relationships indicate that the intrusion of the granodiorites was syntectonic. The Granodiorite of Rocking Chair Lakes was part of an extensive regional felsic magmatic event (Bodwell, 1972).



a)

FIGURE 34.--Description on following page.



b)

FIGURE 34.--Photomicrograph of Foliated Variety (b) of Granodiorite of Rocking Chair Lakes. Photomicrograph (a) of Nonfoliated Variety from sample collected within 10 feet of sample (b) for comparison. a) clouded grains are oligoclase/andesine; twinned grains are microcline; clear grains are quartz; dark gray grains are hornblende, b) clear grains are quartz; clouded grains are albite or oligoclase/andesine; foliated ground-mass is chlorite, albite and quartz. Sample from near center of section 10. Width of field is approximately 4.4 mm. Crossed polars.

DESCRIPTION--Sample 10C7 b). Schistose blastomy-lonite; clouded, 0.3d mm, corroded, anhedral, andesine, commonly in flaser structures, altering to sericite; colorless, 0.19 mm, xenoblastic, albite, in mosaic textured bands; light green, 0.07 mm, lepidoblastic to decussate, xenoblastic, chlorite; colorless, 0.07 mm, anhedral, microcline, in flaser structures; colorless, 0.14 mm, anhedral, quartz, in flaser structures and mosaic textured bands; colorless, <0.01 mm, xenoblastic, sericite; brown, 0.02 mm, xenoblastic, sphene; 0.03mm, idioblastic, pyrite.

MODAL MINERALOGY		CIPW NORM	
And+Alb......	44.0	Albite.......	29.1
Chlorite.....	22.0	Orthoclase...	14.9
Microcline...	14.0	Hypersthene..	13.5
Quartz.......	10.0	Quartz.......	12.0
Sericite.....	9.0	Corundum.....	10.9
Sphene.......	tr	Anorthite....	7.5
Pyrite.......	tr	Magnetite....	2.1
		Ilmenite.....	1.5
		Apatite......	0.6

QUARTZ VEINS

Quartz veins are common in Archean rocks throughout the area, but only the three largest quartz veins could be shown on the map (Plate I). Veins of massive, white quartz are more common than those of white, euhedral quartz (Fig. 35) but the latter are commonly associated with the former textural type. Least common are the massive, bluish-black veins of quartz that occur in pillow interstices in the basalts.

A vein of white, granular to massive, multi-generation quartz greater than 100 ft. wide and of undetermined length is located in section 24. Slabbed sections of the quartz show angular quartz fragments supported in a matrix of white and off-white quartz. The vein contains minor disseminated pyrite and has light red hematite stained zones.

Two quartz veins 20 to 30 feet in width and over 1000 feet long crop out, one in the southwestern corner of section 11 and the other in the north west corner of section 13 (Plate 1). These veins follow faults in the Metavolcanics of Silver Mine Lakes and are associated with altered basalt. The section 11 vein contains chalcopyrite and pyrite, whereas the section 13 vein contains pyrrhotite and pyrite. Smaller quartz veins are common in all Archean rocks in the area and are not shown on Plate 1.

FIGURE 35.--Photograph of euhedral vein quartz from northeast corner of section 24 near granodiorite-basalt contact.

Age of Quartz Veins

The large vein in section 24 cross-cuts the Metavolcanics of Silver Mine Lakes and the Rhyolite Intrusive of Fire Center Mine. Quartz veins are also observed in the Granodiorite of Rocking Chair Lakes. If quartz veins in the area are of similar age, then the large vein in section 24 would be post-Granodiorite of Rocking Chair Lakes, probably Archean in age, but possibly younger.

MICHIGAMME FORMATION

Two outcrops gray to brown, fine-grained, folded, thin-layered and massive graywacke assigned to the Michigamme Formation occur near the Mulligan Creek in section 15. These graywackes are phosphatic and have been investigated by Cannon and Klasner (1976) and C. Hall (1985). Bedded black and gray slates crop out in the Clark Creek Basin. The Michigamme Formation is considered to be Lower Proterozoic (Clark, et. al., 1975 and Sims, et.al., 1984).

LOWER PROTEROZOIC METADIABASE

Lower Proterozoic Metadiabase dikes cut Archean rocks in this area. These dikes are well jointed, up to 60 feet in width, with a strong magnetic signature. They are dark gray, fine-to medium-grained, hypidiomorphic granular, composed of labradorite, hornblende, chlorite, sphene, epidote and skeletal magnetite (Fig. 36). They are easily distinguished microscopically from the Archean metagabbro, whereas the macroscopic distinction is very difficult in the field. Consequently, where metadiabase cut the granodiorite they are interpreted to be Lover Proterozoic. Metadiabases that cut the metavolcanics are interpreted to represent Archean metagabbro.

An interesting thin Lover Proterozoic Metadiabase is crops out in the southeast corner of section 3 (not shown on Plate 1). This thin dike is metamorphosed to lover greenschist facies while the adjacent rocks are metamorphosed to lower and upper amphibolite facies. This dike also contains spherical aggregates of pyrite with minor chalcopyrite (Fig. 37). This is the only observed occurrence of sulfides in the Lower Proterozoic Metadiabase, although the Archean Metagabbro of Clark contain assemblages of pyrrhotite, chalcopyrite and cubanite. The pyritic aggregates in this Lower Proterozoic Metadiabase are interpreted as altered pyrrhotite xenocrysts derived from rocks below (possibly an Archean metagabbro).

KEWEENAWAN DIABASE

Keweenawan diabase dikes are east-west striking and reversely magnetic. They cut all units in the area and many form continuous ridges with sharp vertical sides. The diabase is dark brown to black, medium- to fine-grained, massive and composed of relatively unaltered plagioclase, pyroxene, olivine, and magnetite. The dikes are up to 150 ft. thick and over one and one half miles long. The relatively unaltered Keweenawan diabase dikes are considered to be Middle Proterozoic (Gair and Thaden, 1968; Puffet. 1974, and Clark et.al., 1975) and related to Keveenavan rifting and magmatism.

FIGURE 36,--Photomicrograh of Metadiabase. Light areas are labradorite; gray areas are hornblende; dark gray areas (in labradorite) are epidote/clinozoisite and sphene; dark areas are magnetite. Sample from S center of section 3. Width of field is approximately 4.4 mm. Plane polarized light.

DESCRIPTION--Sample 3G1. Hypidiomorphic granular; green to bluish green, 1.12 mm, subidioblastic, hor-blende (Z^C 18), replacing pyroxene; clouded, 1.50 mm, zoned, corroded, subhedral labradorite, altering to epidote/clinozoisite and sericite; colorless to yellow, 0.02 mm, xenoblastic, epidote/cinozoisite, in fine-grained aggregates with sphene; 0.68mm, skeletal, euhedral, magnetite; brown, <0.01 mm, xenoblastic, sphene; colorless, <0.01 mm, xenoblastic sericite; light green, 0.04 mm, xenoblastic, chlorite, replacing hornblende; colorless, micrographic intergrowths of quartz and K-spar.

MODAL MINERALOGY
Hornblende...45.0
Labradorite..37.0
Ep/Clino.....11.0
Magnetite.... 5.0
Sphene....... 2.0
Sericite..... tr
Chlorite..... tr
K-spar....... tr
Quartz....... tr

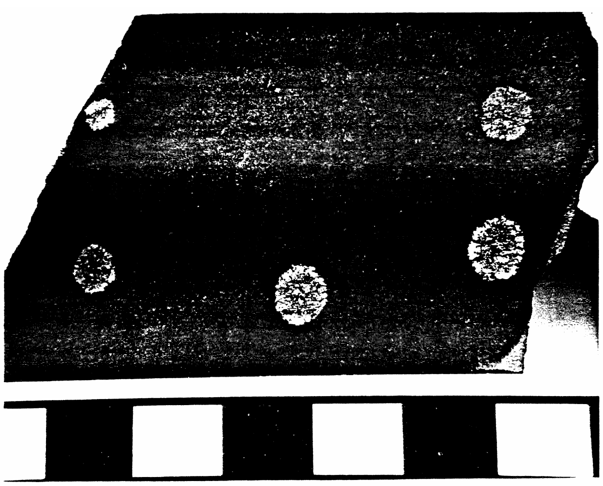


FIGURE 37.--Photograph of pyrite with minor chalcopyrite aggregates in Metadiabase. Sample from thin Metadiabse dike in SE corner of section 3. Scale bar are 1 cm. divisions.

CORRELATION OF ROCK UNITS

The stratigraphic correlation of rock units in the Silver Creek to Island Lake Area in relation to those delineated by Gair and Thaden (1968), Clark et.al. (1975), and Owens and Bornhorst (1985) is shown in Figure 38. The Upper Pillowed Basalt Member of the Metavolcanics of Silver Mine Lakes had previously been mapped as the Metavolcanics of Silver Creek by Johnson et.al. (1986); the new stratigraphic correlation is a result of recent mapping (Baxter et.al., 1987). Stratigraphic correlation of the Metavolcanics of Silver Mine Lakes with the Mona Schist is uncertain, however it is probably roughly the same age. The Metagabbro of Clark Creek is equivalent to that of Owens and Bornhorst (1985) and the metagabbro of Clark et.al. (1975). The Rhyolite Intrusive of Fire Center Mine is equivalent to the felsic intrusive of Clark et.al. (1975) and the Rhyolite Porphyry of Fire Center Mine of Owens and Bornhorst (1985). The Rhyolite Intrusive of Fire Center Mine is a modification of Rhyolite Porphyry of Fire Center Mine in order to incorporate the diverse textural variety observed in the rhyolite intrusives in this area. The emplacement of the Rhyolite Intrusive of Fire Center Mine may have been contemporaneous with the intrusion of the Granodiorite of Rocking Chair Lakes. The Granodiorite of Rocking Chair Lakes is most likely correlated with the granitoid, nonfoliated intrusives of the Compeau Creek Gneiss of Gair and Thaden (1958). This correlation is based on mineralogic similarity and the close spatial relationship to the Compeau Creek Gneiss to the north of the study area.

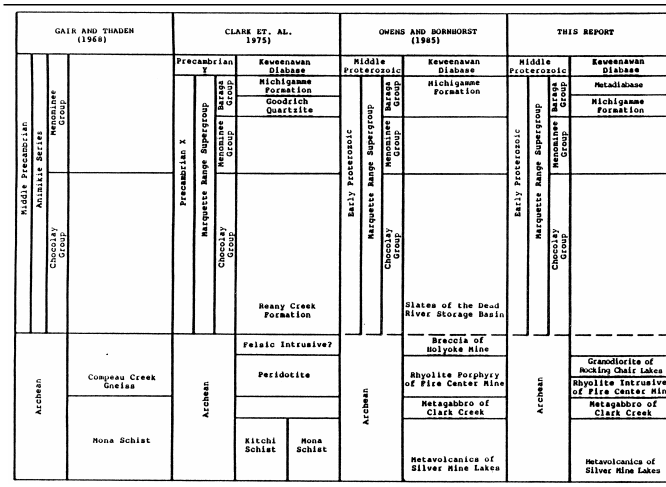


FIGURE 38.--Correlation chart for the rock units in the Silver Creek to Island Lake Area.

METAMORPHISM

METAMORPHIC FACIES

Ideally, the amphibolite facies is indicated by the presence of hornblende rather than actinoiite in metamorphosed mafic rocks (Winkler, 1979). The distinction between hornblende and actinolite in aphanitic and fine-grained rocks is difficult. Consequently, this study used the break between albite and oligoclase (the peristerite gap) to indicate the boundary between green-schist and amphibolite facies. The greenschist facies has been subdivided into lower and upper, based principally on textures. The lower greenschist facies is indicated by relict magmatic textures and the upper greenschist facies is indicated by metamorphic textures, such as granoblastic, lepidoblastic, or nematoblastic textures. The criteria used to determine metamorphic facies in this study are given in Table 8 along with criteria from other metamorphic studies performed in Canadian Archean greenstone belts.

ARCHEAN METAHORPHISM

In this area the Archean rocks were effected by an Archean metamorphic event. It is not certain whether this event is simply local or more regional in extent. Metamorphism to at least greenschist facies is found throughout the Archean rocks in the area, but facies up to upper amphibolite are found gradational to the contacts with the granodiorite plutons in the southern sections and are found across the northern sections. This suggests the higher grades of metamorphism may be contact metamorphic in nature, although a regional amphibolite facies metamorphism cannot be ruled out. The highest grades have been assigned to the amphibolite facies rather than to the hornblende hornfels facies because of the associated well developed schistosity.

Table 8.--Characteristics of metamorphic grade in mafic metavolcanics.

Ermanovics and Froese (1978).	Thurston and Breaks (1978).	Dimroth and Dressler (1978).	This report.
Upper amphibolite facies epidote out	High grade hbl+Ca plag+opx+cpx+ep+bi		Upper amphibolite facies hbl+Ca plag+di
Lower amphibolite facies An 17	Medium grade hbl+Ca plag+ep/clino+bi		Lower amphibolite facies hbl+Ca plag+ep/clino
Upper greenschist facies ep+alm+hbl	Low grade chl+ep/clino+act+Na plag +Ca plag+bi	Biotite-zone ab+ep+act+chl+sp+stil [metamorphic textures]	Upper greenschist facies act+ab+ep/clino+chl+alm [metamorphic textures]
Lower greenschist facies chl+ep+act	Very low grade chl+ep/clino+act+stil+Na plag	Chlorite-zone ab+ep+act+chl+sp+stil [magmatic textures]	Lower greenschist facies act+ab+ep/clino+chl [magmatic textures]

This study was approached on a sufficiently large scale to permit observations on the general distribution of the metamorphic facies (Fig. 39) based on field mapping and limited thin section work. The widespread metamorphic event was probably Archean and lower greenschist. The increase in amphibolite facies to the north suggests that the basalts occur as a thin skin above the granodiorite, and that fault bound segments are moved up in the northern sections.

The distinction between the Archean and Penokean metamorphism is difficult, because both are locally greenschist. The Archean metamorphic event is clearly indicated where basalts of the amphibolite facies (Archean) are cut by Lower Proterozoic metadiabase of the lower greenschist facies (Penokean). Penokean metamorphism in the Archean metavolcanic succession is implied by common retrograde assemblages and fabrics observed in the metabasalts.

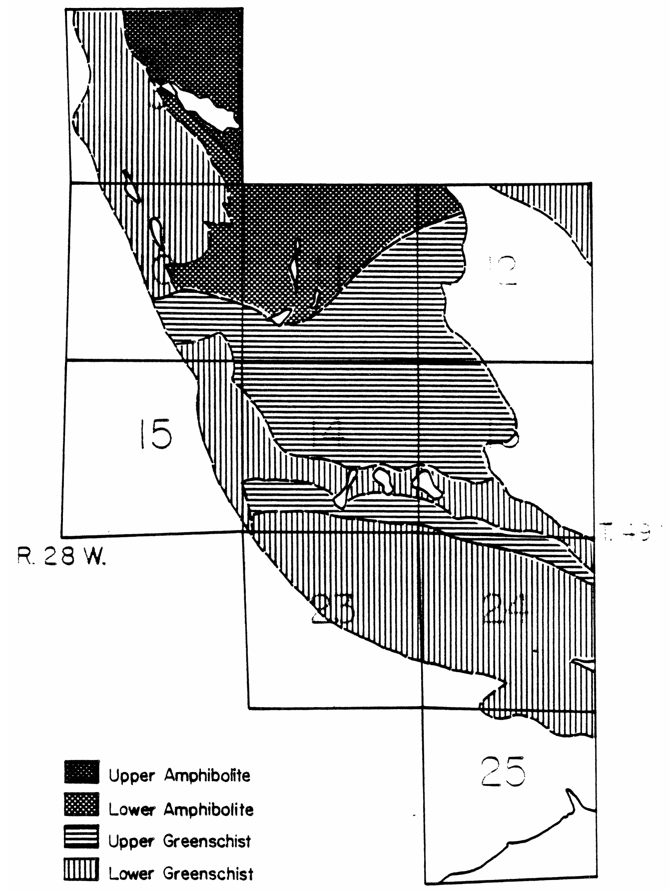


FIGURE 39.--Possible distribution of metamorphic facies in the Silver Creek to Island Lake Area based on field observations and limited thin section work.

LOWER PROTEROZOIC METAMORPHISM

The few outcrops of slates, metagraywackes of the Marquette Range Supergroup and Lower Proterozoic Metadiabase have all be metamorphosed to lower greenschist facies, the equivalent of the chlorite zone of James (1955). The metasediments have also been folded and have a well developed cleavage. The Lower Proterozoic metamorphism and deformation are generally ascribed to the Penokean Orogeny (Gair and Thaden, 1968).

STRUCTURE

INTRODUCTION

The rocks in the Silver Creek to Island Lake Area show evidence of deformation by two major deformational events. The Archean deformational event folded and foliated the Ishpeming Greenstone Belt and the Lower Proterozoic Penokean Orogeny affected the Marquette Range Supergroup metasediments. There is no evidence in the Archean rock units in the area of the Lower Proterozoic deformation.

FOLDS

The Silver Creek to Island Lake Area lies in the nose of a steeply plunging synformal anticline. The fold is expressed by 1) a folded gabbro sill in sections 23, 14 and 13, 2) by the attitude of the Iron Formation Member of the Metavolcanics of Silver Mine Lake which trends to the northwest to the east of this field area (Owens and Bornhorst, 1986; Baxter et.al., 1987) and 3) by the northeast trend of the Pyroclastic of Hill's Lakes (Fig. 40). The anticlinal character of the fold is indicated by younging directions as shown in Figure 40. The axial plane of this large fold has been intruded by the Granodiorite of Rocking Chair Lakes in sections 14 and 13. Mineral lineations have a steep plunge to the east suggesting that the fold is an overturned anticline. No smaller scale folding was recognized within the area.

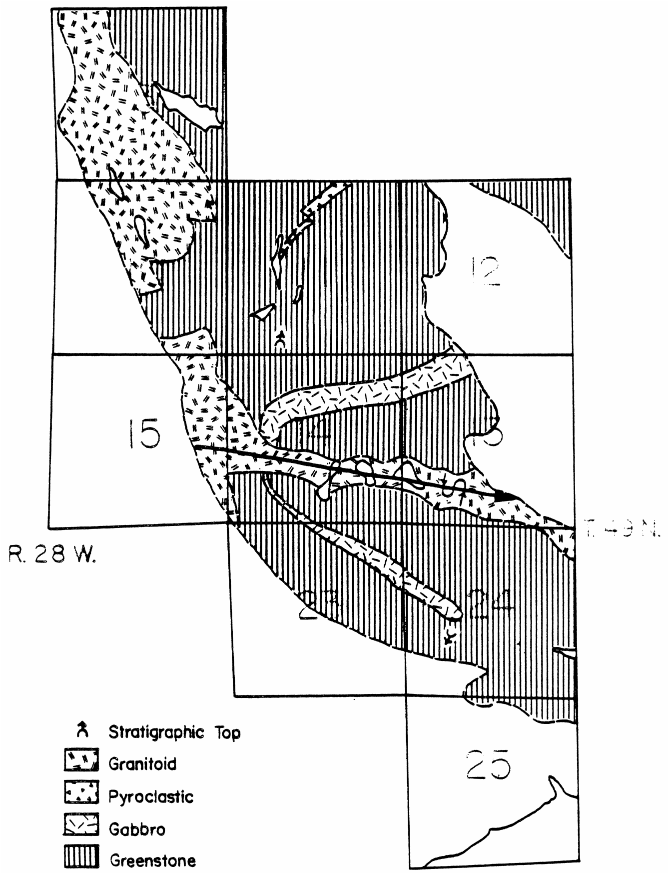


FIGURE 40.--Sketch map showing location of the major fold in the Silver Creek to Island Lake Area.

FAULTS

Several generations of faults are evident in the map area (Fig. 41). In the field faults are recognized by: 1) the presence of foliated rocks, 2) breccias, 3) offset or truncation of units, 4) rhyolite intrusives oblique to the regional foliation (intruding faults) and associated with one or more of the other features, 5) topographic lineaments.

The oldest faults are northeast trending Archean faults many of which are intruded by rhyolites. Interpreted to be contemporaneous with these, are faults which trend east-west to northwest across the field area. Many of these faults follow the contacts of gabbro and rhyolite intrusions. This period of faulting may have accompanied Archean folding. The writer proposes that faults developed along the margins of the older gabbro bodies and that somewhat later, rhyolites were intruded subparallel to the developing axial planar foliation and the faulted gabbro margins. The character of faulted contacts ranges from a major fault along the large northwest trending gabbro in section 23 to thin, sheared margins on rhyolite intrusives.

A unique fault pattern involving a granodiorite intrusion in the east half of section 11 permits the recognition of Archean extensional faulting. This granodiorite intrusion occurs as three faulted segments and all three segments share all or part of a unique stratigraphy. On the south there is a thin margin of porphyritic amphibole quartz diorite. This is succeeded on the north by a variable thickness of metagabbro and to the north by a spotted, light gray granodiorite. In Figure 42 the relationship of the three segments is explained by extensional faulting.

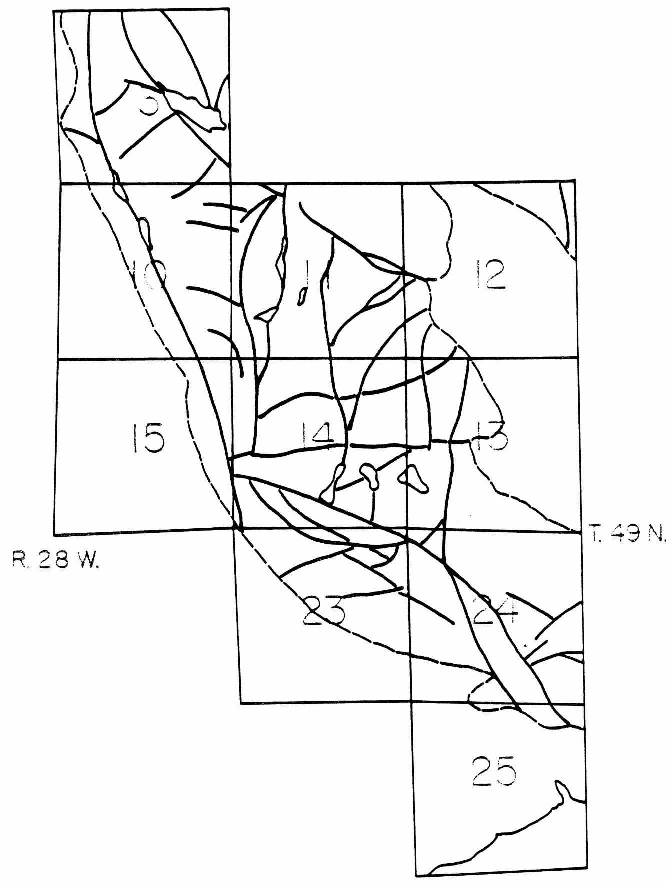


FIGURE 41.--Location map of the major faults in the Silver Creek to Island Lake Area.

The older faults of probable Archean age are truncated by younger faults which trend generally north-south. However, some north-south faults are intruded by rhyolite dikes which suggests they are contemporaneous with the older Archean faults. One of the north-south faults may have controlled the formation of the cliff of

Mulligan Creek and may be coeval with other north-south trending faults which cut the Archean rocks. The fault along Mulligan Creek has juxtaposed Archean and Lower Proterozoic rocks and implies movement during the Lower Proterozoic. However, some or all of them may be reactivated older Archean faults. Keweenawan diabase dikes are east-west trending and may occupy Keweenawan age faults or open tension fractures.

FOLIATIONS

Foliations in the Silver Creek to Island Lake Area are of two ages: 1) a variably developed foliation in the Archean metavolcanics and 2) a well developed cleavage in the Lower Proterozoic metasediments.

The dominant Archean foliation in the area strikes N 60° W to N 70° W and dips near vertical (Fig. 43) and is similar in trend to the majority of rhyolite intrusives and many of the faults. This foliation is poorly developed and irregularly spaced in the lower greenschist facies metabasalts and is expressed in shear zones or locally in more foliated zones within the metabasalts. This foliation is due to the orientation of lepidoblastic chlorite and nematoblastic actinolite. In the amphibolite facies this foliation is expressed as a well developed schistosity due to the orientation of nematoblastic hornblende and lepidoblastic biotite.

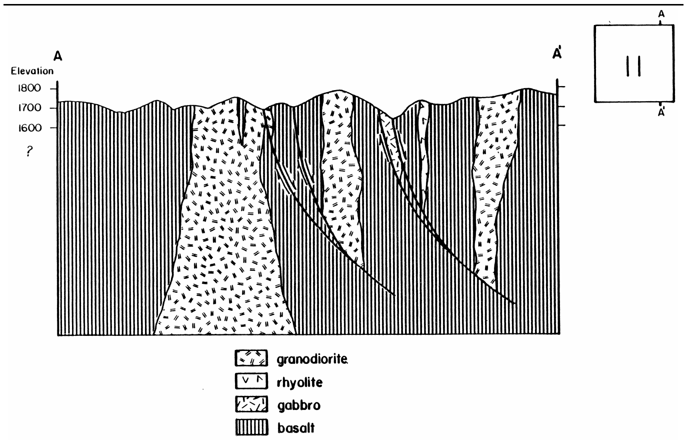


FIGURE 42.--North-south cross-section of the east half of section 11. Note extensional nature of faulting.

The Lower Proterozoic foliation is a well developed cleavage in the slates of the Michigamme Formation. This cleavage strikes N 74° W and dips 51° to the S (Fig. 44). Although the strike of the Archean and Lower Proterozoic foliations are similar (N 68° W and N 74° W) the dips are significantly different. Since the Archean foliation is associated with a downward facing fold and the Lower Proterozoic foliation is associated with upward facing folds, this difference in attitude of foliation suggests the Archean was relatively unaffected by the Penokean event and that the younger strata are allochthonous.

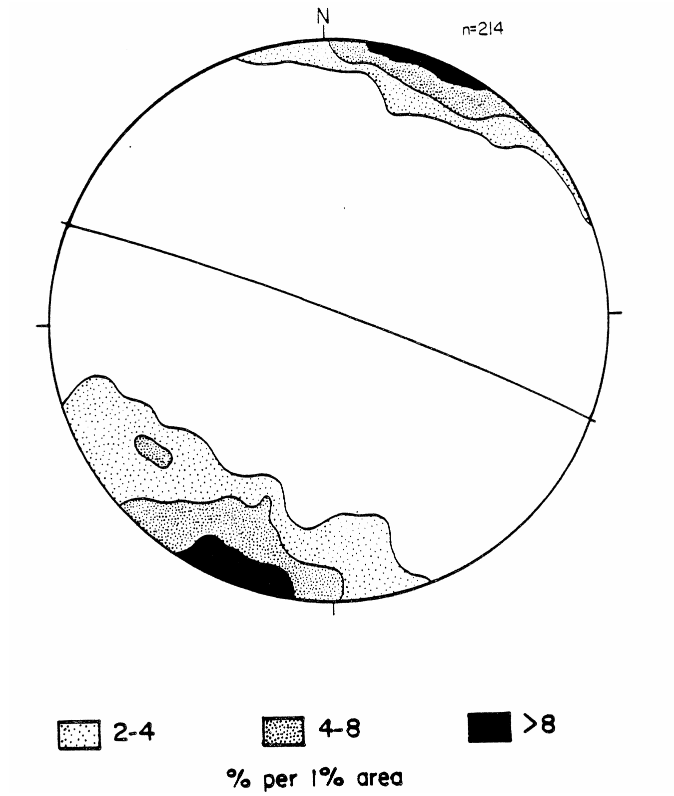


FIGURE 43.--Archean foliation diagram (contoured using the method of Braun (1967)).

CONTACT BETWEEN ARCHEAN AND PROTEROZOIC ROCKS

The contact between Archean and Lower Proterozoic units is not exposed in this field area. The Lower Proterozoic metasediments are thought to be separated from the Archean units by a presumed steeply dipping fault along Mulligan Creek and to the south in sections 23, 24 and 25. The contact relationship in the Clark Creek basin is uncertain, but a relatively horizontal structural discordance is not excluded.

MINERALIZATION

HISTORICAL EXPLORATION ACTIVITY AND AREA OVERVIEW

There are several old prospects in the Silver Creek to Island Lake Area (Fig. 45). Only the existence of the Silver Creek Prospect is generally known and during the 1930's the Norgan Gold Mining Company referred to it as 'old workings'. The Norgan Gold Mining Company also reported an assay of up to 1 oz/ton Au from a 'granite boss' in the center of section 23, T. 49 N., R. 28 W. During this present study, two additional old prospects were located in section 10, one in the NE 1/4, hereafter referred to as the North Section 10 Prospect, and the other in the SE 1/4, hereafter referred to as the South Section 10 Prospect. A third prospect was found near the center of section 14, hereafter referred to as the

Central Section 14 Prospect. These prospects are situated near the basalt-granodiorite contact and consist of several trenches, concentrated on quartz veins, and two test shafts.

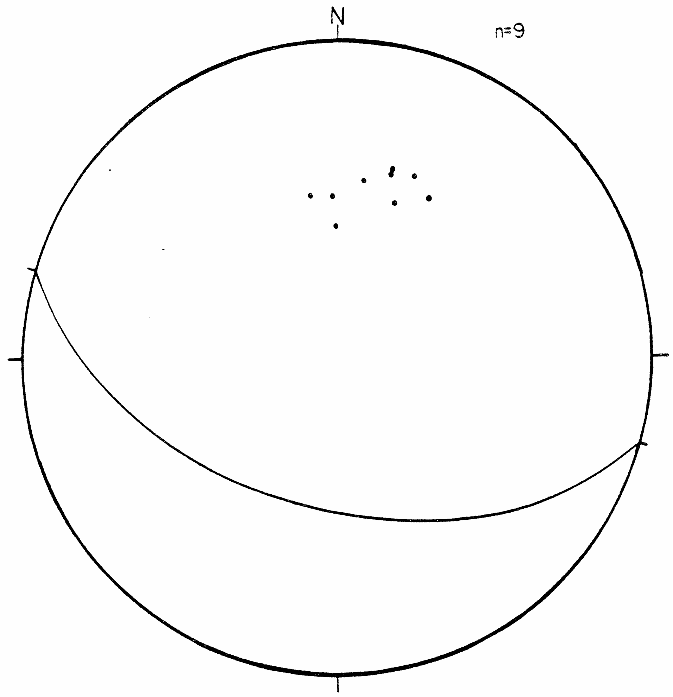


FIGURE 44.--Lower Proterozoic cleavage diagram. Note similar strike of foliation, but significantly different dip relative to Archean foliation (Fig. 43).

[Prospect Description]

The Silver Creek Prospect

The Silver Creek Prospect (Fig. 46) consists of 4 shallow shafts (Kelly, 1936 and Bodwell, 1972) and several trenches that intercept a quartz-carbonate vein (not shown) in section 25, T. 49 N. , R. 28 W. Three shafts were found during this study, the fourth is possibly buried by waste rock from the other shafts. And no recognizable trenches were found in the immediate vicinity. This quartz-carbonate vein is up to four feet thick and contains galena and sphalerite as the major sulfides with lesser amounts of pyrite and chalcopyrite and trace amounts of arsenopyrite and pyrrhotite. The quartz-carbonate vein is hosted in the Altered Basalt Variety of the Upper Pillowed Basalt Member of the Metalvolcanics of Silver Mine Lakes.

The North Section 10 Prospect

The North Section 10 Prospect consists of several trenches and a test shaft (Fig. 47). The trenching follows a quartz vein containing coarse-grained euhedral pyrite and very minor amounts of molybdenite. The quartz vein is hosted by granodiorite and basalt adjacent to the basalt-granodiorite contact. The granodiorite in the immediate vicinity of the vein is quite heterogeneous and consists of: pink to gray medium-grained granodiorite; gray, medium-grained, amphibole diorite; and coarse-grained amphibolite. A fine-grained metagabbro dike (Archean?) intrudes the basalts near the vein and contains fine grained disseminated pyrite.

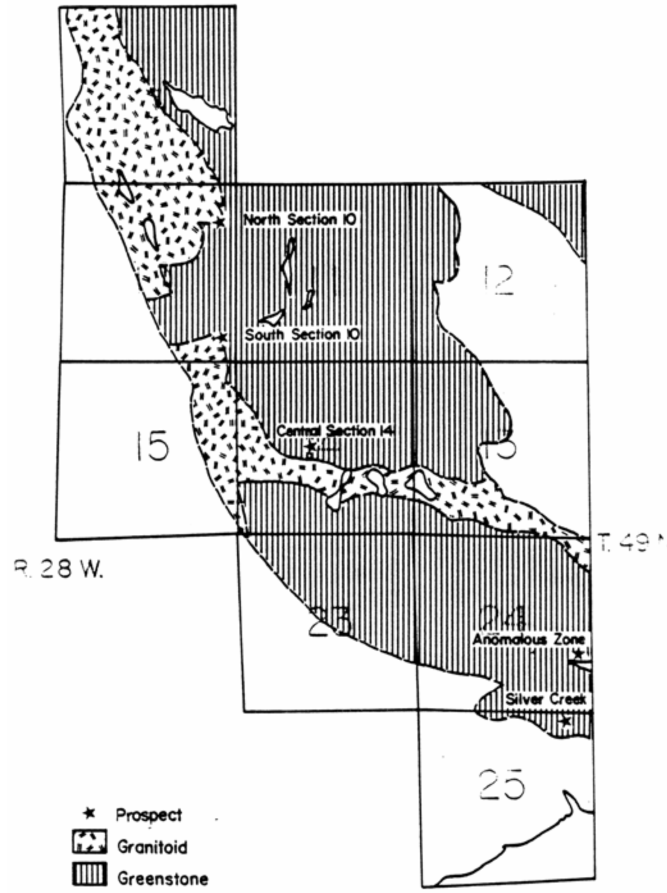


FIGURE 45.--Location map of prospects in the Silver Creek to Island Lake Area.

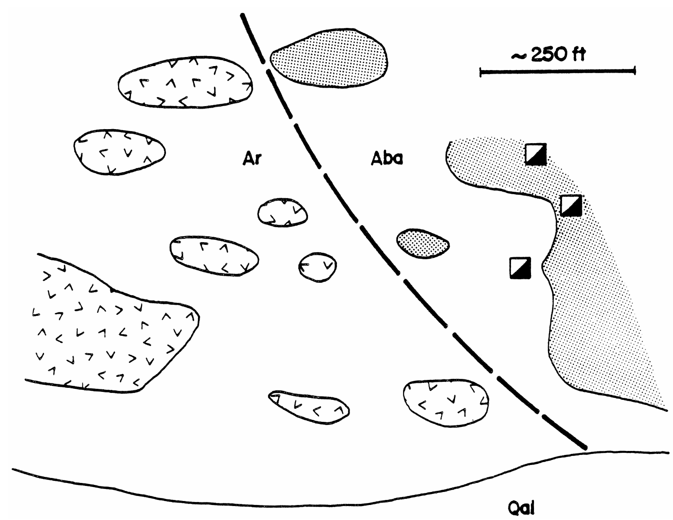


FIGURE 46.--Sketch map of the Silver Creek Prospect. Ar-Monfoliated Rhyolite Variety, Aba-Altered Basalt Variety.

The South Section 10 Prospect

The South Section 10 Prospect (Fig. 48) consists of several trenches which appear to have been for the investigation of a quartz vein. The quartz vein (not shown in Fig. 48) is hosted in Foliated Basalt Variety of the Upper Pillowed Basalt Member along a basalt-granodiorite contact. The dominant sulfide in the quartz vein is chalcopyrite, with minor pyrite. The quartz vein exhibits open space filling. Immediately adjacent to this prospect is a shear zone which cuts the basalts and contains up to 20% disseminated pyrite with minor chalcopyrite.

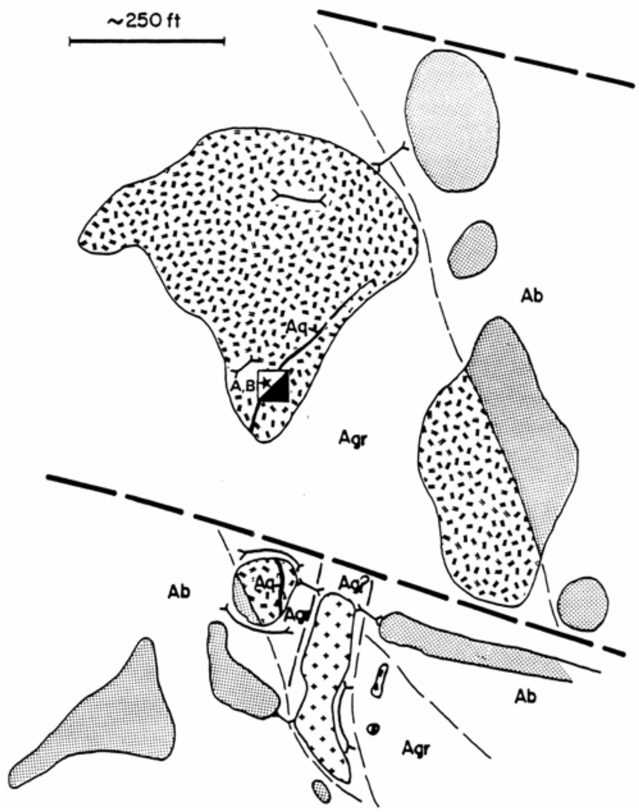


FIGURE 47.--Sketch map of the North Section 10 Prospect. Letters indicate sample locations (Table 9). Ab-Nonfoliated Basalt Variety, Agr-Honfoliated Granodiorite Variety, Aq-Quartz Vein, Ag-Metagabbro.

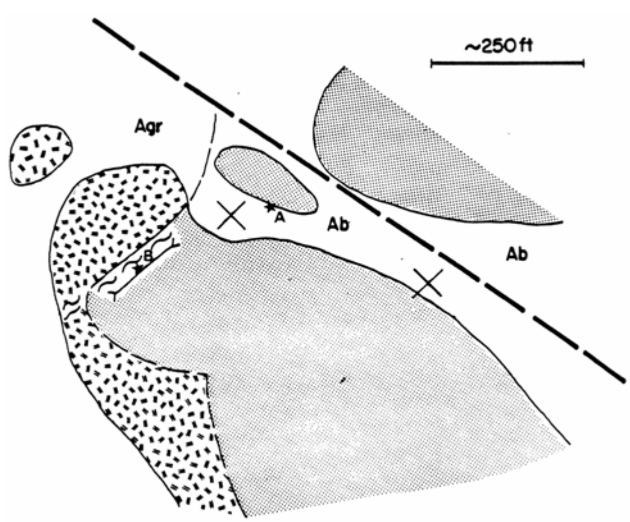


FIGURE 48.--Sketch map of the South Section 10 Prospect. Letters indicate sample locations (Table 9). Ab-Nonfoliated Basalt Variety, Agr-Nonfoliated Granodiorite Variety.

The Central Section 14 Prospect

The Central Section 14 Prospect consists of several trenches and a test shaft (Fig. 49). The test shaft is located on a quartz vein (not shown in Fig. 49) hosted in sheared altered basalts adjacent to a rhyolite. The trenches are found along the quartz vein and in altered basalts. The major sulfide in the quartz vein and altered basalt is pyrite. It occurs in the quartz vein as thin veinlets and disseminations and in the altered basalt as fine-grained, euhedral disseminations. The altered basalts are composed of chlorite, albite, and epidote with minor sericite, quartz and carbonate (Fig. 50).

Anomalous Zone

Assays of field samples have indicated a potential zone of anomalous Au values north of the Silver Creek Prospect in Section 24 (Fig. 51). Two foliated rhyolites, a highly altered basalt, and a quartz vein from a sheared basalt all yielded anomalous gold values. This zone is adjacent to a narrow man-made pond. The sides of the valley are quite steep and foliations suggest that this is a fault or shear zone trending east-west.

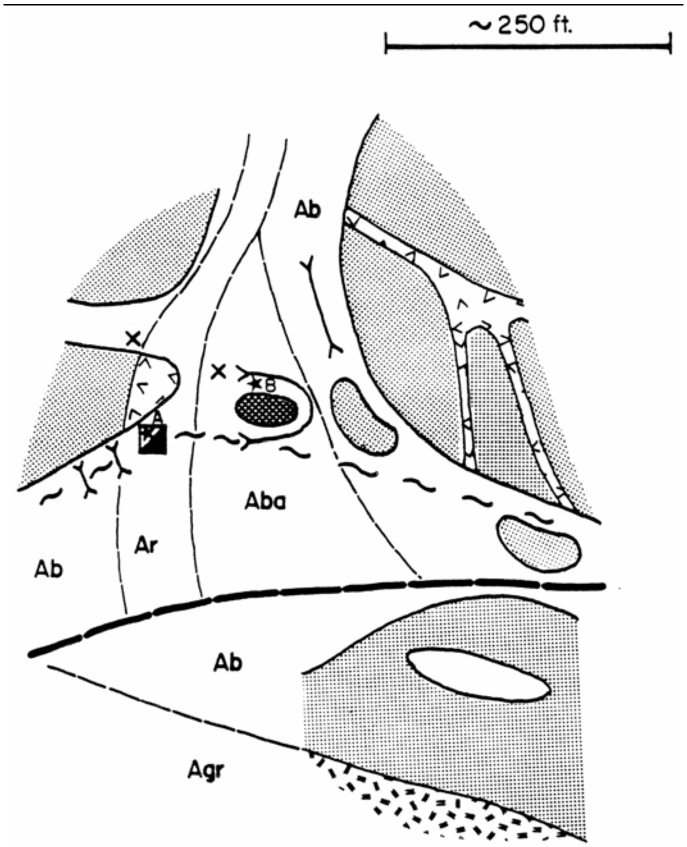


FIGURE 49.--Sketch map of the Central Section 14 Prospect. Quartz vein follows shear zone. Letters indicate sample locations (Table 9). Ab-Nonfoliated Basalt Variety, Aba-Highly Altered Basalt Variety, Ar-Nonfoliated Rhyolite Variety, Agr-Nonfoliated Granodiorite Variety.

FIGURE 50.--Photomicrograph of the Highly Altered Basalt at the Section 14 Prospect. Probably a highly altered mafic tuff. Light areas are albite and quartz? gray areas are actinolite; dark gray areas are epidote; gray area in upper left hand corner is chlorite; black areas are pyrite. Width of field is approximately 1.1 mm. Plane polarized light.

DESCRIPTION--Sample 14E11. Spotted, granoblastic, blastomyionite; colorless, 0.02 mm, granoblastic, albite; light green, 0.02 mm, xenoblastic, chlorite, replacing actinolite; pale to light green, 0.05 mm, subidioblastic, actinolite, with 'ratty' margins; colorless to pale yellow, 0. 11 mm, clinozoisite/epidote, pseudomorphously replacing garnet(?); brown, 0.01 mm, xenoblastic, sphene; idioblastic to subidioblastic, 0.02 mm, pyrite; colorless, 0.01 mm, xenoblastic, sericite; colorless, 0.02 mm, granoblastic, quartz.

MODAL MINERALOGY	
Albite.......	45.3
Chlorite.....	18.3
Actinolite...	18.0
Clino/Ep.....	11.0
Sphene.......	3.5
Pyrite.......	2.8
Sericite.....	tr
Quartz.......	tr
(400 points)	

GOLD AND SILVER ASSAY DATA

Sixty six samples were assayed for gold and eight of these were also assayed for silver. Gold and silver abundance was determined by neutron activation analysis which provides detection limits of 1 ppb for gold and 500 ppb for silver. Table 9 lists assays from the Silver Creek, Central Section 14, North Section 10, and South Section 10 Prospects as well as other anomalous gold occurrences. Anomalous gold occurrences are considered to be those over 10 ppb (Kwong and Crocket, 1978). Table 10 lists samples and levels of gold.

GOLD DISTRIBUTION

The distribution of gold in 170 samples from the Ishpeming Greenstone Belt and reported in previous literature are shown in Table 11. The samples include a small number collected to determine background values and significantly more collected in hopes of finding anomalous values. They include those collected at the Holyoke and Fire Center Wines (Owens and Bornhorst, 1986), the Deer Lake Peridotite in the vicinity of the Ropes Gold Mine, but not the ore host rock (Rossell, 1983), the Pepin, Bjork Lundeen, Ford and Marinesco Prospects (Boben et.al., 1986), the Fire Center Area (Owens and Bornhorst, 1986), the Silver Creek to Island Lake Area (Johnson et.al., 1986 and 1987) and the Clark Creek Area (Baxter et.al., 1987). However, the samples were not collected for the purpose of determining background gold values and are probably biased toward higher than background values.

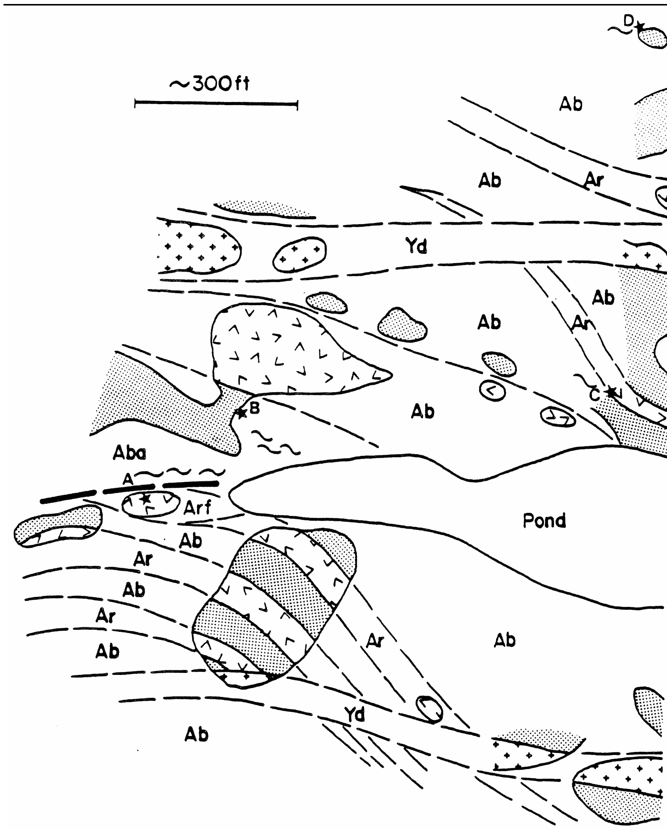


FIGURE 51.--Sketch map of the anomalous zone. Letters indicate sample locations (Table 9). Ab-Nonfoliated Basalt, Aba-Altered Basalt, Ar-Nonfoliated Rhyolite, Arf-Foliated Rhyloite, Yd-Keweenawan Diabase.

TABLE 9.--Gold and silver analyses from old prospects and anomalies with sample descriptions.

SPECIMEN	GOLD(PPB)	SILVER(PPM)	LOCATION
North Section 10 Prospect			
10B9Q	6	<0.5	A
10B9P	7		B
South Section 10 Prospect			
10D7	56		A
10D8	210	<0.5	B
Central Section 14 Prospect			
14E9B	<1		A
14E9Q	<1		A
14E11	1700		B
Silver Creek Prospect			
SC1	38	4.0	
Anomalous Zone			
24H4D	35		A
24I6	170	1.5	B
24K15	46		C
24K20	29		D
Anomalous Values			
3E5	270		Center sec. 3
10B14	14		NE 1/4 sec. 10
11E4	25		SW 1/4 sec. 11
11G1A	210		S center sec. 11
11G3	13		SE 1/4 sec. 11
11I1	13		SE 1/4 sec. 11
11I3	440		SE 1/4 sec. 11
11K4	46		SE 1/4 sec. 11
11Q2	790		SW 1/4 sec. 11
13B6	310		NW 1/4 sec. 13
13B104	76		NW 1/4 sec. 13
14C7	15		NW 1/4 sec. 14
14E5	11		SE 1/4 sec. 14
14G9	36		SE 1/4 sec. 14
14II2C	290		SE 1/4 sec. 14
14K2	21		NE 1/4 sec. 14
15A1	34	<0.5	NE 1/4 sec. 15
24E9E	33		Center sec. 24
24K29	13	<0.5	NE 1/4 sec. 24

Descriptions:

1PB9Q White massive quartz vein with coarse-grained, disseminated, euhedral pyrite.

1OB9P Pink, coarse-grained, albitized tonalite with fine-grained disseminated pyrite.

10D7 Foliated basalt with fine-grained, disseminated pyrite and minor chalcopyrite.

10D8 Quartz vein hosted in foliated basalt. White massive quartz with minor open space filling with fine- to medium-grained, disseminated chalcopyrite and minor pyrite.

14E9B Black, chloritic, foliated basalt with disseminated pyrite.

14E9Q White massive quartz with veinlets of pyrite.

14E11 Gray, altered basalt with disseminated euhedral pyrite.

SC1 Quartz vein hosted in altered basalt. White massive quartz with fine- to medium grained disseminated galena, sphalerite, chalcopyrite and pyrite. Grab sample from dump.

24H4D Foliated rhyolite with abundant, fine-grained, disseminated, euhedral pyrite.

24I6 Quartz-carbonate vein hosted in sheared altered basalt. Quartz white and massive with disseminated pyrite and chalcopyrite.

24K15 Sheared margin of an orange cherty rhyolite with finegrained, disseminated, euhedral pyrite.

24K20 Quartz vein hosted in brecciated basalt. Quartz massive and white with fine-grained disseminated pyrite and pyrrhotite.

10B14 Light red, coarse-grained, albitized tonalite. Moderately foliated with disseminated pyrite. From basalt-tonalite contact.

3E5 Mottled black and white schistose basalt with disseminated pyrite.

11E4 Banded black and white schistose basalt with disseminated pyrite.

11G1A Mottled black and white foliated and altered gabbro with disseminated pyrrhotite.

11G3 Mottled black and white foliated gabbro with disseminated pyrrhotite.

11I1 Mottled white and black quartz diorite with disseminated, fine-grained pyrite.

11I3 Brecciated altered basalt with disseminated fine- to medium-grained pyrite and stringers of fine-grained pyrite.

11Q2 Off-white, massive quartz vein with disseminated chalcopyrite and pyrite.

11K4 Limonitic altered basalt cut by white quartz veinlets with disseminated and stringers of pyrite.

13B6 Light gray altered basalt with disseminated fine- to medium-grained euhedral pyrite.

13B104 Limonite coated black aphanitic basalt with disseminated fine- to medium-grained euhedral pyrite.

14C7 Foliated gabbro with quartz veinlets and disseminated fine- to medium-grined euhedral pyrite.

14E5 Basalt with fine-grained disseminated pyrite.

14G9 Red and white quartz vein with disseminated pyrite and chalcopyrite from basalt-granodiorite contact*

14II2C Black coated fine-grained granular rhyolite dike with abundant sericite and fine disseminated sulfide (Py?).

14K2 Limonite coated basalt with disseminated medium-grained pyrite*

15A1 Black, limonitic schistose mylonite with fine-grained, disseminated, euhedral pyrite. From basalt-tonalite contact.

24E9E White, granular quartz with basalt fragments with fine-grained pyrite concentrated around and in basalt fragments. From eastern margin of large quartz vein.

24K29 2 in. quartz vein with disseminated pyrite. Sample from north face of tonalite.

Sample location letters from prospects and the Anomalous Zone can be found on the following figures: North Section 10 Prospect-Fig. 47, South Section 10 Prospect-Fig. 48, Anomalous Zone-Fig. 51.

TABLE 10.--Gold and silver analyses: background values with specimen descriptions.

SPECIMEN	GOLD(PPB)	SILVER(PPM)	LOCATION
3A2A	<1		SE 1/4 sec. 3
3A6A	4		NE 1/4 sec. 3
3B2	3		SE 1/4 sec. 3
3E4	3		Center sec. 3
10A5	<1		NE corner sec. 10
10A9	<1		N center sec. 10
10A11	1		N center sec. 10
10B15	<1		NE 1/4 sec. 10
11A7B	1		SW 1/4 sec. 11
11C4	1		SW 1/4 sec. 11
11C8	<1		NW 1/4 sec. 11
11C12	1		NW 1/4 sec. 11
11D2	1		SW 1/4 sec. 11
11E14	1		N center sec 11
11G1	5		S center sec. 11
11X1	6		SE 1/4 sec. 11
12X3	2		NE 1/4 sec. 12
13Q	4		NW 1/4 sec. 13
14A1	1		NW 1/4 sec. 14
14A2	<1		NW 1/4 sec. 14
14G3	4		NE 1/4 sec. 14
15A7	4		NE corner sec. 15
15C6	<1		E center sec. 15
23At	<1	<0.5	Center sec. 23
23-1H2	7		Center sec. 23
23Ar	<1		Center sec. 23
24E9W	<1		Center sec. 24
24E9CA	3		Center sec. 24
24E9CB	<1		Center sec. 24
24E25	1		N center sec. 24
24H100	3		NE 1/4 sec. 24
24I20Q	2		NE 1/4 sec. 24
24I20B	4		NE 1/4 sec. 24
24K28	3		NE 1/4 sec. 24
25Aba	<1	<0.5	NE 1/4 sec. 25

Descriptions:

3A2A Metadiabase with spheroidal aggregates of pyrite with minor chalcopyrite.

3A6A Medium- to coarse-grained amphibolite schist (gabbro ?) with disseminated pyrite.

3B2 Medium-grained amphibolite schist with disseminated fine-grained pyrite.

3E4 Altered amphibolite schist with abundant disseminated pyrite.

10A5 Gray, medium-grained, slightly foliated tonalite.

10A9 Red, medium- to coarse-grained, albitized tonalite with minor epidote.

10A11 White massive quartz vein (from small prospect pit).

10B15 Red and black, medium-grained, albitized tonalite with minor disseminated sulfide (Py?). Sample from basalt-tonalite contact.

11A7B Altered gabbro with disseminated pyrrhotite and veinlets of pyrrhotite.

11C4 Altered basalt with disseminated pyrrhotite, chalcopyrite, and pyrite.

11C3 Altered basalt with disseminated pyrrhotite.

11C12 Altered basalt with disseminated pyrite and veinlets of pyrite.

11D2 Altered basalt with disseminated fine-grained pyrrhotite and chalcopyrite.

11E14 Altered basalt.

11G1 Altered basalt with disseminated and veinlets of pyrrhotite and chalcopyrite.

11X1 Limonite coated coarse-grained gabbro with disseminated pyrite.

12X3 Altered basalt with disseminated pyrrhotite.

13Q White massive quartz vein with disseminated and veinlets of pyrrhotite, chalcopyrite and pyrite.

14A1 Quartz vein in altered gabbro with disseminated fine- to medium-grained chalcopyrite.

14A2 Off-white massive quartz vein with no apparent sulfide.

14G3 Altered basalt with disseminated fine-grained pyrrhotite.

15A7 Light green, aphanitic, epidotized basalt with >5% disseminated pyrite. Sample from large basalt pendant (?) west of N-S fault in tonalite.

15C6 Black foliated tonalite with disseminated, fine-to medium-grained pyrite.

23Agr White, massive quartz vein. Sample from tonalite in center of sec. 23. Tonalite is cross-cut by stock work of quartz veins.

23Ar Orangish-pink rhyolite quartz-feldspar porphyry with minor disseminated pyrite.

23-1H2 Greenish-gray, moderately foliated basalt with 1-3% disseminated euhedral pyrite.

24E9W White, granular quartz. Sample from west margin of large quartz vein in section 24.

24E9CA White, granular multi-generational quartz. Sample from center of large quartz vein in section 24.

24E9CB Reddish-white, hematite stained, granular quartz. Sample from center of large quartz vein of section 24.

24E25 White, massive quartz vein.

24H100 Thin, white, massive ptygmatic quartz vein with disseminated, medium- to coarse-grained euhedral pyrite hosted in basalt adjacent to rhyolite dike.

24I20Q White, massive quartz vein with limonitic coating along fractures.

24I20B Bluish-green, aphanitic basalt with 7-10% disseminated pyrite.

24K28 Bluish-green, fine- to medium-grained metagabbro with 3-5% disseminated sulfide (Py?).

25Aba Gray, massive, altered (sericite-chlorite-carbonate) basalt.

Table 11.--Gold distribution values for samples from the Ishpeming Greenstone Belt. The mafic type includes basalts and gabbros. The ‘other’ type includes Archean iron formation and volcaniclastics and Lower Proterozoic metasediments. Values are in ppb.

Type	Number	Minimum	Maximum	Geometric Mean
All	170	<1.0	100000.0	9.4
Mafic	72	<1.0	1700.0	7.1
Granitoids	14	<1.0	39.0	1.6
Rhyolites	14	<1.0	290.0	5.6
Quartz	52	<1.0	100000.0	19.0
Others	18	<1.0	2100.0	22.5

Table 12.--Calculated gold anomalous (threshold) values for the Ishpeming Greenstone Belt. Values are in ppb.

Type	Number	Geometric Mean	Geometric Deviation	Anomalous Threshold
All	170	9.4	14.4	38.2
Mafic	72	7.1	8.6	24.3
Granitoids	14	1.6	7.5	16.6
Rhyolites	14	5.6	18.5	42.6
Quartz	52	19.0	21.1	61.2
Others	18	22.5	18.2	58.9

The distribution of gold in the Ishpeming Greenstone Belt is similar to that described for the Kakagl Lake Area, Northwestern Ontario by Kwong and Crocket (1978). For comparative purposes the Michigan rocks have also been subdivided into mafic, rhyolite, granitoid, quartz vein and metasedimentary types (Fig. 52). The metasedimentary types include Archean iron formation, Archean volcaniclastics, and Lower Proterozoic slates, graywackes and conglomerates.

Although these values may not represent true background values, they can be used to establish the level of anomalous values for exploration. Table 12 lists anomalous values determined for the Ishpeming Greenstone Belt based on this sampling. Threshold anomalies were calculated by adding the geometric mean to twice the geometric standard deviation. It can be concluded that: 1) the gold distribution is skewed (approximately log normal) (Fig, 52), 2) the geometric mean of all samples is 9.4 ppb and 3) certain rock types are associated with slightly elevated values (mafics > rhyolites > granitoids).

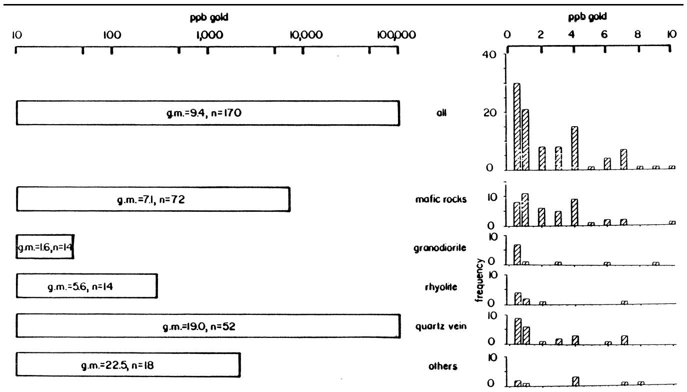


FIGURE 52.--Comparison of the average gold content (geometric mean) and the distribution in the major rock types (0 to 10 ppb range) in the Ishpeming Greenstone Belt.

STRUCTURAL ASSOCIATION

The Silver Creek to Island Lake Area is cross-cut by many faults (see Fig. 41). Commonly, the granodiorites are in sheared fault contact with the basalts and gab-bras. Anomalous precious metal values were found in highly sheared rocks containing sulfides. The sulfides occur as disseminations or as veins within the sheared rock. Faults, sheared fault contacts, and shear zones within this area provide a widespread network for hydrothermal fluid migration.

ROCK TYPE ASSOCIATION

Sulfide minerals occur in all types of rocks, as disseminations and in quartz veins. As noted above, the location and thickness of shear zones is important with regard to sulfide mineralization. Distribution and style of shear zones are controlled to some degree by rock type. For example, shear zones in granodiorite and gabbro tend to be relatively sharp, thin and less common (brittle to brittle-ductile; Ramsay, 1980) as compared to those in basalt (ductile) and rhyolite intrusives cutting across the basalt (ductile to brittle-ductile). The width of the sheared basalt-granodiorite contact varies from less than 6 ft. at the South Section 10 Prospect to widths of greater than 30 ft. inferred from shapes of valleys. Three old prospects in this area are associated with the basalt-granodiorite contact and one, the Silver Creek Prospect, is associated with a highly altered basalt in a rhyolite-basalt contact.

ALTERATION

The rocks in the Silver Creek to Island Lake Area have undergone greenschist to amphibolite facies metamorphism. The alteration associated with the mineralization is retrograde in nature and clearly post-metamorphic and post-deformation (Archean). Locally the rocks in the area are chloritized, epidotized, sericitized, carbonatized and silicified, and at the North Section 10 Prospect there is a thin zone of albitized granodiorite.

Carbonatization has been recognized as an important factor in precious metal mineralization (Colvine et.al., 1984). In this area there is a general area wide increase in carbonate as disseminations and veins to the south and west towards the cliff of Mulligan Creek.

MINERAL ASSOCIATION

The sulfides are significant indicators of precious metal mineralization. No anomalous values were obtained from any sample of country rock or quartz vein where sulfides were not present. The following sulfides were observed in the Silver Creek to Island Lake Area: pyrite, chalcopyrite, pyrrhotite, cubanite, arsenopy-rite, galena, and sphalerite. Pyrite occurs in quartz and quartz-carbonate veins and as disseminations in rocks of all types. At the Silver Creek Prospect pyrite was found to replace pyrrhotite. Chalcopyrite also occurs in quartz and quartz-carbonate veins. Pyrrhotite is found in quartz and quartz-carbonate veins, as disseminations in the gabbros and as disseminations in the altered basalts in the southern part of section 11. Cubanite occurs in minor amounts as intergrowths in chalcopyrite disseminations in the gabbros. Arsenopyrite occurs in minor amounts in quartz and quartz-carbonate veins. Galena and sphalerite occur in quartz-carbonate veins, most notably at the Silver Creek Prospect and surrounding area.

Sulfide separates of galena and sphalerite from the Silver Creek Prospect were analyzed for Ag. The galena separate had 120 ppb Ag and the sphalerite separate <1.0 ppb which indicates that galena is the major site for Ag. A yellow sulfide separate (chalcopyrite, pyrite and pyrrhotite) was analyzed for Au and yielded 180 pph Au.

Sulfides are the apparent host of precious metals in the altered rocks. Hematite and magnetite are common in relatively unaltered rocks, but have been replaced by pyrite and pyrrhotite in altered rocks.

The veins can be divided into three groups: 1) quartz veins, 2) quartz-carbonate veins, and 3) carbonate-quartz veins. The division of these veins is based on paragenesis. Quartz veins are those without carbonate. Quartz-carbonate veins are those showing quartz veins cross-cut by later carbonate veining (as is found at the Silver Creek Prospect). Carbonate-quartz veins are the least common and show carbonate veining crosscut by quartz veins. Anomalous Au values were obtained from quartz and quartz-carbonate veins. This suggests that the Au mineralization is associated with the early quartz in veins. Therefore, the vein mineral paragenesis would be: early quartz associated with sulfides and gold mineralization, carbonate, and a late quartz. However, the carbonate may be of multigenerations and the quartz of a single generation and the paragenesis would be: carbonate, quartz associated with sulfides and gold mineralization, and the late carbonate. This scenario is less likely than the first, because carbonate veining is rare in the area and quartz is certainly of multigenerations.

AGE OF MINERALIZATION

The gold mineralization in this area postdates the intrusion of the basalts by the granodiorites (2,700 m.y.; Trow, 1979) and the Archean metamorphic event. This temporal relationship is indicated by the retrograde assemblages of the altered basalts in the amphibolite facies. The retrograde assemblages and open space filling indicative of a more near surface condition would suggest a hiatus between granodiorite/rhyolite emplacement and gold mineralization. The age of mineralization may be significantly less than 2,700 m.y. The altered areas are off-set and truncated by Late Archean extensional faults indicating that mineralization is pre-Penokean Orogeny,

COMPARISON WITH THE COLVINE MODEL

A model for Archean lode gold deposits has been developed by the Ontario Geological Survey (Colvine et.al., 1984). Comparison of gold mineralization in the Ishpeming Greenstone Belt with the Colvine model reveals many similarities (Table 13).

Significant similarities observed in the Silver Creek to Island Lake Area include the style of structural association, alteration types and the strong sulfide association.

All precious mineralization within the Silver Creek to Island Lake area is directly or indirectly associated with faults or shear zones. Direct association is indicated by mineralized quartz veins and disseminated sulfides along faults and shears, while indirect association is indicated by halos of disseminated sulfides around faults and shears.

Common alterations associated with gold mineralization in the Colvine model are: carbonatization, serici-tization and chloritization. In this area chloritiza-tion and carbonatization are common, particularly in the Silver Creek Prospect area. Sericite is a common mineral in alteration assemblages, but was not found as an intense alteration product.

As stated previously no anomalous gold values were found in any sample not containing sulfides. This strong sulfide association is an indication of hydrothermal fluids similar to those in the Colvine model. These fluids are thought to contain sulfide complexes which are transported with the gold and may react with iron, forming sulfides (sulfidation) and depositing the gold. This is a reasonable explanation for the absence of iron oxides in the altered units.

It may be concluded that the Colvine model fits the characteristics of gold mineralization in the Ishpeming Greenstone Belt and that the application of this model in exploration could be very productive in this area.

TABLE 13.--Summary of similarities of characteristic features of gold mineralization in the Silver Creek to Island Lake Area with the Colvine model of Archean lode gold deposits.

SIMILARITIES
Ductile deformation zones not necessarily manifest as lineaments.
Lineaments are produced by brittle, often late movement.
Deformation zones contain magmatic rocks significantly younger than calc-alkaline volcanism.
Alteration is indicative of hydrothermal fluid passage, but broad scale carbonatization is most commonly a per-cursor to very localized gold deposition.
Alteration directly associated with gold deposition (silicification, sulphidation and alkali metasomatism) rarely forms a significantly broader halo than gold.
Mafic volcanics are a favored host where prepared by carbonatization.
Felsic intrusions are a common host to quartz vein related mineralization.
Sulphidation of iron oxides and silicates is virually ubiquitous in gold deposits.

POTENTIAL EXPLORATION TARGETS

An obvious place to start with industry exploration in this area is the reevaluation of known prospects. Several of these prospects have yielded significant Au anomalies, for example, the Central Section 14 (1,700 pph) and

South Section 10 Prospects (56 and 210 pph). These prospects should be sampled in a systematic manner.

The three mapped large quartz veins are also obvious candidates as targets. The large quartz vein in the south-west corner of section 11 has yielded an anomalous Au value of 790 pph. The other large quartz veins in the north-west corner of section 13 (one sample) and the center of section 24 (three samples) have not yielded anomalous values, but the sampling of these veins has not been approached in a systematic manner.

Prospectors in the past have apparently concentrated their efforts on locating and evaluating quartz veins as potential gold bearing hosts. Quartz veins should still be considered good targets, but areas of disseminated pyrite and pyrrhotite mineralization associated with altered areas (see Fig. 13) should also be considered as good targets. Some of the alteration zones cover a large area, for example, the alteration zone in the southern half of section 11 and the alteration zone near the Silver Creek Prospect in the south-east corner of section 24 and the north-east corner of section 25.

Altered areas are most easily recognized in the field by their lighter color. Relative to unaltered varieties which are generally black to dark green or dark gray the altered varieties are commonly light gray on fresh surfaces. So it is not surprising that in the past altered areas have been confused with and mapped as andesites in this area (Kelly, 1936). Weathered surfaces of the altered varieties are often shades of light green and yellow. Because of the style and scale of mapping (1:6,000) used in this study smaller altered areas (less than 40 feet in width) have not been shown on the map, while other altered areas may not have been intersected by a mapping traverse.

Fault and shear zones should also be considered as targets in this area. It is not uncommon to note thin zones of foliated rock containing quartz veinlets along the sides of narrow valleys outlining faults. On the geologic map (Plate 1) only the larger faults and shear zones are shown. There are numerous smaller ones in the area which were not mapped, yet their size (generally less than 10 feet wide if not mapped) warrants considering them as potential targets. The evaluation of these potential targets was not within the scope of this report which is based on outcrops. The evaluation of the fault valleys as potential targets would require some combination of locally detailed mapping, trenching and/or drilling, geophysics, and soil geochemistry.

The Anomalous Zone (see prospect description section, Table 9 and Fig. 51) is a potential target of the ‘fault valley’ type. The flanks of this valley have indicated a possible halo of low (29 through 170 pph), but anomalous Au values. Deformation and quartz and carbonate veining increase toward the fault from the north. A man-made pond in the valley and a cedar swamp to the east precluded further evaluation of this area in this study.

Another potential target may lie under the Michigamme Formation adjacent to the cliff of Mulligan Creek. Carbonatization in this area increases to the south and west toward the cliff. This suggests that significant carbonate alteration of the Archean rocks may lie beneath the Michigamme Formation. If this reasoning is accepted as an indicator of a potential target then the area south of the Silver Creek Prospect has to be considered as the most likely target of this type. The Silver Creek Prospect area contains significant carbonate alteration and the regional aeromagnetic map indicates a low frequency, deep, regional, south-west trending structure cutting the greenstone belt in this area.

POSSIBLE EXPLORATION TECHNIQUES

It is our opinion that the most valuable exploration tool in this area is detailed outcrop mapping. The scale used for this study (1 inch = 500 feet) is appropriate for ‘regional’ geologic mapping, but due to the complex nature of the area a scale of as small as 1 inch 3 100 feet would probably be needed. Outcrop density in many areas (up to 60%) is such that mapping at small scale can be fruitful. The delineation of shear zones, alteration zones and quartz veins are particularly important in outlining potential targets in this area.

Geochemical analyses of whole rock and soils should also prove useful particularly in outlining targets besides the major ones mentioned above, for example, evaluating fault valleys and areas of limited outcrop. Systematic geochemistry was not done in this study; only the most promising samples were analyzed for Au and it is encouraging that anomalous values were found.

The presence of disseminated pyrrhotite associated with some of the alteration zones suggests that a combination of magnetic and EM surveys may prove useful in delineating likely targets. Disseminated sulfides (pyrite, chalcopyrite or pyrrhotite) suggest that EM, resistivity, IP and SP may work well in outlining potential targets, although the terrain may make the use of IP and resistivity impractical.

ECONOMIC POTENTIAL

The anomalous Au values, large quartz veins, alteration zones, distribution of faults and shear zones and overall geologic setting imply that this area has the potential of containing economic amounts of Au. The scope of this report did not allow the methodical evaluation of potential exploration targets documented in the area, such as, altered areas, prospects, fault valleys and large quartz veins. This report is intended as a fundamental geologic data base upon which further work can be based.

GEOLOGIC HISTORY

In lieu of a conclusion section, the geologic history best summarizes geologic events in this area. Figure 53 shows the temporal relationship of geologic events in the Silver Creek to Island Lake Area. The earliest event recorded in this area is the subaqueous emplacement of tholeiitic basalts. These basalts were probably emplaced in a sea having a depth of 1000 meters or more. This depth is suggested by the general absence of vesicles (Jones, 1969). A date of 2,700 m.y. (Trow, 1979) has been determined for the basalts. This date was determined from a rhyolite within the basalts and may more closely represent the date of the Granodiorite of Rocking Chair Lakes. The basalts were then intruded by gabbro dikes and sills. The mafic rocks were then deformed by compressive tectonism associated with intrusion of rhyolites and granodiorites (2,700 m. y.). The rhyolites probably represent differentiated parts of the granodiorite plutons. This was followed by precious metal mineralization. The last Archean geologic event in this area was extensional faulting.

The Archean rocks were subjected to an extended period of erosion followed by deposition of Lower Proterozoic slates and graywackes of the Michigamme Formation (1.9-2.1 b.y.). These were intruded by the Lower Proterozoic diabase. Again the area was deformed by compressional tectonism (Penokean Orogeny 1830-1890 m. y.) with deformation being most noticeable in the Lower Proterozoic rocks and little in the Archean. After a considerable break in time Keweenawan (1.1 b.y.) diabase associated with continental rifting were intruded.

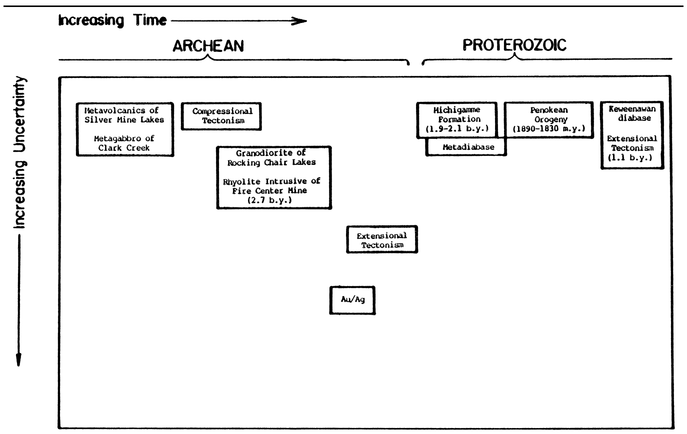


FIGURE 53.--Temporal relationship of geologic events in the Silver Creek to Island Lake Area-Horizontal axis is unsealed increasing time the vertical axis represents the uncertainty of the placemnt in time of certain events. Established dates for specific events are included.

APPENDIX A

Location of samples (Fig. A1) and anlyses performed on samples (Table A1) included in this report.

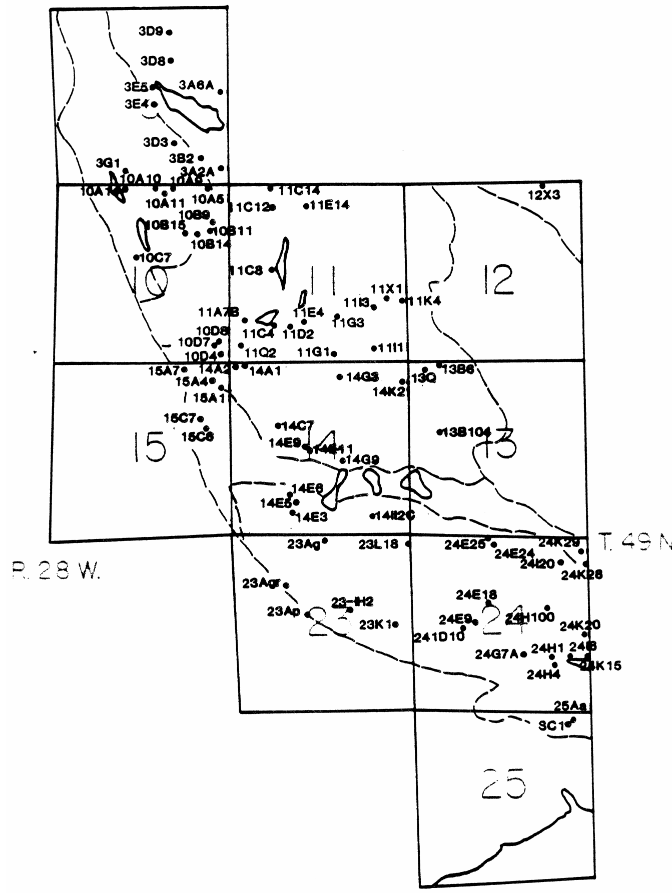


FIGURE A1.--Location of samples included in this study.

TABLE A1.--Table of samples included in this thesis and analyses performed on those samples. Petrographic samples enclosed in brackets are those not included in petrographic descriptions within the text of this thesis.

SAMPLE #	PETROGRAPHY	CHEMISTRY	ASSAY
3A2A	X		X
3A6A	(X)		X
3B2			X
3D3	X		
3D8	X		
3D9	X		
3E4			X
3E5			X
3G1	X		
10A5	(X)	X	X
10A9	X	X	X
10A10	(X)	X	
10A11			X
10A14	(X)	X	
10B9Q			X
10B9P			X
10B11	(X)	X	
10B14	(X)		X
10B15			X
10C7	X	X	
10D4	X	X	
10D7	(X)		X
10D8			X
11A7B			X
11C4			X
11C8			X
11C12			X
11C14	X	X	
11D2			X
11E4			X
11E14			X
11G1	X		X
11G1A			X
11G3			X
11I1	(X)		X
11I3			X
11K4			X
11X1			X
12X3			X
13B6			X
13B104			X
13Q			X
14A1			X
14A2			X
14C7			X
14E3		X	
14E5			X

Table A1 (continued)

SAMPLE #	PETROGRAPHY	CHEMISTRY	ASSAY
14G3			X
14G9			X
14E6	X	X	
14E9B			X
14E9Q			X
14E11	X		X
14II2C			X
14K2			X
15A1			X
15A4	X	X	
15A7			X
15C6			X
15C7	(X)	X	
23Agr	X	X	X
23Agc	(X)	X	
23Agn	X	X	
23Ap	X	X	X
23-IH2			X
23K1	X	X	
23L18	X	X	
241D10		X	
24E9E			X
24E9W			X
24E9CA			X
24E9CB			X
24E18	X	X	
24E24	X	X	
24E25			X
24G7A	X	X	
24H1	X	X	
24H100			X
24H4	X	X	X
24I6			X
24I20B			X
24I20Q			X
24K15	X	X	X
24K20			X
24K28	(X)	X	X
24K29	(X)	X	X
25Aa	X	X	X
SC1			X

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