Manitoba
Energy and Mines
Minerals Division

Report of
Activities
1990

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Manitoba
Energy and Mines

MINERALS DIVISION

REPORT OF ACTIVITIES 1990

1990

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MANITOBA ENERGY AND MINES
Minerals Division

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Figure GS-1:   Location of field projects 1990.

INTRODUCTORY REVIEW

by W.D. McRitchie

1990 proved to be a year in which budgetary constraints and re-organization limited the range and level of activities undertaken by the Provincial Geological Survey. Continued delays in signing a new Mineral Development Agreement resulted in postponement of many provincial projects, and federal contributions in Manitoba dropped to less than $150K.

Workplans were revised again, in mid-season as a result of additional budgetary limitations. Several projects were cancelled, others were severely trimmed, and the remainder suffered significant cutbacks. By late summer, most projects were operating at a maintenance level.

Nevertheless the year proved fruitful, with publication of many new reports stemming from the previous MDA, and good progress being made in completing the main body of work conducted during the previous six year period.

In the Spring of the year, the Minerals Division was reorganized. Promotional and informational services previously provided by the Exploration Services Section of the Mines Branch were transferred to the Geological Services Branch. A Geophysics, Geochemistry and Terrain Sciences Unit, was established in the Geological Services Branch, and the Analytical Laboratory was placed within the Minerals Investigation Section.

Regional offices at The Pas and Flin Flon continued to be active in providing support to local prospectors, and in retrieving drill core from various industry drilling operations. Enquiries are currently being made to establish a new core-storage facility, near Baker's Narrows, to service all companies active in the western sector of the Flin Flon greenstone belt.

The final meeting of the 1984-1990 MDA Management Committee was held in Ottawa, March 14th, at which time Manitoba tabled its most recent draft proposal for future Minerals Programming. Discussions aimed at development of a joint MDA II Workplan continued throughout the summer, together with liaison relating to ongoing EXTECH projects, and proposals for future initiatives under NATMAP, and Lithoprobe. In response to a request from the Mines Ministers (Sudbury 1989), "that federal and provincial geologists explore ways of improving the coordination of geological programming in Canada", managers from both Survey organizations met on several occasions to discuss new mechanisms for enhancing cooperation, and integration of their efforts. Reports on this topic, with contributions from all provinces, were presented to the Mines Ministers by both the Committee of Provincial Geologists, and the National Geological Surveys Committee, at the 47th Annual Mines Ministers Meeting in Winnipeg (August 27-28th).

Federal Cabinet announced its priorities for regional economic programming in western Canada in late August, and authorized initiation of negotiations with Manitoba for a second MDA for the period 1990-1995. Continued input was provided throughout the year to the Evaluation of the 1984-1989 MDA, the results of which should be available prior to year-end.

In Spring, and in the absence of a new MDA, the provincial field program was mounted at an extremely modest level with expenditures significantly lower than those in 1989, the wind-up year of the last Agreement. Twenty-five students were employed to facilitate the summer's program, but for want of funds, several were retained in Winnipeg to expedite data analysis and sundry computer functions.

The main focus of the summer's activities was directed to an evaluation of the mapping potential of areas affected by the 1989 forest fires, more specifically the fire in the Elbow Lake-North Star Lake region, that southwest of Wekusko Lake, and the new burn in the English Lake area of southeastern Manitoba. Feedback from these orientation surveys will be compiled into a major workplan to be implemented over the next 2-3 year period under the acronym of STOMP (Short Term Outcrop Mapping Program).

During the summer, Branch staff led and/or assisted in several field workshops designed to familiarize industry, university, and government geologists with key exploration and research areas, and new concepts arising from previous work. Most notable of these were: 1) a three-day field trip in the Flin Flon/Hanson Lake area, convened by the "Friends of the Reindeer Zone", 2) a two day tour of the Assean/Split lakes area as part of a workshop organized by the "Friends of the Nickel Belt" (20 delegates), and 3) a six-day tour of the Flin Flon/Snow Lake/Thompson region (35 delegates), led jointly by GSC and GSB geologists as Field Trip #10 of the IAGOD (International Association on the Genesis of Ore Deposits) conference.

In the Spring of 1990, Lithoprobe Phase III was approved for 5 years, with a three-year funding level (1990/91-1992/93) of 4.5 million dollars per year. The Trans-Hudson-Orogen Transect (THOT), in Manitoba and Saskatchewan, is one of the projects to be started in 1991; it will commence with reflection seismic geophysical surveys. The Provincial Survey expects to play an active role in providing logistical support for several of the projects to be conducted under the THOT. Projects already started include Uranium/lead geochronology of the Lynn Lake area, the Thompson Belt/Reindeer Zone, and Molson Dyke Swarm paleomagnetism.

Throughout the summer, in cooperation with the Manitoba Energy Authority, and Industry Trade and Tourism officials, Branch geologists gave several presentations on commodity prospects to industry representatives, most notably to the Metal Mining Agency of Japan, Fact Finding Mission on Rare Metals (September 19, 20).

Technical presentations on various aspects of the province's development potential, and geological attributes, were given in Vancouver, Dallas, Hibbings, and in Calgary. Work also continued on the Geological Atlas of the Western Canada Sedimentary Basin, which is being coordinated by the Alberta Research Council. Contributions by the GSB included cross-sections of the lower Paleozoic sequence, corrections to Manitoba's Oil and Gas well database, and stratigraphic core hole information in areas of no deep holes. A complete list of publications issued by the Branch during the year is provided at the end of the volume.

Budgetary limitations again impeded the Branch's ability to conduct cooperative research with universities, and interaction with the Department of Geological Sciences, University of Manitoba, was constrained to several minor projects entailing an exchange of analytical services.

Several new reports in the Mineral Deposit Series were issued during the year, as were two new additions to the Provincial 1:250 000 Atlas. Compilation work on the sub-Phanerozoic Precambrian basement continued for several areas south of Snow Lake, with maps scheduled for release in November 1990 at the annual Meeting With Industry. A review of geophysical assessment reports that encompass the Bissett district is also well advanced; publication of an Open File is scheduled for early 1991. Final drafts of the long-awaited Fox River Report are now complete, and this publication should also be released next year.

Geographic Information Systems (GIS) activities continued at a low level, with continued experimental work on the Division's PAMAP system. Marked progress has been made in developing new systems for standardizing and processing field data, and a new user manual is being widely utilized throughout the Branch. Autocad capabilities are now being used by some geologists, and cartographic staff. Output from Autocad has been especially beneficial in assisting figure production for the Mineral Deposit reports, and also for area-quantification in support of an analysis of "prospectivity" in Manitoba, currently being conducted by B. Mackenzie, Centre of Resource Studies, Queen's University.

DISTRICT SUMMARIES

Lynn Lake/Ruttan Region

In the Lynn Lake area investigations were conducted into the geological setting of part of the Lynn Lake Rhyolite Complex, which hosts massive sulphide type deposits. Geochemical studies on selected volcanic rocks from the Ruttan Mine region confirmed the island-arc affinity of the volcanism.

In June and July the Geological Survey of Canada mounted airborne gamma-ray spectrometer surveys in the Ruttan/Eden Lake and Snow Lake areas as part of its new EXTECH initiative. Advance copies of the maps from the Ruttan area were used by the Provincial Survey to target areas for follow-up ground truthing centred on the Eden Lake monzogranite complex. Detailed ground scintillometer and spectrometer surveys were mounted over uranium highs west of Highway 391, and west of "Spur" Lake, in the hope that REE concentrations, similar to those at Eden Lake, would be encountered. Although zones of elevated radioactivity were found, no REE mineralization was detected, and the host monzogranites contain neither the ubiquitous aegirine augite seen at Eden Lake, nor the widespread fluorine-bearing pegmatites, common south of Kwaskwaypichikun Bay.

Flin Flon/Snow Lake

1:20 000 scale mapping in the Tartan Lake area was completed. This year two major, and similar, fractionated gabbro sills were found to face inward toward the axial zone of the northwest-trending Ruby and Bartley lakes syncline. The relationships between the Mikanagan and Batters lakes sills and the Tartan Lake gabbro complex is uncertain. However, some evidence indicates the sills are contemporaneous with an early phase of the complex. Volcanic units mapped in the Flin Flon/White Lake area, to the south, were traced north into the core of the Ruby and Bartley lakes syncline, which appears to comprise the upper part of the Bear Lake Block section. Best copper and zinc values were obtained at the contacts of the major gabbro intrusions, however significant copper values were also found in veins of quartz and felsite. Eight gold showings were found, most within 3 km of the Tartan Lake Mine.

A detailed mapping program was initiated in the Baker/Patton felsic complex to determine the geological setting of the Don Jon and North Star massive sulphide deposits.

In 1989 a large forest fire between Elbow Lake and Sherridon resulted in greatly improved bedrock exposure in areas previously covered by old-growth mature forest. Several reconnaissance projects were conducted to determine which of the newly exposed areas warranted mapping, and to develop a framework for programming in the region over the next few years.

Supracrustal rocks at Elbow Lake were found to comprise Amisk Group metavolcanics and related intrusions, together with a wide variety of relatively high level intrusions of unknown affinity. The supracrustal rocks form an enclave centred on the lake, and are transected by the 2 km wide Elbow Lake shear zone. Supracrustal rocks east of the shear zone comprise a very strongly deformed package of pillowed mafic lavas and diabase, intruded by tonalite and gabbro. To the west, primary volcanic structures are preserved, and two possible intravolcanic unconformities were defined within the volcanic sequence.

1:20 000 scale mapping at Fay Lake, delineated extensive areas of high strain, and also located new exposures of Missi Group basal conglomerate, unconformably overlying Amisk volcanics. 1:10 000 scale mapping at Webb Lake outlined a moderately well preserved, steeply dipping section of intercalated mafic and intermediate volcanic, volcaniclastic and sedimentary rocks, and extensive areas of rhyolitic and rhyodacitic rocks that are either flows or high-level intrusions. This complex of supracrustal rocks and intrusions appears to be a large roof pendant enveloped within a younger variably quartz-phyric granodiorite intrusion.

A 1:5000 scale geological map was prepared for a small portion of the new outcrops in the North Star Lake area burn. The area is underlain by mafic and felsic volcanic rocks. Although rusty weathering zones were delineated, it was not possible to relate these zones to massive sulphide type alteration. Quartz-vein hosted gold occurrences in the North Star Lake area were documented, and accurately located with the assistance of newly acquired 1:5000 aerial photos.

Three detailed mapping projects were initiated in the vicinity of the Rod, Bee Zone and Spruce Point copper/zinc deposits. The Spruce Point study will be supplemented by a geochemical assessment of mineralization-related alteration.

Detailed mapping at Anderson Lake attempted to clarify the stratigraphic relationship between the copper/zinc massive sulphide deposits in this area, and zinc/copper deposits at Chisel Lake, 8 km to the southwest. This study also examined areally-large footwall alteration zones associated with the base metal mineralization, with the intent of relating the base metal mineralization to the alteration processes, and to synvolcanic intrusions. The study suggests that the Anderson Lake copper/zinc base metal deposits occur lower in the stratigraphic section than the Chisel area zinc/copper deposits. Furthermore the study indicates that the deposits in the two areas may be related to two discrete hydrothermal/geothermal systems generated by two unrelated, synvolcanic tonalite plutons.

At the Copper-Man deposit, Wekusko Lake, outcrops and geology were mapped at 1:2000 scale to provide a geological framework for future geochemical studies.

Regional till sampling was initiated in the Snow Lake area as part of the Exploration Science and Technology project (EXTECH) in cooperation with the GSC. The till sampling will establish the geochemical character of surficial deposits in this region, and may detect dispersion trains related to underlying base metal mineralization.

In the Kisseynew gneiss terrain, investigations centred on evaluating the mapping potential of recently burned areas, and detailed studies of the geological settings of massive sulphide and gold deposits. In the Sherridon structure zones of hydrothermal alteration were investigated and sampled in a newly burnt area. Stratabound gold mineralization was mapped at Lobstick Narrows, and a differentiated intrusion that hosts gold-arsenopyrite occurrences was mapped in the vicinity of Squall Lake. The host rocks to this mineralization are similar to those at the Moon-Gertie and Margaret zones immediately south of Squall Lake.

Thompson Belt

New exposures at the Thompson Mine Open Pit were mapped and sampled in order to determine the internal stratigraphy and composition of a stratabound "iron formation" that is spatially associated with the nickel sulphide ores.

Further south 1:20 000 scale geological mapping was initiated to map soon-to-be-flooded shoreline exposures at the west end of Cross Lake. A major synclinal structure was found in rocks whose metamorphic grade is generally higher than that to the east. Consequently primary structures and stratigraphic sequences are not as well preserved.

Information and assistance was provided to several companies exploring the southwest extension of the nickel belt, and all available drill core was retrieved for future studies.

Island Lake

195 mineral occurrences, that lie within the eastern segment of the Island Lake Greenstone Belt, were sampled and mapped in detail as part of the initial mineral deposit documentation of the northern Superior Province.

Southeast Manitoba

Detailed mapping of a mafic igneous complex southeast of English Lake located massive to layered gabbroic to pyroxenitic phases intruded by tonalite. The complex contains widespread megabreccias and pegmatitic phases, which together with the common occurrence of pyrite, make this an attractive target for platinum group element exploration.

A reconnaissance survey east of Manigotagan, in an area of recent burn, focussed on the northern boundary of the Rice Lake Greenstone Belt supracrustal rocks. The boundary represents a major tectonic break, separating greenschist facies supracrustal rocks from a mid-to lower-crustal section, represented by upper amphibolite grade intermediate to ultramafic breccias of the English Lake magmatic complex to the north.

Industrial mineral activities focussed on a granite dimension stone evaluation in the Medika area.

A pilot study was conducted in the vicinity of the Bernic Lake tantalum mine to investigate the possibility of using vegetation geochemical surveys to detect tantalum-bearing pegmatites buried at depth. Limited data indicates that trunkwood, through routine element procurement, possesses the ability to reflect tantalum occurrences in the substrate, and may therefore prove a useful medium to facilitate exploration for this type of rare-element-enriched pegmatite.

Interlake and Manitoba General

Stratigraphic mapping along the lower Nelson River was carried out to examine Ordovician units from the Hudson Bay Basin. Recent drilling at the proposed Conawapa generating site suggests that all outcrops along the river are Ordovician; this contradicts earlier studies that showed a Silurian outlier within the Ordovician outcrop belt. Palynological analysis will be conducted to confirm/refute the current interpretation. The examination of these outcrops supplements core holes logged from Manitoba Hydro's other dam site investigations, including Limestone, Conawapa DX, and Gillam Island.

In the Grand Rapids area reconnaissance mapping of Paleozoic bedrock between William and South Moose lakes was augmented by three stratigraphic core holes, drilled to provide subsurface control, and depths to basement. One hole intersected an unusual fracture zone in the Red River Formation that may indicate post-Paleozoic tectonism.

Further studies on the Devonian Winnipegosis reef structures were carried out at the Bluff on Dawson Bay, and at the Narrows on Lake Manitoba. Three holes were drilled at the Bluff, and five at the Narrows. Follow-up research is being conducted at these localities, respectively by the universities of Regina and Manitoba.

Four core holes were drilled in the Gypsumville area to help determine the areal extent of the Jurassic gypsum deposits, and red bed sequences, as well as to extract further information from the Lake St. Martin Series, and the Lake St. Martin Structure.

The ongoing evaluation of karst features in the Interlake was also centred this year on the Gypsumville area. A helicopter reconnaissance of this region was used to plan ground traverses, and confirmed that gypsum occurrences were limited to the area south of Township 34 (as indicated on the 1914 map by R.G. Wallace). A provisional terrain morphology classification was developed for those areas exhibiting karst landforms, and several of the caves discovered in 1989 were mapped in cooperation with members of the Speleological Society of Manitoba.

Industrial Minerals activities included an evaluation of high-calcium limestone in the Elm Point Formation at Steep Rock, Kinosota, and the Winnipegosis area, a preliminary inventory of gypsum and anhydrite in the Gypsumville area, and an initial assessment of dolomite in the Ashern Formation and the Interlake Group. A field trip was given for several organizations interested in development of the Wekusko dolomite. Nine sphagnum bogs in the Washow Bay area were assessed for potential as sphagnum peat producers. 5584 hectares, containing an estimated 96.63 million cubic metres of sphagnum peat were delineated. The 1841 hectare Daves Lake bog contains high quality sphagnum to a depth of 4.0 m, and has estimated reserves of 64.4 million cubic metres of peat.

An increasing commitment to sustainable development initiatives, has prompted the Branch to engage in cooperative work with several agencies, most particularly the Department of Natural Resources. The fundamental linkage between the surface and subsurface environments, and past and ongoing geological processes, places the Geological Services Branch in an ideal position to make substantive contributions to an enhanced, and informed environmental awareness.

This summer the newly formed Terrain Sciences Unit embarked upon an investigation of the Holocene history of the Red River Delta, and the modern-day geological processes operating at the south end of Lake Winnipeg. 124 samples were collected to investigate the provenance of the barrier islands; 15 samples were collected for radiocarbon dating to determine the rate of shoreline recession and crustal warping.

A joint project with the Water Resources Branch was initiated at a small site in the Rossburn area, to investigate the composition of tills and their effect on groundwater chemistry. Cores from 10 wells, and data from 48 piezometers, were provided by the Manitoba Hazardous Waste Corporation. Till and bedrock samples (550), will be analysed principally for elements of concern to drinking water quality.

W.D. McRitchie
September 1990

GS-1 MAJOR ELEMENT AND REE ANALYSES FOR SELECTED VOLCANIC AND INTRUSIVE ROCKS IN THE RUTTAN MINE AREA (NTS 64B/5)

by G.H. Gale

Geochemical analyses of volcanic rocks in the Lynn Lake area indicates that tholeiitic basalt underlying the Fox Mine and other massive sulphide type deposits in the area are similar chemically to some modern island arc tholeiites (Syme, 1985). An island arc origin for the host rocks to the Flin Flon massive sulphide type deposit was indicated by Stauffer et al. (1975) on the basis of major element analyses and confirmed by Bailes and Syme (1989) using REE and trace element data. Although the Ruttan Mine area had been mapped in detail (Baldwin, 1988), there was no comparable geochemical evidence to determine the tectonic setting of the volcanic rock formations.

This study attempted to sample volcanic and intrusive rocks, using the field work sheets of D.A. Baldwin (Fig. GS-1-1), in order to provide geochemical information that could be utilized in determining the paleotectonic setting of the Ruttan Mine.

The geochemical data are presented in Table GS-1-1 and displayed graphically in Figures GS-1-2 and GS-1-3. The REE/chondrite data for the mafic flows analyses Rut 3 and Rut 5 have flat to slightly depleted light rare earth patterns. This pattern resembles that of the island arc type tholeiitic rocks associated with the Flin Flon massive sulphide type deposit (Bailes and Syme, 1989). Normalization of these analyses with the N-MORB average values of Saunders and Tarney (1984) also indicates an island arc type tectonic setting (Fig. GS-1-3).

Other than Sr, a mobile element, the N-MORB normalized values for Rut 6, a basaltic andesite pillowed lava, and Rut 8, a mafic sill/flow, indicate that these rocks are more fractionated in the Rb-Hf portion of the profile than the two basaltic flows (Rut 3 and Rut 5), but still indicate profiles similar to those obtained for island arc type rocks (Pearce, 1982). The feldspar-porphyry intrusion, Rut 1A and Rut 2, has a LREE enriched chondrite normalized pattern and probably also formed in an island arc type tectonic environment.

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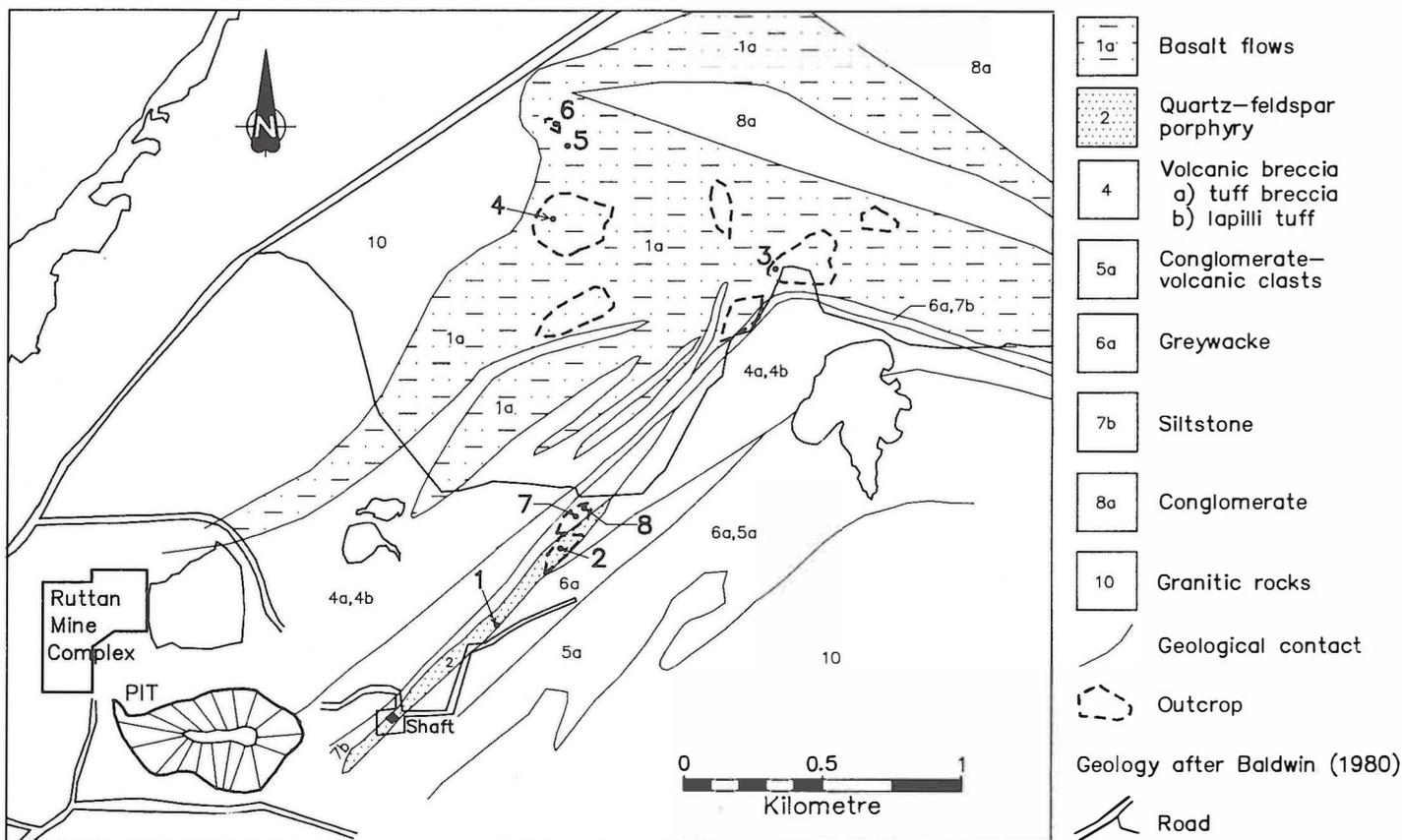
Figure GS-1-1:   General geology of the Ruttan Mine area and location of samples analysed (bold numerals).

Table GS-1-1
Major element, trace element and REE analysis of samples from the Ruttan Mine area

	Rut #1A	Rut #1B	Rut #2	Rut #3	Rut #5	Rut #6	Rut #6A	Rut #8
SiO_2	64.1	63.2	62.7	49.5	46.3	56.0	56.6	50.0
Al_2O_3	15.56	15.51	15.89	13.00	13.70	15.85	15.85	14.44
FeO(T)	6.66	7.13	6.97	12.05	13.75	9.58	9.46	9.77
CaO	5.69	5.78	4.88	12.47	13.58	7.76	8.32	11.54
MgO	1.33	1.40	2.06	8.32	6.97	3.14	3.04	6.87
Na_2O	2.93	2.87	3.06	1.74	1.43	3.44	3.37	2.54
K_2O	2.28	2.27	2.09	0.16	0.21	0.68	0.55	1.27
TiO_2	0.59	0.61	0.61	1.08	1.48	1.36	1.28	0.76
P_2O_5	0.16	0.17	0.23	0.08	0.10	0.19	0.19	0.31
MnO	0.09	0.09	0.10	0.18	0.23	0.17	0.17	0.22
LOI	0.7	0.6	0.8	0.9	0.9	0.5	0.5	1.2
TOTAL	100.09	99.63	99.39	99.48	98.65	98.67	99.33	98.92

Elements (ppm)

	Rut #1A	Rut #1B	Rut #2	Rut #3	Rut #5	Rut #6	Rut #6A	Rut #8
Au*	<2		<2	<2	3	<2		2
Ag	<2		<2	<2	<2	<2		<2
As	<1		3	4	<1	1		<1
Ba	430		490	59	<20	310		390
Br	<0.5		<0.5	<0.5	<0.5	<0.5		1.2
Co	33		33	65	66	37		47
Cr	6.9		7.1	260	110	7.8		470
Cs	0.7		<0.2	<0.2	<0.2	1		<0.2
Hf	3.2		3.5	1.2	0.8	2.4		1.3
Hg	<1		<1	<1	<1	<1		<1
Ir*	3		1	<1	<1	1		<1
Mo	<2		<2	<2	<2	<2		<2
Ni	<50		<50	97	<50	<50		99
Rb	48		33	<10	10	27		21
Sb	0.1		0.3	0.6	0.2	0.2		0.4
Sc	15		16	40	43	29		23
Se	<0.5		<0.5	<0.5	<0.5	<0.5		<0.5
Sr	100		<100	<100	100	300		300
Ta	0.8		1	<0.3	0.4	0.8		<0.3
Th	4.9		5	<0.1	<0.1	2.3		1.8
U	1.5		1.2	<0.5	<0.5	0.7		0.8
W	220		210	130	140	150		94
Zn	69		67	87	100	61		100
La	16		15	2.4	1.7	11		9.3
Ce	33		34	7	6	25		21
Nd	17		16	5	5	14		12
Sm	3.5		3.5	1.9	2	3.4		2.4
Eu	0.9		0.89	0.7	0.79	1.03		0.72
Tb	0.8		0.8	0.6	0.6	0.8		0.5
Yb	2.66		2.83	2.09	2.02	2.44		1.58
Lu	0.45		0.46	0.35	0.33	0.41		0.27

*ppb

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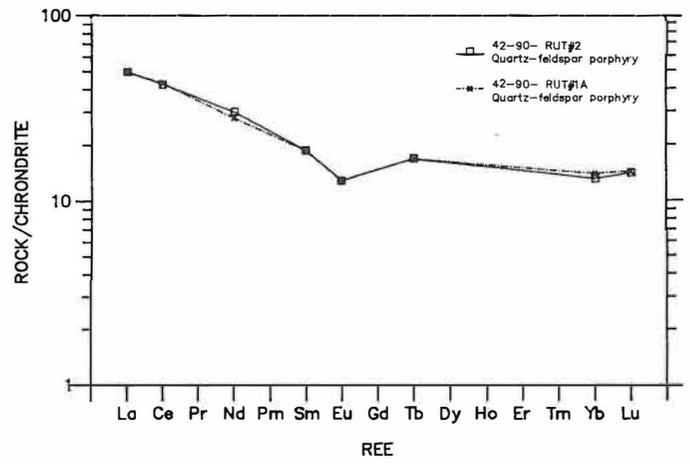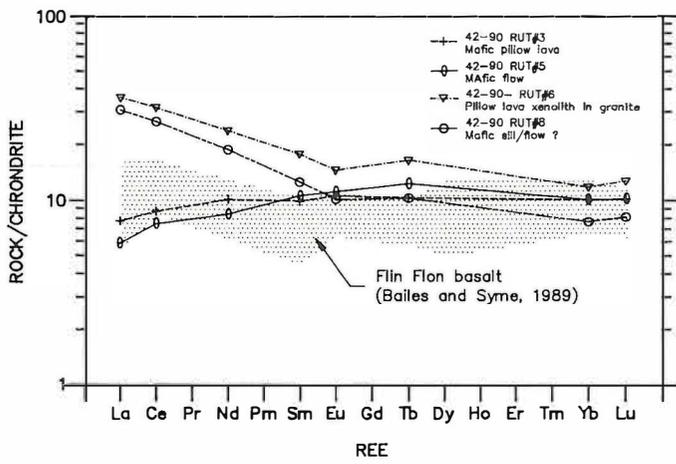
Figure GS-1-2: Rare earth element chondrite normalized patterns for mafic volcanic rocks and feldspar porphyry intrusion (chondrite values from Masada et al., 1973).
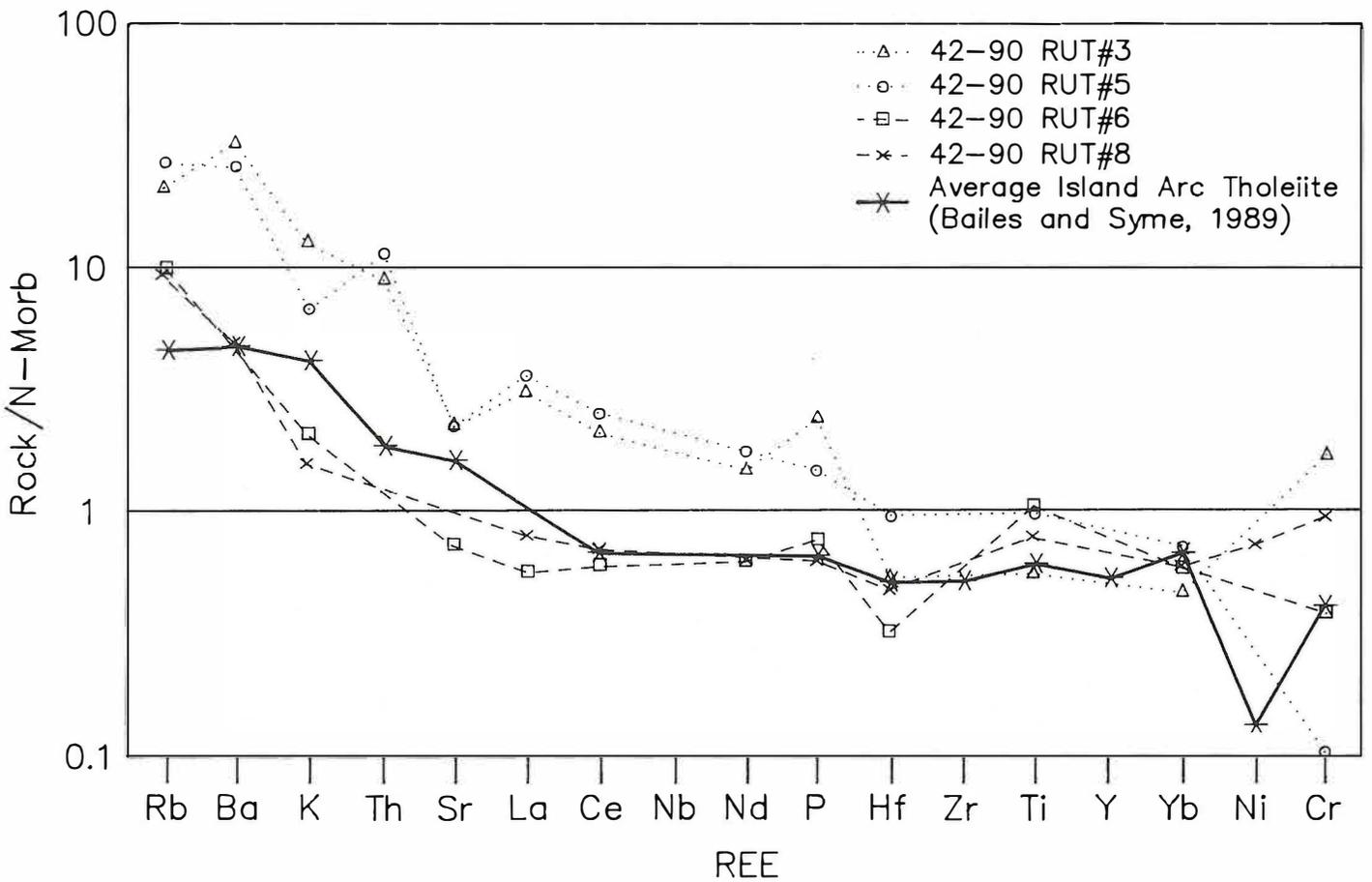

Figure GS-1-3: N-MORB normalized patterns for Ruttan mafic volcanic rocks (N-MORB values from Saunders and Tarney, 1984).

GS-2 GEOLOGY OF THE MAFIC ROCKS IN THE SOUTHERN UNIT OF THE LYNN LAKE RHYOLITIC COMPLEX (NTS 64C/14)

by J. Young

INTRODUCTION

The Lynn Lake Rhyolitic Complex is an 18 km long and up to 3 km thick sequence composed mostly of felsic pyroclastic rocks. Baldwin (1983) subdivided the complex into the Southern, Central and Northern units on the basis of major lithological differences (Fig. GS-2-1). Mafic rocks are a minor constituent of the southern zone (Baldwin, pers. comm., 1990). The objective of this project was to characterize the relationship between the mafic and felsic rocks within the southern unit of this complex.

GENERAL GEOLOGY

Rocks west of Flag Lake comprise a series of felsic tuff to lapilli tuff interfingered with mafic fragmental rocks and minor epiclastic rocks. This complex is adjacent to granodiorite and gabbro to the south and is crosscut by granodioritic to mafic dykes. Massive to pillowed mafic flows occur along part of the contact between the gabbro and granodiorite and the rhyolitic complex (Fig. GS-2-2). A paucity of exposure and strong regional deformation hamper recognition of the relationship between units. Units appear to pinch out along strike or terminate relatively abruptly (Fig. GS-2-2). Felsic tuff occurs along strike to the west of the mafic volcanic rocks. Stratigraphic tops are to the north as defined by pillowed flows and graded mafic fragmental rocks; the top direction agrees with that obtained by Baldwin (1983).

MAFIC VOLCANIC ROCKS

Mafic volcanic rocks comprise a basal sequence of dark green to grey-green weathered massive to pillowed flows with 5 to 10 per cent quartz-filled amygdules, which are up to 2.5 cm long, and up to 2 per cent plagioclase phenocrysts that are 1 to 4 mm. Lenses of mafic breccia occur within the pillowed sequence.

Black and beige weathered mafic fragmental rocks overlie the flows, are intercalated with the felsic sequence, or occur as 2 m thick layers in the epiclastic rocks. They are subdivided into pebbly mafic breccia and blocky mafic breccia. The pebbly breccia consists of trace to 50 per cent, 0.1 to 10 cm long, stretched, angular, beige weathered, aphyric, plagioclase- and/or quartz- phyric clasts in a dark green to black weathered matrix. The blocky breccia comprises red to reddish-beige, stretched, recessed ovoids, which are 1 cm to 1 m long, that occur in a grey to black weathered matrix. Blocky breccia, which is up to 10 m thick, is underlain by pebbly breccia above the flows, and also occurs as layers in the epiclastic rocks.

West-striking beds of dark green mafic siltstone and mudstone either (1) occur above the blocky breccia overlying the flows, or (2) grade upward from pebbly breccia in the northern occurrence of the mafic fragmental rocks (Fig. GS-2-1). The siltstone and mudstones constitute a 0.5 to 1 m thick sequence of 0.3 to 6 cm thick beds.
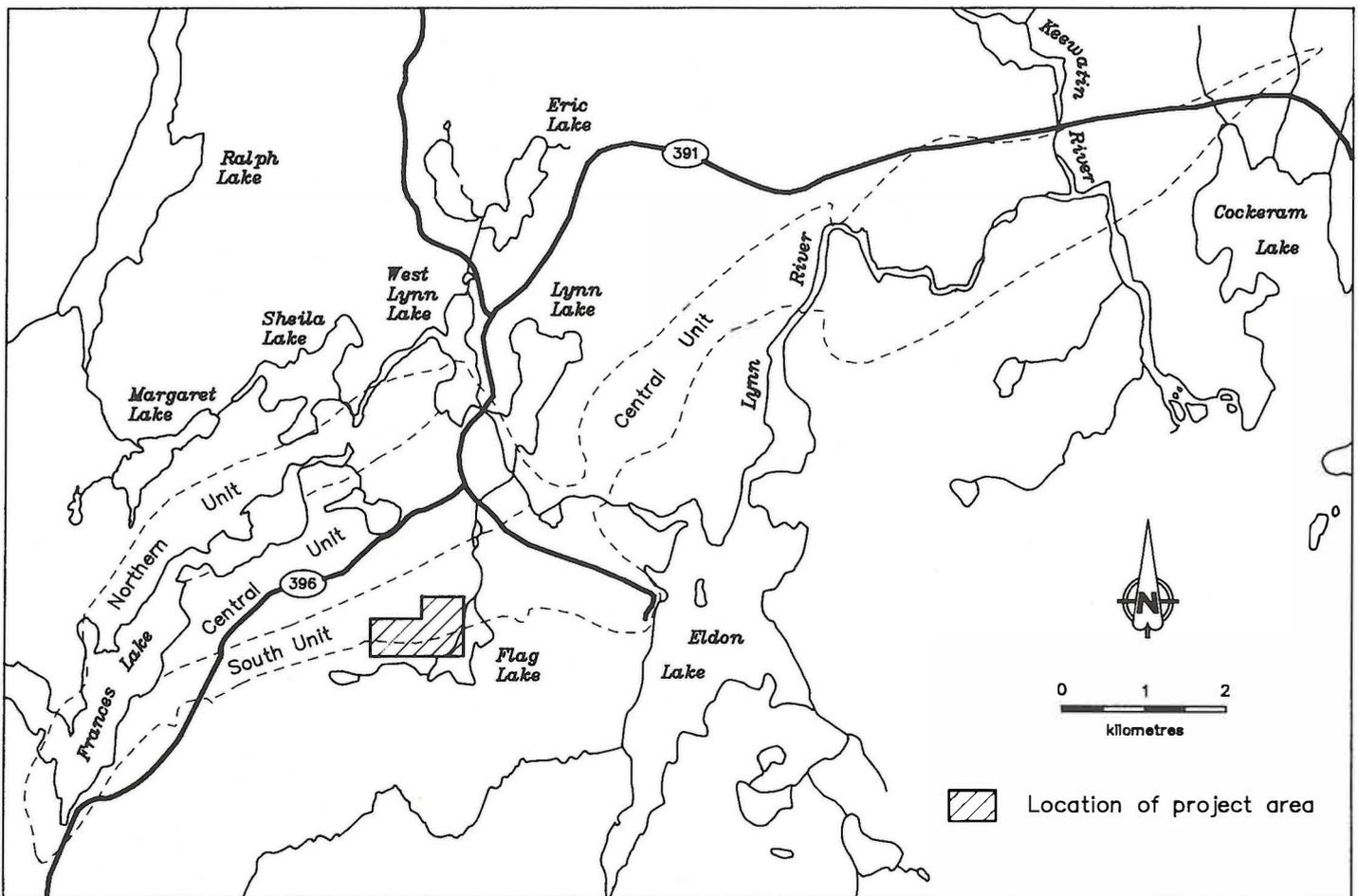
Figure GS-2-1:   General stratigraphy of the Lynn Lake Rhyolitic Complex (after Baldwin, 1983) and location of the project area.
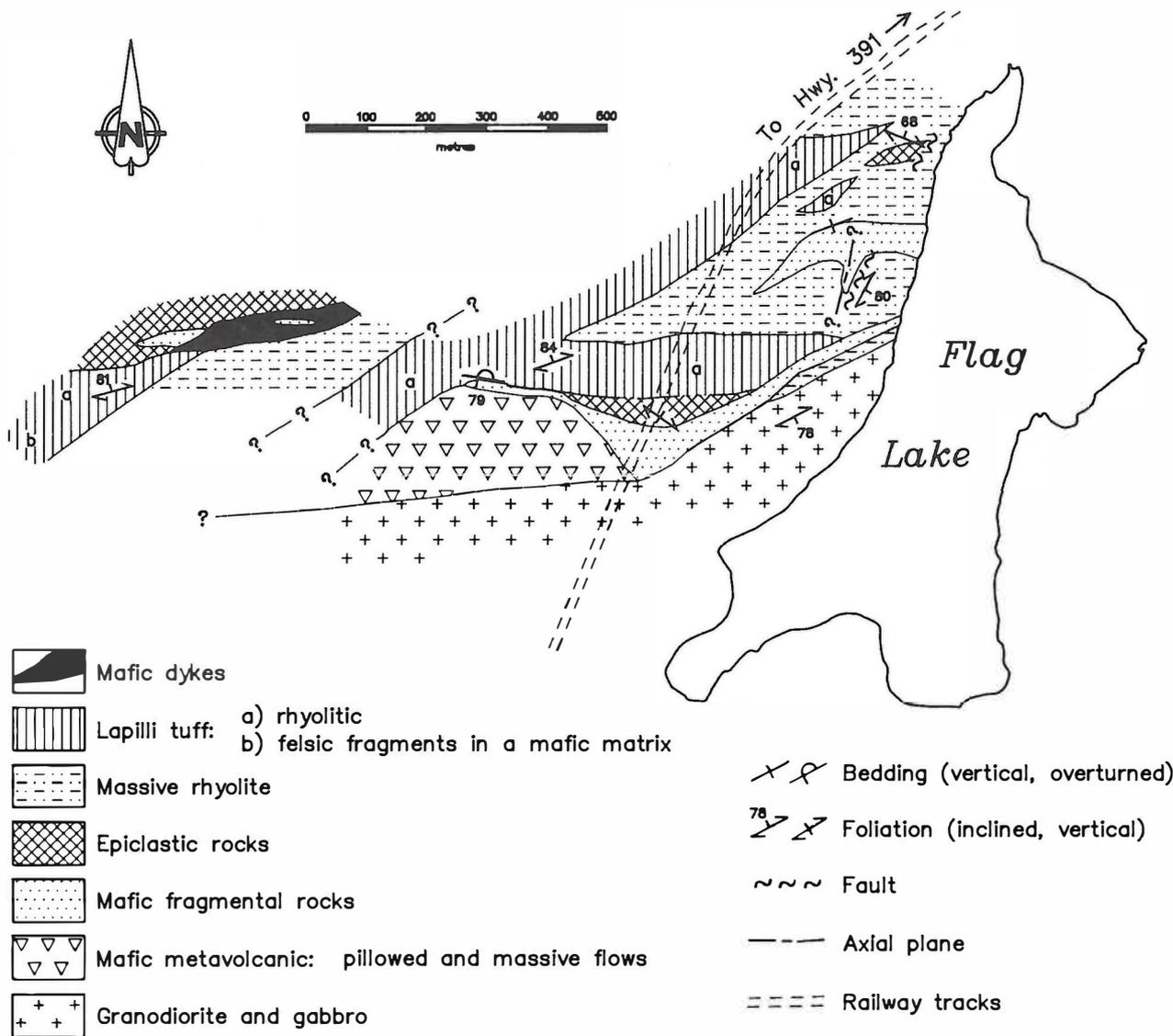
Figure GS-2-2: Geological map of part of the Southern Unit, west of Flag Lake.

FELSIC VOLCANIC ROCKS

The felsic volcanic rocks are subdivided into a) white to beige, quartz- and/or plagioclase-phyric and aphyric, massive rhyolite with lesser lapilli tuff and b) buff to buff-white felsic lapilli tuff with minor massive rhyolite. The massive rhyolite contains trace to 5 per cent, quartz phenocrysts, which are up to 3 mm and 0 to 15 per cent, euhedral to broken, plagioclase phenocrysts that are up to 4 mm. The lapilli tuff occurs in massive to graded beds up to 6 m thick. It consists of 10 to 90 per cent, felsic, stretched, lenticular fragments up to 6.5 cm long in a matrix of similar composition or in a dark grey to green weathered matrix. Felsic breccia comprising 15 to 75 per cent, subangular felsic fragments that are up to 25 cm long is locally intercalated with lapilli tuff. Biotite megacrysts, up to 3 mm, and up to 5 per cent, 1 to 3 mm garnet are present.

EPICLASTIC ROCKS

Matrix-supported pebbly greywacke to conglomerate with clasts up to 8 cm long in a dark green weathered silty matrix occur on two small outcrops. Clast types include: a) felsic aphyric; b) beige weathered amphibole-phyric; c) intermediate to mafic volcanic; and d) gabbro to granodiorite.

STRUCTURE

A moderate to strong penetrative foliation strikes northeast and, on some outcrops, northwest; dips are steep to vertical (Fig GS-2- 1). Local changes in foliation occur near faults or in rocks that have been folded. A closed synformal fold (axial plane at 030°/72°SE) cuts the northern occurrence of mafic fragmental rocks. Minor drag folds occur in nearby rhyolite and mafic fragmental rocks. Other minor folds were observed in conglomerate. Some quartz veins are ptygmatically folded. Beds above the mafic flows are overturned. North-trending and steeply east-dipping faults are suggested by: a) local zones of more intense foliation; b) the rubbly nature of the outcrop; and c) the well developed cleavage fracture in rhyolite.

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GS-3 REE INVESTIGATIONS, EDEN LAKE INTRUSIVE SUITE (NTS 64C/9)

by J. Young and W.D. McRitchie

INTRODUCTION

An airborne gamma ray spectrometer survey was conducted in 1990 by the Geological Survey of Canada over an area that encompasses the Eden Lake intrusive suite and adjacent granitoid rocks (Manitoba Energy and Mines, 1986). Previous gamma ray and geochemical surveys, over parts of the Eden Lake intrusive suite, detected the occurrence of anomalously high levels of radioactivity and associated REE mineralization south of Kwaskwaypichikun Bay. Two additional areas of anomalously high levels of radioactivity north to northwest of Leaf Rapids, which were detected in the 1990 airborne survey, were targeted for a ground based scintillometer survey (Fig. GS-3-1). The objectives of the present study were: 1) to obtain ground scintillometer measurements for the Eden Lake granitoid rocks that could be correlated with the subsequent airborne survey; and 2) to delineate and sample any anomalously high radioactive zones that are probably related to REE enrichment.

PREVIOUS WORK

Airborne gamma ray spectrometer surveys of the region detected anomalously high levels of potassium, equivalent uranium, and equivalent thorium in the Eden Lake area (Geological Survey of Canada, 1977). Follow-up geochemical studies detected anomalous levels of uranium and fluoride in lake waters (Fig. GS-3-2) and uranium in lake sediments (Schmitt et al., 1989). Detailed geochemical sampling by McRitchie (1988) and a later ground scintillometer survey (McRitchie, 1989), along well exposed ridges consisting of aegirine-augite-bearing monzonite and quartz monzonite in the Eden Lake - Kwaskwaypichikun Bay area, demonstrated the association of elevated levels of radioactivity in REE rich samples.

McRitchie (1989) reported the occurrence of several mineralized zones and numerous hot spots. The zones contain brown glassy allanite, as well as coarse grained pyroxene concentrated in layers or lenses. Geochemistry from the better zones detected 12 700 to 45 900 ppm Ce, 5530 to 22 900 ppm Nd, and 7180 to 17 000 ppm La, amongst other elements. Mineral chemistry, on selected samples, has identified the cerium-bearing phosphate mineral, britholite, and confirmed the occurrence of allanite. One analysis of britholite yielded 27.06 per cent cerium oxide (Table GS-3-1). The three allanite minerals that were analyzed contain 13.70 to 13.99 per cent cerium oxide (Table GS-3-1).

CURRENT WORK

Following the method used at Eden Lake (McRitchie, 1989) a Scintrex Broadband gamma-ray scintillometer model BSG-1SL (with a 1.5'' x 1.5'' thallium activated sodium iodide crystal) was used to conduct the survey. Traverses west of "Spur" Lake were planned to cross the regional trend of the zones of REE enrichment (300-024°) defined by McRitchie (1989) south of Kwaskwaypichikun Bay. Spot measurements were taken at 145 stations at waist level, and on the ground. Sweeps were made of the adjacent area so that most of the outcrop was covered. The scintillometer was left on during traversing to determine the counts per second(cps) range, and to locate the occurrence of anomalous zones or hot spots between stations. A McPhar model TV-1 spectrometer (with a 1.5'' x 1.5'' sodium iodide crystal) was used on hot spots that had scintillometer readings greater than 1000 cps. Detection of potassium, equivalent uranium and equivalent thorium could then be compared with the scintillometer readings.

The area defined by the larger western anomaly is underlain by a fine grained biotite monzogranite that is intruded by pegmatite, aplite and red graphic granite (Cameron, 1988). The area is accessible by plane from Lynn Lake. Four days were spent running traverses at a scale of 1:5000. Locations of stations and areas of elevated radioactivity were plotted on air photos. Spot measurements were taken at 102 stations

and sweeps were done on the outcrop in the vicinity of each station. Hot spots and zones were noted, and the zones mapped.

The area defined by the smaller eastern anomaly is underlain by megacrystic monzogranite characterized by 2 to 4 cm K-feldspar megacrysts in a fine- to medium-grained granitic groundmass (Cameron, 1988). The area is accessible from Highway 391. A traverse at a scale of 1:50 000 was run across the ridges. Sixteen spot measurements were taken and sweeps made of outcrop in the vicinity.

Twenty-one spot measurements were taken west of "Spur" Lake and another 10 spot measurements were obtained on roadside outcrops between Eden Lake and Leaf Rapids. These measurements are outside of the airborne gamma ray anomalies and were obtained for regional comparison.

RESULTS

Scintillometer readings from the Eden Lake monzogranite are organized into: a) Table GS-3-2 that includes three subareas in the fine grained monzogranite corresponding to the northern, central and southern traverses west of "Spur" Lake (Fig. GS-3-3); b) Table GS-3-3 corresponding to readings from the megacrystic monzogranite, accessible from Highway 391 (Fig. GS-3-4); and c) Table GS-3-4 corresponding to readings from outcrops adjacent Highway 391, and to readings from outcrops north of the large anomaly in part a. Spectrometer readings are listed in Table GS-3- 5.

Daily background readings for the scintillometer ranged from 15 to 35 cps. Background spectrometer readings were 5 to 40 counts per minute(cpm) for equivalent thorium, 5 to 35 cpm for equivalent uranium and 300 to 750 cpm for equivalent potassium. Readings along traverse were taken at waist level; hot spots were measured at ground level.

Over most outcrops the responses ranged from 120 to 300 cps with most readings ranging from 150 to 200 cps. Drop-off in counts were noted over: a) areas of overburden between stations, especially in swampy areas; b) exposures of boulders; and, c) thin cover on outcrops. Anomalously high responses were associated with the following features:

1. Localized hot spots (10-50 cm) corresponding to individual or clustered radioactive minerals. Responses ranged from 400 to 960 cps, but most range from 400 to 500 cps;

2. Hot spots in irregular areas 1 to 2 m across have responses of 340 to 1120 cps, except for two responses of 1400 and 1600 cps. These mineralized areas are commonly associated with disseminated fine grained pyrite or concentrations of 1 to 3 mm magnetite in areas up to 8 cm across;

3. Hot spots along fractures, which trend 284 to 352°, have responses of 300 to 940 cps, but average 400 to 600 cps. The fractures are up to 3 m long. Higher responses are associated with local hot spots or disseminated pyrite along the fracture;

4. Zones up to 30 x 2 m that are crosscut by mineralized fractures having responses ranging from 400 to 4000 cps. These fractures have trends that vary between north and west. Highest responses are associated with concentrations of magnetite or disseminated pyrite; and

5. Zones of elevated response that are up to 70 m long and 20 m wide with a mostly northerly trend. Responses range from 250 to 1800 cps and average 250 to 400 cps. In the larger zones there are subzones that are 1 to 15 m across and range from 400 to 900 cps. Magnetite is disseminated to concentrated in aggregates, in areas of higher responses, and locally pyrite is disseminated. In some zones mineralization is associated with red weathered aplite dykes or occurs in small areas of coarse grained granite enclosed in the fine grained granite.

Several anomalous zones or hot spots occur along strike over areas 400 m long. The anomalous zones or hotspots are separated by

areas of background radiation, up to 80 m long. These larger zones have a northerly to northeasterly trend.

Although elevated responses are not isolated to one specific phase of the intrusive suite the best responses are associated with: a) fine grained aplite dykes in the smaller anomaly; b) fractures that crosscut the fine grained granite in the larger anomaly; and c) disseminated hot spots in subzones in the fine grained biotite monzogranite.

CONCLUSIONS

Both the background radiation and the elevated responses de-tected in this area are generally lower than those detected by McRitchie (1989) at Eden Lake. The area examined by McRitchie (1989) also contains: a) an unusual aegirine-augite-bearing monzonite; b) layers or lenses of pyroxene in the anomalous zones; c) fluorite-bearing pegmatites; and d) cerium-bearing allanite and britholite in the anomalous zones.

The elevated zones of radioactivity indicate that some REE mineralization may occur in the fine grained biotite monzogranite. The zones are irregular, discontinuous, and commonly random. They lack a diagnostic lithological or structural control that can easily be targeted. None of the zones appear to be of economic significance.
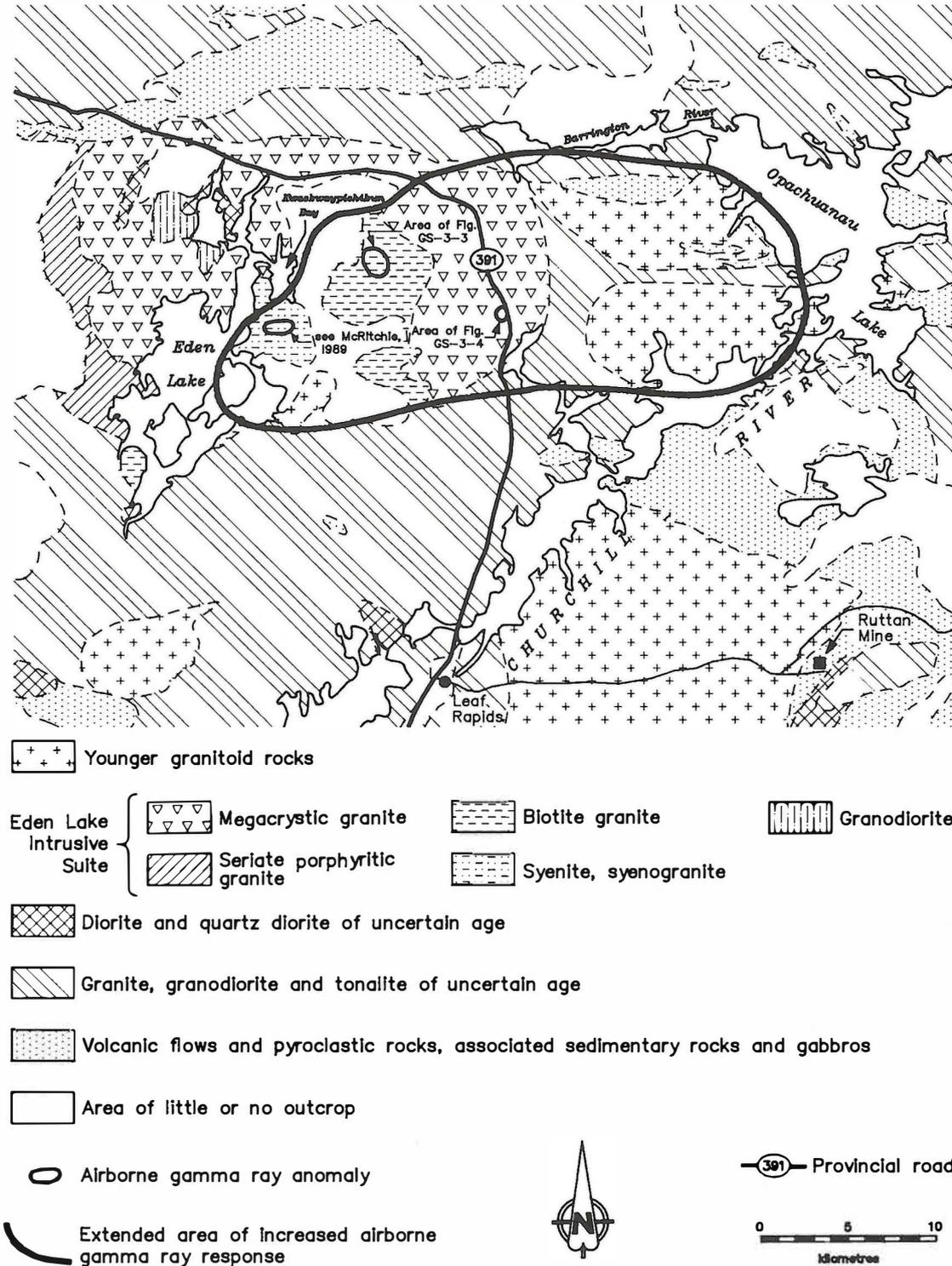
Figure GS-3-1:   Simplified geological map and location of anomalous areas of radioactivity in the Eden Lake area (modified from Manitoba Energy and Mines, 1986).

Legend:

- Outcrop boundary
- .7 Station location and number
- Traverse location and direction
- .19 Regional reading and number
- (391) Provincial road

0   1   2

kilometres

to Leaf Rapids
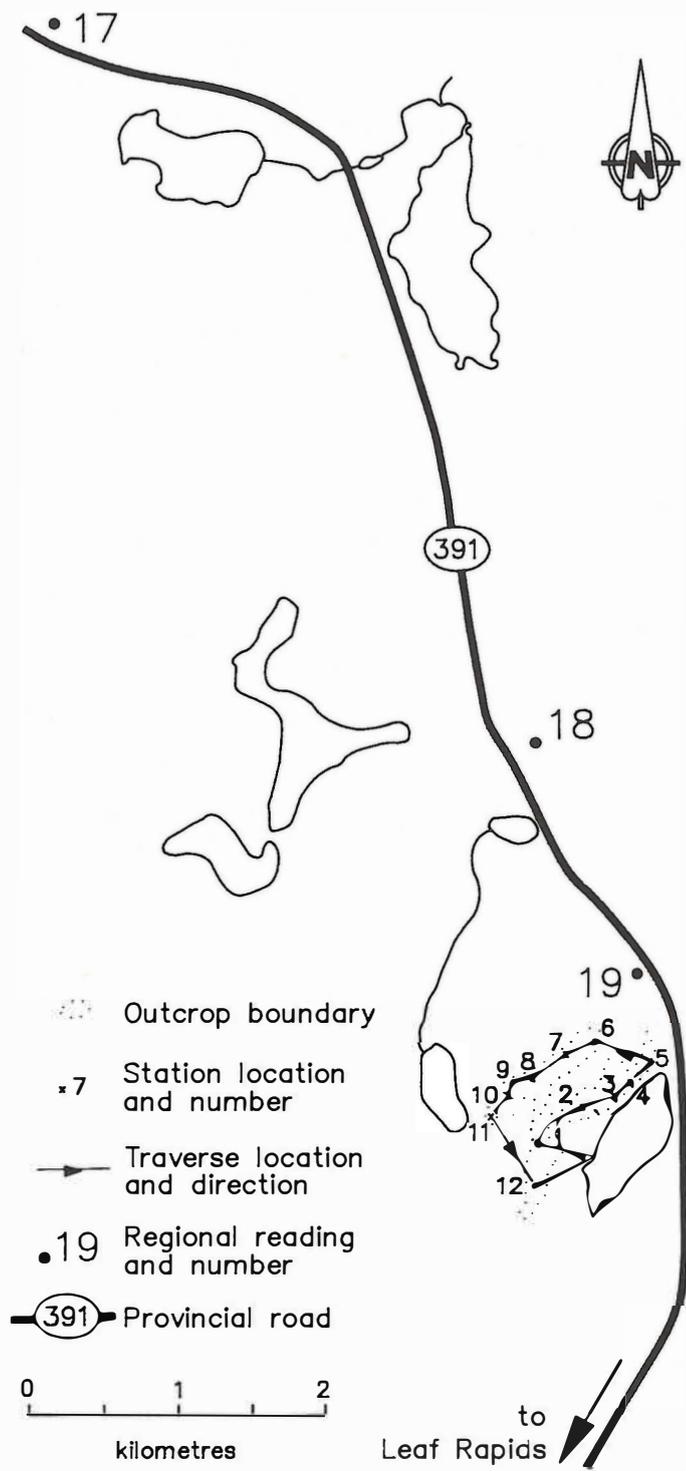
Figure GS-3-2:   *Regional geochemical maps of fluoride in lake water and fluorine in lake sediments (modified from Schmitt et al., 1989).*

Table GS-3-1
Mineral chemical analyses from mineralized zones in the Eden Lake area (McRitchie, 1989)

Oxide (%)	Britholite	Allanite	Allanite	Allanit
SiO_2	11.31	30.51	30.34	30.30
TiO_2	n.d	.85	.81	.86
P_2O_5	4.77	n.d	n.d	n.d
Al_2O_3	.18	10.99	11.13	11.04
MgO	n.d	.86	.98	.86
MnO	.78	.62	.62	.58
FeO	.20	11.70	11.86	11.37
Fe_2O_3	n.d	6.95	6.15	7.53
CaO	2.08	10.47	10.31	10.38
Y_2O_3	1.20	n.d	n.d	n.d
La_2O_3	9.15	5.96	6.46	6.26
Ce_2O_3	27.06	13.70	13.90	13.99
Pr_2O_3	7.26	1.48	1.67	1.60
Nd_2O_3	17.53	3.13	2.92	2.85
Sm_2O_3	2.43	.27	.00	.00
Gd_2O_3	.89	n.d	n.d	n.d
ThO_2	3.28	n.d	n.d	n.d
H_2O	.81	1.51	1.50	1.51
TOTAL	88.93	98.99	98.65	99.12

The minerals were analyzed by Dr. S. Ercit of the Mineral Sciences Section at the Canadian Museum of Nature, using a JEOL 733 electron microprobe, equipped with Tracor Northern 5500 and 5600 automation. Operating conditions were 15 kV and 20 nA using a beam diameter of 5 microns. Data was reduced using standard ZAF corrections. Ferrous and ferric iron and the water content was determined by stoichiometry.

n.d. = not determined

Table GS-3-2
Ground scintillometer survey over fine grained biotite monzogranite
Southern traverse

Station #	O/N/B*	WAIST	GROUND	RANGE	HOT SPOTS	ZONES
Shoreline	N			120-170		
43	O	140	170			
43-44	O			120-180		
44	O	150	160	140-180		
44-45	O			140-160		
45	O	150	175	140-180		
45-46	O			130-160		
46	O	140	160	140-220	340-380	3m/300-380
46-47	O			160-195		
47	O	170	170			
47-48	O			150-210		
48	O	240	245			
48-49	N			150-160		
49	O	160	170			
49-50	O			170-195		
50	O	170	200			6m/340-560
					7m/300-600	
50-51	O			160-170		
51	O	170	185			
51-52	O			140-185		
52	O	155	180			
52-53	N			125-150		
53	O	150	170			
53-54	O			150-170		
54	O	160	230			
54-55	O			140-170		
55	O	145	160			
55-56	N			135-180		
56	O	185	170			
56-57	O			180-200		
57	O	180	190	150-220	940	
57-58	N			120-170		

STATION #	O/N/B*	GROUND	WAIST	RANGE	HOT SPOTS	ZONES
58	O	150	175			
58-59	N/O			115-170		
59	O	145	160	150-180		
59-60	O			160-220		
60	O	210	235	160-230		
60-61	O			180-210		
61	O	165	180			
61-62	N/B			150-180		
62	O	160	200			
62-63	B/N/O			150-170		
63	O	160	210	140-180		
63-64	N			150-170		
64	O	340	700	200 +	400-960 4m/400-980	5m/400-600
64-65	O			170-240		
65	O	210	265	180-240	400-500	
65-66	O			170-220		
66	B	165	170			
66-67	O			150-270		
67	O	170	215	200-260	500	
67-68	B			160-190		
68	O	200	320	190-250		
68-69	N/O			120-170		
69	O	305	320	190-280	400 10m/300-1300 17m/300-1300	70m/260-1150
69-70	O			140-270		
70	O	230	230	210-280	400-1120	3m/400-700
70-71	O			170-270		
71	O	200	360	200-270		
71-72	O/N			170-270		
72	O	170	180	180-210		
72-73	O			160-250		
73	O	170	175			
73-74	O			200-300		
74	O	235	305	170-270		
74-75	O			160-240		
75	O	225	245			
75-76	N/O			90-230		
76	O	180	175			
76-77	O			180-200		
77	O	230	200			
77-78	O			170-230		
78	O	165	185			
78-79	O					
79	O	150	180			
79-80	O			190-210		
80	O	210	290			
80-81	N/O			170-215		
81	O	215	240			
81-82	N/O			70-210		
82	B	170				
82-83	B			150-170		
83	O	170	190	150-190		
83-84						
84	O	270	360	170-300		6m/400-4000
84-85	O			160-220		
85	O	210	280			
85-86	O			150-240		
86	O	230	360	170-210		
86-87	O			150-230		
87	O	230				
88	O	160	175	150-170		

STATION #	O/N/B*	GROUND	WAIST	RANGE	HOT SPOTS	ZONES
89	N	115				
89-90	N			50-200		
90	O	160	170	140-170		
90-91	N			100-140		
91	O	160	170	130-170		
91-92	O			130-150		
92	O	140	145			
92-93	O			140-170		
93	O	165	175			
93-94	N			130-160		
94	O	155	170	150-210	400-700	
94-95	N/O			130-180		
95	O	230	210	170-250	400-440	
95-96	O			230-280	640	
96	O	250	200		380-900	
96-97	O			190-230		
97	O	170	185	170-230		
97-98	O/N			150-230		
98	O	200	235	190-270	300-500	
98-99	N/O			170-220		
99	O	200	225	170-260		
99-100	N			90-140		
100	O	200	200	180-210		
100-101	O/N			100-230		
101	O	160	185			
101-102	O			75-265		
102	O	150	170	160-290		18m/300-1600
102-103	O			150-230		
103	O	180	185			
103-104	B/O			135-190		
104	O	150	150	160-230	680	
104-105	B/O			130-190		
105	O	190	195	160-210	400-880	
105-106	O			170-230		
106	O	205	260	170-250		
106-107	B/N			130-170		
107	O	160	205	180-250	780-1600	3.2m/400-1450
107-108	B			120-150		
108	B	140				
108-109	B			120-150		
109	O	130	160			
109-110	B/N			140-180		
110	O	165	175	150-230		
110-111	O/B			145-230		
111	O	260	260	170-250		4m/400-780
						10m/400-1400
111-112	O			150-250		
112	O	230	400	160-270		2m/400-870
112-113	O			130-290		
113	O	165	165			
114	O					12m/400-2600
115	O	230	280	150-300	400-660	
115-116	O			150-180		
116	O	170	170			
116-117	O			170-250		
117	O	200	185	160-250		
117-118	O/N			135-250		
118	O	165	160	150-250		
118-119	O/N			75-170		
119	O	140	170	140-180		
120	O					57m/250-660
120-121	O			130-240		
121	O	175	175			
121-122	O/N			120-240		
122	O	160	165	170-270		3m/400-780
122-123	B/N/O			140-200		
123	O	180	190	150-270		

14

STATION #	O/N/B*	WAIST	GROUND	RANGE	HOT SPOTS	ZONES
Shoreline	N/B			120-160		
124	O	160	160			
124-125	O			150-170		
125	O	190	240	160-290	400-2100	
125-126	N/O			30-200		
126	O	165	170	160-230		
126-127	O			170-250		
127	O	225	290	180-250		
127-128	N			130-150		
128	O	200	215	180-270	400-1400	
128-129	N/O			140-210		
129	O	175	200	200-270		2.5m/400-770
						7m/700-700
129-130	O			200-270		
130	O	235	420	230-280	400-740	
130-131	O			190-200		
131	O	185	185	180-270	400	
131-132	O			170-240		
132	O	150	160	130-280		
132-133	O			130-200		
133	O	200	205	130-260		
133-134	O			160-180		
134	O	205	250	160-250	460	
134-135	O			150-240		
135	O	160	150			
135-136	O			130-230		
136	O	170	260	130-260		20m/300-1800
136-137	O/N			150-230		
137	O	230	270	180-270		
137-138	O			180-270		
138	O	270	440	160-240		5.5m/400-1200
138-139						
139	O			200-300	400-800	
139-140	N/O			110-210		
140	O	150	160	150-230		
140-141	N/B			120-150		
141	O	220	260			
141-142	N/O/B			110-200		
142	O	190	200	160-245		
142-143	O			200-260		
143	O	265	275	210-250	400-700	
143-144	O			180-230		
144	O	210	230	180-295	400-780	
144-145	N/B			130-150		
145	O	220	240	180-290		
145-146	O			150-180		
146	O	140	150			
146-	O/N			110-180		

*O = outcrop, B = boulders, N = non-outcrop

ACKNOWLEDGEMENTS

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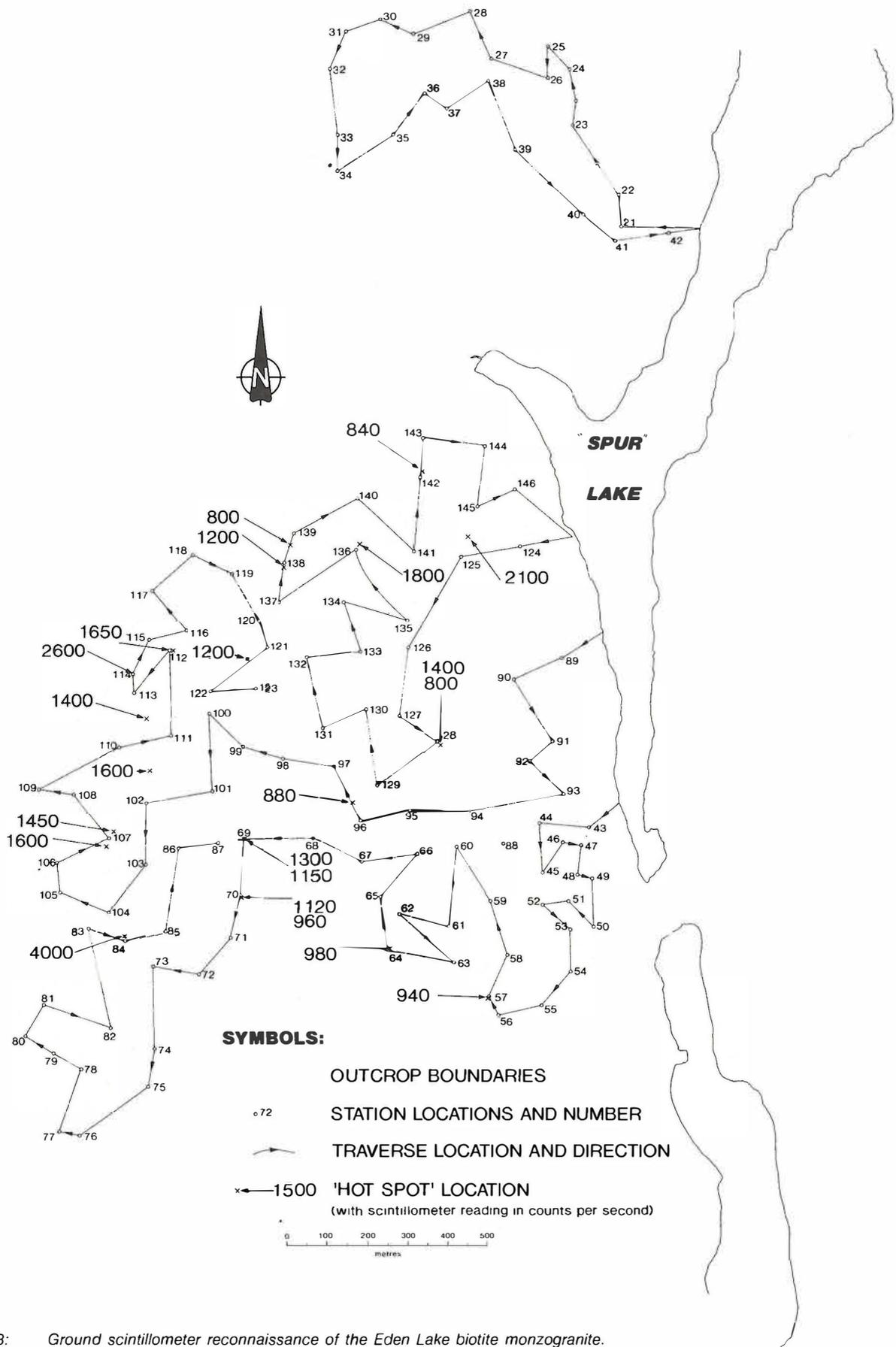
Figure GS-3-3: Ground scintillometer reconnaissance of the Eden Lake biotite monzogranite.

FLUORINE IN
LAKE SEDIMENTS

PPM	%tile
1000	Max.
830	95
760	90
590	70
440	50
10	Min.

FLUORIDE IN
LAKE WATERS

PPB	%tile
380	Max.
160	95
130	90
74	70
56	50
20	Min.

Kilometres

0   10

Extended area of increased
airborne gamma ray response

X 1   Anomalous zones of high response
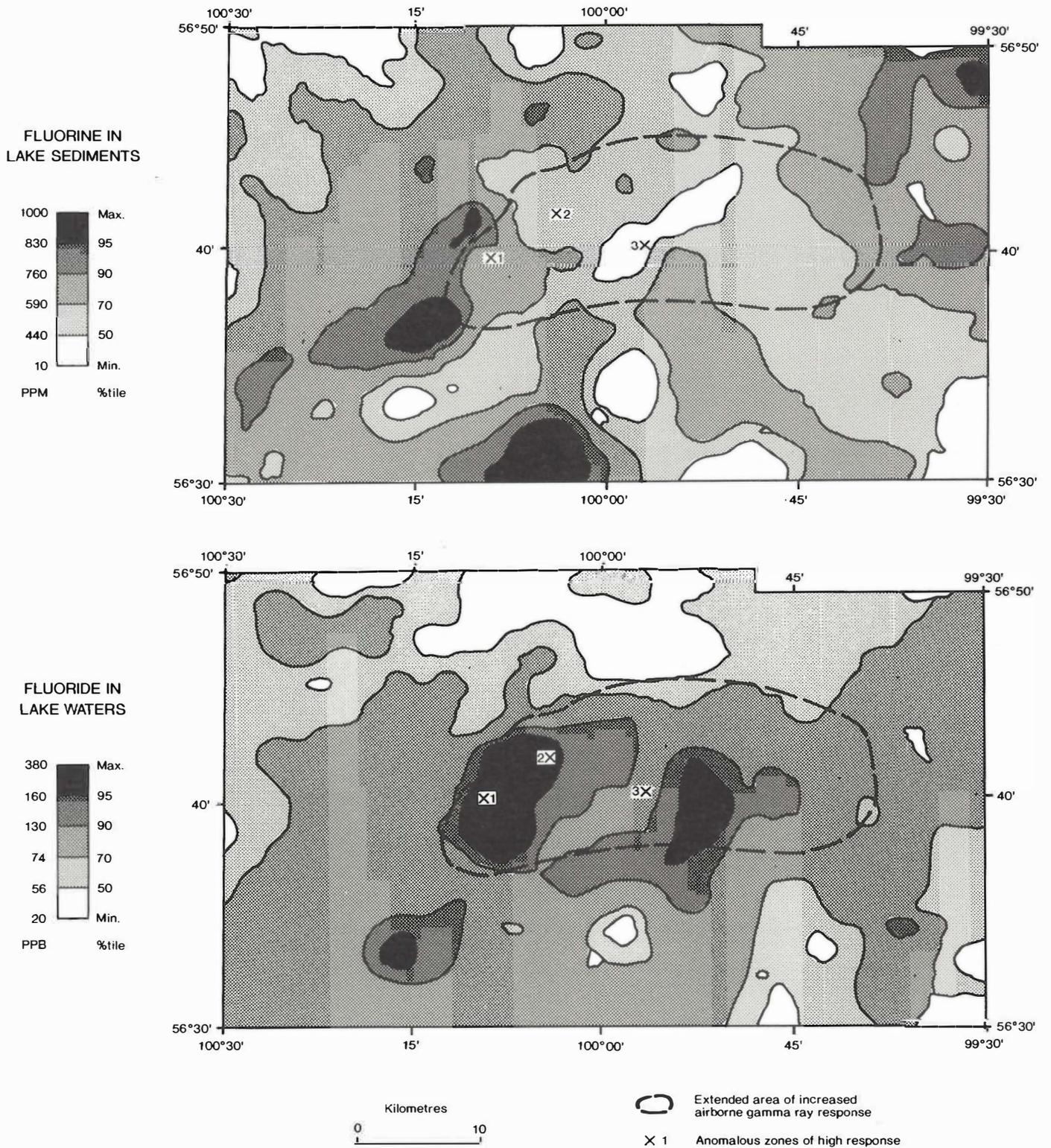
Figure GS-3-4:   *Ground scintillometer reconnaissance of the Eden Lake megacrystic monzogranite and selected regional locations.*

Table GS-3-3
Ground scintillometer survey of the megacrystic monzogranite

STATION #	O/N/B*	WAIST	GROUND	RANGE	HOT SPOTS	ZONES
Shoreline	N/O			100-220		
1	O	210	240	200-260	600-900	5m/380-900
1-2	N/B			110-160		
2	B	160				
2-3	B			140-200		
3	B	160				
3-4	N/B			100-160		
4	O	175	230	140-210		
4-5	N/O/B			100-200		
5	B	160	200			
5-6	B/N			100-160		
6	O	170	195		400-440	
6-7	O			140-180	400	
7	O	180	180	150-210		
7-8	O			130-180		
8	O	180	190	150-210		
8-9	O			140-170		
9	O	165	175	150-180		
9-10	O/B			130-180		
10	B	150	180			
10-11N/B				70-165		
11	N	120	120			
11-12N/B				95-195		
12	N/B					

*O = outcrop, B = boulders, N = non-outcrop

Table GS-3-4
Regional granitic rocks
Scintillometer readings on outcrops adjacent Highway 391

STATION #	O/N/B*	WAIST	GROUND	RANGE	HOT SPOTS	ZONES
Shoreline	O	140	175	30-150		
14	O	140	185	100-170		
15	O	160	190	110-170		
16	O	120	135	110-130		
17	O/B	120	145	110-150		
18	O	150	180	155-185		
19	O	205	210	170-230		26m/380-640
20	O	73	73			
20a	O	60	62	60-70		

Scintillometer readings on outcrops north of the anomaly

STATION #	O/N/B*	WAIST	GROUND	RANGE	HOT SPOTS	ZONES
21	O	150	150	130-170		
21-22	O			130-190		
22	O	130	150	130-170		
22-23	N/B			130-160		
23	O	130	140	130-170		
23-24	O/N			130-140		
24	O	130	150	130-190		
24-25	O			130-170		
25	O	135	150	130-190		
25-26	O			140-170		
26	O	165	175	140-185		
26-27	O			140-160		
27	O	160	155			
27-28	B/O			110-160		

STATION #	O/N/B*	GROUND	WAIST	RANGE	HOT SPOTS	ZONES
28	O	175	210	160-220		
28-29	O			170-220		
29	O	200	240	180-240	660	
29-30	O			150-230		
30	O	220	250	200-250	380-600	
30-31	O/N			150-250		
31	O	155	180	130-160		
31-32	O/N			180-210		
32	O	210	240	200-240		
32-33	N/O			175-210		
33	O	150	170	150-210		
33-34	N/B			140-200		
34	O	200	250	180-220		
34-35	N			130-145		
35	O	140	150	140-200		
35-36	O/N			150-200		
36	O	110	140	140-180		
36-37	O			140-160		
37	O	165	175	150-200		
37-38	N/B			130-150		
38	O	175	215	150-220	420	
38-39	O			150-160		
39	O	165	185	150-200		
39-40	N/B			45-150		
40	O	155	180	150-170		
40-41	N			110-150		
41	O	155	170			
41-42	N			130-150		
42	B	155	180			

*O = outcrop, B = boulders, N = non-outcrop

Table GS-3-5
Spectrometer readings for potassium, equivalent uranium and equivalent thorium

Station #	Scintillometer Readings (cps)	Spectrometer Readings (cpm)			
		T1F	T1S	T2	T3
69	1300	30500	30000	675	150
1800	42000	41000	1000	175	
84	4000	100000+	98000	2500	425
102	1600	37500	38000	775	170
107	1450	38000	38000	875	175
1600	39500	35000	1300	145	
111	1400	41000	40000	625	80
114	2600	69000	73000	1750	275
124	2100	52500	63000	1400	17
127	1400	33500	33000	775	95
135	1400	60500	55000	1100	125
1120	30000	30000	525	70	
137	1200	33000	33000	425	55

Spectrometer readings were taken at ground level. All readings are listed in counts per minute (cpm). The threshold levels are: a) 2.5 Mev at T3 measures diagnostic thorium radiations only; b) 1.6 Mev at T2 to measures characteristic uranium and thorium radiations; and, c) 0.2 Mev at T1F and T1S measures the total count across the entire gamma energy spectrum for maximum sensitivity. T1F has a 1 second time constant and T1S, T2, and T3 have time constants of 10 seconds.

GS-4 GEOLOGICAL INVESTIGATIONS IN THE TARTAN LAKE-MIKANAGAN LAKE AREA (PART OF NTS 63K/13)

by H.P. Gilbert

INTRODUCTION

Mapping was completed to the east margin of the project area, along the north flank and in the area west and northwest of Mikanagan Lake. The main objectives were to:

1. investigate the stratigraphy and structure of the Amisk Group,
2. complete geochemical sampling of volcanic rocks and mineralized occurrences; and
3. investigate major gabbroic intrusions in the area between Tartan and Mikanagan lakes (Fig. GS-4-1).

SUMMARY

The Amisk Group section from Animus Lake (in the northeast) to Krasny Lake (in the southwest) consists largely of mafic volcanic flows and derived schist and amphibolite, intruded by gabbroic units. A northwest-trending synclinal axis, extending from the west shore of Mikanagan lake through Bartley Lake to the south part of Tartan Lake (Bartley Lake syncline), has been mapped through this section (Figs. GS-4-1 and GS-4-2). The axial zone of the fold extends through a unit of subaqueous pyroclastic flows and related epiclastic rocks with subordinate felsic volcanic flows that compose the north end of the Vick Lake tuff (Bailes and Syme, 1989). A lensoid unit of Amisk Group metasedimentary rocks up to 900 m wide, and a fault slice of Missi Group conglomerate are confined to the north limb of the major syncline; the south limb in the vicinity of Krasny Lake is notable for the occurrence of several felsic volcanic units (up to 90 m thick) within the mafic volcanic flows.

The Mikanagan Lake sill (Bailes and Syme, 1989) extends northwest from the area west of Mikanagan Lake to Tartan Lake, where it terminates 1 km south of Tartan Lake Mine; the total strike length is 13.5 km and maximum thickness 1 250 m. Six stratigraphic units are recognized in the sill west of Mikanagan Lake, but only a part of this internal stratigraphy persists to the north end of the sill. The Batters Lake sill, extending west- northwest between Batters and Tartan Lakes, is a layered intrusion comparable with the Tartan Lake gabbro sill (Gilbert, 1987). The internal stratigraphy of the Batters Lake sill is also similar to that of the Mikanagan Lake sill, suggesting possible continuity of these intrusions across the Bartley Lake syncline (Fig. GS-4-1).

STRUCTURE

The major syncline extending from Mikanagan Lake to Tartan Lake, identified by Bateman and Harrison (1945) has been confirmed by abundant top indicators in the widespread mafic volcanic flows, sporadic data in the reworked pyroclastic deposits extending from Mikanagan Lake to Bartley Lake, and the opposed internal stratigraphy of the northeast-facing Mikanagan Lake sill and south- to southwest-facing Batters Lake sill. The exact position of the axial plane of the major fold (Bartley Lake syncline) is uncertain owing to paucity of data in the centre of Mikanagan Lake. The irregular pattern of islands in the centre of Mikanagan Lake may be due to deformation in the axial zone of a major fold, suggesting the syncline may extend from the centre of the lake northwest through the core of the Tartan Lake gabbro complex. However, several southwest-facing pillows east of Bartley Lake indicate the axial zone of the syncline occurs south of the Tartan Lake gabbro complex and extends through Bartley Lake to the south part of Tartan Lake (Fig. GS-4-1). Continuity of the Bartley Lake syncline westward with the major fold extending through Ruby Lake is conjectural; the axial plane of the fold is possibly offset by the inferred northwest-trending fault through the south part of Tartan Lake (Fig. GS-4-1). Minor north- to northwest-trending faults and shear zones in the Tartan Lake-Mikanagan Lake area occur sporadically within mafic volcanic sections and in relatively massive gabbros. Carbonatization, development of chloritic schist and localized pyrite are characteristic of some shear zones.

The major fault between the Whitefish-Mikanagan Lake Block and the Bear Lake Block (Bailes and Syme, 1989) has been extrapolated north and northeast through central Mikanagan Lake and the northeast arm of the Lake. The extension of this fault is conjectural and further mapping east of the project area is required for confirmation. Another fault has been inferred through Swordfish Lake along the southwest margin of the fine grained metasedimentary unit at that locality. The inferred fault, which is characterized by a marked topographic lineament, has been extrapolated northwest through Batters Lake and the small lake to the west; this structure may be related to the east-northeast- trending fault at Tartan Lake Mine, which is approximately on- strike with the inferred fault (Fig. GS-4-1). The Swordfish Lake metasedimentary unit is also flanked to the northeast by a fault which extends northwest to west through the north side of Batters Lake. Cataclasite derived from aphyric basalt, and highly foliated metasedimentary schist locally define this fault east of Swordfish Lake at the basalt/siltstone contact. A northwest-trending syncline has been inferred through the Swordfish Lake metasedimentary unit from very limited structural data (Fig. GS-4- 2). This interpretation implies a stratigraphic discontinuity between the metasedimentary unit and contiguous southwest-facing basalt southwest of Swordfish Lake, possibly due to displacement at the fault which is inferred along the southwest margin of the metasedimentary unit.

Minor, approximately north-trending faults, which are prominent in the northwest part of the project area (Gilbert, 1989), postdate earlier strike-slip faults. These north-trending faults, and related faults approximately normal to regional stratigraphic trends, are not conspicuous in the Tartan Lake- Mikanagan Lake area.

STRATIGRAPHY

Whitefish-Mikanagan Lakes Block

Exposures of the Whitefish-Mikanagan Lakes Block (Bailes and Syme, 1989) are confined to the southeast corner of the current project area (Preliminary Map 1990F-1). The northward termination of a plagioclase-phyric rhyolite unit (at least 230 m thick) has been delineated close to the southeast extremity of the area. The felsic volcanic unit is mainly fragmental with subordinate massive zones and is interpreted as extrusive; the extent of this unit to the south and east is unknown. The mafic volcanic rocks, which are predominant in this part of the fault blocks, are mainly aphyric, commonly pillowed and vesicular, with subordinate plagioclase- ± hornblende-phyric units. At least two distinctive variolitic flows (35 m and 20 m thick) occur in the mafic volcanic section (Fig. GS- 4-3). Columnar jointing was observed in one basalt flow. A small northeast-trending stock of leucocratic diorite to quartz diorite, over 1 km long, is emplaced in the mafic flows close to the inferred west margin of the Whitefish-Mikanagan Lakes Block.

Bear Lake Block

The Bear Lake Block consists largely of basaltic andesite flows and related breccia (up to 3.3 km thick) with an overlying tuffaceous section, related epiclastic rocks and minor felsic volcanics (Bailes and Syme, 1989; Gilbert, 1987, 1988, 1989). The major part of the fault block is monoclinal in the Bear Lake area (Bailes and Syme, 1989), but a syncline extends through the block in the Tartan Lake-Mikanagan Lake area (Bartley Lake syncline). The northeast limb of this major fold attains a width of at least 6 km between Mikanagan Lake and Tartan Lake, although almost half of this section consists of mafic intrusive rocks (Fig. GS-4-1). An parasitic anticline-syncline pair has been mapped in the north limb of this major fold through the northwest arm of Tartan Lake; this fold pair cannot be traced further east or west due to the lack of structural data. The section from the north shore of Tartan Lake to the north margin of the project area is monoclinal and south to southwest facing. North

Figure GS-4-1: Geology and major structural elements of the Tartan Lake-Mikanagan Lake area.
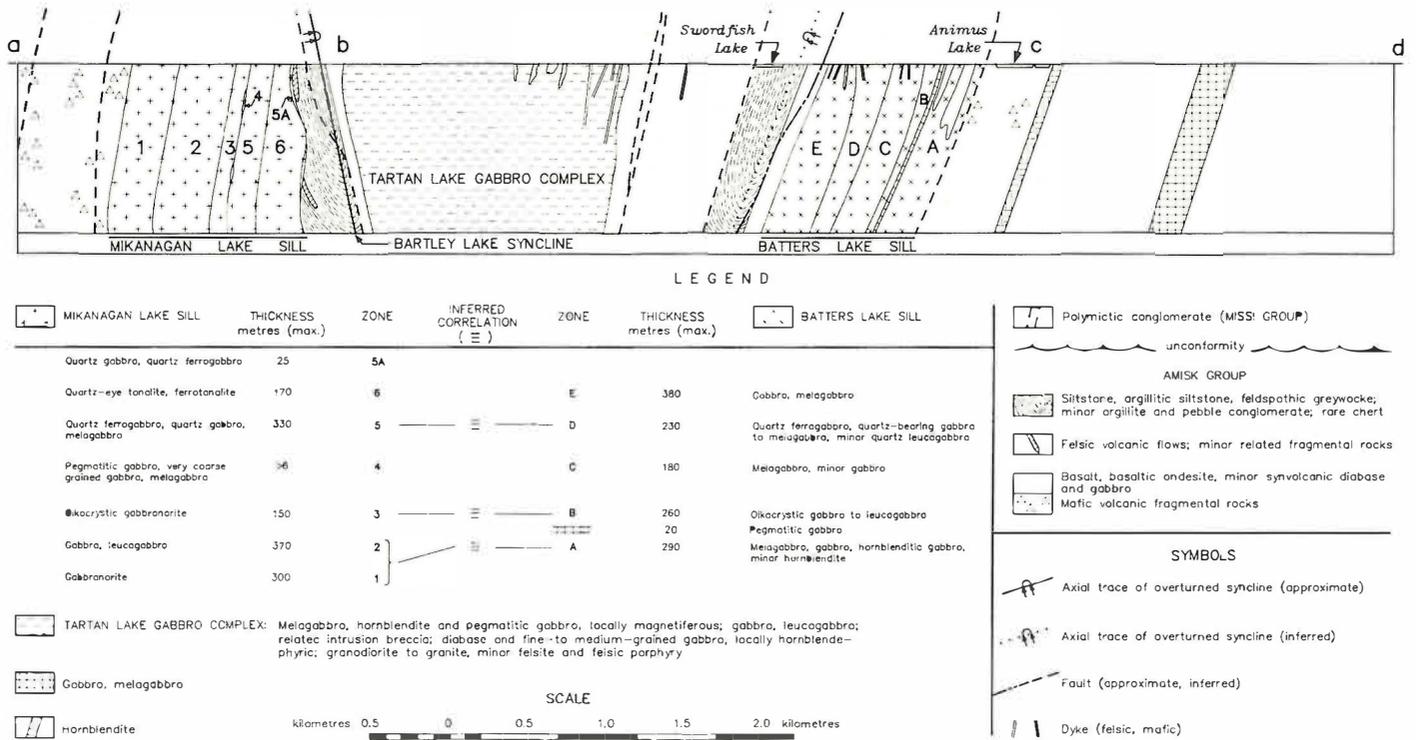
Figure GS-4-2: Composite transverse section through the Bear Lake Block from the area south of Bartley Lake to the area north of Animus Lake. abcd section line is shown in Figure GS-4-1.

Figure GS-4-3: Variolitic basalt close to the west margin of Whitefish-Mikanagan Lakes Block.

of the project area an 8 km wide section of basalt and derived mafic gneiss and schist, containing several granitoid and dioritic intrusions, extends to the margin of the Kisseynew Gneiss belt (Bateman and Harrison, 1945; McRitchie, 1985; Ashton, 1989).

The mafic volcanic section northeast of Tartan Lake is mainly aphyric, commonly pillowed and locally amygdaloidal, with subordinate intercalated hornblende- ± plagioclase-phyric flows; several units are variolitic. One flow is distinguished by large pillows up to 5 by 1 m, with quartz amygdales up to 6 by 2.5 cm (Fig. GS-4-4). Mafic fragmental rocks were observed at two localities in this section, in contrast to the south limb of the Bartley Lake syncline, which contains approximately equal amounts of massive and fragmental mafic volcanic rocks over extensive areas.

The mafic volcanic section north of Tartan Lake displays variable intensity of deformation; sections which are only moderately flattened contain 1 to 10 m wide zones of deformation in which the flows are highly attenuated and locally altered to amphibole-chlorite schist. The frequency of deformed zones apparently increases toward the west, with a concomitant decrease in the degree of preservation of primary structures; thus the section south of Precipice Lake at the west margin of the project area is virtually devoid of reliable pillow-top indicators. This regional variation may reflect an increase in deformation northwestward toward the east-northeast-trending contact between mafic volcanic rocks of the Flin Flon belt, and metasedimentary gneisses of the Kisseynew Gneiss belt (Bateman and Harrison, 1945; Ashton, 1989).

Basaltic andesite flows and related fragmental rocks are exceptionally well exposed in the section extending southeast through the south end of Tartan Lake. This section (Gilbert, 1986, 1987) is characterized by pillowed and subordinate massive flows, intimately intercalated with related fragmental rocks including pillow-fragment breccia, autoclastic breccia (Fig. GS-4-5) and hyaloclastic tuffs that contain lapilli of angular pillow fragments and tabular selvage chips. Some pillows are internally brecciated (Fig. GS-4-6). The flows include both aphyric and hornblende- ± plagioclase-phyric types; ovoid to pipe-shaped amygdales and fine (1 mm) white varioles are widely developed. Northeast to east-northeast facing pillows in this section locally display internal zonation of pillows, in which amygdales and secondary epidosite bodies are commonly located toward the upper margins of the pillows (Fig. GS-4-7). Synvolcanic mafic dykes (1- 10 m thick) are commonly laminated toward the margins and locally amygdaloidal; these fine grained dykes are distinct from sporadic fine- to medium-grained gabbroic dykes that are probably related to the large gabbro sills flanking the mafic volcanic section. Along the contact with the sill southwest of the volcanic section 3 to 6 m wide hornfels, with up to 20 per cent hornblende porphyroblasts (0.5-1 cm), and/or epidotic alteration is locally developed.

The fine grained metasedimentary unit extending northwest through Swordfish Lake has an inferred thickness of 300 m and comprises grey to black siltstone to argillitic siltstone and minor argillite, feldspathic greywacke, and intraformational pebble conglomerate. Bedding is commonly well preserved but top- indicatives (grading and scour) are rare. Chert beds (1-1.5 m thick) were encountered at two localities close to the northeast shore of Swordfish Lake; one unit is associated with irregular chert-filled fractures in the adjacent bed of siltstone interpreted as dewatering structures in the (inferred) underlying rocks. The Swordfish Lake metasedimentary unit is on strike with and may be laterally equivalent to the siltstone/greywacke unit immediately northeast of Tartan Lake Mine. Further west, a fault- bounded metasedimentary unit 330 m thick, (between Tartan and Ruby Lakes), is lithologically and probably stratigraphically equivalent to the metasedimentary unit at Swordfish Lake.

A heterogeneous assemblage of intermediate to felsic tuffs and related sedimentary rocks, which extends for 4 km from the west shore of Mikanagan Lake northwest through Bartley Lake, has been correlated with the pyroclastic Vick Lake tuff. The latter extends for approximately 12 km from the south margin of the project area to White Lake Mine (Bailes and Syme, 1989). The tuffs and crystal tuffs are massive to poorly bedded with diffuse 1 to 20 cm layering and localized fine (1-5 mm) lamination; derived greywacke/siltstone turbidites display Bouma A to E zonation, with parallel lamination, primary slump folding (Fig. GS-4-8) and

localized ovoid calc-silicate bodies interpreted as post- depositional concretions. Greywacke units consist of angular, partially corroded feldspars, with minor lithic grains and localized hornblende fragments (Fig. GS-4-9). A one metre thick intraformational pebble conglomerate, several chert beds (up to 1 m) and thin (2 cm) beds of felsic wacke to pebbly wacke also occur in the section. Massive aphyric to sparsely plagioclase-phyric rhyolite (up to 20 m thick) occurs at the south side of the volcaniclastic section. The felsic volcanic unit contains minor fragmental zones and sporadic felsitic (synvolcanic?) dykes at the west shore of Mikanagan Lake and one occurrence of flow lamination at the south end of Bartley Lake. The tuffaceous section at Mikanagan and Bartley Lakes has a maximum thickness of 220 m and represents a relatively distal section of the Vick Lake tuff, which is 900 m thick in the vicinity of the northeast arm of Schist Lake (Bailes and Syme, 1989).

INTRUSIVE ROCKS
Mikanagan Lake Sill

The subvertical Mikanagan Lake sill (Table GS-4-1)* was emplaced prior to early folding (Bartley Lake syncline) within, or just below, the Vick Lake tuff in the upper part of the Bear Lake Block (Bailes and Syme, 1989). Strong fractionation is demonstrated by the sill stratigraphy (gabbronorite- zone 1, to tonalite- zone 6) and by compositional variation within several zones (especially zone 2) indicating an east to northeast facing direction. Smaller scale igneous layering (at 2-50 cm scale) occurs sporadically; rare crossbedding and igneous lamination were also observed. Regional metamorphism has resulted in widespread recrystallization of pyroxenes to green hornblende, but the gabbro has generally retained a massive texture, in contrast to the less competent Amisk volcanic rocks flanking the sill; localized foliation near some interzone contacts is probably due to minor strike-slip movements. A 0.5 m wide shear zone containing chloritic schist is locally coincident with the contact between zones 2 and 3. The internal stratigraphy recognized in the south part of the sill (Bailes and Syme, 1989) extends, in part, to the north end of the intrusion. Zone 3 (oikocrystic gabbronorite) is discontinuous, and does not occur in the section west of Bartley Lake. Zone 6 (tonalite) terminates in the vicinity of the south end of Bartley Lake; the transition zone (4), upper micrographic leucotonalite zone and marginal quartz ferrodiorite zone are represented by vestigial remnants in the section southeast of Bartley Lake, and have not been observed further northwest. The leucotonalite and quartz ferrodiorite zones have been recognized as sporadic occurrences of leucotonalite and quartz-eye ferrotonalite (respectively) in the upper part of zone 6 (Table GS- 4-1). Zone 6 is interpreted as the latest phase, emplaced along the upper margin of the sill, in contrast to zones 1 to 5, which probably represent in situ differentiation. However, the upper part of zone 3 is locally intruded by melagabbro dykes correlated with the overlying zone (4 or 5). Only two mineralized localities were encountered, both in zone 5 of the intrusion: a sulphide- bearing aphyric basalt enclave, and a gold-bearing quartz vein in melagabbro near the north end of the sill (samples 5 and 14, Table GS-4-3). Bailes and Syme reported disseminated chalcopyrite and Fe- Ti oxides up to 15 per cent in ferrogabbro of zone 5; the geochemistry of the sill shows a marked tholeiitic trend and provides evidence for a synvolcanic (Amisk Group) intrusive origin (Bailes and Syme, 1989).

Batters Lake Sill

Batters Lake sill extends east from Tartan Lake along the north side of Batters Lake to Animus Lake (6.4 km). Although the thickness of the sill increases eastward, from approximately 730 m in the west to 1.0 km at the east margin of the project area, mapping by Bateman and Harrison (1945) indicates the sill terminates just east of the project area at Animus Lake (possibly due to the inferred extension of the fault between the Bear Lake Block and Whitefish-Mikanagan Lakes Block, Fig. GS-4-1). At the west end of the sill, inferred north- to northwest-trending faults may have caused the truncation between Batters Lake sill and Tartan Lake gabbro sill, which is characterized by similar internal stratigraphy (Gilbert, 1987).

Gradational contacts between the main zones (except for the zone B/C contact), are consistent with development of internal zonation after emplacement of the sill. The gabbros are generally massive and
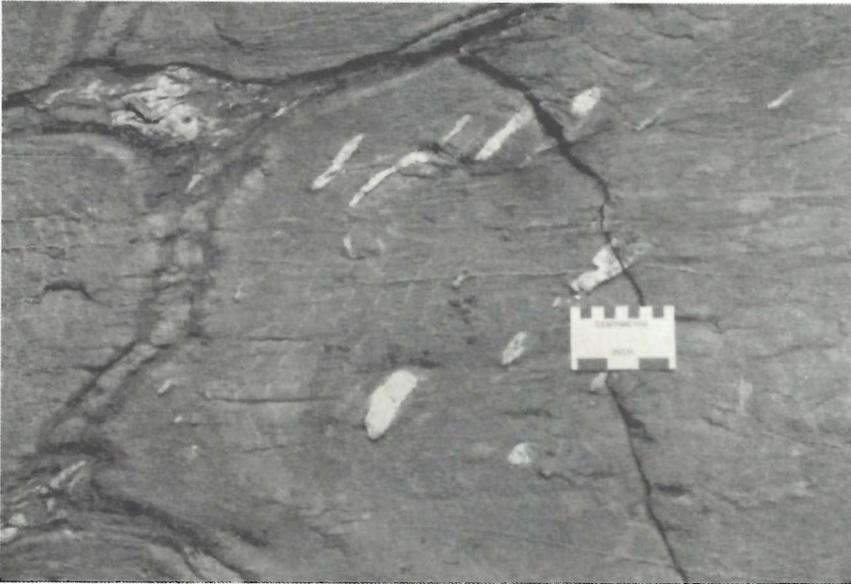
Figure GS-4-4: Quartz amygdales close to the upper margin of a large pillow in basalt northeast of Tartan Lake.

Figure GS-4-5: Autoclastic breccia in basaltic andesite section south of Tartan Lake.
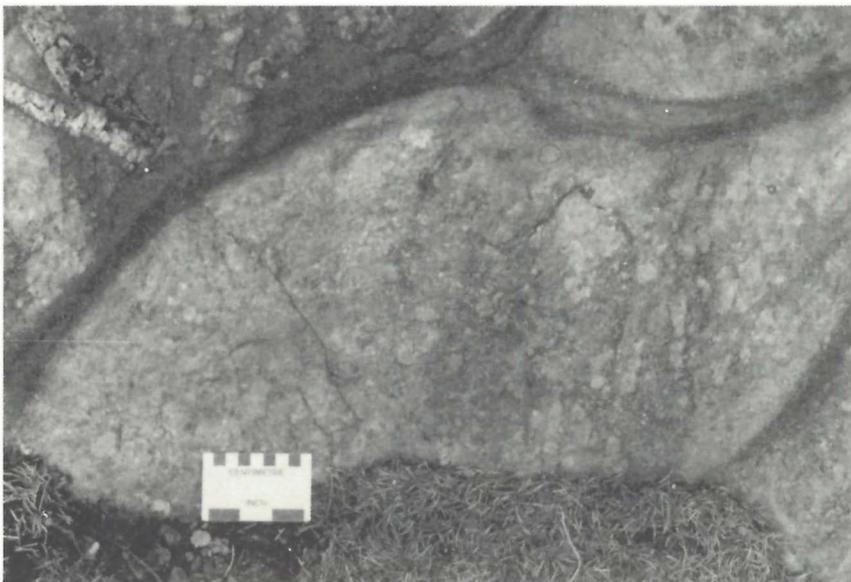
*Figure GS-4-6:* Internally brecciated pillow in basaltic andesite south of Tartan Lake.

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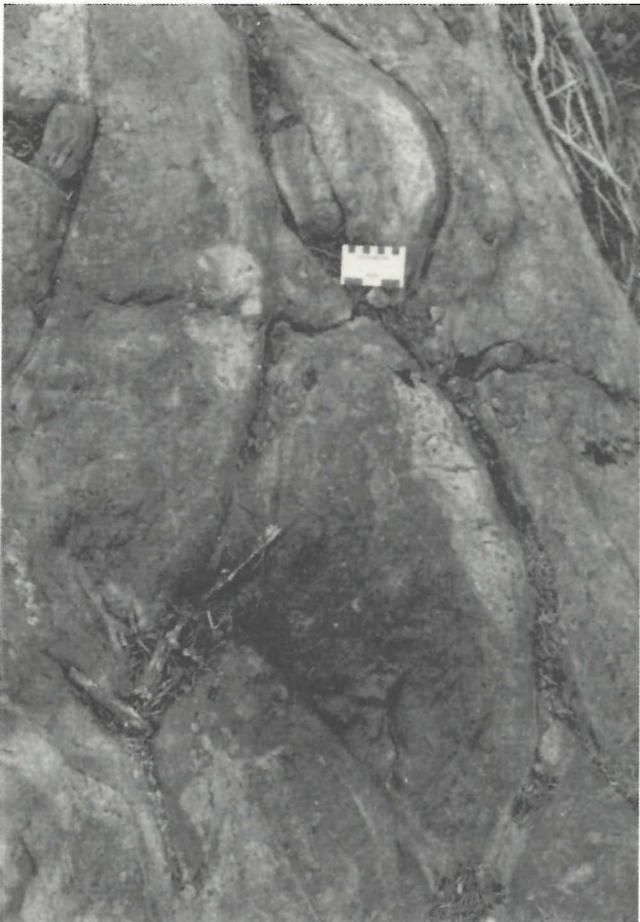
Figure GS-4-7:   Pillowed basaltic andesite south of Tartan Lake with epidosite alteration domains at the upper margins of pillows.

Figure GS-4-8:   Volcanic-derived turbidite within the north part of Vick Lake tuff, showing Bouma divisions B to E, with part of the A division of the overlying bed.
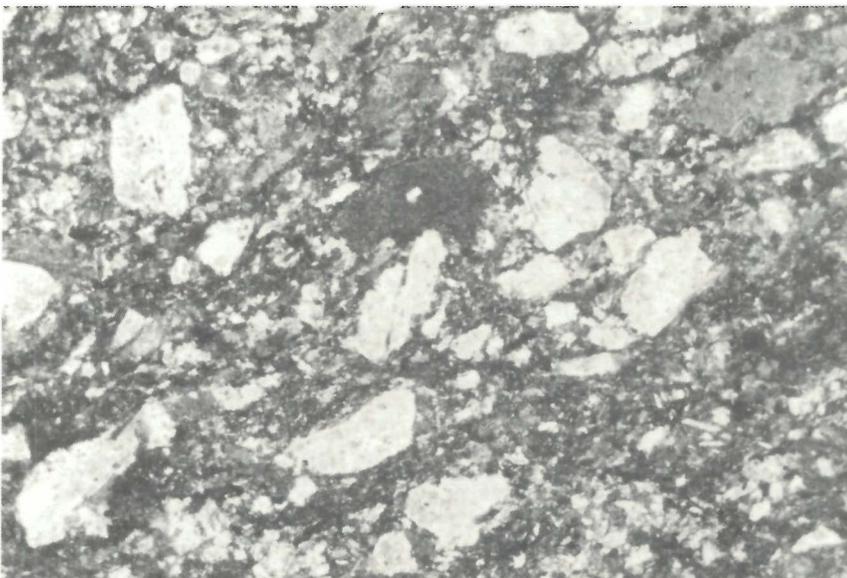
Figure GS-4-9:   Feldspathic greywacke within the north part of Vick Lake tuff (photomicrograph magnification X33).

Zones	Thickness, (m) max.	Notes
Country rock		(a) Intermediate to felsic tuffs, tuffaceous sedimentary rocks and rhyolite at Mikanagan Lake, locally with 6 m diabase dyke at contact (b) Aphyric basalt at Bartley Lake.
6 Quartz-eye tonalite, ferrotonalite	170	Medium grained, hypidiomorphic plagioclase, with quartz eyes, (1 mm-1 cm, up to 30% of the rock); massive to cataclastically foliated. Localized pervasive epidotization but generally homogeneous and free of metasomatic alteration. Hornblende-bearing, except for localized uppermost subzone (20 m) of stilpnomelane-bearing quartz-eye ferrotonalite (yellowish-brown weathering). Minor occurrence of fine-to medium-grained leucotonaltie at upper margin, and as veins in host-rock. Interpreted as youngest, silica-rich fraction emplaced along upper margin of sill.
5A Quartz gabbro, quartz ferrogabbro	25	Medium grained mesocratic to melanocratic gabbro, with granophyric quartz aggregates (10-20% of the rock) and related stilpnomelane-bearing phase, as in zone 5. Localized layering of alternating leucocratic/mesocratic units (0.2 mm-2 cm, up to 8 cm). Sporadic irregular pegmatitic zones with quartz aggregates. Interpreted as upper part of zone 5 where tonalite (zone 6) has locally been emplaced laterally within ferrogabbro (zone 5) rather than above it. Zone 5A is confined to the area just west of Mikanagan Lake, where it occurs either within or structurally above zone 6.
5 Quartz ferrogabbro, quartz gabbro, melagabbro	330	Predominantly melanocratic, stilpnomelane-bearing quartz ferrogabbro, fine- to medium-grained, with granophyric quartz aggregates (up to 20% of the rock). Stilpnomelane-free, hornblende-bearing quartz gabbro and melagabbro occur as a lower subzone or intercalated with stilpnomelane-bearing ferrogabbro. Generally homogeneous, with rare compositional layering (at 2-4 cm, and 20-50 cm). Sporadic dykes of pegmatitic gabbro (up to 7 m) and leucogabbro (0.5 m). Mineralized enclave (8 m) of aphyric basalt occurs within the zone (sample 5, Table GS-4-3). At base: medium- to coarse-grained hornblenditic gabbro to hornblendite locally comprises a basal unit (>15 m) directly overlain by mesocratic gabbro; elsewhere the basal unit consists of intercalated hornblenditic gabbro and mesocratic gabbro. The hornblenditic gabbro locally displays primary lamination (of subparallel hornblende after pyroxene) and contains sporadic diffuse lensoid zones of leucogabbro. Elongate very coarse grained to pegmatitic zones (up to 0.5 m wide) are gradational with medium grained gabbro in the basal part of zone 5. At top: upper part of zone consists of either stipnomelane-bearing quartz gabbro alone, or with stilpnomelane-free phases; rare occurrence of chilled margin interpreted as result of emplacement against country rock, with later emplacement of tonalite (zone 6) along margin of sill.
4 Transition zone	>6	Discontinuous zone of pegmatitic gabbro with quartz aggregates (8 mm), hornblende prisms (4.5 x 1.5 cm) and irregular aggregates of magnetite (up to 2 x 1 cm) associated with very coarse grained gabbro and melagabbro. Margins locally sheared.
3 Oikocrystic gabbronorite	150	Pyroxene (partly altered to green hornblende) oikocrysts (0.5-1.5 cm) comprise 10 to 20 per cent of the rock; these are widespread but not ubiquitous. Ovoid oikocrysts weather rusty brown, with margins indistinct from the matrix of medium- to coarse-grained mesocratic gabbronorite. Rare diffuse igneous layering (at 2-10 cm). Sporadic fine grained feldspathic bodies up to 2 by 0.5 m (xenolith or vein origin). Upper 40 m of zone 3 locally characterized by grain size variation with sporadic pyroxene megacrysts up to 3 cm and diffuse very coarse grained to pegmatitic zones with hornblende up to 6 cm. Minor melagabbro to hornblenditic gabbro dykes (of zone 4 or 5) near top of zone 3 contain sporadic altered pyroxenes (2 cm) and veins of very coarse grained hornblendite.
2 Gabbro, leucogabbro	370	Massive, medium- to coarse-grained; systematic decrease in hornblende (after pyroxene) content from mesocratic gabbro (55% hornblende) at southwest, to leucogabbro (20% hornblende) at northeast, where there are localized elevated carbonate contents. Sporadic compositional layering (based on hornblende variation) at 0.1 cm to 0.5 m scale. Upper and lower contacts both gradational with adjacent zones.
1 Gabbronorite	300	Massive, medium grained, with hornblende (after pyroxene) range 50 to 65 per cent. At base: localized increase of hornblende toward base (up to 75%) and basal zone (30 m) of "knotted" melagabbro with altered pyroxene aggregates (up to 1 cm). Localized chilling over 10 m at lower contact, which is characterized by carbonatization, and a quartz (± ankerite) vein 0.2 to 1.5 m thick. A one metre felsitic dyke occurs in melagabbro adjacent to the contact.

Zones	Thickness, (m) max.	Notes
Country rock		Aphyric basalt and pillowed basalt, strongly foliated and attenuated in contrast to relatively more competent gabbro sill. Minor zone of chloritic schist in basalt may represent a fault almost coincident with the basalt/gabbro contact.

SOUTHWEST (Base)

homogeneous, except for minor, locally carbonatized shear zones (20-50 cm, up to 1 m). Igneous lamination, generally defined by subparallel hornblende (at one locality by plagioclase) occurs sporadically; igneous layering (Fig. GS-4-10) defined by variations in pyroxene (hornblende) and plagioclase contents, is more common, especially in zone B. Chilled margins occur toward both upper and lower contacts, together with localized felsite and felsic porphyry dykes. Hornblende-phyric diabase dykes occur sporadically in the sill. Minor base metal mineralization occurs at the basal contact with basalt (sample 3, Table GS-4-3), and at the margins of basalt ($\pm$ chert) enclaves in zone A. Melagabbro within 120 m of the base of the sill contains up to 10 per cent disseminated magnetite, and is locally intruded by a hornblendite vein (12 cm) with marginal massive magnetite zones.

The internal stratigraphy of the south- to southwest-facing Batters Lake sill is partly comparable with the northeast-facing Mikanagan Lake sill zonation (Tables GS-4-1 and GS-4-2, Fig. GS-4- 2); zone A (Batters Lake sill) is correlated with zones 1 and 2 (Mikanagan Lake sill); zone B with zone 3, and zone D with zone 5. Mikanagan Lake sill zone 6 (tonalite/ferrotonalite) does not occur in Batters Lake sill, although there are minor quartz eye tonalite dykes and veins in zones B, D, and E. Uppermost zones of micrographic leucotonalite and marginal quartz ferrodiorite, mapped in Mikanagan Lake sill by Bailes and Syme (1989) are also absent in Batters Lake sill. There is also no distinctive counterpart of transition zone (4), although a pegmatitic gabbro zone and pegmatitic dykes at two localities, close to the contact between zones B and C, may be analogous to the transition zone in Mikanagan Lake sill. In spite of these differences, the stratigraphic and lithologic similarities exhibited in the oikocrystic gabbro/gabbronorite zones and the ferrogabbro zones in both sills are striking.

The upper half of Batters Lake sill is intersected obliquely by the inferred fault at the north margin of the supracrustal section extending through Batters Lake. The fault oversteps zones E, D and C in the vicinity of Batters Lake, and extends along the south margin of zone B further west. Zone F is interpreted as the uppermost part of Batters Lake sill at the west end, where it is gradational with underlying zone B; zone

F is also apparently continuous with a gabbro phase within the Tartan Lake gabbro complex to the south. Sporadic igneous layering displays trends that suggest structural continuity between the west end of Batters Lake sill, through the northwest end of Tartan Lake gabbro complex, to the north end of Mikanagan Lake sill (Fig. GS-4-1). A discontinuity in oikocryst-bearing rocks within zone B north of Batters Lake may be analogous to a similar discontinuity in the oikocrystic gabbronorite (zone 3) in Mikanagan Lake sill southwest of Bartley Lake.

Tartan Lake Gabbro Complex

The Tartan Lake gabbro complex differs from the layered Tartan Lake, Mikanagan Lake and Batters Lake sills in its multiphase character, greater compositional diversity, and more widely developed tectonic fabric. Four main phases of intrusive rocks have been recognized in the gabbro complex (I to IV), each consisting of several subordinate phases (e.g. IA, IB). The oldest phase (IA) consists of massive magnetite-bearing melagabbro to hornblendite, ranging from medium grained to very coarse grained or pegmatitic. Remnants of hornblendite locally occur within coarse grained melagabbro (Fig. GS-4-12); elsewhere these lithologies are gradational. Phase IA varies locally to mesocratic gabbro, and locally includes minor anorthositic gabbro. Phase IB consists of fine- to medium-grained gabbro to melagabbro, locally with diffuse compositional layering at a scale of 1 to 40 cm. IB represents the oldest phase at some localities in the northwest part of the complex, whereas IA is more widely developed; the relative ages of IA and IB are unknown, IC is a minor early diabase phase which occurs in IA, truncated by phase II (Fig. GS-4- 13).

Phase II is the most abundant and most diverse of the four main phases, consisting of at least five subordinate penecontemporaneous units. IIA is a widely developed fine- to coarse-grained gabbro ranging from leucocratic to melanocratic at outcrop scale (hornblende content equals 20-70%). A diffuse layering defined by variable composition and grain-size is common, probably resulting from fractionation and irregular flow during emplacement. Assimilation of phase I is locally demonstrated by irregular remnants of hornblendite in IIA (Fig. GS-4-14),
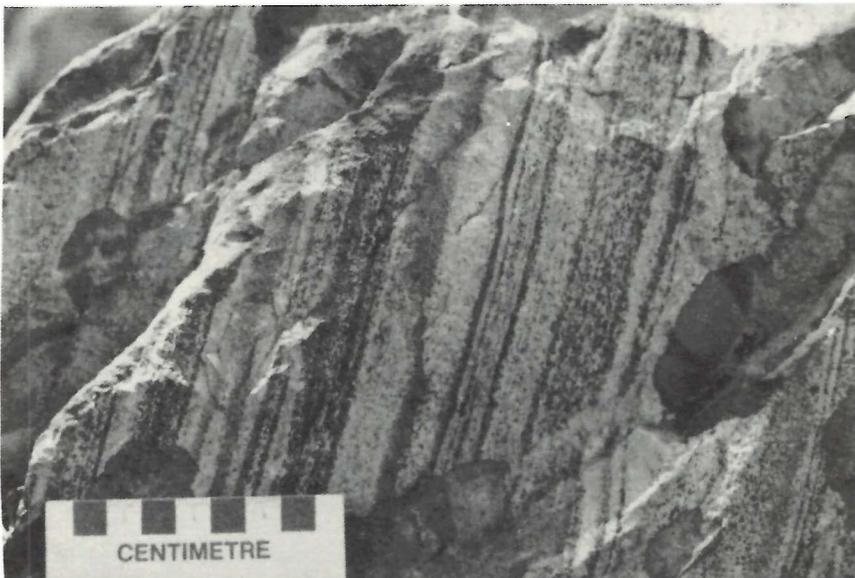

Figure GS-4-10: *Igneous layering in zone A at the east end of Batters Lake sill.*

Table GS-4-2
Stratigraphy of Batters Lake Sill
SOUTH (top)

Zones	Thickness, (m) max. West	East	Notes
Country rock			Aphyric basalt; locally the gabbro margin is only 12 m below chert and siltstone of the Swordfish Lake metasedimentary unit which overlies the basalt; related metasediments occur in a 5 m wide enclave in gabbro (zone E) 100 m below the top of the sill. The upper margin of the sill (zone E) is characterized by a contact zone with aphyric basalt intercalations (1-10 m) and chilled gabbro zones. At west end of the sill: uppermost zone (F) is apparently gradational with mesocratic gabbro in the northwest part of Tartan Lake gabbro complex.
F Gabbro	365		Relatively homogeneous, mesocratic, massive, medium grained with localized cataclastic foliation and sporadic shear zones (amphibole-chlorite schist $\pm$ carbonate). Rare diffuse igneous layering at 2 to 20 cm. Zone F is the uppermost unit of the west end of the sill, and directly overlies zone B; the gradational contact with B is marked by an increase of hornblende content (35-50%) and loss of oikocrysts over a 10 m wide section. Zones F and E are possibly laterally equivalent.
E Gabbro, melagabbro	140	380	Massive, with hypidiomorphic hornblende or localized fascicular texture (with amphiboles up to 3 cm); locally igneous lamination (parallel hornblende). Medium- to coarse-grained, locally very coarse grained; at the east end of the sill zone E grades from coarse grained (near the base) to medium-/ fine-grained (at the top). The gradational contact with underlying zone D is marked by a 5 to 10 m zone of melagabbro with minor quartz (1-3%) and sporadic occurrences of greater gabbro in the basal 30 m of zone E; the base of zone E also locally shows an upward increase of hornblende content and grain size away from zone D. Sporadic skialithic enclaves of aphyric pillowed basalt (25 m) and pebbly siltstone (5 m). Minor dykes of hornblende-phyric diabase, leucogabbro, felsite and plagioclase porphyry occur locally at the south (upper) margin of zone E. Quartz-eye tonalite veins occur near the lower margin; chloritic shear zones (1-2 m) are also present.
D Quartz ferrogabbro quartz-bearing gabbro to melagabbro; minor quartz leucogabbro	175	230	Quartz aggregates and grains (1-3 mm) comprise 10 to 15 per cent (up to 20%) of the gabbros, which consist of: a) melanocratic stilpnomelane- bearing quartz ferrogabbro (fine- to medium-grained, dark brown-grey to yellow-brown), and (b) hornblende-bearing quartz gabbro to melagabbro (medium-grained, medium to dark green); minor quartz leucogabbro. The two phases occur throughout zone D and appear to be largely gradational; however, dykes of phase (b) within phase (a) were observed at two localities. The upper margin of zone D locally shows gradation from phase (a) to phase (b) to melagabbro of the adjacent zone E, with concomitant decrease of quartz (8%$\rightarrow$3%$\rightarrow$zero) and increase in grain size (fine-/medium-grained to coarse grained). A reverse trend of increasing quartz (2%$-$8%) occurs over a 50 m section upward from the base of zone D which is locally gradational with underlying zone C. The quartz gabbros are typically massive, locally with fascicular aggregates of hornblende, but igneous lamination is locally developed. Subconcordant intrusions of hornblende-phyric diabase (2 m), ferrotonalite (12 m) and quartz-phyric leucotonalite (2 m) occur in the upper part of zone D. Minor quartz leucogabbro occurs sporadically in the section north of Batters Lake.
C Melagabbro, minor gabbro	180	180	Massive, fine- to medium-grained, locally with diffuse primary layering (at 0.5-20 cm scale) and rare igneous lamination; disseminated pyrite-pyrrhotite are locally conspicuous. The lower contact with zone B is sharp, with a leucocratic quartz diorite vein (2-10 cm) at or just below the contact, which is locally marked by minor chloritic schist. At another locality, the contact between zones B (mesocratic oikocrystic gabbro) and C (melagabbro) is sharp, but oikocrysts persist in a 5 m zone immediately above the contact; melagabbro above this zone contains a lensoid leucocratic zone of pegmatitic gabbro (1.5 x 5 m); 40 m above the contact the melagabbro is intruded by a subconcordant magnetiferous pegmatitic gabbro dyke (1.5 m) zoned with a leucocratic core and pegmatitic margins, with hornblendes up to 12 cm long. Other subconcordant dykes in zone C include plagioclase $\pm$ hornblende-phyric diabase and pegmatitic quartz leucogabbro.
B Oikocrystic gabbro to leucogabbro	260	180	Medium grained, generally massive with ovoid, anhedral oikocrysts of pyroxene (altered to amphibole) (0.5-1.5 cm, 10-20% of the gabbro), Fig. GS-4-11). Oikocrysts are widespread but not ubiquitous; oikocrystic gabbro grades through zones with incipient oikocrysts to equigranular gabbro without oikocrysts. Hornblende content of the matrix is generally 30 to 45 per cent (variable 20-50%), commonly more leucocratic than the (probably equivalent) oikocrystic mesocratic gabbronorite in zone 3 of Mikanagan Lake sill. The upper contact of zone B with C is sharp, with localized coarse grained zones along the margin of B; some oikocrysts persist in the basal part of zone C. At the west end of the sill melagabbro of zone A grades systematically southward (hornblende 75%$\rightarrow$60%) toward the contact with zone B, marked by a minor pegmatitic gabbro dyke and the appearance of oikocrysts. Hornblende content continues to grade southward from the base of zone B (50%) to the top (25%), which is characterized by a 3 m wide shear zone

Zones	Thickness, (m) max.		Notes
	West	East	
			(fault) with amphibole- chlorite schist; anorthositic gabbro (without oikocrysts) 10 m wide occurs locally at the top of zone B. Oikocrystic gabbro is generally massive, but locally displays anastomosing cataclastic foliation and sporadic strongly foliated zones (10-30 cm wide). Igneous layering (generally at 1-6 cm, up to 20 cm) is locally conspicuous, and more widely developed than elsewhere in the sill; northeast to north-northeast trending layering at the west end of the sill is discordant to the trend of the main zones, reflecting either circulating convection currents or a southward tectonic deflection at the west end of the sill. Minor intrusions (1-2 m) in zone B include hornblende ± plagioclase-phyric diabase and quartz-eye tonalite, which is associated with carbonatization, minor iron-staining and shearing at a locality near the west end of the sill. Oikocrystic gabbro is absent in the sill north of Batters Lake; in this area zone B is represented by equigranular phases of leucogabbro to melagabbro (locally magnetiferous) interpreted as laterally equivalent to oikocrystic gabbro to the east and west (Fig. GS-4- 1).
Pegmatitic gabbro	0.5	20	The contact between zones A and B is locally marked by massive pegmatitic gabbro units at the west and east ends of the sill.
A Melagabbro, gabbro, hornblenditic gabbro, minor hornblendite	120	290	The west part of zone A (extending along the south side of the northeast arm of Tartan Lake) is mainly melagabbro with minor hornblenditic gabbro, grading from chilled phases along the north margin south to medium-grained relatively less mafic gabbro. This transition also occurs further east, between Batters Lake and Animus Lake, where zone A consists of roughly equal melagabbro and mesocratic gabbro, with fine- to medium-grained chilled phases intercalated with irregular enclaves of mafic volcanic rocks. Igneous layering is very well developed at one locality close to a contact with basalt (Fig. GS-4-11); feldspathic and hornblendic laminae alternate at a scale of 2 to 25 mm, up to 12 cm; the layering is highly contorted adjacent to the basalt contact. Elsewhere the gabbros are generally massive, except for one occurrence of igneous lamination (subparallel plagioclase) in melagabbro at the west shore of Animus Lake. Contacts with aphyric to porphyritic basalt are locally associated with minor iron-staining or sulphide mineralization and hornblende blastesis (e.g. sample 3, Table GS-4-3). Minor sulphides are also associated with a 1 m bed of laminated chert in a 25 m wide enclave of aphyric basalt within zone A. Minor intrusions of felsic porphyry and felsite occur near the base of zone A close to Animus Lake.
Country rock			Aphyric basalt, locally with rare laminated mafic tuff. Contacts are locally highly sheared, with localized silification of the host rock associated with minor intrusions of felsite.

NORTH (base)

Figure GS-4-11:   Oikocrystic gabbro (zone B) at the west end of Batters Lake sill.
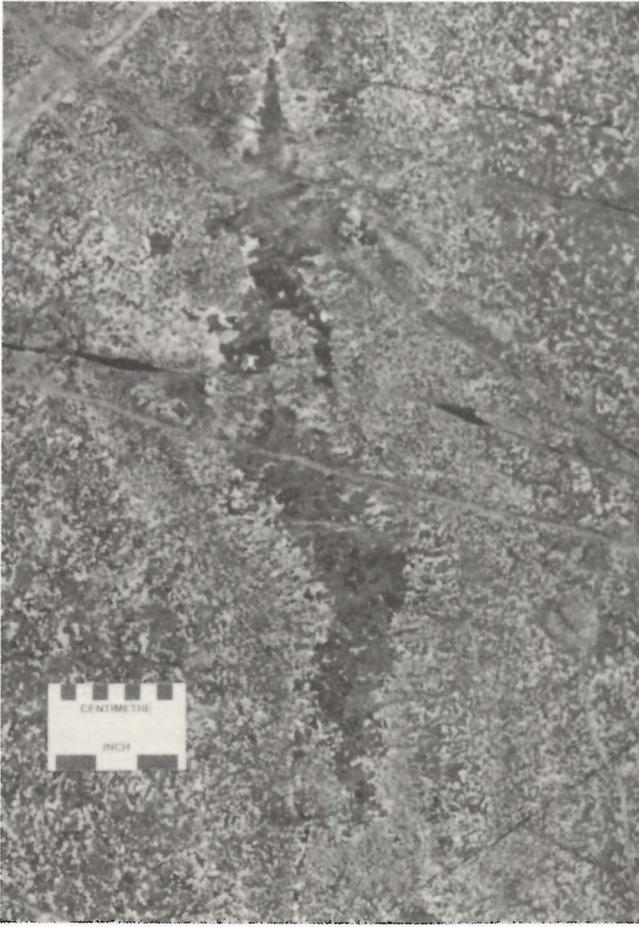
Figure GS-4-12: Very coarse grained hornblendite body with coarse-to medium-grained gabbro halo interpreted as a xenolith remnant within coarse grained melagabbro (IA) in Tartan Lake gabbro complex. Same locality as sample 15, Table GS-4-3 and Figure GS-4-16.
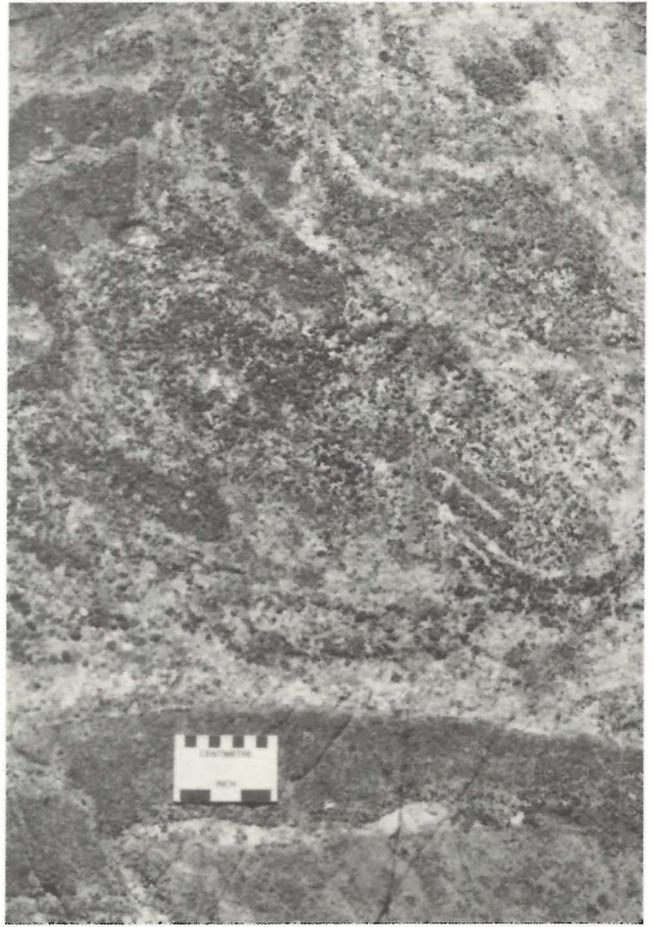

Figure GS-4-14: Remnants of hornblendite (IA), largely assimilated by gabbro (IIA). Tartan Lake gabbro complex.
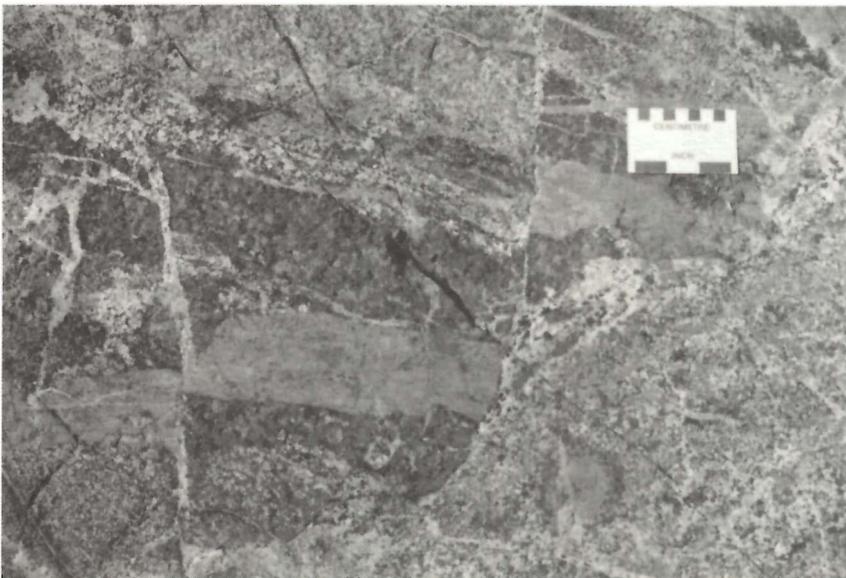
Figure GS-4-13: Tartan Lake gabbro complex: an enclave of coarse grained magnetiferous hornblendite (IA) with early diabase vein (IC) is intruded by mesocratic gabbro (IIA) and cut by sinistral faults, with later displacement along a fracture filled with hornblende-phyric leucogabbro (IID).

resulting in localized concentrations of magnetite (in clots up to 5 x 25 cm) in the younger phase (Fig. GS-4-15). Compositional variation of IIA is locally directly related to the amount of assimilation of I. IIA is intruded by feldspathic veins and medium grained leucogabbro dykes (IIB) which are associated with minor gold and copper mineralization (chalcopyrite-pyrite-malachite) 1 km southeast of Tartan Lake Mine (sample 15, Table GS-4-3; Fig. GS- 4-16). Intrusion breccia, which occurs sporadically in the Tartan Lake gabbro complex, is well developed in the northwest part. The breccia consists of angular to subangular blocks of phase IA ± IB in a leucocratic to mesocratic matrix of IIA or IIB. These rocks are gradational to zones of phase I with agmatitic veins of II. IIC is a very coarse grained to pegmatitic gabbro which occurs as dykes and irregular bodies within older rocks of I or IIA and is commonly magnetiferous (5-10%, up to 15% magnetite in aggregates up to 4 cm across, Fig. GS-4-17). The dykes locally display pegmatitic margins with hornblendes (up to 1 x 10 cm) oriented normal to dyke contacts, and com-

positional zoning with relatively more leucocratic or more melanocratic cores. IID is a medium grained leucogabbro with hornblende phenocrysts (up to 1.5 cm long) which is emplaced along minor faults truncating the earlier phases of II and I (Fig. GS-4-13). IIE consists of minor fine- to medium-grained melagabbro dykes which truncate IIC (pegmatitic gabbro), but are cut by younger diabase (phase III).

Fine grained diabase (IIIA) is widespread as minor dykes and veins cutting earlier gabbroic phases, locally in irregular cross- cutting vein systems. Related fine- to medium-grained gabbro occurs in an extensive zone several hundred metres across in the northwest part of the gabbro complex, and porphyritic (hornblende ± plagioclase) gabbro and diabase (IIIA) occurs locally at the margins of the complex (e.g. northwest of Swordfish Lake). Minor veins of IIIB consist of fine- to medium-grained melagabbro which truncate IIIA. Phase III probably comprises less than 10 per cent of the complex, which consists largely of IA, IIA, IIB and IIC.
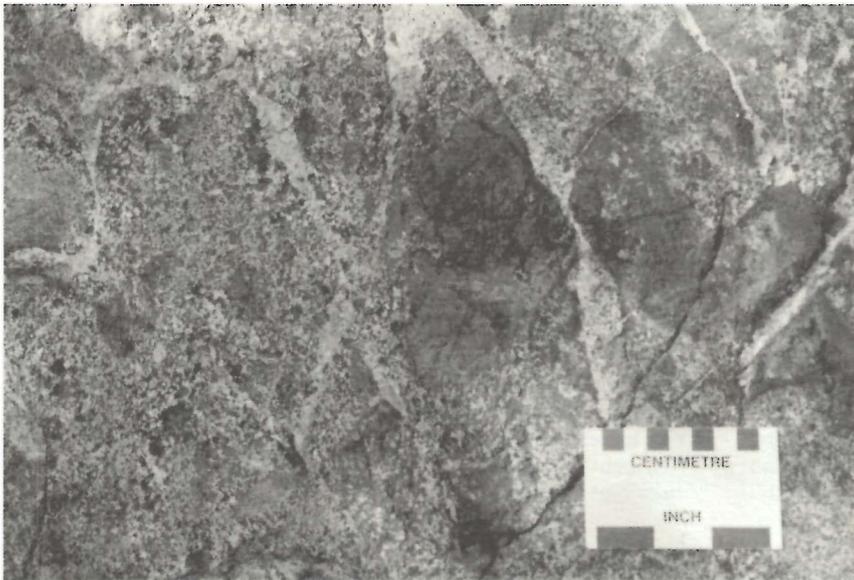

Figure GS-4-15:   Massive magnetite body within hornblendite remnant (IA) largely assimilated by gabbro (IIA), with later feldspathic veining (IVA). Tartan Lake gabbro complex.

Figure GS-4-16:   Gold-copper mineralization in a 15 cm massive sulphide vein with malachite halo within leucogabbro (IIB). Tartan Lake gabbro complex (sample 15, Table GS-4-3).

Figure GS-4-17: *Magnetiferous pegmatitic gabbro (IIC). Tartan Lake gabbro complex (same locality as sample 17, Table GS-4-3).*

White to pink granodiorite to granite (phase IVA) is widespread in the complex as minor dykes and veins. Phase IVA also and occurs in several larger bodies up to 250 m across in the eastern part of the complex (e.g. at the north shore of Bartley Lake, and at a small lake between Batters Lake and Bartley Lake). The granitoid rocks are generally fine- to medium-grained with minor pink pegmatite in some veins. Phase IV is locally associated with a late intrusion breccia which consists of angular gabbroic blocks within the granitoid phase. The breccia is gradational with zones of agmatitic granitoid veining in gabbro. Large euhedral hornblende prisms (up to 1 x 10 cm), which occur locally as sporadic crystals or in irregular clusters in pink granitic veins, are interpreted as xenocrysts derived from an older pegmatitic gabbro phase (Fig. GS-4-18). Felsic porphyry dykes (IVB) are common in the gabbro complex, typically with abundant plagioclase and minor quartz phenocrysts, in dykes 1 to 10 m wide, trending west-northwest to northwest. The age of the porphyry relative to the equigranular granitoid phase (IVA) is unknown, but both phases post-date the regional foliation that occurs locally in the gabbroic rocks (I, II). Copper/zinc $\pm$ Au mineralization occurs in some porphyry intrusions (e.g. sample 8, Table GS-4-3) and gold occurs in altered feldspar porphyry at Tartan Lake Mine (Gale and Ferreira, 1988).

Most of the Tartan Lake gabbro complex displays more than one phase. Several zones (up to 0.5 km wide) consisting exclusively of massive, medium grained gabbro of uncertain affinity (I or II), are conspicuous south and southeast of Tartan Lake Mine, and directly south of Batters Lake. At a few localities all four main phases of intrusion may be distinguished.

Minor faulting (displacements less than 1 m) affects all phases of the gabbro complex; at least two ages of faults are recognized. Chloritic shear zones (0.5-3 m wide) occur sporadically in the gabbro complex but are best developed in the northwest, where the zones vary from east to northeast to northwest. The shears locally contain minor disrupted quartz veins and are locally mineralized with gold ($\pm$ pyrite $\pm$ carbonate - sample 17, Table GS-4-3). Four distinct types of shear zones have been recognized in the vicinity of Tartan Lake Mine (J. Fedorowich, 1990 pers. comm.).

Contacts between the gabbro complex and basalt are locally characterized by extensive hornblende metasomatic and recrystallization of the volcanic rocks. A contact zone 300 m to 600 m wide at the east margin of the gabbro complex northwest of Mikanagan Lake consists of intercalated gabbro and fine grained basalt with variable altera-

Figure GS-4-18: *Hornblende xenocrysts within a granitic vein (IVA) cutting gabbro. Tartan Lake gabbro complex.*
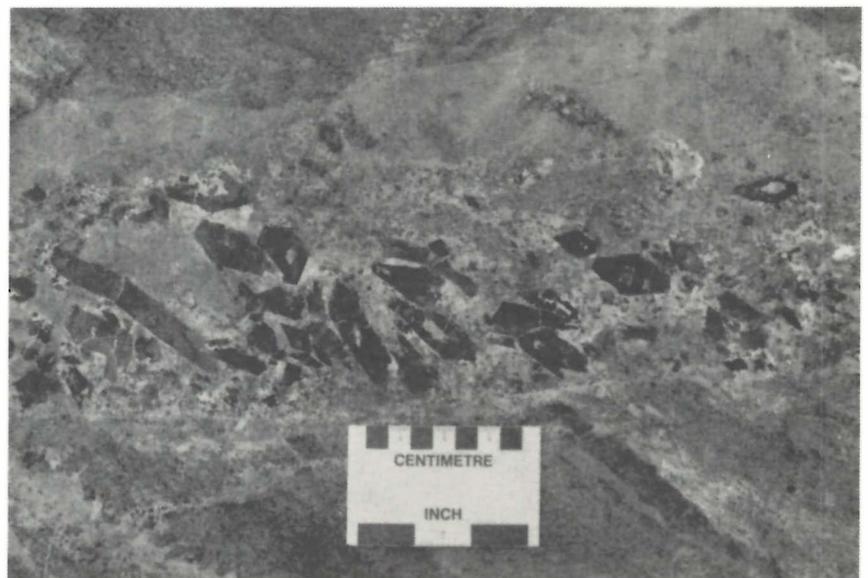
Mineralized occurrences in the Tartan Lake-Mikanagan Lake area. Data are from 1990 sampling, except for the following gold-bearing samples from earlier work - 1986: samples 10, 12, 13, 16. 1987: sample 11. Sample locations (except for 2 and 11) are shown in Fig. GS-4-1.

Lithology/Setting	Number	oz/ton		per cent			Notes
		Au	Ag	Cu	Ni	Zn	
Basalt	1	0	0	.09	.01	.03	0.4 m wide zone of basalt with disseminated sulphides, partly silicified, roughly normal to regional stratigraphy.
Basalt	2	Tr.	Tr.	.07	.01	.03	Disseminated sulphides occur in 3 m wide zone of amphibole-chlorite schist (derived from basalt) with quartz veins, subparallel to regional stratigraphy. Location 1.2 km northwest of the west end of Tartan Lake.
At contact between major gabbro intrusion and basalt	3	0	Tr.	.11	.03	.48	At contact between Batters Lake sill and aphyric basalt; disseminated sulphides (up to 15%) occur in basalt and hornblendite, and at the contact, due to mobilization and concentration by the intrusion, which also caused hornblende blastesis in the basalt; mineralization occurs in 30 cm zones over 5 m width.
At contact between major gabbro intrusion and basalt	4	Tr.	Tr.	3.34	.06	.16	At south margin of Tartan Lake gabbro complex, in contact zone with basalt. A southeast-trending massive sulphide vein (10 cm) with magnetite stringers occurs in a 3 m wide gossaned zone in basalt, with adjacent pervasive gabbroic dykes.
Basalt enclave within major gabbro intrusion	5	0	Tr.	.03	.01	.01	In aphyric, amygdaloidal basalt enclave within gabbro (zone 5 of Mikanagan Lake sill). Disseminated sulphides occur over half the 8 m width of the skialithic basalt enclave.
Basalt enclave within major gabbro intrusion	6	Tr.	Tr.	.06	Tr.	Tr.	In aphyric basalt enclave (10 m wide) within Tartan Lake gabbro complex. The basalt is partly assimilated by the gabbro/hornblenditic gabbro, which has caused mobilization and concentration of sulphides in the basalt.
Sill	7	Tr.	Tr.	.57	0	.01	Disseminated pyrite and chalcopyrite (up to 8%) and sulphide aggregates occur in 12 m wide felsite sill emplaced at a basalt/gabbro contact. Adjacent basalt is locally gossaned in 0.5 to 2 m zones over a 15 m width; mineralization increases up-section. The section is locally silicified and contains a 1 m wide shear zone (fault).
Dyke	8	0	0	.06	.01	.01	Plagioclase porphyry dyke (1.5 m) with disseminated sulphides intrudes granodiorite (phases IVB and IVA of Tartan Lake gabbro complex).
Vein	9	0	Tr.	.45	0	.01	Quartz-carbonate- tourmaline-chlorite vein (30 cm) with pyrite-chalcopyrite and malachite occurs in siltstone/argillite section, locally gossaned.
Vein	10	.02	0	Tr.	Tr.	Tr.	Quartz vein (1 m) with chloritic schist screens intrudes plagioclase-phyric pillowed basalt.
Vein	11	.23	.15	.08	Tr.	Tr.	Quartz vein with pyrite + chalcopyrite (over 0.5 m thick) occurs between a greywacke/siltstone section with concordant felsic porphyry and gabbro units to the north, and amygdaloidal, aphyric pillowed basalt to the south. Location at north shore of Ruby Lake.
Vein	12	.15	0	Tr.	Tr.	Tr.	Quartz vein with arsenopyrite (0.5-1 m) occurs in the basalt/gabbro contact zone at the south margin of Tartan Lake gabbro complex. The vein is hosted by amphibole-chlorite schist and carbonatized, locally silicified leucogabbro with related cataclasite.
Vein	13	2.1	Tr.	.83	0	0	Quartz vein with tourmaline, pyrite and chalcopyrite (3 m wide) contains enclaves of mineralized amphibole-chlorite-carbonate schist. The north-trending vein is emplaced in gabbro 200 m south of Tartan Lake Mine.
Vein	14	.09	0	.04	.01	0	Quartz vein (1-2 m wide) with pyrite crystals up to 3 cm and sulphide aggregates up to 4 cm across is emplaced in melagabbro (zone 5 of Mikanagan Lake sill) at the north end of the sill, close to the margin of Tartan Lake gabbro complex.
Vein	15	.07	Tr.	2.81	.01	.01	Massive sulphide vein (15 cm) with malachite halo occurs in leucogabbro (phase IIB of Tartan Lake gabbro complex, Fig. GS-4-16).
Gabbro	16	.02	0	.05	.01	Tr.	Pyrite/chalcopyrite are disseminated and in stringers, comprising up to 10 per cent of hornblende-phyric gabbro in 3.5 m wide mineralized zone, 650 m east-northeast of Tartan Lake Mine. The gabbro, which is within Tartan Lake gabbro complex, contains 50 to 65 per cent hornblende, mainly as subhedral pseudomorphs after pyroxene (2- 10 mm).

Lithology/Setting		oz/ton		per cent			Notes
	Number	Au	Ag	Cu	Ni	Zn	
Mafic schist (late shear zone)	17	.02	Tr.	.04	.01	.01	Pyrite/chalcopyrite occur in aggregates (up to 3 cm) in amphibole-chlorite schist in an east-southeast-trending shear zone (1-2 m) within Tartan Lake gabbro complex.

FOOTNOTE

*Classification of gabbroic rocks is based on mafic mineral content, partly after Streckeisen (1976), as follows: hornblendite (>90%); hornblenditic gabbro (80-90%); melagabbro (65-80%); mesocratic gabbro (35-65%); leucogabbro (20-35%) and anorthositic gabbro (10-20%).

tion to mafic gneiss and localized epidotization. Assimilation of the mafic volcanics is commonly associated with minor concentrations of pyrite, scattered iron- staining, and locally significant base metal mineralization (sample 4, Table GS-4-3). The east part of the complex, characterized by the wide contact zone of alternating gabbro and basalt, and abundant granitoid dykes and small stocks (IV), contrasts with the west part which is largely devoid of mafic volcanic enclaves and granitoid phases.

The relationship between the layered sills (Tartan Lake, Mikanagan Lake and Batters Lake) and the Tartan Lake gabbro complex is not well defined. There are no clear cross-cutting relationships between the sills and the various gabbroic phases of the complex except for one occurrence in the north part of Mikanagan Lake sill, where melagabbro (zone 5 of the sill) is intruded by magnetiferous pegmatitic gabbro (phase IIC of the Tartan Lake gabbro complex). The contact between Batters Lake sill and the Tartan Lake gabbro complex close to Tartan Lake is apparently gradational where gabbro in zone B of the sill is continuous with a zone of homogeneous mesocratic gabbro in the north of the complex.

Other Intrusive Rocks

Gabbro and melagabbro sills up to 160 m thick are prominent in the mafic volcanic section north of Batters Lake sill; related intrusions in the south of the section include a hornblendite sill (65 m thick) and a quartz-bearing melagabbro and magnetiferous quartz leucogabbro sill (>5 m) (Figure GS-4-1). The mafic sills are medium grained, massive to slightly foliated, and locally display chilled margins. Sporadic related diabase dykes are similar to host basalts, except for the presence of subhedral pseudomorphic hornblende crystals (2-6 mm, 15-75% of the dykes). Hornblende phenocrysts, which occur in only a minority of the flows, are smaller and less abundant than those in the dykes, and are commonly deformed to lenticular aggregates. Field relationships do not indicate the gabbroic intrusions are directly related to the mafic volcanic flows, but a synvolcanic age cannot be ruled out; the intrusives have been provisionally assigned to unit 5 (Tartan-Embury Lakes, Preliminary Map 1990F-1).

The tonalite intrusion, which extends east from Precipice Lake along the north margin of the project area, postdates an elongate gabbro sill extending part way along the south side of the tonalite. Both units are well foliated and porphyritic with 25 to 35 per cent plagioclase phenocrysts (1-3 mm in the gabbro; 2-10 mm in the tonalite). The tonalite also contains lenticular aggregates of quartz (1-10 m long), sporadic mafic xenoliths, and locally displays minor cataclastic shear zones.

ECONOMIC GEOLOGY

Twelve sulphide showings which returned significant base-metal and/or gold assay values are described in Table GS-4-3, together with five gold-bearing assays from previous mapping. The best Cu and Zn values occur at gabbro/basalt contacts at Animus Lake (north margin of Batters Lake sill) and at Mikanagan Lake (southeast margin of Tartan Lake gabbro complex). At these localities the intrusion of hornblendite (pyroxenite-derived) and gabbro into basalt has resulted in mobilization and concentration of sulphides, which are disseminated or occur as massive veins in both the intrusive and host rocks (samples 3 and 4, Table

GS-4-3). Minor base- metal showings in basaltic enclaves within major gabbro intrusions (samples 5 and 6) result from similar intrusive/host-rock interactions. Minor mineralized zones within mafic volcanic sections may be subconcordant (sample 2) or roughly perpendicular to the regional flow trends (sample 1); these zones are commonly associated with shearing and/or alteration of the basalt to mafic schist silicification. Base metals mineralization is also locally associated with minor intrusions of felsite and feldspar porphyry (samples 7 and 8) and quartz veins (sample 9). Quartz veins (± carbonate ± tourmaline) are widely distributed in virtually all lithologic units; most veins are barren but disseminated sulphides, locally accompanied by gold (± silver), are not uncommon. Gold-bearing quartz veins have been discovered:

a) within pillowed basalt east of Tartan Lake Mine (sample 10),
b) at the greywacke/basalt contact at Ruby Lake (sample 11),
c) in melagabbro (zone 5) of the Mikanagan Lake sill (sample 14), and in the Tartan Lake gabbro complex as follows:
d) in the basalt/gabbro contact zone at Mikanagan Lake (sample 12),
e) in gabbro close to the north margin of the complex (sample 13).

Gold also occurs in a massive sulphide vein (sample 15) within leucogabbro (phase IIB of the complex, Fig. GS-4-16) and in amphibole-chlorite schist in a late shear zone in the northwest part of the complex (sample 17). Hornblende-phyric gabbro in the Tartan Lake gabbro complex 650 m east-northeast of Tartan Lake Mine also contains gold in a zone with disseminated sulphides (sample 16).

Gold in the Main Zone of the Tartan Lake Mine occurs in a feldspar porphyry intrusion which was apparently mineralized during alteration and carbonatization after emplacement (Gale and Ferreira, 1988). Feldspar porphyry also occurs in an auriferous zone of alteration, carbonatization and quartz veining in gabbro within Tartan Lake gabbro complex (cancelled assessment files 90457, 91582).

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GS-5 KISSEYNEW PROJECT: BURN RECONNAISSANCE AND REVIEW
(NTS 63N/1,2,3

by H.V. Zwanzig

INTRODUCTION

In 1989 about 400 km^2 of forest were burned in that part of the Kisseynew Project area centred on Nokomis Lake (Fig. GS-5-1). The newly exposed outcrops facilitate a review of the geology on the Kisseynew south flank. Local remapping and an evaluation of the quality of new outcrops were carried out during July 1990. The work concentrated on the vicinities of Puffy Lake, Evans Lake and Jungle Lake, where most of the bush on high ground was fully burned, creating some excellent exposures. About 40 per cent of the forest burned in fringe areas to the north and east.

The remapping, and a brief survey carried out with staff members of the Federal (GSC) and Saskatchewan geological surveys in June, has addressed some fundamental questions about the geology of the Kisseynew belt - Flin Flon belt boundary zone. Highly metamorphosed equivalents of Amisk Group volcanic rocks have not been clearly identified everywhere, and their field relationship to predominantly metasedimentary rocks (Burntwood Suite or Amisk Group) is uncertain. The Missi unconformity and the presence of Missi volcanic rocks should be reinvestigated. Structural styles, which change with increasing metamorphic grade towards the north, need better documentation. This should be done in the next few years, before moss and lichen regrow on the new exposures.

DISTRIBUTION OF AMISK GROUP ROCKS IN THE GNEISSES

A volcanic origin has been suggested for some amphibolites north of the Flin Flon belt (Bateman and Harrison, 1946; Froese and Goetz, 1981; Ashton, 1989; Ashton et al., 1987; Zwanzig and Lenton, 1987). These rocks have been interpreted as highly metamorphosed equiva-
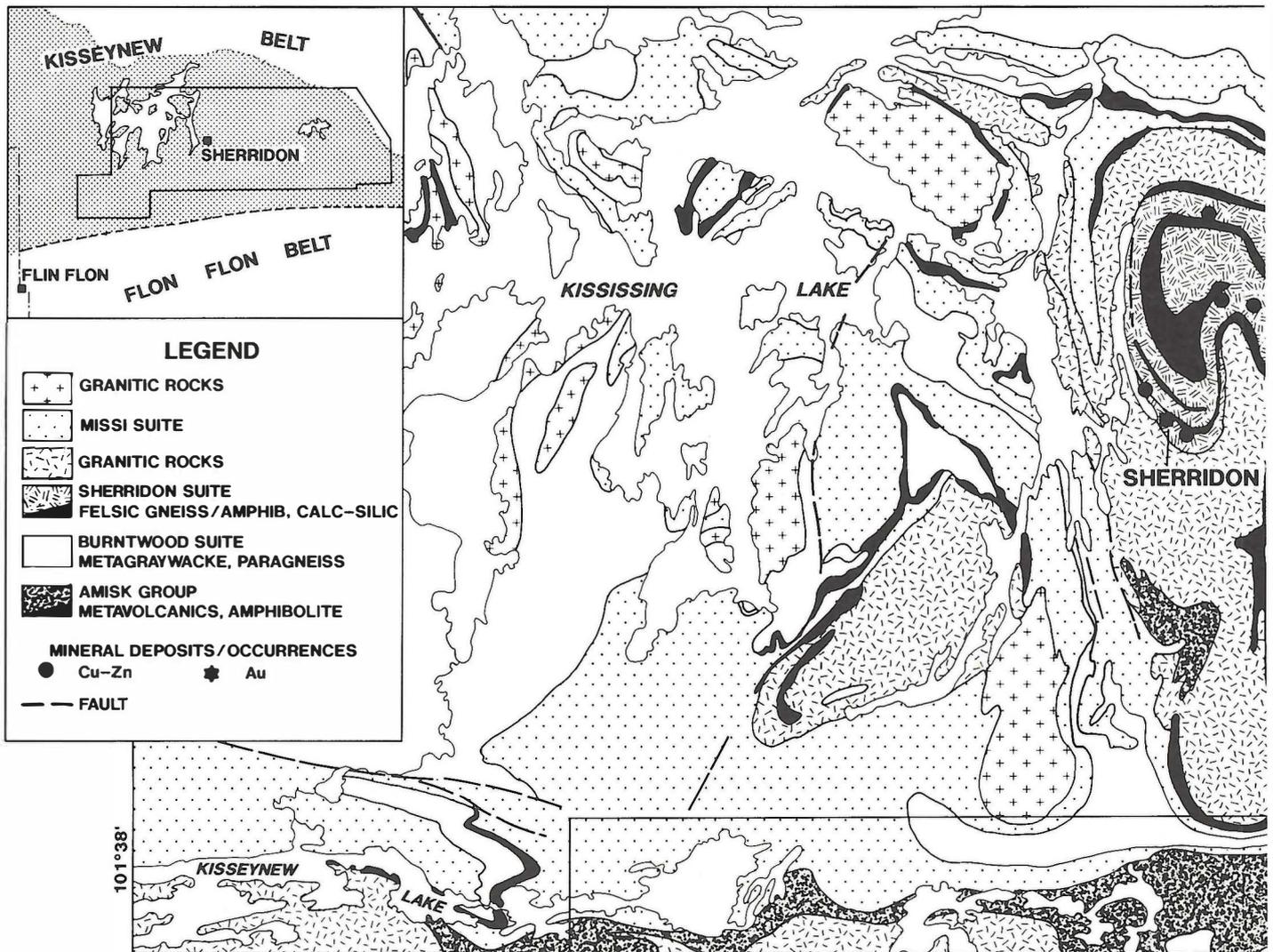

Figure GS-5-1: Kisseynew Project area with simplified geology and location of structural subareas (1 to 4). The key map shows its geological setting on the Kisseynew belt south flank (shaded) as bounded by the northern exposure limit of the Missi Suite (dotted line) and the sillimanite isograd (dashed line).

lents of lower grade rocks to the south (Harrison, 1949; Byers and Dahlstrom, 1954). Some felsic gneisses, including those hosting the Sherritt Gordon and other massive sulphide deposits in the Sherridon area, previously interpreted as metasedimentary rocks, are now regarded as metamorphosed felsic volcanic rocks equivalent to the Amisk Group (Ashton and Froese, 1988; Froese, written communication, 1990). Other felsic components in the area have been interpreted as orthogneisses derived mainly from intrusive rocks (Zwanzig and Lenton, 1987).

Clean outcrops of fine grained amphibolite, along the road to the abandoned Puffy Lake Mine and along strike with the gold deposit, display remnants of pillow selvages (Fig. GS-5-2). Diopside-bearing lenses were likely derived from epidosite alteration domains. Thin units of felsic rocks derived from rhyolite dykes or flows are locally interlayered with the amphibolite. The rocks resemble those of the Amisk Group south of Puffy Lake and in the lower grade parts of the Flin Flon belt. Clear intrusive relationships of gneissic tonalite into the amphibolite exist 2.5 km west of the mine. The tonalite at the mine has been dated by U-Pb zircon method at 1890 Ma (Hunt and Zwanzig, 1990). Outcrops will be sought where the relationship between the dated tonalite and host rocks can be further tested. Inclusions of probable Amisk Group amphibolite

occur in tonalitic gneiss as far north as Jungle Lake. A pre-Missi age for the gneiss is now confirmed by a newly exposed part of the Missi unconformity east of the lake.

Fine grained felsic gneisses with or without oval quartz eyes are exposed north and south of Jungle Lake (Fig. GS-5-3). They were considered part of the Sherridon Group of metasedimentary rocks (Robertson, 1953). The southern exposure lies near the Jungle Lake massive sulphide deposit and is part of the Sherridon type-area of quartz-rich gneisses. On burned-over exposures they can be recognized to be either subvolcanic dykes or rhyolite flows, *but not metasedimentary rocks*. The same rocks were seen at three separate localities about 2 km north of Sherridon. Schledewitz (GS-8, this volume) describes nearly identical rocks from hypabyssal intrusions in the Webb Lake area. A traverse through the burned-over area south of Jungle Lake indicates that fine grained felsic rocks are not abundant everywhere in the Sherridon structure. The main rock type is coarse grained quartz- rich gneiss with large garnet porphyroblasts. Patches with abundant garnet and amphibole interpreted as Fe-Mg-enrichment alteration (Fig. GS-5-4) suggest a volcanic environment of deposition for the Sherridon gneiss, but the nature of the protolith remains uncertain.
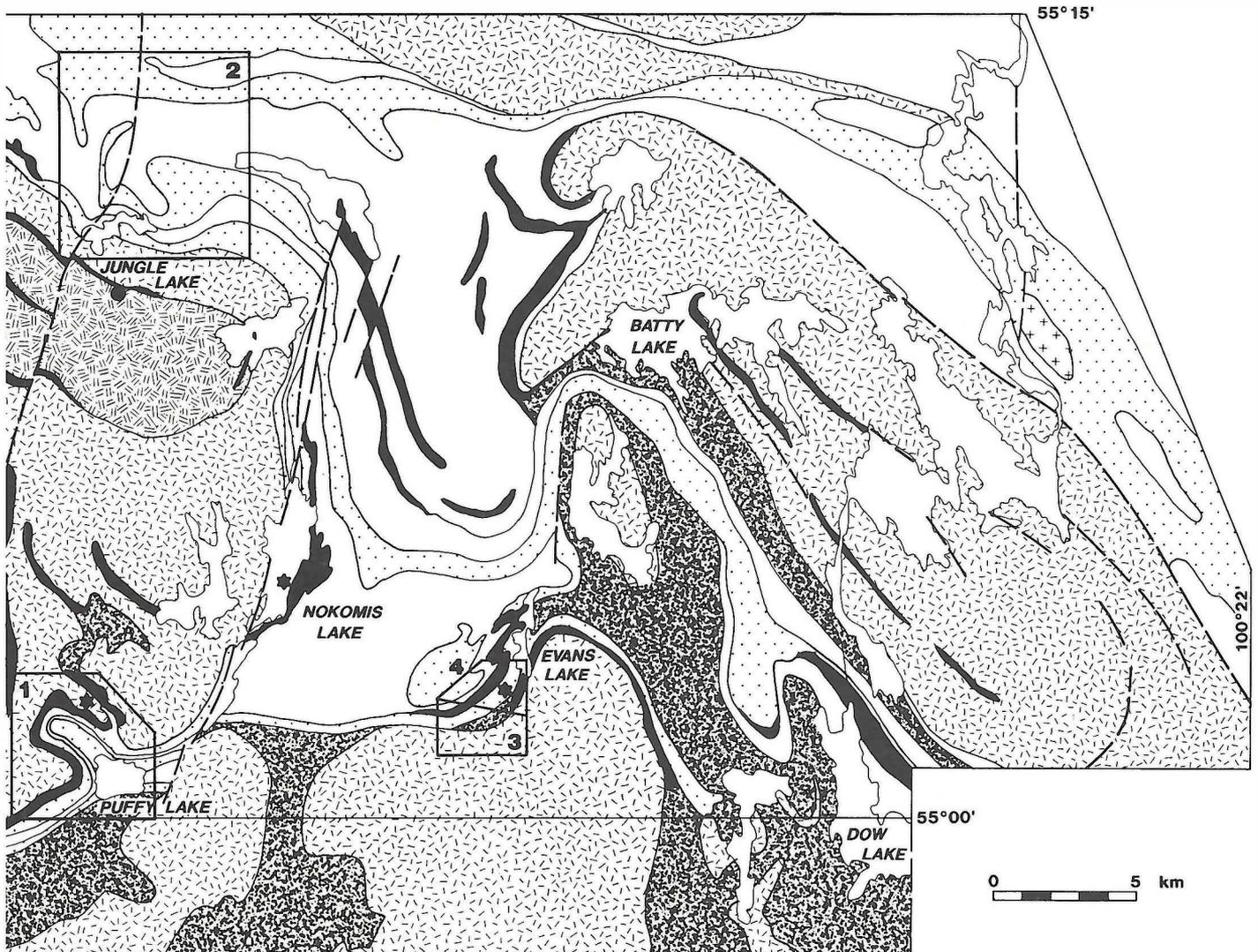
Figure GS-5-2:   Pillowed metabasalt of high-grade Amisk Group, showing white selvages with dark green margins, west of Puffy Lake Mine.

Figure GS-5-3:   Felsic gneiss with dark oval quartz eyes, derived from quartz-phyric rhyolite flow or hypabyssal intrusion within Sherridon-type gneiss, north of Jungle Lake.
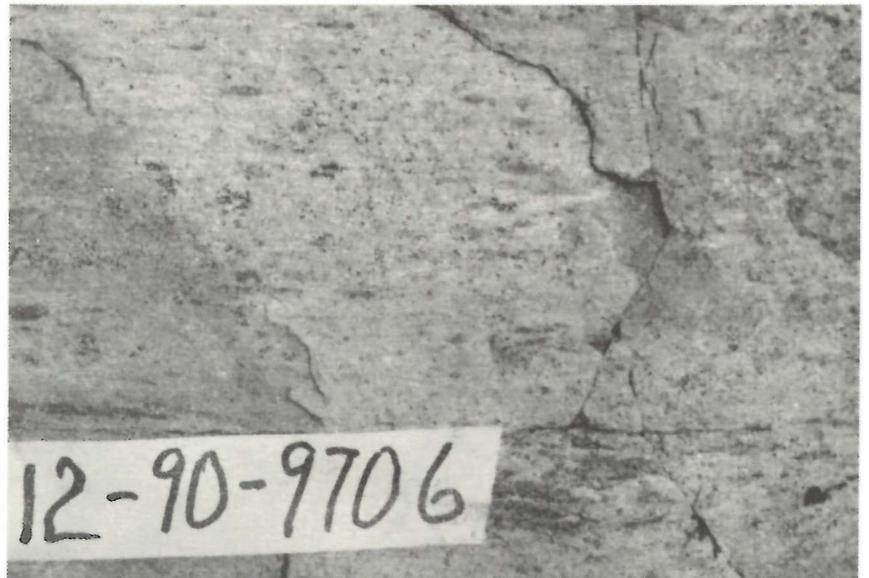
Figure GS-5-4:   Felsic gneiss of the Sherridon Suite with irregular zone (darker grey) with excess amphibole and garnet interpreted as Fe-Mg- enrichment in premetamorphic alteration.

Similar coarsely garnetiferous rocks northwest of Walton Lake that were originally mapped as Sherridon Group are well exposed on high, burned-over ridges. They contain more biotite and commonly sillimanite and cordierite, and grade into typical Burntwood Suite migmatites. They are interpreted as highly metamorphosed pelites. However, nearly every rock type found at Sherridon also occurs within a small area 2.5 km north of Jungle Lake, west of the C.N.R. tracks (and the Molly Lake fault). These rocks lie between the coarse Burntwood pelites and the Missi Suite, but further work is required to delineate the local structure in detail.

Amisk Group amphibolite is heavily intruded by tonalite or granodiorite south of Evans Lake. Fine grained biotite gneiss forms a *lit par lit* complex with these intrusive rocks. The gneiss contains magnetite, small amounts of pale brown garnet and less biotite than typical Burntwood Suite gneiss. It is correlated with similar rocks at Dow Lake (Zwanzig and Lenton, 1987) and is interpreted as a sedimentary rock in the Amisk Group. The Missi Suite, which unconformably overlies the biotite gneiss, and the Burntwood Suite metasedimentary rocks are not intruded by the early dykes.

RELATIONSHIP BETWEEN AMISK GROUP AND BURNTWOOD SUITE

An interlayered relationship between graphitic garnet-biotite gneisses (metagreywacke-mudstone) and volcanic rocks is reported west of the project area where the succession is mapped as Amisk Group (Ashton, 1987). Southeast of the project area metagreywacke is considered to be a formation (File Lake Fm.) at the top of the Amisk Group and is overlain by the Missi Group (Bailes, 1980). Garnet-biotite gneisses, apparently with the same field relationship, occur southeast of Moody Lake, but the area was not burned and contacts are not exposed. The identical gneiss occurs elsewhere in the project area where volcanic rocks are generally absent. They are called Burntwood Suite and are also considered to be equivalent to part of the Amisk Group. They extend north to the Lynn Lake volcanic belt and west into Saskatchewan, and probably represent a sedimentary basin facies of the volcanic rocks. The Burntwood Suite is distinguished from the metasedimentary rocks in the Amisk Group because it delineates a distinctive sedimentary domain that is over 800 km long and was probably several hundred kilometres wide (Zwanzig, 1990 press). Newly exposed outcrops may provide better contact relationships and may be used to test if the Burntwood Suite had a different tectonic history than the Amisk Group.

MISSI UNCONFORMITY

A unit of metaconglomerate occurs at the unconformable base of the Missi Suite. Most outcrops of conglomerate were previously noted along the south margin of the project area. This year exposures of conglomerate were seen farther north on, and east of, Jungle Lake: apparently the unconformity is preserved throughout the entire south flank of the Kisseynew belt.

Generally the conglomerate overlies Amisk Group volcanic rocks, amphibolite of uncertain affinity, or the gneissic intrusive rocks. Accordingly, the base of the conglomerate has a mafic to intermediate composition and clasts of fine grained amphibolite (metabasalt) and intrusive rocks are not uncommon. On the road to Puffy Lake Mine and north of Spider Lake it overlies Burntwood Suite metagreywacke, but no greywacke clasts or greywacke composition conglomerate has been found. Moreover, no conglomerate has been found along the many structural repetitions of the Burntwood-Missi contact throughout most of the area. On a large clean outcrop southwest of Evans Lake, beds of Missi metasandstone appear to lie conformably on Burntwood metagreywacke. These observations, and the apparent absence of early intrusions into the Burntwood Suite indicate that a different tectonic history for the sedimentary and volcanic rocks cannot be ruled out. Pre-Missi deformation and uplift may have been greater in the volcanic belt than in the sedimentary domain.

MISSI SUITE VOLCANIC ROCKS

Clearly recognizable volcanic rocks in the Missi Group (at low- to medium-grade of metamorphism) are restricted to the northeast end of the Flin Flon belt near Wekusko Lake (Gordon and Lemkow, 1987). High-grade metavolcanic rocks were reported from the Lobstick Narrows area

(Zwanzig, 1983) and have since been traced east to Evans Lake (Zwanzig, 1988). They comprise metarhyolite, which occurs as fine grained pink felsic gneiss, and metabasalt, which occurs as amphibolite, and mafic tuff with relict plagioclase phenocrysts (Fig. GS-5-5). Recrystallization and high strain have obliterated most volcanic features, but some are clearly visible on the newly burnt-over outcrops. The volcanic rocks are clearly established as part of the Missi Suite. South of Puffy Lake Mine, for example, they occur in an F_1 syncline that contains basal conglomerate in each limb (Fig. GS-5-6).

Basalt flows lie above the conglomerate in the south limb of the syncline. Flows are about 0.5 m thick (over 1.5 m in unstrained state as indicated by flattened clasts and amygdales). The top and bottom 15 cm of the flows (>45 cm unstrained) are amygdaloidal with large (<25 mm) oval plagioclase-epidote filled amygdales at the base and up to 7 mm quartz filled amygdales at the top. Two beds of laminated intermediate composition mudstone (biotite-hornblende gneiss) separate three of the flows. Amygdales are abundant next to the sedimentary rocks. In the core of the syncline the succession is overlain by pale pink- to buff-weathering meta-arkose. This unit contains laminated beds and thicker layers with pink pegmatitic mobilizate.

On the north limb of the syncline there is dark grey mafic tuff spotted with hornblende phenocrysts up to 6 mm long that probably pseudomorphs pyroxene. Lighter grey felsic fragments up to 2 cm long and small plagioclase phenocrysts occur in some beds of the tuff. An amygdaloidal layer is probably a flow. These rocks stratigraphically overlie a 1.5 m unit (>5 m unstrained) of partly remobilized felsic volcanic rock comprising fine grained pink gneiss with pegmatitic veins. The base of the felsic bed is sharp and the top grades abruptly into grey meta-arkose. The bed is interpreted as an ash-flow tuff.

The volcanic successions in the two limbs of the F_1 syncline probably represent a single stratigraphic horizon. They can be traced 4 km west and then south and southeast around an F_3 fold. The association that is interpreted as amygdaloidal basalt, porphyritic tuff and mafic mudstone exists throughout the southern part of the project area. Abundant amygdales, lack of pillow structure and association with cross-bedded arkose argue for a subaerial origin (Zwanzig, 1984). Layers of felsic tuff (pink gneiss) are locally present.

STRUCTURAL PROBLEMS

Deformation in the Flin Flon - Kisseynew boundary zone was polyphase, but structural styles vary across the area and the structural history is not yet well known. Large, early, sheet-like isoclines are curved around several generations of later folds: a unique age generally cannot be assigned to a specific trend of cross folds. Relative ages of minor structures are poorly understood because interference of small folds is rare. Deformed lineations exposed on burnt-over outcrops may be useful to solve this problem.

At Puffy Lake a narrow belt of Missi Suite rocks clearly defines an early (F_1) major syncline and the Burntwood Suite lies in the core of the adjacent anticline (Fig. GS-5-6). These structures are refolded into large reclined folds that produce a great-circle girdle of poles to metamorphic layering and schistosity and a strong northeasterly plunging linear fabric (Fig. GS-5-7A). Work in the burn may resolve these cross folds into several phases.

At Jungle Lake there are two sets of cross folds (Fig. GS-5- 7B); those plunging north-northeast are tentatively designated as F_2 and those plunging west-northwest as F_3. Both sets are reclined to recumbent folds, which apparently formed at peak metamorphic conditions during migmatization. The relationship of these folds to large domes and recumbent sheets containing intrusive orthogneisses and volcanic rocks merits further investigation.

South of Evans Lake is a transition from the steeply dipping, steeply plunging, simple structures typical of the Flin Flon belt (Fig. GS-5-7C) to the moderately dipping, complexly folded structures typical of the Kisseynew belt. A stereogram of poles to layering and schistosity measured in subarea 4, where cross folds first become prominent, consists of a girdle with a shallow northerly plunging beta-pole (b_4) and a partial girdle with a westerly plunging beta-pole (b_2) (Fig. GS-5-7D). F_2 minor structures comprise mineral- and stretching-lineations, and rare folds that were
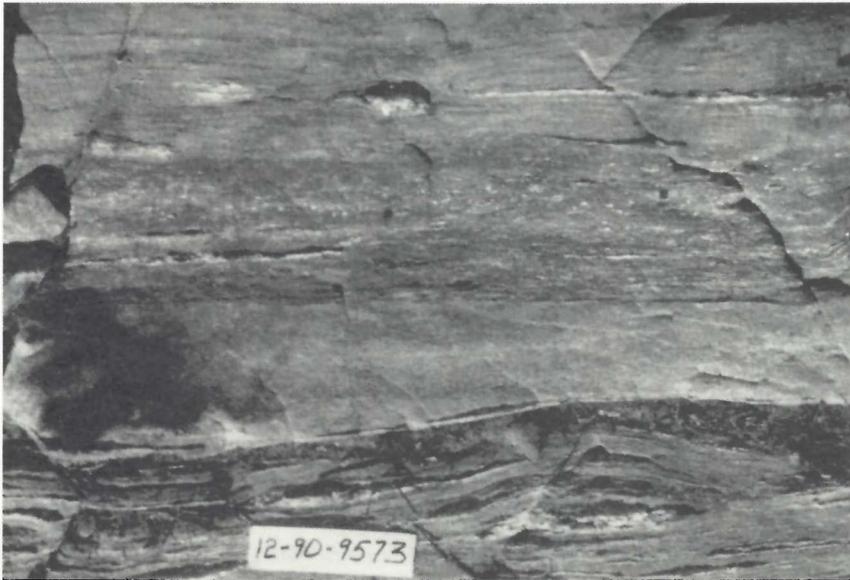
Figure GS-5-5: *Missi Suite mafic tuff (dark layers) with relict plagioclase phenocrysts (white) interbedded with grey metasandstone, south of Evans Lake.*


LEGEND

MISSI SUITE
QUARTZOSE AND INT. PARAGNEISS
MAFIC (VOLCANIC) GNEISS
FELSIC (VOLCANIC) GNEISS
BASAL METACONGLOMERATE

GRANITE GNEISS

TONALITE GNEISS

BURNTWOOD SUITE
METAGREYWACKE, MINOR AMPHIBO-LITE

AMISK GROUP
AND HIGH GRADE EQUIVALENTS

F_1 ANTICLINE/SYNCLINE

0   0.5   1 Km

MINE

PUFFY LAKE

NO OUTCROP
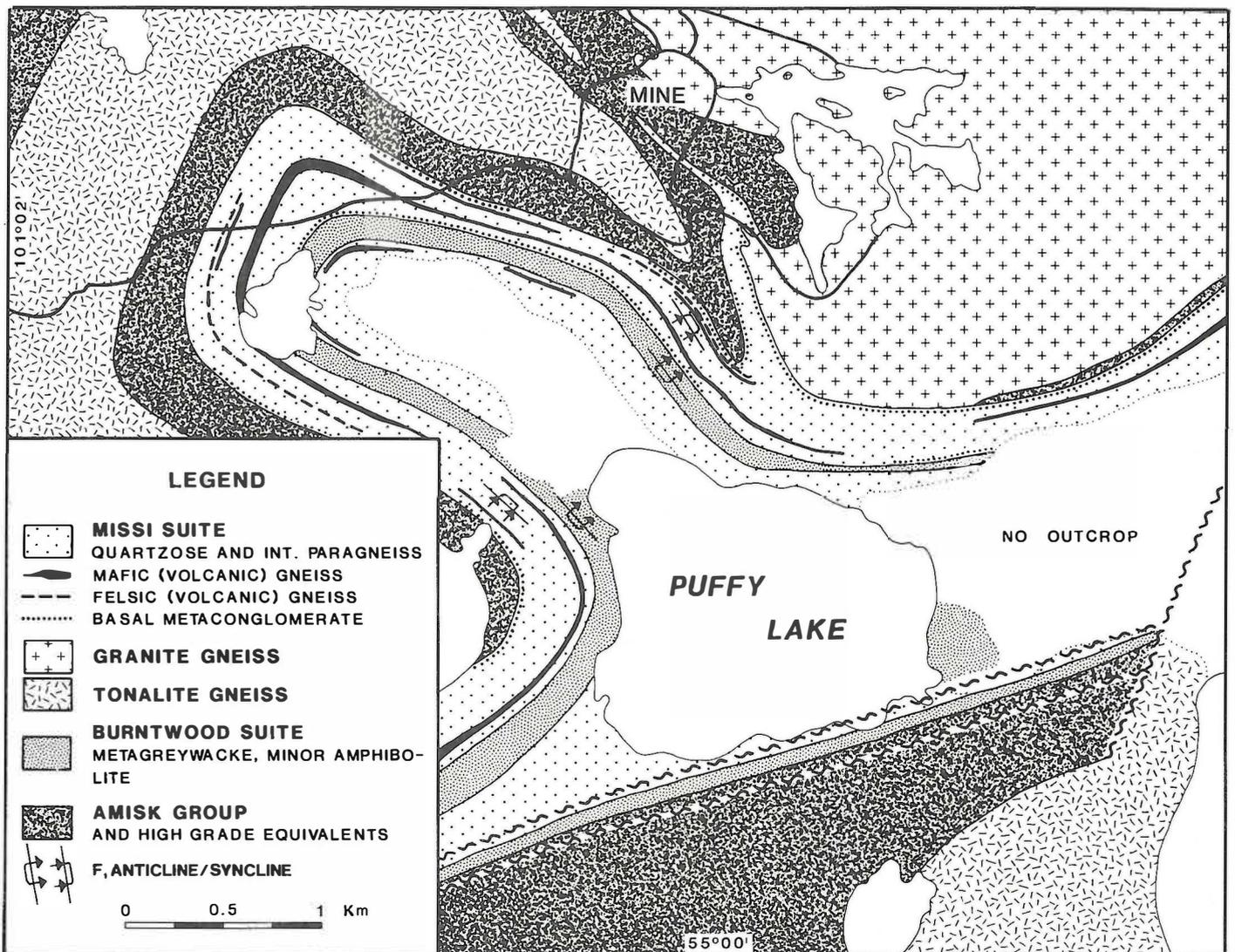
Figure GS-5-6: *Map of the Puffy Lake area showing sheet-like F_1 folds defined by stratigraphic repetition. These are refolded by northwest-trending open to closed structures.*
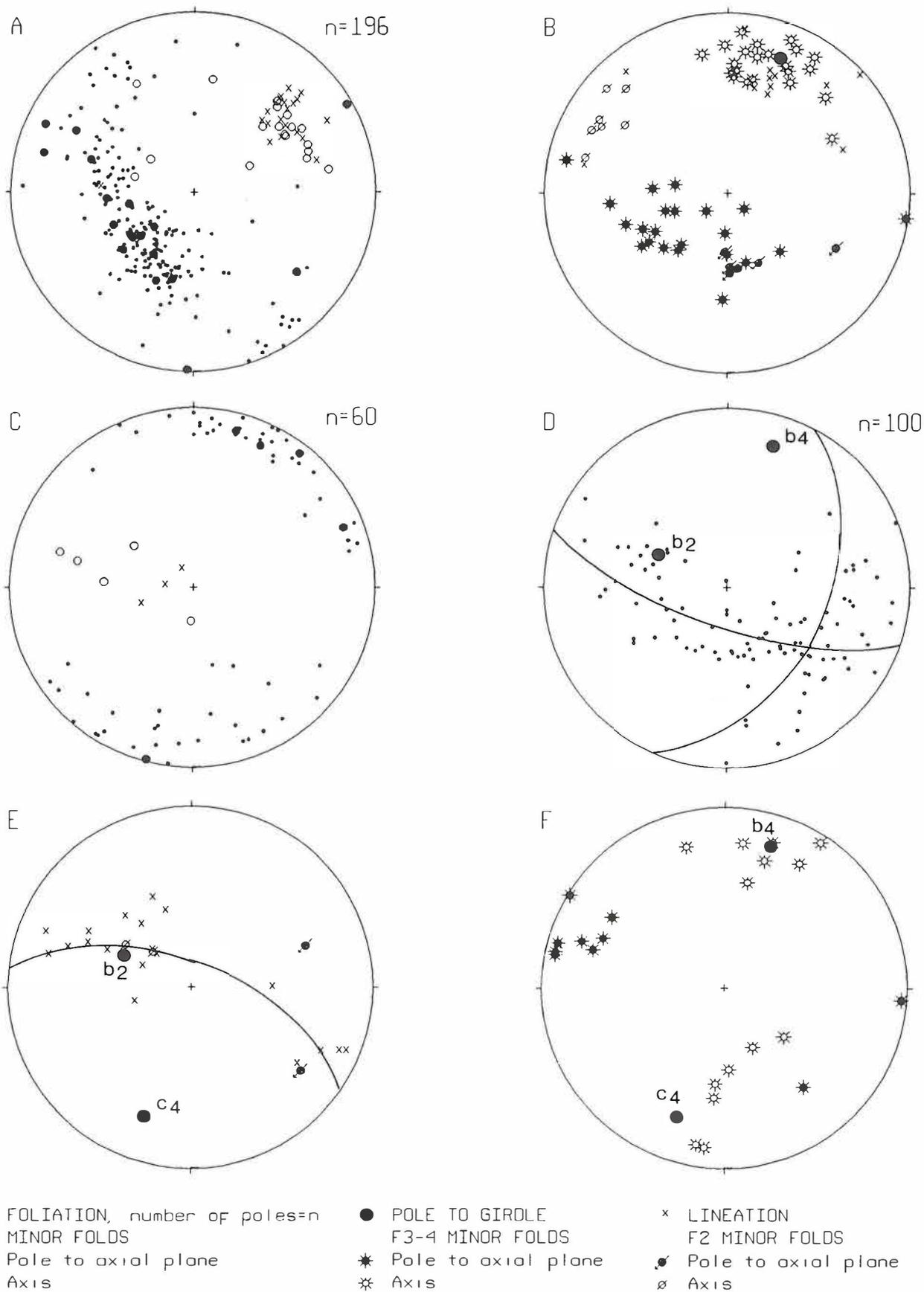
Figure GS-5-7: Equal area stereoplots of various subfabrics. For explanation see text. Location of subareas is shown on Fig. GS-5-1: A subarea 1; B subarea 2; C subarea 3; D, E and F subarea 4.

later refolded. In the burn, L_2 can be traced around the hinges of outcrop-scale northerly-trending folds. Plots of L_2 have a small-circle distribution with cone axis c_4 (Fig. GS- 5-7E). The younger structures comprise upright flexure folds, kinks, crenulations and high-strain zones tentatively assigned to F_4. Axes plunge north or south, lying at the intersection of the previously deformed layering and the north-northeast-trending F_4 axial planes (Fig. GS-5-7F). The folds die out against the steeply plunging structures to the south, but F_4 high-strain zones are prominent in the south. Folding of the high-grade rocks in the Kisseynew belt was accompanied by development of ductile shear zones in the Flin Flon belt.

REGIONAL AND ECONOMIC IMPLICATIONS

Recent work indicates that high-grade metavolcanic rocks of the Amisk Group and Missi Suite and pre-Missi intrusive gneisses extend to the north shore of Kississing Lake. They are structurally and stratigraphically interleaved with the metasedimentary rocks of the Burntwood and Missi suites. These rocks were called the Kisseynew gneisses (Bruce, 1918) and this term has since been applied as far north as the boundary of the Lynn Lake volcanic belt (e.g. Milligan, 1960). However, they do not constitute a purely metasedimentary belt as implied by the term "Kisseynew Metasedimentary Gneiss Belt" used by Bailes and McRitchie (1978). The change to entirely sedimentary and intrusive rocks coincides with the northern limit of the Missi Suite. The shorter name, Kisseynew gneiss belt should be used for the entire high-grade domain as outlined by Zwanzig (1990 in press). The term, Kisseynew belt south flank, was used where Amisk Group volcanic rocks and the Missi Suite occur as gneisses (north of the sillimanite isograd).

Important mineral deposits occur on the south flank of the Kisseynew belt. They include six massive sulphide Cu-Zn deposits in the Sherridon area, the structurally controlled Au deposit at Puffy Lake, the stratiform Au deposit at Nokomis Lake, and showings at Evans Lake. Hydrothermally altered rocks are associated with the deposits.

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GS-6 CHISEL-ANDERSON PROJECT (NTS 63K/16SE)

by Alan H. Bailes

INTRODUCTION

The Chisel-Anderson Lakes Project entails 1:20 000 mapping of Early Proterozoic metavolcanic, metasedimentary and intrusive rocks at the east end of the Flin Flon metavolcanic belt. This mapping program is a continuation of 1:20 000 scale mapping begun during the previous Chisel-Morgan Lakes Project (Bailes, 1987,1988). The two projects provide 1:15 840 coverage of the all of NTS area 63K/16SE (Preliminary Map 1990S-1) and of most of the strata known to contain significant base metal mineralization in the Snow Lake area (Fig. GS-6-1).

Mapping in the Chisel-Anderson lakes area was conducted during the 1989 and 1990 field seasons, in conjunction with joint federal-provincial 1:5000 scale mapping of areas in the immediate vicinity of major Zn-Cu and Cu-Zn base metal deposits near Chisel Lake and Anderson Lake respectively (Bailes and Galley, 1989; Galley and Bailes, 1989; Bailes and Galley, 1990). The 1:20 000 and 1:5000 scale mapping provide an improved geological data base for future mineral exploration in the Snow Lake area, a better definition of the stratigraphic setting of known mineral deposits, and provide a geological framework for data collected under the federal EXTECH (Exploration Science and Technology) program that was initiated this year.

GEOLOGICAL SETTING

The Early Proterozoic rocks of the Flin Flon belt comprise an island arc assemblage (Amisk Group), calc alkaline plutons, and an unconformably overlying sequence of terrestrial sediments (Missi Group). U-Pb zircon ages date the Amisk Group at Flin Flon at 1886 Ma, plutons between 1860-1830 Ma and the Missi group at 1832 Ma (Gordon et al., 1990). The rocks underwent polyphase deformation and reached peak metamorphic conditions at about 1815 Ma (Gordon et al., 1990).

At Snow Lake the Amisk Group, as exposed between the Berry Creek fault and the McLeod Road fault, comprises approximately 6 km of north-facing subaqueously deposited rocks, broadly folded by the northeast-trending Threehouse syncline and related folds (Fig. GS-6-1). The Amisk Group is intruded by the Sneath Lake and Richard Lake tonalite plutons that have U-Pb zircon ages of 1886 Ma and 1889 Ma respectively (Bailes et al., 1988, 1990); these ages are consistent with the widespread interpretation that these tonalite plutons are synvolcanic (Walford and Franklin, 1982; Bailes, 1986, 1987).

The Amisk Group between the Berry Creek and McLeod Road faults contains six main subdivisions (Fig. GS-6-2). Although the schematic section and the subdivisions shown in Figure GS-6-2 were constructed prior to the 1990 field season they are a reasonably accurate representation of the main components of the geology of the Snow Lake area, with the exception that the upper part of the Threehouse mafic volcaniclastics is now known to consist of a separate unit of mafic heterolithologic breccias and the base of the greywacke-mudstone sequence is occupied by a fault (Bailes, 1990; Bailes and Galley, 1990). The first, and lowermost subdivision, includes over 3 km of pillowed aphyric to sparsely porphyritic basalt, basaltic andesite and andesite flows (e.g. Welch Lake basalt) and an overlying unit of thick bedded felsic breccia (e.g. Stroud Lake felsic breccia); within the basalt sequence there are local units of aphyric to sparsely quartz- phyric rhyolite (e.g. Daly Lake rhyolite). Overlying this basal division is a diverse suite of volcanic rocks that includes porphyritic basalt flows (e.g. Snell Lake basalt) and thick bedded mafic breccias (e.g. Edwards Lake mafic breccia). This second group of rocks is overlain by up to 1 km of mafic to felsic flows characterized by high incompatible element and elevated light REE abundances, combined with low Ni and Cr and elevated Th and U (Moore-Powderhouse-Ghost sequence). The fourth subdivision comprises mafic tuff, lapilli tuff, tuff breccia and related porphyritic basalt flows (e.g. Chisel Basin mafic tuff, Threehouse mafic volcaniclastics). These latter

rocks are important as they form the stratigraphic hanging wall to most of the major base metal deposits in the Snow Lake area and because they do not display the ubiquitous hydrothermal alteration characteristic of stratigraphically underlying rocks. North of Anderson Lake the Chisel Basin-Threehouse sequence is overlain by a fifth group of rocks consisting of heterolithologic mafic breccias, aphyric basalt flows and felsic breccias. The sixth subdivision, which is in fault contact with underlying strata, consists of volcaniclastic greywacke-mudstone turbidites that are truncated to the north by the McLeod Road Thrust. Bailes (1980a) concluded that the greywacke-mudstone sequence, termed the File Lake formation, was part of a submarine dispersal system composed mainly of unconsolidated felsic volcanic detritus eroded from Flin Flon belt volcanoes.

RESULTS OF 1990 MAPPING

In 1990 the eastern twenty five square kilometres of the Chisel-Anderson Lake area was mapped at 1:20 000 scale; in the immediate vicinity of Anderson Lake mapping was conducted at 1:5000 scale by the author and Alan Galley of the Geological Survey of Canada. Although the volcanic rocks in this area are not as well exposed and are more deformed than those to the east they are extremely important as portions of them host significant Cu-Zn massive sulphide deposits. Perhaps the most important consequence of this mapping is that it now permits comparison of the setting of the Cu-Zn massive sulphide deposits of the Anderson Lake area with that of the Zn-Cu massive sulphide deposits of the Chisel Lake area. Some of the more important outcomes of the 1990 field program are:

1. the Anderson Lake Cu-Zn massive sulphide deposit occurs at a stratigraphically lower position in the volcanic succession than the Zn-Cu massive sulphide deposits of the Chisel Lake area.
2. the Threehouse mafic volcaniclastic rocks are identical to the Chisel Basin mafic tuff and breccia (Fig. GS-6-2).
3. alteration of volcanic rocks is virtually restricted to those that lie stratigraphically above the Sneath Lake pluton supporting the widely held view that this pluton is the heat source that drove the geothermal-hydrothermal system responsible for both alteration of volcanic rocks and formation of attendant base metal mineralization (Walford and Franklin, 1982; Bailes, 1987; Galley et al., 1990).
4. the Moore-Powderhouse-Ghost mafic to felsic volcanic flows, that form a thick distinctive unit in the footwall to the Chisel Lake, Ghost Lake, Lost Lake and North Chisel Zn-Cu massive sulphide deposits, are virtually absent in the Anderson Lake area as are the distinctive suite of associated subvolcanic dyke swarms that characterize the Chisel Lake area. This suggests that this cycle of volcanism, although intimately related to Zn-Cu base metal mineralization in the Chisel Lake area (Skirrow, 1987; Bailes and Galley, 1989; Galley et al, 1990), may not be related in the same manner to the Cu-Zn base metal mineralization in the Anderson Lake area.
5. the zone of silicification that characterizes the upper 300- 500 metres of the Welch Lake basalts in the Chisel Lake area (Galley et al., 1990) has been traced to the southwest end of Anderson Lake where it merges with Fe-Mg and Fe-Mg-Ca metasomatized rocks along strike. This Fe-Mg and Fe-Mg-Ca alteration is along strike from a "lower semiconformable zone" of alteration encountered in drill holes below Anderson Lake and reported by Walford and Franklin (1982). According to Walford and Franklin (1982) this semiconformable zone of alteration is intimately related to the massive Cu-Zn base metal mineralization of the Anderson Lake area.
6. a zone of altered rocks characterized by abundant coarse actinolite occurs 1.4 km southwest of the Anderson Lake mine. This zone is identical to actinolite-rich alteration observed 1 km south of the Chisel
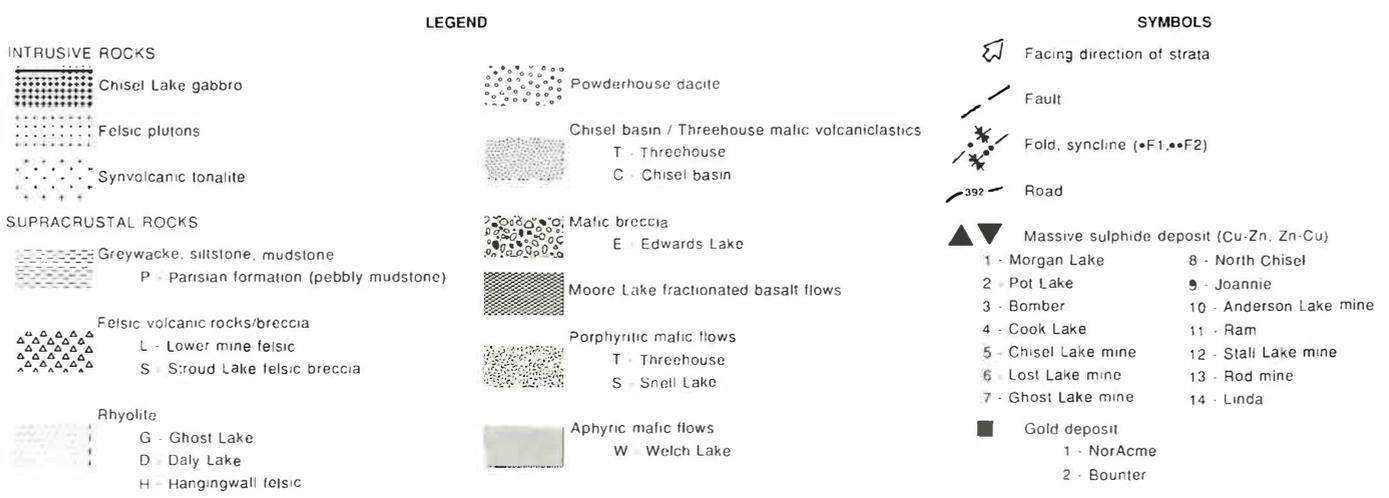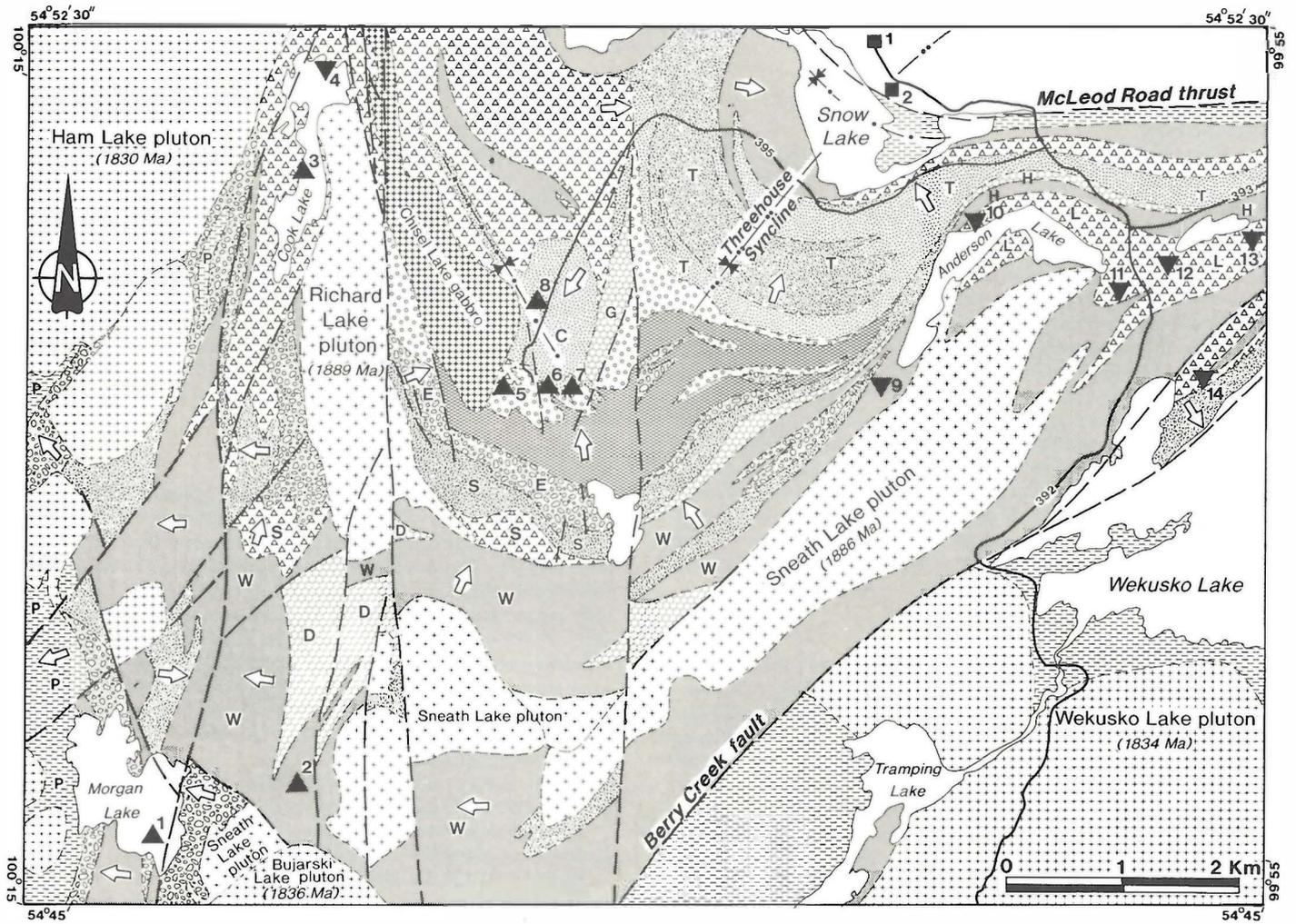
Figure GS-6-1: General geology of the Snow Lake area (after Harrison, 1949; Hutcheon, 1977; Froese and Moore; 1980; Walford and Franklin, 1982; Trembath, 1986; Bailes, 1989; Zaleski, 1989).

LEGEND

INTRUSIVE ROCKS

Chisel Lake gabbro

Felsic plutons

Synvolcanic tonalite

SUPRACRUSTAL ROCKS

Greywacke, siltstone, mudstone
  P - Parisian formation (pebbly mudstone)

Felsic volcanic rocks/breccia
  L - Lower mine felsic
  S - Stroud Lake felsic breccia

Rhyolite
  G - Ghost Lake
  D - Daly Lake
  H - Hangingwall felsic

Powderhouse dacite

Chisel basin / Threehouse mafic volcaniclastics
  T - Threehouse
  C - Chisel basin

Mafic breccia
  E - Edwards Lake

Moore Lake fractionated basalt flows

Porphyritic mafic flows
  T - Threehouse
  S - Snell Lake

Aphyric mafic flows
  W - Welch Lake

SYMBOLS

Facing direction of strata

Fault

Fold, syncline (•F1, ••F2)

Road

Massive sulphide deposit (Cu-Zn, Zn-Cu)
  1 - Morgan Lake
  2 - Pot Lake
  3 - Bomber
  4 - Cook Lake
  5 - Chisel Lake mine
  6 - Lost Lake mine
  7 - Ghost Lake mine
  8 - North Chisel
  9 - Joannie
  10 - Anderson Lake mine
  11 - Ram
  12 - Stall Lake mine
  13 - Rod mine
  14 - Linda

Gold deposit
  1 - NorAcme
  2 - Bounter

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CHISEL LAKE SECTION

SUBDIV.

Chisel basin mafic tuff and breccia

4

Chisel-Lost-Ghost Lakes Zn-Cu deposits

Ghost Lake rhyolite

Powderhouse dacite

3

Moore Lake basalt

Aphyric basalt

Edwards Lake mafic breccia

2

Snell Lake basalt

Stroud Lake felsic breccia

Daly Lake rhyolite

Unnamed rhyolite

1

Welch Lake basalt

Pot Lake Zn-Cu deposit

Sneath Lake pluton
(synvolcanic tonalite)

ANDERSON LAKE SECTION

SUBDIV.

Townsite felsic

Mcleod Road Thrust

Greywacke-mudstone   6

5

Aphyric basalt

Felsic breccia

Threehouse mafic
volcaniclastics   4

Threehouse
basalt

Hangingwall felsic

Hangingwall mafic

2 Km

*Anderson Lake-Stall Lake-Rod
Cu-Zn deposits*

Lower mine felsic

Barren sulphide zone

Mafic flows and breccia

1

Tonalite

0

Figure GS-6-2:   *Schematic composite stratigraphic section, Snow Lake area. Chisel Lake section is from Bailes and Galley (1989) and the Anderson Lake section is slightly modified from Walford and Franklin (1982). Anderson Lake unit thicknesses are exaggerated to compensate for greater tectonic flattening of units at Anderson Lake relative to Chisel Lake.*

Lake mine (Bailes and Galley, 1989) and to another zone associated with the Cook Cu-Zn deposit (Jackson, 1983). This type of alteration has not been reported to be associated with mineralization in other base metal areas, but appears to be significant at Snow Lake.

7. although hydrothermal alteration in the Snow Lake area appears to have largely terminated by the time of deposition of the Chisel Basin-Threehouse mafic volcanic sequence, their is minor , but significant, Fe-Mg and Fe-Mg-Ca alteration in strata southeast of Snow Lake that postdate the Chisel Basin- Threehouse mafic volcaniclastic rocks. This suggests that, at least locally, the hydrothermal activity and related base metal mineralization may have continued into the hangingwall sequences of both the Chisel Lake Zn-Cu and Anderson Lake Cu-Zn deposits.

8. the tabular shape of the Sneath Lake pluton, south and southwest of Anderson Lake, is largely a consequence of east northeast trending faults that offset pluton margins (Preliminary Map 1990S-1). Stretch lineations in exposed fault surfaces plunge steeply indicating that motion on these faults is dominantly dip slip. Since faults offsetting the pluton parallel the Berry Creek fault and this fault also has steeply plunging stretch lineations and dip slip motion, it is likely that the faults are subsidiary to the main Berry Creek structure.

COMPARISON OF ANDERSON LAKE AND CHISEL LAKE SECTIONS

One of the chief objectives of mapping the Anderson Lake area was to establish the relative ages of the Cu-Zn and Zn-Cu massive sulphide deposits at Anderson Lake and Chisel Lake. Walford and Franklin (1982) using Pb isotope data from Sangster (1978; pers. com., 1980) concluded that the Anderson Lake Cu-Zn and Chisel Lake Zn-Cu deposits

are compositionally different and do not share a common metal source. The 1:20 000 and 1:5000 scale mapping at Anderson Lake support this conclusion as they suggest that Anderson Lake Cu-Zn deposits occur at a stratigraphically lower interval than do the Chisel Lake Zn-Cu deposits. The exact position of the Anderson Lake deposits relative to the Chisel Lake deposits will have to await chemical analysis of the host volcanic rocks of the Anderson Lake area, but at this point it is clear that they either directly underlie equivalents of the Moore- Powderhouse-Ghost sequence or they occur further down in the section.

Regardless of the precise stratigraphic setting of the Anderson Lake Cu-Zn and Chisel Lake Zn-Cu deposits it is clear that the volcanic sections differ substantially in the two areas (Fig. GS-6-2). In the Chisel Lake area the Moore-Powderhouse-Ghost sequence, that forms the footwall to the Zn-Cu base metal mineralization, is up to 1 km thick but is either absent or very thin in the Anderson Lake area. In addition, there is no equivalent in the Chisel Lake area to the thick sequence of Lower Mine Felsics that host base metal mineralization in the Anderson Lake area. This suggests that construction of small, local volcanic structures, with resultant rapid lateral facies variations, accompanied development of the base metal mineralization in the Snow Lake area. In the Chisel Lake area the Moore-Powderhouse-Ghost is underlain by dyke complexes that are clearly related to this sequence. In the Anderson Lake area Walford and Franklin (1982) have tentatively suggested, on the basis of chemical similarity, that the Lower Mine Felsic unit may be an extrusive equivalent of the Sneath Lake pluton. If this is valid then the base metal mineralization in the two areas may be affiliated with discreet, unrelated magmatic episodes.

Large semiconformable alteration zones of regional extent have

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been identified in the Chisel-Anderson Lakes area (Bailes, 1989; Galley et al., 1990). In the Chisel Lake area three such zones have been identified in the stratigraphic footwall to the Chisel area Zn-Cu deposits; from base to top these zones are the Welch, Edwards and Moore (Galley et al., 1990). The Edwards and Moore zones occur in strata that appear to postdate the Cu-Zn deposits of the Anderson Lake area, suggesting they are related to a geothermal-hydrothermal episode that is unrelated to the event that formed the Anderson area base metal deposits. The Welch zone, on the other hand, occurs in strata in the footwall to, and is spatially associated with, the Anderson area mineralization. This zone displays a lateral zonation from silicification in the west to Fe-Mg metasomatism in the east, and appears to connect with a zone of disconformable alteration underlying Anderson Lake (Walford and Franklin; 1982). Walford and Franklin (1982) suggested that this latter zone "may represent a zone of fluid ponding" where "intrastratal water, heated by the subvolcanic tonalite" (referring to the Sneath Lake pluton) "collected and leached metals". They further suggest that this "subconcordant reservoir was tapped by several conduits" to form the various Cu-Zn base metal deposits of the Anderson Lake area. In the Chisel Lake area the Welch alteration zone does not affect overlying strata of the Stroud Lake felsic breccia (Fig. GS-6-2), suggesting that these rocks had not been deposited when the Welch alteration zone formed. If this is valid, and if this alteration is related to the underlying subvolcanic Sneath Lake pluton, then this pluton must have been emplaced at a depth of less than 2 km in the Chisel Lake section, and less than 500 metres in the Anderson Lake area.

One implication of the foregoing is that the geothermal-hydrothermal system that generated the Anderson area mineralization is unrelated to that associated with the Chisel area deposits. The latter deposits may instead be related to a geothermal-hydrothermal system generated by the Richard Lake synvolcanic pluton. The fact that the Richard Lake pluton displays the same elevated light REE abundances as the Moore-Powderhouse-Ghost is consistent with this hypothesis.

THREEHOUSE AND SUBSEQUENT FORMATIONS

Amisk Group formations that host the base metal deposits in the Chisel Lake and Anderson Lake areas are described by Bailes (1987, 1989) and Walford and Franklin (1982). The upper part of the Amisk Group, comprising the Threehouse and overlying formations (Fig. GS-6-2), has not been adequately described in the past. In 1990 these formations were mapped in the Anderson Lake area at 1:20 000 scale by Bailes (Preliminary Map 1990S-1) and at 1:5000 scale by Bailes and Galley (Preliminary Map 1990S-2). A brief description of these rocks is given below.

Threehouse mafic volcaniclastic rocks

The Threehouse formation in the Anderson Lake area comprises of a basal 30 to 50 metres of well bedded mafic wacke and siltstone abruptly overlain by 250 to 300 metres of unbedded to crudely bedded scoria rich mafic lapilli tuff and tuff breccia. The basal unit of mafic sediments are crystal rich, display excellent graded bedding, scour channels, load structures, crossbedding and sporadic bomb sags, and were clearly deposited from turbulent subaqueous density currents. The contact with the overlying scoria-rich mafic lapilli tuff and tuff breccia is gradational over a few metres. The mafic lapilli tuff and tuff breccia are composed largely of juvenile plagioclase-phyric and plagioclase-and pyroxene-phyric scoria with subsidiary amounts of accessory porphyritic basalt clasts similar to associated flows. Included within this sequence are minor beds of heterolithologic mafic breccia composed of diverse lithologies that may include up to 50 per cent scoria fragments; scoria clasts in these beds display wide variation in size and amount of contained phenocrysts. Nonvesicular to moderately vesicular porphyritic and aphyric basalt fragments are a common component of the heterolithologic mafic breccia beds.

West of Anderson Lake the basal unit of mafic wacke and siltstone remains the same thickness, but the mafic lapilli tuff and tuff breccia are gradually replaced by increasing amounts of intercalated plagioclase-phyric and plagioclase-and pyroxene-phyric basalt flows (Preliminary Map 1990S-1). West of Snow Lake the Threehouse formation, above the basal

mafic wacke, consists entirely of basalt flows. The flows are texturally similar to the lapilli tuff and tuff breccia, and presumably represent a lateral facies change within the Threehouse formation rather than an interfingering of two separate units. The significance of this facies change is not known.

One of the striking aspects of the Threehouse formation at Anderson Lake is its similarity to the Chisel Basin lapilli tuff and tuff breccia. Both sequences are characterized by a basal unit of turbidity current deposited mafic wacke and siltstone and an overlying unit of scoria rich mafic lapilli tuff and tuff breccia. At the Chisel Lake minesite, the contact between the Chisel Basin mafic wacke and the underlying Ghost Lake rhyolite is marked by a thin sulphide-chert unit that appears to be a stratigraphic equivalent to the massive sulphide deposit (Galley and Bailes, 1989; Galley et al., 1990). The sulphide-rich layer is gradational upwards into overlying mafic sediments suggesting that this contact may be an important locus for further sulphide mineralization, even in the Anderson Lake area. Gale and Koo (1977) made a similar observation and further suggested that the Snow Lake area had two mineralized horizons, a lower and an upper horizon, that correspond to the Anderson Cu-Zn and Chisel Zn-Cu zones respectively.

Heterolithologic mafic breccia

The Threehouse formation is overlain by 200 to 350 metres of crudely and thickly bedded heterolithologic mafic breccia (Preliminary Maps 1990S-1 and 1990S-2). The breccia includes porphyritic scoriaceous mafic detritus derived from the underlying Threehouse formation, as well as abundant aphyric and porphyritic nonvesicular to weakly vesicular basalt fragments. The aphyric basalt clasts are similar in colour, and in lack of vesicularity, to mafic basalt flows that directly overlie the Threehouse formation west of Snow Lake. Also contained in the breccia are fragments of distinctive mafic dyke rocks that are elsewhere observed to cut the underlying Threehouse formation. In some localities where the heterolithologic mafic breccia contains abundant scoria fragments and outcrops have heavy lichen and moss cover, it is difficult to define the contact between the heterolithologic mafic breccia and the underlying Threehouse formation.

Basalt flows, felsic breccia and flows

The Threehouse formation, in the west, and the heterolithologic mafic breccia, in the east, are overlain by a distinctive unit of basalt flows and associated felsic flows and breccia. The basalt is characterized by a uniform grey-green weathering and by virtual absence of vesicles. Pillowed flows generally have well defined pillows with thin selvages and thin domains of interpillow hyaloclastite. Massive divisions of flows tend to be gabbroic textured, and in thicker flows are virtually indistinguishable from associated bodies of contained gabbro. With the exception of a small area at the southwest corner of Snow Lake the basalts display no indication of alteration, including an absence of epidotization.

Felsic flows and breccia form a 100 to 150 metre thick unit that lies within the mafic flows in the west and at their base in the east. The flows and breccia are composed of massive aphyric to sparsely quartz-phyric rhyolite. Southwest of Snow Lake Fe-Mg alteration selectively affects interfragment domain in breccia.

Metagreywacke, metasiltstone and metamudstone

The basalt flows and felsic flows and breccia are structurally overlain by metamorphosed greywacke, siltstone and mudstone that outcrop on the north shore of Snow Lake (Preliminary Map 1990S-1). They correlate directly to the west with the File Lake formation that has been described by Bailes (1979, 1980a, 1980b) as the deposits of a subaqueous fan system that dispersed detritus from unconsolidated subaerial felsic volcanoes of the Flin Flon belt. At Snow Lake these metasediments are recrystallized to lower almandine-amphibolite facies mineral assemblages and are isoclinally folded by a prominent east-trending syncline and by the later east northeast trending Threehouse synform.

Harrison (1949) described the greywacke, siltstone and mudstone unit to be in fault contact with the underlying Amisk Group volcanic rocks at Snow Lake; he named this structure the Snow Lake fault. Subsequently

Russell (1957) and Froese and Moore (1980) found no evidence of a faulted contact. Mapping by Galley (Preliminary Map 1990S-2) supports Harrison's faulted contact as there is ample evidence of brittle deformation and associated carbonate impregnation of these structures along the south shore of Snow Lake. In addition there is a low angle truncation of Amisk Group volcanic stratigraphy at this contact. This combined with Harrison's description of approximately 15 metres of strongly sheared and carbonatized greywacke and siltstone adjacent to the contact (encountered in a drill hole) strongly support the faulted character of this contact. Consequently, the stratigraphic relationship between Amisk Group volcanic rocks and the File Lake formation at Snow Lake is not known.

BERRY CREEK FAULT

Mapping in 1990 shows that the Berry Creek fault is part of a major zone of dislocation in which there are several discrete subsidiary faults. The fault has considerable magnitude and can be traced on gradiometer maps over 50 km to the west southwest and for over 35 km to the northeast. Although the fault is likely a discrete narrow structure it is contained within an over half kilometre wide zone in which rocks have a strong imposed foliation parallel to the fault and oblique to the normal regional trend of foliations (Preliminary Map 1990S-1) suggesting that the entire zone was affected by the fault-producing deformational event. Stretch lineations in the subsidiary faults, in the main Berry Creek fault and in the strongly deformed rocks in this structural zone all plunge steeply indicating dominantly dip slip movement. Since rocks south of this structure are lower metamorphic grade than those to the north the south side likely moved down relative to the north side.

Lode gold mineralization has been identified on a subsidiary fault that cuts the Sneath Lake pluton and this indicates that some of the other related fault structures (Preliminary Map 1990S-1) may also be auriferous. Galley et al. (1986) noted that gold occurrences in the Superior province are commonly on subsidiary faults to main faults that form a contact between sedimentary and volcanic rocks, which is precisely the situation represented by the Berry Creek fault and its' subsidiary structures in the Snow Lake area.

The Berry Creek fault truncates the north margin of the Wekusko Lake pluton and appears to offset metamorphic isograds. Therefore this fault definitely postdates 1834 + 8/-6 Ma, the age of the pluton (Gordon et al., 1990), and is likely younger than 1815 Ma, the approximate age of the peak metamorphic episode in the area (Gordon et al., 1990). This would place this Berry Creek structure and the related gold mineralization in the same time frame as has been indicated for other faulting and lode gold mineralization in the Snow Lake area (Galley et al., 1986, 1990)

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GS-7 ELBOW LAKE PROJECT (PART OF NTS 63K/15W)

by E.C. Syme

INTRODUCTION

During the hot, dry summer of 1989 Manitoba had one of the worst forest fire seasons on record: several hundred thousand hectares were burned across the central and northern parts of the province. Nevertheless, one positive result of the 1989 fire season is that bedrock exposure has been greatly improved in some areas previously covered by old growth mature forest. The largest fire in the Churchill Structural Province burned between File Lake - Elbow Lake in the south and Sherridon to the north (Fig. GS-7-1). Supracrustal rocks in this area were previously heavily covered with lichen and moss, precluding detailed mapping of the sort recently conducted in Flin Flon (Bailes and Syme, 1889; Syme, 1989) and Snow Lake (Bailes and Galley, 1989). The next three to five years were seen as an opportunity to significantly upgrade the mapping in the Elbow Lake area. Accordingly, reconnaissance mapping was conducted during a 5 week field season in 1990. The purpose of the reconnaissance was to determine the extent of favourable burn, the amount of clean outcrop, and the state of preservation and lithologic variability of supracrustal rocks. It was found that significant improvements to pub-

lished maps can be made, and it is anticipated that 1:20 000 mapping will continue at Elbow Lake in 1991.

PREVIOUS WORK

The Elbow Lake area lies within the Early Proterozoic Flin Flon metavolcanic belt, 65 km east of Flin Flon and 90 km west of Snow Lake (Fig. GS-7-1). The earliest concerted geological work in the region was by Bruce (1918) and Alcock (1920). Gold was discovered at Elbow Lake in 1921, and the deposits were subsequently examined by Armstrong (1922). Wright (1931) investigated a few of the gold deposits at Elbow and Morton lakes.

After a brief hiatus, prospecting was renewed in the Elbow Lake area in 1934. In the same year Stockwell (1935) studied most of the known gold occurrences and revised earlier geological maps of the area, assigning all volcanic and sedimentary rocks to the so-called Wekusko Group. Stockwell (1935) provides detailed descriptions of some 34 gold occurrences at Elbow Lake. He found that although some gold is associated with massive sulphides, the great majority of deposits are in quartz
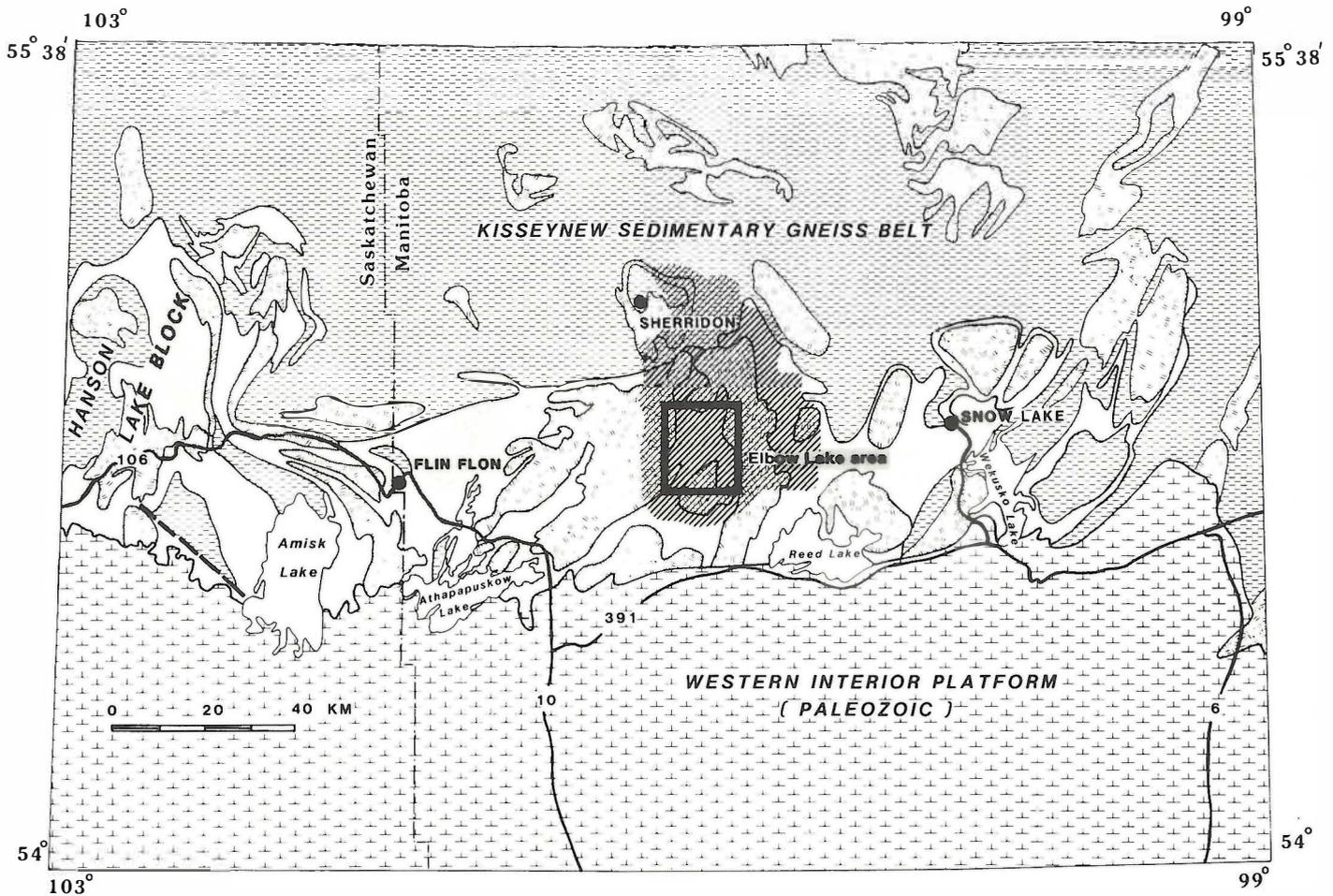

Figure GS-7-1: Simplified geological map of Flin Flon belt with location of the Elbow Lake project area. Metavolcanic rocks of the Amisk Group shown in dark pattern, plutons in hatched pattern. Diagonal ruled lines indicate approximate extent of the 1989 Elbow Lake burn.

veins within shear zones, commonly associated with felsic dykes. A genetic relation was held to be present between the gold deposits and large or small bodies of "quartz-eye granite" (now mapped as quartz megacrystic tonalite); this is perhaps the only outdated concept in an otherwise excellent documentation of occurrences.

McGlynn (1959) mapped the Elbow - Hemming lakes area at a scale of 1 inch: 1 mile and considered the volcanic rocks to be equivalent to the Amisk Group (Bruce, 1918) at Flin Flon. He found few primary structures reliable for top determinations, and described a broad zone of altered and sheared rocks forming most of the shoreline and island exposures at Elbow Lake. Like Stockwell (1935), McGlynn (1959) recognized two deposit types: quartz veins containing minor amounts of sulphides and gold, and sulphide deposits with small amounts of quartz carrying minor gold and, in some deposits, copper and zinc. The quartz veins were found to occur in shear zones, most of which were parallel to regional fabric. The veins are commonly near small bodies of "quartz eye granite" or dykes of quartz-feldspar porphyry; McGlynn (1959) considered the relationship to reflect competency contrast control in the localization of shear zones and contained quartz veins. Sulphide deposits (disseminated and massive) are described to occur in schistose mafic rocks around the north end of Elbow Lake; these are dominantly iron sulphides with minor chalcopyrite and sphalerite. The gold occurs in quartz veins and lenses within the sulphides. McGlynn (1959) provides descriptions of 4 gold properties on Elbow Lake that had received attention after Stockwell (1935).

Syme (1978) conducted a brief examination of the Elbow Lake area to determine whether a 1:20 000 mapping project could be mounted. It was concluded at that time that although inland outcrops are abundant, detailed mapping was not feasible because of heavy lichen and moss cover. On the basis of limited shoreline information major folds were outlined, shearing was noted in the lavas on central Elbow Lake, and a tentative stratigraphic sequence was proposed for the Amisk Group.

Galley et al. (1987) produced the first map (at 1:20 000 scale) to attempt subdivision of the Amisk Group; the work was conducted in order to set the numerous gold showings in a coherent regional context. Three generations of folds were recognized, and shear zones were found to cross cut the regional fabric at a high angle. The sheared rocks noted by McGlynn (1959) were mapped to define the north-northeast-trending Elbow Lake shear zone (ELSZ), a series of parallel to anastomosing ductile shear zones up to 2000 m wide characterized by transposition of stratigraphy, development of mylonite and conjugate shear bands, and potassic-carbonate alteration. Movement along the ELSZ is interpreted to be reverse dip-slip, with a dextral component. Galley et al. (1987) report that gold occurs in epigenetic, sulphide-bearing, quartz-carbonate-albite veins in zones of intense deformation within the ELSZ or in discrete fault zones of similar age. Within the shear zones the mineralization is associated with felsic dykes, jasper-magnetite iron formation, mafic intrusions, and mafic or felsic phyllonite. Like McGlynn (1959), Galley et al. (1989) recognize that in most of the deposits mineralization is hosted by lithologies more competent than the surrounding rock. The host lithology is interpreted to have reacted in a more brittle fashion during shearing, providing open spaces for the formation gold-bearing veins.

ELBOW LAKE BURN

The Elbow Lake fire was typical of most large forest fires in that the intensity of the burn varied considerably; topography and wind direction appear to have been the major controlling factors.

From a boat on Elbow Lake little evidence of the fire is apparent: almost the entire shoreline retains a mantle of green forest, with burnt ridges visible in the inland areas. Most of the islands in the lake are unburned, although some of the larger islands (Big Poplar Island, McDougalls Point, Webb Island; Fig. GS-7-2) have extensive burned areas. Shorelines are intensely burned in the southwest, in the bays leading to the Grass River.

Inland areas suffered the most destruction: burn intensity varies from smaller areas of completely untouched forest, through areas in which tree trunks are only charred, to areas where a very hot burn has left only charred trunks standing in the sand and gravel that underlies most of the forest floor. All of the bushy undergrowth is destroyed in areas of moderate to hot burn, so that access and visibility is greatly improved (Fig. GS-7-3).

Areas of outcrop tend to form hills and ridges and these are almost always burned (Fig. GS-7-4): apparently they were driest in 1989 and were extremely susceptible to fire. Lower lying treed areas and swamps between outcrop ridges often escaped the burn; in some areas 50 to 60 per cent of the forest is still green. Only where there was a moderate to hot burn has the moss and lichen been significantly removed from outcrops. Large, treeless outcrops are still lichen covered, even in burn areas, because there was little combustible organic material present.

To the west, north and northeast of Elbow Lake a hot burn resulted in considerable improvement in bedrock exposure. Outcrop areas are very large, and much of the burned moss and soil which carpeted the rock has been subsequently washed away. As in most of the Elbow Lake area, however, the outcrops contain a high proportion of frost shattered material that tends to degrade the quality of information that can be recorded.

On the east side of Elbow Lake outcrop is much less abundant than on the west. Most outcrop ridges have been burned, but the area contains 50 to 60 per cent green trees and a fair amount of swamp. The intensity of the burn increases southeast towards Claw Lake, and is most extreme for 1 km east of Claw Bay on Elbow Lake (Fig. GS-7-2).

North of Claw Lake there are 60 per cent green treed areas, but as usual the higher outcrop ridges are preferentially burned. Islands in Claw Lake are, like Elbow Lake, largely green. The large central peninsula on Claw Lake has a considerable amount of green trees, but the very large outcrops are burned; most are still covered with lichen.

The country south and southeast of Claw Bay, for 1 to 2 km inland, is not burned. In this area even the outcrop ridges are not touched and the rock is covered with lichen and moss; exposure quality is very low. Further to the south, in a tonalite pluton (Fig. GS-7-2), the trees are completely burned and exposure is excellent. Similarly, the mainland east of McDougalls Point had a very hot burn and the outcrops are perfectly clean.

West, between Elbow Lake and Long Lake, the outcrop hills are burned with a considerable improvement in exposure quality; pillow tops can be observed on every outcrop in an area where top determinations were previously impossible. Green trees are common between outcrop areas. On the east side of Long Lake the trees are green, while to the northeast the trees have been killed by the fire without significant burn-off; exposure quality is not significantly improved.

GENERAL GEOLOGY

Supracrustal rocks in the area comprise Amisk Group metavolcanic rocks and related intrusions, and a wide variety of relatively high level intrusive rocks of unknown affinity. The supracrustal rocks form a five-pointed, star-shaped enclave centered on Elbow Lake and surrounded by 5 separate granitoid plutons (Fig. GS-7-2). Foliation in metavolcanic rocks is in general parallel to the margins of the enclosing plutons; however, Galley et al. (in prep.) recognize at least three separate schistosities. Elbow Lake is transected by the Elbow Lake shear zone (ELSZ; Galley et al., 1987), a north-northeast-trending structure up to 2 km wide (Fig. GS-7-2). Galley et al. (1987) and Syme (1988) speculated that the ELSZ and South Athapapuskow shear zone are portions of one large structure over 80 km in strike length.

Supracrustal rocks east of the ELSZ comprise a very strongly deformed package of pillowed mafic flows and diabase, intruded by tonalite and heterogeneous gabbros. Primary structures are almost totally obliterated in the rocks east of Elbow Lake; for 4 km, to the contact with the granodiorite batholith, the mafic rocks are strongly foliated and flattened, tectonically banded and recrystallized to upper greenschist facies assemblages.

A large (5 by 2 km) mafic complex comprising massive and layered gabbro, and minor pyroxenite, occurs on southeast Elbow Lake, east of McDougalls Point.

West of the ELSZ primary volcanic structures are preserved in central Elbow Lake, the Long Bay - Long Lake area, and southwest Elbow Lake (towards the Grass River inlet). In these areas a volcanic stratigraphy can be defined and the rocks are at middle greenschist grade,
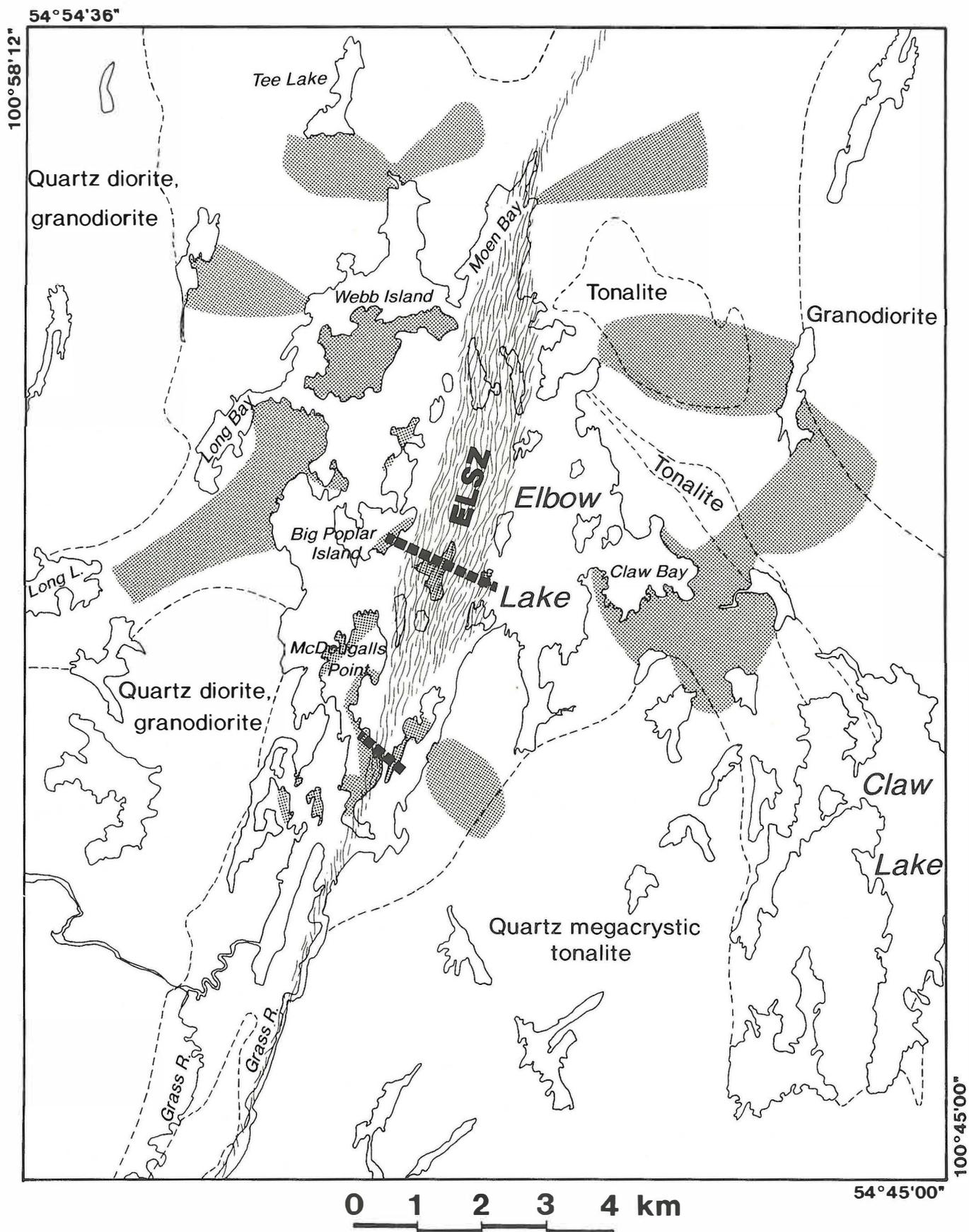
Figure GS-7-2: Geological outline map of the Elbow Lake area with supracrustal/granitoid contacts shown with dashed lines; the supracrustal rocks are centered on Elbow Lake (geology from McGlynn (1959) with minor modifications from Galley et al. (1987)). Elbow Lake shear zone (ELSZ) after Galley et al. (1989). The areas mapped at 1:15 840 in 1990 are shaded. Mapped transects across the ELSZ (discussed in text) are shown with heavy dashed lines.

Figure GS-7-3: Typical exposure in burned areas. Note the abundance of relatively clean but frost-shattered outcrop.

Figure GS-7-4: Aerial view of burn area. Outcrop ridges are preferentially burned.

but are hornfelsed in aureoles around the granitoid plutons. Tight north-northeast-trending folds are present in the volcanic rocks, but have not yet been mapped in detail.

In the northwest part of the belt (northwest of Long Bay and Webb Island) the supracrustal assemblage is dominated by high level intrusive rocks (dyke swarms) within which metavolcanic rafts form a very small part. The dykes form a complex that includes diabase, andesite, rhyolite, various porphyries, gabbro and quartz diorite; the ages probably range from syn-volcanic to syn-plutonic.

EAST SIDE OF ELBOW LAKE

The eastern portion of the Elbow Lake area, from the eastern shore of Elbow Lake to the contact with the granodiorite batholith, is composed of very strongly deformed mafic supracrustal rocks, diabase, gabbro and plug- and sill-like bodies of quartz-megacrystic tonalite. These rocks were mapped in 1990 east of Claw Bay and north of Claw Lake, and east of Moen Bay (Fig. GS-7-2). They are interpreted to underlie most of the eastern portion of the belt. The area is remarkable in that it represents

a wide zone (3-4 km) of intense ductile strain, apparently overprinted in the west by the ELSZ. The rocks have been metamorphosed in the upper greenschist to lower amphibolite facies, characterized by complete recrystallization and development of hornblende.

Mafic flows are almost completely unrecognizable in much of the area. Basalt is recrystallized, fine grained (0.2-0.5 mm) and has a banded, almost gneissic appearance (Fig. GS-7-5) interpreted as tectonic lamination produced by extreme attenuation of primary pillow structures. Locally, pillow selvages and amygdales are preserved, and individual highly flattened pillows with aspect ratios of 10 to 20:1 are recognizable. Epidosite domains in the cores of pillows are flattened to lenticular shapes which deflect the northwest-trending S_1 foliation. Diabase and, locally, tonalite dykes are parallel to S_1 and may be as narrow as a few centimetres; these too are strongly deformed and tectonically laminated. Open upright folds trending northeast warp the S_1 tectonic lamination; these F_2 structures locally have axial planar quartz veinlets or S_2 amphibole blastesis.

The tonalite plug emplaced within the supracrustal rocks east of

Figure GS-7-5:   Tectonic banding in strongly deformed pillowed basalt, east of Claw Bay.

Elbow Lake (Fig. GS-7-2) is a white-weathering, quartz-megacrystic body containing 10 to 25 per cent variably chloritized amphibole and biotite. Quartz forms equant irregular to oval megacrysts up to 2.5 cm long that stand out in relief from the groundmass. Biotite locally occurs as euhedral books to 6 mm. Foliation in the plug is generally weak and oriented east to northeast, except along the margins where there is a stronger foliation parallel to the northwest S_1 in the country rocks. The plug is mesoscopically similar to the large, quartz-megacrystic, biotite-phyric tonalite pluton lying south of Elbow Lake (Fig. GS-7-2); McGlynn (1959) shows them as the same unit.

The sill-like tonalite body east of Elbow Lake is apparently not continuous with the tonalite plug (Galley *et al.,* 1987). This rock is white weathering, relatively fine grained, leucocratic and equigranular to quartz-megacrystic (quartz up to 5 mm). The tonalite contains a strong northwest-trending S_1 foliation and parallel high strain/shear zones. It is intruded by dioritic and diabasic mafic dykes within the body and along the southwest margin, in contact with a thick unit of mafic intrusions.

East of Moen Bay the banded mafic tectonites are intruded by mafic rocks including several types of gabbro, melagabbro, pyroxenite and peridotite. These intrusions coincide with magnetic anomalies in a large zone east of Moen Bay; they have not yet been mapped in their entirety.

WEST SIDE OF ELBOW LAKE

The west side of Elbow Lake, north of Long Bay, has a very high proportion of bedrock outcrop, nearly all of which has been burned. The outcrops are, however, frost shattered so that only portions of the exposures are useable for mapping purposes.

Information from two traverses in the area suggest that the supracrustal belt west of Elbow Lake, between Long Bay on the south and at least to Tee Lake in the north (Fig. GS-7-2), is composed almost entirely of intrusive rocks, with only a few small screens and rafts of deformed mafic metavolcanic rocks. Potential for volcanogenic massive sulphide deposits in this area is considered to be low. The intrusive rocks can be subdivided into two main units:

1. diabase dyke complex comprising a wide variety of fine- to medium-grained diabase, diabase intrusion breccia, and oikocrystic diabase; and
2. heterogeneous complex composed of diabase, rhyolite, plagioclase porphyry, plagioclase-amphibole porphyry, leucotonalite, andesite, basalt, pegmatitic diabase, tonalite, quartz diorite, melagabbro. and gabbro pegmatite. These intrusions occur as dykes, irregular bodies and pods that are much too small to map individually at 1:20 000 scale; even crosscutting relationships are difficult to resolve, but the coarse

porphyries appear to be youngest. South of Tee Lake a small homogeneous body of quartz diorite has been mapped.

SOUTHWEST ELBOW LAKE

Pillow structures are well preserved in southwest Elbow Lake, and provide a clue to some of the folding that has occurred. West of the south end of McDougalls Point (Fig. GS-7-2) aphyric pillowed flows weather buff to buff brown and are light grey on fresh surface. Pillows have thick selvages (1-1.5 cm) and are characterized by an abundance of inter-pillow chert (Fig. GS-7-6). Pillows are only slightly flattened, and tops indicate that the flows are tightly folded in a northeast-trending syncline, parallel to the nearby ELSZ.

WEBB ISLAND

Webb Island, the location of the only once-producing gold mine in the area, plus the mainland peninsula to the southwest were mapped in their entirety (Fig. GS-7-2). In this part of the area preservation of volcanic structures is moderate to good. The geology of Webb Island and environs is unique in the Flin Flon belt in that one and possibly two major unconformities appear to be present within the Amisk Group (further mapping may clarify relationships). The major units are described below, with reference to Fig. GS-7-7.

Pillowed flows and amoeboid pillow breccia form the oldest part of the Webb Island sequence. They occur on the northern half of the island, and are commonly rather strongly flattened and foliated. Aphyric types predominate, with a plagioclase-phyric unit directly overlying rhyolite (below). Amoeboid pillow breccias predominate (Fig. GS-7-8), commonly intercalated with thin pillowed flows. The flows generally trend northeast and top northwest; however, Webb island is transected by a conjugate set of northeast- and northwest-trending faults and one fault block contains southeast-trending strata.

Rhyolite occurs as a massive, aphyric flow 150 m thick conformable within the mafic sequence (Fig. GS-7-7). It weathers a cream colour, with contorted, buff and dark grey flow bands. It locally contains poorly-defined enclaves of felsic microbreccia or hyaloclastite.

Heterolithologic felsic breccia forms a southeast-trending unit at least 670 m thick; beds top to the southwest. The angular, nonconformable relationship between the breccias and stratification in underlying mafic flows suggests that the contact may represent a volcanic unconformity (Fig. GS-7-7). The breccias are dominated by subangular to subrounded felsic fragments: white, sparsely quartz-phyric rhyolite and buff aphyric dacite. Buff aphyric andesite(?) is a minor clastic component. Bedding is thick, with local intercalation of well-bedded tuffaceous material.

Figure GS-7-6:   Pillows with thick selvages and abundant inter- pillow chert, southwest Elbow Lake.

Webb Island mafic volcaniclastics form an east-trending, south-topping unit at least 600 m thick in the south part of Webb Island (Fig. GS-7-7). These heterolithologic breccias/volcanic conglomerates are highly distinctive: Galley *et al.* (1987) show them to also occur along the north shore of Long Bay and in the large bay north of Webb Island. The unit appears to trend across strike of the underlying felsic breccias, and trends at a high angle to stratification in the mafic flow sequence. To the southwest, mafic flows on the peninsula adjacent to Webb Island also appear to be discordant with respect to the Webb Island mafic volcaniclastics (Fig. GS-7-7). These contact relationships seem to require that units are either unconformable or fault-bounded; further mapping may resolve this problem. The breccias are quite unlike any other unit in the Elbow Lake area: the rocks weather a distinctive medium green and are composed a wide variety of clasts including rounded, aphyric mafic scoria, massive aphyric basalt, amygdaloidal porphyritic basalt, amygdaloidal aphyric basalt, epidosite, and a suite of angular hypabyssal clasts such as diabase, plagioclase-phyric diorite, plagioclase-hornblende-phyric diorite, gabbro, and melagabbro. Clasts are predominantly pebble and cobble sized (Fig. GS-7-9), with rare boulders. Bedding is thick, and normal grading to pebbly tops was observed locally. Mafic scoria commonly comprises 50 per cent or more of the clast population, but the large variety of hypabyssal clasts and rounding of the fragments suggests that the unit is not a simple pyroclastic deposit.

Pillowed flows on the peninsula southwest of Webb Island (Fig. GS-7-7) include some of the better-preserved supracrustal rocks in the Elbow Lake area. They trend northeast and top southeast; the distribution of tops suggests that the peninsula represents the west limb of an upright, northeast-trending syncline. The pillowed sequence can be subdivided into plagioclase-phyric and aphyric members, both of which weather a distinctive light buff, and are light grey on fresh surface. The pillows are generally non-amygdaloidal and have thin selvages. Within 450 m of granitoid plutons the flows display effects of contact metamorphism: they weather dark grey to black, are fine grained and hard, and are not foliated. Similar hornfels aureoles occur around felsic plutons in the Athapapuskow Lake area (Syme, 1987), where the hornfels formation is interpreted to predate regional metamorphism.

ELBOW LAKE SHEAR ZONE

Galley *et al.* (1987) first defined the extent and importance of the Elbow Lake shear zone. They interpret the zone as an anastomosing system of ductile shear zones characterized by specific alteration assemblages; movement is essentially reverse dip-slip with a dextral component. Epigenetic vein-type Au deposits in the Elbow Lake area are interpreted by Galley *et al.* (1987, 1989) to be hosted by the ELSZ and related structures.

During the 1990 field season the ELSZ was investigated in two transects that provided particularly good exposure across the zone. One transect is at the south end of McDougall's Point where the ELSZ is narrow (330 m), and the other is southeast of Big Poplar Island where the zone is 1580 m wide (Fig. GS-7-2).

On McDougalls Point the east and west margins of the ELSZ are abrupt. Pillowed flows 150 to 300 m west are only weakly to moderately flattened parallel to the ELSZ; the flows trend southeast into the north-northeast-trending ELSZ. High strain (shear) zones parallel to ELSZ occur within the less-strained flows. Flattening increases towards the west margin of the zone, so that the long axes of pillows are nearly transposed into a plane parallel to the ELSZ. At the west margin of the zone there are an increasing number of 1 to 2 m wide high strain zones within the flattened flows, followed by an abrupt transition to strongly foliated rocks (phyllonites) in the ELSZ proper.

Within the shear zone the dominant rock type is a green chloritic phyllonite; locally within the phyllonite are highly elongate lensoid tectonic domains (e.g. 30 cm by 2 m) in which the protolith of buff pillowed flows can be recognized. A large number and wide variety of dyke rocks intrude the phyllonites; these dykes are generally absent in the rocks immediately outside the shear zone. The dykes, including quartz-phyric rhyolite, diabase, tonalite, aphyric andesite and white plagioclase porphyry, display structures such as strong foliation and boudinage which indicate they were emplaced prior to at least some of the deformation within the ELSZ. In the core of the zone there is a mappable unit of heavily carbonatized, strongly foliated felsic heterolithologic breccia and derived schist. Bedding in this unit is transposed parallel to the ELSZ.

The east margin of the shear zone is, like the west margin, abrupt. Pillowed flows on the east margin contain a few discrete shear zones parallel to the ELSZ, but in general are well preserved, weakly foliated and not significantly flattened. More highly strained rocks occur on an island to the east (Fig. GS-7-2), but at present it is unknown whether these too are part of the ELSZ proper.

Southeast of Big Poplar island the ELSZ is nearly 1600 m wide (Fig. GS-7-2). Strain is inhomogeneously distributed within the zone, with relatively weakly foliated and weakly flattened flows occurring as small- to large-scale tectonic lenses within a multicomponent mafic phyllonite: here the ELSZ can be considered an anastomosing system of subparallel shears.

The margins of the ELSZ are abrupt, as at McDougall's Point. At the eastern margin of the zone (on Chinaman Island), the shear zone

Webb Island

ELBOW LAKE

Long Bay

Big Poplar
Island

0   500 m

	Aphyric mafic flows, amoeboid pillow breccia		Rhyolite
	Porphyritic mafic flows		Diabase, gabbro, quartz diorite
	Felsic heterolithologic breccia		Strongly foliated mafic flows
	Webb Island mafic volcaniclastics		Shear zone: mafic phyllonite

Pillows, top known
Flow contact, top known
Foliation

Bedding, top known
Bedding, top not known

Figure GS-7-7:   Geological map of Webb Island and surrounding area. Intravolcanic unconformities are interpreted to occur at the base of two of the units: felsic heterolithologic breccia and Webb Island mafic volcaniclastics (see text for discussion).
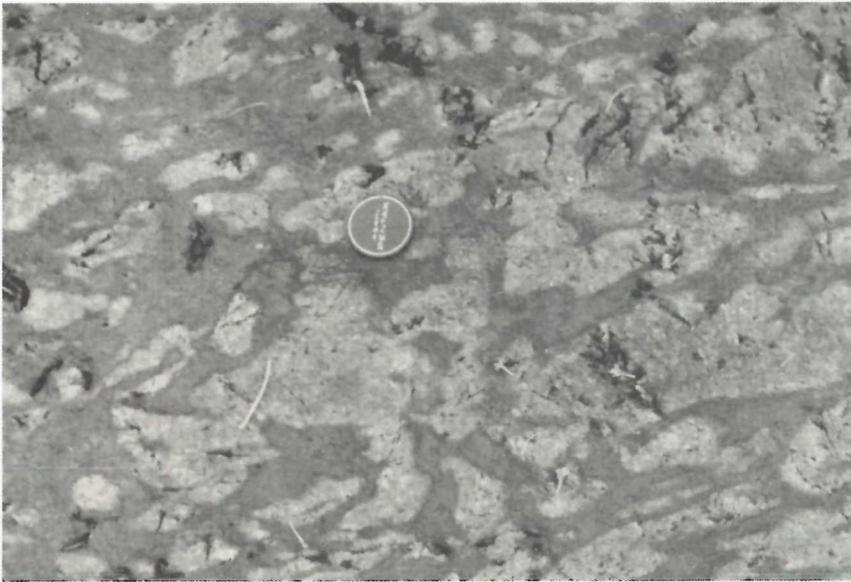
Figure GS-7-8:   Amoeboid pillow breccia, Webb Island.

Figure GS-7-9:   Webb Island mafic vol-
caniclastics. The breccia is
dominated by pebble- and
cobble-sized, strongly vesic-
ular, basaltic scoria clasts,
but there is also a significant
component of amygdaloidal
mafic accessory fragments.
Mafic hypabyssal clasts (dia-
base, gabbro) are also com-
mon in this unit.
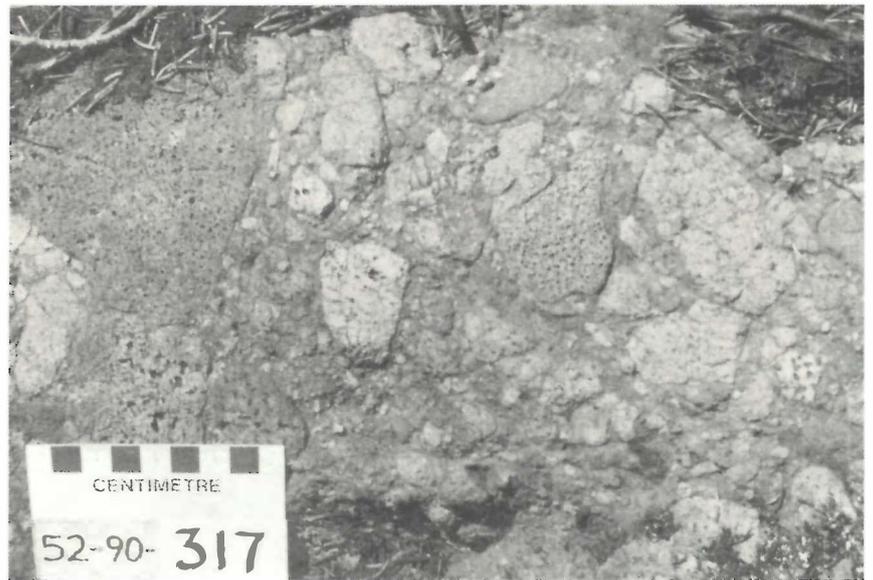
crosses stratigraphy at a high angle. A dramatic increase in strain oc-
curs over 60 m, with equant to slightly flattened pillows grading west-
ward to very strongly flattened pillows at the edge of the ELSZ. The
flattening is accompanied by tight chevron folding of lithologic and flow
contacts. The west margin of the ELSZ is not exposed, but there is a
similar abrupt increase in strain that marks the western margin of the
zone. Sheared rocks on the western margin of the zone contain consider-
able amounts of intrafolial carbonate.

Much of the ELSZ southeast of Big Poplar Island consists of
featureless green chloritic phyllonite derived from pillowed mafic flows.
This material typically contains few quartz veins and little intrafolial car-
bonate. Aphyric felsic dykes are strongly boudinaged. A distinctive subunit
is a strikingly colour banded mafic phyllonite in which the (tectonic) band-
ing is isoclinally folded. The banded phyllonite is derived from mafic flows:
bands of all colours contain oval quartz amygdales.

There is considerable evidence that the ELSZ records not only
shear displacement, but also a significant component of compression.
Tectonic banding is isoclinally folded, quartz veins crosscutting foliation
are tightly folded, and primary structures at zone margins are strongly
flattened and chevron folded.

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GS-8 WEBB LAKE - FAY LAKE (NTS 63K/15)

by D.C.P. Schledewitz

INTRODUCTION

One of the many forest fires in Northern Manitoba in the summer of 1989, burned a large area southeast of Sherridon. Outcrops previously concealed by vegetation and lichen are now exposed. One of several projects initiated to collect geological information from burned-over areas is centred on Webb Lake, where a four week reconnaissance program was conducted in the summer of 1990.

The reconnaissance mapping program carried out in June of 1990 focused on the Webb Lake, and the Fay Lake area (Fig. GS-8- 1). In addition, the terrain west of Webb Lake to Rodwalsh Lake and east of Webb Lake to Loonhead Lake were covered by low level areal reconnaissance. The region from Webb Lake to Fay Lake was established as a project area (Fig. GS-8-1) on the basis of the information gathered.

PREVIOUS WORK

The proposed Webb Lake-Fay Lake project area was mapped (McGlynn, 1959) at a scale of one inch to the mile as part of the Elbow-Heming Lakes Area. Detailed mapping of the geology and mineral occurrences was carried out at the south end of the prominent peninsula near the east end of Fay Lake by Parbery (1986) (Fig. GS- 8-2). Webb Lake was briefly examined by Syme (1978).

GENERAL GEOLOGY

Fay Lake

1:20 000 scale mapping was carried out in the east half of the Fay Lake area primarily along the north and east shores. Amisk Group metavolcanic rocks of predominantly intermediate to mafic composition are overlain to the north by Missi Group quartzofeldspathic metasedimentary rocks that become increasingly hornblende-bearing to the north. The Missi Group rocks are in turn overlain by garnet-biotite-feldspar-quartz gneiss of the Burntwood River Metamorphic Suite.

Amisk Group metavolcanic rocks in the eastern part of Fay Lake, comprise a sequence of intercalated mafic pillowed flows, pillow breccias, flow breccias, heterolithic breccias and massive fine grained variably amygdaloidal mafic flows. The mafic volcanic rocks are cut by diorite-gabbro bodies and layered mafic to ultramafic intrusions. Hornblende-phyric metabasalt and plagioclase-phyric metabasalt occur within the mafic flows; it is uncertain whether they are massive flows or intrusions. These observations are consistent with those of Parbery (1986).

The Amisk Group metavolcanic rocks are folded about an easterly-trending fold axis plunging at 55 to 65°. At Fay Lake the layering has a westerly trend with northerly dips of 45 to 85° but swings to a more northerly orientation with easterly dips of 45 to 65° at the east end of
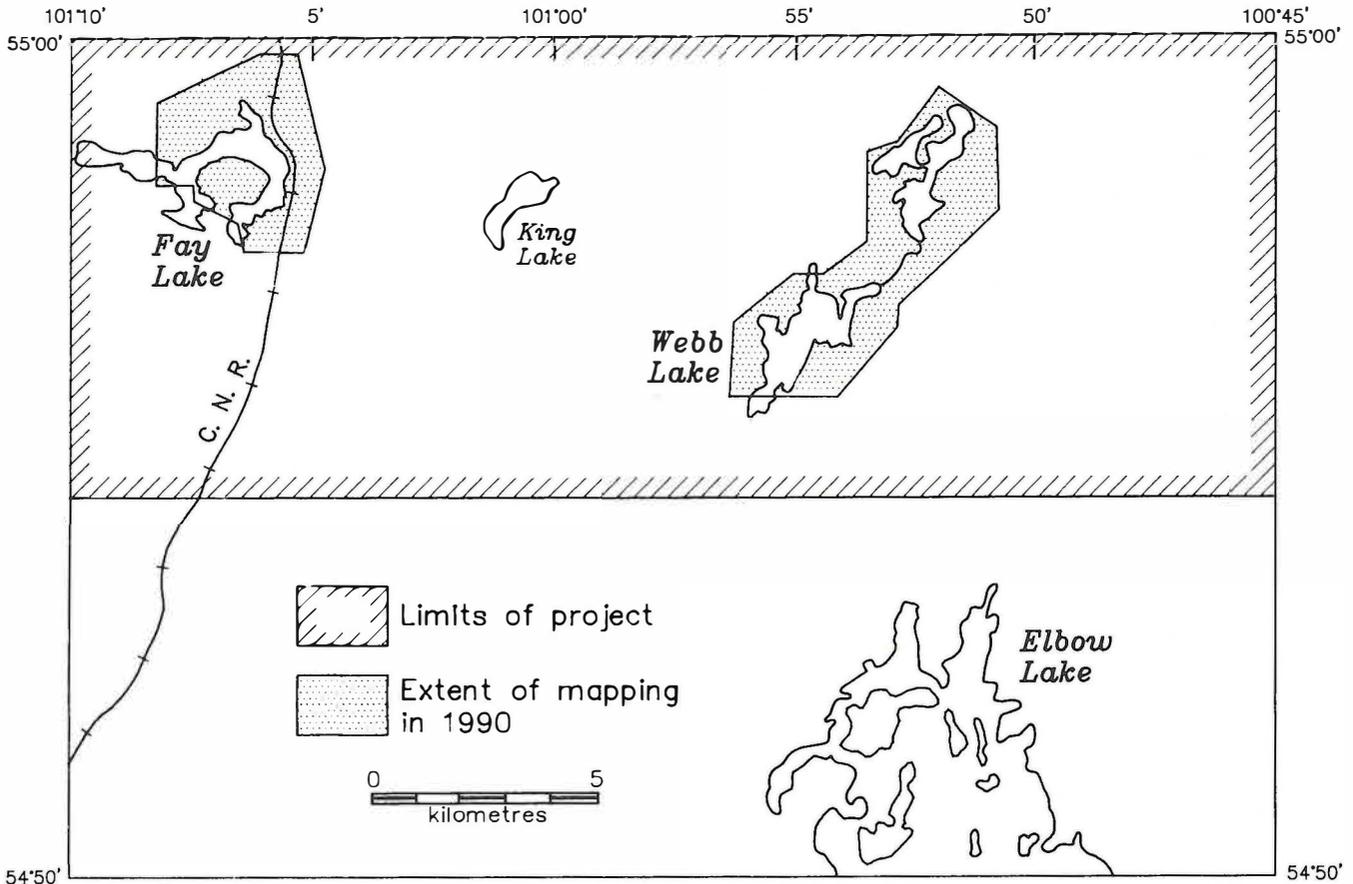

Figure GS-8-1:   Outline of Webb Lake-Fay Lake Project area.
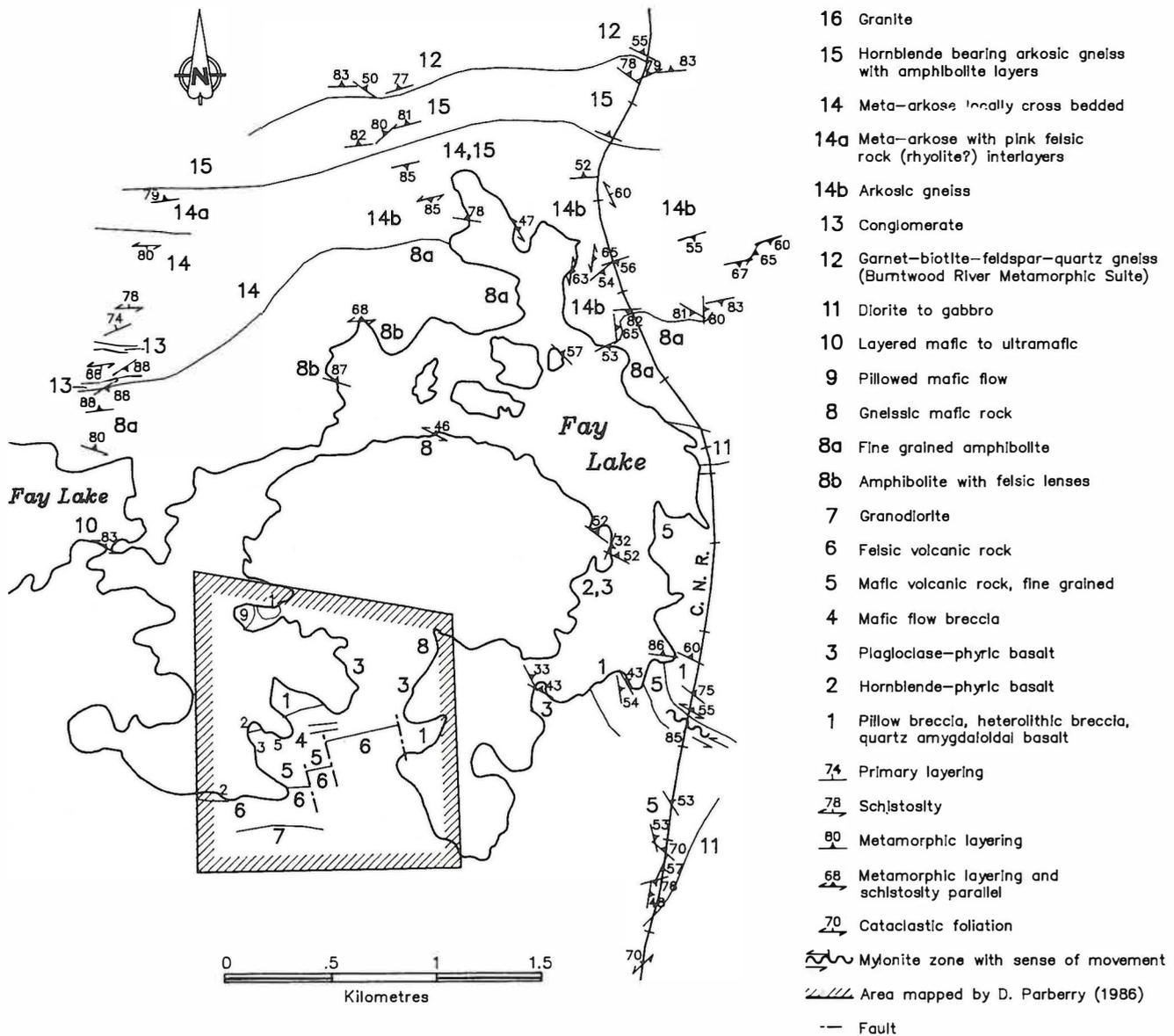
Figure GS-8-2: Simplified geology of the east half of Fay Lake.

Legend:

16 Granite
15 Hornblende bearing arkosic gneiss with amphibolite layers
14 Meta—arkose locally cross bedded
14a Meta—arkose with pink felsic rock (rhyolite?) interlayers
14b Arkosic gneiss
13 Conglomerate
12 Garnet—biotite—feldspar—quartz gneiss (Burntwood River Metamorphic Suite)
11 Diorite to gabbro
10 Layered mafic to ultramafic
9 Pillowed mafic flow
8 Gneissic mafic rock
8a Fine grained amphibolite
8b Amphibolite with felsic lenses
7 Granodiorite
6 Felsic volcanic rock
5 Mafic volcanic rock, fine grained
4 Mafic flow breccia
3 Plagioclase—phyric basalt
2 Hornblende—phyric basalt
1 Pillow breccia, heterolithic breccia, quartz amygdaloidal basalt
74 Primary layering
78 Schistosity
80 Metamorphic layering
68 Metamorphic layering and schistosity parallel
70 Cataclastic foliation
⌇⌇ Mylonite zone with sense of movement
▨ Area mapped by D. Parberry (1986)
-— Fault

Fay Lake. The contact between the Amisk Group and the younger Missi Group also has a westerly trend and dips steeply north or south. At the east end of Fay Lake, and also east of the Canadian National Railway track, Amisk Group rocks appear to overlie gneisses derived from Missi Group rocks.

In general the rocks tend to be highly strained and recrystallized. However on the north side of Fay Lake (Fig. GS-8- 2). The rocks on either side of the Amisk Group/Missi Group contact contain primary features. The base of the Missi Group is defined by a conglomerate with clasts supported in a pebbly matrix. The clasts become more numerous and the matrix more epidotic towards the basal contact. The clasts comprise quartz plus magnetite, vein quartz, cream coloured granitic rock, and quartz-epidote. The upper part of the Amisk Group that directly under-lies the conglomerate is highly ribbed due to the presence of quartz vein-ing, and contains lenticular rusty patches suggestive of a metamorphosed regolith. The Missi Group rocks overlying the basal conglomerate are variably pebbly and crossbedded. A second conglomerate lies approxi-mately 140 m above (north) the basal conglomerate. This intraformational conglomerate is clast supported and the clasts comprise white milky vein quartz and aphanitic grey quartz clasts. This conglomerate is overlain by sporadically crossbedded meta-arkose that becomes thinly laminat-

ed upwards and in turn grades upward into a more massive thickly bed-ded meta-arkose thin fine grained pink quartzofeldspathic layers. This fine grained pink rock is similar to the "pink felsic gneiss" mapped to the west in the Piat Lake, Cleunion Lake and Lobstick Narrows areas of the Kisseynew Project, where it is interpreted as felsic metavolcanic rock or as a high level subvolcanic intrusion (Schledewitz, 1988). The top (most northerly) of this section contains hornblende-bearing layers.

Webb Lake

1:20 000 scale mapping was initiated in the area surrounding Webb Lake. Mapping on Webb Lake was carried out at a scale of 1:10 000 due to the highly variable thickness and discontinuous nature of the units.

Based on the results of this, and previous mapping (McGlynn, 1959; Syme, 1978), it is concluded that the sequence of supracrustal rocks at Webb Lake is part of a large, complex roof pendant, compris-ing supracrustal and intrusive rocks, in regionally dominant younger, vari-ably quartz-phyric granodiorite. The supracrustal sequence was first intruded by mafic to ultramafic intrusions followed by quartz diorite to diorite and later by leucocratic tonalite. These in turn were intruded by very fine- to fine-grained quartz-porphyry. A large area of intrusion brec-cia, comprising blocks of quartz diorite and supracrustal rocks within the

59

leucocratic tonalite and quartz-porphyry, extends northeast for several km from the north end of Webb Lake. This area was previously mapped as gneisses and migmatites derived from basic volcanic and sedimentary rocks (McGlynn, 1959).

STRUCTURE AND METAMORPHISM

The rocks in the Webb Lake-Fay Lake area were metamorphosed to upper greenschist and lower amphibolite facies based on the presence of garnet and hornblende in rocks of intermediate composition. The supracrustal rocks at Webb Lake define a steeply southerly-dipping homoclinal structure that has been deformed by north-trending shear zones. However, the small number of facing determinations cannot rule out the existence of isoclinal folds. A north-trending, west-dipping *en echelon* shear zone occurs near the centre of Webb Lake. The 800 m thick homoclinal sequence east of the shear zone has an easterly-trending strike, but the layering is deformed about northeast-trending axial planes with southwest- trending minor fold axes plunging at 50 to 70°. The east end of the steeply dipping homocline is truncated against the younger quartz- phyric biotite granodiorite. West of the shear zone the layering is more discontinuous because large areas are underlain by felsic volcanic and hypabyssal intrusive rocks. This layering appears to define a large S-fold with a southwest-trending steeply plunging fold axis.

AMISK GROUP LITHOLOGIES AND INTRUSIVE ROCKS AT WEBB LAKE

There are considerable lithological differences between the east and the west half of Webb Lake. The east half is underlain by a sequence of mafic flows, interlayered intermediate volcaniclastic rocks and intermediate to mafic greywackes. Quartz- phyric rhyodacite occurs as thin, widely spaced units (Table GS-8- 1). The mafic flow rocks are massive with isolated pillows, to flows with a massive lower unit grading upward into amygdaloidal zones overlain by pillow breccia.

Sulphide mineralization and related alteration occurs at two points in the stratigraphy in the northeast corner of Webb Lake. The stratigraphically lowest occurrence lies at the top of a sequence of volcaniclastic rocks of intermediate composition intercalated with thin mafic flows and discontinuous lenses of intermediate to mafic metagreywacke (Table GS-8-1). The zone of alteration comprises an anastomosing network of garnet, green amphibole and biotite, and areas with disseminated garnet and rosettes of green amphibole. The alteration is approximately 200 m in strike length and 10 to 15 m thick. Pyrite and trace chalcopyrite occur in a 50 m long by 5 m wide siliceous-sericitic lens near the top of the alteration zone. The second zone of mineralization lies 350 m up section (south). It overlies a series of mafic flows separated by interlayered quartz-phyric rhyodacite (Table GS-8-1). The lower mafic flow contains lenticular felsic fragments and has an amygdaloidal top with localized pillow breccia. The upper mafic flow grades from a massive base into a thick amygdaloidal pillow breccia at the top. This is overlain by 6 m of thin bedded mafic sedimentary rock with some pillow breccia that in turn is overlain by a 5 m thick garnetiferous felsic layer. The latter grades upward into an altered rusty, felsic rock with concentrations of garnet and green amphibole, and more siliceous parts that contain pyrite and chalcopyrite. This alteration zone has a minimum strike length of 700 m, and is up to 30 m thick.

Table GS-8-1
Table of formations for east half of Webb Lake

SOUTH	YOUNGEST		Quartz-porphyry (Intrusive)
		YOUNGEST	Mafic flow, plagiclase-phyric, with isolated pillows
			Intermediate volcaniclastic and interlayered greywacke
			Pillowed mafic flow with flow top breccia
			Stratigraphic interval covered by water (Webb Lake)
			Mafic flow and interlayered mafic greywacke
			Rhyodacite overlain by felsic tuff
			Mafic flow
			Rusty, mafic sediment overlain by siliceous sericitic-plagioclase-sulphide layer
			Massive mafic flow grading upward through an amygdaloidal zone into pillow breccia
			Quartz-phyric rhyodacite
			Mafic flow
			Felsic to mafic greywacke
			Localized alteration zone (siliceous sericitic-sulphide layer in larger area of hornblende-garnet alteration
			Felsic to intermediate volcaniclastic rocks and intercalated mafic flows
			Quartz-phyric rhyodacite
			Mafic greywacke
		OLDEST	Mafic flow
NORTH			Quartz-porphyry(intrusive)

Table GS-8-2
Table of formations for west half of Webb Lake

NORTHWEST   Bimodal felsic fragmental
rock (felsic fragments in
a more mafic matrix)

Iron formation

Magnetiferous mafic
sediment

Magnetiferous greywacke
      Mafic flow rock

      Sulphide-bearing alteration
      zone

      Rhyolite breccia

Note: The mafic flow rock, sulphide-bearing alteration zone and the rhyolite breccia lie on an island to the northeast and along strike of the contact between the magnetiferous greywacke and the interlayered felsic to intermediate flow and fragmental rock

      Interlayered felsic to
      intermediate flow and
      fragmental rock

      Quartz-phyric to aphyric
      volcaniclastic and
      fragmental layers

SOUTHEAST   *Mafic flow with pillow*
      breccia

The west half of Webb Lake is characterized by discontinuous layering and a large volume of felsic volcanic and hypabysal intrusive rocks. The intrusive rocks occur as discrete bodies or as dyke swarms. The youngest intrusions are subvolcanic gabbro that is crosscut by rhyolite and rhyodacite. These high level intrusive rocks are deformed with the surrounding layered rocks and were possibly, all or in part, feeders of Amisk Group volcanism. Quartz-porphyry and tonalite intrusions are younger; they in turn are cut by hornblende-pyroxene-phyric felsic dykes and diabase dykes. The youngest intrusions are quartz-hornblende- gabbro and hornblende-biotite granodiorite.

The felsic volcanic and felsic hypabysal rocks are most common along the central west shoreline of Webb Lake. They are variably quartz- and/or plagioclase-phyric to massive, very fine grained, weather white to light grey, and are greenish grey on the fresh surface. A single upright southeast facing stratigraphic top direction is based on the identification of a synvolcanic alteration zone.

A layered sequence, 650 m thick, in the south and southeast corner of central Webb Lake comprises (Table GS-8-2) a pillowed mafic flow structurally overlain by a 300 m thick layer of felsic to intermediate volcaniclastic rocks with localized intermediate flows. The intermediate flow rocks contain autoclastic breccia characterized by garnet and acicular green amphibole in the matrix, and amphibole rosettes in the fragments (Table GS-8-2). Garnet and green amphibole also occurs in anastomosing veins forming a pseudobreccia within more finer grained variably silicified volcaniclastic rocks that immediately structurally underlie the mafic pillowed flow. The felsic to intermediate volcaniclastic rocks structurally overlie a magnetiferous greywacke that in turn overlies a magnetiferous iron formation and mafic sedimentary rock. The most northwesterly unit of this stratigraphic section is a bimodal felsic fragmental rock. The fragments are plagioclase-phyric and occur in a matrix that is more mafic than the fragments. The northwest edge of this unit is in contact with a complex of mafic and felsic intrusive rocks. The layered sequence is truncated to the southwest by a quartz-gabbro intrusion, whereas its northeast extension is disrupted by the presence of quartz-phyric rhyolite, quartz-porphyry and tonalite intrusions. A stratigraphic top direction is indeterminate at the present time.

A 300 m long and 100 m wide alteration zone occurs to the northeast, on an island along strike of the contact between the magnetiferous greywacke and the structurally overlying felsic to intermediate fragmental and interlayered flow rocks (Table GS-8- 2). However, on the island the layered sequence is different; a quartz-phyric rhyolite with a brecciated flow top occurs on the southeast side and a mafic flow rock on the northwest side. The alteration zone occurs in the rhyolite, which is highly brecciated. The matrix contains green acicular amphibole and sporadic garnet; the hornblende-garnet assemblage is best developed in the southeast corner of the island. A siliceous- sericitic sulphide-bearing zone (pyrite-trace chalcopyrite) lies at the contact between the rhyolite and the mafic flow rock, and strikes northeast along the length of the island. The structurally overlying mafic flow contains large pyrite nodules that may be fragments derived from the underlying sulphide layer.

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GS-9 THE GEOLOGICAL SETTING AND GEOCHEMICAL ALTERATION OF THE SPRUCE POINT CU-ZN DEPOSIT, SNOW LAKE AREA, MANITOBA (NTS 63K/9)

by M.A.F. Fedikow and A. Lebedynski[1]

INTRODUCTION

Three weeks were spent underground at the Spruce Point Cu-Zn deposit (Fig. GS-9-1) washing, mapping and sampling the host rocks to the mineralization. Detailed work was undertaken along the 274 m and 574 m exploration crosscuts. The project was initiated to: (i) document the stratigraphy, structure and style of mineralization of the deposit; (ii) investigate the geochemical alteration of the host rocks; and (iii) provide geological information on the nature of sub-Paleozoic formations and contained mineral deposits in the Reed Lake area. A program of logging and sampling Spruce Point drill core to support underground observations has also been initiated.

Prior to this project the most recent information regarding the Spruce Point deposit was presented by Ferreira and Fedikow (1990) as a personal communication from F. Bill (HBMS, 1989).

Generally, the deposit can be described as a series of copper and zinc-rich sulphide lenses hosted by rhyolite breccia. The deposit strikes 015° with an average dip of 80°E and plunges 36° southeast. The strike length is 500 m, with a maximum width of 18 m and an average width of 9 m. The orebody contains medium grained pyrite, sphalerite, chalcopyrite and pyrrhotite with an internal metal zonation of Cu-rich in the north and Zn-rich in the south. An argillite unit with pyrrhotite and graphite occurs in the hanging wall rocks and is marked by erratic gold concentrations associated with arsenopyrite. Metal contents in the deposit are quoted (F. Bill, pers. comm., 1989; Mineral Inventory Card 63K/9, Cu1) as follows:

"Proven reserves as of January 1, 1981 were 616 000 tonnes averaging 2.7 per cent Cu, 4.3 per cent Zn, 1.9 g/t Au, and 32 g/t Ag (Mineral Inventory Card 63K/9 Cu1). Reserves as of December 31, 1987 were 567 000 tonnes grading 2.15 per cent Cu, 1.7 per cent Zn, 1.44 g/t Au and 15.04 g/t Ag. Total production to the end of 1988 was 1 364 000 tonnes averaging 2.36 per cent Cu, 2.8 per cent Zn, 2.0 g/t Au and 25.0 g/t Ag."

[1]University of Winnipeg, Winnipeg, Manitoba
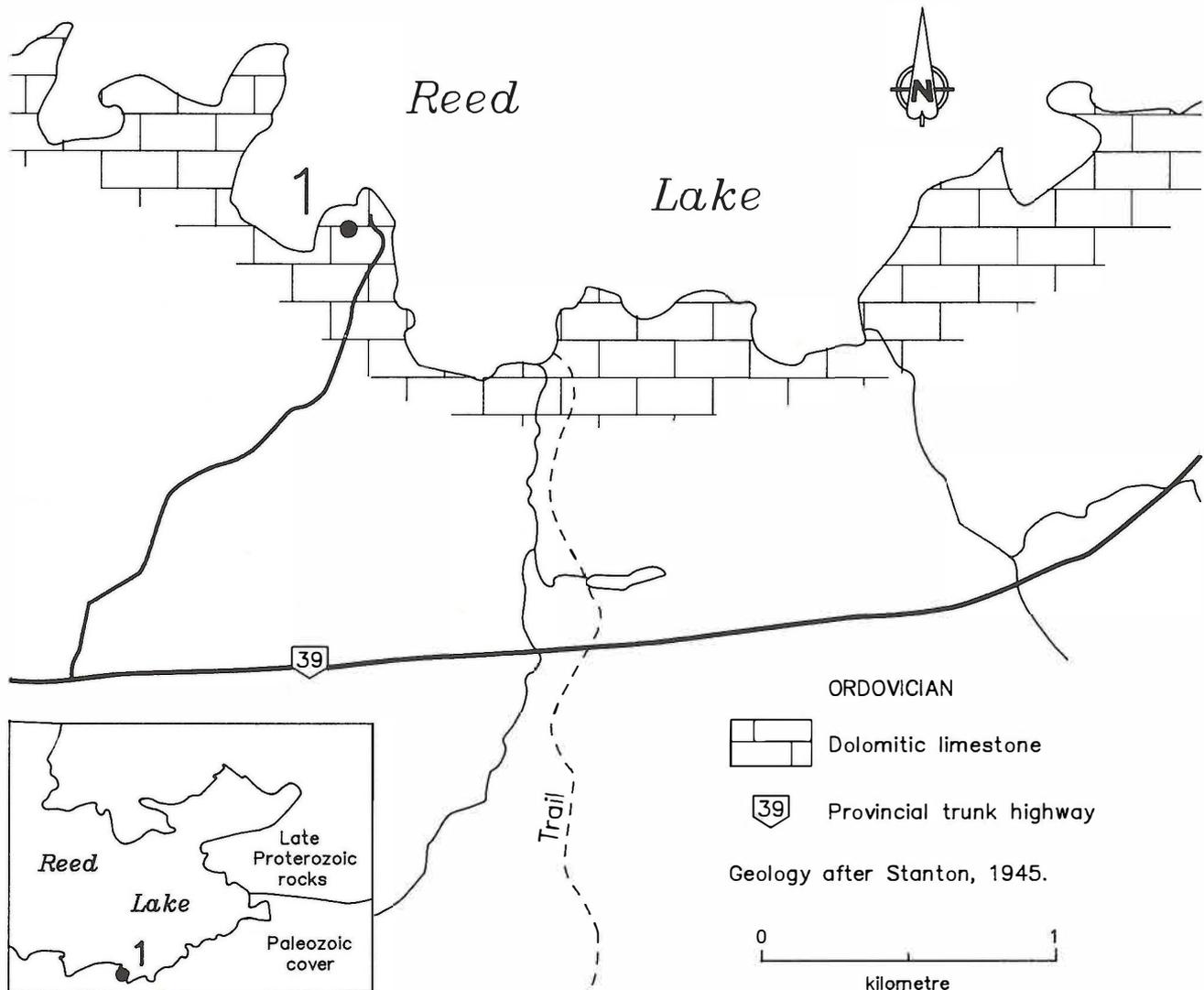
Figure GS-9-1:   Location map for the Spruce Point Cu-Zn deposit.

STRATIGRAPHY

The stratigraphic succession at the deposit is dominated by a thick (>200 m) sequence of felsic pyroclastic and autobrecciated volcanic rocks (Fig. GS-9-2, GS-9-3). These units are intruded by fine- to medium-grained mafic intrusions and overprinted by the effects of alteration that accompanied the formation of the Spruce Point Cu-Zn deposit. Samples collected from the various stratigraphic units on the 274 m and 574 m levels are illustrated in Figures GS-9-4 and GS-9-5.

The stratigraphic components of the succession are described as follows:

(i) Stratigraphic Hangingwall/Structural Footwall

The stratigraphic hangingwall consists of fine grained, aphyric rhyolite (tuff?) and poorly sorted, unimodal rhyolitic fragmental rocks. On the 574 m level the hangingwall rocks are characterized by fragmental rhyolites with poorly sorted, aphyric, unimodal, very fine grained rhyolitic fragments that appear to have been brecciated *in situ*. Rhyolitic fragments vary in size from 8 cm by 1 cm to 80 cm by 40 cm; cores of the larger fragments have been altered to an epidote-amphibole-pyrite as-

semblage. On the 274 m level the hangingwall rocks are represented by pyritic and sericitic fragmental rhyolite for up to 5 m stratigraphically above the orebody; these rocks are truncated at this point by mafic intrusions. Adjacent to the ore zone fragments within the rhyolitic wallrocks are barely discernible , having been altered to a sericite-chlorite-pyrite-chalcopyrite-sphalerite assemblage. Generally, the hangingwall rhyolite breccias are matrix supported. Hangingwall graphitic argillite identified in drill core was not observed on the 274 m and 574 m levels. The extent of mineralization-related alteration in the hangingwall rocks is unknown due to the truncation of the stratigraphy by mafic intrusions.

(ii) Stratigraphic Footwall/Structural Hangingwall

The stratigraphic footwall rocks are characterized by a strongly and variably altered sequence of fine grained rhyolitic tuff and unimodal fragmental rhyolite that varies from matrix- to fragment-supported. These units are aphyric with a brown biotite- sericite matrix to the fragments. With proximity to the orebody the matrix is replaced by a sericite-chlorite ± pyrite ± chalcopyrite ± sphalerite assemblage. Locally, the rhyolite is massive, but fragmental rhyolite can be traced from a matrix- supported
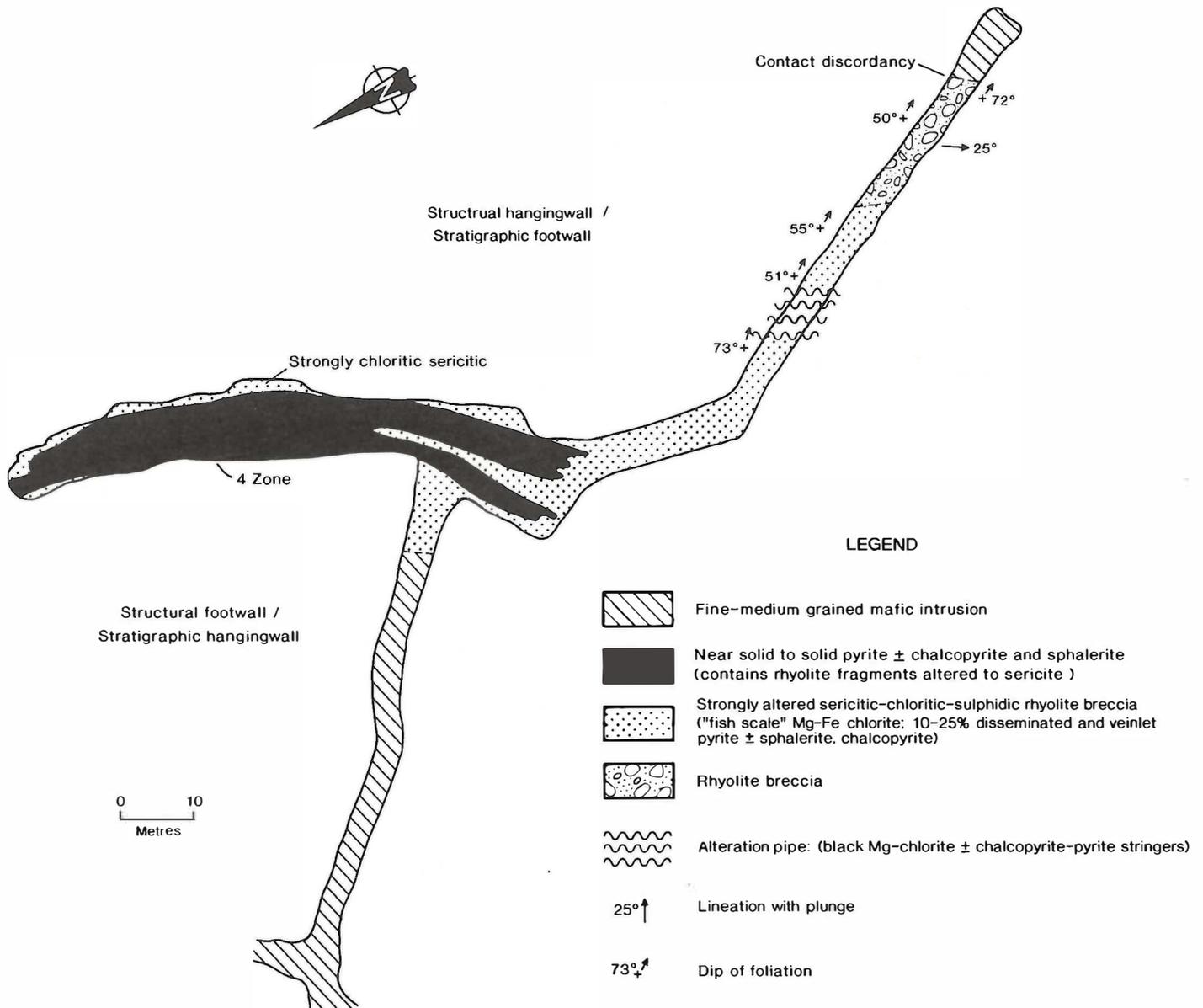

Figure GS-9-2: Geology along the 274 m exploration crosscut, 4 Zone, Spruce Point Cu-Zn deposit. Geology modified after Hudson Bay Mining and Smelting Co. Ltd.

LEGEND

- Fine-medium grained mafic intrusion
- Near solid to solid pyrite ± chalcopyrite and sphalerite (contains rhyolite fragments altered to sericite)
- Strongly altered sericitic-chloritic-sulphidic rhyolite breccia ("fish scale" Mg-Fe chlorite; 10-25% disseminated and veinlet pyrite ± sphalerite, chalcopyrite)
- Rhyolite breccia
- Alteration pipe: (black Mg-chlorite ± chalcopyrite-pyrite stringers)
- 25° Lineation with plunge
- 73° Dip of foliation

LEGEND

▒	Massive rhyolite
▓	Rhyolite breccia ("Fragmental"rhyolite) ± sericite. chlorite. sulphide
■	Near solid to solid pyrite ± chalcopyrite and sphalerite (contains rhyolite fragments altered to sericite)
▨	Fine grained mafic rock (includes dykes and "basalt")
□	Rhyolite dyke

+76°   Foliation dip

↗49°   Lineation

+76°   ↗49°
+67°   ↗52°
+62°
Rhyolite dyke (aphyric?)

+59°
+61°   ↗45°

+67°
+71°
                                 1-3% diss./vein Py
                                 First 0.5m is massive ; prob. fragmental
+79°   : sericitic-chloritic-sulphidic
                                 "grey gneiss" 1-3% diss./vein Py
+70°
+60°   "grey-gneiss"
+67°   1-5% diss./vein Py. Cp
+70°
+67°
+70°
+62°
                                 1cm NSS-SS Py
+76°
                                 1-10% diss./ vein. Py
+75°
+76°
+82°   25-30% diss./vein Py
                                 Near solid Py± Sph. Cp (<40%) [ORE EQUIVALENT]
+61°
+66°
+73°   10-15% diss./vein Py. Sph "pea"-sized fragments
+66°
+62°   40°
+65°   Coarse rhyolite fragments (max. 63x17 cm)
                                 altered to epidote-amphibole-pyrite in cores
                                 52°
+60°
+79°   72°   1m f.g. rhyolite with 10-15%
                                 diss.+veinlet Po at contact: rubbly contact
+63°   20° ↗

+54°

chlorite + silicification + sulphide
sericite + silicification + sulphide

Figure GS-9-3:   Geology along the 574 m exploration crosscut, Spruce Point Cu-Zn deposit.

Figure GS-9-4:   *Rock geochemical sample locations along the 274 m, Spruce Point Cu-Zn deposit.*

felsic fragmental to a fragment-supported rhyolite to a near massive white rhyolite (Fig. GS-9-6). This feature is interpreted to represent autobrecciation with minor reworking of the rhyolite fragments. An aquagene breccia origin for the fragmental rhyolite is not rejected although the absence of an alteration rind on any of the rhyolite fragments is unusual. Fine grained, silicified tuff is intercalated with the rhyolite breccias; a weakly quartz-phyric rhyolite dyke intrudes the footwall rhyolites on the 574 m level. Lithologic boundaries assigned to the footwall rhyolites are based on size and abundances of fragments; some boundaries may be considered arbitrary.

(iii) Fine-to medium-grained mafic intrusions

Fine- to medium-grained, unaltered, nonmineralized mafic units are intercalated with the rhyolites. These units are dark green to black, generally structureless and featureless and somewhat enigmatic. The intrusions may be massive to foliated and discordant to the foliation with the rhyolite at the rhyolite/intrusion contact. An increase of 22° in the dip of the foliation of the rhyolite at the rhyolite/mafic intrusion contact on level 274 (Fig. GS-9-2) suggests deflection of the foliation around the intrusion. An approximate 1 m zone of disseminated pyrrhotite occurs in strongly foliated to fissile rhyolite at the contact between the mafic intrusion and rhyolite on the 574 m level. Pyrrhotite is uncommon in the deposit and this disseminated mineralization is interpreted to represent sulphide mobilizate at an intrusive boundary.

(iv) Near solid to solid sulphides

The Four Zone massive sulphide orebody is characterized by a medium grained mineral assemblage of pyrite, sphalerite and chalcopyrite. The recrystallized orebody contains remnants of finer grained laminated pyrite and sphalerite, as well as partially assimilated rhyolitic fragments now altered to sericite schist. Siliceous cherty fragments are visible in ore equivalent wallrocks on the 574 m level (Fig. GS-9-7) and reflect the less intense alteration history that has affected the host rocks away from the main mineralized zone. The wallrock/sulphide contact is marked by intense sericitization and locally abundant green and black chlorite. Disseminated, up to 40 per cent pyrite ± sphalerite and chalcopyrite, and solid pyrite layers 4 to 5 cm thick occur within 15 to 20 m of the orebody.

ALTERATION

The rhyolite host rocks have been altered by fluids that ultimately were responsible for the formation of the Spruce Point deposit. This alteration appears as overlapping and interfingering zones of sericitization, chloritization, silicification and sulphidization.

Sericite ± fuchsite is developed asymmetrically about the No. 4 zone, although the asymmetry is in part related to the truncation of the stratigraphic hangingwall succession by a fine grained mafic intrusion. In proximity to the mineralized zone green and black "fish scale" and

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LEGEND

Massive rhyolite

Rhyolite breccia ("Fragmental"rhyolite)
± sericite, chlorite, sulphide

Sericitc –chloritic–sulphidic rhyolite
(probable fragmental, locally gneissose)

Fine grained mafic rock (includes dykes and
"basalt")

Rhyolite dyke

05011
Geochemical chip sample

05039
05038
05037
05036
05035
05034
05033
05032
05030
05029
05031
05028
05027 (2)
05026
05025
05024
05023
05022
05021
05020
05019
05018
05017
05016
05015
05014
05013
05012
ORE
EQUIVALENT
05011
05010
05009
05008
05007
05006
05005
05004
05003
05002
05001

Figure GS-9-5: Rock geochemical sample locations along the 574 m exploration crosscut, Spruce Point Cu-Zn deposit.
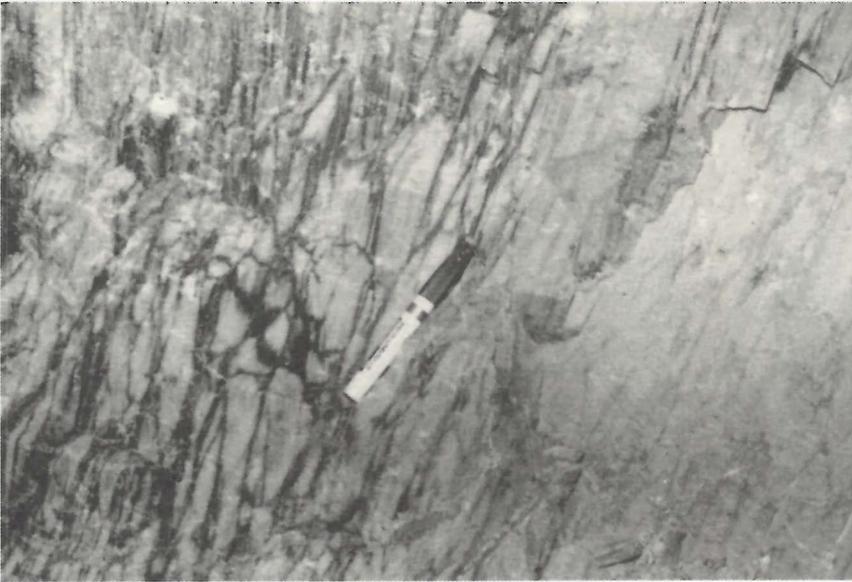
Figure GS-9-6: *Brecciated to massive aphyric, fine grained rhyolite, 574 m exploration crosscut, Spruce Pont Cu-Zn deposit.*

Figure GS-9-7: *Partially assimilated sericitic rhyolite fragments in near solid sulphide (NSS) pyrite ± chalcopyrite, sphalerite mineralization, 574 m exploration crosscut, Spruce Point Cu-Zn deposit.*

veinlet Fe- and Mg-rich (?) chlorite are abundant. On the 274 m level, a 7 to 9 m wide zone of 5 to 7 cm thick black chlorite-chalcopyrite veins are developed in a grey fragmental rhyolite. This zone is interpreted to represent a portion of the mineralizing conduit network for the deposit and represents the most intensely altered portion of the wallrocks examined on both the 274 m and 74 m levels. Silicification appears to be restricted to the outer limits of the alteration envelope. It has effectively homogenized the felsic fragmental rocks within the alteration zone producing a fine grained massive rhyolite that can be traced into an unaltered fragmental equivalent.

STRUCTURE

The Spruce Point Cu-Zn deposit occurs within an overturned sequence of felsic volcanic rocks that dip moderately to steeply to the east and strike northeast. Deflections in the dip of the foliation of the wallrocks are documented along both the 274 m and 574 m exploration crosscuts. On the 274 m level a 22° deflection in the foliation (50 to 72°) is attributed to the intrusion of a fine- to medium-grained mafic rock. A general steepening of the dip of the foliation in the wallrocks is documented from the 574 m exploration crosscut (Fig. GS-9-4). This steepening is developed over a 7 to 9 m wide zone in proximity to a tightly folded, intercalated sericitic rhyolite-sulphide layer (Fig. GS-9-8) reminiscent of

parasitic folds that occur on the flanks of larger scale fold structures. The folded sericitic rhyolite-sulphide layer represents the stratigraphic equivalent to the orebody. An "S" folded fine grained mafic dyke occurs within rhyolite breccia on the 274 m level (Fig. GS-9-9).

A well developed lineation is present in the rhyolite breccia. Rhyolite fragments have been deformed to produce approximate 20:1 length to width ratios. The deformation that produced the lineation has also rotated the alteration conduit so that it is close to subparallel to the Four Zone orebody on the 274 m level.

DISCUSSION

The Spruce Point Cu-Zn deposit may be classified as a massive sulphide type deposit with an associated footwall alteration zone developed within rhyolite breccias. The host rocks have been variably altered to sericite-chlorite-sulphide mineral assemblages in proximity to the various ore lenses; continuous sampling profiles through the hangingwall-footwall section (Fig. GS-9-4, GS-9-5) will be used to document the geochemistry and mineralogy of this mineralization-related alteration. The alteration appears to be most extensively developed in footwall rocks, although hangingwall rocks are sericitic and contain disseminated iron sulphide minerals and ghosts of rhyolitic fragments. This is a clear indication of ongoing seafloor fumarolic activity subsequent to the deposi-

Figure GS-9-8: *Parasitic "M" style folds in layered sericite (white) - pyrite (grey), 574 m exploration crosscut, Spruce Point Cu-Zn deposit.*

tion of the main sulphide lens. The presence of partially assimilated rhyolite fragments within the sulphide ore indicates that the mechanism for sulphide deposition probably includes a component of replacement of rhyolite detritus in a basin setting that was receiving metal-charged brines from either a single hydrothermal conduit or a series of conduits. The presence of multiple sulphide ore lenses, each with distinctive metal contents (Cu-Zn, Cu-Au, Cu, Zn-rich) and the relatively small size (?) of the hydrothermal conduits may support a multiple conduit plumbing system depositing a sulphide lens. Subsequent to deposition, deformation may have produced multiple lenses from a single original lens and rotated the originally discordant footwall alteration pipes into near concordancy, as observed on the 274 m level. Alternatively, the distinctive metal contents in the sulphide lenses may indicate the lenses represent discrete orebodies associated with its own feeder system.

A key element to the understanding of residual base metal exploration potential in the Reed Lake area is an appreciation of the structural characteristics of the deposit host rocks. Repetition of pyrrhotite-graphite "markers", parasitic style folds and "S" folded mafic dykes have been cited as evidence to support the presence of an anticlinal or synclinal structure in the area and the localization of the deposit on one limb of this structure. The location of the deposit and its enclosing wallrocks beneath 3 m of Ordovician dolomitic limestone makes the structural geological interpretation of this deposit critical for exploration purposes. It is hoped that the logging of drill core in and around the deposit and further synthesis of data acquired this season will clarify these relationships.

ACKNOWLEDGEMENTS

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Mineral Inventory Card 63K/9, Cu1 Manitoba Energy and Mines, Minerals Division.

Figure GS-9-9: *S-folded mafic dyke in silicified rhyolite breccia, 574 m exploration crosscut, Spruce Point Cu-Zn deposit.*

GS-10 THE GEOLOGICAL SETTING OF THE ROD AND BEE ZONE CU-ZN DEPOSITS, SNOW LAKE AREA, MANITOBA (NTS 63O/4)

by M.A.F. Fedikow, C. Malis[1], A. Lebedynski[1] and K. Cooley[2]

INTRODUCTION

As part of the Federal Government EXTECH program, currently underway in the Snow Lake area, detailed mapping was undertaken in the immediate area of the Rod Cu-Zn deposit. The geological base produced from this project will serve as input for the spatial analysis of multiple data sets from the region and will complement previous geochemical studies centered on the Rod deposit since 1986 (cf. Fedikow, 1986; Fedikow and Amor, in press; Ferreira and Fedikow, 1988, 1990).

The Bee Zone Cu-Zn deposit represents one of the few Cu-Zn occurrences documented from rocks in the Herblet Lake Gneiss Dome Complex. As such, a detailed geology map of the general area of the occurrence was constructed to ascertain the nature of this mineralized zone and whether significant alteration accompanies the mineralization at surface. A detailed geologic reconstruction of the Bee Zone based upon diamond drill holes is currently under preparation and will form part of an upcoming mineral deposit series report for the Wimapedi Lake area, NTS 63O/4.

Rod-Cu-Zn Deposit

The Rod deposit is a complexly deformed volcanogenic massive sulphide type deposit hosted by quartz-phyric felsic pyroclastic volcanic rocks. Mineralization is contained in two zones. Zone 1 comprises a lens of near solid to solid pyrite, chalcopyrite, sphalerite and arsenopyrite that strikes N28°E, has a 40° to 45° northwest dip, and a plunge of 32°E. The lens had a maximum length of 67 m and a variable width of 0.6 to 7.6 m. The No. 2 ore zone contained 60 to 90 per cent solid and disseminated sulphides including pyrite, chalcopyrite, sphalerite, pyrrhotite, arsenopyrite, galena and marcasite. This lens had a length of 533 m with an average thickness of 3.65 m and a width of 46 to 61 m. The zone is concordant to the host rocks, dips 50° to 60° northwest and plunges 25° to 30° at 25°E. The predominant style of alteration at the

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deposit is pervasive, fracture-fillings and coarse grained mosaics of carbonate. The No. 1 ore zone contained 22 680 tonnes grading 5.0 per cent Cu and 4.5 per cent Zn. The No. 2 ore zone contained 412,600 tonnes grading 7.21 per cent Cu and 3.0 per cent Zn. The deposit does not outcrop, and the vertical depth to the No. 2 ore zone on the southern end is 183 m, and on the northern end is 732 m. The most recent publication describing the deposit is that of Coats et al. (1970).

A 1 km long baseline with pickets at 30 m intervals was established over the geophysical expression of the deposit. Picket lines were 365 m long on either side of the baseline. Outcrop was located and mapped using standard pace and compass techniques.

Owing to the lichen and moss covered outcrop, mapping is not complete. The project will be continued in 1991 with the release of a geology map accompanied by the results of a rock geochemical survey undertaken in the area of the deposit.

Bee Zone Cu-Zn Deposit

The Bee Cu-Zn deposit is a 600 m by 3 m zone of disseminated and veinlet pyrite, pyrrhotite, sphalerite and chalcopyrite that occurs in oligoclase-quartz granitoid gneisses on the western flank of the Pulver Lake gneiss dome, part of the Herblet Lake Gneiss Dome Complex (Bailes, 1975). Rusty weathered oligoclase- quartz gneiss has been mapped in the general area (Fig. GS-10-1, GS-10-2) and these zones have been tested by trenches. During mapping of the study area these trenches (Fig. GS-10-2) were systematically sampled (Fig. GS-10-3) for base and precious metal analysis.

The general area is characterized by north-trending, steeply east dipping white- to light grey-granitoid gneiss, unaltered and rusty weathered and silicified amphibolite gneiss and salmon pink granitoid gneiss. White and pink pegmatite dykes intrude each of these units. Although the bulk of the alteration in the area occurs in the amphibolite
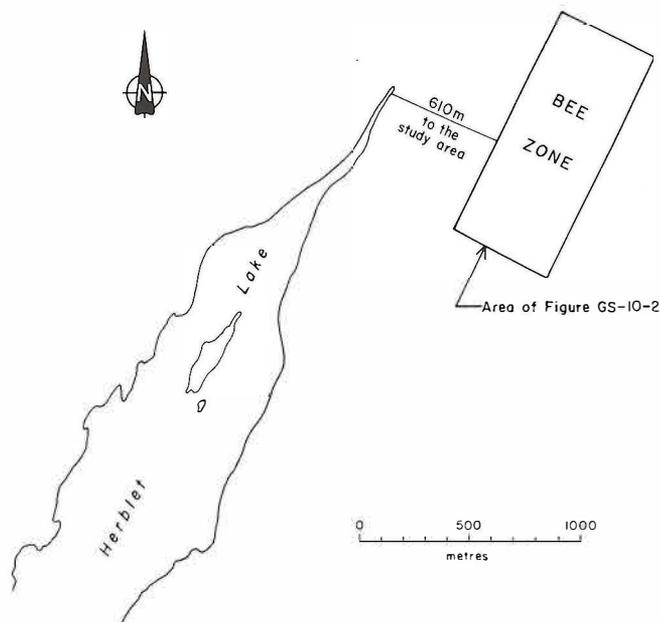
Figure GS-10-1: Location map for the study area, Herblet Lake.

LEGEND

White to light grey granitoid gneiss (C1)

Unaltered amphibolite gneiss (C2)

Variably altered (rusty weathered±silicification) amphibolite gneiss (C2)

Pink granitoid gneiss (C3)

White/pink pegmatite

× Outcrop/small outcrop

80 Gneissosity (inclined, dip unknown)

Geological boundary

Trench

△ Rubble

Swamp

0   50   100   150   200
metres
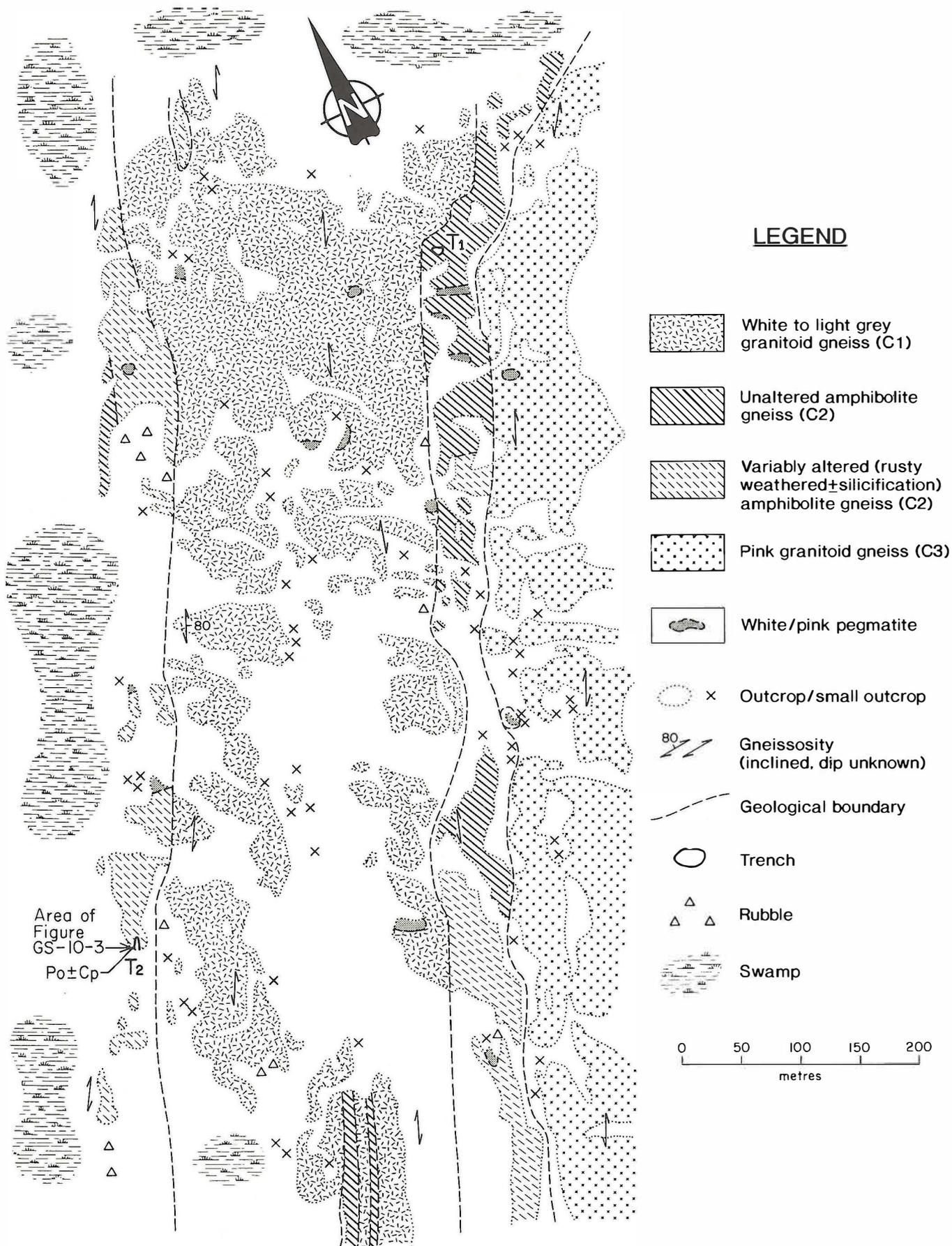
Figure GS-10-2: Detailed geology in the area of the Bee Zone.
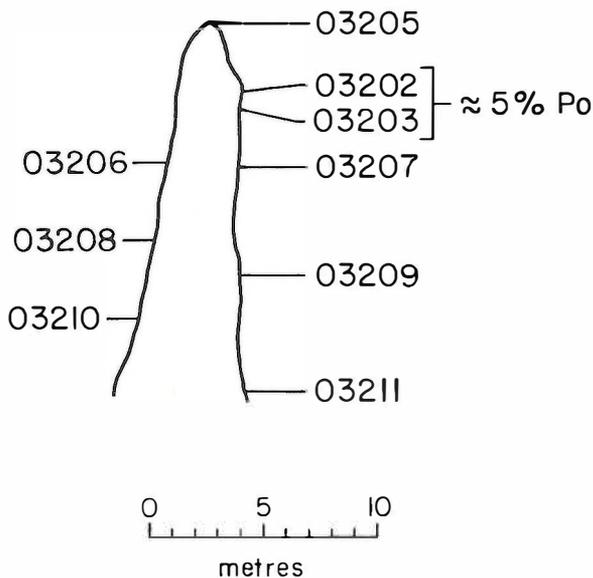
Figure GS-10-3:   Sample locations in Trench 2, Bee Zone.

gneiss, numerous long (>50 m), sinuous, rusty weathered zones with 1 to 5 per cent disseminated pyrite and 1 to 2 cm red garnets are common in the granitoid gneiss.

Diamond drill holes, collared to test long and short strike length ground EM geophysical conductors in the area, intersected up to 90 per cent graphite with disseminated chalcopyrite and diffuse zones of disseminated pyrite, pyrrhotite, sphalerite and chalcopyrite. The host rocks to these mineralized zones are described as rusty weathered and quartz-rich gneisses. Abundant quartz-feldspar segregations are present in the granitoid gneisses near the mineralized zones.

The Bee Zone Cu-Zn deposit is considered to represent sulphide mobilizate associated with granitized granitoid gneisses. The disseminated and veinlet iron and base metal sulphide minerals may have been derived from the graphite-iron sulphide chemical sediment type deposits that occur in the area.

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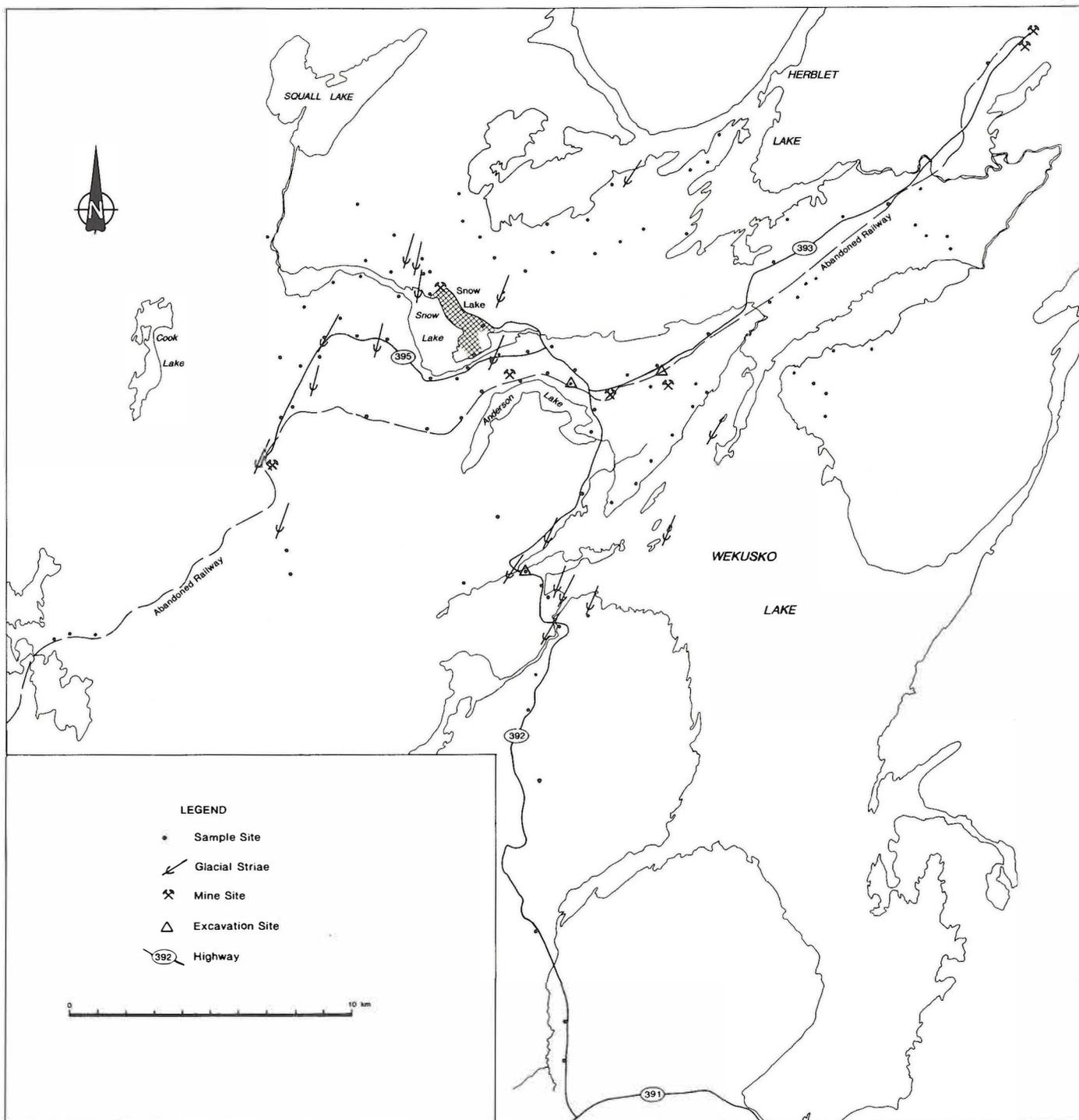
Figure GS-11-1:   Sample location map.

GS-11 TILL GEOCHEMISTRY OF THE SNOW LAKE AREA
(NTS 63K/16, 63J/13, 63J/12)

by G. Gobert

INTRODUCTION

Regional till sampling was initiated in the Snow Lake area as part of the Exploration Science and Technology (EXTECH) project being implemented by the Mineral Resources Division of the Geological Survey of Canada. The goal of the EXTECH program is to develop mineral deposit models and exploration concepts through multi-disciplinary data integration. The surficial geochemistry contribution involves establishing the geochemical character of surficial materials and mapping the size and shape of till geochemical dispersal anomalies associated with base metal mineralization.

Regional sampling, from hand-dug pits, covered parts of 63K/16, 63J/13, and 63J/12. A total of 130 samples from 108 locations were collected along roads, railways, powerlines, fire breaks and lakes, (Fig. GS-11-1). Sample size averaged 7 kg of till from pits varying in depth between 0.15 and 1.0 m. 114 samples of "C" horizon till were collected. 16 "B" horizon samples were taken at locations where well developed "B" and "C" horizons were present.

Detailed sampling from hand-dug pits and backhoe excavations were conducted by C.A. Kaszycki (GSC) near known base metal deposits and at sites of thick till accumulation. Till fabric analysis was conducted at two backhoe excavations to determine the ice flow direction associated with till deposition, and to attempt to identify tills of different provenance.

SURFICIAL GEOLOGY

Glaciolacustrine clay and coarser proglacial sediments blanket much of the area. At elevations below 275 m, these sediments constitute the predominant surficial material with a thickness often excceding 5 m. At elevations above 305 m, clay is thin or absent. Nearshore sand and gravel commonly flank bedrock ridges with accumulations exceeding one metre.

Till is 'commonly' visible along road or rail cuts and thick sequences occur at several locations, (Fig. GS-11-2). Generally, the till is thin (< 1 m), mantling bedrock ridges or draping the lee-side of bedrock knolls, and is 'commonly' covered by a veneer of clay or nearshore sand and gravel. At elevations above 305 m, till is often exposed at the surface.

Striations in the northern and central regions of the area record ice flow between 190° and 215°, averaging 205°. A Paleozoic outcrop along Hwy. 391 near the southern margin of the study area records multiple ice flow directions, with a predominant direction of 210°. This direction approximates the regional striae found in the northern and central portions of the area.

GEOCHEMICAL ANALYSIS

Geochemical analysis will focus on the < 2 micron and the < 63 micron fractions. Atomic absorption analysis of the < 2 micron fraction will involve V, Cr, Mg, Fe, Co, Ni, Cu, Zn, Mo, Ag, Cd, Pb, As, and Hg. Geochemical analysis of the < 63 micron fraction has not been finalized at this date. Carbonate determination of the < 63 micron fraction using the Leco Induction Furnace will be used to aid in establishing till provenence and to augment stratigraphic studies.

Petrographic examination of the heavy mineral fraction will be performed on heavy mineral concentrates (S.G. > 2.96) being prepared by Overburden Drilling Management Ltd.

Figure GS-11-2:   Till exposure along roadcut.

Legend:

- Quartz–feldspar porphyry, granodiorite
- Hornblende metagabbro, metadiorite
- Rhyolite, porphyritic dacite and minor intrusive equivalents
- Mafic to intermediate volcanic rocks: pillow lava with interbedded pyroclastic rocks

Geology by: Bateman, J.D. and Harrison, J.M. (1945)
Tanton, T.L. (1941)
Bailes, A.H. and Syme, E.C. (1987)

- #3 — North Star
- #4 — Don Jon
- #5 — Pine Bay
- #6 — Baker Patton
- #11 — Leo Lake
- #23 — Cabin Zone
- #24 — Bryan Lake

Detailed map area

Alberts Lake

Thompson Lake

Bryan Lake

Sourdough Bay

Athapapuskow Lake

0 1 2 3
Kilometres
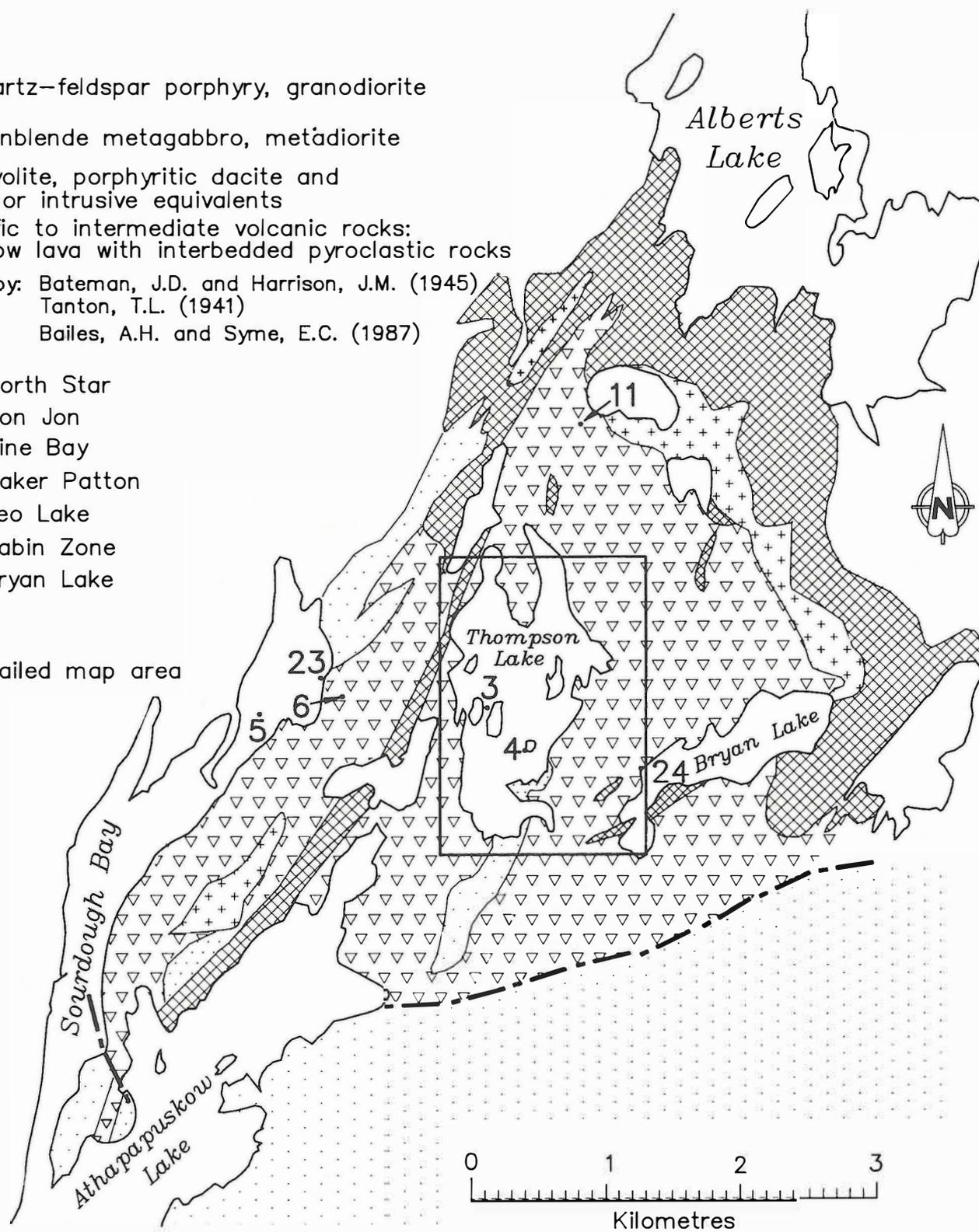
Figure GS-12-1: Distribution of mineral occurrences in the Baker Patton felsic complex.

GS-12 GEOLOGICAL SETTING OF BASE METAL MINERALIZATION IN THE BAKER PATTON FELSIC COMPLEX, FLIN FLON AREA (NTS 63K/13)

by L.I. Norquay and G.H. Gale

The Baker Patton Felsic Complex (Fig. GS-12-1) is the largest exposed mass of felsic volcanic rocks in the Flin Flon area. Detailed maps prepared for the Baker Patton and Lee Lake areas within the Complex reveal previously unknown complications of the local geology that have a direct bearing upon the interpretation of past exploration programs in these areas (Gale and Foote, 1989; Ferreira, 1988). As a result of difficulties in the interpretation of the geological setting of the North Star and Don Jon deposits (Gale and Eccles, 1988a, 1988b), a program to systematically map the remainder of the Complex at 1:5000 scale was initiated this year.

The six week program was directed mainly towards outlining major lithologic units and the stripping and javexing of exposures for future studies. Although it is premature to draw any indepth conclusions from the studies conducted to date, several units have been recognized and delineated (Fig. GS-12-2) but relative stratigraphic relationships are considerably more complex than that depicted by Gale and Eccles (1988a, 1988b).

A 400 m thick unit of quartz- and feldspar-phyric (rhyolitic) pyroclastic rocks is exposed on a number of islands in Thompson Lake, as well as on the mainland near the northeast shore of Thompson Lake and on
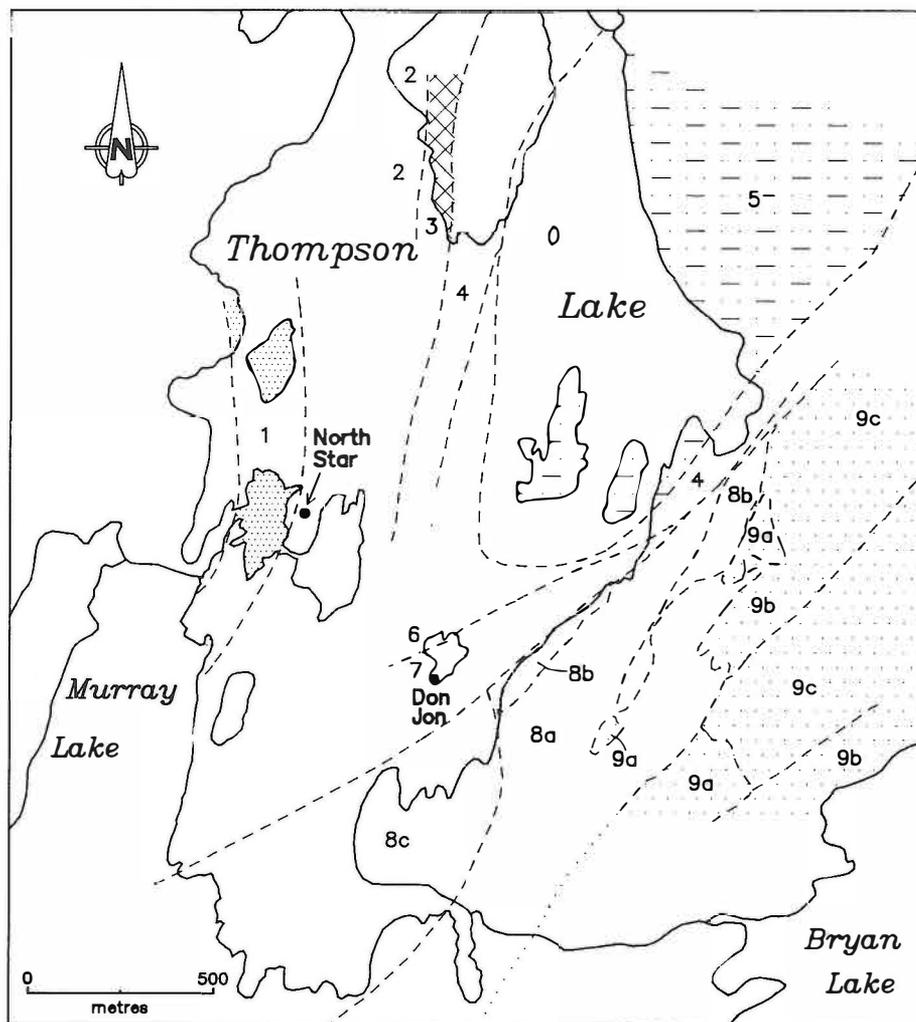
Figure GS-12-2: *Geology of the Thompson Lake area. Legend: 1. Rhyolite, aphyric, microbreccia with vesicular white rhyolite lobes and massive rhyolite; 2. Rhyodacitic flow, aphyric, pale green, amygdaloidal; 3. Rhyolite flow(s) quartz-phyric, pumiceous, flow breccia, ± amygdaloidal; 4. Rhyolitic tuff, layered, in part quartz-phyric (<1% quartz phenocrysts); 5. Quartz-rich pyroclastic rocks, <1-4 mm quartz and/or feldspar crystals, in part layered; 6. Basaltic flow, amygdaloidal; 7. Rhyolitic flow and tuff (waterlain?), in part rhyolite breccia; 8. Rhyolite, (a) aphyric, pumiceous, (b) breccia (reworked?), (c) massive, amygdular; and 9. Rhyolite flows, (a) feldspar-phyric, (b) quartz phyric, (c) feldspar-phyric.*

the eastern shore of the northern peninsula (Fig. GS-12-2). Locally this unit contains poorly defined layers that are distinguished by variable quartz and/or feldspar phenocryst contents. The unit is composed of <1 to 5 mm angular, broken quartz phenocrysts (5-20%) ± coarse feldspar phenocryst fragments (≤2%) in a fine ash felsic matrix. Rare lithic lapilli (≤1 cm) were noted. Elsewhere, especially towards the southeast, this unit consists of breccia fragments in a matrix of pyroclastic tuffaceous material. Towards the northeastern extremity of this unit the quartz-phyric tuffaceous rocks are interbanded with aphyric rhyolitic rocks. In general, the northwestern portions of this unit exhibit a greater degree of layering than in the southeast. The reason for the abrupt termination of this unit immediately north of the Don Jon deposit is not known. Immediately west of the above unit, there is a rock with smaller (≤1 mm) and lesser (<5%) broken quartz phenocrysts,, but it is not known if this western unit is related to the quartz-rich felsic pyroclastic rocks. The unit is extensively chloritized and is a dark green to pale green on fresh surfaces. The intensity of alteration tends to decrease towards the north.

A thick unit of rhyolitic flows and pyroclastic rocks occurs immediately east of the Don Jon deposit (Fig. GS-12-2). This unit is characterized by locally abundant, several meter thick layers with lapilli felsic rock fragments. The lithic fragments can range up to 15 cm but are usually less than 3 cm in length. These fragments are usually aphyric, but do have rare subhedral quartz phenocrysts. The matrix is aphyric to very fine grained and contains lithic fragments, feldspar and rare quartz grains. Chloritization of the matrix ranges from pervasive alteration throughout the matrix to a weakly chloritized, pale green, siliceous matrix.

Other exposures of this unit consist of microbrecciated rhyolite with a pitted rough weathered surface.

The easternmost part of the map area contains a thick sequence of aphyric to slightly quartz- and/or feldspar-phyric felsic flows and pyroclastic rocks. The quartz and feldspar phenocrysts (≤1 mm) are euhedral to subhedral and compose ≤3 per cent of the rock. Alteration ranges from a slight yet pervasive chloritization to undulating chlorite veins in the foliation or cleavage.

West of the North Star deposit there is a well exposed 100 m thick unit of rhyolite. This unit is composed predominantly of microbrecciated rhyolite and 1 to 2 m thick massive white to buff amygdaloidal rhyolite lobes. Some parts of the flow are pumiceous. This unit probably represents a single rhyolite flow.

At the south end of Thompson Lake there are a number of units of pale green aphyric massive rhyolitic rocks with scattered to abundant gas cavities (1.0-10 cm). Some of these may represent rhyolitic sills/dykes, but locally flow contacts and flow top breccias were recognized. The unit appears to grade towards the east into amydaloidal (quartz amygdales) rhyolitic flows with pumiceous sections. Alteration in this unit varies from weak chloritization on the south shore of Thompson Lake to strong, pervasive chloritization, with black chlorite partially filling the gas cavities, immediately to the south/southeast of the Don Jon deposit. Carbonatization of this unit is pervasive as evidenced by abundant 2 to 5 mm reddish carbonate crystals.

Outcrops on Don Jon island, which were recently cleaned by Minnova Corporation, contain a unit of waterlain tuffaceous rocks with scour channels that indicate the sequence tops to the southeast. Gas cavities with flattened bases and rounded tops in rhyolite flows south of the Don Jon deposit indicate that locally the flow tops are towards the northwest.

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GS-13 MINERAL INVESTIGATIONS IN THE NORTH STAR LAKE AREA
(NTS 63K/15)

by G.D. Trembath, L.I. Norquay and G.H. Gale

INTRODUCTION

The 1989 forest fires provided new outcrops in the North Star Lake area. Previous exploration indicated several areas with the potential to contain massive sulphide type deposits (A.F. 90488, 90489, 91607, 91608, 92828), as well as a large number of known gold occurrences (Stockwell, 1935). Airphoto coverage at 1:5000 scale was obtained at the start of the field season and a portion of the area was mapped at 1:5000 scale during a six week period (Preliminary Map 1990F-2).

The area mapped (Fig. GS-13-1) is underlain predominantly by felsic and mafic volcanic rocks. Other lithologies include pyroxenite and amphibolitic dykes and granodiorite. South and west of the map area supracrustal rocks have been intruded by a large felsic pluton (McGlynn, 1959).

RHYODACITIC ROCKS

This felsic volcanic unit is a thick sequence of fine grained rocks that vary from aphanitic, pinkish, massive rhyolitic rocks to layered, felsic rocks with variable biotite and quartz contents. Layering in the unit is generally indistinct, but locally is easily distinguished on the basis of colour variations. Quartz and feldspar are generally <0.5 mm, but locally quartz ± feldspar phenocrysts are up to 1 mm. This unit has been subdivided on the basis of textural features and/or composition.

Rhyolitic rocks

These white-grey to faintly pinkish and in some locations reddish stained, fine-grained (0.1-0.5 mm) volcanic rocks form a thick sequence in the southern part of the map area (Preliminary Map 1990F-2).
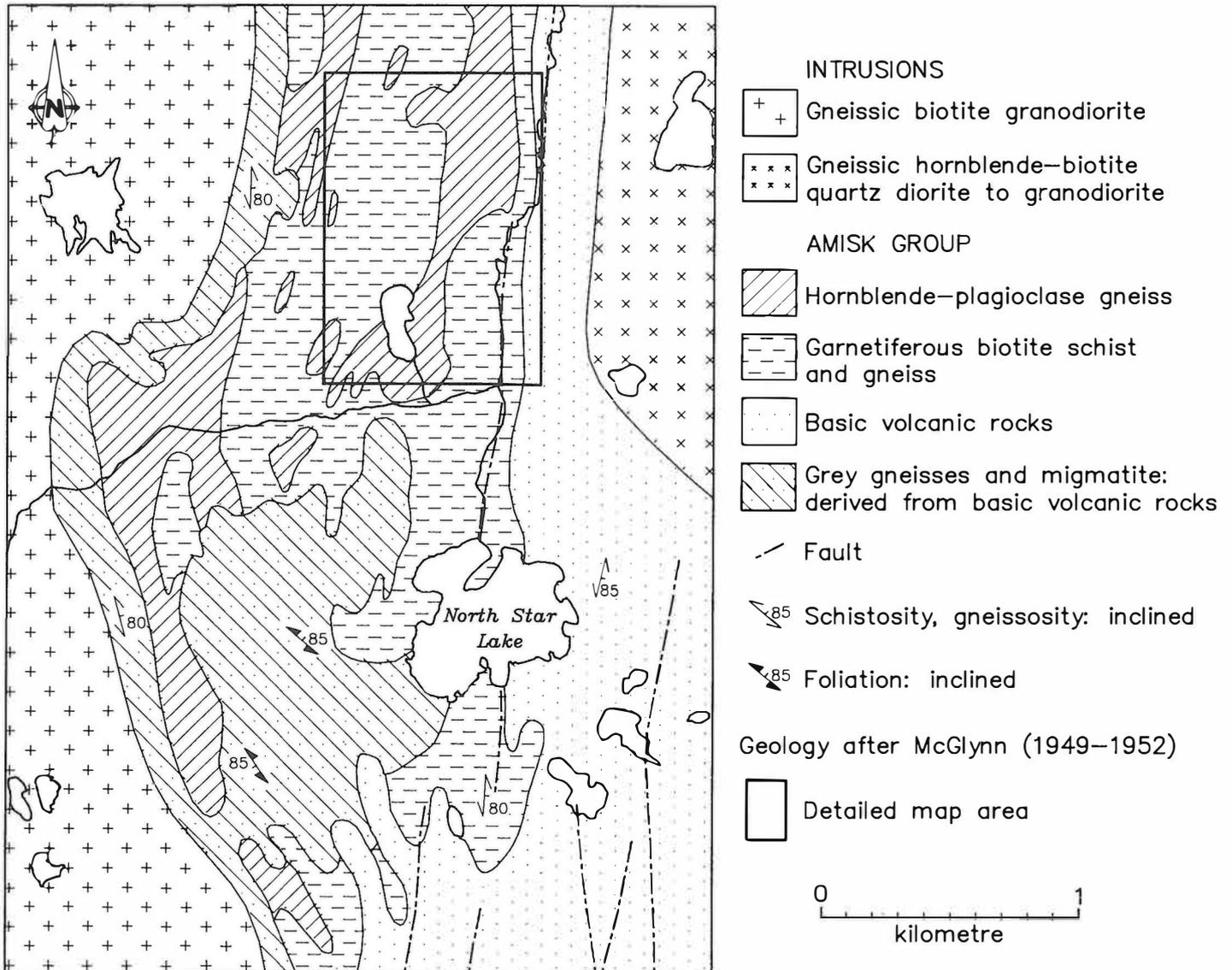

Figure GS-13-1: *General geology of the North Star Lake area (after McGlynn, 1949).*

Layering is indistinct, but locally can be distinguished on the basis of colour and variations in biotite and garnet contents. Layers range from less than 1 m to several metres thick.

These rocks are predominantly feldspathic, and generally have quartz to feldspar ratios of 1:2 to 1:4. Biotite, which varies from 2 to 5 per cent, occurs as fine grained, disseminated, flecks that grade into wisps and thin bands; some biotitic concentrations contain quartz and/or feldspar phenocrysts ($\leq 3\%$, ≤ 1 mm). Garnet ($\leq 3\%$) occurs at numerous locations as pinhead garnets (≤ 1 mm) or as metacrysts up to 5 mm. Trace magnetite (≤ 1 mm) occurs locally.

Locally within this subunit, there are areas hundreds of metres in length and tens of metres in width, that are rusty weathered and are a distinctive reddish brown. In general, the rusty weathered zones do not appear to be restricted to any particular layer, but can be followed intermittently along compositional layers.

Biotite-rich volcanic rocks

This unit is a thick sequence of grey to buff brown, fine grained, rhyodacitic/dacitic volcanic rocks. The unit ranges from massive and homogeneous to indistinctly layered. The layers are distinguished by variations in colour and mineralogy over thicknesses of < 1 m to several metres. Locally, there are rusty weathered areas that follow the layers and contain fine grained biotite, chlorite, muscovite, and coarse grained garnet. The predominantly feldspathic groundmass has a grain size that is ≤ 0.5 mm and a quartz to feldspar ratio that varies from 1:3 to 1:4. Biotite (5-12%) occurs as fine grained disseminated flecks, wisps and thin bands. Orange red garnet ($\leq 8\%$) varies from minute pinhead garnets (≤ 1 mm) to metacrysts (polygranular?) up to 7 mm.

Laminated rhyodacitic rocks

These grey to cream rocks range in composition from feldspathic ($< 5\%$ biotite) to biotitic ($\leq 10\%$) and garnetiferous ($\leq 1\%$). Biotite occurs as wisps that grade into thin laminations. The more massive areas have a strong, widely spaced cleavage. On the west side of the small lake (Preliminary Map 1990F-2) the biotite-rich garnetiferous unit is gradational into the laminated unit.

Tuffaceous rocks

Layered tuffs, or sedimentary rocks, occur in the southwestern portion of the map area as xenoliths within the granodioritic intrusion. The layers are folded in contorted irregular patterns, but are easily recognizable. Individual beds are 1 to 5 cm thick, composed predominantly of feldspar and quartz and separated by biotite-rich laminae 1 to 8 mm thick (Fig. GS-13-1).

AMPHIBOLITIC ROCKS

Foliated amphibolite occurs throughout the rhyodacitic unit as several tens of centimetres to several tens of metres thick layers. Texturally, they vary from lineated massive amphibolite to irregular centimetre thick laminae. Locally, these rocks have a wispy texture defined by 1 by 15 mm white lenses that are deformed amygdales and/or plagioclase phenocrysts.

Although generally parallel to the foliation and layering in the rhyodacitic unit, the amphibolites also occur as slightly discordant sills and/or dykes. The amphibolites occur very uncommonly in the rhyolitic unit that structurally overlies the basaltic unit (Preliminary Map 1990F-2). Therefore, the amphibolites are interpreted to be genetically related to the immediately overlying basalt unit (see below) and to represent mafic tuffs, mafic flows or feeder dykes. Definitive volcanic textures were not observed in these amphibolites.

BASALTIC ROCKS

This unit consists of massive to amygdaloidal basaltic flows, pillowed basaltic flows, amphibolites derived from deformation of flows, fragmental basaltic rocks, tuffaceous rocks and banded iron formation. Locally, the unit is up to 300 m thick.

Basaltic flows

Massive, amygdaloidal and pillowed basaltic flows occur through-out the basaltic rock unit. Massive flow contacts are difficult to distinguish even where flows are bounded by tuffaceous or fragmental rocks, but flows of 10 to 20 m thickness were outlined. Pillowed flows, 3 to 20 m thick, which occur throughout the northern half of the map area, are interlayered with massive and amygdaloidal flows.

Massive flows and amphibolites are dense, fine grained, dark grey to black, foliated and locally have a penetrative lineation. The rock consists of 50 to 80 per cent amphibole, 20 to 45 per cent plagioclase and < 5 per cent quartz.

Amygdaloidal flows resemble the massive flows, but contain 5 to 35 per cent subrounded white amygdales. Locally, they grade into massive basalt. A 3 to 15 m thick massive grey amygdaloidal flow can be followed along strike for a considerable distance (Preliminary Map 1990F-2). The amygdaloidal flows have a mineralogical composition similar to the massive flows, but in addition the amygdales are composed of plagioclase, quartz and minor biotite or amphibole.

Pillowed flows have distinct to indistinct pillow outlines that vary from a few tens of centimetres in diameter to 0.2 by 4.0 m lenses outlined by 1 to 3 cm thick darker coloured rims. Locally the pillowed flows contain epidosite altered pillow cores and epidosite lenses tens of centimetres in diameter.

Tuffaceous rocks are distinguished on the basis of indistinct layers. A mafic lapilli tuff, which underlies the grey amygdaloidal flow, is composed of graded beds. A sequence of 1 to 5 cm thick tuffaceous layers of variable composition is associated with a banded iron formation.

FRAGMENTAL BASALTS

At the northern limits of the map area there is a transition from basaltic rocks, through polymodal fragmental basalts to a fragmental andesitic/dacitic rock. This fragmental basalt consists of several units that vary from 3 to 20 m thick. Dacitic to andesitic fragments range from 1 by 3 cm to 10 by 60 cm and compose 25 to 50 per cent of the rock; basaltic fragments are less common. Some fragments are amygdaloidal or porphyritic textured. Most fragments, except those near or within fold hinges, are flattened. The fragments appear to be matrix supported. The matrix is fine- to medium-grained, black, amphibole-rich and has zones with feldspar phenocrysts or amygdales.

The andesitic/dacitic unit appears to be approximately 100 m thick and composed of several layers of flattened fragments that range in size from 0.5 by 8 cm to 3 by 80 cm and constitute 20 to 50 per cent of the unit by volume. The white to light grey fragments are very fine grained and rhyolitic to dacitic in composition. The fine grained matrix, which is darker than the fragments, contains less than 15 per cent biotite and twice as much feldspar as quartz.

BANDED IRON FORMATION

The banded iron formation (BIF) consists of two layers, 1 to 10 m thick, separated by 1 to 30 m of mafic tuffaceous rocks. It occurs at the stratigraphic top(?) of a mafic volcanic sequence. Individual layers within the bands range from 1 to 120 cm thick. Locally, the BIF layers are repeated by isoclinal folds. Compositional end members consist of: a) quartz; b) garnet (95%) - amphibole-chlorite-quartz; c) amphibole-chlorite $\pm$ quartz $\pm$ feldspar; d) magnetite (5-60%) - quartz; and e) green fibrous amphibole. A felsic layer that occurs in association with the BIF consists of plagioclase (50-90%), - quartz ($< 50\%$), - garnet ($< 5\%$), - acicular amphibole ($< 3\%$), - biotite ($< 10\%$), and - magnetite ($< 1\%$).

RHYOLITIC ROCK

This unit of rhyolitic rocks is light grey-white to faintly brown or pink and rarely contains rusty weathered rocks. It consists of near massive- to faintly-layered tuffs and massive rocks (possibly welded tuffs) with ovoid cavities that are up to 2 cm in length. The massive rocks, which are common in the northern portions of the unit, are homogeneous in appearance and foliated, but this is difficult to see due to a paucity of phyllosilicates. Outcrops towards the southern and eastern limits of this unit contain layers that are 1 to 10 cm thick. The layers are defined by recessive weathering patterns and subtle changes in biotite content. Outcrops were limited in the third dimension, but the foliation in many areas gives an impression of layers. The foliation planes range from 3 to 20

cm apart, but in some areas an anastomosing pattern is apparent, particularly with a decrease in the density of the foliation planes. These rocks have a grain size of 0.1 to 0.5 mm, are foliated and consist of 35 to 70 per cent feldspar, 20 to 50 per cent quartz, 2 to 5 per cent biotite, trace to 5 per cent garnets and locally, trace magnetite. Local zones and bands of the unit contain trace to 3 per cent, 0.5 to 2.0 mm quartz phenocrysts and/or trace to 1 per cent, <1 mm plagioclase phenocrysts.

Cavities within the massive rhyolite are smooth edged and only have a thin quartz lining in biotite filled cores. Carbonate aggregations, similar in shape to the cavities, were noted in several places on fresh surfaces of this rock. Other massive portions of this unit contain bands of biotite-rich clots (up to 6 cm long) that may represent thin mafic tuff beds, clay beds, or exotic inclusions.

PYROXENITE DYKE

A 10 m thick pyroxenite dyke, which occurs near the northern limit of the map area, has chilled margins and consists of 85 to 90 per cent hornblende pseudomorphs after pyroxene and <10 per cent feldspar and calcite.

LATE MAFIC DYKES

Fine grained dark green, mafic dykes, ranging from 10 cm to 10 m in width, postdate all structural and intrusive events recognized within the project area. They crosscut strata and foliation in a general westerly trend, but a few are subparallel to strata and foliation. They are not foliated and tend to have chilled margins. Compositional types noted are: a) fine grained dark green homogeneous amphibole dykes; b) fine grained dark green dykes with an amphibole-rich groundmass and 1 to 8 per cent equigranular plagioclase lathes, 3 to 30 mm in length, and trace to 15 per cent, up to 7 mm hornblende phenocrysts; and c) fine grained dark green dykes with an amphibole-rich groundmass and trace to 15 per cent, less than 7 mm rounded, white, plagioclase phenocrysts (altered?) and, trace to 10 per cent, less than 2 cm, clear, red stained, equigranular phenocrysts with good to perfect cleavage; the equigranular phenocrysts were not identified, but may be adularia or another K-feldspar.

GRANODIORITE

A large granodioritic intrusion, which occurs at the western limit of the mapped area, is probably the source of 1 to 3 m thick, irregular west-trending granodiorite dykes that cut the supracrustal rocks. This rock is massive, white to light grey, but has pink zones (potassic?) in the main intrusive body. The dykes consists of 10 to 35 per cent hornblende needles up to 6 mm long and finer grained hornblende interstitial to 85 per cent plagioclase and 5 per cent quartz. The main intrusion contains less than 10 per cent hornblende ± biotite interstitial to 60 to 75 per cent plagioclase (<3 mm), trace to 15 per cent K-feldspar (<1.5 mm) and 15 to 20 per cent quartz (<2 mm). It is crosscut by late mafic dykes, but intrudes all other units except the pyroxenite dyke (age relationship unknown). In some areas the intrusion contains up to 80 per cent xenoliths of layered tuffs/metasedimentary rocks. The margin of the intrusion is irregularly defined due to the variable portions of tuffs within the granodiorite. The xenoliths are folded, but are still recognizable as distinct lithologies. Rusty weathered zones were noted in some xenoliths.

ALTERATION AND MINERALIZATION

Small areas and bands of metamorphosed hydrothermal alteration occur within the rhyodacite. Biotite, chlorite, garnet, and staurolite, and less commonly, kyanite and ferrogedrite (pseudomorphosed by chlorite), were observed in zones of characteristically <5 mm wide anastomosing fractures. In other places, 0.3 to 10 cm wide bands and small areas with variable amounts of biotite (5-15%), staurolite (trace-10%), garnet (trace- 5%), chlorite (trace-3%), and feldspar more common then quartz, were observed within lithologic layers of more than 100 m in length and up to 5 m thick. Less than 2 mm clots, or platelets, of muscovite crosscut the main foliation of the rhyodacite, particularly near and within rusty weathered areas.

Staurolite occurs as small anhedral, light to dark brown grains, as well as flattened, euhedral, twinned grains up to 2 cm. Red almandine garnets up to 1 cm across, and less commonly a peculiar pinkish purple garnet less than 1 mm, occur in garnet-quartz aggregates. Biotite occurs as platelets up to 2 mm. Kyanite occurs as blades and knots less than 1 cm across; the colour is usually white to greyish-yellow; crystals of blue kyanite were observed at one location. Ferrogedrite occurs as clusters of needles less than 8 mm in length, but most appear pseudomorphosed by chlorite.

Rusty weathered zones, and bands were observed within the rhyodacite; trace to 1 per cent pyrite was rarely found within these areas. One small area with trace to 2 per cent pyrite and trace to 1 per cent galena occurs within late vuggy quartz fractures and appear to be mobilizate in fractures that crosscut foliation. Traces of chalcopyrite were seen in a zone of possible silicification within the basalt.

STRUCTURE

The most distinctive structural feature in the area is a strong penetrative foliation that is axial planar to isoclinal folds (F_1). This early deformation resulted in strong flattening of pillow lavas and extension of F_1 fold hinges within the regional schistosity (S_1). Refolding of S_1 during a second deformation event (D_2) produced abundant minor Z folds (F_2) and distinctly fewer S folds with wave lengths of <1 m to tens of metres. Some regional flattening appears to have been produced on the long limbs of these minor folds during the D_2 event.

Locally, especially in massive rhyolitic rocks with little or no micaceous minerals, there is a well developed cleavage/foliation that appears to postdate the F_2 fold event and represents a late D_2 event or a younger deformation.

Although top determinations were noted in a number of places, systematic structural observations were not made and consequently facing directions are not known.

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GS-14 DOCUMENTATION OF GOLD OCCURRENCES IN THE NORTH STAR LAKE AREA (NTS 63K/15)

by R. Pippert[1] and G.H. Gale

A major forest fire in the North Star Lake area during 1989 provided abundant new exposures and facilitated the location of old exploration activities (Stockwell, 1935; Ostry, 1985). Consequently, a four week program was undertaken as part of the systematic documentation of mineral occurrences within NTS 63K/15. Activities during this past season included: establishing the accurate location of old trenches on 1:5000 scale air photos; preparation of 1:100 scale sketch maps of selected sites; and a preliminary examination of the geological setting of mineralization. Detailed examinations of the geological settings of mineral occurrences will be undertaken during completion of the documentation in 1991.

The mineral occurrences documented during the 1990 field season are all gold-bearing quartz veins located east and southeast of North Star Lake (Fig. GS-14-1). These occurrences are located within an area of predominantly mafic volcanic rocks that include basaltic pillowed and massive flows, pyroclastic rocks and sills and small gabbroic intrusions (Fig. GS-14-1).

The rocks in the area have undergone intensive strain. Pillow lavas have been flattened within the plane of the regional foliation and exhibit length to thickness ratios of 20:1 and greater.

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The individual mineralized zones are variable and will be described in detail in a mineral deposit series report. Stockwell (1935) provides descriptions of a number of these occurrences. In general, the gold-bearing quartz veins have been deformed by boudinage and faulting into lozenge-shaped semi-continuous lenses. Initial studies indicate that the emplacement of the quartz veins postdated the regional flattening of the host rocks.

White to grey quartz veins contain 1 to 5 per cent pyrite and trace amounts of chalcopyrite; grains of native gold up to 1 mm in diameter were found in quartz rubble surrounding the old shafts at the Jupiter vein (Fig. GS-14-2).

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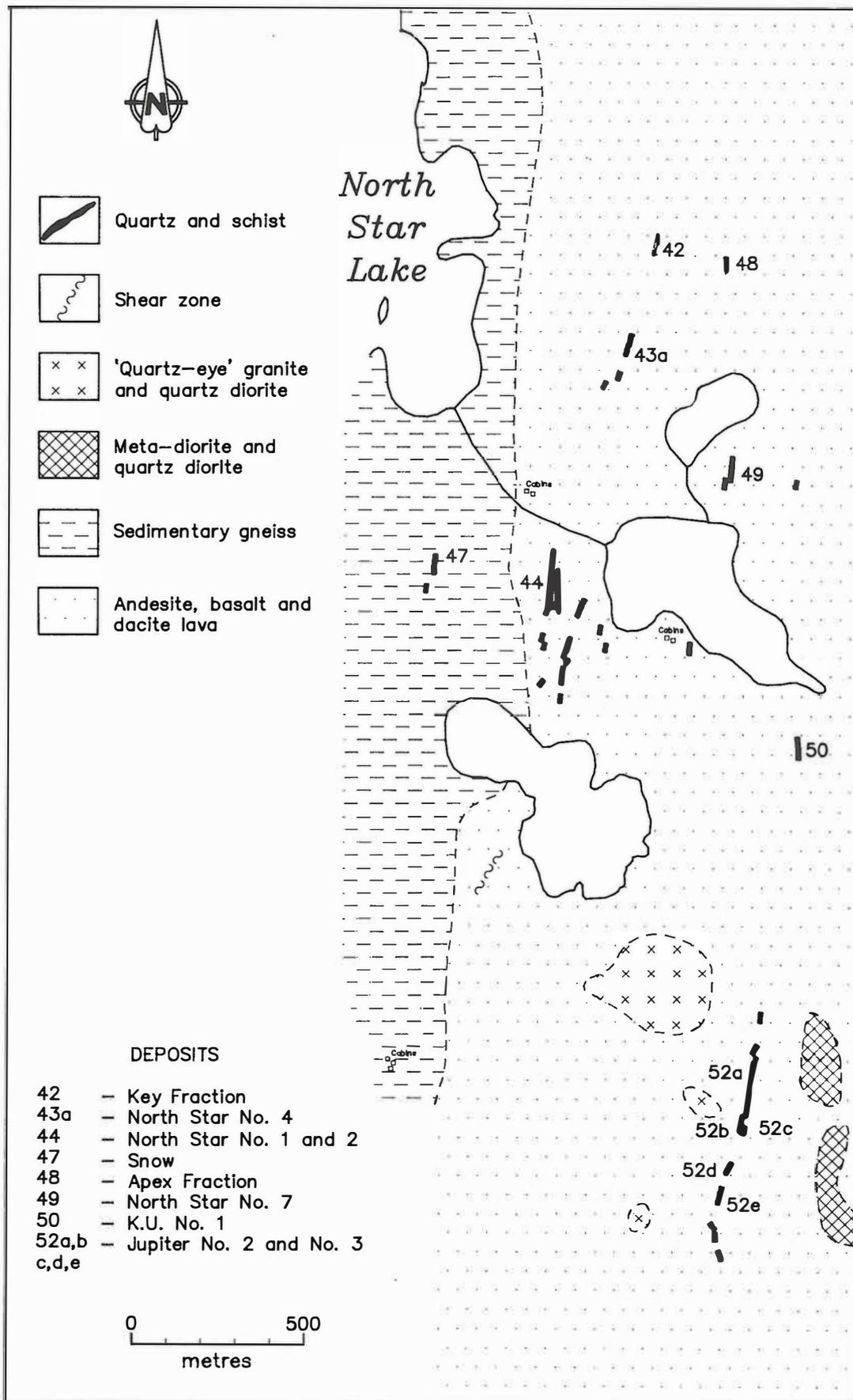
Figure GS-14-1: *General geology of the North Star Lake area and location of mineral occurrences examined (occurrence numbers after Stockwell, 1935).*
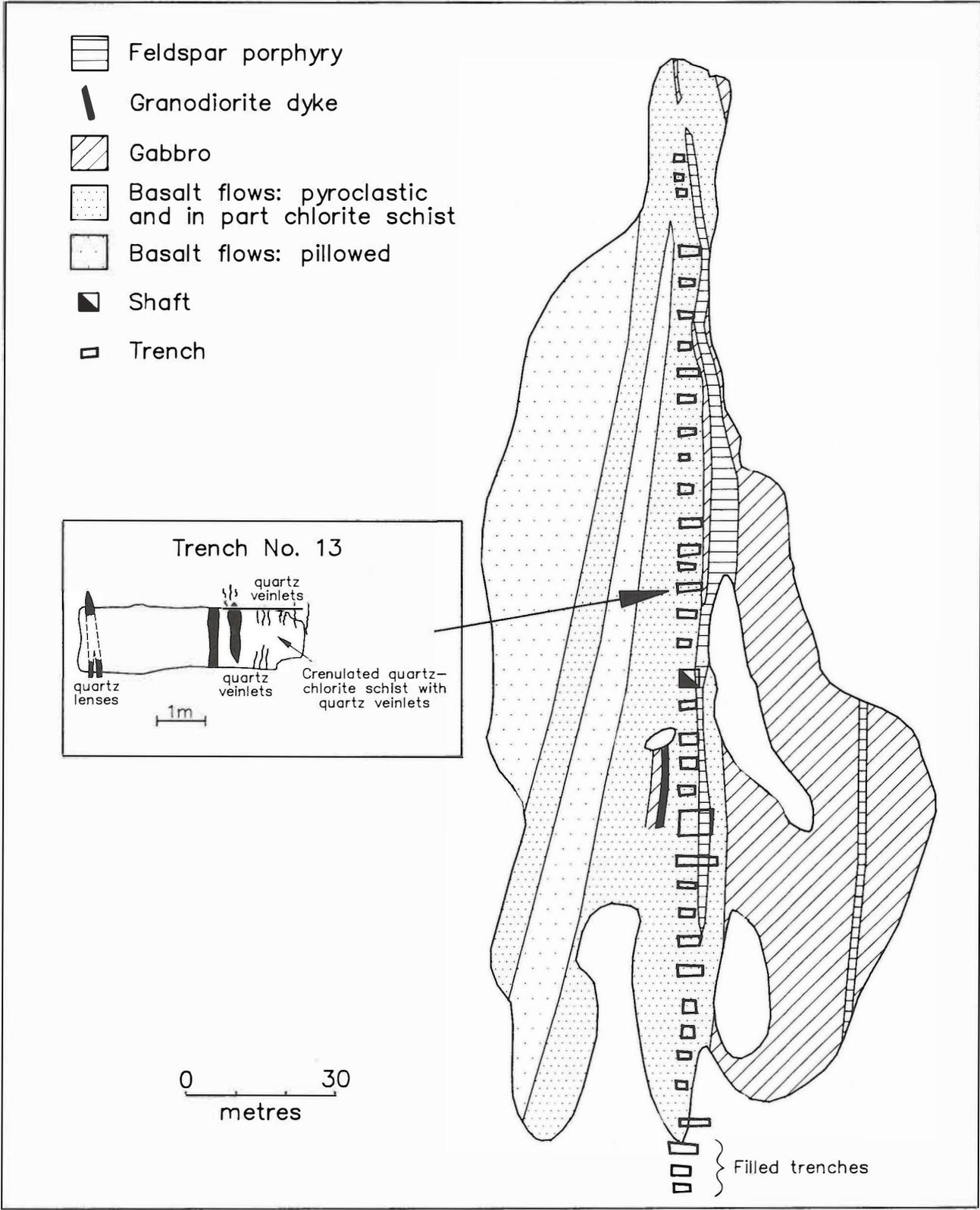
Figure GS-14-2: *Geological setting and trenches at the Jupiter occurrence (use detailed sketch map from notes).*

The legend includes:
- Feldspar porphyry
- Granodiorite dyke
- Gabbro
- Basalt flows: pyroclastic and in part chlorite schist
- Basalt flows: pillowed
- Shaft
- Trench

Trench No. 13 detail shows:
- quartz veinlets
- quartz lenses
- quartz veinlets
- Crenulated quartz-chlorite schist with quartz veinlets
- 1m scale

Scale: 0 — 30 metres

Filled trenches

GS-15 DOCUMENTATION OF MINERAL OCCURRENCES IN THE FLIN FLON AREA (NTS 63K/11, 12)

by G.H. Gale, G. Ostry, and G.D. Trembath

The systematic documentation of mineral occurrences in the Flin Flon area has been completed and reports have been completed (Gale and Eccles, 1988a, 1988b) or are in draft form. During the compilation and writing of the reports for NTS 63K/11 and 12, additional data became available that necessitated additional field work in areas where previously reported occurrences had not been located and in areas where new information indicated the presence of mineralization that required documentation.

Twenty-two occurrences were investigated (Fig. GS-15-1). The information obtained will be detailed in forthcoming MDS reports 11 and 16, but will be released to individual property owners upon request.

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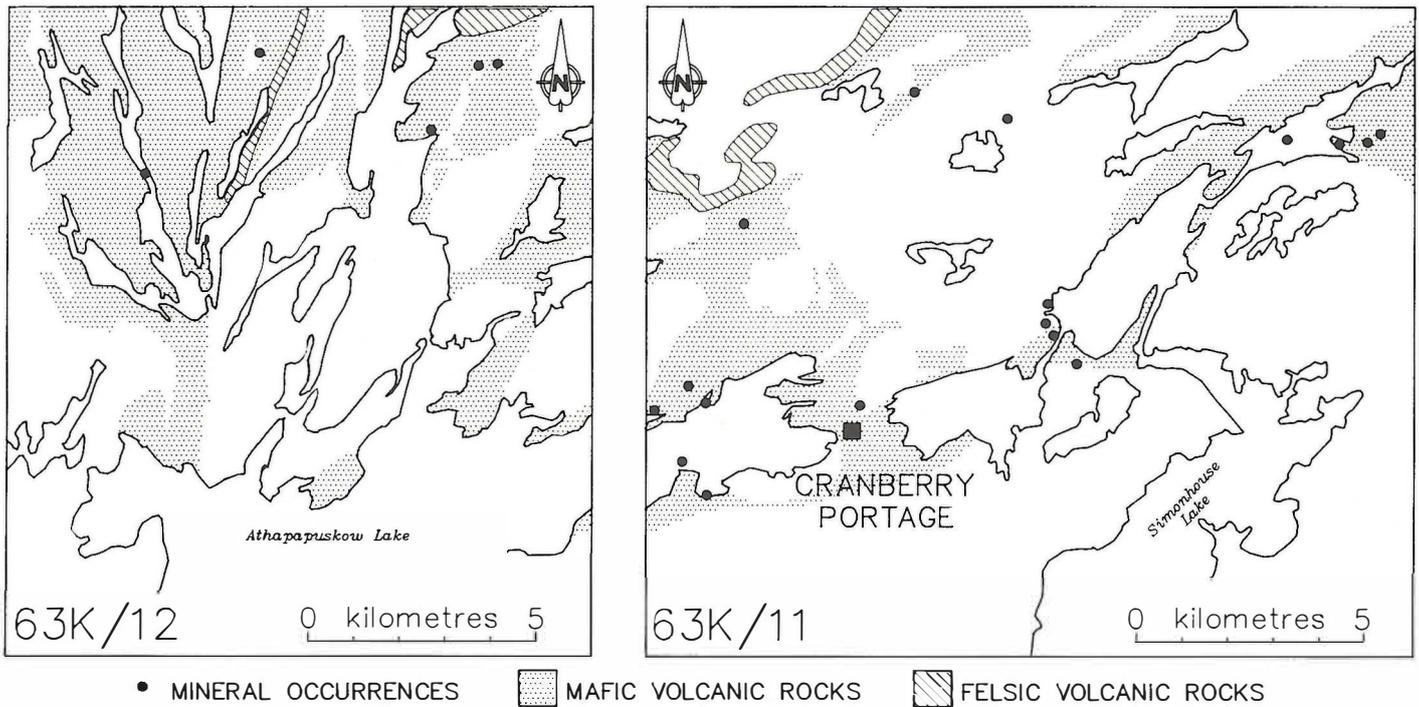

Figure GS-15-1: Location of mineral occurrences investigated in NTS areas 63K/11 and 63K/12.

GS-16 GEOLOGICAL SETTING OF THE COPPER-MAN BASE METAL DEPOSIT
(63J/12)

by G.D. Trembath and M.A.F. Fedikow

INTRODUCTION

The Copper-Man deposit is located near the southwest corner of Wekusko Lake, approximately 27 km southeast of the town of Snow Lake, Manitoba (Fig. GS-16-1). It is accessible from Provincial Highway 39. The area of the deposit was burned by forest fires in 1989 and accordingly was included in the STOMP (Short Term Outcrop Mapping Program) project. This study was undertaken to examine the geologic setting of the deposit and to develop a data base for future studies. Two weeks were spent examining outcrop in the vicinity of the deposit. Mapping was undertaken at 1:2000. Rock unit descriptions are based on the examination of outcrop and hand samples.

The vicinity of the deposit was staked as early as 1926, first trenched in 1927, and drilled as early as 1928 (McCannell, 1967). The occurrence was visited by Wright (1931) who described a northeasterly-striking, mineralized outcrop, then on the shores of Wekusko Lake, 160 by 30 m in size and consisting of greyish-green, quartz, chlorite, and sericite schists cut by quartz veins up to 45 cm wide. The veins, and portions of the schist, contain pyrite, sphalerite, and chalcopyrite. The predominant lithologies in proximity to the deposit are described as andesites (sometimes massive), tuffs, and quartz gabbro. Brecciated and pyroclastic schists containing fragments of black lava and cherty material were observed south of the massive andesite. Wright (1931) described the quartz gabbro as a massive to coarse grained rock consisting of plagioclase and hornblende with lesser amounts of quartz interstitial to the plagioclase. The map of Armstrong (1941) describes the area as unexplored, while the most recent regional geology map Bailes (1971),

shows the deposit to be located in granodiorite or diorite, possibly derived from metasedimentary rocks. Ferreira and Fedikow (in prep.) have described the deposit and included chemical analyses of samples collected from trenches on the property.

GEOLOGY

The deposit is located within a sequence of Amisk Group basaltic flows and fragmental rocks. Poorly exposed and isolated outcrops make the determination of the exact nature of the host rocks difficult. Future work may include the examination of available drill core. Characteristic rock units from the area are described below.

Basaltic Flows

Outcrops northeast of the surface expression of the deposit consist of basalt flows (Fig. GS-16-2). The flows are green, very fine grained and generally massive, but contain local evidence of flow breccias less than 30 cm thick and ovoid pillow forms 60 by 120 cm. The flows are chlorite-rich, contain trace to 20 per cent, seriate to 3 mm, feldspar phenocryst laths, trace to 15 per cent, 1 to 7 mm (average 1-2 mm) pale green amygdales, trace to 5 per cent vesicles with epidote altered edges and amphibole porphyroblasts. Minor amounts of quartz veins, and quartz-epidote- calcite-filled tension gashes are observed on some outcrops.

Fragmental Basalts

A series of fragmental basalts, lapilli tuffs and tuff $\pm$ lapilli tuffs, with 5 per cent intercalated fine grained, green, massive flows, are located south and east of the deposit (Fig. GS- 16-2). The matrices range from green, very fine grained, chlorite to black, medium grained amphibole. Individual units are as thin as 1 m; the upper limits of thickness are undefined. These basalts are monolithologic to heterolithologic breccias/debris flows. The fragment content ranges from trace to 40 per cent. One distinctive subunit consists of 1 to 20 per cent very fine grained, light grey, rounded, flattened silicic fragments from 1 by 3 cm to 25 by 100 cm. Two such subunits have been recognized (Fig. GS-16-2). Mafic and felsic fragments apparently have been relatively resistant to recrystallization.

STRUCTURE

The deposit occurs near a post metamorphic fault. Two cleavages, approximately 15 to 30° apart, are present in some outcrops. This has resulted in elongation of some lapilli (Fig. GS- 16-3). Most outcrops only show one foliation. The schistosity is deformed (folded) locally, and cut by a cleavage. Late, iron- carbonate-filled, wispy fractures, that show slight sinusoidal deformation, and in places contain fragments of host rock, are related to the late fault.

Altered rocks in the vicinity of the deposit display two foliations; besides mineral foliations, one or both foliations may also be a cleavage. Slight deformation (crenulation) of compositional layering and a sulphide mineralized zone occurs about a lineation of 58°/091°. Quartz veins, which locally contain chalcopyrite, sphalerite, or pyrite, crosscut the foliations.

METAMORPHISM AND ALTERATION

Metamorphism is greenschist facies, as typified by the fine grained chloritic matrices of fragmental basalts and epidote- quartz intergrowths in amygdales. The presence of trace to 15 per cent, up to 8 mm, angular amphibole porphyroblasts within the basalts infers upper greenschist facies metamorphism. Portions of the matrix within outcrops of lapilli tuff are recrystallized to medium grained black amphibole. This is accompanied by carbonate enhancement, which may be related to the fault.
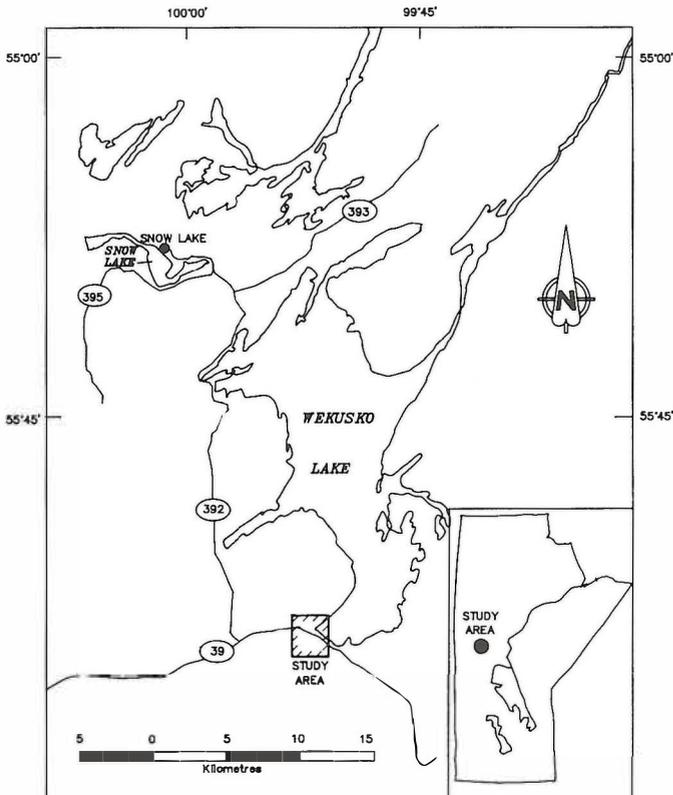

Figure GS-16-1:   Sketch map showing location of Copper-Man base metal deposit.

2 Fragmental Basalt, minor massive flows
  a tuff
  b lapilli tuff
  c heterolithic
  d with lt. grey silicic fragments
  e altered: epidote + Fe-oxide +/- Fe-carbonate
  f altered: quartz + biotite + chlorite + Fe-carbonate

1 Basalt Flows
  a massive
  b pillowed
  c amygdaloidal
  d feldspar-porphyritic
  e altered: quartz + epidote +/- garnet + Fe-carbonate

Area of outcrop
Geological contact, assumed
Drill hole collar
Trench
Schistosity
Cleavage
Lineation (crenulation)
Fe-carbonate +/- quartz vein
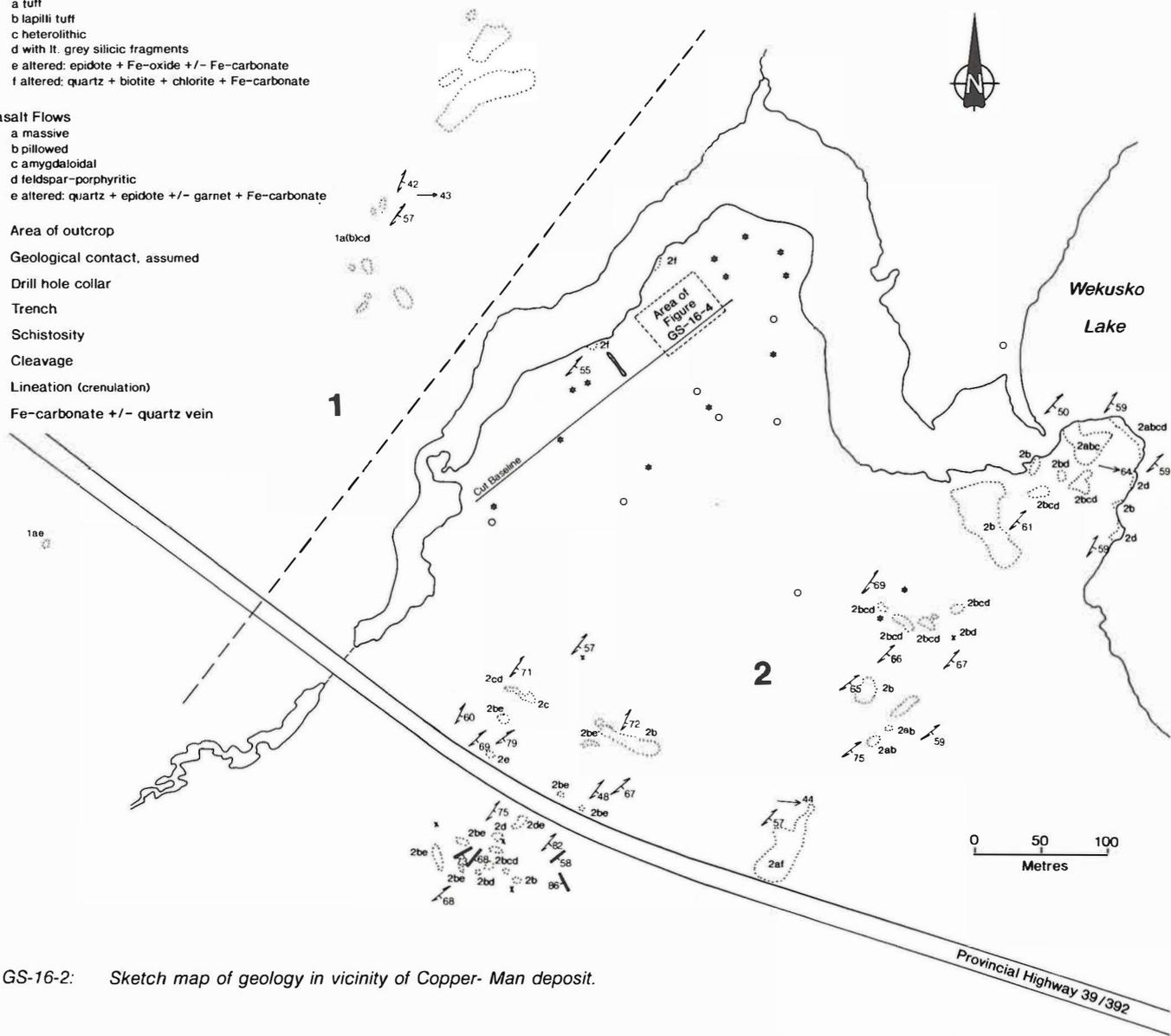
Figure GS-16-2:   Sketch map of geology in vicinity of Copper- Man deposit.

Figure GS-16-3:   Altered fragmental basalt in fault zone, note elongation of fragments lapilli in two orientations. Broken rock at top due to faulting and breakage along cleavage foliations.

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Alteration has been characterized as chloritic, quartz- chlorite-biotite, and siliceous, in the vicinity of the trenches (Fig. GS-16-2, 4). Chloritic alteration is fine grained, green, and contains 60 to 90 per cent chlorite, quartz and trace to 10 per cent biotite. Traces of disseminated iron oxide were observed locally. Epidotized, fine grained, feldspar phenocrysts occur locally in small patches and zones less than 30 cm wide.

Quartz-chlorite-biotite alteration locally grades into siliceous alteration. Quartz-chlorite-biotite alteration is pale greyish-green, fine grained (<1.0 mm) and contains minor quartz stringers. It consists of quartz with up to 10 per cent interstitial chlorite, trace to 3 per cent, <1 mm clots and disseminations of biotite, trace garnet <3 mm, and trace to 3 per cent disseminated pyrite. Pyrite also occurs as thin layers on sheared surfaces. Some sheared or fracture surfaces are enriched in chlorite, biotite and pyrite. Irregular quartz-filled fractures, <7 mm wide, form a network that locally crosscut the unit and are affected by a stretching lineation. Outcrops by the creek (Fig. GS-16-2) contain minor late carbonate ± hematite-filled fractures.

The siliceous alteration is fine- to very fine-grained, light grey to greyish green, moderately foliated, and displays some vague compositional zoning. It consists of quartz, trace to 5 per cent chlorite, trace to 3 per cent chalcopyrite, trace to 5 per cent sphalerite and trace to 2 per cent pyrite. Locally, the silicification grades into diffuse quartz veins.

MINERALIZATION

Examination of surface exposure revealed trace to 3 per cent disseminated fine grained pyrite within the quartz-chlorite- biotite alteration and traces of pyrite locally within the chloritic alteration. The silicified alteration contains up to 5 per cent disseminated sulphides and locally vague stringer and/or fracture hosted sulphides. Sulphides within the silicified zone include chalcopyrite, sphalerite, and lesser pyrite; these minerals appear to be recrystallized and mobilized, in some part due to metamorphism, and possibly due to structural events related to the post-metamorphic fault. The deposit is classified as a volcanic rock associated massive sulphide type alteration zone with mobilized sulphides. A detailed sketch map illustrating the geology and mineralization exposed at the occurrence is given in Figure GS-16-4.

Ore reserves calculated by McCannell (1967) indicated possible reserves of 170,000 tons in the 'A' zone grading 3.13 per cent Cu and 4.71 per cent Zn, while the 'B' zone with possible total reserves of 74,200 tons graded 1.49 per cent Cu and 3.91 per cent Zn. Up to 0.24 per cent Cd over five foot lengths was found in some samples (McCannell, 1967). McCannell (1967) considered that the mineralization occurred in fracture zones striking 017°/53°, and had been localized in stretched shoots that obliquely crosscut the strike of the rock units and a shear.

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LEGEND

Chlorite alteration

Quartz–chlorite–biotite alteration

Silicification

Area of quartz veins

Rubble

Schistosity

Cleavage

Lineation (crenulation)

10 metres
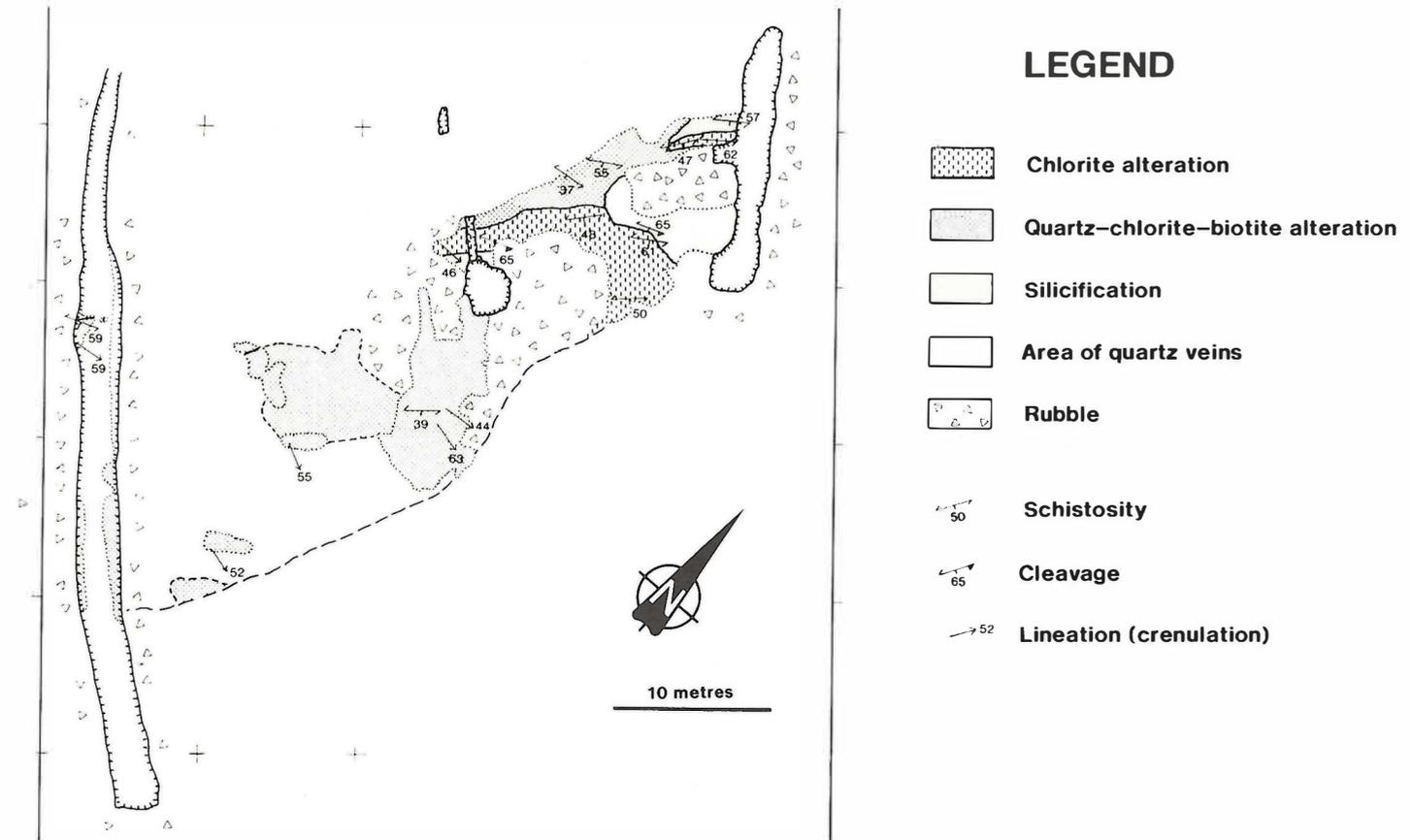
Figure GS-16-4:   Detailed sketch map of the main mineralized zone exposed on surface showing geology.

GS-17 MINERAL OCCURRENCE INVESTIGATIONS IN THE LOBSTICK NARROWS AND ELBOW LAKE AREAS (NTS 63K/14, 63K/15)

by D. Parbery

INTRODUCTION

An arsenopyrite-bearing amphibolite that occurs at the transition between the Flin Flon greenstone belt and the Kisseynew Sedimentary gneiss belt (KGB) was mapped at a 1:2000 scale. A two day reconnaissance of gold occurrences was conducted in the Elbow Lake area.

GENERAL GEOLOGY

An arsenopyrite-bearing amphibolite occurs within the Kisseynew Sedimentary gneiss belt, 3.5 km north of Lobstick Narrows, Kisseynew Lake, (Fig. GS-17-1). The Kisseynew gneisses stratigraphically overlying the amphibolite are considered to be Missi age (Ashton, 1989; Ashton


MISSI GROUP

| 4 | Felsic conglomerate and quartzite |

| 3 | Mafic conglomerate |

AMISK GROUP

| 2 | Amphibolite |

| 1 | Greywacke |

Outcrop, small outcrop

Geological contact (defined, assumed)

Diamond drill hole

Trench

Cut line

Road

Swamp
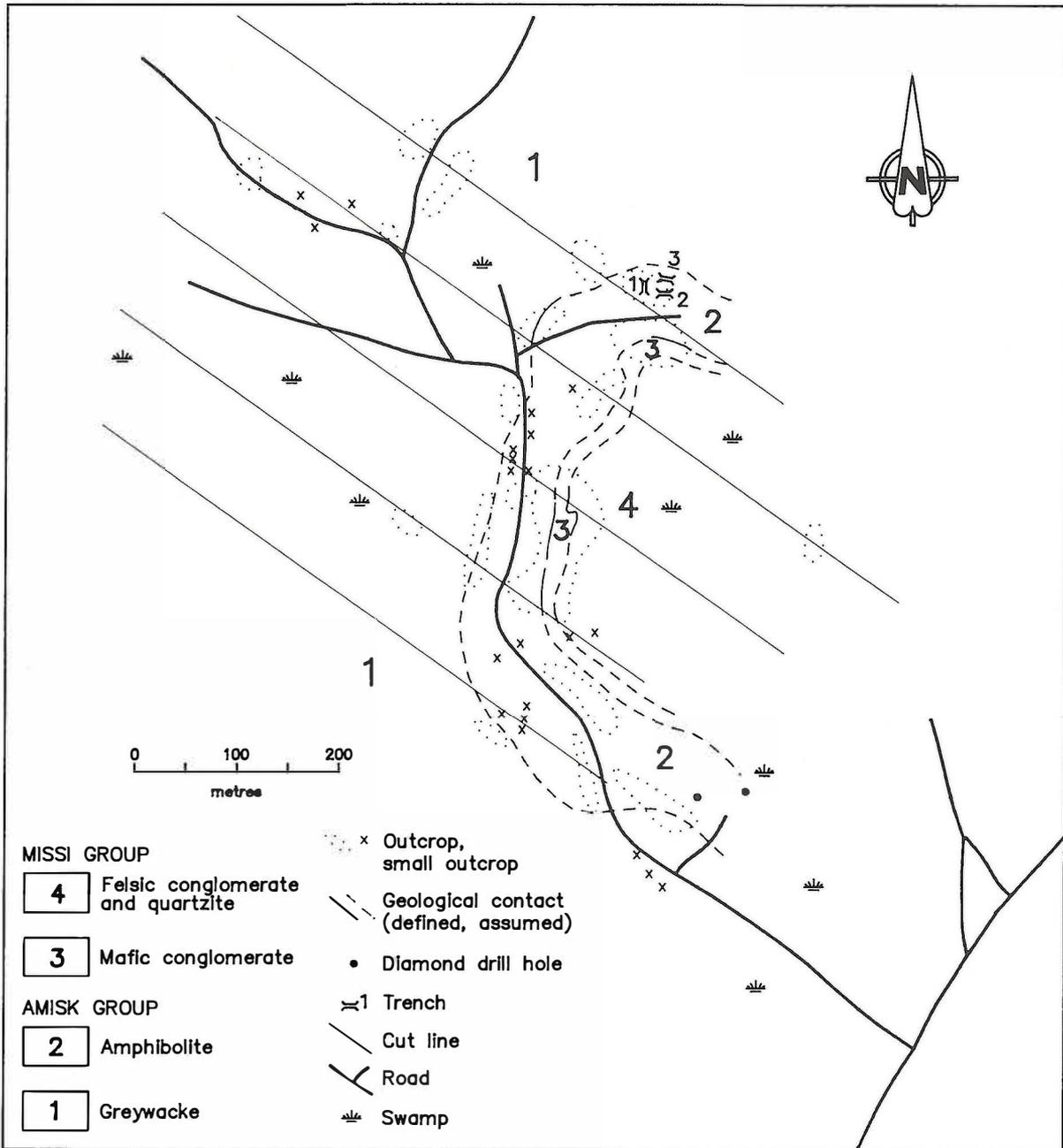
Figure GS-17-1: Map of the study area.

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et al., 1986) and consist predominantly of quartzofeldspathic metasedimentary rocks that were deposited in shallow water, alluvial environments (Zwanzig, 1984). The rocks have been metamorphosed to middle amphibolite grade.

The Burntwood rocks were thought to be distal equivalents of Amisk Group sedimentary and volcanic rocks (Bailes, 1980; Zwanzig, 1988). The amphibolite and greywacke (Fig. GS-17-1) are part of a volcano-sedimentary suite of rocks that were assigned to the Burntwood metamorphic suite, which occurs throughout the KGB (Gilbert et al., 1980). 1), but were subsequently assigned to the Amisk Group of the Flin Flon belt (Ashton et al., 1986).

The Amisk Group/Missi Group contact is an unconformity. It has been delineated in several places in the KGB in Manitoba, and in Saskatchewan (Ashton et al., 1986, 1987; Zwanzig, 1983, 1984). This contact is easily recognized north of Lobstick Narrows by the presence of a basal conglomerate, which is a distinctive and widespread metasedimentary rock unit that unconformably overlies a volcano-sedimentary suite of rocks that comprise amphibolite and greywacke.

The major rock types found in the area (Fig. GS-17-1) are described below.

AMISK GROUP ROCKS
Greywacke

The greywacke is fine grained and weathers a light grey; large areas of outcrop are stained brown-orange to rust. The rock consists of 30 to 35 per cent quartz, 25 per cent feldspar (plagioclase), < 30 per cent biotite, and contains 10 to 15 per cent pink-mauve garnet porphyroblasts that average 2.5 mm in diameter. White mica is locally present. Many garnets have a bleached halo.

Subtle changes in biotite content, and grain size of felsic minerals, define a crude lamination; laminae are 1 to 10 cm thick. A foliation is defined by the alignment of biotite crystals. There a difference in orientation between the laminae and the foliation (foliation 178°/60°, lamination 200°/60°).

Quartz knots are locally abundant. Quartz veinlets strike subparallel to the foliation and in places are strongly kink folded. These veinlets are parallel, to subparallel, to the minor (kink) fold axes. Garnets occur both within the foliation and randomly throughout the rock.

The greywacke has a sharp contact with an overlying amphibolite; the contact is exposed along a drill road west of the trenches (Fig. GS-17-1). Veins and pods of medium- to coarse- grained quartz, and plagioclase ± garnet occur in the greywacke.

Amphibolite

Gale et al. (1980) recognized that gold mineralization at Lobstick Narrows, Nokomis Lake and elsewhere in the KGB is associated with a thin unit of volcanogenic and sedimentary rocks and is related to fumarolic activity. Zwanzig (1984) described the amphibolites that underlie the Missi Group rocks at Lobstick Narrows, Puffy Lake and Nokomis Lake, as a combination of mafic ash and chemical precipitates.

The Lobstick Narrows amphibolite is very fine- to medium- grained, massive- to strongly-foliated and laminated. It is predominantly dark grey to black, with minor intercalated, intermediate layers and is mild rusty weathered. Garnet-rich layers are common in the upper portion of the amphibolite near the contact with the Missi Group, and next to the rusty weathered siliceous zones; diopside is also present. The amphibolites are presumed to be graded tuffs.

On an outcrop scale the amphibolite varies in composition, grain size and texture. Most units are several centimetres to a few metres thick. A common variety of the amphibolite is a fine- to coarsely-laminated, fine grained unit with minor intercalated, intermediate very fine grained, 2 to 10 cm thick, light grey layers. Amphibolite laminae are 0.1 to 5.0 cm thick, with grain size ranges from 0.5 to 1.5 mm. Laminae with grain size and compositional variation can be traced for the length of an outcrop (2-3 m). Well laminated units may be up to 3 m thick (Fig. GS-17- 2).

Amphibolite exposed in trenches 1 and 2 (Fig. GS-17-1) resemble thinly- to coarsely-laminated mafic tuffs; some laminae are reversely(?) graded.

Nonlaminated amphibolite layers up to 5 m thick are massive, or weakly foliated, fine- to medium-grained, with some coarse grained sections, and contain anhedral garnets that are up to 4 mm.

Pink-orange, anhedral to subhedral, 0.5 to 2.0 mm, broken and corroded garnets are present in the darker coloured amphibolitic layers and constitute up to 20 per cent of the rock. Locally garnets are bleached and occur as "strings" parallel to foliation and as small pods (5 x 20 cm). Garnets are commonly elongated parallel to the plunge of kink folds.

Garnet-rich amphibolite contains coarsely laminated, very fine- to medium-grained, 2 to 5 cm thick laminae that contain up to 50 per cent, 0.5 to 5.0 mm garnets. These units are common near or at the amphibolite/Missi Group contact, and may represent a silicate facies iron-formation, or an altered regolith (Fig. GS-17- 3); the latter origin was suggested for a similar rock in the Batty Lake area (Zwanzig, 1988).

Massive medium- to coarse-grained dioritic to gabbroic rock (sills?) occurs within the central and northwestern amphibolitic units. Contact relationships between these (intrusive?) rocks and the surrounding amphibolitic rocks are uncertain.

Several amphibolitic units contain "aggregates" of quartz, feldspar, pyrobole, and garnet. These mineral aggregates occur as irregular, 5 by 15 cm pods and compose 5 to 10 per cent of the rock; the mineral grains are less than 1.5 mm. The centres of the mineral aggregates are 0.5 cm vugs. Attenuated pods appear as 4 mm to 4 cm thick, tightly folded laminae.

Barren quartz veins, up to 10 cm wide, cut the amphibolite in many places.

In the central part of the map area, a reversely(?) graded mafic sedimentary rock is in contact with the amphibolite.

MISSI GROUP ROCKS
Conglomerate

At Lobstick Narrows, two polymictic conglomerates (termed "mafic" and "felsic" depending on matrix composition) lie at the base of the Missi Group. The mafic matrix conglomerate directly overlies the amphibolite, but the felsic matrix conglomerate occurs several metres above the contact. The conglomerates are associated with sandstones and protoquartzites.

The mafic matrix conglomerate has a dark green to grey, very fine- to fine-grained, amphibolitic matrix that contains granular rounded quartz (20-30%), feldspar (10-20%), and amphibole (50- 70%). Trace to 1 per cent magnetite occurs in the matrix and appears to be concentrated at clast rims. This several metre thick unit is matrix to clast supported and contains a variety of clast types that compose up to 60 per cent of the rock. The clasts are sub-rounded, elongated parallel to foliation and subparallel to layering, and contorted by the kink folds that affect rocks in this area (Fig. GS-17-4).

Clasts comprise purple-grey banded iron-formation (with magnetite), aphanitic pink-grey siliceous rock, epidotized felsic rock, fine- to medium-grained gabbro, tonalite, and granite and fine grained intermediate rocks that are considered to be sedimentary rocks. Zwanzig (1983) noted rhyolitic clasts and quartz pebbles in the (felsic matrix?) conglomerate. Gabbroic and metasedimentary clasts are more elongate and slightly smaller than the granitoid clasts.

The felsic matrix conglomerate is matrix supported. It contains more intercalated sandstone layers, has less amphibole in its matrix, and contains a greater proportion of felsic and siliceous clasts than the mafic matrix conglomerate. In addition, clasts are more elongate and quartz veins are common in the felsic matrix conglomerate. Quartz veins are orientated parallel and subparallel to the foliation.

Protoquartzite and Sandstone

Protoquartzite and sandstone are intercalated with Missi Group conglomerates. The protoquartzite weathers grey to grey-pink and consists of very fine- to fine-grained (< 0.5 mm), rounded quartz (70%), anhedral orange-pink < 2 mm garnet aggregates (< 5%), biotite (10-15%), ± feldspar (10%). Protoquartzite units are up to 15 m thick, and locally crossbeds are preserved. The foliation is defined by biotite alignment. Numerous barren quartz veinlets, 0.1 to 10 cm thick, cut the protoquartzite parallel to subparallel to the foliation, and sub-parallel to the minor kink-fold axes.

Figure GS-17-2:   Layered amphibolite.

Figure GS-17-3:   Garnet-rich layer in amphibolite near the Amisk Group/Missi Group contact.
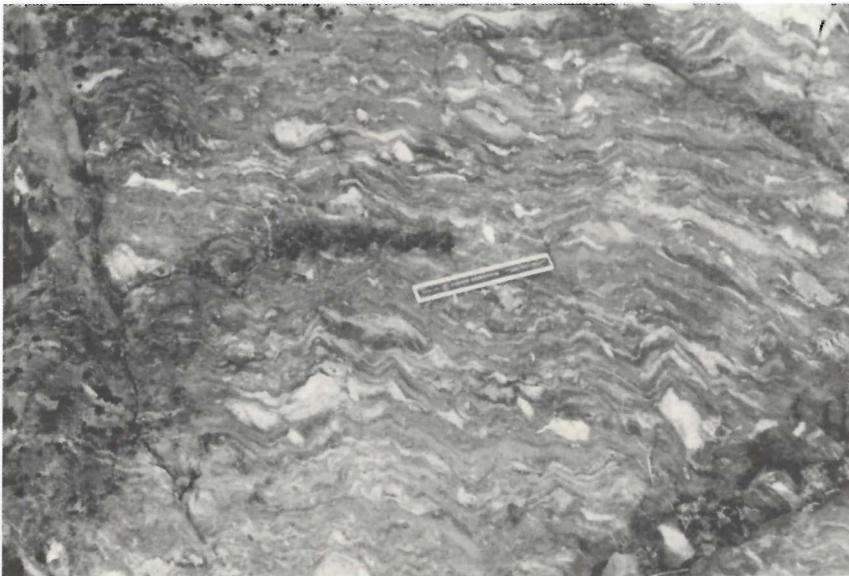
Figure GS-17-4:   Kink folds in Missi basal conglomerate.

Sandstone weathers pink-orange, and is composed of fine grained (<0.5 mm) feldspar (40%), mafic minerals (10 to 15% amphibole and minor biotite), quartz (30%) and up to 20 per cent, 1 to 3 mm, sub-angular quartz grains; many of the quartz grains are elongated parallel to kink-fold axes. The sandstone is pale pink adjacent to fractures, the underlying protoquartzite and the overlying conglomerate. Sandstone layers, 0.7 to 1.5 m thick, have sharp contacts with underlying and overlying rocks; quartz- feldspar veinlets are common at these contacts.

A weak foliation parallels layer boundaries. Locally, the sandstones exhibit a cleavage that parallels the kink-fold axial planes.

STRUCTURE

Interpretations of structures in the Lobstick Narrows area and the southern flank of the KGB are given in Zwanzig (1983) and Zwanzig (1984), respectively.

The southern flank of the KGB has undergone several phases of deformation. The amphibolite and surrounding rocks lie on the east limb of an overturned anticline (F_1) that has been refolded (F_3) about an east-northeast-trending axis (Zwanzig, 1983, 1984). The regional foliation, which is parallel to subparallel to amphibolite laminae and the elongation of clasts in the conglomerates, has been kink folded. The kink folds are not ubiquitous throughout the map area and difficult to distinguish within massive amphibolitic rocks. Tight chevron-like folds have developed in some differentially weathered amphibolite laminae.

MINERALIZATION

Sulphides, including arsenopyrite and gold are associated with amphibolite at several locations in the KGB (Gale, 1980; Gale and Ostry, 1984). Two well documented occurrences are Nokomis Lake and Evans Lake (Ostry, 1986). In both areas an amphibolitic sequence contains arsenopyrite and gold in quartz veins and quartz- rich strata. The stratigraphic position of the amphibolites is similar to that of the amphibolite north of Lobstick Narrows, i.e. at or near the Amisk Group/Missi Group contact.

Two trenches at Lobstick Narrows, which are located in the north-western part of the map area, expose three 0.75 to 3 m wide, rusty weathered layers intercalated with amphibolite. The rusty weathered layers consist of thin, alternating fine grained, felsic- and mafic-rich laminae, but they become more siliceous towards the center of these layers. The central portions consist of dense siliceous, rusty weathered rocks that contain minor sericite and trace to 5 per cent arsenopyrite. The siliceous layers are interpreted as chemical sedimentary rocks and the mafic volcanic rocks as tuff, (cf. the silicic gneiss at the Nokomis Lake deposit, Gale and Ostry, 1984).

In the central part of the map area, rusty weathered rocks in up-turned blocks of amphibolite along the access road (Fig. GS-17- 1), can be traced for over 50 m. Sporadic, rusty weathered areas occur in most of the amphibolites, and may form discontinuous layers with low sulphide contents in the fine grained, massive to weakly foliated amphibolite (Fig. GS-17-1).

Mineralization in the eastern part of the map area consists of trace to 2 per cent disseminated, anhedral arsenopyrite in fine grained, massive to weakly foliated amphibolite.

ELBOW LAKE AREA (63K/15)

Gold mineralization appears to be associated with magnetite- bearing siliceous rock units (Galley and Ames, 1987); some are identifiable as oxide facies banded iron formation. Intense shears occur throughout the area (Syme, GS-7, this volume). Detailed mapping of the mineral occurrences will be carried out during the 1991 field season as part of the Mineral Deposit Series documentation of NTS 63K/15.

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GS-18 MINERAL INVESTIGATIONS IN THE SQUALL LAKE AREA (NTS 63N/2)

by G. Ostry

INTRODUCTION

Approximately three weeks were spent in the Squall Lake area north of the town of Snow lake (Fig. GS-18-1). A 1:5000 geological mapping program (Fig. GS-18-2) was initiated in the vicinity of a new gold - arsenopyrite occurrence located north of Squall Lake (Peter Dunlop, prospector - personal communication).

UNIT DESCRIPTIONS

Four principal rock units form a northwest-dipping homoclinal sequence (Fig. GS-18-2). These are described from the structurally lowermost to highest. Unit 1 is a massive, grey weathered, fine grained quartz-feldspar-biotite-garnet gneiss similar to the greywacke-derived gneisses mapped by Robertson (1953) east of Nokomis Lake. Unit 2 is a layered (on the order of cms and tens of cms) sequence of biotite-rich pelitic gneisses that contain very coarse- to coarse-grained quartz-sillimanite knots and/or porphyroblastic growths of euhedral to subhedral staurolite (rare) and/or garnet. Unit 3 is up to 80 m thick and comprises a layered,

possibly differentiated, mafic rock sequence (Units 3a, 3b and 3c) that was mapped as biotite diorite by Robertson (1953). It occurs near or at the contact between pelitic rocks of Unit 2 and quartzofeldspathic rocks of Unit 4. Unit 3a comprises an approximately 1 m thick basal layer/zone that is gradational from a very fine grained, locally feldspar phyric, mafic rock upward through fine grained diorite into pyroxenitic gabbro and an upper, up to 10 m thick, medium- to coarse-grained pyroxenitic gabbro that grades upward into a medium grained porphyritic pyroxene- phyric diorite. The gabbro contains up to 60 per cent medium- to coarse-grained cumulus pyroxene, fine- to medium-grained interstitial plagioclase and locally, up to 2 by 0.5 cm of cumulus plagioclase laths. The porphyritic diorite contains up to 25 per cent medium- to coarse-grained pyroxene crystals. Pyroxene is pseudomorphed by amphibole. The upper contact with Unit 3b is gradational. Unit 3b is an up to 35 m thick fine- to medium- grained diorite. Sill-like intrusions up to 25 m thick of fine- to medium-grained diorite that locally grade into pyroxene-phyric diorite were observed within Unit 4 and to a lesser extent, within Units
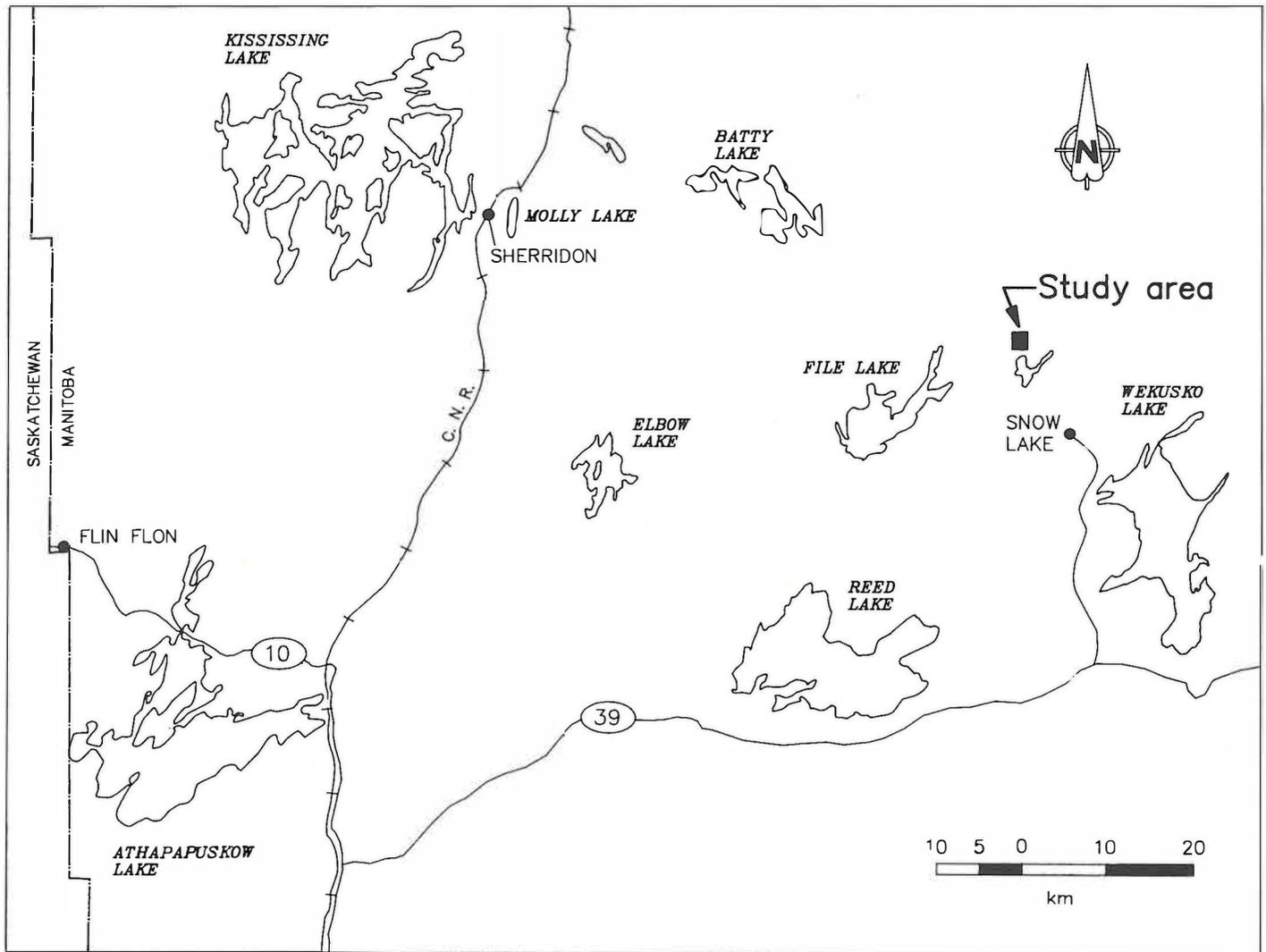

Figure GS-18-1: Location map of study area (63N/2) north of Squall Lake, Manitoba.
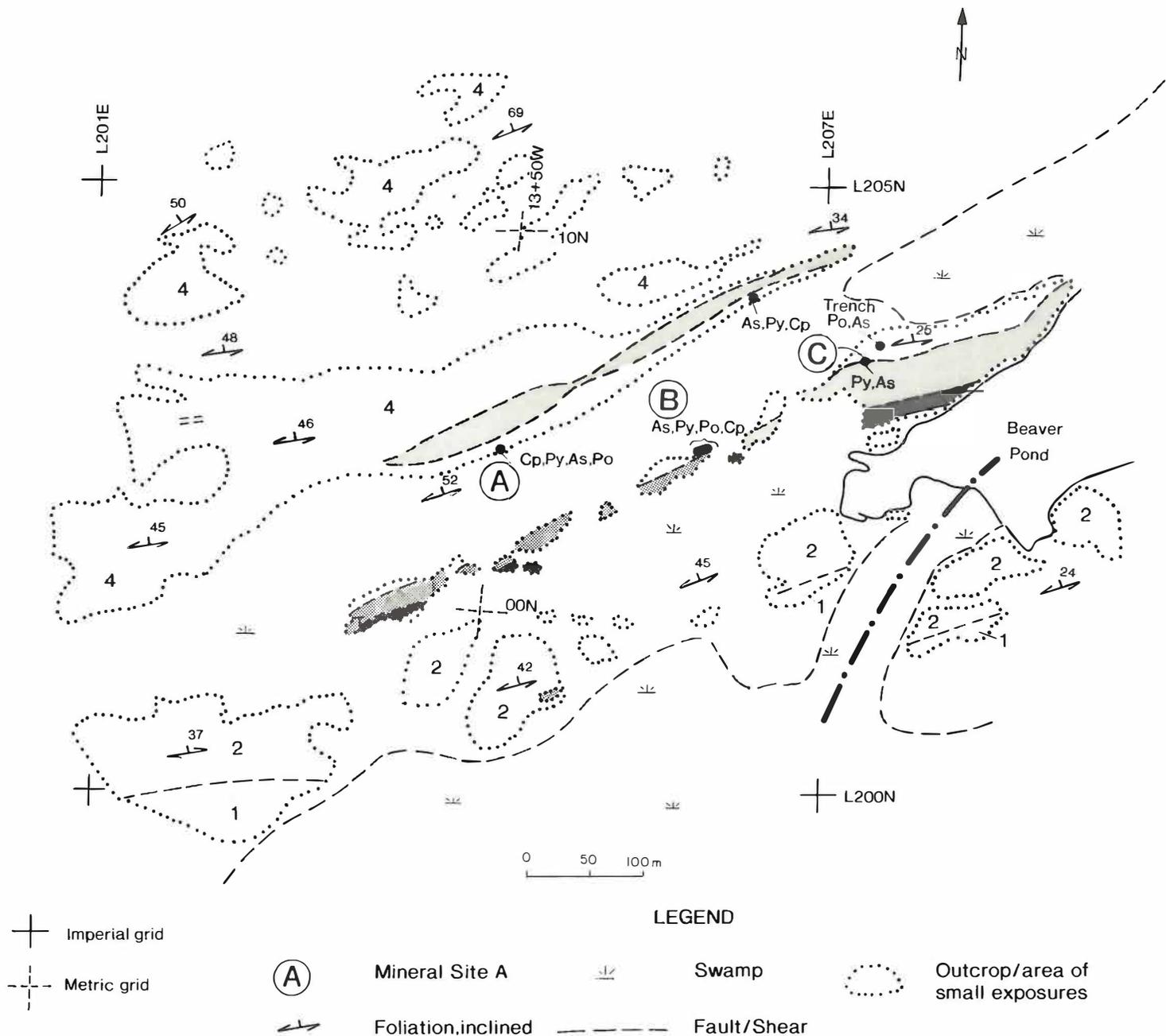
Figure GS-18-2: Outcrop, geology and trench location map for study area. Abbreviations: Py = pyrite; po = pyrrhotite; cp = chalcopyrite; as = arsenopyrite.

1 and 2 (Fig. GS-18-2). Pyroxene is pseudomorphed by amphibole. The diorite is in sharp contact with Unit 3c. Unit 3c comprises an up to 25 m thick variable fine- to medium-grained felsic to intermediate mottled rock that locally contains up to 80 per cent white feldspar ± quartz, and up to 40 per cent biotite ± garnet. The mottled appearance is created by up to 5 by 10 cm aggregations of fine grained white feldspar ± quartz separated by thin, biotite-rich rock (Fig. GS-18-3). Less than 1 per cent pyrite or pyrrhotite mineralization is associated with small rusty weathered areas. The composite layered mafic unit (Units 3a-3c) is crosscut by very fine- to fine-grained mafic dykes. These dykes range in thickness from a few centimetres to less than a metre, exhibit chilled margins and, locally, feldspar-phyric centers. The dykes exhibit foliation and lineation identical to that observed in the mafic host rocks. In the east portion of the study area, Unit 3 is underlain by Unit 4 felsic quartzofeldspathic gneiss. and in the west by Unit 2 pelitic gneiss (Fig. GS-18-2). Unit 4

is massive to well layered (layering on the order of centimetres to metres), felsic (arkosic?) gneiss that consists of fine grained quartz - feldspar - biotite ± garnet ± magnetite sillimanite. Numerous biotite laminations are locally prominent. Possible primary top criteria, i.e., trough cross-bedding, that indicate tops to the north was documented at one location (Fig. GS-18-4).

STRUCTURE

At least two periods of deformation have affected the rocks in the study area. The earliest deformation (D_1) produced a well developed foliation (S_1) defined by biotite and/or hornblende alignment parallel to compositional layers. The second deformation (D_2) produced a well developed penetrative fabric that is axial planar to small scale folds defined by S_1, and parallel to the predominant foliation in the study area (Fig. GS-18-5).

Figure GS-18-3:   Unit 3c felsic to intermediate mottled gneiss.

Figure GS-18-4:   Possible trough crossbedding defined by biotite laminations within quartzofeldspathic gneiss of Unit 4.
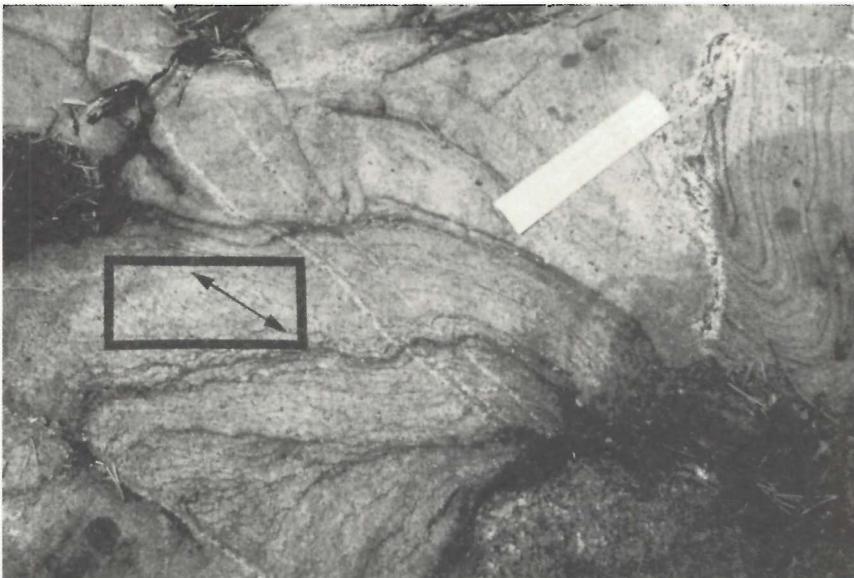

Figure GS-18-5:   Penetrative fabric axial planar to minor folds within quartzofeldspathic gneiss of Unit 4, and parallel to prevalent foliation in study area. Box encompasses area with a well developed penetrative fabric. Arrow is parallel to penetrative fabric.

MINERALIZATION

Veins of arsenopyrite, Fe-sulphide ± chalcopyrite, interpreted to represent post-metamorphic mobilizate, were documented at three locations (Fig. GS-18-2): Site A) the 'Dunlop' occurrence located on the south side of a prominent northeast-trending ridge within Unit 4 at or near the Unit 3/Unit 4 contact; Site B) three shallow trenches, located east of Site A, that expose Unit 3b/Unit 3c contact; and Site C) a rusty weathered zone at the Unit 3b/Unit 3c contact located near the eastern extent of the map area.

At Site A, arsenopyrite, Fe-sulphide and chalcopyrite mineralization occur within a 1 to 2 m wide rusty weathered zone hosted by fine grained quartzofeldspathic gneiss of Unit 4. Very fine- to fine-grained sulphides including in descending order of abundance, chalcopyrite, arsenopyrite, pyrite and pyrrhotite, constitute up to 5 or 10 per cent of the zone. The sulphides occur as disseminations and coatings on fracture surfaces. Up to 2 cm thick crosscutting and foliation parallel, quartz veins locally containing coarse grained arsenopyrite (with or without chalcopyrite, pyrite and pyrrhotite) are concentrated in a 10 to 30 cm wide section with the rusty zone.

At Site B, an approximately 1 m wide rusty weathered zone, located at the Unit 3b/Unit 3c contact, is exposed for 15 m. Three shallow trenches, ranging from 0.2 to 3 m in length, expose variably silicified, leached and mineralized rock over a strike length of approximately 7 m. The silicified rock is very fine grained to cherty in appearance, up to 10 cm wide, and contains up to 3 per cent fine grained disseminated pyrrhotite with minor amounts of pyrite and arsenopyrite. This rock was observed in all three trenches. The leached rock (exposed in all three trenches) is up to 75 cm wide, and contains less than 2 per cent ar-

senopyrite with lesser amounts of pyrite. The sulphides occur as fine grained disseminations and fine- to medium-grained blebs. Up to 2 cm wide veins of quartz mobilizate (with minor amounts of Fe- sulphide and arsenopyrite), and an up to 20 cm thick mobilizate vein(s) or lens(es) (that contains greater than 60 per cent very fine- to coarse-grained arsenopyrite ± pyrite), crosscut the leached rock. Gangue minerals within the near solid sulphide vein include fine- to medium-grained quartz and leached feldspar. Within the sulphide portion of this vein, very coarse grained 'ghost' crystals of arsenopyrite were observed under sunny conditions. The near solid sulphide mineralization is exposed in the east and west trenches.

At Site C, a 1 m wide rusty weathered zone was observed over a strike length of approximately 10 m at the Unit 3b/Unit 3c contact. The zone contains up to 3 per cent fine grained disseminated pyrite ± arsenopyrite. An up to 3 by 20 cm lens of 50 per cent or more fine grained arsenopyrite ± pyrite was observed within the zone.

All mineralized rocks were sampled and the samples have been submitted for geochemical analysis and/or assay.

ACKNOWLEDGEMENTS

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GS-19 INVESTIGATION OF BASE METAL POTENTIAL IN THE SHERRIDON AREA
(NTS 63N/2)

by G. Ostry and M. Bieri[1]

INTRODUCTION

A multi-year mineral investigations project designed to establish the geological setting of base metal deposits/mineralization within the Kisseynew gneiss belt was initiated in 1990. A 1:5000 mapping project and lithogeochemical sampling program were begun in an area of recent (1989) burn northeast of Sherridon, Manitoba (Fig. GS-19-1).

STUDY AREA

Pyrrhotite ± chalcopyrite mineralization within ridgy weathering, garnetiferous quartz-rich gneiss exposed in a number of trenches (Robertson, 1953) and near solid sulphide layer(s) composed of pyrrhotite, pyrite ± chalcopyrite ± sphalerite intersected by diamond drilling (documented in Manitoba Energy and Mines cancelled assessment files (A.F.) 91598

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[1]University of Manitoba, Winnipeg, Manitoba

and 90663) occur within the study area (Fig. GS-19-2).

Surface exposures in the map area comprise a north-dipping homoclinal sequence of medium- to coarse-grained, white, and variably rusty weathered, quartz-rich, quartzofeldspathic ± garnet gneiss, calc-silicate gneiss and mafic hornblende-feldspar-garnet ± calcite gneiss (Fig. GS-19-3). Sericite, sillimanite and chlorite were observed locally. Disseminated pyrite and/or pyrrhotite ± minor chalcopyrite mineralization was recognized in rubble at the trenches and locally in outcrop. Fine grained disseminated graphite was recognized within rubble at the south end of the large trench located in the east portion of the study area, and in outcrop south of the trenches (Fig. GS-19-3). An early (deformed) pervasive alteration, where greater than 50 per cent of an outcrop is replaced, rusty weathered and leached, was documented locally within the quartz-rich gneiss unit (Fig. GS-19-3). Nonaltered portions within these exposures resemble felsic fragments (Fig. GS-19-4). The majority of outcrops have been sampled for silicate whole rock and/or geochemical analysis.
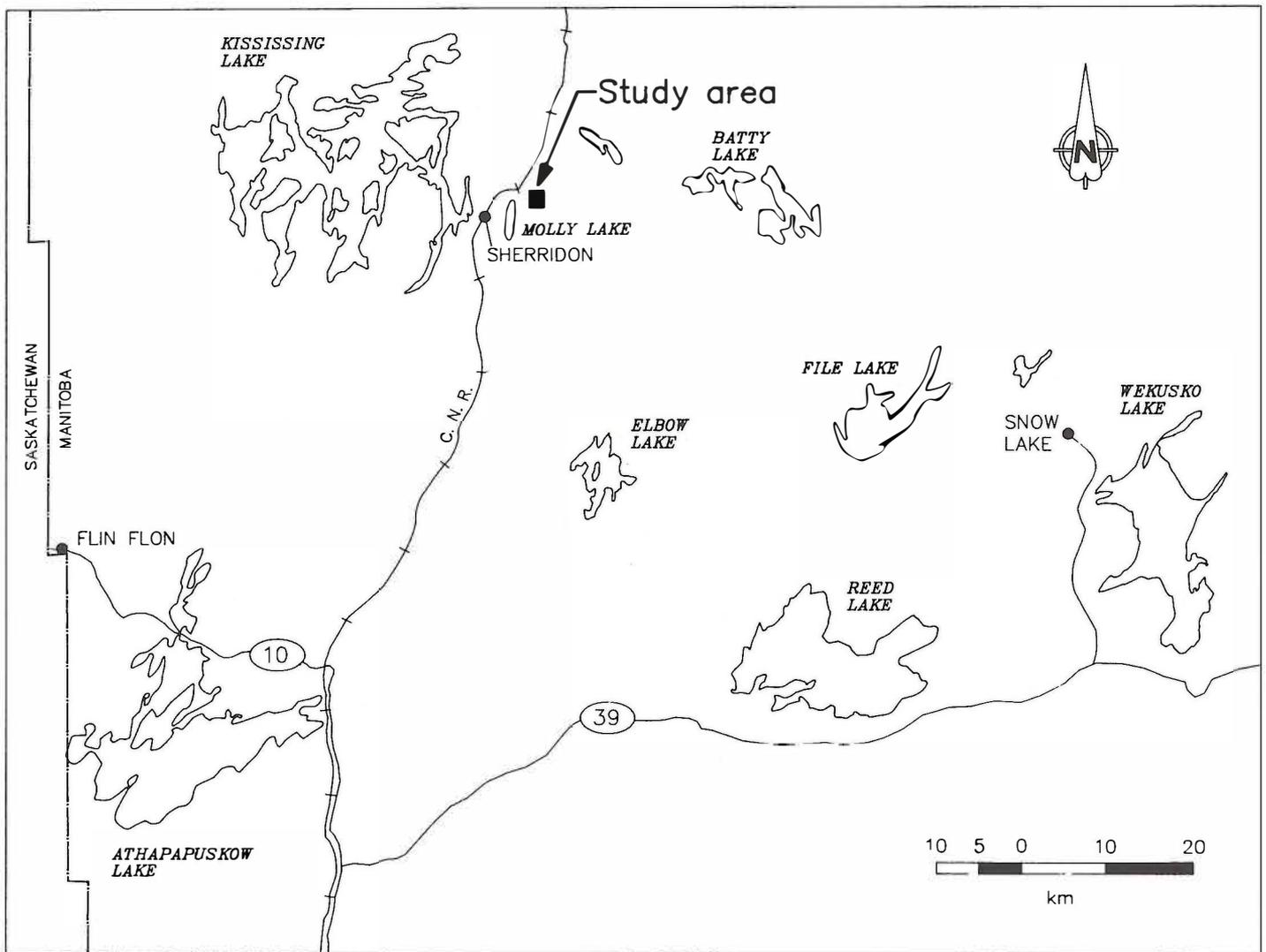

Figure GS-19-1:   Location map of study area (63N/2) northeast of Sherridon, Manitoba.
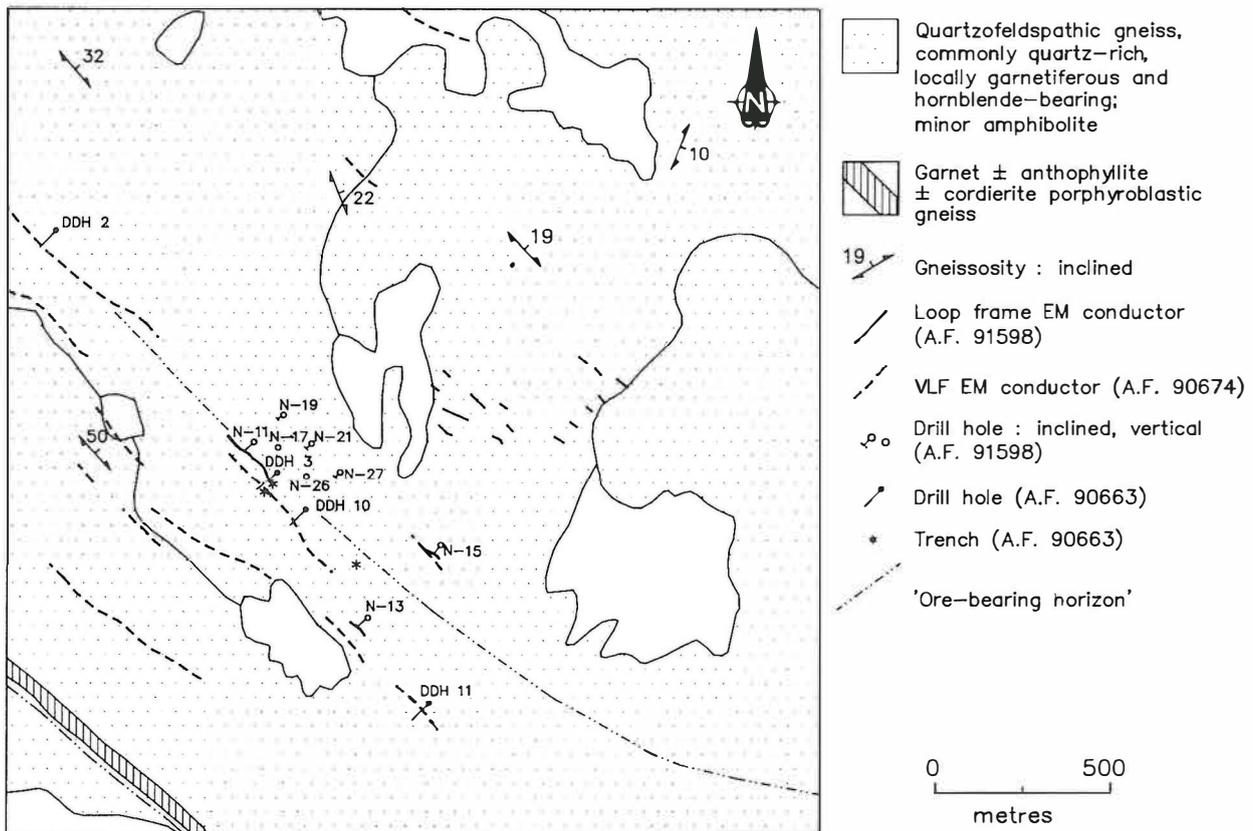
Figure GS-19-2: General geology, geophysical anomalies, drill hole locations and trench locations in study area. Geology after Zwanzig et al. (1988).
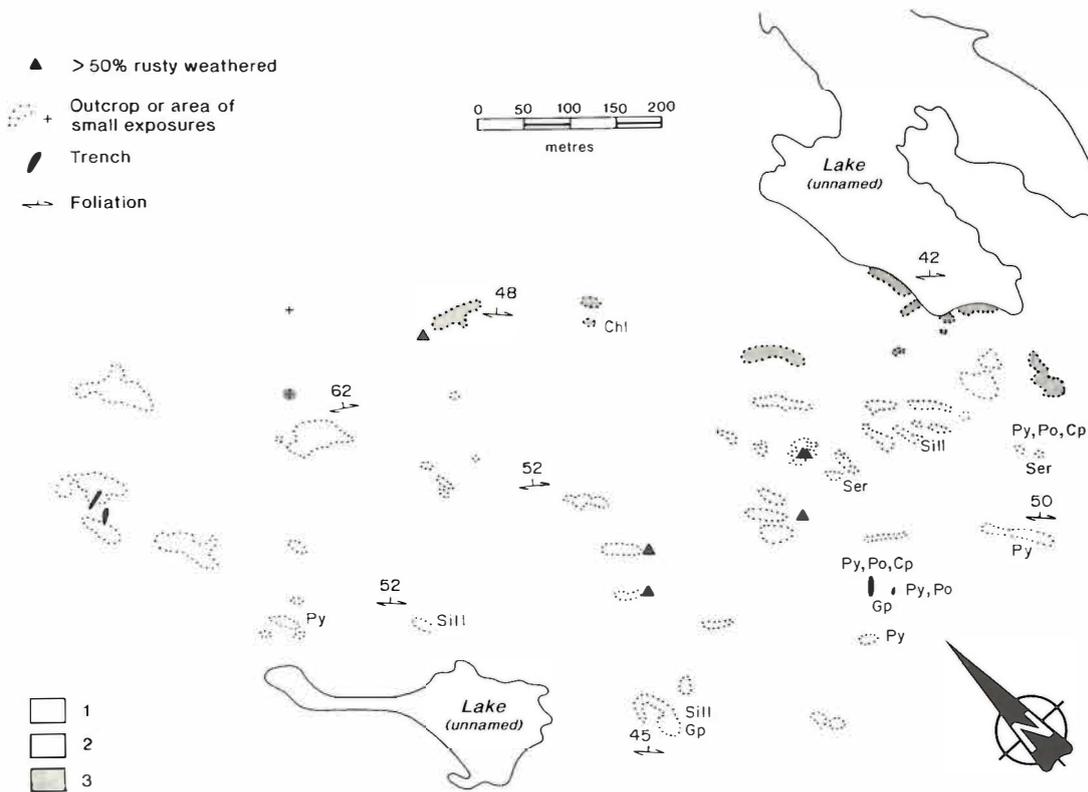
Figure GS-19-3: Outcrop and trench location map for study area. 1. quartz-rich, quartzofeldspathic ± garnet gneiss; 2. calc-silicate gneiss; 3. mafic hornblende-feldspar-garnet ± calcite gneiss. Abbreviations: Py = pyrite; po = pyrrhotite; cp = chalcopyrite; gp = graphite; sill = sillimanite; ser = sericite; chl = chlorite.
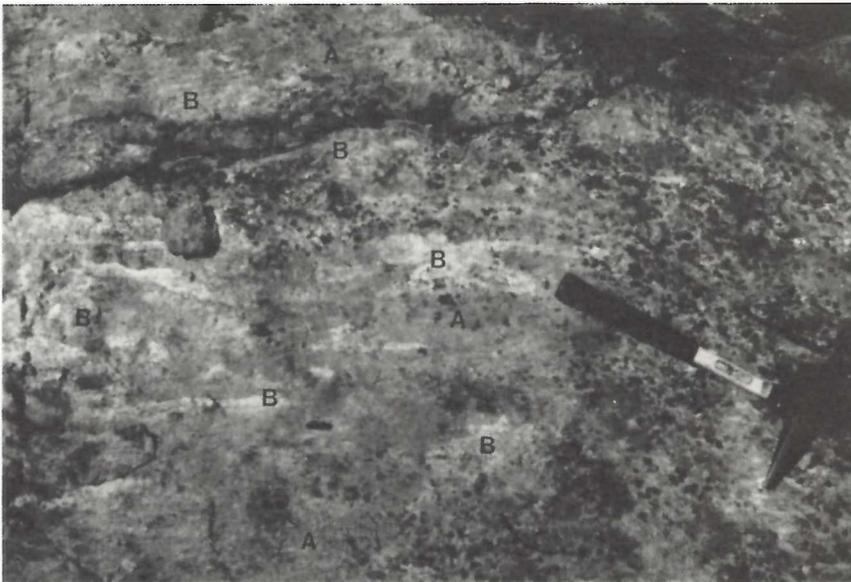
Figure GS-19-4: Pervasive rusty weathered alteration (A) within quartz-rich quartzofeldspathic gneiss (B).

The position of twelve diamond drill holes, VLF EM conductors and loop frame EM conductors are illustrated on Figure GS-19-2. Eight holes (N-11, 13, 15, 17, 19, 21, 26, 27) were drilled (total length 1082 m) in 1958 (A.F. 91598) and four holes (DDH No. 2, 3, 10, 11) were drilled (total length 370 m) during the winter of 1968-69 (A.F. 90663). The drill holes intersect a layered sequence of oligoclase quartz gneiss, quartz - biotite - feldspar ± hornblende ± garnet gneiss, quartz - hornblende ± biotite gneiss, hornblende - plagioclase ± biotite gneiss and quartzite. Sulphide minerals, chlorite, carbonate, sericite and siliceous sections are locally an important constituent of the rock sequence uphole from the sulphide layer(s). Graphite occurs exclusively downhole from the sulphide layer(s).

SUMMARY

The disseminated nongraphitic sulphide mineralization and/or near solid to solid sulphide layer(s) intersected in the drill holes, and exposed in the trenches, is tentatively interpreted to represent massive sulphide-type mineralization. Local concentrations of chlorite, sericite, carbonate, siliceous (silicified?) rock and disseminated nongraphitic sulphide mineralization that occur exclusively uphole from the sulphide layer(s) in drill core, and the local pervasive replacement of the quartz-rich gneiss in outcrop observed north of the trenches, suggests alteration associated with massive sulphide type deposits. In addition, the stratigraphic position of the sulphide layer(s) coincides with the stratigraphic position ('ore-bearing horizon') of the mineralization at the Bob Lake and Fidelity massive sulphide type deposits (NTS 63N/3), within the study area (Fig. GS-19-2), as extrapolated by Froese and Goetz (1981).

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GS-20 GEOLOGICAL INVESTIGATIONS IN THE ENGLISH BROOK AREA, SOUTHEASTERN MANITOBA (62P/1)

by W. Weber

INTRODUCTION

A reconnaissance survey was conducted in the English Brook area, east of Manigotagan, (where a forest fire in the spring of 1989 burnt ca. 400 km^2 of timber), to evaluate the feasibility of a detailed mapping program at a scale of 1:20 000. Previous geological mapping was published by Russell (1940) at a scale of 1/2 mile to 1 inch, and by Ermanovics (1970, 1981) at a scale of 1:250 000 and ca. 1:80 000, respectively. This summer's reconnaissance mainly consisted of mapping short sections (at 1:20 000) along and perpendicular to Highway 304, logging roads and shorelines.

RESULTS

The area between Wanipigow Lake and English Brook was examined (Fig. GS-20-1). Between the Wanipigow River and English Lake previous logging and the 1989 forest fire created excellent exposures. However, south of the river the forest fire was spotty, and soil cover too thick over metavolcanic rocks to improve exposure conditions, except in the topographically higher quartz diorite south of Highway 304.

The central part of the examined area forms the western extension of the Rice Lake greenstone belt. It is underlain by metavolcanic and metasedimentary rocks (V, Fig. GS-20-1) similar to those of the Rice Lake Group in the Bissett-Beresford Lake area (Weber, 1971). The metavolcanic rocks comprise metabasalts (massive, fine grained and pil-

lowed flows), massive hornblende (after pyroxene) -phyric metagabbro(?) and felsic pyroclastic rocks. With the exception of metagabbro the metavolcanic rocks are generally strongly sheared, and pillow structures are highly flattened and hardly identifiable. These metavolcanic rocks occur along the Manigotagan River and are in (unexposed) contact with biotite-hornblende-quartz diorite (D, Fig. GS-20-1) south of Highway 308. This quartz diorite is petrographically similar to the 2738 ± Ma Ross River pluton (Turek et al., 1989) southeast of Bissett.

Along the Wanipigow River the metavolcanic rocks are in strongly sheared contact[1] with Manigotagan metasedimentary rocks (Ermanovics, 1981; M, Fig. GS-20-1). This unit comprises, in the least deformed part of the map area near Curries Landing, thick bedded massive greywacke (1-8 m thick) grading into argillite (0.5- 1 m thick). The unit is similar to turbidites of the Edmunds Lake formation south of Long Lake (cf. Weber, 1971). Facing directions in the west central part are east to southeast. Towards the adjoining units, the metavolcanic rocks to the south and hornblende tonalite (T, Fig. GS-20-1) to the north, the primary thick bedded sequence has been transposed into an east-southeast striking sequence characterized by attenuated beds. These are commonly Z folded, with steeply south dipping axial planar cleavages and steep southeasterly plunging axes. The contact with the northern hornblende tonalite is defined by a linear gulley, with mylonitic rocks[2] and steep cliffs along its sides, suggesting a fault contact.

Shallow (30°) plunging rodding in the tonalite, and the transposed structures in the metasedimentary and metavolcanic rocks to the south, is consistent with the interpretation that the supracrustal sequence is a compressed fault bounded block with a sinistrial movement compo-

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[1]tuffaceous rocks shown by Russell (1949) are in fact highly sheared rocks now mapped as either metavolcanic or metasedimentary rocks
[2]mapped as rhyolite by Russell (1949)
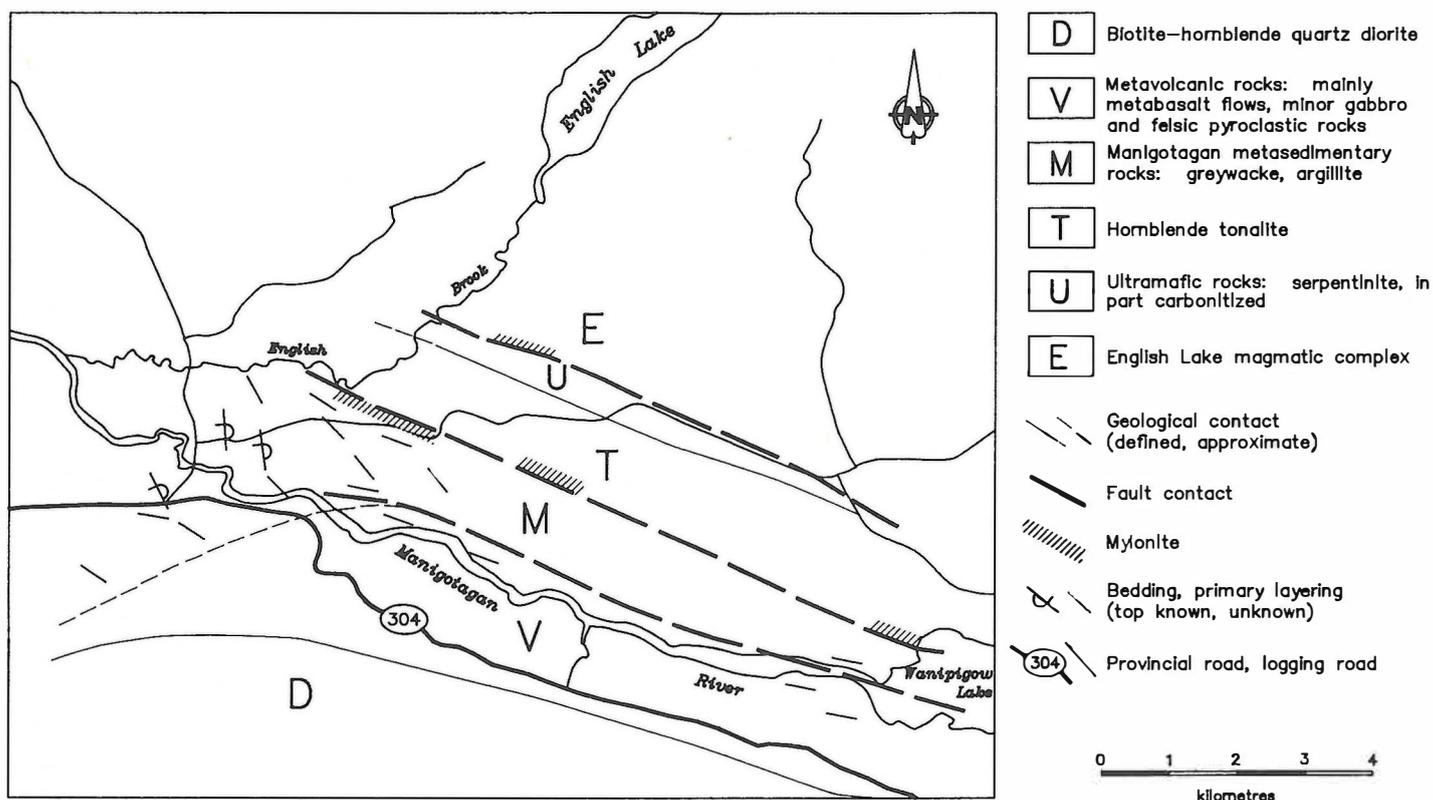
Figure GS-20-1: Geology of the English Brook area.

nent along both contacts. According to Russell (1949) and Ermanovics (1981), the hornblende tonalite extends west to the shore of Lake Winnipeg where a U-Pb zircon age of 2999 ± 10 Ma was determined (Ermanovics, 1981). The northern margin of the tonalite is defined by an up to 600 m wide linear topographic low with isolated knobs of massive serpentinite (U, Fig. GS-20-1), locally completely carbonatized. There is some evidence in hand specimens that the original rocks were coarse grained olivine cumulates. The absence of any associated supracrustal rocks, and their position relative to the adjacent units (see below), suggests that the ultramafic rocks are fault-related, mantle-derived rocks unrelated to the supracrustal rocks of the Rice Lake greenstone belt.

The English Lake magmatic complex (E, Fig. GS-20-1), north of the ultramafic rocks, comprises layered amphibolite, metagabbro and tonalitic gneiss with younger felsic and mafic-ultramafic phases. The complex represents a mid- to lower-crustal level, lithologically similar to Pikwitonei granulites (except of slightly lower grade), and is unrelated to the upper crustal volcano-plutonic terrain to the south. Whereas metamorphic grade in the supracrustals to the south is biotite-chlorite grade (greenschist facies), the rocks of the English Lake magmatic complex exhibit upper amphibolite facies mobilizates of plagioclase, hornblende ± quartz.

The mafic rocks of the complex include metapyroxenites and layered anorthosite gabbro anorthosite. The young intrusive rocks range in composition from quartz diorite-anorthosite to hornblendite-pyroxenite. This compositional range is the result of differentiation of a mafic-ultramafic parent magma. This differentiation was possibly initiated through melting of older rocks by a mafic-ultramafic magma at a low crustal level. The young intrusive phases form spectacular intrusive breccias (Fig. GS-20-2, and GS-20-3). For further descriptions of the magmatic complex see Young and Theyer (GS-23, this volume).

Economic geology

Young and Theyer (GS-23, this volume) describe mineralization in gabbroic rocks of the English Lake magmatic complex. In addition, the writer observed minor sulphide mineralization associated with a quartz vein in a shear zone and carbonate alteration in the southern part of the complex.

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Figure GS-20-2: *Intrusive breccia: pyroxenite intruding layered tonalite gneiss-amphibolite complex; English Lake magmatic complex.*
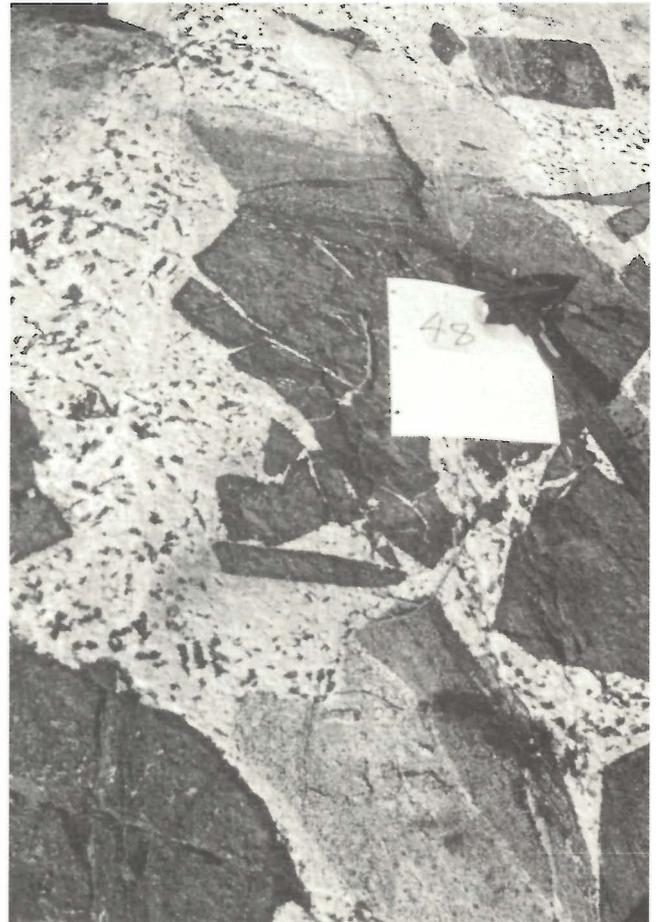

Figure GS-20-3: *Intrusive breccia: pegmatitic anorthosite intruding layered amphibolite; English Lake magmatic complex.*

GS-21 ANOMALOUS TRACE ELEMENT CONCENTRATIONS IN VEGETATION FROM THE AREA OF THE TANCO PEGMATITE, BERNIC LAKE, MANITOBA (NTS 52L/6)

by M.A.F. Fedikow and C.E. Dunn[1]

INTRODUCTION

An orientation program of vegetation sampling and analysis was undertaken at the Tanco Ta-Li-Cs deposit at Bernic Lake (Fig. GS-21-1, GS-21-2) to assess the viability of using vegetation as a sampling medium to assist in the search for Ta mineralization. A variety of species of vegetation were sampled in an attempt to determine which, if any, was most effective in concentrating Ta and other associated elements.

Previous work has indicated that under certain physico- chemical regimes Ta may be concentrated in vegetation. Brooks (1972) suggests that elements with low mobility (Ta, Nb, Zr) are generally inaccessible to vegetation root systems and accordingly there will be insufficient amounts of these elements present in plant tissue to make vegetation geochemical surveys a viable exploration technique. Kovalevsky (1987) describes low contrast Ta and Nb in vegetation collected in proximity to outcropping deposits of Ta and Nb. The low mobility of these elements and the generally higher contrast anomalies available from pedogeochemical counterparts has precluded the use of vegetation in exploration surveys. Kovalevsky (1987) indicates, however, that higher contrast biogeochemical anomalies for these elements have been obtained when samples were collected from cryogenic taiga-type soils.

Material for this study was collected near the Tanco tailings area, an obvious source of Ta. Although airborne particulate contamination was considered to be a certainty, the analysis of trunkwood from available vegetation types was undertaken to determine if there was sufficient uptake of Ta by the root systems of the trees. If measurable quantities of Ta are present in trunkwood then the acquisition of this element by the root system of a particular vegetation type would indicate that vegetation represents a viable sampling medium for Ta exploration in non-contaminated areas.

SAMPLING AND ANALYSIS

A total of 57 vegetation samples representing twigs, outer bark

[1]Exploration Geochemistry Subdivision, Mineral Resources Division, Geological Survey of Canada, Ottawa.

Figure GS-21-1:   Location map for the study area.

and trunkwood from black spruce, pine, birch, poplar and alder (Table GS-21-1) were collected from the general area of the Tanco tailings pond (Fig. GS-21-3). Sampling was conducted over a four day period in March, 1990 when sap flow in vegetation was effectively static.

Samples were air dried for six weeks then transferred to clean, dry, pre-labelled sample bags and shipped to the laboratories of the Geological Survey of Canada (Ottawa) for some of the analytical work.

Samples were ashed and analysed for a multielement suite using neutron activation (Activation Laboratories Ltd., Ancaster), ICP-AAS/hydride generation (Bondar-Clegg and Co. Ltd., Ottawa) and wet chemical methods in the laboratories of the Geological Survey of Canada.

GEOLOGICAL SETTING OF THE TANCO PEGMATITE

The Tanco pegmatite, occurs approximately 180 km east-northeast of Winnipeg, close to the Manitoba-Ontario border on the northwest shore of Bernic Lake. The pegmatite intrudes foliated metagabbro of the Archean Bird River greenstone belt close to the contact with a synvolcanic granodiorite stock (Fig. GS-21-1). Pegmatite emplacement occurred along joints and fractures in the gabbro.

The Tanco pegmatite occurs as a bilobate, subhorizontal, doubly plunging body with a shallow north dip. At its margin the pegmatite is characterized by swarms of interfingering pegmatite dykes. The pegmatite has a maximum thickness of 100 m and can be traced for 1440 m along strike. A width of 820 m for the pegmatite is attained in a north-south direction. Based upon mineral composition and texture the pegmatite is divided into nine units, all of which are surrounded by a contact metasomatic halo developed within gabbroic wallrocks (Crouse et al., 1979; Ferreira, 1984). A thorough review of the mineralogy and textures in the Tanco pegmatite is provided by Cerny (1982). An extensive reference list in Cerny (1982) provides a source for papers describing research undertaken on the various aspects of the deposit.

As of January 1, 1990 reserves at Tanco were calculated as follows:

Ta_2O_5 1 317 466 tonnes at 0.103%
Li_2O (spodumene)   3 608 884 tonnes at 2.73%
Cs_2O (pollucite)   317 485 tonnes at 23.3%

Additionally, Cerny (1982) quotes "sizeable reserves" of Rb in lepidolite and Ga in mica and feldspar.

RESULTS

Table GS-21-2 summarizes the limited geochemical data available at the time of writing. Analyses are based upon wet chemical analyses of ashed samples of jack pine (Pinus banksiana).

A comparison of the trace element contents of the various portions of the jack pine for six trace elements indicates a substantial difference between trunkwood, twigs and outer scaly bark. Contents of Zr, Nb, Hf, Ta and Be are much higher in the twigs and outer bark; Mo follows this same trend although the difference in concentration is smaller. The outer scaly bark contains higher Zr, Nb, Hf and Be, lower Mo and similar Ta when compared to the twigs. The high concentrations of these elements in both the outer bark and twigs probably represents airborne particulate contamination of the samples; an hypothesis substantiated by the identification of probable pollucite grains on the surface of some of the vegetation samples. The samples were examined with a scanning electron microscope.

The trace element contents of the trunkwood, in particular the Ta concentrations (range 5.03 - 46.5 ppm), are notable. This observation is critical to this orientation survey since it demonstrates that the root system of the jack pine has the capability of acquiring Ta from the substrate through its root system.

Regardless of the source of Ta, be it anthropomorphic or naturally occurring, the indication is that the jack pine is capable of reflecting
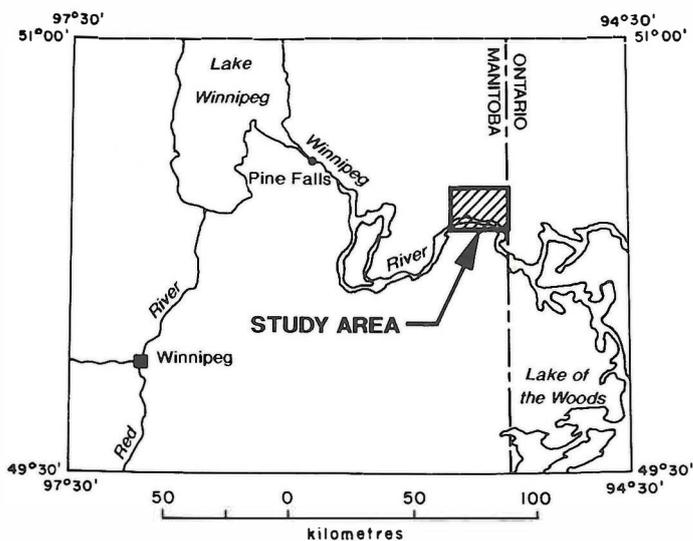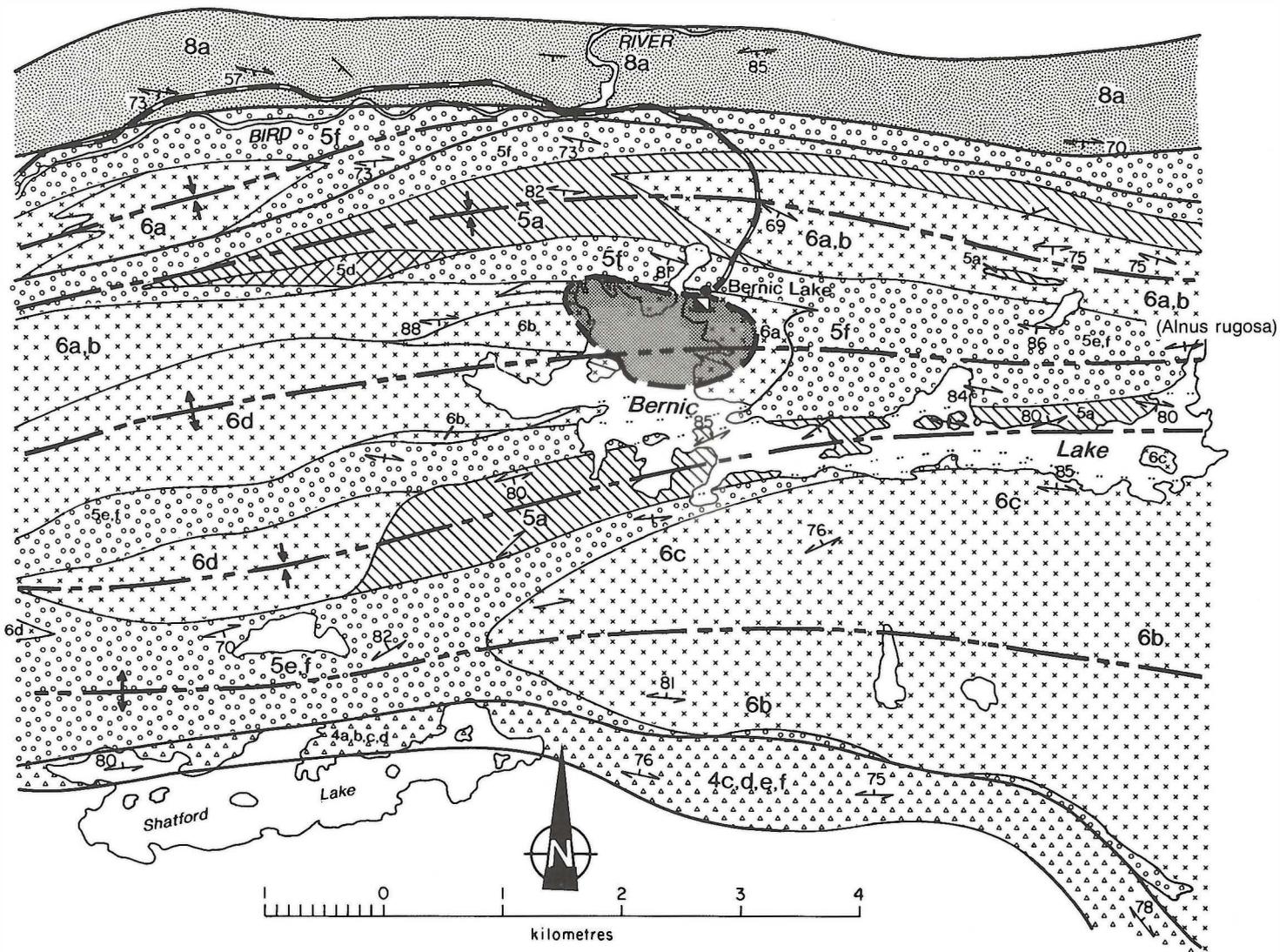
METAVOLCANIC, METASEDIMENTARY AND SYNVOLCANIC INTRUSIVE ROCKS

Booster Lake Formation; 8a greywacke mudstone; 8b conglomerate/metamorphosed equivalents

UNCONFORMITY

Composite synvolcanic intrusive rocks; 6a gabbro; 6b diorite; 6c quartz-feldspar porphyry; 6d granodiorite/metamorphosed equivalents
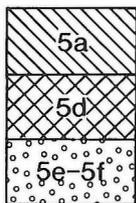
UNCONFORMITY

Bernic Lake Formation; 5a basalt

5d rhyolite

5e polymictic conglomerate; 5f oligomictic conglomerate

UNCONFORMITY

Peterson Creek Formation; 4a rhyolite; 4b breccia; 4c lapillistone; 4d lapilli/tuff; 4e tuff; 4f volcanic sandstone/metamorphosed equivalents

Vertical projection of the Tanco pegmatite (Crouse et al, 1979)

Geological boundary (defined, underwater)

Fault
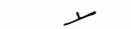
Bedding (tops unknown)

Schistosity (dip known, dip unknown, vertical)

f_2 anticlinal trace / f_2 synclinal trace

Mine (active)

Road

Geology by D.L. Trueman, 1980

Figure GS-21-2:   Regional geological setting of the Tanco Ta- Li-Cs deposit.

Table GS-21-1

Sampling summary for the Tanco vegetation geochemical survey. Abbreviations as follows: T-twigs, B-outer bark, TRW - trunk wood

Site No.	Black Spruce (Picea mariana)			Pine (Pinus banksiana)			Birch (Betula papyrifera)			Poplar (Populus tremuloides)			Alder (Alnus rugosa)
	T	B	TRW	T	B	TRW	T	B	TRW	T	B	TRW	T
1	X	X	X	X	X	X	X			X			
2				X	X	X							
3				X	X	X							
4				X	X	X							
5				X	X	X							
6	X			X	X	X							
7				X	X	X	X						
8	X	X	X				X						
9				X	X	X							
10							X						
11										X			
12										X			
13							X			X			
14							X						X
15													X
16													X
17													X
18										X			
19							X						
20													X
21	X												
22													X
23										X			
24										X			
25													X
26										X			
27													X
28										X			
29													X

the general levels of Ta in the substrate through analysis of trunkwood. The same observation can be made for each of the other elements reported, albeit at much lower concentration levels and corresponding background:anomaly contrasts. Furthermore, in areas devoid of contamination the acquisition, transport and distribution of Ta from the root system through the trunkwood to the branches and other organs of the vegetation will permit the more easily sampled twigs and outer bark, rather than the trunkwood, to be used in a geochemical survey.

ACKNOWLEDGEMENTS

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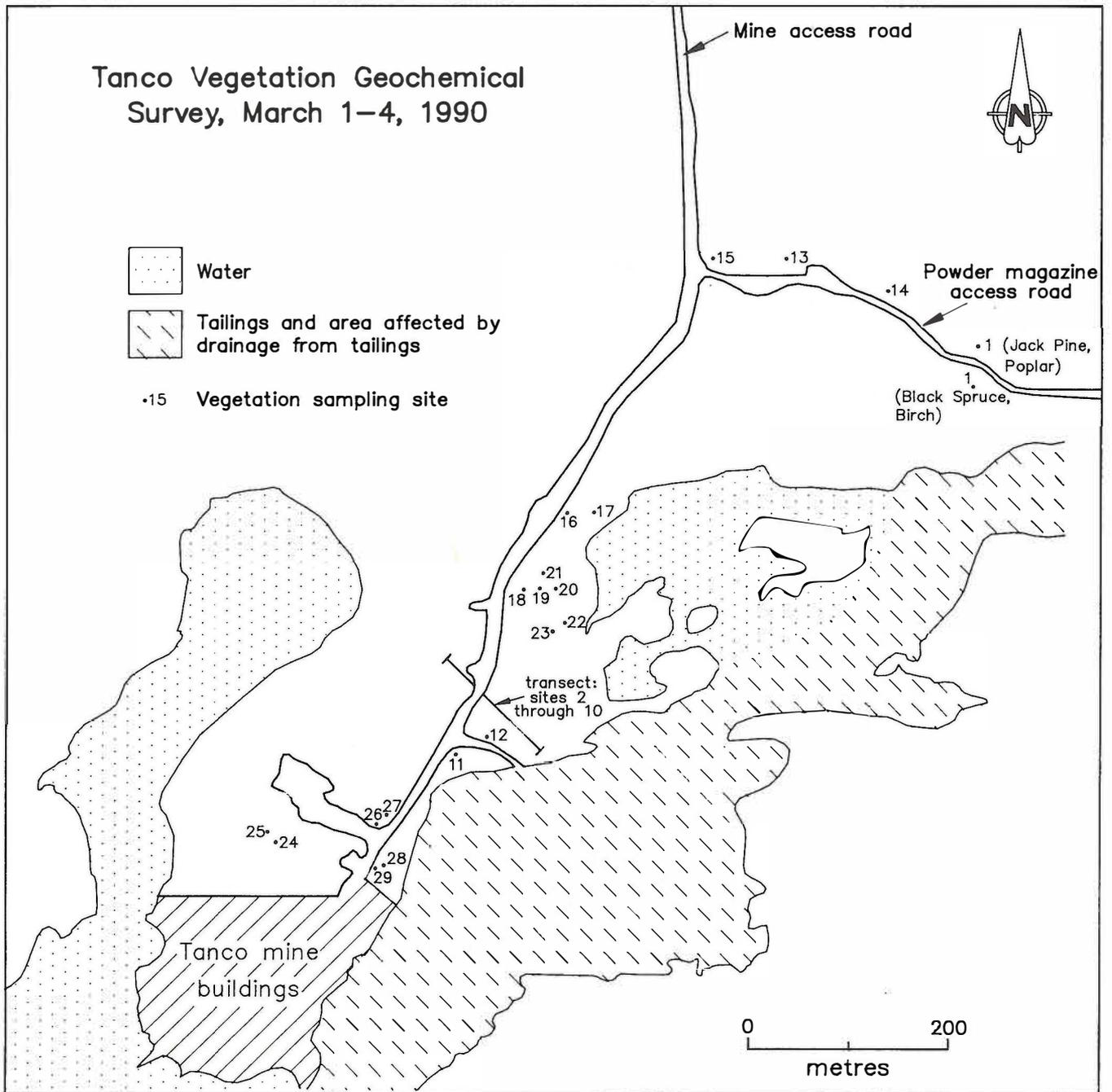
Figure GS-21-3: Vegetation sample locations, Tanco Ta-Li-Cs deposit. Samples collected at each site are specified in Table GS-21-1.

The following labels appear on the map:

Tanco Vegetation Geochemical Survey, March 1–4, 1990

Mine access road

Powder magazine access road

•15 •13
•14
• 1 (Jack Pine, Poplar)
1. (Black Spruce, Birch)

Water

Tailings and area affected by drainage from tailings

•15   Vegetation sampling site

•16 •17

•21
18 •19 •20
23• •22

transect: sites 2 through 10

•12

11

26• •27
25• •24
•28
29

Tanco mine buildings

0   200
metres

Table GS-21-2
Summary of Geochemical Data from Jack Pine Samples, Vicinity of
Tanco Ta-Li-Cs Deposit. All values in ppm based on ashed samples.

Jack Pine Twigs		Zr	Nb	Hf	Ta	Mo	Be
Sa.#	1	39.9	25.2	3.65	257	1.0	38
	2	42.9	71.6	6.60	749	1.1	116
	3	40.3	75.3	6.28	834	1.3	112
	4	45.1	77.2	6.45	814	1.1	108
	5	32.8	46.3	5.00	500	1.2	56
	6	37.4	25.2	2.88	218	1.3	30
	7	39.7	44.8	4.99	453	1.1	56
	9	38.4	36.1	4.25	369	1.1	50
	10	35.6	1.7	0.93	nd	3.9	nd
Outer Bark							
	1	66.2	38.6	7.03	336	1.2	113
	2	47.0	82.8	8.83	786	0.9	171
	3	44.4	75.7	7.54	745	1.0	189
	4	48.6	70.3	8.40	706	0.8	190
	5	49.9	74.8	8.40	620	0.8	182
	6	55.6	64.8	7.66	556	1.0	161
	7	63.8	58.0	6.73	497	1.1	123
	9	45.3	44.5	6.19	417	0.8	123
	10	48.8	43.5	6.91	477	0.8	115
Trunkwood							
	1	1.8	0.7	0.10	9.4	0.31	2.5
	2	2.2	2.7	0.38	33.0	0.91	6.0
	3	3.0	4.4	0.41	46.5	0.72	13.0
	4	4.3	3.5	0.38	36.5	0.32	13.0
	5	2.6	3.2	0.39	38.9	0.27	17.0
	6	5.8	4.5	0.57	39.4	0.46	16.0
	7	1.8	1.2	0.16	12.3	0.34	3.0
	9	1.8	0.5	0.11	5.03	0.30	1.4

nd - not detected

GS-22 VERTICAL SEDIMENTARY SEQUENCE AND MORPHOLOGY IN TRANSGRESSIVE BARRIER ISLANDS ALONG THE RED RIVER DELTA (NTS 62I/7)

by E. Nielsen

INTRODUCTION

A new project has been initiated in the Netley-Libau marshes, also known as the Red River Delta (Fig. GS-22-1), to investigate modern ongoing geological processes and the late Holocene history.

The Red River and its tributaries have drained much of the southern prairies of Manitoba, Saskatchewan and adjacent parts of the United States since early Holocene times. Water draining this huge watershed has deposited sediments in Netley-Libau marshes and adjacent parts of Lake Winnipeg that have recorded and continue to record geomorphic and climatic changes, isostatic tilting and anthropogenic modifications to the surrounding landscape. The continued rapid southward transgression of Lake Winnipeg, due to isostatic tilting has resulted in onlapping sedimentation in the South Basin of the lake. Thus, the delta affords a unique area for establishing a comprehensive record of late Holocene climatic and geomorphic changes.

The proximity of the delta to Winnipeg and Selkirk and the fact that the Red River flows through these communities and large agricultural regions makes it an ideal area for studying human modification, (including pollution), that has occurred in southern Manitoba in historic and pre-historic times.

Detailed work in the area will be undertaken in the next few years to:

1. map the morphology, distribution and composition of surface sediments using air photos and surface samples;

2. determine sediment budgets (including rates of sedimentation and erosion) using radiometric dating, lithofacies analysis, beach profiling and air photos;

3. determine the rate and magnitude of crustal warping (past, present and future) using detailed radiocarbon dating, pollen, lithofacies analyses and dendrochronology;

4. establish a detailed record of late Holocene environmental changes including anthropogenic changes using pollen analysis and radiometric dating; and

5. collect baseline geochemical data against which anthropogenic impact can be measured by analysing surface samples and cores for selected trace elements.

During the 1990 field season work was concentrated along the barrier islands forming the south shore of Lake Winnipeg.

GENERAL DESCRIPTION

The Red River Delta comprises approximately 24 000 hectares of marshes separated from the south end of Lake Winnipeg by a narrow (up to 100 m wide) 22 km long barrier island system. The Red River forms a natural division of the delta separating Netley Marshes to the west from Libau Marshes to the east. The Red River branches into the three smaller West, Main and East channels 3.2 km south of Lake Winnipeg. Salamonia Channel branches off West Channel 2.4 km south of the lake. The major channels are separated from the surrounding marshes by almost
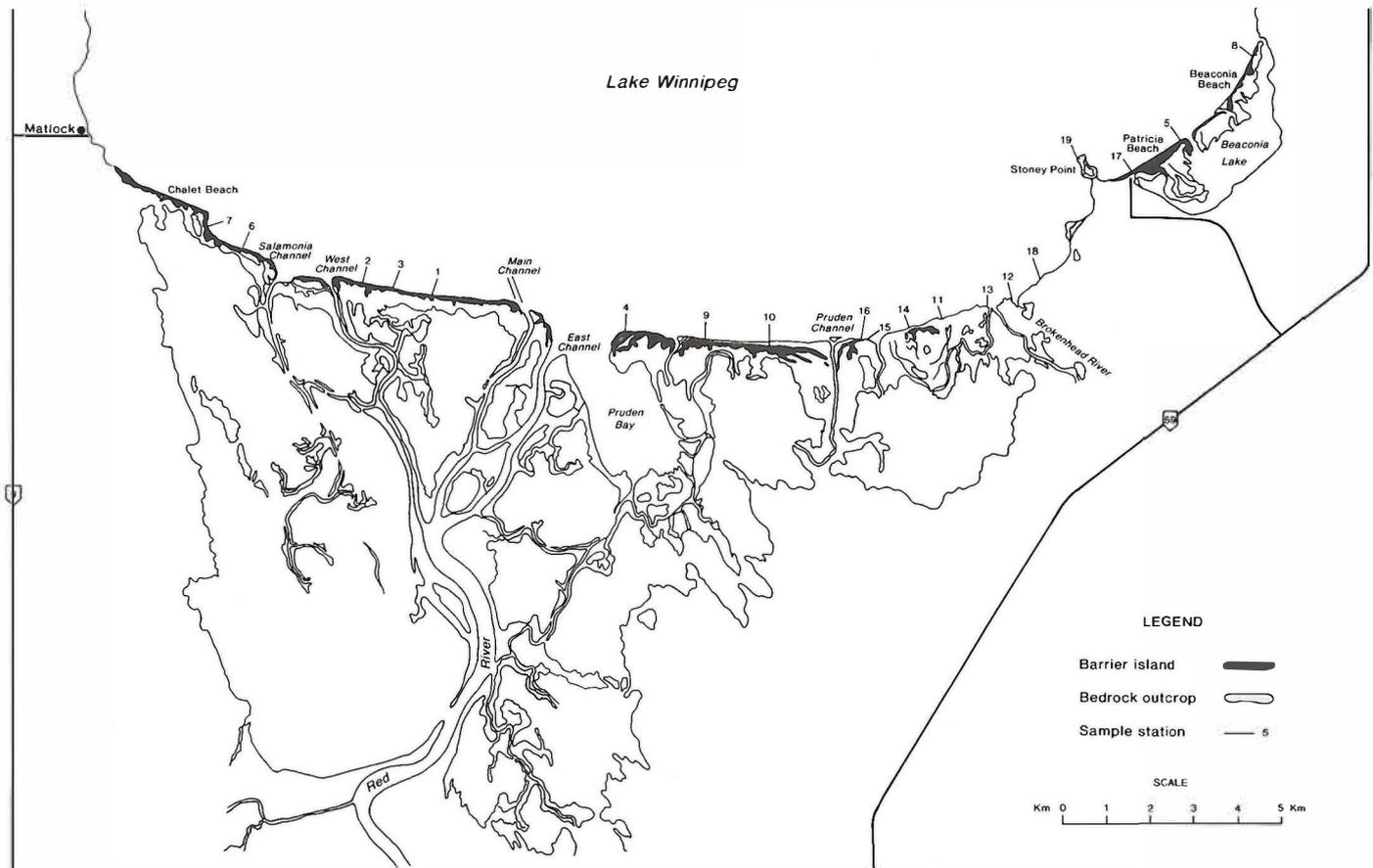

Figure GS-22-1: Location map of the Red River Delta and the barrier islands along the Lake Winnipeg shoreline.

continuous levees, which in places are breached by crevasses. The interchannel areas forming the delta plain are occupied by numerous marshes and lakes. The extensive arcuate barrier islands at the north end of the Red River Delta identifies this as a high-destructive, wave-dominated delta.

Sediment supply to the barrier islands is thought to be mainly by coastal erosion and long shore drift from the east and west shores of Lake Winnipeg. This is believed to produce approximately 2.8×10^5 tons of silt and clay and approximately 2.3×10^5 tons of sand and gravel each year (Penner and Swedlor, 1974; Veldman, 1969). Estimates by Penner and Swedlor (1974) indicate the Red River transports approximately 2.5×10^6 tons of silt and clay and 8.0×10^4 tons of sand to Lake Winnipeg each year. Work by K.C. Tam and V.T. Chacko (unpublished) indicate that bottom sediments in Main, East, West and Salamonia channels consist on average 5 to 58 per cent sand, 16 to 64 per cent silt and 15 to 35 per cent clay (Fig. GS-22-2). Much of the fine grained suspended sediment brought to the prodelta environment by the Red River and coastal erosion is transported inland through breaches in the barrier island system and deposited in lagoons on the delta plain during periods of high wind set-up. Wind set-up, which may account for water level fluctuations up to 1.2 m (Penner and Swedlor, 1974) in the delta, is probably responsible for the formation of the numerous minor channels joining the lakes and marshes of the delta plain (Fig. GS-22-1). Wind set-up produces many features in the delta that are generally characteristic of tidal deltas.
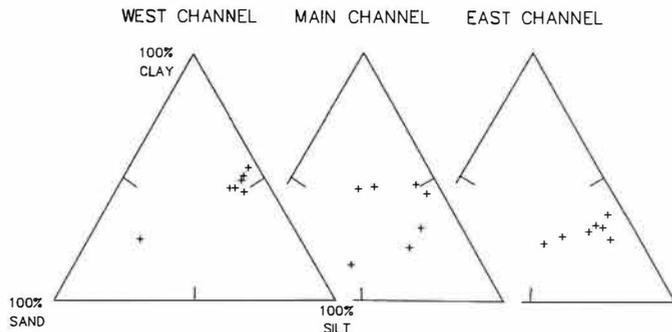

Figure GS-22-2:   Texture of bottom sediments from the Red River (K.C. Tam and V.T. Chacko, unpublished data). Note sand = 2.00 to 0.075 mm, silt = 0.075 to 0.005 mm and clay = <0.005 mm.

BARRIER ISLANDS
Morphology and Grain Size
Detailed profiles were surveyed across the barrier islands at eight locations along the Red River Delta front and at three locations along the bay-mouth bar at Beaconia Lake on two separate occasions to determine temporal changes in the beach morphologies, to define facies and locate samples.

West of Salamonia Channel the barrier island is typically about 70 m wide and 3 m high and comprises a variety of foreshore and backshore sand and gravel facies and a single heavily vegetated dune ridge.

Between West Channel and Main Channel the backshore becomes wider and the slope lower. Multiple chenier ridges have developed at the eastern end of this reach near the mouth of Main Channel. The grain size of the sediment becomes finer towards the east. The width of the barrier island and the height of the chenier ridges increase toward the east. Near the western end of this reach at station 2 (Fig. GS-22-1), the barrier island was breached some time between 1946 and 1979 during a period of high water. Air photos from 1946 show the barrier island to be continuous, but by 1979 there was an open water passage 200 m wide across the beach. By 1987 longshore drift had transported enough sand into the area and filled the gap; the only evidence of the breach being the absence of large trees on this part of the barrier island. Ob-

servations on tree size along other parts of the barrier islands indicates washovers and subsequent infilling of breaches of similar magnitude have been common occurrences in the past.

In the reach, between Main Channel and Pruden Channel the barrier islands are less than 2 m high. The width varies from approximately 22 m in places near the west to over 100 m in the east. The profile of the backshore becomes lower toward the east. The sediment is fine sand.

East of Pruden Channel the barrier islands are so low as to be almost nonexistent and the shore is low and marshy with abundant cattails and bullrushes.

The bay-mouth bar at Beaconia Lake is 2 to 4 m high and from 30 m to more than 100 m wide in places. The backshore profiles are relatively steep in the northeast and in places along the central part of the bar. The southwestern end of the bar is the widest and has the lowest profile. The northeastern end of the bar along Beaconia Beach is mainly gravel and sandy gravel. The mean grain size decreases toward Patricia Beach where fine sand dominates.

The decrease in the height of the beaches, the lower profile, and the decrease in the mean grain size of the sediment from Chalet Beach in the west to the mouth of Brokenhead River in the east, suggests the main sand supply for the barrier islands is the west shore of Lake Winnipeg. Similarly, the main sand supply for the bay-mouth bar at Beaconia Lake is the headland to the north.

Carbonate Content
Preliminary interpretation of the calcium plus magnesium carbonate content of the 125 to 177 micron fraction of 108 samples indicates the highest values occur at the west end of the barrier island system. Values up to 24 per cent carbonate occurs west of Salamonia Channel. The carbonate content diminishes toward the east where values as low as 7 per cent occur between Pruden Channel and Brokenhead River. These values are in marked contrast to the 1.6 to 3.7 per cent carbonate content of Beaconia and Patricia beach samples.

Differences in the carbonate content of sand samples from the Red River Delta and the bay-mouth bar at Beaconia Lake suggest different provenances. The sand along the Beaconia bay-mouth bar is derived from the north and the sand along Red River Delta is derived from the west. The carbonate data further indicates that sand is not transported around the bedrock headland formed by Stoney Point.

Stratigraphy and Dating
The beach and nearshore facies of the barrier islands comprising sand and in places minor gravel, overlies peat and organic-rich silt and clay at sites 2, 4, 9, 5 and 8 (Fig. GS-22-1). These fine textured organic-rich sediments, interpreted as lagoonal sediments, typically outcrop in runnels or in the swash zone of the foreshore and can be exposed by trenching in places on the backshore (Fig. GS-22-3). Rooted tree stumps, logs and bison bones, characteristic of the lagoonal sediments, are exposed on the foreshore at several sites (Fig. GS-22-4). Radiocarbon dating of these sediments will help determine the rate of southward transgression of the barrier islands and the rise of lake level. A total of 15 samples were collected for radiocarbon dating.

High Water Levels
Evidence for higher lake levels were observed at three stations. At stations 6 and 7 (Fig. GS-22-1) prominent fossiliferous gravel layers, occurring in places up to approximately 1.5 m above present lake level, are interbedded with dune sand (Fig. GS-22-5). At station 19 a coarse gravel beach, 1.5 to 2 m above lake level, is found inland, but parallel to the present shore around most of Stoney Point. Shells and driftwood are common in this raised beach (Fig. GS-22-6). Large trees that are still alive, but partly buried by gravel, suggest the raised beach at Stoney Point is a relatively recent feature, and may in fact be related to the high water levels of 1966. The shell beds at stations 6 and 7, on the other hand, occur in sections with large 40 to 50 year old oak trees on top. As these trees are not buried by sediment it suggests the washovers recorded by the fossiliferous gravel occurred before 1965. It is hoped that the age of these high water levels may be determined by radiocarbon dating or dendrochronological analysis.
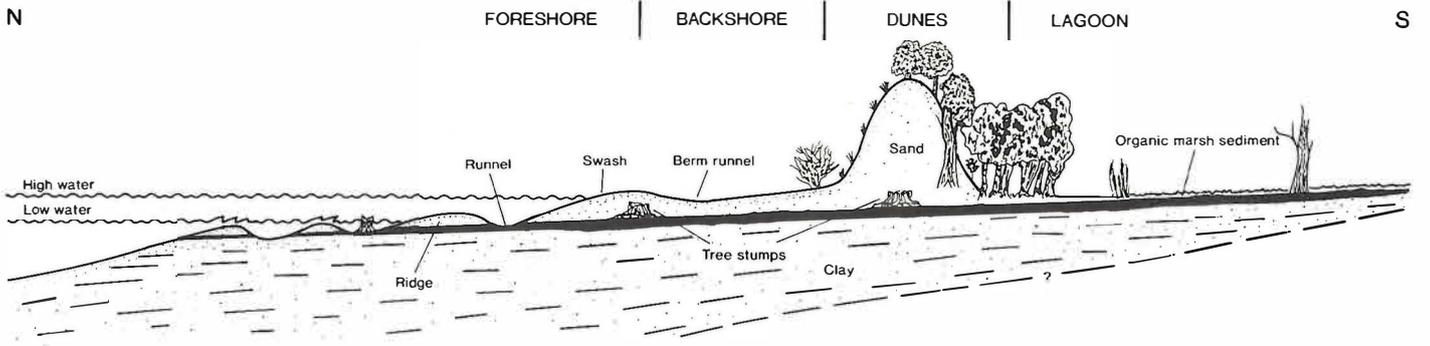
Figure GS-22-3:   General north-south profile of the nearshore, beach and lagoonal facies.
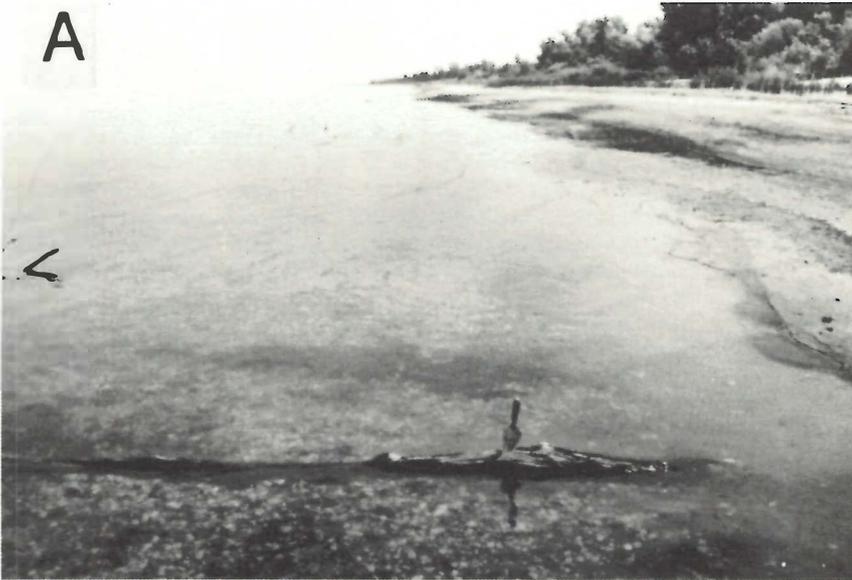
Figure GS-22-4A: Rooted stumps and logs capped by lag gravel on the foreshore at Station 2.

Figure GS-22-4B: Lagoonal peat eroding out on the foreshore at Station 4.

Figure GS-22-4C: Submerged tree stumps on the lower foreshore at Beaconia Beach.

Man-made Structures

Gabion walls and riprap have been used at Matlock, Chalet Beach and on the west side of the mouth of Salamonia Channel, and groynes have been constructed north of Beaconia in an attempt to halt coast erosion (Fig. GS-22-7). Other notable structures are two parallel sea walls trending perpendicular to the shore at the mouth of Red River.

At present it is uncertain what effect these structures have on the sediment budget of the barrier islands. Cutting-off the sand supply from the west shore of Lake Winnipeg may cause erosion of the barrier islands east of Chalet Beach. Similarly, the groynes north of Beaconia may cause accelerated erosion along Beaconia Beach and Patricia Beach.

CONCLUSIONS

Preliminary interpretation of the beach morphology, sediment texture and carbonate content of sand samples suggest that the main sediment source for the barrier islands along the Red River Delta is the West shore of Lake Winnipeg. The sediment source for the bay-mouth bar at Beaconia Lake is the headland to the north. Sediment eroded from the east and west shores is moved south- eastward and south-westward by longshore drift. There is no evidence that sand is transported around the natural barrier produced by Stoney Point. The limited observations to date on the morphology of the barrier islands between the Red River and Salamonia Channel suggests these beaches are accreting. The beaches west of Salamonia Channel, between Pruden Bay and Pruden Creek and most of the beaches along Beaconia Lake, appear to be eroding.

Periodically, the barrier islands are breached by high water and large waves and washovers are produced which may form open water channels into the lagoons. As long as the sediment supply to the barrier islands is maintained these breaches are quickly filled again by longshore drift of sand from the west side of the lake.

Stratigraphic evidence indicates the barrier islands are moving southward over the lagoons (delta plain) although the transgression has temporarily halted in places by local progradation of the beaches. The coastal erosion along the shore of Lake Winnipeg is a consequence of this transgression. Stabilization of the shore at Chalet Beach and Matlock, while the lake level rises, may lead to a permanent lack of sand along the barrier islands. Under natural conditions the shore line at Mat-

Figure GS-22-5: Dune sand (A) overlying fossiliferous beach gravel (B) deposited during high water stand of Lake Winnipeg at Station 6. Loonie for scale.

Figure GS-22-6A: Raised gravel beach on Stoney Point. Shovel for scale.

Figure GS-22-6B: Details of driftwood in the raised beach. Loonie for scale.
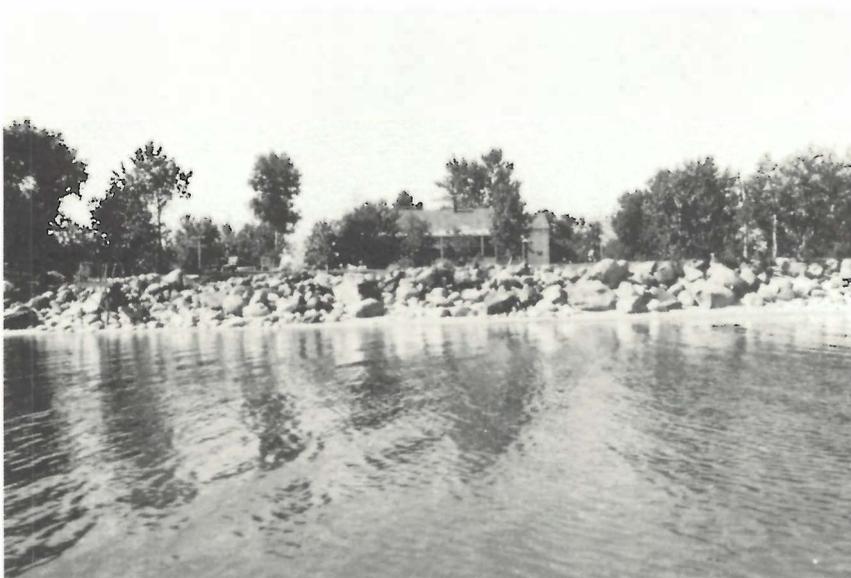
Figure GS-22-7: Riprap along the shore at Chalet Beach.

lock and the southwest side of Lake Winnipeg in general and the barrier islands including Chalet Beach would adjust to the rising lake level by simply migrating landward, but this is prevented by 'fixing' the shoreline. As a result there will be a lack of sediment on the shores necessary for the landward migration of the barrier islands through the process of washover and dune migration.

ACKNOWLEDGEMENTS

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Addendum

Subsequent to the writing of this report the following radiocarbon dates have been obtained on samples illustrated in Figures GS-22-4 and GS-22-6.

Figure	Station	^{14}C date	Lab. No.	Material
4A	2	335 ± 65 yrs. BP	BGS-1439	wood
4B	4	290 ± 70 yrs. BP	BGS-1440	wood
4C	8	185 ± 65 yrs. BP	BGS-1444	wood
4C	8	260 ± 65 yrs. BP	BGS-1443	organic muck
6B	19	modern	BGS-1451	wood

GS-23 GEOLOGY OF MAFIC-ULTRAMAFIC INTRUSIVE ROCKS IN THE ENGLISH LAKE AREA (NTS 62P/1)

by J. Young and P. Theyer

INTRODUCTION

Investigations at a scale of 1:15 840 in the English Lake area followed up the reconnaissance work of Theyer (1987). Theyer (1987) compared the igneous brecciation and development of pyroxene-plagioclase pegmatites in the mafic and ultramafic rocks of this area with similar features observed at the Lac des Isles (Ontario) PGE deposit. The objective of this project was to delineate the distribution of mafic to ultramafic rocks and to document their potential for PGE mineralization.

GENERAL GEOLOGY

The project area is underlain by a northern and a southern complex of gabbroic rocks, intruded by a central tonalitic mass (Fig. GS-23-1). These rocks were in turn intruded by: a) pyroxenitic plugs and dykes; and b) leucogabbroic megabreccias. Mafic to felsic dykes crosscut this sequence. These rocks are in fault contact with serpentinites to the south (Fig. GS-23-1).

MAFIC INTRUSIVE ROCKS

The mafic intrusive rocks comprise a series of layered leucogabbro, gabbro and melagabbro and lesser anorthosite and pyroxenite that are separated into four areas by tonalitic rocks, namely: a) a southern area up to 400 m wide and at least 2.5 km long; b) a northern area that extends at least 1.5 km north of the limit of mapping (Theyer, 1987); and c) two areas of gabbro and brecciated gabbro in the central tonalitic complex (GS-23-1).

South of the tonalitic mass the gabbroic rocks are subdivided into three units. Banded leucogabbro and gabbro, which make up 80 per cent of the area, are flanked to the south by 10 per cent layered gabbro and flanked to the north by 10 per cent layered leucogabbro. North of the tonalitic mass gabbroic rocks are subdivided into four units: a) gabbro and melagabbro; b) layered gabbro and leucogabbro; c) banded melagabbro, gabbro and leucogabbro; and d) layered leucogabbro, gabbro and pyroxenite.

Units in the north and south areas consist of similar lithologies and a similar style of layering that is marked by interlayered sequences and layered zones. In both areas the abundance of brown and white weathered gabbro and melagabbro decreases to the north. The occurrence and thickness of layered igneous zones also decreases to the north. Tonalitic rocks, which are intimately associated with the mafic complex, crosscut, and are concordant to, layers in the gabbroic layered sequences. The abundance of tonalitic rocks in the gabbroic rocks generally decreases away from the central tonalitic mass and the contact between the two units is gradational.

Lithological descriptions of the mafic rocks are as follows:
Banded leucogabbro and gabbro: 1 m to several tens of metres thick leucogabbro zones consisting of massive, layered and irregular areas that are separated by zones, up to 53 m thick, of brown and white weathered gabbro that is interlayered with lesser leucogabbro and anorthosite. Brecciated areas occur locally.
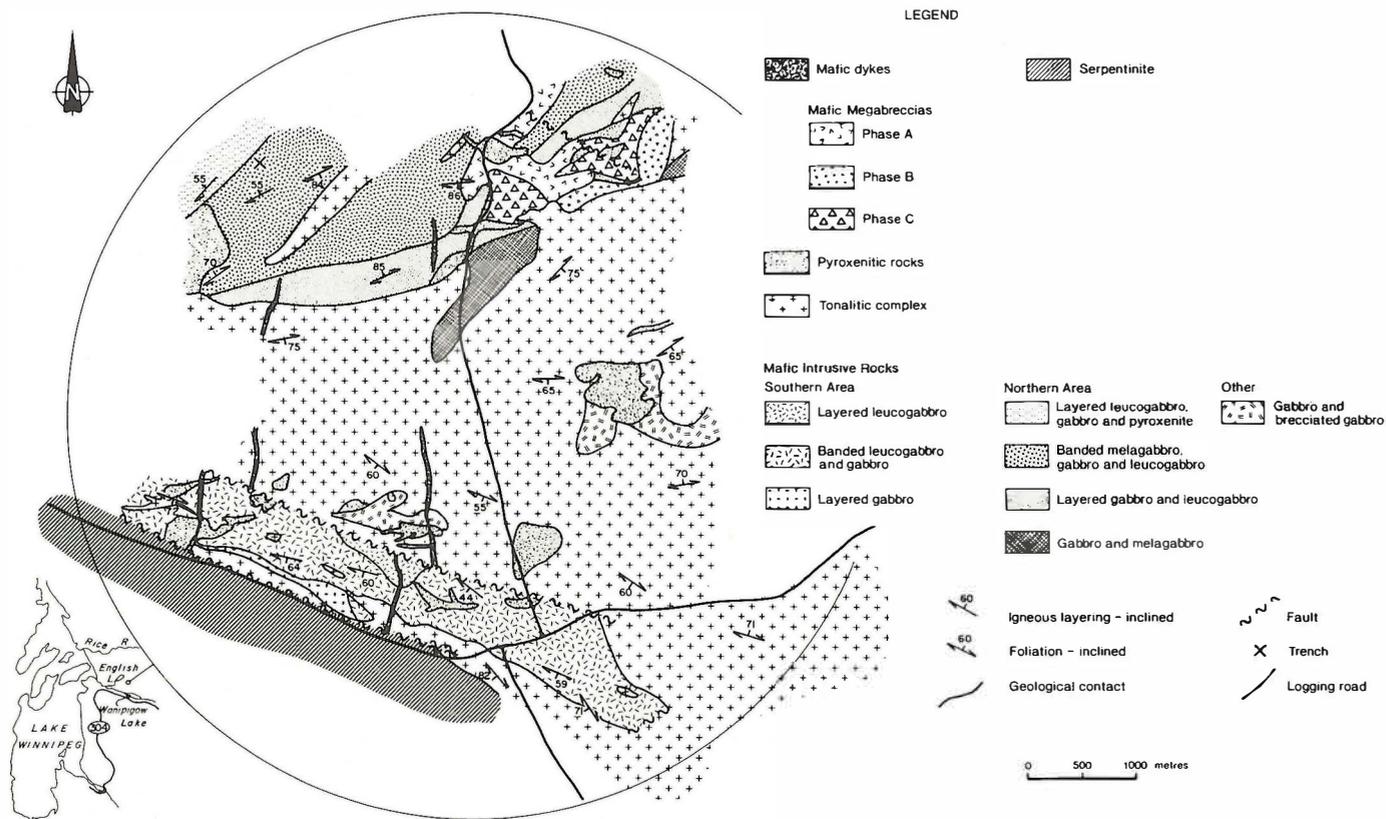

Figure GS-23-1: Geological map of the mafic-ultramafic intrusive rocks in the English Lake area.

Layered gabbro: brown to black and white weathered gabbros occur in 2 mm to several m thick layers with lesser abundances of gabbro to leucogabbro.

Layered leucogabbro: mm to m thick layers of leucogabbro and gabbro.

Gabbro and melagabbro: massive and layered brown and white weathered gabbro; locally with layers of 1 cm to 1.2 m thick leucogabbro.

Layered leucogabbro and gabbro: brown and white weathered gabbros are interlayered with 10 to 50 per cent leucogabbros 3 mm to 5 m thick.

Banded melagabbro, gabbro and leucogabbro: several metres to tens of metres thick layered gabbro and melagabbro are separated by layered zones of leucogabbro and gabbro

Layered leucogabbro, gabbro and pyroxenite: leucogabbro, gabbro, melagabbro and pyroxenite occur in layers 1 cm to 5 m thick.

TONALITIC COMPLEX

This complex comprises tonalites, quartz diorites and diorites. There are two main phases: a) medium- to coarse-grained, well foliated, white weathered tonalite; and b) fine- to medium- grained, relatively massive, grey to white weathered quartz diorite to diorite that occur as small areas in the tonalite and as associated intrusions. These rocks enclose trace to 25 per cent, generally deformed, several centimetre to 25 metre thick bands and 1 cm to 5.5 m fragments of massive to layered leucogabbro, gabbro, melagabbro, pyroxenite and amphibolite.

PYROXENITIC ROCKS

Pyroxenites, feldspathic pyroxenites and melagabbro occur as plugs, breccias, dykes, layers, and fragments. The rocks are largely green to locally reddish-green weathered with a grey to green fresh surface. The pyroxenites are partially to completely recrystallized to coarse grained, black weathered, hornblende.

Plugs

Equant to elongate plugs intrude the gabbroic rocks and the tonalitic complex. The plugs consist of massive and/or layered zones and less abundant irregular zones defined by lithologic variations. They comprise medium- to coarse-grained pyroxenite, which is locally magnetic, feldspathic pyroxenite and melagabbro. The pyroxenites grade into, or change abruptly to, feldspathic pyroxenite and melagabbro. Trace to 35 per cent, 2 mm to 2.7 cm long, white to reddish weathering plagioclase occurs as oikocrysts, individual crystals, or parts of possible gabbroic fragments. The plagioclase-rich zones occur in millimetre to 8 cm thick layers that are separated by centimetres to metres thick pyroxenite layers and in irregular areas up to 15 m long and several metres across. Banded to patchy pegmatoidal phases range from 3 cm to 3.5 m across.

Breccias

Breccia matrix occurs as partial margins to the plugs, and varies from massive pyroxenite, and feldspathic pyroxenite to irregular areas of feldspathic pyroxenite in pyroxenite. Along some contacts, however, the matrix consists of layered medium- to coarse-grained gabbro, anorthosite and plagioclase megacrystic gabbro. The pyroxenite and feldspathic pyroxenite are locally mixed with the gabbroic rocks. Fragments are subrounded to subangular and 1 cm to 6.5 m long. They comprise pyroxenite, amphibolite, and massive to layered gabbro.

Dykes

The dykes are subdivided into: a) dyke-shaped zones that occur over areas that are metres to tens of metres in width; and b) dykes with sharp margins. In dyke-shaped zones the matrix comprises medium- to coarse-grained pyroxenite and feldspathic pyroxenite that is gradational to melagabbro and local quartz melagabbro. Plagioclase occurs as megacrysts up to 3 cm long or as tabular to rounded grains or oikocrysts 1 mm to 1.7 cm long. Fragments of leucogabbro, gabbro, melagabbro, pyroxenite, amphibolite and tonalite comprise 40 to 70 per cent of the dyke- shaped zones and 10 to 60 per cent of discrete dykes (Fig. GS-23- 2). Pyroxenite veins, ranging from 10 to 50 cm thick, occur locally outside the dyke-shaped zones. Locally discrete dykes have 9 mm to 62 cm thick layers over a thickness of several metres.

Layers

Pyroxenite layers are a minor component of the layered units in the mafic intrusions. Individual layers range from 2 mm to 2.7 thick.

Fragments

Pyroxenite fragments constitute up to 15 per cent of any one outcrop. These fragments range from 1 cm to 6 m across.

MAFIC MEGABRECCIAS

Mafic megabreccias occur in an 1100 m long northeast-trending area (Fig. GS-23-1). The megabreccias are subdivided into phases A, B, and C on the basis of: a) grain size of the matrix and composition of the matrix; b) type and relative proportions of the fragments; and c) intrusive relationships.

In phase A the matrix comprises fine- to medium-grained white to buff weathered gabbro, leucogabbro and anorthosite. Fragments, up to 8 m long, consist of gabbro, quartz gabbro, massive and layered gabbro, massive pyroxenite and breccia that is similar to breccias in the dyke-shaped zones of pyroxenite.

Phase B matrix consists of a fine- to coarse-grained grey to white

Figure GS-23-2: Leucogabbro, gabbro and pyroxenite fragments in a dyke-like zone of pyroxenite.

weathering leucogabbro and anorthosite, with local interstitial areas of white weathering pegmatitic tonalite. The fragments, which range from 7 mm to 10 by 27 m, consist of dark weathering gabbro and melagabbro, fine- to medium-grained gabbro and leucogabbro, massive pyroxenite or a breccia that is similar to the breccias in dyke-shaped zones of pyroxenite.

In phase C the matrix consists of fine- to coarse-grained white to grey weathering gabbro and leucogabbro, with local areas of anorthosite. Fragments range from 1 cm to tens of metres and consist of massive and layered gabbro, melagabbro and pyroxenite.

STRUCTURE

A south-dipping, northwest penetrative foliation occurs in the southern part of the area, but to the north the foliation changes northeast. Foliation parallels igneous layering. In areas of more intense deformation the layers pinch and swell.

Two major northwest-striking faults flank the southern area of the mafic intrusive complex. The south fault (GS-23-1) is defined by anastomosing zones of mylonitization, abrupt lithological change to serpentinites, and small scale faults in the outcrop. The north fault occurs in a topographic depression, offsets the late mafic dykes and outcrops at one location where it forms a highly foliated zone of chloritized rocks up to 15 m wide. Local thrust faults cause repetition of stratigraphy. Isoclinal folds with an axial plane parallel to igneous layering cause local thickening of the sequence.

MINERALIZATION

Sulphides occur as trace, disseminated, pyrite and pyrrhotite in some pyroxenitic layers of the northern layered mafic intrusion. At one occurrence there are three southeast-trending trenches in the banded gabbros (GS-23-1). These trenches expose massive green to oxidized pyroxenite with trace to 7 per cent pyrite and pyrrhotite in fractures.

Pyroxenite plugs and associated breccias contain trace to 5 per cent disseminated pyrite and pyrrhotite. The dyke-like zones of pyroxenite contain up to 7 per cent pyrite; these dyke-like zones locally occur with areas of sulphide-bearing anorthosite and leucogabbro along brecciated contacts between two units in the northern area of the mafic intrusion. In some areas magnetite occurs in the pyroxenitic fragments, whereas in others it occurs in the matrix.

Some bands in a pyroxenite dyke, that occurs along the northern edge of the map area, contain about 5 per cent pyrite.

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Theyer. P.
1987: Platinum Group Elements in Southeastern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Field Activities 1987, p. 115-118.

GS-24 INVESTIGATION OF PEAT RESOURCES IN THE WASHOW BAY AREA (NTS 62P)

by P. Elias and B.E. Schmidtke

INTRODUCTION

During the 1990 field season, nine peat bogs in the Interlake area of Manitoba were sampled to assess:

1. reserves of horticultural quality sphagnum and,
2. accuracy of thematic LANDSAT imagery maps of peatlands in the Interlake area.

METHODOLOGY

Bogs with potential to contain commercial quantities of high quality sphagnum were identified on aerial photograph mosaics and 1:50 000 scale LANDSAT imagery maps. Selected sites were accessed by foot or all terrain vehicle. A Hiller-type peat sampler was used to take samples of the bogs at 0.5 m intervals. The samples were dried and visually analyzed for percentage and quality of sphagnum. Profiles and preliminary reserve estimates were prepared from the results.

BOG DESCRIPTIONS

1. Pine Dock Bog

An irregularly shaped bog with a surface area of 5.3 km^2 extends west from PTH 204 near Pine Dock in Twp 31 Rge 5E (Fig. GS- 24-1).
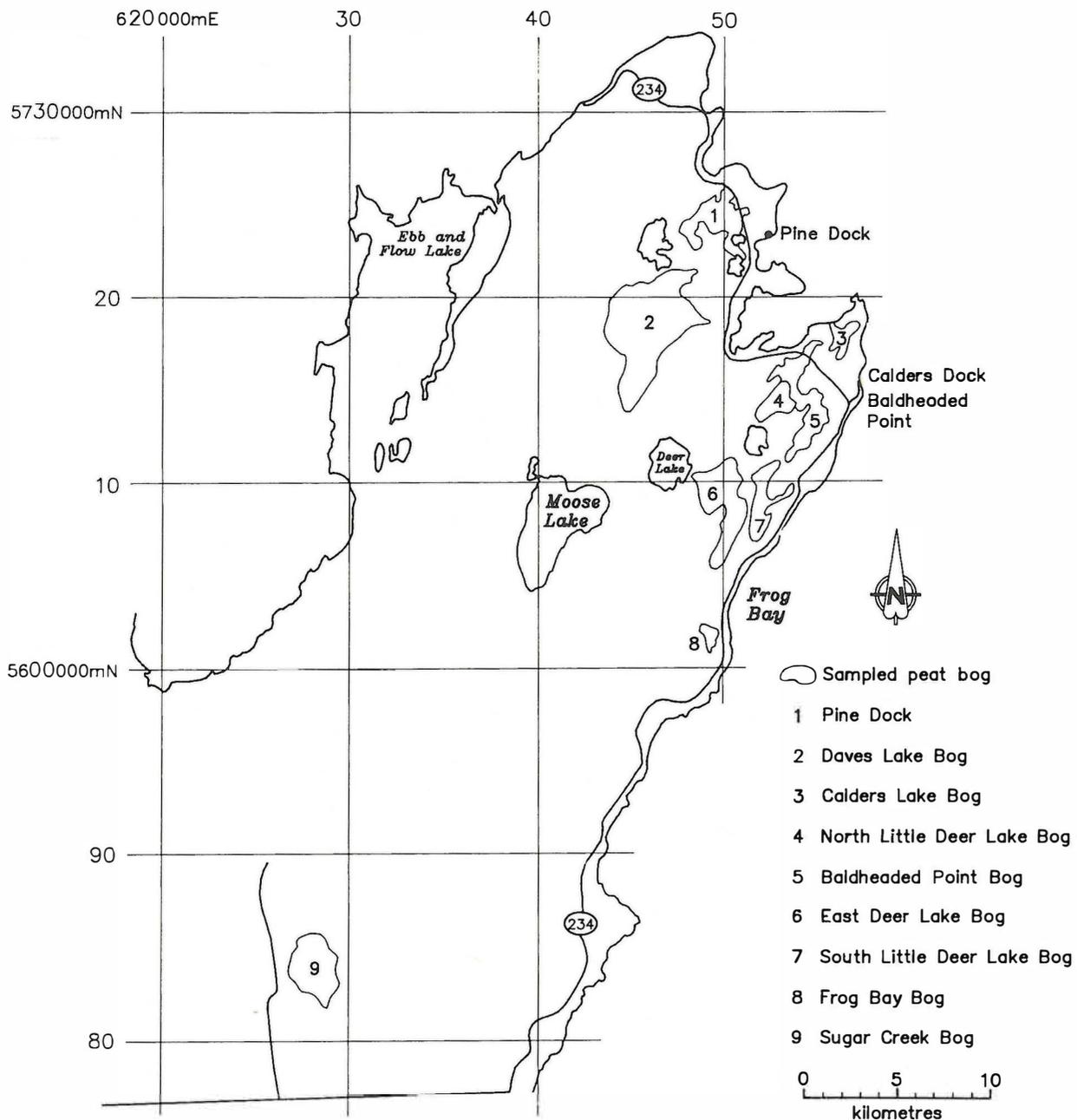

Figure GS-24-1:   Locations of sphagnum bogs sampled in 1990.

The surface cover consists of dense- to very dense-black spruce, abundant labrador tea, leatherleaf fern, a live sphagnum cover approximately 30 cm thick and local areas of reindeer moss.

Seven sites were sampled in this bog. The peat is medium to low quality and moderately humified. The average depth to the underlying clay is 1.1 m. The top 0.5 m of peat is brown with moderate to high wood fibre content, and high fine plant fiber content.

2. Daves Lake Bog

The Daves Lake bog is located approximately 4 km west of Big Bullhead Bay in Twp 30, Rge 4E and 5E, immediately north of the Biscuit Harbour Bog described by Bannatyne (1980). The Daves Lake bog has a surface area of 13.8 km^2. Total surface area of both bogs is 18.41 km^2. The sample sites are accessible by ATV on the winter logging road (Fig. GS-24-2).

Surface cover on the Daves Lake bog consists of dense black spruce, labrador tea, leatherleaf fern and sparse pitcher plants. Surface sphagnum cover is approximately 35 cm thick at the sample sites. Local patches of reindeer moss were noted. At least 5.0 m of peat over a clay base were found at most of the sample sites (Fig. GS-24-3).

Bannatyne (1980) described the Biscuit Harbour peat as good quality sphagnum to a depth of 2.0 m; it is nonhumified, very light brown and has a low wood fibre content. The samples taken in the Daves Lake bog in 1990 are nonhumified, light brown, coarse textured and low in wood fibre to a depth of 3 to 4 m. In general, below the 4.5 m depth, the peat is moderately humified with medium- to fine-coarseness. The average depth of high quality peat containing more than 75 per cent sphagnum is 3.5 m; this will provide an estimated peat reserve of 64.4 million cubic metres of product (Table GS-24-1).

3. Calders Dock Bog

This is a small, approximately 1.85 km^2 bog located directly south of Big Bullhead Point in Twp 30 Rge 6E (Fig. GS-24-1). At sample sites ER315 to ER317, the surface consists of 30 cm of surface moss with dense black spruce and dense labrador tea. At other sample sites the surface cover consists of grassy areas, alder bushes, equisetum, tamaracks, various shrubs and deciduous trees. The peat at these sites is moderately to strongly humified, with medium to low coarse fiber content and low sphagnum content. The higher quality peat, found at sample sites ER315 to ER319 in the east central portion of the bog is nonhumified, and contains coarse fibre and 95 per cent sphagnum to a depth of 1.5 m. An average depth of 0.5 m of high quality sphagnum is estimated to provide reserves of 0.93 million cubic metres of peat (Table GS-24-1).

4. North Little Deer Lake Bog

The 2.7 km^2 bog is located directly north of Little Deer Lake in Twp 30 Rge 5E (Fig. GS-24-1). The surface cover consists of a 30 cm layer of live sphagnum with local areas of reindeer moss and very dense black spruce interspersed with clumps of moderately dense tamarack.

Three sites were sampled in the east central portion of the bog. Approximately 4 m of peat overlies clay at sample sites. Above the 3.5 m depth, the peat is nonhumified, light brown, and has coarse plant fibre, low wood fibre and high sphagnum contents. Below the 3.5 m depth, the peat is humified and contains a low percentage of sphagnum. There are an estimated 9.45 million cubic metres of peat to the 3.5 m depth.

5. Baldheaded Point Bog

The 6.67 km^2 Baldheaded Point Bay bog is located in Twps 29 and 30 Rge 5E (Fig. GS-24-1). Surface cover in the northern portion of the bog consists of moderately dense black spruce, labrador tea sporadic tamaracks and grasses. The surface sphagnum moss is 15 cm thick with minor areas of reindeer moss. The moss is moderately humified to a depth of 0.5 m and contains approximately 70 per cent sphagnum. Below 0.5 m, the peat is moderately- to strongly- humified and has a medium wood fibre content and a low percentage of sphagnum.

The surface cover at site ER331 consists of dense tamarack, minor black spruce and moderately thick labrador tea. Surface sphagnum is 15 cm thick. The 3 m of peat have a high sphagnum content to a depth of 1.75 m.

The central portion of the bog was sampled at sites ER335 to ER337. ER335 and ER336 are areas of low quality peat. One and a half metres of high quality sphagnum was intersected at ER337.

In the south portion of the bog, the cover consists of varying percentages of tamarack, black spruce and labrador tea. The peat is, in general, moderately humified and contains 70 to 95 per cent sphagnum with a medium wood fibre content to a depth of 0.5 to 1.0 m.

The average depth of high quality sphagnum throughout the bog is 0.9 m, this provides an estimated reserve of 6.0 million cubic metres of sphagnum peat.

6. East Deer Lake Bog

An 8.95 km^2 bog is located east of Deer Lake in Twp 29 Rge 5E (Fig. GS-24-1). The surface has a moderately dense cover of black spruce, labrador tea and a 30 cm thick surface layer of sphagnum. High quality sphagnum was intersected to a depth of 1.0 m.

7. South Little Deer Lake Bog

The 4.39 km^2 bog is located directly south of Little Deer Lake in Twp 29 Rge 5E (Fig. GS-24-1). The surface of the bog is very wet and covered with dense black spruce, deciduous trees, labrador tea, grasses and reeds. Samples have a low sphagnum content, high fine plant fibre content and are strongly humified.

8. Frog Bay Bog

A 1.0 km^2 bog is located 1 km southwest of Frog Bay. The surface cover consists of black spruce, labrador tea, leatherleaf fern and a 25 cm thick layer of surface sphagnum moss. Sphagnum peat is 0.5 m thick and has a high wood fibre content. This bog has low potential as a source of sphagnum.

9. Sugar Creek Bog

The 6.85 km^2 oval shaped Sugar Creek Bog located in Twps 26 and 27, Rge 3E (Fig. GS-24-1) Surface cover consists of low- to medium-density black spruce, with abundant leatherleaf fern, areas of grass and labrador tea. The surface layer is 50 cm of sphagnum.

Nine sites were sampled in the Sugar Creek Bog. The maximum depth of 3.3 m was intersected at site ER350, near the centre of the bog. High quality sphagnum was intersected to a depth of 2.0 m. The peat is nonhumified, has a high coarse plant fiber content, a low wood fibre content and contains over 75 per cent sphagnum. The estimated reserves of high quality sphagnum in this bog are 13.2 million cubic metres.

CONCLUSION

Large reserves of high quality sphagnum were identified in the Washow Bay area. The bogs with the highest potential to be sources of horticultural sphagnum based on quality and reserves are the Daves Lake, North Little Deer Lake and Sugar Creek bogs. The Daves Lake and Little Deer Lake bogs are within 3 km of PTH 234 and approximately 200 km north of Winnipeg. The Sugar Creek Bog is approximately 185 km north of Winnipeg and is accessible from a wild life management road off PTH 325.

The Daves Lake Bog is classified as a "sphagnum/ericoid" and "ericoid/sphagnum" bog with areas of "open bog with low shrub" on the LANDSAT maps. The North Little Deer Lake Bog is classified as an "open bog with low shrub". In 1989 study, in the St. Lakes area "sphagnum/ericoid bogs" were found to have low potential as future producers because the sphagnum is restricted to a thin surface cover (Elias and Schmidtke, 1989). These studies illustrate that the LANDSAT maps have limited use in peat evaluation since they indicate only surface potential.
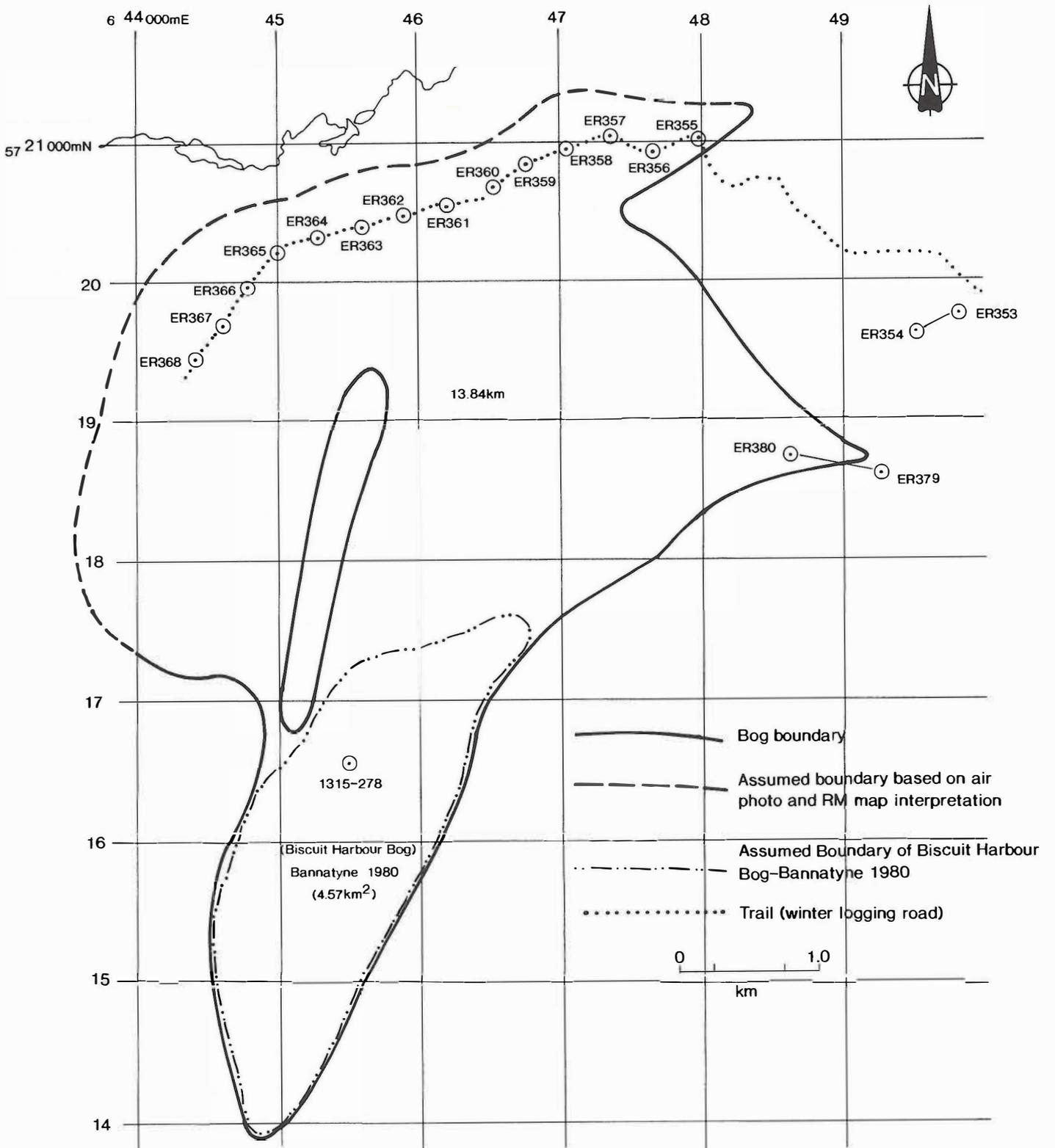
Figure GS-24-2:   Sample sites in the Daves Lake Bog.
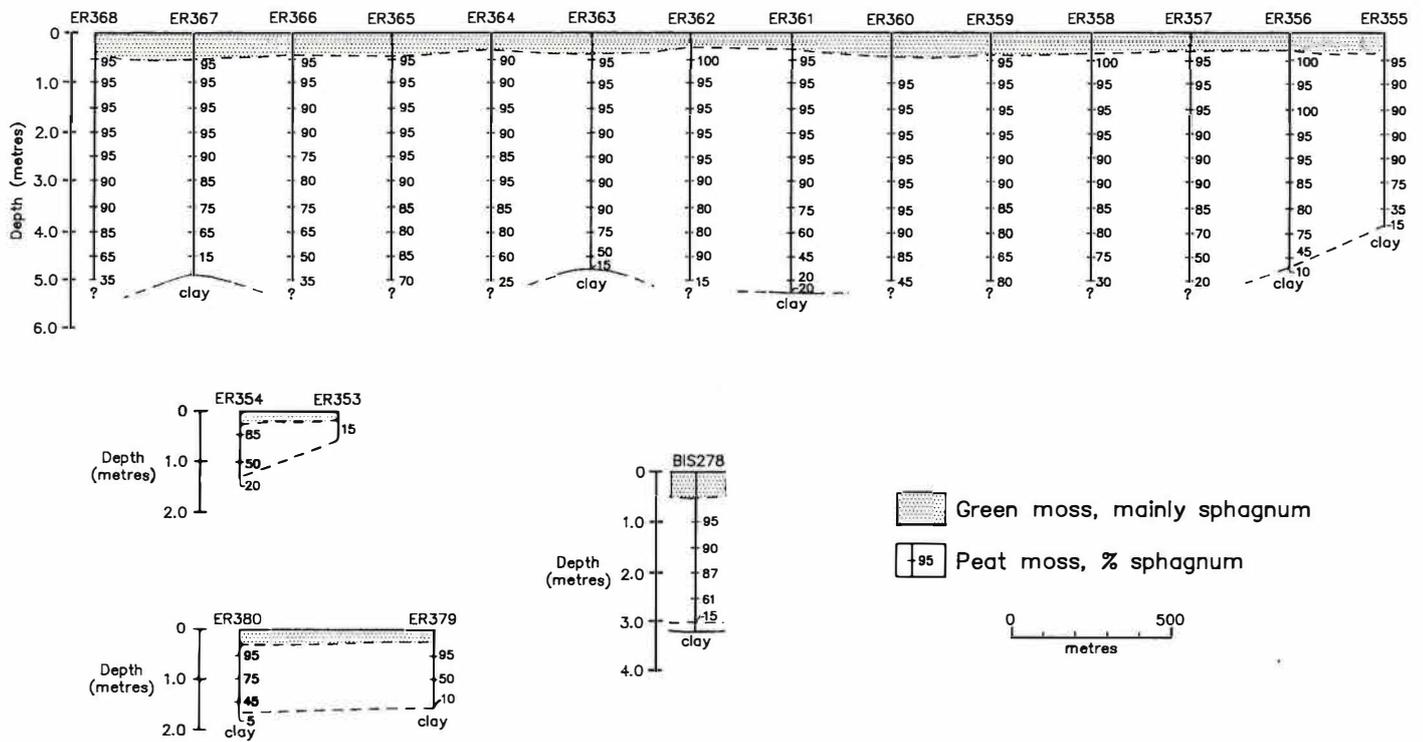
Figure GS-24-3:   Cross sections through the Daves Lake Bog.

Table GS-24-1
Estimated high potential sphagnum peat reserves in the Washow Bay area

Bog	km²	Acres	Average Depth (m)	Volume (million m³)	Tonnes of Product (x1000)	% Sphagnum
Pine Dock	5.30	1309	0.5	2.7	270	75-90
Daves Lake	18.41	4547	3.5	64.4	6440	75-100
Calders Dock	1.85	457	0.5	0.93	93	60-95
North Little Deer Lake	2.70	667	3.5	9.45	945	70-90
Baldheaded Point	6.67	1647	0.9	6.0	600	70-95
East Deer Lake	8.95	2220	1.0	8.95	895	85-95
South Little Deer Lake	4.39	1089	0	0	0	<60
Frog Bay	0.99	246	0.75	0.75	75	80-95
Sugar Creek	6.58	1632	2.0	13.2	132	75-95

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    1989:   Industrial minerals investigation in southern Manitoba; in
             Manitoba Energy and Mines, Minerals Division, Report
             of Field Activities 1989, p. 132-138.

GS-25 DOCUMENTATION OF DIMENSION STONE RESOURCES IN THE MEDIKA AREA (NTS 52E)

by P. Elias and B.E. Schmidtke

Eight sites within the same pluton as the recently opened Canital Granite quarry near Medika, Manitoba (Fig GS-25-1) were examined to determine potential sources of dimension stone. All sites are located east of P.R. 506 in an area of flat granitic outcrops surrounded by swamp (Fig. GS-25-1). Spacing of fractures, in addition to colour, texture, mineralogy, and the presence of veins, dykes and xenoliths were documented. The outcrops are mapped as a younger brick red microcline granite and an older fine- grained gneiss by Janes (1979).

The rock at sites 1 and 2 (Fig. GS-25-1) is a homogeneous, medium grained pink granite; average spacing between subvertical fractures is < 1 m.

Site 3 is a 0.5 km long outcrop located 3.5 km from P.R. 506. The granite is medium- to coarse-grained, pink and homogeneous. Subvertical fractures are spaced at least 2 m apart in most areas of the outcrop. Samples taken from the outcrop surface are pale pink, but are weathered and friable and may not represent the colour of the underlying rock. The dominant fracture set strikes at 210 to 220°; few widely spaced fractures crosscut this set. Five cm to 1.5 m wide xenoliths of hornblende-biotite gneiss occur in an area 10 by 15 m in size.

The granite at site 4 is highly fractured, medium- to coarse- grained, pink, and contains local pegmatitic blebs. Most fractures strike 290° and are spaced 0.5 to 1.5 m apart. These fractures are crosscut by numerous other fractures and granitic dykes.

The granite at site 5 is similar to that at site 4 except that fractures are spaced 2 to 3 m apart in the north portion of the outcrop. The granite at site 6 is similar to that at sites 4 and 5 except that fractures are spaced 0.3 to 1.5 m apart.

The granite at site 7 is coarse grained and pink. It contains quartzofeldspathic pegmatites, xenoliths of biotite gneiss and is intruded by a fine grained pink granite. The subvertical fractures are spaced 0.5 to 3 m apart. Ledges up to 1.5 m high were observed.

Medium- to coarse-grained, highly fractured pink granite occurs at site 8. The fractures are usually spaced < 1 m apart. Pegmatites and xenoliths are abundant.

Granite at site 3 is a potential source of dimension stone because it is homogeneous in colour and texture and has widely- spaced fractures. The other sites are not viewed as potential sources of dimension stone because they contain closely spaced fractures, pegmatites and inclusions.

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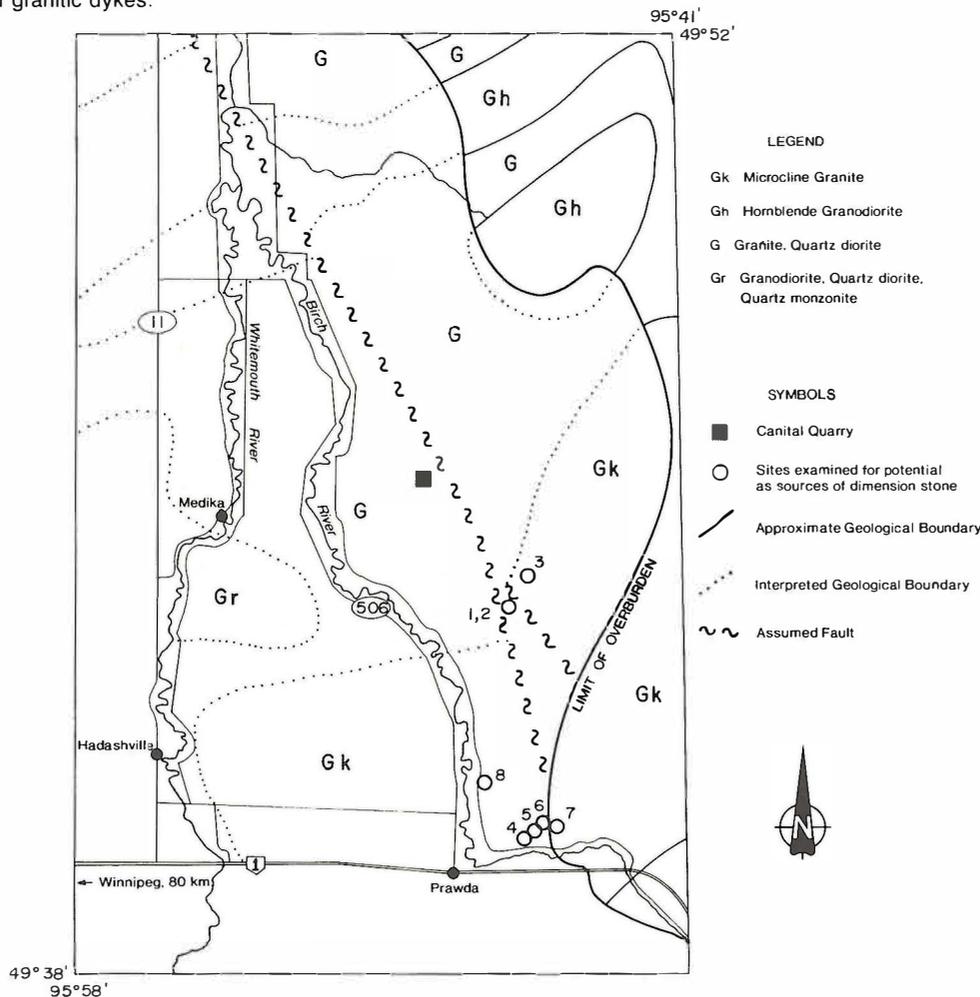
Figure GS-25-1:   *Locations of sites examined for potential as sources of dimension stone.*

GS-26 Cross Lake Supracrustal Investigations (Part of NTS 63J/9)

by M.T. Corkery

Geological mapping at a scale of 1:20 000 was initiated, during a 10 day field season, to map shoreline outcrop on the west end of Cross Lake (part of NTS 63J/9SE and 63J/9NE). Manitoba Hydro has scheduled construction of a weir on the Nelson River to restrict flow from Cross Lake. This will return the lake level to historic values by the fall of 1991. Mapping is scheduled to gather maximum geologic data prior to the expected 1.5 to 1.8 m increase in lake level.

Mapping in the west end of Cross Lake extended previously defined geologic units (Corkery, 1983, 1985; Corkery and Lenton, 1984, 1989; Corkery et al., 1988; and Corkery and Cameron, 1987). Table GS-26-1 outlines the major lithologies and geological events in the Cross Lake area.

Distribution of major rock types indicate a large synclinal structure for the west end of the Cross Lake supracrustal belt. Remnants of the Pipestone Lake Group are restricted to the south and north flanks of the belt, in contact with granitic terrains of the Molson Lake and Pikwitonei domains. Rare occurrences of Gunpoint Group are in contact with Pipestone Lake Group. The Cross Lake Group forms the center of the belt. Basal conglomerates and coarse clastic fluvial deposits are abundant on the south and north shores of the lake with various crossbedded sandstones forming the core of the large scale structure. Further mapping is required to refine details of folding and faulting in the east end of the belt.

Primary structures and stratigraphic sequences are not as well preserved in the west end of the Cross Lake belt as they are to the east. Deformation, in the form of folding and numerous shear zones, hinders interpretation of primary relationships of the three groups. However, major units and subunits are recognizable and although attenuated could be followed for considerable distances across the map area (Preliminary map 1990K-1). Cross Lake Group is in contact with both Pipestone Lake and Gunpoint groups in several locations. The typical garnetite regolith at the base of the Cross Lake Group occurs in several of these locations, however, deformation has transposed all primary features into orientations parallel to the structural fabric direction. This, combined with the high degree of recrystallization, does not allow recognition of the unconformable relationships documented elsewhere.

The metamorphic grade and degree of recrystallization is generally higher than in areas previously mapped to the east. In conglomer-

Table GS-26-1
Order of Geological Events (Cross Lake area)

16) Late brittle deformation manifested by fault breccia, pseudotachylite and erratic foliation developed in some Molson dykes

15) Intrusion of Molson dyke swarm; most abundant in the major NE shear zones. (1883 Ma)[3]

14) Periodic reactivation of shear zones accompanied by minor folding

13) Main Kenoran orogenic event: intrusion of granite plugs (2653 Ma) and pegmatites (largely controlled by the major shear zones) during the waning stages. (2658 - 2637 Ma)[1]

12) Intrusion of small gabbro dykes and plugs.

Intrusive contact

11) Initiation of high potassium basalt volcanism contemporaneous with fluvial to marine sedimentation.

10) Deposition of Cross Lake group alluvial and fluvial conglomerate and sandstone.

Unconformity

9) Regional metamorphism and deformation, granite plutonism (2719 Ma) and folding concomitant with activation of major linear shear zones. Spans the period of deposition of Cross Lake Group. (2713 - 2695 Ma)[1]

8) Intrusion of hornblende porphyritic gabbro dykes.

Intrusive contact

7) Deformation and metamorphism: produced northeast trending migmatites that overprinted east-west D_1 foliation. Contemporaneous with, to post deposition of, Gunpoint Group. (circa 2738 Ma)[2]

6) Deposition of the predominantly continental Gunpoint Group fragmental rhyodacite and alluvial, fluvial and marine sediments.

Unconformity

5) Pipestone Lake group incorporated into a cratonic land mass during a period of cratonization concomitant with Whiskey Jack Complex intrusions, (2734 Ma)

Oceanic Association

4) Deposition of Pipestone Lake Group basalts and subordinate sediments. Intrusion of anorthosite-gabbro complex with deposition of associated feldspar porphyritic basalts.(2760 Ma)

Old Cratonic Masses

3) Deformation and metamorphism: produced strong foliation (currently east-west) in Clearwater Bay Complex.

2) Formation of cratonic masses of Molson Lake Domain (includes Teacher Group) and Pikwitonei Domain on the south and north flanks of the supracrustal belt. (2839 Ma)

1) Early supracrustal sequence - Teacher Group - metabasalt, metagabbro and metasediments

[1] Krogh et al., 1985
[2] Mezger et al., in press
[3] Heaman et al., 1986

ates this recrystallization is especially severe. In many outcrops clast boundaries for many clast types can not be distinguished with certainty. However, major layering characteristics such as unsorted framework conglomerate beds and interbedded conglomerate-sandstone fluvial deposits can be distinguished. Remnants of primary structures such as crossbedding, graded bedding, pillow selvages, pillow breccias and gabbroic textures are preserved. These are highly discontinuous and rarely of any value other than recognition of the original lithologies.

Primary characteristics are further disrupted by a 3 to 10 per cent granitic component in most outcrops. These consist of several ages of injected pegmatite, granite, granodiorite and tonalite dykes and sills. In many exposures post intrusive deformation produces a *lit par lit* paragneiss. In several locations 1 to 5 per cent pegmatitic mobilizate is present.

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GS-27 INVESTIGATIONS OF THE 'IRON FORMATION' AT 1A PIT, THOMPSON MINE (NTS 63P/12)

by G.H. Gale and M.A.F. Fedikow

An 'iron formation' (Gale *et al.*, 1982) that is conformable to the nickeliferous sulphide orebodies at the Thompson mine was exposed in several places during excavations for the Thompson 1A pit. This visually distinctive rock unit, which occurs within a sequence of quartzitic metasedimentary rocks, can be traced intermittently along the length and depth of the Thompson orebodies (Fig. GS-27-1).

The new exposures reveal a consistent internal stratigraphy (Fig. GS-27-2) identifiable even where portions of the 'iron formation' have been removed by the injection of locally derived pegmatite - the missing layers occur as rafts within the pegmatite in the same relative position as shown in Figure GS-27-2.

From structural base to structural top, the 'iron formation' (Fig. GS-27-2) consists of:

1. layered, black, garnet-hornblendite with 1 to 10 cm boudinaged layers of greenish calc-silicate minerals near its upper margin;
2. green weathering calc-silicate unit;
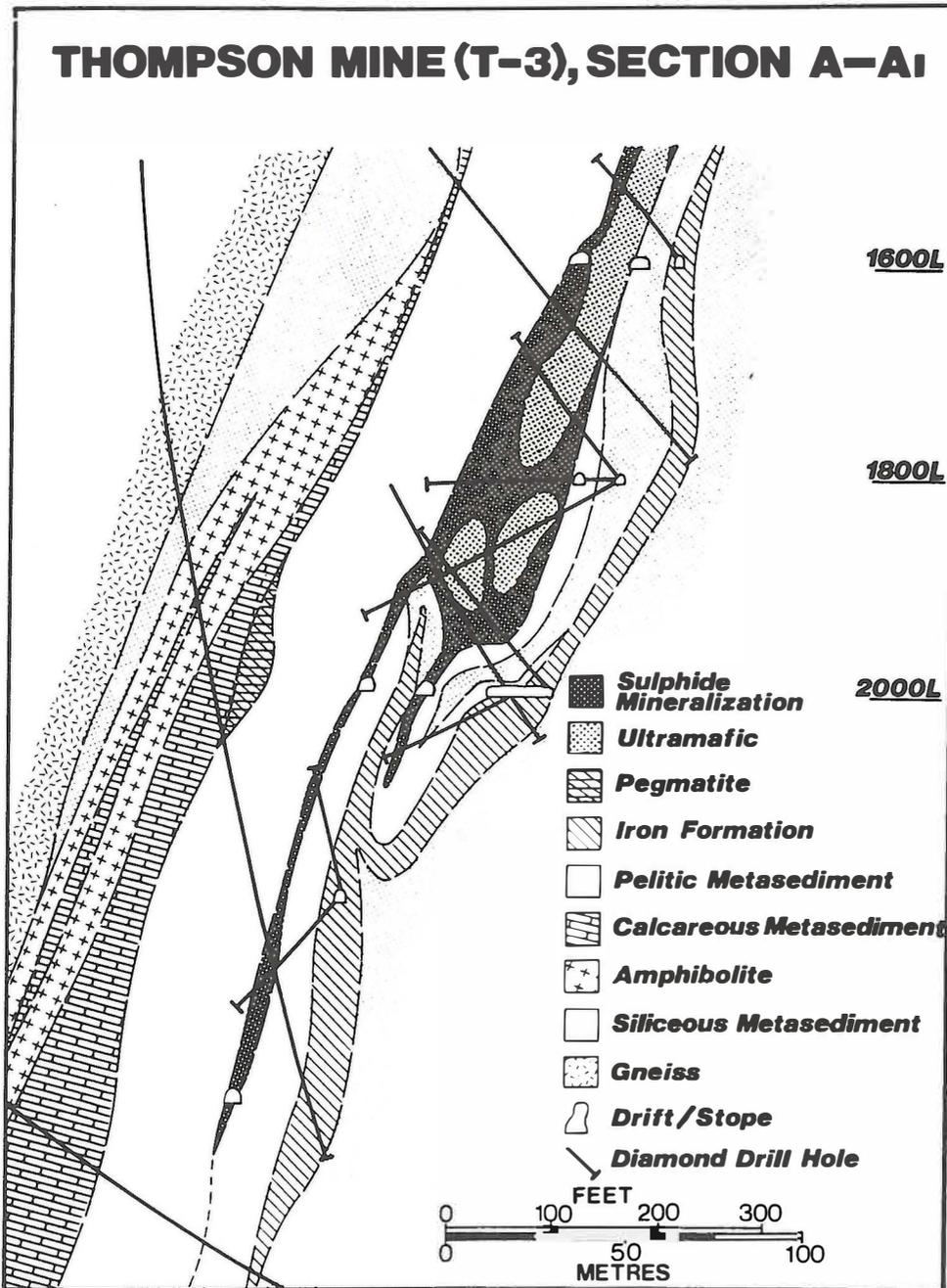
Figure GS-27-1: Geological cross section of the Thompson Mine (from Gale et al., 1982).
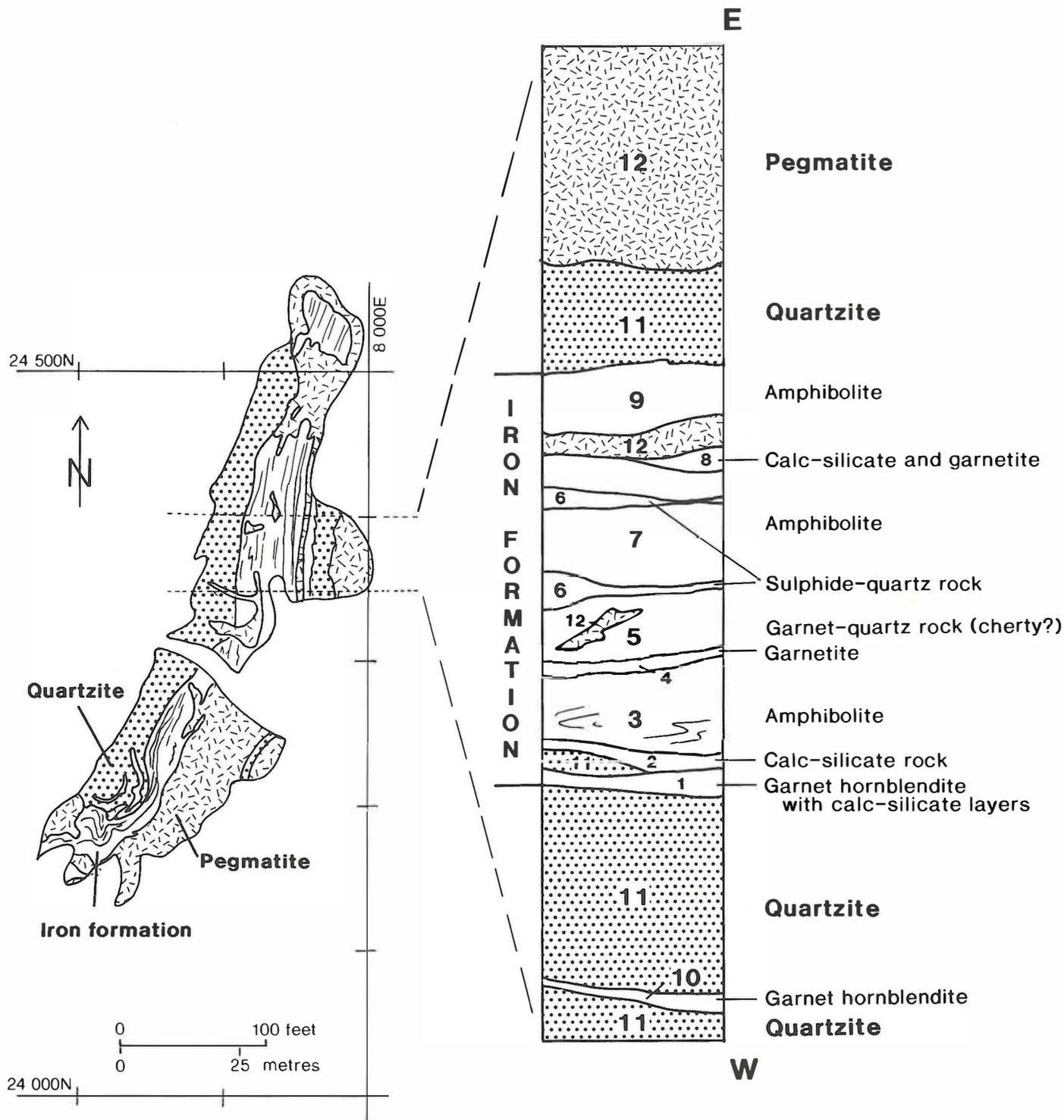
Figure GS-27-2: Section through the 'iron formation' at Thompson 1A pit.

3. black mafic rock (amphibolite) with minor amounts of thin quartzite layers and *lit per lit* lenses of quartz;
4. reddish garnetite layer that locally contains up to 75 per cent garnet;
5. reddish garnet-quartz layer with abundant *lit per lit* quartz lenses;
6. one or more quartz-rich layers with 10 to 20 per cent pyrrhotite ± pyrite;
7. mafic rock (amphibolite) with thin layers and lenses of 5 and 6;
8. calcsilicate-rich layer with thin garnetite layers; and
9. a black amphibolite layer(?) that is garnet free. Locally a medium grained felsic pegmatoid layer occurs between layers 8 and 9.

Quartzite occurs structurally above and below the 'iron formation' rocks.

The 'iron formation' has been systematically sampled using a rock saw. Mineralogical and petrochemical analyses will be undertaken to determine if the unusual chemistry represents chemical sediments, mafic tuffs or both.

Table GS-27-1 contains chemical analyses of samples that were collected from an INCO drill hole through the sulphide-bearing unit and enclosing host rocks. The pegmatite injection into the 'iron formation' is considered to be similar to the displacement features commonly observed in the open pit and probably does not represent a repetition of the 'iron formation'. The structural sense in Figure GS-27-3 is similar to that of the south pit where the samples were cut (Fig. GS-27-2) in that the 'iron formation' is structurally below the sulphide lense. The main difference between the sections represented in Figures GS-27-2 and -3 is the absence of a quartzite unit between the 'iron formation' and the sulphide ores in the drill hole section (Fig. GS-27-3).

Five samples of 'iron formation' were collected from DDH 65-178-1. Two of the five samples were analysed for major elements and all samples for nine trace elements. Data are summarized in Table GS-27-1 and sample locations plotted against a stratigraphic column constructed from the log of DDH 65-178-1 (Fig. GS-27-3).

Although the chemical data from the 'iron formation' is limited, there are some initial comments that can be made regarding the variation in concentration of trace elements in the samples. The Fe content is variable but simply reflects the abundance of pyrrhotite and pyrite in the samples. Most trace elements have a restricted concentration range with the exception of F and Ba. These elements have a wide variation in concentration and suggests possible application to the characterization of iron formations on a regional basis.

The iron formation geochemical data base will be expanded in the future with the aim of identifying unique geochemical parameters that can distinguish those associated with Ni-Cu mineralization from non-mineralized sequences.

The footwall quartzite unit, which was well exposed during excavations for the Thompson 1B and 1C pit, contains a number of anastomosing biotitic schist lenses/layers with sillimanite porphyroblasts and pyrite commonly present. These biotitic schists and some of the quartzite layers have a rusty weathering appearance over an extensive area of the footwall rocks. Locally, it appears as if the biotitic schist lenses are superimposed on the quartzite layers. Some 20 chip samples were collected from the biotitic schist and quartzite footwall rocks to test the genesis of the deposit (Gale *et al.*, 1980) by determining if these footwall rocks have a distinctive geochemical signature such as that produced by magmatic hydrothermal fluids percolating through the rocks.

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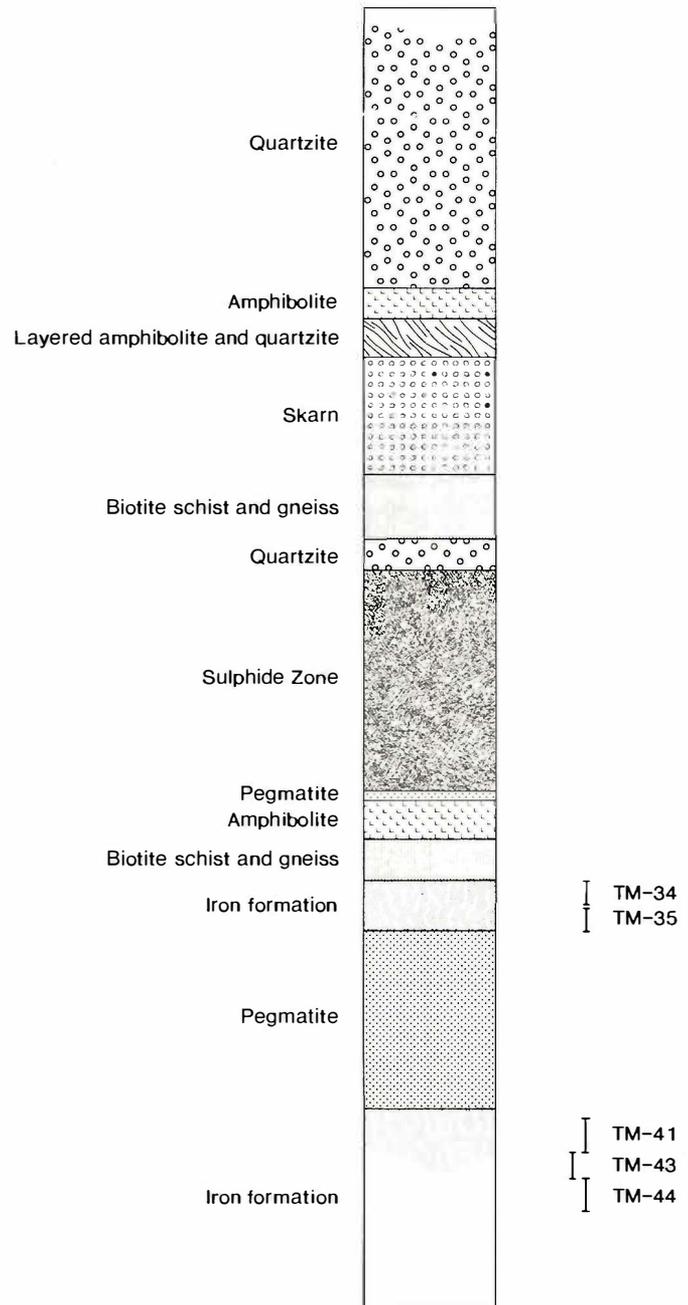
Figure GS-27-3:   Sample locations for 'iron formation' intersected in DDH 65-178-1. Stratigraphic column based on drill core log.

Table GS-27-1

Summary of Analytical Data from DDH 65-178-1, Thompson Ni-Cu Deposit. Silicate Whole Rock Data in Weight Percent. For Trace Element Data: Ni and Cr by Lithium Metaborate Fusion (Total); Cu, Pb, Zn, Co, Mn, Ba and Fe Represent Partial Analyses Subsequent to Aqua Regia Dissolution; F by Selective Ion Electrode. All Trace Elements in ppm

Sa.#	TM-34 (366.9-368.4 m)	TM-41 (376.1-377.5 m)	TM-35 (368.4-364.3 m)	TM-43 (379.1-380.6 m)	TM-44 (380.6-382.2 m)
SiO_2	56.0	66.2			
Al_2O_3	5.5	10.0			
FeO	22.56	12.05			
Fe_2O_3	1.57	1.32			
CaO	4.53	2.25			
MgO	5.27	3.39			
Na_2O	0.19	0.26			
K_2O	0.24	2.18	N/A	N/A	N/A
TiO_2	0.20	0.43			
P_2O_5	0.12	0.10			
MnO	1.51	0.80			
H_2O	0.77	0.95			
S	2.27	0.10			
CO_2	0.23	0.25			
Total	100.96	100.28			
FeOt	23.97	13.24			
Ni	64	29			
Cr	94	50			
Cu	272	37	18	91-176	
Pb	<2	<2	<2	5	<2
Zn	23	59	1.05	74	53
Co	46	54	44	51	57
Mn	1760	1045	1450	1600	1910
Fe (%)	6.50	6.25	8.15	12.40	12.45
Ba	191	601	976	247	111
F	488	1160	980	1020	1700

N/A - not analysed

GS-28 Mineral occurrence studies and documentation in the Island Lake area (NTS 53E/10, 53E/15, 53E/16, 53F/13)

by P. Theyer

INTRODUCTION

Mineral occurrence documentation in the Island Lake (NTS 53E/15, 53E/16), Wapus Bay (NTS 53E/10) and Sagawitchewan Bay (NTS 53F/13) map areas (1:50 000 scale) is completed. One hundred ninety-five mineral occurrences recorded in assessment files, company reports, geological papers and geological maps were examined and, where warranted, sampled and studied in detail. This report presents the highlights of this study; detailed occurrence descriptions are available on request. A compilation of the results of this study is in preparation and will be published as part of the Mineral Deposit Series.

EXPLORATION HISTORY

The mineral exploration history of the Island Lake area may be subdivided into four major exploration initiatives, beginning with a gold prospecting rush in 1928. Initial activities resulted in the discovery of two major areas of gold-bearing quartz veins in eastern Island Lake (Jack of Hearts and Gold Island). Discovery of the gold-bearing quartz veins at Gold Island led to the opening of the Island Lake Gold Mine in 1934. This mine was closed within six months due to exhaustion of ore reserves. In 1937 interest shifted to development of a gold-bearing quartz vein (Ministik Mine) on Henderson Island (formerly High Rock Island). A shaft was sunk and drifting was done at the 68 m level; however, the project was abandoned in the fall of 1937 due to lack of funds.

Large scale mineral exploration, in search of nickel-copper deposits, resumed in the mid 1950's. Ultramafic rocks in the northwest part of Island Lake were the initial targets. A nickel-copper mineralization of "low grade" (Quinn, 1960) was defined by Canadian Nickel Company Limited in the Linklater Island area. A later phase of nickel-copper exploration in the early 1970's concentrated on ultramafic rocks north and south of Loonfoot Island in western Island Lake. These activities coincided with a third exploration phase executed by Barringer Research Limited and were directed toward the search for porphyry copper-molybdenum mineralization in granitoid plutons (Bella Lake pluton) and massive sulphide type deposits in the Jubilee and Confederation islands area. The late 1970's witnessed a revival of massive sulphide and porphyry copper exploration mainly by Manitoba Exploration Services.

The fourth and most recent exploration phase started in 1981 and signalled a revival of gold exploration. Initially, BP Minerals concentrated their efforts in eastern Island Lake (Jack of Hearts area) and Sagawitchewan Bay. They later proceeded with a re-evaluation of the Island Lake Gold Mines property. Bighorn Development Corporation undertook development on the former Ministik Gold Mine on Henderson Island, including rehabilitation of the shaft, underground workings and construction of a pilot mill. The most recent exploration has been by Corona Corporation in the area east of the Jack of Hearts occurrence.

SULPHIDE AND GOLD MINERALIZATION ASSOCIATED WITH QUARTZ VEINS

Three generations of gold $\pm$ sulphide-bearing quartz veins may be distinguished in the Island Lake area. These are: 1) post-deformational crosscutting quartz veins; 2) post-deformational concordant quartz veins; and 3) pre- to syn-deformational quartz veins.

1) Post-deformational crosscutting quartz veins

These quartz veins are emplaced in generally north-striking faults that crosscut the tectonic fabric of the greenstone belt.

MINISTIK MINE

Recent development of the Ministik occurrence on Henderson Island included stripping overburden along most of the "Main" and the "Juniper" quartz veins, refurbishing of the shaft and installation of a pilot mill (Fig. GS-28-1). The resulting exposures permit detailed observations of quartz veins and host rocks.
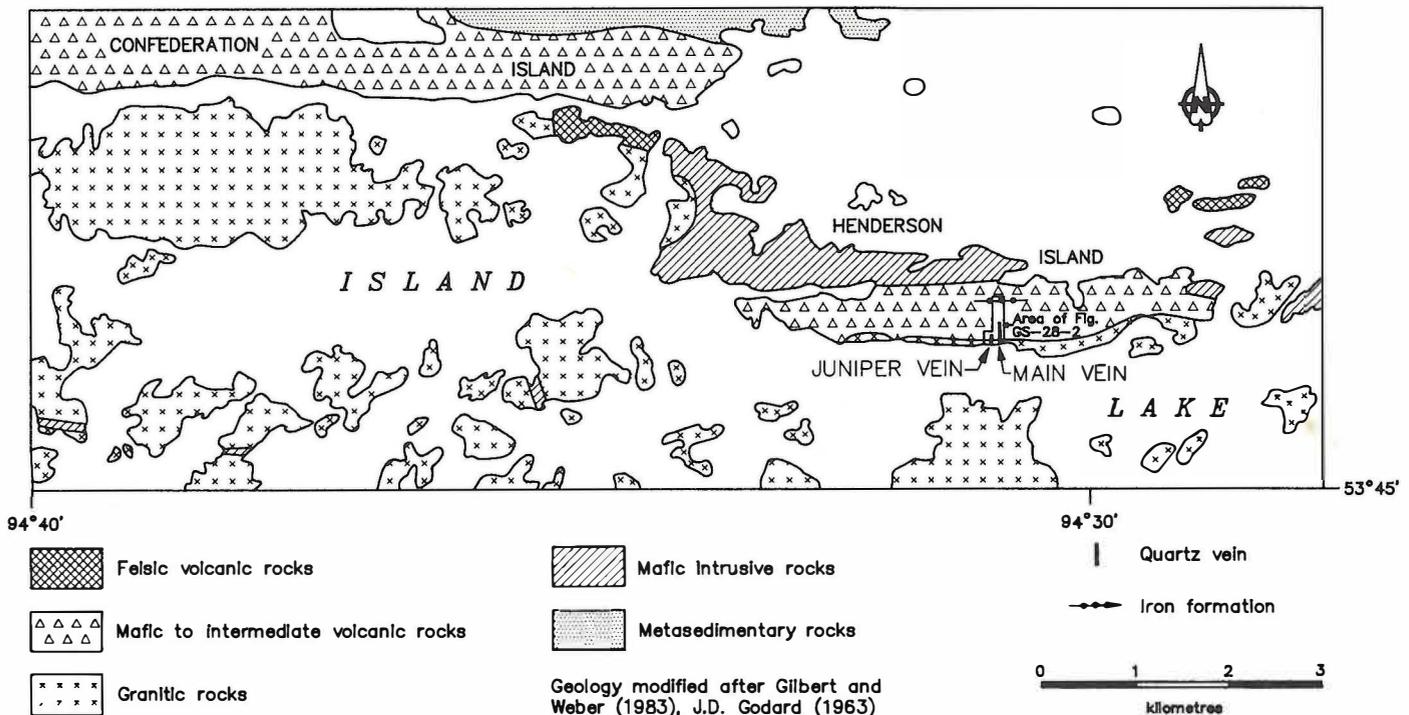

Figure GS-28-1: Geological sketch map showing the location of Henderson Island, the Ministik main vein and the Juniper vein.

The Main quartz vein is intermittently exposed over approximately 180 m strike length. The main vein terminates to the north at a roughly east-striking, up to 10 m thick, unit of silicate facies iron formation (Fig. GS-28-2). The southern extension of the main vein has been intersected in drill cores 45 m south of Henderson Island under the lake (Bighorn Development Corporation, news release, April 1, 1987).

The main quartz vein is hosted by a northerly striking right lateral fault. Associated with this fault are two sets of quartz- filled tension fractures oriented approximately 45° to the main vein. The main vein is up to 200 cm wide with an average width of 50 to 70 cm.

The fracture hosting the Main quartz vein intersects, from south to north, granitoid rocks that grade into massive, fine grained to aphanitic mafic rocks interlayered with banded sedimentary rocks. This rock suite is epidotized and intruded by 5 to 30 cm thick quartz-feldspar porphyry dykes. The host rocks to the north are shear folded pillowed basalts and mafic volcanic breccia. Fracturing of the host rocks and emplacement of the quartz vein postdated development of the regional foliation. Networks of fractures occur within the quartz vein. Many of these fractures are lined with tourmaline and mineralized with pyrite, and traces of galena and pyrrhotite. Sulphide mineralization is abundant (3-5%) in the vicinity of a pit (Fig. GS-28-2), however, the remainder of the quartz vein exhibits trace amounts or is barren of sulphides.

JUNIPER QUARTZ VEIN CLUSTER

The Juniper quartz vein cluster is located approximately 50 m southwest of the Ministik Mine headframe (Fig. GS-28-2) and consists of several 10 to 20 cm thick, southwest-striking quartz veins that intersect granitic gneisses, mafic dykes and quartz-feldspar porphyry dykes. Similarities in composition and orientation between these quartz veins and the quartz veins hosted by the tension fractures of the Ministik Mine main vein, suggest they are equivalent in age. Sulphide mineralization consists of trace pyrite in some of the quartz veins.

REX (Climpy)

Several quartz veins occur in north-trending faults in granodiorite intruded by granitic and fine grained mafic dykes (A.F. 92398). A quartz
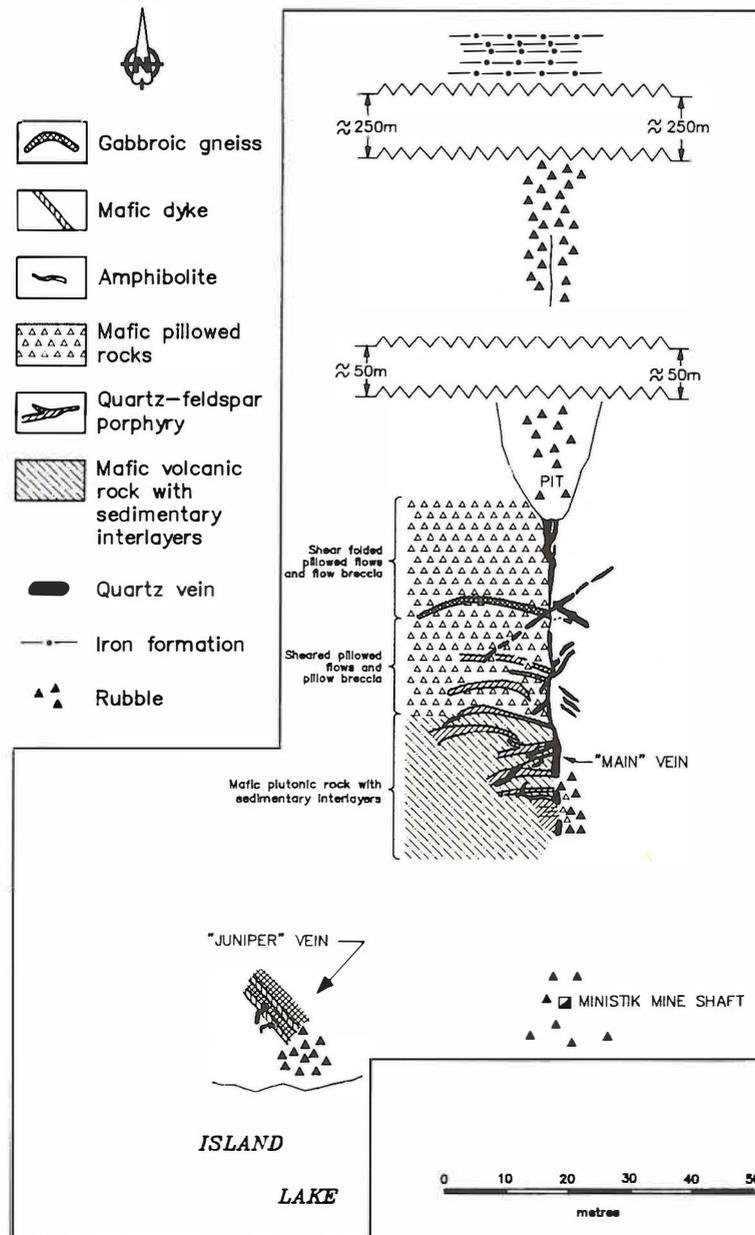

Figure GS-28-2: Schematic geology of the Ministik main vein and the Juniper vein.

vein located at the southwest end of the island, ranges from a few centimetres to approximately 1 m thick and is approximately 0.5 km long. Sulphide mineralization comprises erratically distributed seams and knots of pyrite, minor chalcopyrite and traces of galena and molybdenite. Gold is associated with sulphides; grab samples reportedly contain from 1 to 3.5 g Au/tonne (A.F. 92398).

2) Post-deformational concordant quartz veins

These quartz veins are emplaced in east-striking faults that are concordant to the fabric of the greenstone belt. They tend to have great length and continuity.

JACK OF HEARTS

Recent overburden stripping by Corona Corporation and BP Minerals (non-confidential parts of A.F. 70354) east and west of the Jack of Hearts area, especially on Reahil Island (Fig. GS-28-3), exposed several mineralized quartz veins. The largest exposure is underlain by a foliated, silicified, chloritized and carbonatized sericite schist that hosts a discontinuous east-striking (100°) quartz vein. The vein pinches and swells seven times over approximately 30 m of strike length to a maximum thickness of 1.5 m, but it was not observed in two additional stripped areas to the east. An area stripped of overburden on an unnamed island, approximately 100 m east of Reahil Island (Fig. GS-28-2), is underlain by mafic to felsic fragmental volcanic rocks. These rocks host a quartz-ankerite lens approximately 1.5 m thick. The lens occurs in an east-striking fracture zone characterized by intense foliation that completely obliterates the original fragmental rock texture and replaces it with a banded silicate ankerite rock. Mineralization in this vein consists of approximately 1 per cent disseminated pyrite. The Jack of Hearts vein proper is the most persistent vein in linear extent and has substantial thickness.

3) Pre- to syn-deformational quartz veins.

These quartz veins are randomly oriented, discontinuous and intensely deformed.

ISLAND LAKE MINE

The rocks underlying the Island Lake Mine comprise a suite of intensely folded, sedimentary and volcanic rocks that are intruded by felsic dykes and stocks. Gold is hosted by quartz lenses, veins and stockworks near the contact of black argillaceous slates and sericitic schist (Theyer, 1981). Abundant sinuous carbonate layers are thought to be of primary origin (Stewart, 1980).

The mine produced 186.2 kg of gold from April 1934 until exhaustion of reserves in March 1935 (Richardson and Ostry, 1987).

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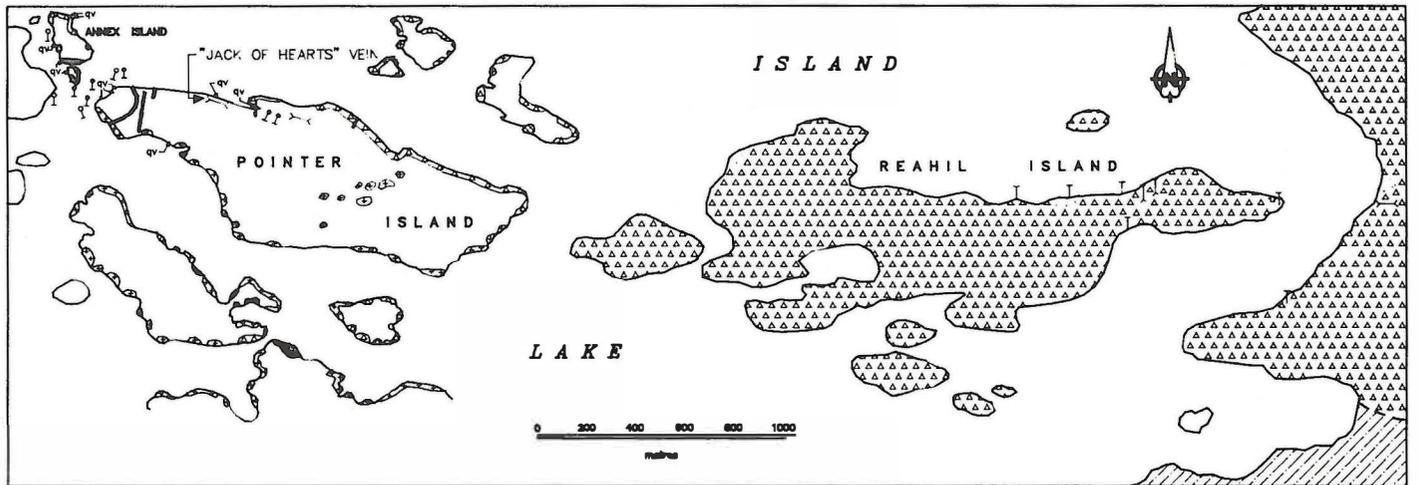
LEGEND

HAYES RIVER GROUP

Symbol	Description
Granitic intrusive rocks	
Ultramafic extrusive and intrusive rocks	
Mafic intrusive rocks	
Mafic to intermediate volcanic rocks	
Conglomerate, greywacke, argillite	
Felsic volcanic rocks	

qv   Quartz vein

Pit

Trench in rock

Trench in overburden

Area cleared of overburden

6 Drill holes (A.F. 91162)

6 Drill holes (Ventures Ltd., A.F. 91145)

4 Drill holes (BP Minerals Ltd., A.F. 92731)

Geology after BP Minerals Ltd., 1984 (A.F. 92731), Ventures Ltd., 1935 (A.F. 91145) and J.D. Godard, 1963 (A.F. 91162)

Figure GS-28-3:   Geological sketch map of the Jack of Hearts area.
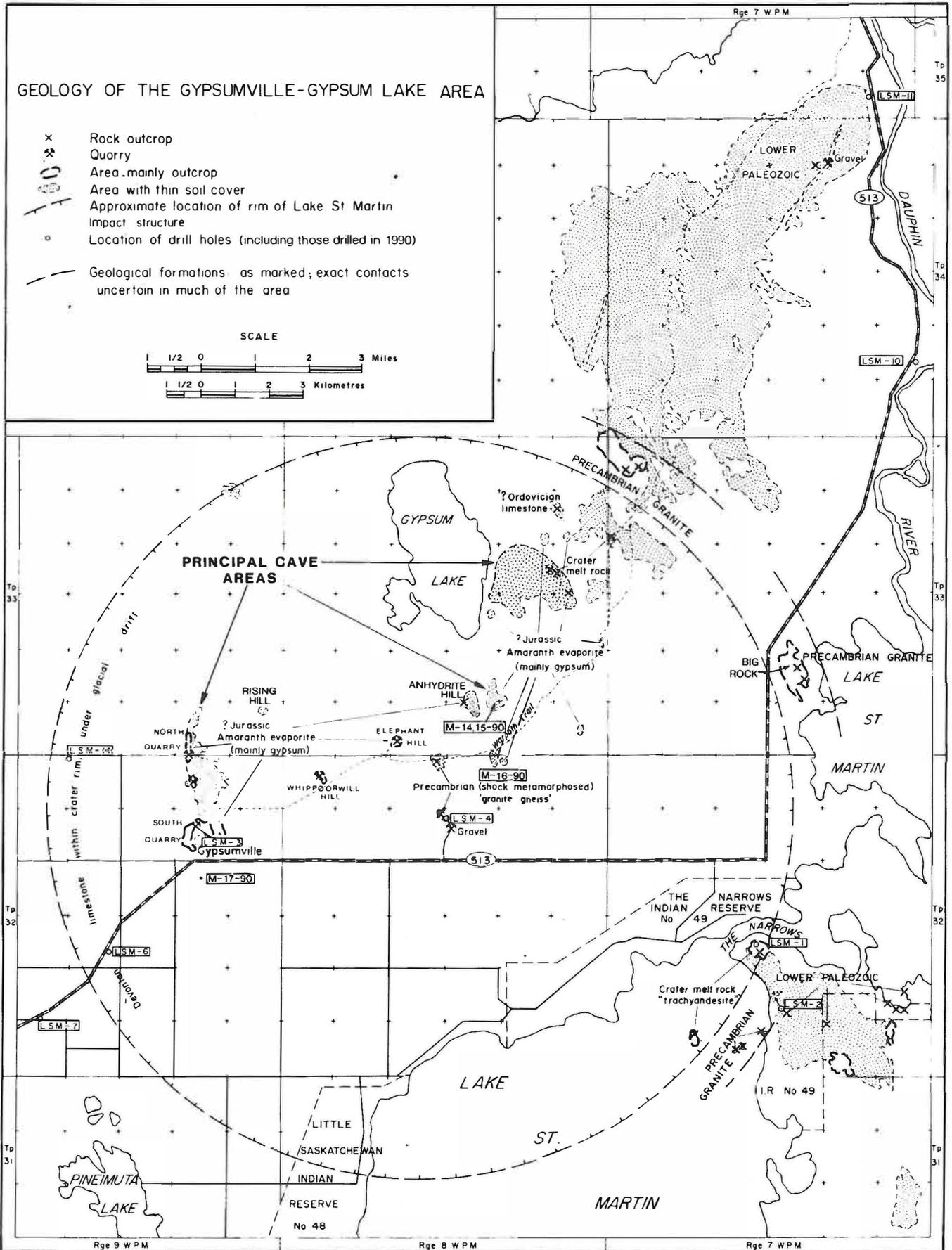
Figure GS-29-1: Principal areas containing caves, Gypsumville region (Geology modified after McCabe and Bannatyne, 1970).

GS-29 KARST LANDFORMS IN THE GYPSUM LAKE AREA; CHARACTER AND DISTRIBUTION

by W.D. McRitchie and P. Voitovici[1]

During 1990 Karst studies in Manitoba's Interlake region concentrated mainly on the task of documenting the distribution and character of bedrock solution features near Gypsumville and Gypsum Lake. Numerous new discoveries, made late in 1989, of caves, shafts and cockpit karst east and south of Gypsum Lake, provided an even sharper focus for much of the summer's investigations. An initial inventory of these features is presented in this report.

Elsewhere in the Interlake, several reconnaissance traverses were conducted in the Grand Rapids region, and in the country between Ashern, Mantagao, and St George Lakes, where recent forest fires (1989) have revealed extensive new areas of bedrock exposure.

GYPSUMVILLE/GYPSUM LAKE

An introductory description of the karst landforms in the Gypsumville and Gypsum Lake area was presented by Voitovici and McRitchie (1989). Earlier references to the caves in the region are found in reports by J.B. Tyrrell (1888), D.B. Dowling (1902), E.M. Kindle (1913), L.H. Cole (1913), G.M. Broenell (1931), and M. Hoque (1967). Tyrrell's comments were restricted to the area north of Gypsumville itself, with active quarrying by the Manitoba Union Mining Company beginning in 1901. By 1912, the region appears to have been more extensively explored, most gypsum occurrences (including those east and south of Gypsum Lake) had been staked, and presumably the existence of caves throughout the region was known. Kindle (1913) noted, "The surface of the gypsum deposits is deeply pitted with sink holes which carry much of the drainage into subterranean channels", and these features were routinely used by the early explorers to denote areas underlain by gypsum bedrock. Hoque's (1967) study of the folding and linear structures in the region provides the first quantitative information on sinkhole distribution including a detailed map depicting the distribution of sinks in the immediate area of the quarries north of Gypsumville. No further studies appear to have been made in the twenty year period following, until the caves were rediscovered by members of the Speleological Society of Manitoba (SSM).

[1]Speleological Society of Manitoba

REGIONAL INVENTORY

With the knowledge that gypsum occurrences and karst features were widespread in the Gypsumville area (Fig. GS-29-1), a plan was developed to mount a systematic inventory that would build on the discoveries made in 1989. Ground traverses were laid out to cover the entire region east and south of Gypsum Lake, together with a helicopter reconnaissance of the broader region. In late May, eleven east/west flight lines, spaced one mile apart, were flown between Gypsumville and Big Rock (Fig. GS-29-1), with Highway 513 as the southern boundary of the study area.

All bedrock occurrences were noted, and several photographs taken of representative topographic and karst landforms (Fig. GS- 29-2, -3, -4, -5). Thick and continuous tree cover thwarted attempts to develop a quantitative classification of the karst morphologies during the limited duration of the aerial survey. Areas underlain by gypsum bedrock are limited in large part to those defined on Wallace's 1914 map (Fig. GS-29-6), the region to the north being covered by extensive boulder till, moraine, and other recent deposits.

A subsequent attempt was made to obtain systematic aerial coverage of the karst landforms using a video camera from a Piper Supercub, but this also proved unsuccessful. Consequently it was concluded that systematic ground traverses would be the best approach to continue comprehensive documentation of the karst landforms, and much of the summer was spent in this endeavour (Fig. GS-29-7).

Results have been compiled into a provisional terrain morphology classification for the regions east and south of Gypsum Lake, based on topographic relief, sinkhole density, depth, diameter and shape (Fig. GS-29-8, GS-29-9). A second order classification describing the relative frequency of cave openings is also presented in these figures that attempt, for the first time, to rank the relative importance of karst landforms.

Topographic relief in the northern sector is locally extreme with ridges 10 to 15 m above the base of the larger sinks. This is the main region of polygonal karst, and future studies should be undertaken to complete a systematic morphometric analysis of the dolines. The importance of suffosion in developing many of the landforms was suggested by D. Ford during a visit to the area, and the restricted "clustered" distribution of many of the caves near the edge of topographic highs (and

Figure GS-29-2: Iceberg scours in the region south of Gypsum Lake.

Figure GS-29-3: Sinkhole infested terrain, south of Gypsum Lake.

Figure GS-29-4: Typical sinkholes west of "Hook" Sleugh.

Figure GS-29-5: 5 m high escarpment of folded gypsum near Fold Cavern, northern sector, Gypsum Lake, east.
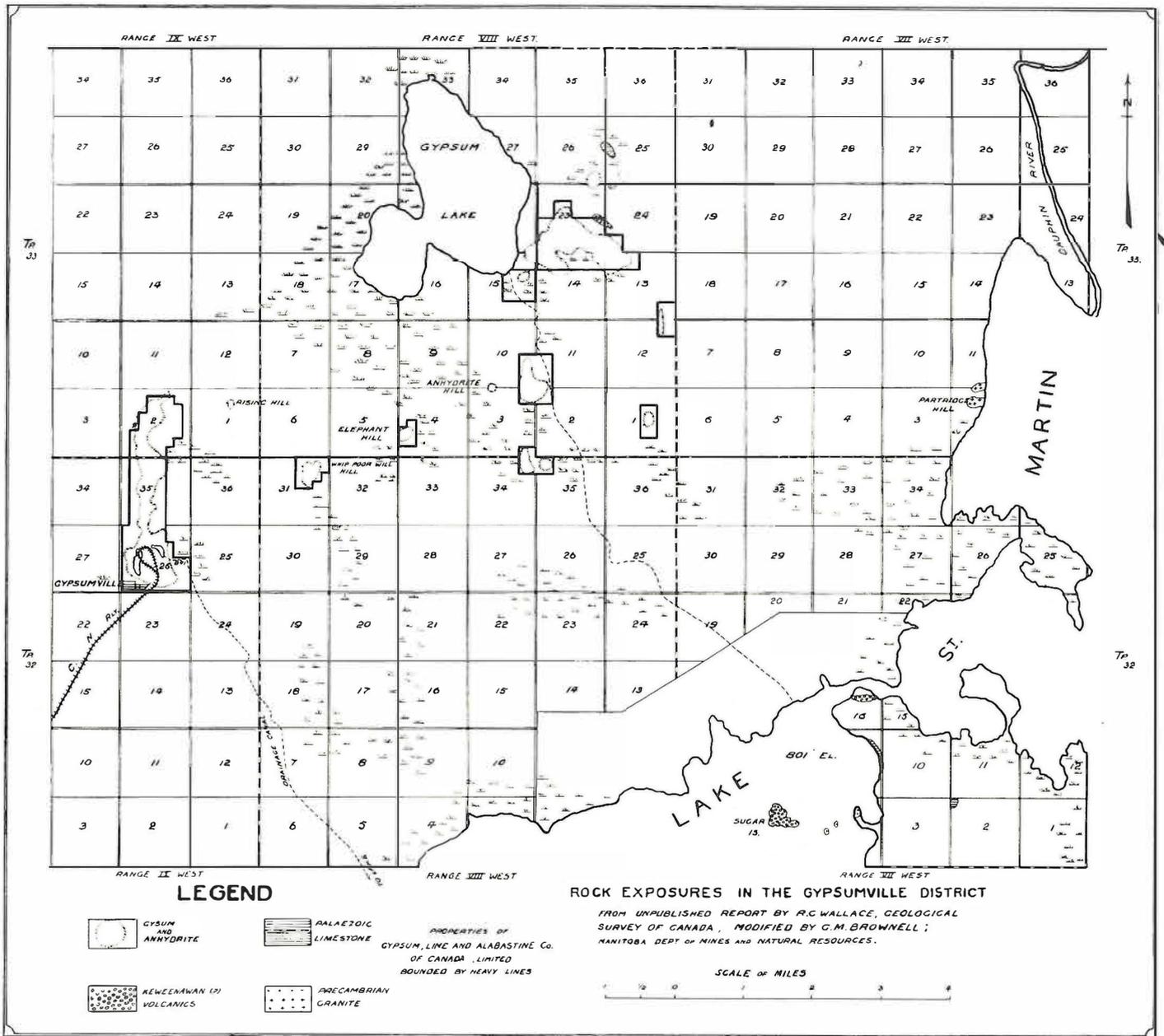
Figure GS-29-6: Rock exposures in the Gypsumville district (from unpublished report by R.C.Wallace (1914), modified by G.M. Brownell (1931).

ELEVATED AREAS (UNDERLAIN BY NEAR—SURFACE GYPSUM BEDROCK)
TWP. 33 RGE. 8W
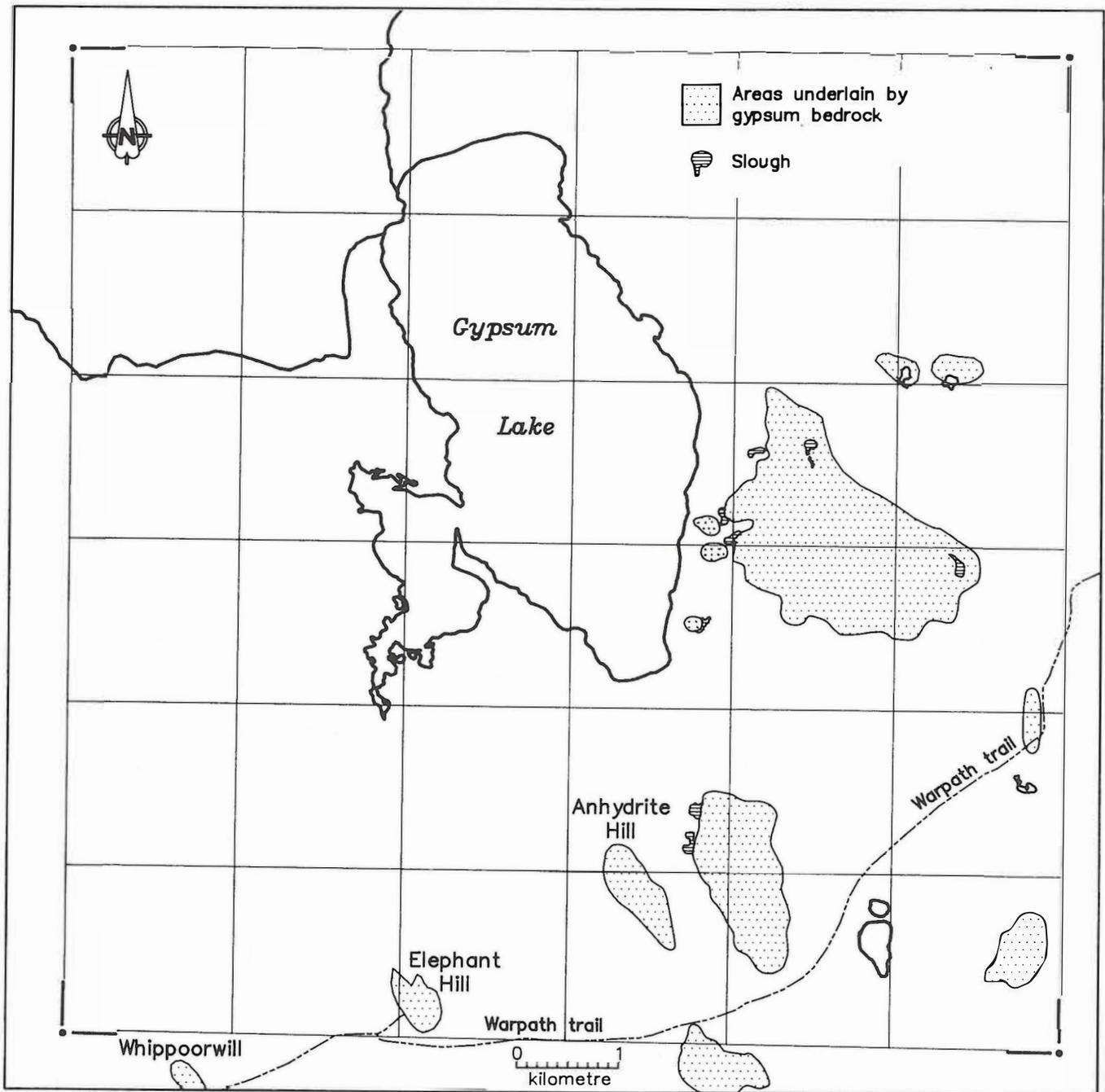
Figure GS-29-7: Gypsum Lake; elevated areas potentially underlain by near-surface gypsum bedrock (including associated red beds).

GYPSUM LAKE: PROVISIONAL TERRAIN MORPHOLOGY CLASSIFICATION
(Northern Sector)

Legend:
- Approximate boundary for gypsum ridges (3.39 km²)
- High density caves/shafts (244 486 m²)
- Abundant sinkholes, minor caves (817 930 m²)
- Dispersed sinkholes, no caves (472 382 m²)

Gypsum Lake

I RELIEF:
High
Moderate
Low
Flat

II SINKHOLE DISTRIBUTION:
Juxtaposed
Concentrated
Dispersed
Sporadic
Isolated
Absent
Beaded

III SINKHOLE DEPTH:
Shallow   1–2m
Deep   >2m

IV SINKHOLE DIAMETER:
X   <5m
Y   5–20m
Z   >20m

V MORPHOLOGY:
Funnel shaped
Shaft (vertical walls)

(T – till covered)

*Figure GS-29-8:   Gypsum Lake; provisional terrain morphology classification (northern sector). Note; **FISXF** translates as Flat (relief), Isolated (sink-hole distribution), Shallow (sinkhole depth), 5 m (sinkhole diameter), Funnel- shaped (morphology).*

GYPSUM LAKE: PROVISIONAL TERRAIN MORPHOLOGY CLASSIFICATION
(Southern Sector)

Anhydrite Hill

Legend:
- Approximate boundary for gypsum ridges (2.19 km²)
- High density caves/shafts (41 026 m²)
- Abundant sinkholes, minor caves (77 422 m²)
- Dispersed sinkholes, no caves (171 119 m²)

I RELIEF:
High
Moderate
Low
Flat

II SINKHOLE DISTRIBUTION:
Juxtaposed
Concentrated
Dispersed
Sporadic
Isolated
Absent
Beaded

III SINKHOLE DEPTH:
Shallow   1–2m
Deep   >2m

IV SINKHOLE DIAMETER:
X   <5m
Y   5–20m
Z   >20m

V MORPHOLOGY:
Funnel shaped
Shaft (vertical walls)

(T – till covered)

*Figure GS-29-9:   Gypsum Lake: provisional terrain morphology classification (southern sector). Note; **HJDYF** translates as High (relief), Juxtaposed (sinkhole distribution), Deep (sinkhole depth), 5-20 m (sinkhole diameter), Funnel- shaped (morphology).*

adjacent to beaver ponds), bears a strong resemblance to the progressive development of "Schlotten" topography in massive gypsum near Windsor, Nova Scotia (Ford and Williams, 1989, p. 459).

CAVE EXPLORATION

Numerous small cave entrances have been discovered east and south of Gypsum Lake (Fig. GS-29-10 , GS-29-11; Table GS-29-1). Several of the bigger caves were mapped in late 1989 (Fig. GS-29- 14), the largest being the **Catacomb-Satin Spar** complex (Fig. GS-29- 14a), which at 202 m, now represents the longest cave documented in Manitoba.

Traverses north and east of the Labyrinth Cluster and due east of the same feature came close to the eastern limit of the karst highlands, and uncovered numerous new cave entrances including **Fold Cavern** (Figs. GS-29-12, GS-29-13 and GS-29-14b), which possesses not only the largest chamber yet discovered in gypsum bedrock of this region, but also rooms with the greatest depth below the surface (8 m). Striking two metre relief folds are the cave's most noticeable feature (Fig. GS-29-13). Although these are typically chevron folds with sharp axial closures, more gentle open structures also exist and it is these that appear to provide the arches that support the ceiling of the cavern's main chamber. Enterolithic and nodular structures are also abundant in both anhydrite and gypsum beds. Salt solution fretworks observed in a nearby escarpment (Fig. GS-29-5) possibly denote the prior occurrence of halite in the evaporite sequence.

Other caves discovered in the region tend to be low (50 cm) semicylindrical crawlways, 2 to 4 m below the surface that follow the principal joint directions (see **Wishbone**, Fig. GS-29-14c). Several display preferred solution with one stratigraphic unit yielding extensive low (39-50

Figure GS-29-10: Caves explored east of Gypsum Lake.
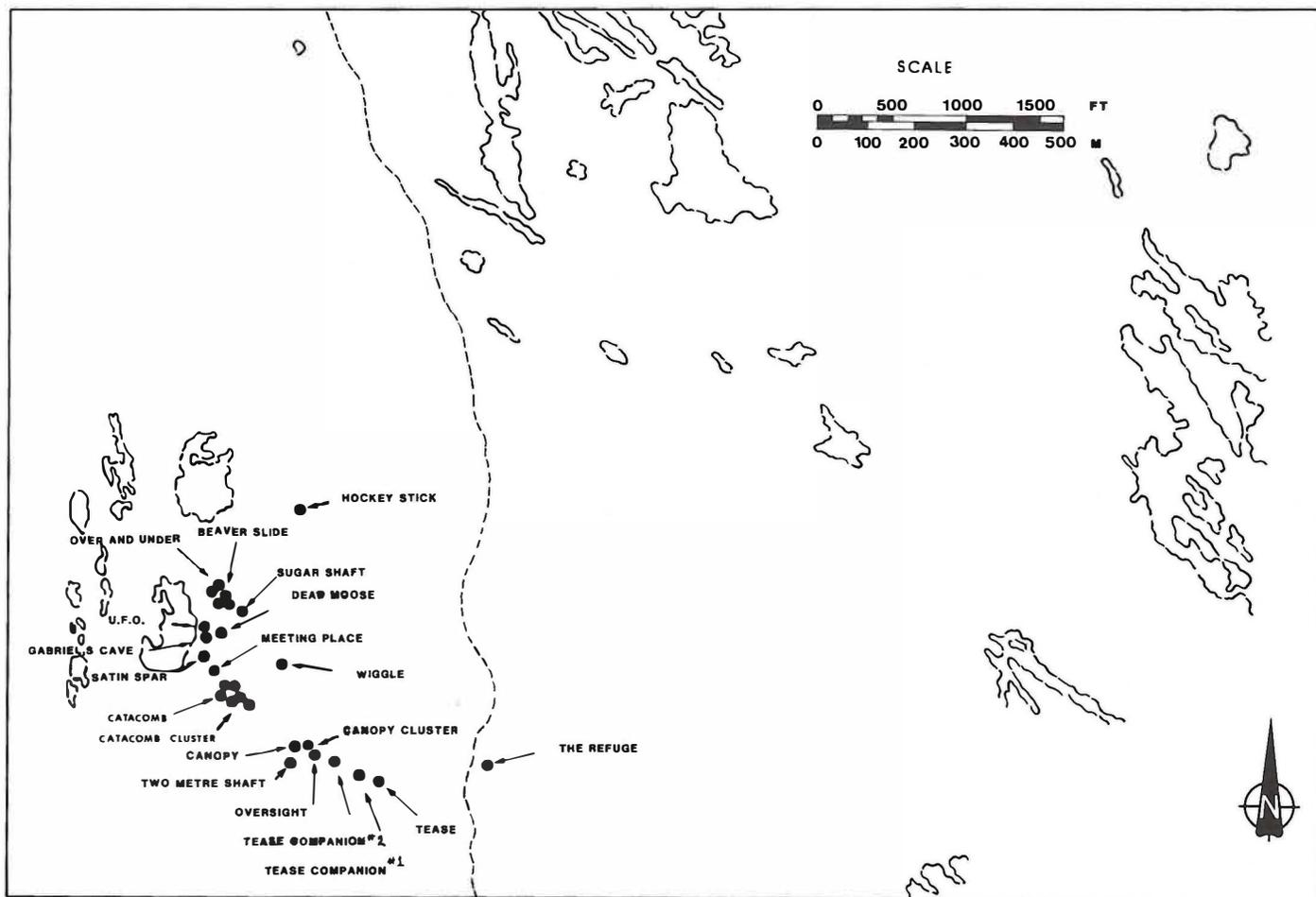
Figure GS-29-11:   Caves explored south of Gypsum Lake.

Table GS-29-1
Caves, Sinkholes and trenches in the Interlake region, status of investigations
for discoveries made during 1989/90

	Cave Name	Unconfirmed Report	Located	Sketched	Mapped	L (Metres)	D
GRAND RAPIDS:							
GR1	Ice Organ	.....	xxxx	.....	xxxx	36.0	8.6
GR2	Mouldy-moth	.....	xxxx	.....	xxxx	12.5	3.4
GR3	Chain	.....	xxxx	.....	.....	3.5	2.0
GR4	Lookout Crevice	.....	xxxx	.....	.....	43.0	5.0
GR5	Wet Memory	.....	xxxx	.....	.....	2.0	1.0
GR6	Skull trench	.....	xxxx	.....	.....	15.0	5.0
GR7	Cliff Cave	.....	xxxx	xxxx	.....	10.0	7.0
GR8	Drop-in	.....	xxxx	xxxx	.....	11.0	2.4
GR9	Wine Cellar	.....	xxxx	xxxx	.....	27.0	9.4
					Subtotal	160.0	
GYPSUMVILLE:							
GQ1	Crystal Kingdom	.....	xxxx	.....	xxxx	19.5	1.5
GQ2	Long Crawl	.....	xxxx	.....	xxxx	125.5	3.0
GQ3	Octopus	.....	xxxx	.....	xxxx	46.0	1.2
GQ4	Log Barricade	.....	xxxx	xxxx	.....	-	-
GQ5	Short Crawl	.....	xxxx	.....	xxxx	23.0	1.4
GQ6	Moth's Cellar	.....	xxxx	.....	xxxx	23.5	2.0

	Cave Name	Unconfirmed Report	Located	Sketched	Mapped	L (Metres)	D
GQ7	Jaws	.....	xxxx	.....	xxxx	16.0	1.5
GQ8	Snuggy Crawl	.....	xxxx	.....	xxxx	19.0	1.5
GQ9	Honeypot	.....	xxxx	.....	xxxx	37.0	1.8
GQ10	Bear's Den	.....	xxxx	.....	.....	14.0	0.5
GQ11	Too-tight	.....	xxxx	.....	xxxx	-	-
GQ12	Iceslide	.....	xxxx	.....	xxxx	38.0	1.5
GQ13	Maze	.....	xxxx	.....	xxxx	76.5	1.2
GQ14	Small Maze	.....	xxxx	.....	xxxx	31.0	1.0
GQ15	Vertebrae	.....	xxxx	.....	xxxx	23.0	0.5
GQ16	Spike	.....	xxxx	.....	xxxx	16.5	0.5
GQ17	"Y"	.....	xxxx	.....	xxxx	33.0	1.4
GQ18	Chamber	.....	xxxx	.....	xxxx	55.0	1.4
GQ19	Tunnel	.....	xxxx	.....	xxxx	7.0	1.0
GQ20	Transverse	.....	xxxx	.....	xxxx	14.0	0.5
GQ21	Steepsink	.....	xxxx	xxxx	.....	-	-
GQ22	Cliff	.....	xxxx	xxxx	.....	-	-
GQ23	Slab	.....	xxxx	.....	xxxx	16.5	3.6
GQ24	Bear Den	.....	xxxx	.....	xxxx	14.0	0.5
GQ25	Nine foot pole	.....	xxxx	.....	xxxx	12.5	1.8
					Subtotal	660.5	
GYPSUM LAKE EAST (NORTHERN SECTOR):							
GLN1	Stormcloud	.....	xxxx	.....	.....	-	-
GLN2	Phantom Bear	.....	xxxx	xxxx	.....	39.5	5.5
GLN3	Labyrinth	.....	xxxx	.....	xxxx	189.0	4.8
GLN4	Zig-zag	.....	xxxx	xxxx	.....	24.5	2.6
GLN5	Meander	.....	xxxx	.....	xxxx	73.5	5.5
GLN6	Crystal Palace	.....	xxxx	.....	xxxx	92.6	3.4
GLN7	Dusty	.....	xxxx	.....	.....	15.0	2.0
GLN8	Mole-Hole	.....	xxxx	.....	.....	-	-
GLN9	Blocky Pocket	.....	xxxx	.....	.....	-	-
GLN10	Fold Cavern	.....	xxxx	.....	xxxx	62.5	7.5
GLN11	Bear Den #1	.....	xxxx	.....	.....	-	-
GLN12	Wright's Cluster (#1)		xxxx	xxxx	.....	8.0+	1.0
GLN13	Wright's Cluster (#2)		xxxx	.....	xxxx	16.0+	2.4
GLN14	Wright's Cluster (#3)		xxxx	.....	.....	-	-
GLN15	Wright's Cluster (#4)		xxxx	.....	.....	-	-
GLN16	Wright's Cluster (#5)		xxxx	.....	.....	-	-
GLN17	Jumble	.....	xxxx	.....	.....	-	-
GLN18	Slot	.....	xxxx	.....	.....	-	-
GLN19	Marble	.....	xxxx	.....	.....	-	-
GLN20	Marie's Den	.....	xxxx	.....	.....	-	-
GLN21	Bear-den #2	.....	xxxx	.....	.....	-	-
GLN22	Chicken-wire	.....	xxxx	.....	.....	-	-
GLN23	Shaft & Slot	.....	xxxx	.....	.....	-	-
GLN24	S & S Cluster #1	.....	xxxx	.....	.....	-	-
GLN25	S & S Cluster #2	.....	xxxx	.....	.....	-	-
GLN26	S & S Cluster #3	.....	xxxx	.....	.....	-	-
GLN27	S & S Cluster #4	.....	xxxx	.....	.....	-	-
GLN28	Wishbone	.....	xxxx	.....	xxxx	22.0	3.0
					Subtotal	542.6 m	
GYPSUM LAKE EAST (SOUTHERN SECTOR):							
GLS1	The Refuge	.....	xxxx	.....	.....	-	-
GLS2	Tease	.....	xxxx	.....	xxxx	10.5	2.2
GLS3	Tease Companion (#1)		xxxx	.....	.....	-	-
GLS4	Tease Companion (#2)		xxxx	.....	.....	-	-
GLS5	Oversight	.....	xxxx	.....	.....	-	-
GLS6	Canopy	.....	xxxx	xxxx	xxxx	38.0	1.5
GLS7	Canopy Cluster (#1)		xxxx	.....	.....	-	-
GLS8	Canopy Cluster (#2)		xxxx	.....	.....	-	-
GLS9	Two metre shaft		xxxx	.....	.....	-	-
GLS10	Catacomb	.....	xxxx	.....	xxxx	201.0	2.7

Cave Name		Unconfirmed Report	Located	Sketched	Mapped	L (Metres)	D
GLS11	Meeting Place	.....	xxxx	.....	xxxx	-	-
GLS12	Satin Spar	.....	xxxx	.....	xxxx	-	-
GLS13	Catacomb Cluster (#1)		xxxx	.....	.....	-	-
GLS14	Catacomb Cluster (#2)		xxxx	.....	.....	-	-
GLS15	Catacomb Cluster (#3)		xxxx	.....	.....	-	-
GLS16	Catacomb Cluster (#4)		xxxx	.....	.....	-	-
GLS17	Satin Spar Cluster (#1)		xxxx	.....	.....	-	-
GLS18	Satin Spar Cluster (#2)		xxxx	.....	.....	-	-
GLS19	Gabriel's Cave	.....	xxxx	.....	.....	-	-
GLS20	U.F.O.	.....	xxxx	.....	.....	-	-
GLS21	Beaver Slide	.....	xxxx	.....	.....	-	-
GLS22	Over and Under	.....	xxxx	.....	.....		
GLS23	BS Cluster (#1)	.....	xxxx	.....	.....	-	-
GLS24	BS Cluster (#2)	.....	xxxx	.....	.....	-	-
GLS25	BS Cluster (#3)	.....	xxxx	.....	.....	-	-
GLS26	BS Cluster (#4)	.....	xxxx	.....	.....	-	-
GLS27	Sugar Shaft (3Entr)	.....	xxxx	xxxx	.....	-	-
GLS28	Dead Moose	.....	xxxx	.....	.....	-	-
GLS29	Wiggle	.....	xxxx	.....	.....	-	-
GLS30	Hockey Stick	.....	xxxx	.....	.....	30.0	3.0

| | | | | | Subtotal | 279.5 m | |

FAIRFORD:

Snakepit		.....	xxxx	.....	xxxx	18.3	4.8
Cockpit		.....	xxxx	.....	.....	3.0	1.5
Baillie's pit		.....	....	.....	-	-	

DALLAS:

Doug's Den....		xxxx	.....	xxxx	10.5	4.5
Clarence's Cave		xxxx	.....	xxxx	11.0	4.0

SPENCE LAKE:

The Tomb		xxxx	.....	xxxx	13.5	1.8

	Passage length	Overall Total	1698.9

Total number of cave entrances located during 1989, 100 plus 14 referrals not yet confirmed.

	Cave entrances	Overall Total	114

Others reported from Mafeking (1), Highrock (5), Peonan Point (2), Mantagao (3), Ashern Road east (2), Vidir (1) and St. George Rd. (3).

Figure GS-29-12: Entrance to **Fold Cavern**, east of Gypsum Lake.

Figure GS-29-13: Tightly folded gypsum beds in entrance chamber of **Fold Cavern**, east of Gypsum Lake.

cm) chambers up to 15 m in diameter, similar in many respects to the main chambers of **Phantom Bear** and **Crystal Palace** Caves (Voitovici and McRitchie 1989).

Vertical solution-grooved shafts (2-3 m diameter and 3-4 m deep) are not uncommon, and two caves (**Marble** and **Chicken-Wire**) contain good exposures of chicken-wire texture with 5 to 12 cm gypsum nodules separated by thin buff to red stringers of dolomitic mud. Gypsum popcorn is widespread in the **Jumble** and **Slot** Cluster, and was also noted in several other caves.

Traverses south of Gypsum Lake (Fig. GS-29-11 southern sector) located an extensive array of solution-grooved shafts and sinks at the western limit of the upland area, bordering on two prominent beaver ponds. The density of sinks in this region rivals that observed in the quarry north of Gypsumville. In many respects the two groups are similar, with both phreatic tubes and vadose passageways being represented. Several of the 50 to 60 cm high, flat-roofed cylindrical crawlways display widespread lenses and cross-cutting veinlets of satin spar, as well as preferentially eroded coarse grained gypsum and selenite. The largest of the mazes (**Catacomb-Satin Spar**) links several of the entrances, which are typically tight horizontal squeezes exposed at the base of massive gypsum beds forming the walls of the sinkholes. The **Catacomb** system contains several offshoot passageways that have not yet been fully explored; return visits during the summer of 1990 were thwarted by winter-ice and pools of standing water.

To the north, **Sugar Shaft** exhibits smooth concave solution-grooved passageways and chambers in a relatively massive, coarse grained and thickly bedded unit of white saccharoidal gypsum, quite dissimilar to the thinly layered and commonly shaley beds observed in the walls of **Catacomb**, a short distance to the south. This extreme lateral variation in the nature of the bedrock was also confirmed during the industrial minerals drilling program conducted during the latter part of 1990 (see Report GS-30, this volume).

Traverses further to the west located the ridge historically referred to as "Anhydrite Hill" together with the northeast- trending ravine containing beds of blue anhydrite, originally worked by Messrs. Fry and Dulman in 1913 (Parks, 1916, p. 271,272). One small blind cave entrance was noted at the northern end of this ridge that is prominently cratered by several overlapping and beaded 3 to 5 m deep dolines.

South of the Warpath Trail a small area of polygonal karst was encountered in the northeast corner of Section 34, Twp. 32, Range 8W (Fig. GS-29-1). Two small blind cave entrances were encountered in gypsum outcrops at the edge of a nearby beaver pond; one shows signs of axe or claw marks around the entrance.

Several attempts were made to extend the mapping during 1990, but deep snowfall during the winter, ice blockages during the spring, and standing water and local ice during the summer handicapped the process well into September, some passageways in **Labyrinth** and **Crystal Palace** were totally impassible. Further efforts will continue into October, with results being published at a later date.

DRILLING PROGRAM

Three holes were drilled south of Gypsum Lake to provide additional information regarding the thickness and extent of gypsum deposits in this region, and to investigate the possibility of other potentially economic deposits in the evaporite sequence. A full report on the drilling program is provided by Bezys and Gunter (Reports GS-30 and GS-31, this volume), together with drill logs for these holes, and others in the Gypsumville region.

The drilling program yielded good sections of gypsum, lying directly above thick shaley red beds with minor anhydrite nodules, and underlying "meltrock" and highly kaolinized granite breccias. This sequence is similar in most respects to sections encountered in previous drilling to the west (McCabe, 1983), and appears typical for the Gypsumville structure. Extreme variations were noted in the thickness of gypsum encountered, most noticeably in hole M-14-90 where only 50 cm of gypsum was found in an area flanked, on both sides, by sinkholes containing exposed massive gypsum beds 2 to 3 m thick. Extreme, locally focussed solutioning, or local small scale faulting might account for the inconsistencies and lateral variations in the lithologies, observed between drill holes and between adjacent caves. No new evaporite minerals were encountered. Several additional holes are planned for the northern sector during 1991.

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Figure GS-30-1:   Location of 1990 stratigraphic and industrial mineral core holes in Manitoba. See Table GS- 30-1 for coordinates and elevations.

GS-30 STRATIGRAPHIC MAPPING (NTS 63G) AND CORE HOLE PROGRAM 1990

by R.K. Bezys

INTRODUCTION

Studies were carried out for five separate projects in 1990: continued drilling of the Winnipegosis reef at the Bluff (Dawson Bay, Lake Winnipegosis) and Narrows (Lake Manitoba) areas; regional Silurian outcrop mapping and drilling in the South Moose - Davidson - William lakes area (north of Grand Rapids); regional mapping and core hole compilation along the lower Nelson River (Hudson Bay Lowland); continued stratigraphic drilling in the Gypsumville area; and data compilation for the Western Canada Sedimentary Basin atlas project. A total of 15 core holes were drilled totalling 1166.9 m.

THE BLUFF AND NARROWS PROJECTS

A) The Bluff

Drilling continued on the Bluff (Dawson Bay)(Fig. GS-30-1, holes M-7-90 to M-9-90) to delineate the extent of the Winnipegosis Formation reef complex. Outcrop in the area reveals a highly fossiliferous, stromatoporoid-rich limestone that probably represents a reef-framework lithology. A sparsely fossiliferous unit with poor horizontal bedding that possibly represents an interior lagoon facies occurs towards the center of the outcrop area. In 1988, stratigraphic drilling was initiated to delineate the extent of the reef (McCabe, 1988). Five holes were drilled, two of which intersected the entire thickness of the Winnipegosis Formation and into the Ashern Formation; three holes had to be abandoned due to sand infill. Drilling in 1988 revealed Winnipegosis Formation thicknesses of 81.7 and 84.0 m that appear to be the true thickness of the unit in this area.

Drill core from the 1988 program was intensively studied by Dr. D. Kent and J. Minto (University of Regina) to determine the petrographic, faunal and facies distribution of the formation. This study became part of J. Minto's M.Sc. research. As a result of this drilling and research, three holes were drilled in 1990. Hole M-7-90. intersected 12.25 m of overburden and was abandoned. Holes M-8-90 and M-9-90 were successful in penetrating the complete thickness of probable Dawson Bay Formation, Second Red Beds, and the Winnipegosis Formation to the Ashern Formation (at 81.2 and 81.6 m) (Table GS-30-1). These two holes are located to the extreme southeast of the Bluff and may actually be

Table GS-30-1
SUMMARY OF CORE HOLE DATA 1990

Hole No.	Location and Elevation	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
M-1-90 Nina Lake Q.	5-17-24-9W + 249.9	DEVONIAN-Winnipegosis	0.0-32.4	Dolomite: light brown-tan to buff; very fine crystalline; medium to thick bedded; massive to very porous; scattered crinoidal and coral debris; reef-like in places.
			32.4-39.6	Dolomitic Limestone: light brown-tan to grey; very fine to fine crystalline; generally massive; thin to thick bedded; becoming darker brown in colour towards the base.
		Ashern	39.6-42.0	Argillaceous Dolomite: light green to red-yellow; faintly laminated; very fine grained to clayey; slightly brecciated.
M-2-90 Gunnlaugson Ridge	6-35-24-10W + 249.3	DEVONIAN-Winnipegosis	0.0-19.2	Dolomite: light brown-tan to buff; very fine to fine crystalline; alternating light and dark coloured beds; thin to thick bedded; scattered porous zones; scattered crinoidal and coral debris; reefal.
			19.2-25.4	Limestone and Dolomitic Limestone: light brown-tan to grey; very fine crystalline; rare fossil debris; thin to thick bedded.
			25.4-28.1	Limestone: grey to dark brown; very fine to fine crystalline; scattered bituminous partings fossiliferous with crinoidal debris; slightly brecciated beds in places.
			28.1-44.6	Limestone and Dolomitic Limestone (similar to interval 19.2-25.4): slight increase in dark brown, bituminous intervals; scattered stylolites.
		Ashern	44.6-47.0	Argillaceous Dolomite: light green-grey to purple-red; faintly laminated and mottled; slight brecciations at top.
M-3-90 Gunnlaugson Point	3-35-24-10W + 247.0	DEVONIAN-Winnipegosis	0.0-19.5	Dolomite (with dolomitic limestone): light brown to brown-tan; very fine crystalline; quite porous; medium to thick bedded; slightly granular in places; reef-like in places.
			19.5-27.3	Dolomitic Limestone: brown to dark brown; bituminous; granular and arenaceous in places; very fine to fine crystalline; thin to medium bedded; irregularly laminated and mottled; faintly stylolitic.
			27.3-43.6	Dolomitic Limestone: slightly bituminous to mottled limestone; light to dark brown; very fine to fine crystalline; medium to thick bedded; stylolitic throughout; fossiliferous with crinoidal debris.

Hole No.	Location and Elevation	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
		Ashern	43.6-46.7	Argillaceous Dolomite: olive-green to purple-red; very fine grained; clayey in places; appears brecciated throughout.
M-4-90 Gunnlaugson Point	12-35-24-10W +249.3	DEVONIAN-Winnipegosis	0.0-16.0	Dolomitic and Dolomitic Limestone: light brown-tan to buff; very fine to fine crystalline; granular; upper 75 cm laminated (stromatolitic?); medium to thick bedded; slightly fossiliferous (crinoidal); scattered argillaceous and bituminous partings.
			16.0-24.0	Argillaceous Dolomitic Limestone to Limestone: brown to dark brown-black; very fine grained to shaley; irregularly laminated and mottled; between 17.3 to 17.7, very dark black/brown argillaceous dolomite.
			24.0-41.7	Dolomitic Limestone: light brown to brown-tan; very fine crystalline; mottled to nodular; stylolitic; scattered argillaceous laminations.
		Ashern	41.7-44.7	Argillaceous Dolomite: green-grey to purple-red; very fine grained; slightly clayey; faint brecciation; thin bedded.
M-5-90 Sand Pile Ridge	13-17-24-9W +251.5	DEVONIAN-Winnipegosis	0.0-43.4	Dolomite to Dolomitic Limestone: light brown to dark brown-tan; extremely vuggy and porous throughout; very fine crystalline; slightly sucrosic in places; scattered indiscernible fossil material (crinoidal?); stylolitic at base; reef-like.
		Ashern	43.4-44.6	Argillaceous Dolomite: light green-grey to purple-red; very fine grained; minor brecciation.
M-7-90 The Bluff #6	10-35-45-25W +256.0	Overburden	0.0-12.3	Boulder Till: dolomitic limestone, calcitic dolomite and Precambrian clasts.
M-8-90 The Bluff #4	1-35-45-25W +259.1	DEVONIAN-Winnipegosis	0.0-81.58	Variable lithologies of dolomite, limestone and shale: colours variable, predominantly tan-brown with reds, greens and greys; dolomite is very clean and massive with minor fossil material; some intervals brecciated (between 12.2-26.35) and very argillaceous (possibly Dawson Bay Formation?); scattered silt infill; bituminous calcitic dolomite at 66.6-73.1; slightly brecciated at base.
		Ashern	81.58-84.4	Argillaceous Dolomite to Dolomitic Shale: red-brown to olive-grey; some brecciation; very fine grained; minor fracturing; medium to thick bedded.
M-9-90 The Bluff #5	8-35-45-25W +262.1	DEVONIAN-Winnipegosis	0.0-81.3	Variable lithologies of dolomite, limestone and dolomitic shale; colours range from light brown, red-green to tan; limestone beds are clean, very fine crystalline; interbedded dolomitic and calcitic shale beds (possibly Dawson Bay Formation?) - some intervals slightly brecciated; unit becoming dolomitic towards the base; probable cavity infill between 60.1-61.0 m containing light brown silt.
		Ashern	81.3-85.4	Dolomitic shale: dark grey to red; very fine to fine grained; thin to medium bedded; slight brecciation at top; faintly laminated.
M-10-90 Davidson Lake	11-16-55-15W +272.8	SILURIAN-East Arm	0.0-13.4	Calcareous Dolomite: sublithographic to arenaceous; very fine crystalline; thin to medium bedded; buff. to green-grey tan; shelly zone at 6.5 m.
		Atikameg	13.4-19.0	Calcarenaceous Dolomite: very porous; orange buff; medium crystalline; scattered green-grey clay infill; slight brecciation; friable.
		Moose Lake	19.0-34.9	Dolomite: very fine to medium crystalline; massive to slightly laminated in places; porosity, up to 20% in places; light brown to tan; faint grey argillaceous mottling; minor intraformational breccias.
		Fisher Branch	34.9-42.5	Slightly Calcareous Dolomite: very fine to fine crystalline; massive with dark brown mottled argillaceous zones; well developed zone of *Virgiana* at 40.2 m.

Hole No.	Location and Elevation	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
		SILURIAN/ORDOVICIAN Stonewall	42.5-62.9	Dolomite: very fine to medium crystalline; dark brown to tan; massive and dense; containing two argillaceous zones, dark grey to tan in colour, occurring at 44.4-45.2 and 59.3-60.2 m, respectively.
		ORDOVICIAN-Stony Mountain	62.9-90.8	Dolomite: fine to medium crystalline; brown to tan; very mottled at top; very dense and massive; scattered fossils-mainly crinoids.
		Red River (undifferentiated)	90.8-139.8	Dolomite (slightly calcareous in places): Fort Garry Member between 90.8-106.9; very mottled and argillaceous; containing fine brecciated zones at top (about 5 cm thick); dark grey to green-grey in colour; good *Chondrites* bioturbation; Lower Red River is very massive and dense; light brown; scattered fossil hash; scattered chert nodules; very fine crystalline dolomite; becoming arenaceous at base.
		Winnipeg	139.8-149.0	Quartzose Sandstone: very fine to medium grained; light grey; massive; minor fossil material at top-probably brachiopods; sand becoming more argillaceous towards the base and green-grey in colour; faintly laminated and containing sulphide nodules; becoming very coarse grained at basal contact.
		PRECAMBRIAN-weathered	149.0-157.2	Very kaolinized, altered granite or gneiss with weathered garnet-rich graphite schists.
M-11-90 South Moose Lake	6-35-55-16W +271.3	SILURIAN-Cedar Lake	0.0-9.1	Dolomite (very similar to East Arm): very fine crystalline; light brown to tan; minor brecciated zones; minor high angle laminations (possibly stromatolitic).
		East Arm	9.1-18.8	Dolomite: very fine to fine crystalline; sublithographic; brown to grey in colour; very thin to thick bedded; minor green-grey sand infilling breccia zones; minor salt molds.
		Atikameg	18.8-24.9	Dolomite: brown to buff-yellow; very vuggy in places; very fine to fine crystalline; minor brecciation; thin to thick bedded; minor fossil debris.
		Moose Lake	24.9-30.8	Dolomite: grey to brown-buff; microcrystalline; sublithographic; minor arenaceous intervals; slightly stromatolitic; very massive; minor green-grey floating sand grains.
		Fisher Branch	30.8-39.7	Dolomite: light brown, tan to buff-white; very fine crystalline; some beds sublithographic; slightly arenaceous; medium to massive bedded; no *Virgiana* found.
		SILURIAN/ORDOVICIAN Stonewall	39.7-61.0	Dolomite: variable colours, brown, grey, buff-yellow; very fine crystalline; slightly sublitho-graphic; minor intraformational breccia; containing two prominent red argillaceous zones, at 45.7-46.5 and 57.7-57.9 m, respectively.
		ORDOVICIAN-Stony Mountain	61.0-79.4	Upper Stony Mountain: dolomite, light to dark brown, buff; very fine crystalline; slightly arenaceous; thin to thick bedded; distinctly mottled; minor brecciation.
			79.4-91.0	Lower Stony Mountain: dolomite; light brown to buff; very fine crystalline; medium to massive bedded; minor mottling.
		Red River (Fort Garry)	91.0-107.3	Dolomite: interbedded argillaceous, burrow mottled dolomite and buff-white, clean dolomite; brown to grey; very fine crystalline; minor sulphide mineralization-pyrite; scattered bituminous partings; very chert-rich between 101.3-103.1 m; minor brecciated.
		Lower Red River	107.3-137.9	Dolomite: brown to grey; very fine crystalline; slightly granular; fossiliferous with crinoidal and coral debris; medium to massive bedded; becoming arenaceous at base.
		Winnipeg	137.9-140.8	Quartzose Sandstone: grey to grey-white; faintly argillaceous in places; very fine to fine grained; smokey quartz grains, angular to sub-rounded; indistinctly mottled; thin to thick bedded.
M-12-90 William Lake	7-21-55-14W +266.7	SILURIAN-Cedar Lake	0.0-5.3	Dolomite: brown to buff; microcrystalline; thin to thick bedded; very vuggy at base; slightly stromatolitic.
		East Arm	5.3-10.4	Dolomite: grey-brown to buff; thin to thick bedded; slightly sublithographic; floating sand grains throughout; minor brecciation.

Hole No.	Location and Elevation	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
		Atikameg	10.4-13.9	Dolomite: brown-buff to yellow; cavernous and vuggy; fine to medium crystalline; thin to medium bedded.
		Moose Lake	13.9-22.3	Dolomite: microcrystalline; slightly sub-lithographic; faint argillaceous partings; generally tight and massive; minor salt molds; minor floating sand grains associated with breccia zones; abundant coral debris.
		Fisher Branch	22.3-30.4	Dolomite: microcrystalline; brown to buff-white; thin to thick bedded; rare chert; minor intraformational breccias; *Virgiana* found at 27.3 and 29.9 m.
		SILURIAN/ORDOVICIAN Stonewall	30.4-53.8	Ranging from argillaceous to slightly fossiliferous dolomite: very fine to medium crystalline; thin to thick bedded; slightly sublithographic; containing two distinct argillaceous zones, dark grey to dark brown in colour.
		ORDOVICIAN-Stony Mountain	53.8-67.6	Upper Stony Mountain: dolomite; brown to tan; fine crystalline; medium to massive bedded; distinctly mottled; minor brecciation; bituminous partings throughout; minor gypsum needle casts.
			67.6-81.4	Lower Stony Mountain: dolomite; brown to tan; fine crystalline; medium to massive bedded; indistinctly mottled; slightly fossiliferous.
		Red River (Fort Garry)	81.4-93.6	Dolomite: microcrystalline; slightly sub-lithographic; brown to grey to blue-grey; slightly argillaceous; thick to massive bedded; minor brecciation; slightly arenaceous.
		FRACTURE ZONE	93.6-128.6	Vertically fractured Red River dolomite infilled with light to dark grey calcitic clay and siltstone; infill up to 2 cm wide; no slickensides evident.
M-14-90 Gypsum Lake S.	8-10-33-8W +260.6	JURASSIC-Amaranth (Evaporite)	0.0-0.5	Gypsum: white to light pink; very fine to coarse crystalline; slightly selenitic; minor green-grey dolomite at top with gypsum infilled fractures.
		Amaranth (Red Beds)	0.5-66.6	Shale with interbeds of gypsum, limestone and sand: alternating laminated and massive bedded; red-brown scattered sand beds at base; gypsum and/or anhydrite beds and nodules increasing in abundance upwards; minor satin-spar; gypsum beds present between 4.95-5.22, 7.36-8.0, and 42.47-42.85 m; at base, 3 cm green-grey limestone bed-sharp upper and lower contacts.
		PERMIAN(?)-St. Martin Series	66.6-107.6	Intermixed lithologies of altered gneiss, pseudo-trachyandesite (meltrock) and breccia: colours are predominantly purple-red, green, buff and yellow; altered gneiss intervals are weathered and kaolinized, slightly brecciated and hematitic, with crosscutting veins of meltrock; pseudo-trachyandesite intervals are purple-grey to red-grey and brown, in places vesicular and massive; breccia occurs. predominantly in altered gneiss intervals; most contacts are gradational.
M-15-90 Gypsum Lake S.	8-10-33-8W	JURASSIC-Amaranth (Evaporite)	0.0-0.3	Interbedded Gypsum and Dolomite: gypsum is clear to light yellow in colour, slightly nodular and selenitic; dolomite is light green-grey, very fine crystalline, sublithographic; dolomite is quite fractured and healed with gypsum.
			0.3-5.0	Gypsum (lost core): massive; coarse crystalline; cream-white to light pink and grey; selenitic in places; rare dolomite laminations.
		Amaranth (Red Beds)	5.0-14.2	Shale: dark red-brown to green; very fine grained with some silt; scattered gypsum blebs and laminations throughout.
M-16-90 S. Warpath Trail	16-34-32-8W +256.0	Overburden	0.0-7.9	Boulder Till: clasts of light tan and buff limestone, dolomite and Precambrian.
		JURASSIC-Amaranth (Evaporite)	7.9-23.9	Intermixed lithologies of gypsum, anhydrite?, and limestone: very coarse crystalline; very dark grey to black to pink-white; more calcite at base with abundant stylolites; very dense and massive; becoming less calcitic at top; limestone bed (15 cm) thick) at base.

Hole No.	Location and Elevation	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
		Amaranth (Red Beds)	23.9-25.0	Shale: red-brown, some green; very faintly laminated, most are horizontal, some at 30°; becoming sandy and calcitic at top; upper contact not well preserved.
		PERMIAN(?)-St. Martin Series	25.0-105.7	Intermixed lithologies of altered gneiss, pseudo-trachyandesite (meltrock) and breccia; colours range from red to purple, brown, buff to yellow; altered gneiss and breccia zones are very kaolinized and fractured, slightly hematitic; meltrock intervals more abundant than other zones - very distinctly vesicular, with calcite and chlorite? infill, some portions very friable to granular.
M-17-90 Red Rock Quarry	7-23-32-9W + 248	PERMIAN(?)-St. Martin Series	0.0-3.4	Rubbly core consisting of clasts of red conglomerate, dolomite and limestone. Some lost core.
			3.4-29.7	Red, polymict conglomerate: dominant colour is red, red-pink with buff-yellow, brown and greys; some clasts are quite angular (appears brecciated in places); clasts range from <1 mm to 25 cm in diameter clasts consist of altered to unaltered granites and gneisses, limestone and dolomite, with minor gypsum, red shale and meltrock fragments; unit is cemented by gypsum; rare satin spar laminations; some zones are very friable and granular, especially at the base.
			29.7-105.65	Intermixed litholoiges of sandstone-conglomerate, breccia, possible meltrock and welded tuffs(?), vari-coloured; predominantly sharp contacts, some are gradational; some intervals very dark brown to black-vesicular and porous; some calcite infill of vesicles.

off the reef core, which is located in the centre of the Bluff. Research on the Winnipegosis Formation will continue.

B) The Narrows

Five core holes (M-1-90 to M-5-90, Fig. GS-30-1) were drilled in the vicinity of the Lake Manitoba Narrows, an area believed to represent a basin-edge facies of the Devonian Winnipegosis Formation. A total of 225 m of core were retrieved; all holes successfully penetrated the Winnipegosis Formation into the Ashern Formation. Thickness of the Winnipegosis Formation ranged from 39.6 to 44.6 m.

Three core holes were drilled at Gunnlaugson Farm as a follow-up to a 1987 core hole (M-1-87) (McCabe, 1987). The farm is a flat, low-lying, roughly circular peninsula about 1.6 km in diameter representing a large, flat-topped, platform-type reef. The drill core consists of fragmental to micritic dolomites with interbedded relict limestones. The limestones are variably fossiliferous with brachiopod, crinoid and gastropod debris. Towards the middle of the Winnipegosis Formation interval, a 2 to 8 m thickness of black, laminated, bituminous, argillaceous dolomitic limestone is intersected. These bituminous beds appear identical to the bituminous interreef facies developed in the deeper portions of the basin (in the Winnipegosis and Dawson Bay areas of Manitoba). This lithology was not previously known to be present in this area, since it was thought that shallower water conditions towards the edge of the basin would have raised the depositional interface above the anoxic level (if it was present) and thus preclude the deposition and/or preservation of bituminous material. McCabe (1987) suggested that the anoxic level within the basin must have been higher than presumed, giving a relatively shallower (surface) oxygenated zone and allowing for the deposition of extremely dark, bituminous beds.

Two holes were drilled in the vicinity of the Nina Lake Quarry (M-1-90 and M-5-90), located southeast of Gunnlaugson Farm on Highway 235. The holes encountered typical reefal facies of the Winnipegosis Formation, comprising horizontally bedded, vuggy, variably fossiliferous dolomite to dolomitic limestone. Bituminous intervals were not intersected. A detailed petrographic and facies analysis of the Gunnlaugson and Nina Lake Quarry reef structures is being undertaken by Dr. N. Chow (University of Manitoba).

GRAND RAPIDS PROJECT
A) Stratigraphic Mapping

Shoreline mapping of the northwest portion of NTS 63G (Preliminary Map 1990M-1) was carried out in the summer of 1990, as a follow-up to previous work in the area (McCabe, 1986; 1988). This completes the regional mapping, on a reconnaissance level, of the Paleozoic outcrop in NTS 63G, although extensive areas of outcrop pavements and scarps are as yet not mapped in detail. Shoreline outcrops along the southeastern arm of South Moose Lake, Davidson Lake, and the southern basin of William Lake were mapped, as well as outcrops along topographic highs (Fig. GS-30-2). Access into this area is now possible by all-terrain vehicle via the Davidson Lake winter road.

Ninety-four outcrop stations were examined and/or sampled. The geology in this area consists of the Silurian Interlake Group, specifically the Moose Lake, Atikameg, East Arm and Cedar Lake formations (in ascending stratigraphic sequence) (Table GS-30-2). Most outcrop exposures in this area reveal the East Arm Formation. Figures GS-30-3 and GS-30-4 show typical structures in East Arm Formation dolomites. Generally the stratigraphy appears conformable to regional trends and isopach thicknesses, although formation contacts are difficult to place due to thin exposures, their recessive nature, and similar lithology of the formations (dolomite). Also, contacts between the East Arm/Atikameg formations and Cedar Lake/East Arm formations appear gradational. Topographic elevations of the formational contacts were determined where possible and the extension of these contacts tend to follow topographic contours in NTS 63G (where overburden thickness is thin).

Much of this area overlies the Churchill/Superior Boundary Zone of the Precambrian basement, and some emphasis was placed on observing evidence of recent movement (neotectonism) in the Paleozoic outcrops. If movement (at least since the Silurian) has occurred in basement rocks, an expression of this movement may be revealed at surface in Paleozoic outcrops. Obvious evidence of neotectonism or lineament development has not been revealed, except in core hole M-12-90, which will be discussed below. Some areas reveal well-developed joint patterns in near surface exposures of Paleozoic pavement, but these have probably resulted from inherent stresses in the rocks and rather than basement tectonics. This topic will continue to be addressed in future work in this area.
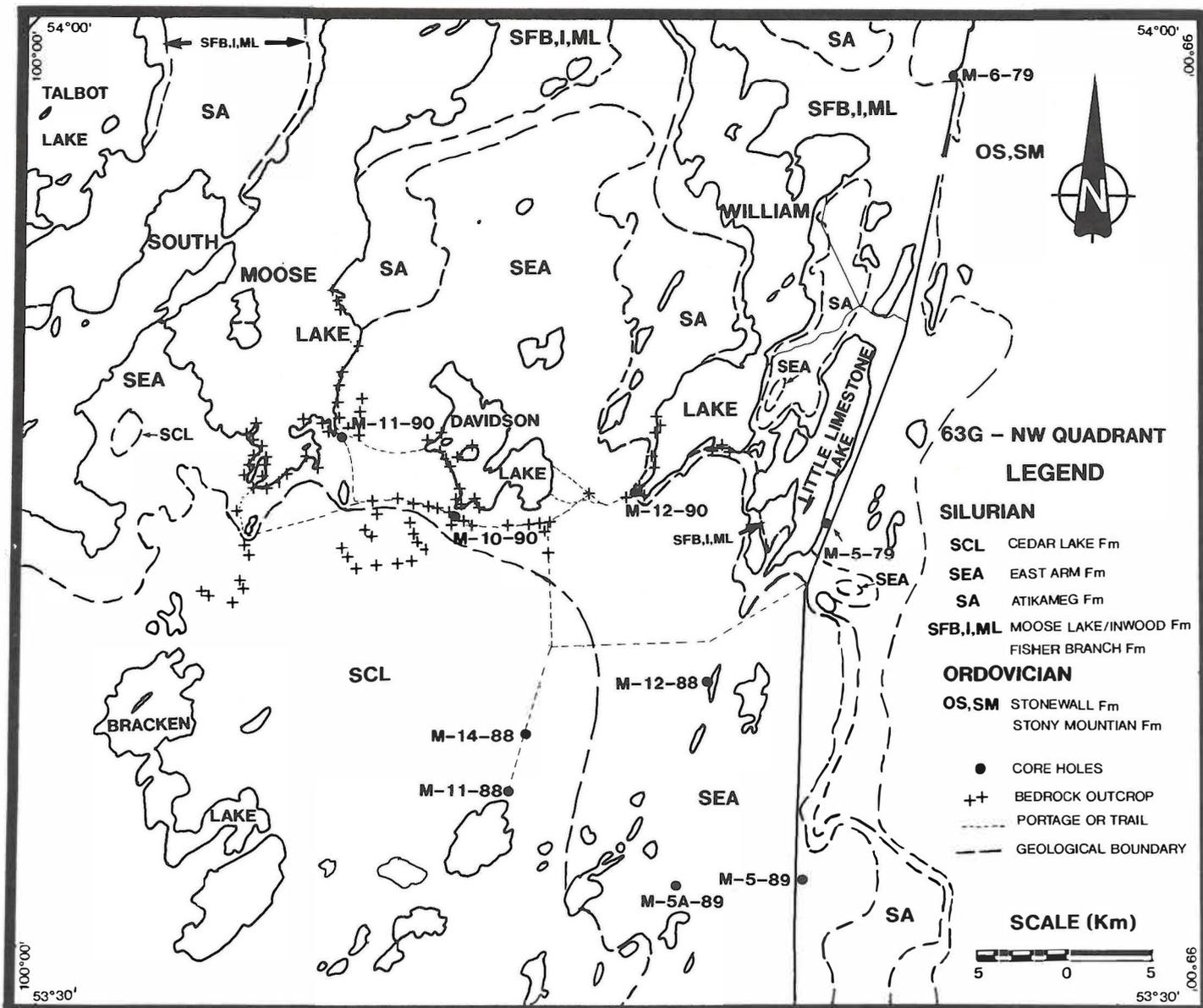
Figure GS-30-2:   Outcrop and core hole locations in the Grand Rapids area, 1990.

Table GS-30-2
Table of Formations in the Grand Rapids area
and their Average Thicknesses (or Range)

ERA	PERIOD/EPOCH	FORMATIONS	THICKNESS (m)
Paleozoic	Devonian	Ashern	0 - 8.0
			Disconformity
	Middle Silurian	Cedar Lake	46.0
		East Arm	12.0
		Atikameg	5.0
		Moose Lake/Inwood	21.0
		Fisher Branch	5.0
			Disconformity
	Upper Ordovician	Stonewall	15.0
		Stony Mountain	35.0

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Figure GS-30-3: Intraformational breccia dolomite in the East Arm Formation, east of South Moose Lake. Station M-64-90.

Figure GS-30-4: Stromatolitic dolomite beds overlain by planar laminated beds in the East Arm Formation, Davidson Lake. Station M-90-90.
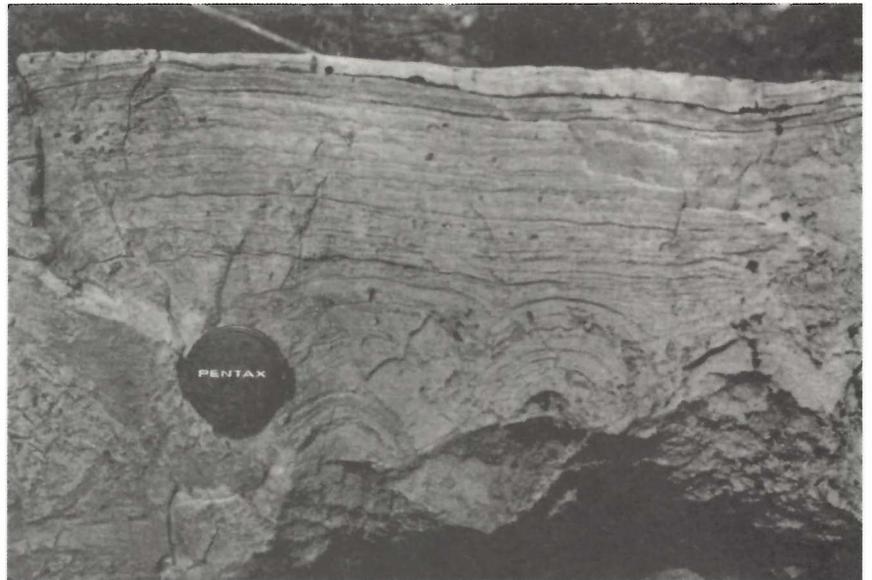
B) Stratigraphic Drilling

Three core holes (M-10-90 to M-12-90, Fig. GS-30-2) were drilled in the Grand Rapids area to: provide better regional stratigraphic control; possibly intersect any basement structure anomalies; and obtain groundwater samples for hydrological analysis. The holes were drilled in a west to east transect along the Davidson Lake winter road from South Moose Lake to William Lake (Fig. GS-30-1 and GS-30-2). A total of 426.6 m of core were drilled, with one hole, M-10-90, reaching weathered Precambrian rocks (Table GS-30-1). Lithologically, the geology in the holes appear to conform to regional trends, as do the isopachs. Although only one hole intersected Precambrian basement, regional thicknesses of the Red River and Winnipeg formations can be extrapolated to the other holes to determine basement structure elevations. All three holes appear to have conformable basement structure contour values.

An anomalous 35 m fracture zone was intersected in the William Lake Hole (M-12-90). The Red River Formation dolomite in this hole is vertically fractured with a light to dark grey calcitic clay and sand infill (up to 2 cm wide in thickness). No slickensides were evident and drilling was abandoned at 128.6 m in the fracture zone. This type of fracture zone has not been previously reported in Paleozoic rocks in Manitoba; this may be evidence of basement tectonics reflected in the Paleozoic rocks. Mineralogy and palynology will be attempted on the infill material.

During the stratigraphic drilling program, three water samples were collected. The samples are being analyzed by the Water Resources Branch (Natural Resources) to determine if the ground water, in this area, is entirely fresh or if some saline aquifers exist at depth. Additional stratigraphic wells will be attempted in the Norris Lake area in 1991. A preliminary Paleozoic map will be published in the near future, as well as a preliminary basement structure contour map.

LOWER NELSON RIVER STUDY

Outcrops along the lower stretches of the Nelson River expose units from the Hudson Bay Basin, namely the Ordovician Bad Cache Rapids and Churchill River groups, the Red Head Rapids Formation and the Silurian Severn River Formation (Table GS-30-3). Outcrops of Paleozoic units begin to appear approximately 36 km downstream from the town of Gillam. From here to the Angling River (approximately 90 km from Gillam) exposures are intermittent (Fig. GS-30-5). From the Angling River to the mouth of the Nelson River, Paleozoic units are not known to be exposed.

Outcrops along the Nelson River were initially investigated by Bell (1879), Savage and Van Tuyl (1919) and Nelson (1964). Since Nelson's report, the last geological study carried out along the river and the surrounding area was done by the Geological Survey of Canada during Oper-

Table GS-30-3
Summary of Stratigraphic Succession along the Lower Nelson River and Correlations to Manitoba Hydro Terminology

| ERA	PERIOD	GROUP and FORMATIONS	THICKNESS (m)	MANITOBA HYDRO UNITS
Paleozoic				
	Silurian	Ekwan River	41.0	n/a
		Severn River	240.0	n/a
	Ordovician			
		Red Head Rapids	14.0	n/a
		CHURCHILL RIVER GROUP:		
		Chasm Creek	58.0	11,12
		Caution Creek	13.0	8,9,10
		BAD CACHE RAPIDS GROUP:		
		Surprise Creek	18.0	4,5,6,7
		Portage Chute	25.0	2,3
		Unconformity		
Precambrian				1a,1b
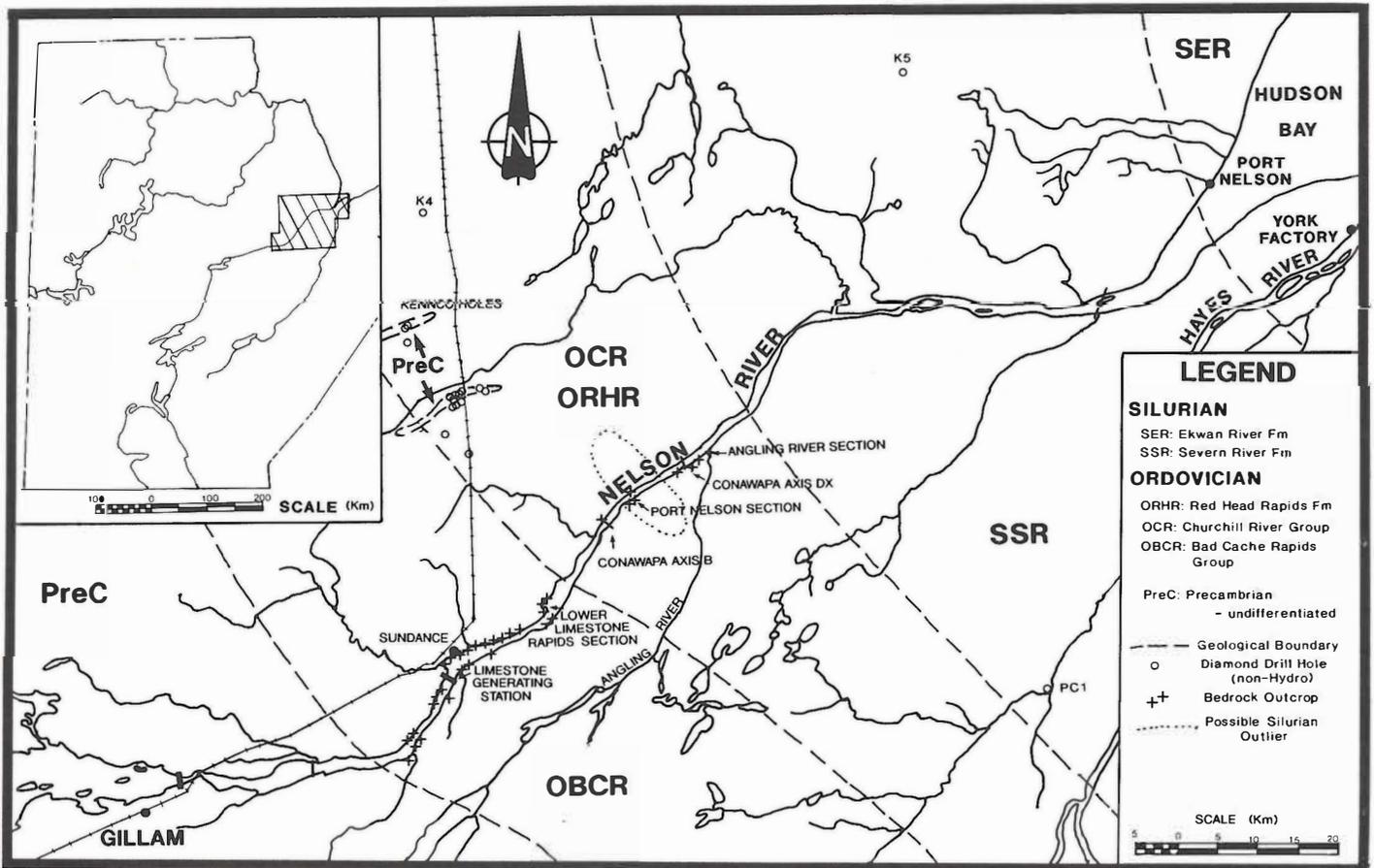
Figure GS-30-5: Location of outcrops, drill holes, and Manitoba Hydro investigation sites along the lower Nelson River. The Pennycutaway No.1 test hole is indicated as PC1.

ation Winisk (Sanford et al., 1968). Recent studies since 1967 include those by Norford (1971) on the Silurian, and Cummings (1971, 1975) on the Ordovician. Much of their work was supplemented by recent drilling which provided substantial intervals of core. Some of these wells include the Kennco holes and the Pennycutaway No.1 test hole (Fig. GS-30-5), as well as the Comeault and the Kaskattama wells (not shown in Fig. GS-30-5).

Since the late seventies, Manitoba Hydro has carried out extensive drilling programs along the river to investigate sites for hydroelectric generating stations. A large repository of drill core is now available, especially from the Limestone Generating Station, Conawapa Axis B and Axis DX, and Gillam Island sites (Fig. GS-30-5). The Limestone site is located on approximately 7 m of lower Ordovician (Portage Chute Formation) limestone and sandstone that overlie Precambrian basement rocks (gneisses and granites). Eleven core holes were logged from this site for this study. The proposed Conawapa Generating Station, located 27 km downstream from the Limestone Generating Station, will be located on approximately 40 to 50 m of lower Ordovician strata. The Conawapa site is located on Axis B, but Axis DX, about 11 km downstream from Axis B, was also intensively drilled as a possible site for the Conawapa dam. A total of 46 core holes were logged from Axis B and 8 holes from Axis DX. Drill core from the Gillam Island site is also available and a total of 3 holes were logged for this study. Some of the core holes extended into the Precambrian basement and thus allowed for a complete representation of the stratigraphy at that particular site.

In total, 68 core holes were logged from the four sites along the

Nelson River. Outcrops along the river were also investigated, including the Sundance, Lower Limestone Rapids, Port Nelson, and Angling River sections (Fig. GS-30-5). The outcrop investigations supplemented the section that was exposed in the Conawapa Test Pit in 1989, which is presently flooded. The pit was examined in October 1989; it revealed approximately 40.7 m of Ordovician section. The lower portion of the section is correlatable with the Portage Chute Formation (Hydro units 2 and 3, Table GS-30-3), whereas the upper part of the section is probably correlatable with the Surprise Creek Formation (units 4 to 7). The extreme top of the section may be part of the Caution Creek Formation (unit 8). Drilling in and around Axis B confirms the presence, in the subsurface, of the rocks exposed in the pit, as well as sections higher up in section (i.e. in the Caution Creek Formation).

A problem arises with the Port Nelson Section, which is only 5 km downstream from Axis B (Fig. GS-30-6). Cummings (1971, 1975) and Norford (1971) identified the top of the section to be part of the Silurian Severn River Formation, making the underlying unit the Red Head Rapids Formation. Some of the Kennco holes (specifically holes 1 and 2) have also been identified as containing Silurian Severn River Formation (Norford, 1971). Between Axis B and the Port Nelson Section, there is a stratigraphic difference of 85 m (between the Bad Cache Rapids and Severn River formations) that is not demonstrated in the rocks. If this Silurian outlier is genuine, tectonics must be a factor, due to either folding or faulting to cause such a rapid difference in the stratigraphic thickness. Conodont work will be carried out on the suspect Severn River Formation unit to confirm its Silurian age. If it is not Silurian, the unit probably represents the Ordovician Caution Creek Formation. Work is to continue on subsurface correlations of the units and the geology of the outcrops along the river.

GYPSUMVILLE STRATIGRAPHIC DRILLING

Four core holes were drilled in the Gypsumville area to further delineate the subsurface geology of the possible Lake St. Martin crater structure and the surface extent of the gypsum reserves. This year's drill program supplements those from 1969, 1977, and 1983 (McCabe and Bannatyne, 1970; McCabe, 1977; 1983) (Fig. GS-30-7 and Table GS-30-1). Three of the core holes (M-14- 90, M-15-90 and M-16-90) were placed in areas of little subsurface stratigraphic control, and were drilled to define more accurately the nature and distribution of the "crater" infill and overlying gypsum and red shale deposits. Hole M-17-90, located in the Red Rock Quarry (south of the town of Gypsumville), was drilled to define the stratigraphic framework of the red, polymictic conglomerate/breccia unit.

Core holes M-14-90 and M-15-90 were drilled in an area of known near-surface outcrops of gypsum (as revealed by numerous sinkholes and caves in the surrounding area). It was suspected that approximately 10 m of gypsum would be intersected. Instead, hole M-14-90 intersected 0.5 m of gypsum and about 66 m of red shale. These two units probably represent the Evaporite and Red Bed members of the Jurassic Amaranth Formation. The Jurassic units are underlain by a variety of Permian(?) St. Martin Series lithologies, including altered granites and gneisses, breccias, and trachyandesites (meltrock). McCabe and Bannatyne (1970) suggested that this series of rocks represent crater infill from a meteor impact event, but evidence for a volcanic event has not been ruled out.

Hole M-15-90, drilled approximately 30 m from M-14-90, intersected about 5.0 m of gypsum (including a core loss of approximately 60%) and bottomed-out in red shale at 14.2 m. This revealed the variability of the gypsum in this area. Hole M-16-90 was drilled south of the Warpath Trail (Fig. GS-30-8) and intersected about 8.0 m of boulder till, 16 m of evaporite, and 1.0 m of red shale. The hole continued to a depth of 105.7 m and contained variable lithologies from the St. Martin Series. Surprisingly, hole M-16-90, which is only 2.8 km from hole M-14- 90, shows a considerable increase in the thickness of gypsum with a corresponding decrease in red bed thickness. Obviously, the surface structure contours on the pre-Jurassic surface are quite variable and may result from several depositional highs and lows to allow for the inconsistent thicknesses of the overlying Jurassic evaporite and red bed sequences. This surface may possibly be fault controlled.
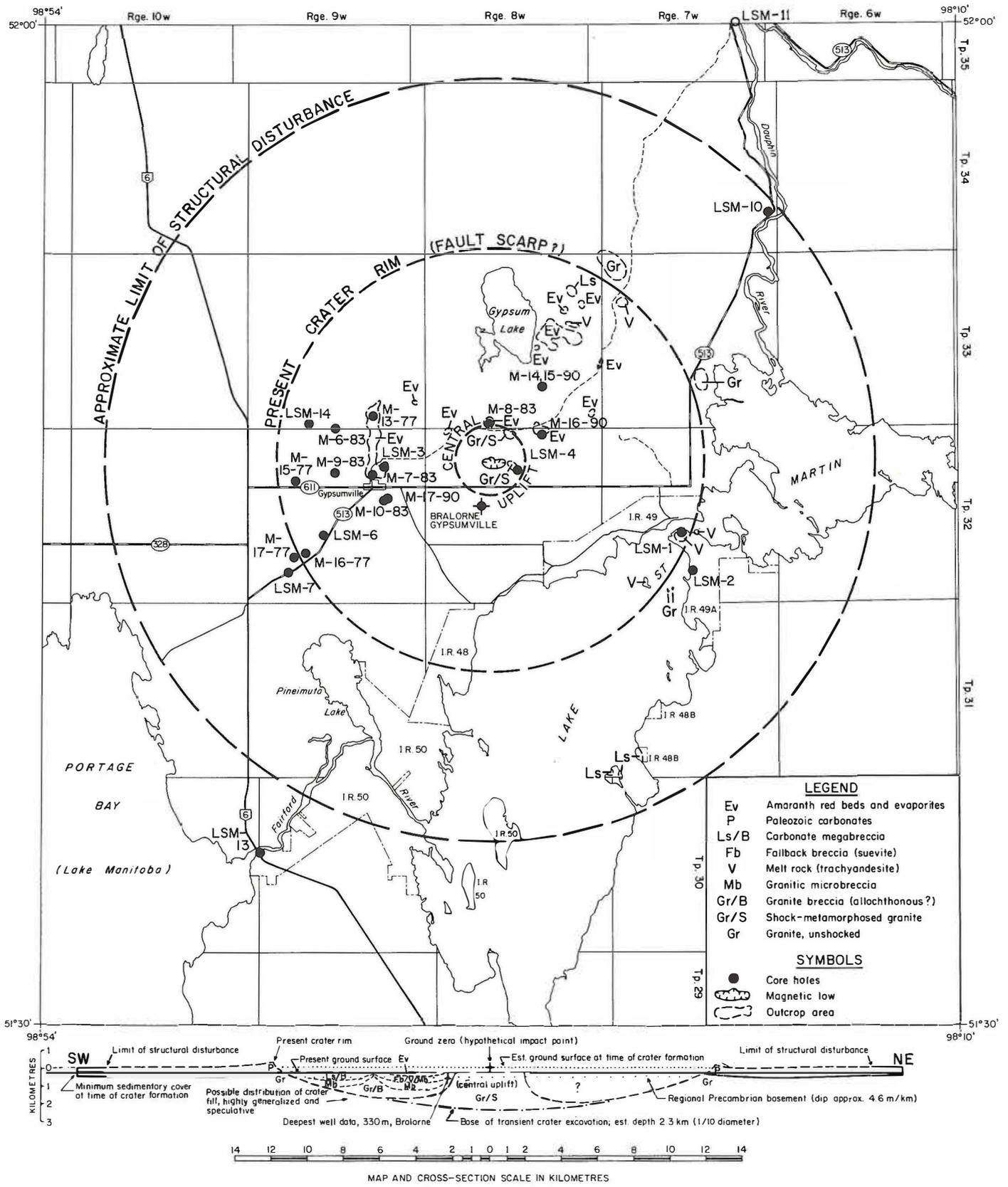
Figure GS-30-7: General geology and location of stratigraphic core holes in the Gypsumville area (after McCabe, 1983).

Hole M-17-90 was drilled in the same location as M-10-83, where 26.5 m of red, polymict conglomerate was intersected. M-10- 83 had to be abandoned due to drilling problems. Hole M-17-90 intersected approximately 29.7 m red conglomerate, which overlies rock units from the St. Martin Series. The conglomerate contains clasts of limestones and dolomites, altered and unaltered granites, and minor gypsum and meltrock units. The conglomerate is cemented by gypsum.

The lithologic units of the St. Martin Series intersected in core hole M-17-90 are different from those encountered in the previous core holes (M-14-90, M-15-90, and M-16-90). Red conglomerate grades downward into a sandy breccia and conglomerate unit containing larger clasts of meltrock, altered granites and limestones. Downward, toward the end of the hole (at 105.65 m), meltrock units, granite breccia, altered granites, conglomerates and a possible welded tuff or heterolithic pyroclastic breccia unit are intermixed. Contacts between these units are predominantly sharp, although some are gradational. Jurassic evaporite and red bed sequences were not encountered, which did not allow for the red conglomerate to be stratigraphically positioned relative to the Jurassic and St. Martin Series units. Further work will continue to address this topic and to attempt regional correlations of the core holes. In addition, petrographic and palynological investigations will be conducted. Other work that has been carried out in the area is reported by McRitchie and Voitovici (GS-29, this volume) on the gypsum karst topography and Gunter (GS-31, this volume) on the industrial mineral potential in the area.

WESTERN CANADA SEDIMENTARY BASIN ATLAS PROJECT

On behalf of the Geological Services Branch, the author and H.R. McCabe (retired) have been contributing subsurface and surface outcrop information from Manitoba to the new Western Canada Sedimentary Basin Atlas. The project is a tectono- stratigraphic synthesis and basin analysis that encompasses the three Prairie provinces. The project is being coordinated by the Alberta Research Council in Edmonton, with contributions by federal and provincial agencies, academia, and the private sector. One well per township has been selected in Manitoba, constituting approximately 300 oil and gas wells (150 of these are deep holes) and about 100 stratigraphic holes. This well data is being compiled into a computer database that will accompany the volume.

Manitoba's contribution involved a systematic check of all atlas well picks, especially those in the Jurassic and Lower Paleozoic sequences. The Branch was also involved in the construction of basin-wide cross-sections that extend into Manitoba. This information, as well as computer generated isopach maps and accompanying text and figures, will be released in 1991.

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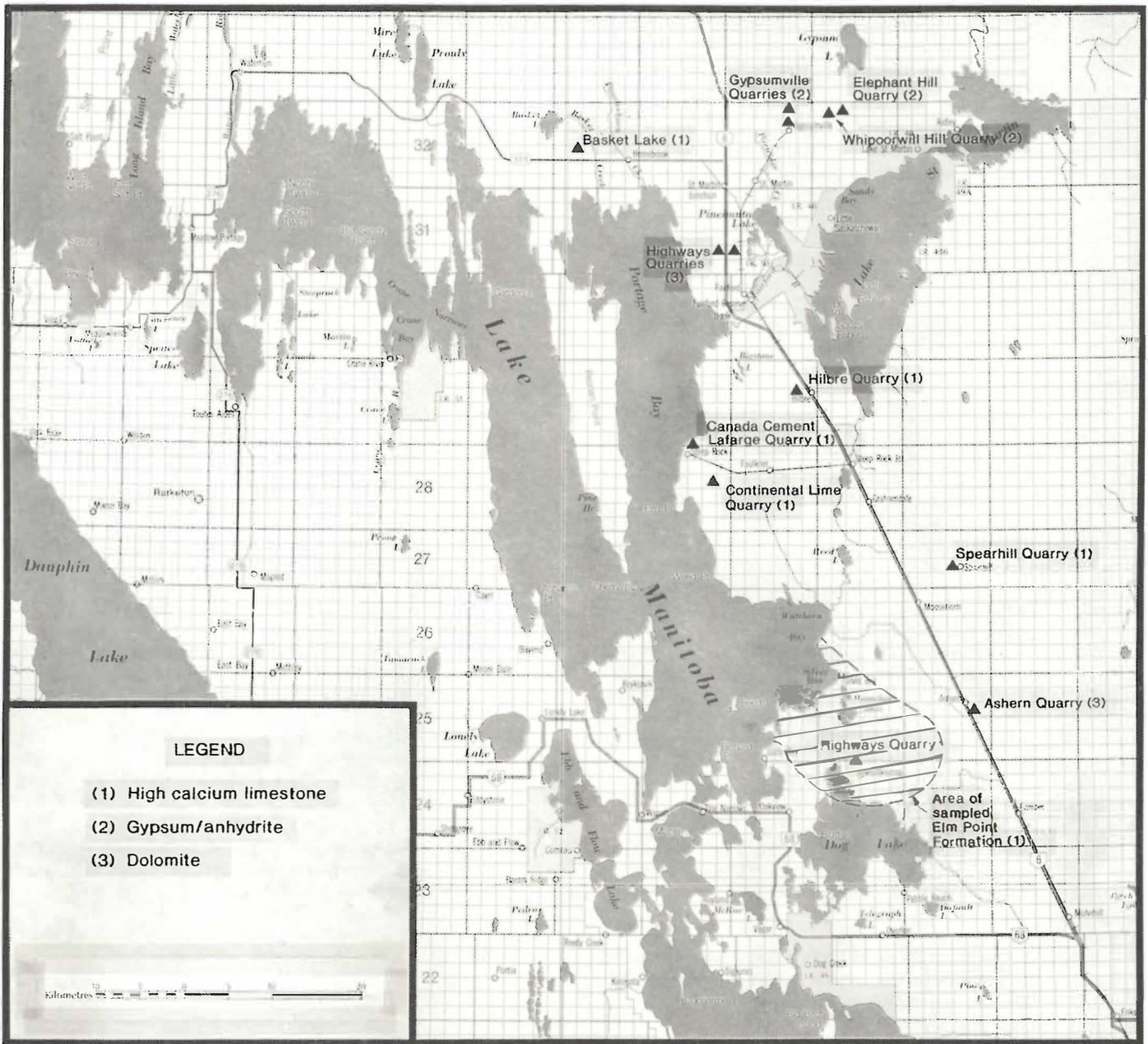
Figure GS-31-1:   Location map, northeast corner NTS 62O.

GS-31 INDUSTRIAL MINERALS INVESTIGATIONS IN THE GYPSUMVILLE-STEEP ROCK AREA (NTS 62O)

by R. Gunter

INTRODUCTION

Industrial Minerals mapping program was continued into the area of NTS 62O. The area is underlain by Ordovician to Devonian sedimentary rocks. This investigation was confined mainly to a detailed study of:

1. evaporites and related rocks in the Gypsumville area;
2. high-calcium limestone of the Elm Point Formation; and
3. dolomites of the Ashern Formation and the Interlake Group.

Current and past producing properties in NTS 62O are:

1. Steep Rock quarry operated by Canada Cement LaFarge Ltd. produces high-calcium limestone for cement;
2. Faulkner quarry operated by Continental Lime Ltd. produces high-calcium limestone for lime;
3. Spearhill quarry, formerly operated by Steel Bros. Canada Ltd., produced high-calcium limestone for lime;
4. Gypsumville quarries, formerly operated by Domtar Construction Ltd., produced gypsum for wallboard and as a setting agent in Portland Cement;
5. Hilbre quarry, formerly operated by Steele Bros. Canada Ltd., produced dolomite for dolomitic lime; and
6. Aggregate is quarried in seven pits along Highway 6 south of Gypsumville, where extensive areas of thin overburden limit the availability of sand and gravel resources.

EVAPORITES

Evaporite deposits in the Gypsumville area occur as gypsum/anhydrite cored ridges that rise several metres above the surrounding marshes. Gypsumville south, Gypsumville north, Elephant Hill and Whippoorwill Hill (Fig. GS-31-1) are the four major gypsum/anhydrite quarries that were worked by Domtar at various times between 1901 and 1986.

The Gypsumville north and south quarries were mapped in detail. The Gypsumville north quarry was sampled in detail to determine if any differences in chemistry existed between the various types of gypsum. The Gypsumville north and south quarries were mapped to determine the extent of the three main textures.

Three types of gypsum were noted, namely:

1. a fine- to medium-grained bedded gypsum with local reddish clay interbeds;
2. a very coarse grained selenitic gypsum; and
3. a fine grained, friable white gypsum that may be a weathered product of type 2.

A detailed section of Type 2, which has not been previously recorded in the Gypsumville evaporite sequence, is presented (Table GS-31-1) to illustrate this lithology. This section occurs on the east side of the quarry road at the southernmost bay in the Gypsumville north quarry.

Table GS-31-1
Stratigraphic Section South End of Gypsumville-north Quarry

Datum - Water Level (at base of section)

0.0 - 0.15 m

Finely laminated light grey clay-rich beds, thinly laminated 2 to 4 cm thick and white fine grained gypsum with brown mottled coarse grained gypsum;

0.15 - 0.80 m

Fine- to medium-grained gypsum, 4 to 5 cm thick beds: with grey clay-rich thinly bedded (1-2 cm) interlayers. Clay-rich layers are disrupted, but not folded; upper contact is sharp;

0.8 - 3.00 m

Coarse- to very coarse-grained selenitic gypsum. Gypsum crystals 5 to 10 cm in length, growing either subperpendicular to the parting, as fan-shaped aggregates or, locally, as bow-shaped crystals with both ends attached to the same parting plane. The parting planes are open and occur at 5 to 10 cm intervals. Some selenite crystals have grown across two or more parting planes;

Elephant Hill and Whippoorwill Hill quarries were mapped and sampled to determine the presence of minor elements. Minor element distribution may indicate whether or not deposits of other evaporite minerals, such as borates, are present.

HIGH CALCIUM LIMESTONE

The Elm Point Formation is the oldest unit of Devonian high-calcium limestone in the Manitoba Paleozoic section (Norris et al., 1982). This formation is a facies equivalent of the lowermost member of the Winnipegosis Formation dolomites and grades into that formation (Norris et al., 1982). An increase in the MgO content marks the boundary between the two formations. Bannatyne (1975) outlines the occurrences of high-calcium limestone and the relationship of the Elm Point Formation to the Winnipegosis Formation.

The Elm Point Formation, exposed in the map area, is a fine grained, light to medium brown-grey, mottled, limestone. In the operating quarries rust-orange dolomitic lenses occur, having higher MgO than the normal brown-grey limestone (0.25% vs >0.3%) the rust-orange lenses occur at random throughout the Elm Point Formation exposures. These lenses are flattened parallel to bedding and have a 2:1 to 3:1 width to thickness ratio; a typical lens is 4 by 2 m. The boundaries of the lenses are generally sharp and over a 0.5 m transition zone along bedding change to unaltered limestone. These lenses are a source of MgO contamination in the use of the limestone as a raw material for high-calcium lime or cement.

Sand and clay-filled caves (from 10 x 10 cm to 2 x 3 m) occur to a greater or lesser extent in all the investigated exposures of the Elm Point Formation. The sand and clay introduce silica, alumina and some magnesium to the limestone product. The rounded surfaces and abundant secondary mineralization of pyrite/marcasite, first generation calcite and locally abundant second generation calcite and barite in the caves, indicate that there has been low temperature fluid flow from external sources. The secondary calcite occurs as both parallel growth aggregates lining the cave walls and as crystals to 10 cm in length growing in the clays. Locally, cave walls are lined with a very fine grained, travertine-like, calcite coating. Rosettes of barite occurring on the surface of the calcite linings indicate that this secondary mineral growth occurred after the caves had been dissolved and the cave lining precipitated. The largest concentration has been found in the Canada Cement LaFarge quarry at Steep Rock, but minor amounts have been found at all other quarries within the Elm Point Formation. The barite mineralization in the Manitoba Paleozoic section, may be an indicator of more widespread barite mineralization.

Exposures of the Elm Point Formation, south of Basket Lake, have been stripped of the overlying aggregate and a pit excavated, for use as road aggregate, in the high-calcium limestone. The northern portion of the Basket Lake occurrence was mapped in detail. The beds of this location dip to the east at 15° to 20°. Minor rusty-orange areas of dolomitized limestone were found throughout the map area (Fig. GS-31-2). The road aggregate pit was chip sampled for analysis of the MgO content. Several holes will be drilled to determine the depth and chemical composition of the high-calcium limestone at this location.

Figure GS-31-2: Detailed map, Basket Lake occurrence.

The northern portion of the Basket Lake occurrence was mapped in detail. The beds dip to the east at 15° to 20° and minor rusty-orange areas of dolomitized limestone are found throughout the mapped area (Fig. GS-31-2). The pit was chip sampled for analyses of MgO content. Several holes will be drilled to determine the depth and chemical composition of the high-calcium limestone at this location, since there is no other outcrop in the vicinity to establish the composition or the stratigraphic position of this exposure within the Elm Point Formation.

In the vicinity of Dog Lake, south of Gypsumville, Bannatyne (1975) suggested that the MgO content of the Elm Point Formation increases to the south. Outcrops in this area were mapped and sampled to determine if there was any macroscopic guide that could be used in exploration for' high-calcium limestone south of the Steep Rock quarries. The Elm Point Formation is macroscopically similar in texture to the known high-calcium limestone in the quarries at Steep Rock. The limestone north of Dog Lake is slightly darker grey, but the rust-orange dolomitization is similar in grain size and texture to that found in all of the other exposures of the Elm Point Formation examined. An aggregate quarry east of Dog Lake was sampled to determine the MgO content of the limestone, which has normal colour and texture. A high-calcium limestone occurrence at Dog Lake would have a transportation cost advantage over presently producing quarries in the Steep Rock area.

DOLOMITE

Dolomites of the Ashern Formation and the Interlake Group are exposed as bedding plane outcrops in several areas along Highway 6 south of Gypsumville. Three dimensional exposures occur in aggregate quarries along the highway and in a dolomitic lime quarry at Hilbre. The dolomites are fine grained, yellow-orange and have few macroscopically visible impurities. In the quarries examined, the clay- and sand-filled caves are small and confined to bedding planes and widened joints. An analysis from the Hilbre quarry is given as 54.33 per cent $CaCO_3$ and 44.68 per cent $MgCO_3$ (Energy and Mines, Non-confidential files). Bannatyne (1988) reports an analysis of dolomite from an aggregate quarry north of Fairford; 30.7 per cent CaO, 21.4 per cent MgO, 0.17 per cent SiO_2 and 47.54 per cent LOI. Both analyses indicate a high quality dolomite that could be used in the production of dolomitic lime and magnesium metal.

Further investigations of the gypsum, high-calcium limestone and dolomite occurrences in the map area will be conducted in 1991.

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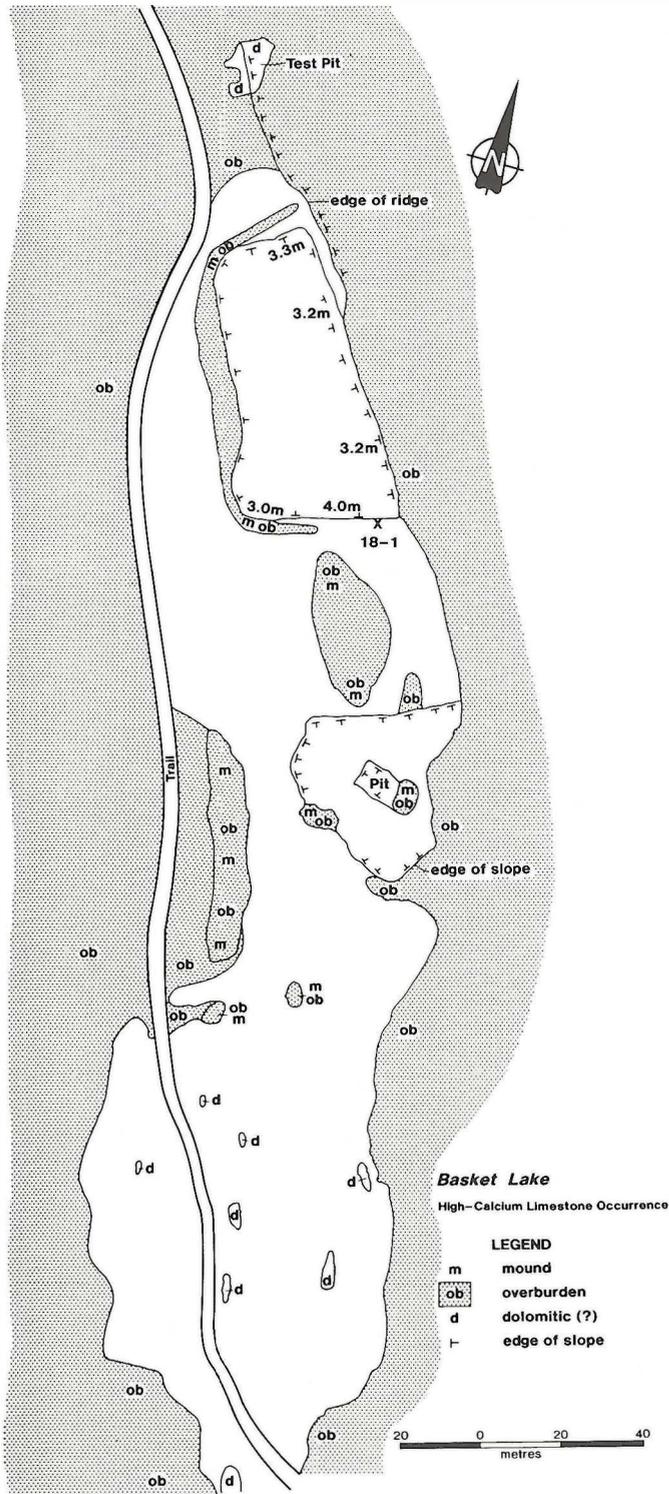
GS-32 GEOLOGY AND HYDROGEOLOGY OF TILLS, ROSSBURN STUDY SITE

by R.N. Betcher[1] and E. Nielsen

A co-operative project was initiated between Geological Services and the Manitoba Water Resources Branch to study the surficial geology and hydrogeology of a small (quarter section) site located approximately 6 km south of the town of Rossburn (Fig. GS-32-1). The primary purpose of the study is to develop an understanding of the physical hydrogeology and hydrogeochemical development within "typical" tills developed on the Cretaceous shales of western Manitoba. This study

[1]Manitoba Natural Resources, Water Resources Branch

complements similar work being undertaken on tills developed over Paleozoic carbonate bedrock near Teulon.

A detailed evaluation of overburden stratigraphy and geochemistry at each of these sites will provide a basis for understanding variations in hydraulic properties and the development of specific hydrogeochemical patterns in the groundwater systems both within and between each of these sites. We also hope to develop an improved understanding of the mineral- water interactions controlling the evolution of a number of trace elements of concern to drinking water quality which


Figure GS-32-1: *Location of drill holes and piezometers in the Rossburn area. Redrawn from Kontzamanis, Graumann and Smith Inc. (1990).*

appear to develop to significant concentrations in groundwaters in some tills. These include arsenic, chromium, fluorine, boron, barium, uranium, zinc and selenium.

The Rossburn site was initially chosen by the Manitoba Hazardous Waste Corporation (MHWC) for investigation as a potential location for a waste treatment and disposal facility. Geotechnical and environmental studies were undertaken by a consultant during the fall of 1989 including the drilling of 26 holes, 10 of which were continuously cored using a hollow stem auger rig. Many of the holes were drilled to shale bedrock. Site geology consists of seven to more than 30 metres of till overlying brittle fractured shales of the Odanah Member of the Riding Mountain Formation. The tills consist of an upper massive clay till of intermediate plasticity overlying a lower silty clay till of low plasticity which contains occasional sand and gravel lenses. Forty-eight piezometers were constructed in these holes. Adverse public opinion eventually resulted in the MHWC abandoning the site. The Water Resources Branch then assumed responsibility for the site in early 1990. All field installations were left intact by the MHWC and all cores were transferred to the Geological Services Branch.

During 1990 the cores were re-examined with particular attention being paid to the depth of weathering of the tills and the transition zone from weathered to unweathered tills. The tills were found to be highly oxidized in the upper 3 to 6 m with the transition from brown oxidized material to dark grey unoxidized material occurring abruptly in some cores and gradually over a metre or more in other cores. Oxidation in the transition zone was found mainly along subhorizontal and subvertical fractures and around the rims of large pebbles indicating the paths of preferential flow of oxidizing groundwaters. Fracturing was commonly observed in the weathered and transition zones but no fractures were observed in the unweathered cores. The question remains as to whether the unweathered till is fractured. Fractures may be present but are not visible due to the absence of colour changes associated with oxidation or, alternately, fracturing is a result of processes associated with oxidation and is not present below the transition zone. Secondary gypsum deposition was seen partially filling fractures in the weathered zone in some of the cores. A log of one core hole showing the stratigraphy typically found at the site is given in Figure GS-32-2.

Samples of the cores from all 10 core holes were collected at 0.5 m intervals. The samples were dispersed and approximately 0.50 grams of the <2 micron fraction was retained for analysis. Samples will be analysed for Cu, Pb, Zn, Ni. Co, Cr, Fe, Mn, Cd, Ba, F, As, B, U and Se. Carbonate and sulphur content will be determined on the <63 μm fraction of the tills. The concentrations of acid soluble trace elements will be used as an indication of the availability of these elements for solubilization by groundwaters.

Groundwater samples were collected from most piezometers and have been submitted for major, minor and trace element analysis as well as oxygen-18, deuterium and tritium analysis.

ACKNOWLEDGMENTS

We would like to thank the Manitoba Hazardous Waste Corporation for providing the cores and transferring responsibility for the piezometers to the Geological Services Branch and the Water Resources Branch.

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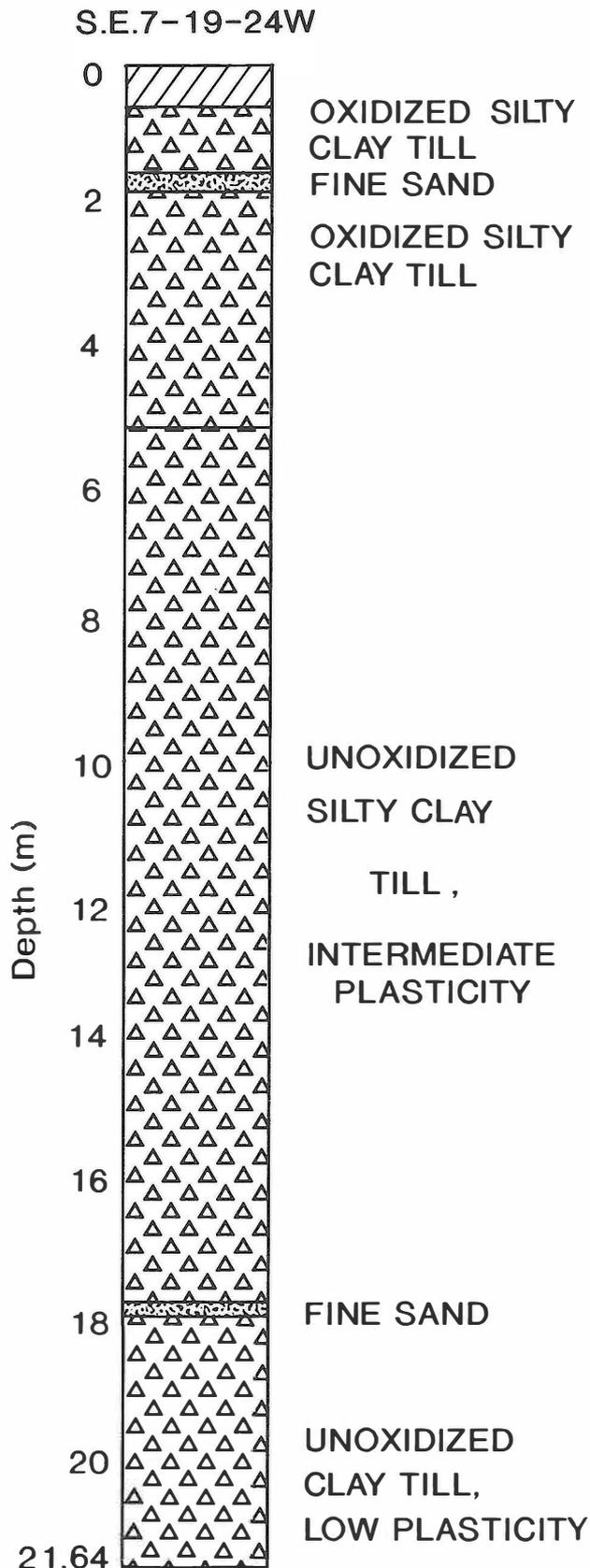
Figure GS-32-2:   Lithologic log of the core from drillhole #19. Redrawn from Kontzamanis, Graumann and Smith Inc. (1990).

GS-33 DEPARTMENTAL GEOGRAPHIC INFORMATION SYSTEMS (GIS)

by L. Chackowsky and A. Bibik

PURPOSE

In March, 1988, Manitoba Energy and Mines purchased PAMAP GIS software for maintaining and updating the Mines Branch mining claim maps. After being in operation for 2 years, it became clear that a second system would be required to handle all of the other applications being proposed. After a series of demonstrations, five applications were selected as pilot projects to test the system's capabilities.

BASAL TILL GEOCHEMISTRY - NTS 63N/3

Geochemical data of two particle size fractions were imported from LOTUS into GIS. This included data from 255 sample locations covering most of the map area. Colour thematic maps of 8 elements from the <2 micron fraction were produced. A Cu-Zn-Pb overlay was generated from the data showing the spatial relationships between the three elements.

GEOLOGICAL FIELD DATA - NTS 63K/12

Positions for some 3500 field stations for 63K/12 were digitized and merged with an existing geological database. This allowed for the automatic generation of structural map symbols (e.g. 2200 schistosities) and will allow for analytical modelling of structural data.

STRATIGRAPHIC MAP SERIES - SOUTHWEST MANITOBA

Formation top data for oil wells in SW Manitoba will be loaded into a GIS point database. Precambrian structural data will form one layer which will be merged with GIS-generated formation thickness contours to produce 1:1 000 000 isopach maps for all major Phanerozoic formations.

MINING RECORDING SYSTEM - NTS 63K/12

Information stored on mainframe will be tied to Mining Claim Maps. A user will be able to call up map areas of interest and obtain all information of past and present activity on that area.

MINING ENGINEERING PLANNING SYSTEM - AREA TO BE SELECTED

A GIS application will be developed to allow information concerning quarry mineral dispositions and deposits to be correlated with other resource planning activities currently undertaken through the interdepartmental Crown Lands Committee. This will show the geographic relationship of all parks, wildlife management areas, ecological reserves, etc. with existing and proposed mineral dispositions.

GS-34 MANITOBA'S PRECAMBRIAN DRILL CORE COLLECTION PROGRAM: AN UPDATE AND REVIEW

by D.E. Prouse

INTRODUCTION AND HISTORY

The Minerals Division realizes that retrieved exploration drill core is a valuable data source that can be utilized by explorationists and researchers. For this reason the province has been retrieving and storing Precambrian drill core since the early 1970's.

The core collection program was started in the early 1970's to assist exploration companies and prospectors working in the province. The construction of core sheds at The Pas (1972), Thompson (1973), and Lynn Lake (1974) provided storage space that allowed for a concerted effort towards core collection. The acquisition of storage space in 1980 for core from southeastern Manitoba meant that there was a core storage facility for drill core collected and donated from companies carrying out drill programs in the major greenstone belts in Manitoba.

Precambrian drill core collection has been the responsibility of various Energy and Mines personnel. From 1971 to 1977, it was the responsibility of the Resident Geologist in The Pas. When the Resident Geologist position was discontinued in 1977, core collection was administered by various Mines Branch employees, or core was delivered to core storage facilities by exploration companies. By the end of 1982, 88 600 metres of drill core had been collected. However, due to limited staff during the 1970's, much of this core was not properly inventoried nor was it stored in an organized manner.

In April, 1984, the Governments of Canada and Manitoba embarked on the Canada-Manitoba Mineral Development Agreement (MDA). Under the terms of this five year Agreement $24.7 million was allotted for activities that were key to strengthening Manitoba's mineral industry. During the term of the five year Agreement, $631,000 was spent on capital and operating costs of Manitoba's Precambrian Drill Core Libraries Program. This funding allowed for the expansion of all the northern core storage facilities as well as better documentation and organization of inventories. During MDA approximately 800 000 metres of core were collected and added to the system and about 58 000 metres of core were discarded.

Industry and public use of the core library program facilities and services increased during the early years of MDA (Fig. GS-34-1); but markedly declined in fiscal years 1987-88 and 1988-89. This trend was
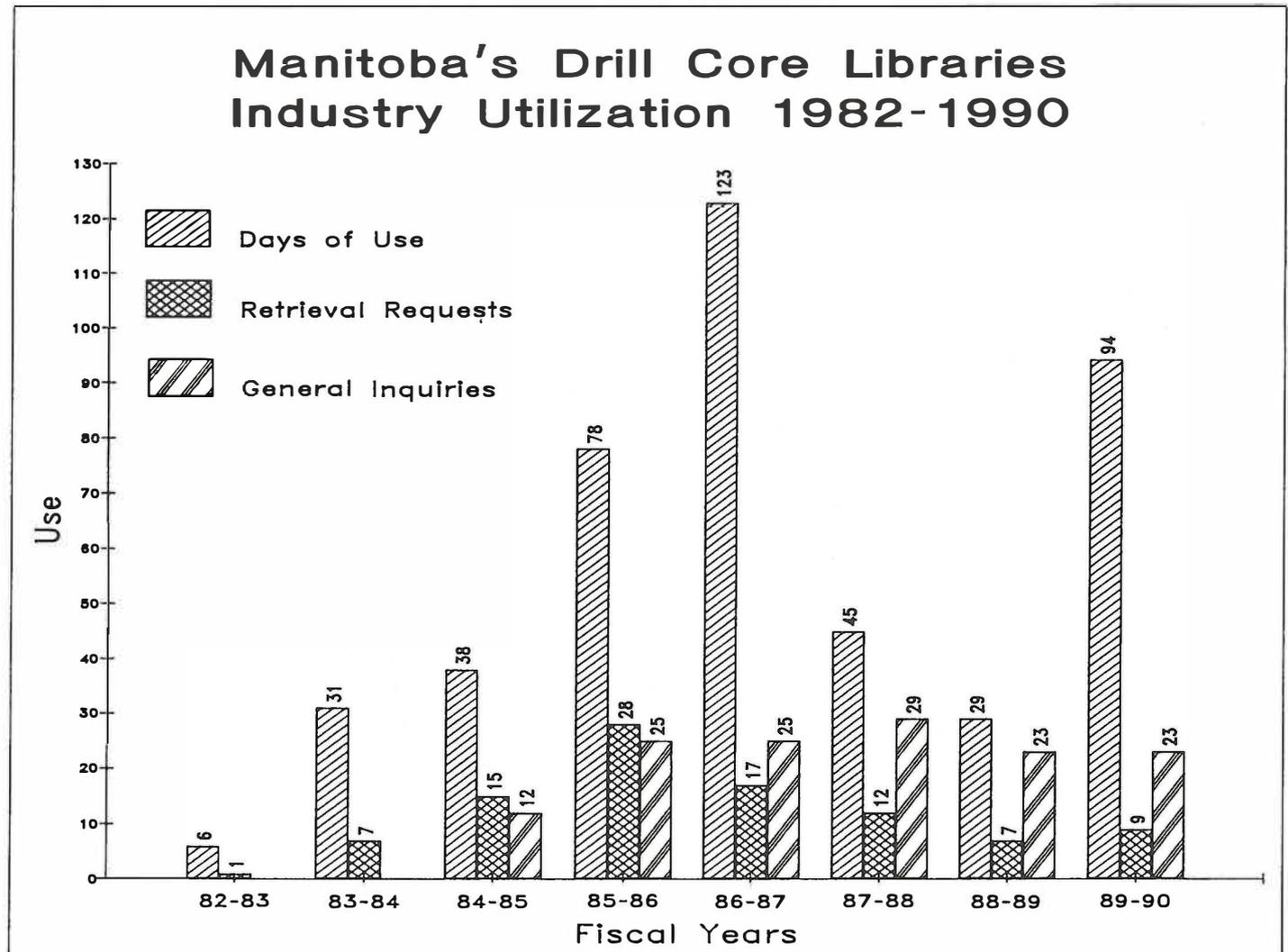

Figure GS-34-1:   Use of core library system.

PRESENT CORE HOLDINGS IN CORE LIBRARIES (Fig. GS-34-2)
The four libraries currently hold 189 474 metres of core.

Table GS-34-1
Drill Core Libraries Holdings

Library Location	Present Inventory	% Capacity Utilized
Lynn Lake	49 628 m	64
Thompson	32 683 m	55
The Pas	76 215 m	46
Winnipeg	30 948 m	94

reversed in 1989-90 when usage was three times higher than in the previous fiscal year. This renewed interest may be in part due to the 1989 release of the open file listing of holdings within Manitoba's drill core libraries.

1990 PROGRAM
Core inventory in The Pas library increased by 29 holes totalling 2915 metres. In Lynn Lake, 45 holes totalling 4250 metres were added to the inventory holdings. Thompson library inventory increased by 3 holes totalling 1131 metres. Building maintenance was carried out at all three northern core libraries. At the Winnipeg library, 27 new drill holes totalling 1585 metres were added to the inventory. As of September 1, 1990, the provincial core storage system had increased in 1990 by 104 holes totalling 9881 metres of core.

HOW TO USE MANITOBA'S CORE LIBRARIES
The four core libraries have well lit, heated inspection rooms, with benches and a core splitter. A rock saw for cutting core is available for use at The Pas library.

Department core libraries are not permanently manned, therefore enquiries and permission for access must be made to:

D. Prouse, Resident Geologist
Geological Services
Manitoba Energy and Mines
Provincial Building, Third and Ross Avenue
The Pas, Manitoba R9A 1M4
Phone: (204) 623-6411 ext. 251

OR

B. Esposito, Assessment Geologist
Geological Services
Manitoba Energy and Mines
555-330 Graham Avenue
Winnipeg, Manitoba R3C 4E3
Phone: (204) 945-6535

Permission to access the Lynn Lake or Thompson libraries, for viewing only the non-confidential core, must be granted by Mr. Prouse or Mr. Esposito who will make appropriate arrangements with local Government representatives on behalf of the user.

The representatives are:

Lynn Lake: Conservation Officer
Manitoba Department of Natural Resources
675 Halstead Avenue
Lynn Lake, Manitoba R0B 0W0
Phone: (204) 356-2413

Thompson: H. Schumacker or W. Comaskey
Manitoba Department of Labour
Workplace Safety and Support Division
Mines Inspection Branch
Provincial Building, 59 Elizabeth Drive
Thompson, Manitoba R8N 1X4
Phone: (204) 677-6819

In special cases where a user requires assistance in locating specific holdings, the Resident Geologist in The Pas will travel to Lynn Lake or Thompson to assist the user.

The master file of drill hole logs, collar locations and assays for non-confidential drill core holdings in the northern libraries is available for inspection at the Mines Branch office in The Pas. Information pertaining to non-confidential drill core stored in the Winnipeg library can be viewed at the Geological Services Branch office in Winnipeg.

Viewing, Storage and Sampling Policy
Access to confidential drill core is allowed only with written permission from the company that holds the respective property. This written permission must be presented to the Resident Geologist in The Pas, or the Assessment Geologist in Winnipeg, prior to inspection.

Core boxes placed in a library will be managed by drill core personnel. Library users will not be permitted to remove core from the library premises. Users wishing to examine drill core must be prepared to physically handle the core boxes and return them to the racks. Permission is required to sample core contained in the libraries.

Assay results and pulps from these samples must be forwarded to the Resident Geologist or Assessment Geologist if so requested. Quartering of previously sampled core will not be permitted.

ACKNOWLEDGEMENTS
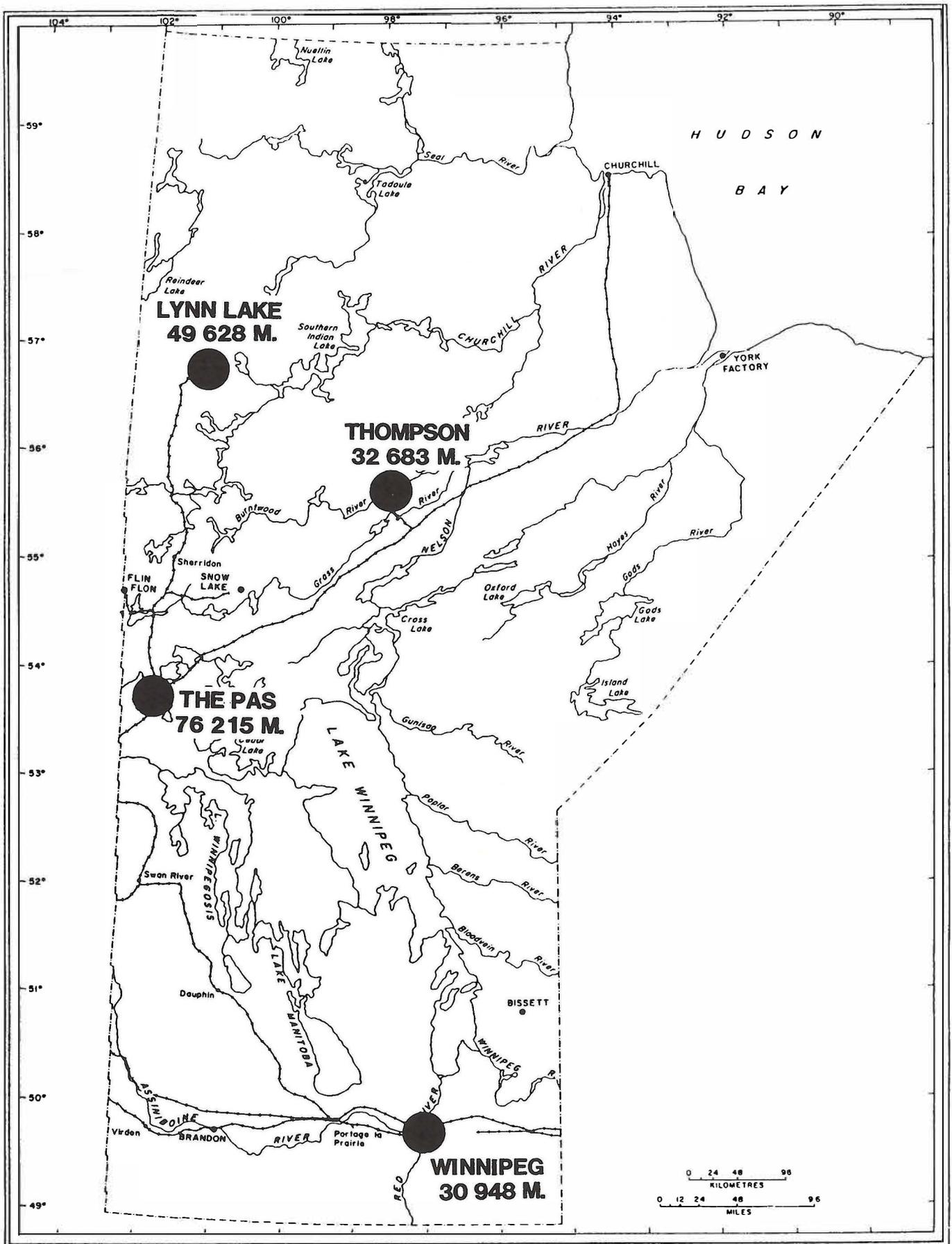
Figure GS-34-2: Manitoba core library locations and present holdings.

GS-35 MANITOBA MINERAL INVENTORY

by P. Athayde

From mid-April to July 1990, 45 mineral inventory cards describing mineral deposits/occurrences in the Island Lake greenstone belt were updated and 11 additional cards for this area were compiled. Updating of mineral cards describing base metal occurrences of the Flin Flon-Snow Lake and Lynn Lake greenstone belts is continuing.

Between September 1989 and August 1990, more than 135 clients used the Mineral Inventory and Corporation Files.

GSC-1 THE RELATIONSHIP OF DYKES TO HYDROTHERMAL ALTERATION IN THE EDWARDS LAKE FORMATION, SNOW LAKE, MANITOBA (NTS 63K/16)

by A.G. Galley[1] and J.S. Scoates[2]

INTRODUCTION

During the 1990 field season 1:500 scale mapping was conducted by James Scoates over an exposure of hydrothermally altered mafic volcaniclastic rocks belonging to the Edwards Lake formation. The study area is located 1500 m southeast of the Chisel Lake open pit. The purpose of this detailed mapping project was to further define the relationship between hydrothermal alteration, host lithology and synvolcanic dykes. The study area was chosen because of continuous, along-strike exposure of both the moderately to intensely altered Edwards Lake formation and contained dykes for over 400 m along strike.

Preliminary results of the study are:

1. silicification is more pervasive within breccia layers than in thin-bedded wacke layers; actinolite-garnet alteration is best developed in the latter;
2. silicification is present in several forms, one of which is spatially related to dyke margins;
3. fracture-controlled chlorite-garnet-magnetite-(sulphide) alteration is most intense in association with dacite dykes;
4. dacite dykes, the most felsic of three dyke lithologies present, show the greatest degree of silicification and Fe-Mg alteration;

[1]Mineral Resources Division, Geological Survey of Canada Ottawa, Ontario
[2]University of Wyoming, Laramie, Wyoming

5. dykes are synvolcanic, with crosscutting relationships that indicate synchronous igneous activity from several different magma sources; and
6. dykes clearly focussed the hydrothermal activity responsible for the creation of the volcanogenic massive sulphide deposits.

GEOLOGICAL SETTING

The study area covers part of the hydrothermally altered Edwards Lake formation. This mafic volcaniclastic formation is part of the footwall stratigraphy to the Chisel-Lost-Ghost volcanogenic massive sulphide horizon that includes over 2000 m of volcanic stratigraphy above the synvolcanic Sneath Lake Pluton (Bailes, 1988). Skirrow (1987) previously defined the stratigraphy within this formation and was the first to indicate the presence of a semiconformable zone of silicification. The regional setting of the Edwards Lake formation and its contained zone of alteration is described by Bailes and Galley (1989) and Galley et al., (1990).

In the detailed 1:500 scale map area (Fig. GSC-1-1) Edwards Lake formation consists of a 130 m wide sequence of layered mafic wacke and overlying heterolithologic mafic breccia. Sedimentary layering strikes

INTRUSIVE ROCKS	
Dacite	
Basalt	
Diorite	
Gabbro/pyroxenite	

Mafic boulder breccia

Mafic cobble breccia

Mafic cobble/boulder breccia

Mafic pebble/cobble breccia

Intercalated mafic wacke/pebble breccia

Figure GSC-1-1: Geology of a part of the Edwards Lake formation and associated dykes from 1:500 scale mapping.

northwest and dips and tops steeply to the northeast. The mafic wacke consists of well-layered, coarse- to fine-grained rock, with AB bouma cycles indicating emplacement by subaqueous density flows. Coarser layers commonly contain 1 to 4 mm plagioclase phenoclasts and mafic volcanic fragments, grading upwards into finer grained, finely laminated, aphyric wacke and mudstone. Graded bedding and flame structures indicate that the sequence tops to the northeast. The top of the mafic wacke sequence contains thin interlayers of mafic pebble breccia.

The mafic wacke is overlain by up to 140 m of mafic heterolithologic breccia that contains 15 to 50 m wide beds of matrix supported pebble- to cobble-breccia interlayered with 10 to 20 m wide layers and lenses of matrix- to clast-supported cobble and boulder breccia (Fig. GSC-1-2a). Clasts are subangular to rounded, and composed of plagioclase and plagioclase-pyroxene porphyritic basalt (80%), aphyric basalt (15%) and possible aphyric felsic volcanic clasts (5%). Within the clast supported boulder breccia, fragments average 40 cm in diameter, and can exceed 100 cm. Many of the aphyric basalt fragments are amygdaloidal pillow fragments.

Breccia beds display no internal structure, and no wacke interlayers. This, combined with the coarse, clast supported nature of the breccia beds, suggests a proximal source. The upward coarsening of the sequence from turbiditic wacke to breccia suggests uplift of the source area accompanied sedimentation. Primary sedimentary features such as flame structures, and general thinning of the unit to the east indicate a westerly source for the Edwards Lake formation.

INTRUSIVE ROCKS

The study outcrop of Edwards Lake formation is flanked to the southwest by a differentiated gabbro/pyroxenite sill and to the northeast by a sill of plagioclase porphyritic diorite; both are believed to be synvolcanic. Approximately 20 per cent of the volume of the outcrop between these two sills consists of semiconformable to disconformable dykes (Fig. GSC-1-1).

Dacite dykes are most abundant, and are typified by a very fine grained, siliceous matrix containing 1 to 2 mm long plagioclase phenocrysts. Weathered surfaces vary from light grey to white, depending on the degree of alteration. Dacite dykes are 1.5 to 5 m wide, commonly with flow-banded margins (Fig. GSC-1- 2b). Basalt dykes are next in abundance. They are fine grained and aphyric, with dark green to dark grey weathered surfaces. Basalt dykes range from 50 cm to 1.5 m wide. The least abundant dykes are plagioclase porphyritic diorite. They have a dark grey weathered surface, fine grained texture, aphyric margins and densely plagioclase porphyritic cores (Fig. GSC-1-3a). Diorite dykes are similar in composition to the sill located at the northeast end of the study outcrop.

Dacite dykes form a rectilinear pattern, with the majority striking semiconformably with the sedimentary layering (Fig. GSC-1- 1). Basalt dykes also form a crudely rectilinear pattern offset from the dacite dykes, striking at shallow and high angles to stratigraphy. The diorite forms a series of irregular, elongate bodies clustered near the centre of the outcrop (Fig. GSC-1-1).

Figure GSC-1-2a: Contact between cobble and pebble mafic breccia. Note silicified rims about some of the larger fragments. Clipboard for scale.

Figure GSC-1-2b: Altered, flow-banded margin to dacite dyke on right half of photo. Lens cap for scale.
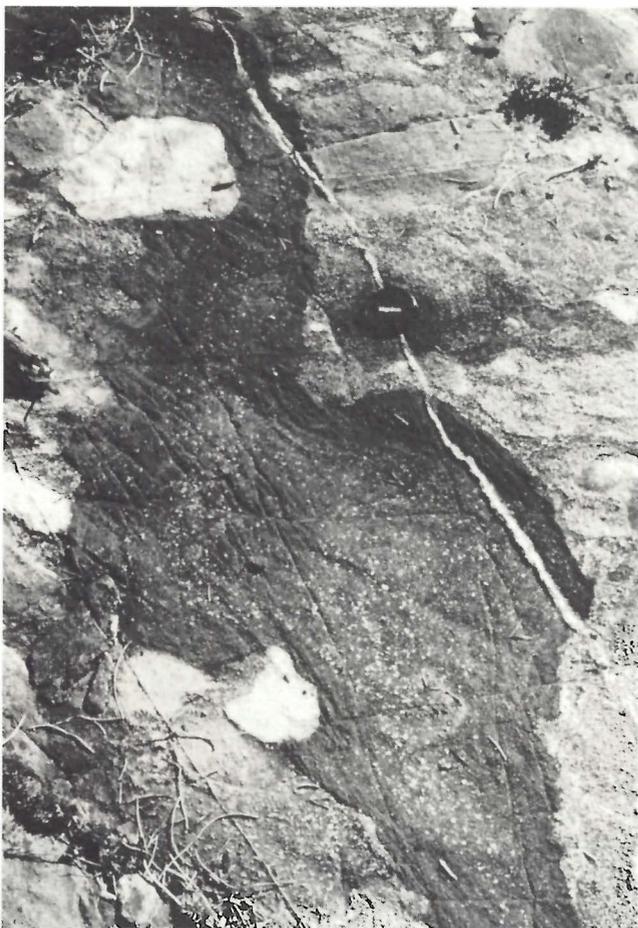
Figure GSC-1-3a: Irregularly-shaped, plagiocalse porphyritic diorite dyke surrounding silicified fragments in mafic cobble breccia. Lens cap for scale.

Figure GSC-1-3b: Ameboid, pillow-like margins to basalt dykes. Note chilled and altered rim. Camera lens for scale.

Dacite dykes are continuous across the outcrop, and have sharply defined, linear contacts, whereas the mafic dykes commonly have irregular widths (Fig. GSC-1-3a). Some mafic dykes have ameboid, pillow-like margins, with dyke material invading interstices between large volcanic clasts (Fig. GSC-1-3a, GSC-1-3b). Locally these dykes pinch out, only to reappear a few metres along strike. The irregular shape of mafic dykes indicate emplacement within unconsolidated, fluid-rich volcaniclastic sediments.

Crosscutting relationships between the different dyke types indicate that they intruded one another during emplacement (Fig. GSC-1-1, GSC-1-3c). In some cases, mafic dykes have intruded along the margins or cores of the dacite dykes. These relationships suggest contemporaneous emplacement of the dykes.

ALTERATION

An estimated 30 to 40 per cent of the mafic volcaniclastic rocks of the Edwards Lake formation have been affected by alteration involving silicification and iron-magnesium metasomatism. In the study area all of the volcaniclastic rocks have been moderately to strongly altered (Fig. GSC-1-4).

Silicification is volumetrically the most important type of alteration, and is present in a number of forms. One is the selective alteration of clast margins and, in some instances, the entire fragment. This type of silicification of the mafic fragments is easily recognized because of the contrast between dark, less altered cores and light coloured, quartz-rich silicified margins (Fig. GSC-1-5a). Pervasively altered breccia fragments display a wide variety of compositional zoning. Typically, fragments have an epidozite-rich core surrounded by a silicified rim, but some fragments display a more complex zoning that can include actinolite-rich

cores, actinolite-garnet rich margins, or both (Fig. GSC-1-5b). Although not understood, these zonation patterns indicate a complex interchange of Ca, Mg and Fe between hydrothermal fluids and the host sediment.

A second type of silicification of the sediments is referred to as mottled, and consists of millimetre- to centimetre-size oval to irregular domains composed of fine grained quartz-plagioclase- (epidote) (Fig. GSC-1-5c). Typically, these oval domains are distributed randomly throughout both matrix and fragments, indicating that this type of silicification post-dated deposition of the volcaniclastic rocks. Other, less prominent types of silicification include selective replacement of interfragment matrix, silicification of wallrock adjacent to fractures, and adjacent to dykes contacts.

Dykes have been altered to varying degrees along with the sedimentary rocks. Dacite dykes are pervasively silicified. This pervasive silicification has affected the sedimentary rocks in contact with the dykes for tens of centimetres away from the contact such that the two originally different lithologies are so similar that they can be differentiated solely on the presence of flow banding along dyke margins and on the presence of abundant iron-magnesium chlorite-garnet-magnetite-rich veins within the dykes. Orbicular quartz-epidote growths, so common in the sedimentary rocks, are also observed in moderately silicified segments of the dacite dykes.

Mafic dykes are less affected by silicification. They most commonly display centimetres-wide, pervasively silicified margins and fracture-controlled silicification in their cores (Fig. GSC-1- 3c, GSC-1-6a). Some of these fractures parallel the margins of the dyke(s) and are most likely a product of thermal contraction during cooling; others are quite irregular. Silicification has also affected host sediments, but to a lesser degree than that associated with the dacite dykes (Fig. GSC-1-6b).

Figure GSC-1-3c: Silicified basalt dyke crossing Fe-Mg altered dacite dyke (lower left) and mafic pebble breccia (upper left). Note fracture- controlled silification in the basalt dyke. Scale card for scale.

SILICIFICATION

quartz ±albite ±actinolite ±garnet ±magnetite

- pervasive (strong)
- mottled to pervasive (strong)
- mottled to pervasive (moderate)

FE–MG (±CA) ALTERATION

garnet + chlorite ± magnetite ± actinolite (±epidote)

- pervasive (strong)
- pervasive (weak to moderate)

× Staurolite
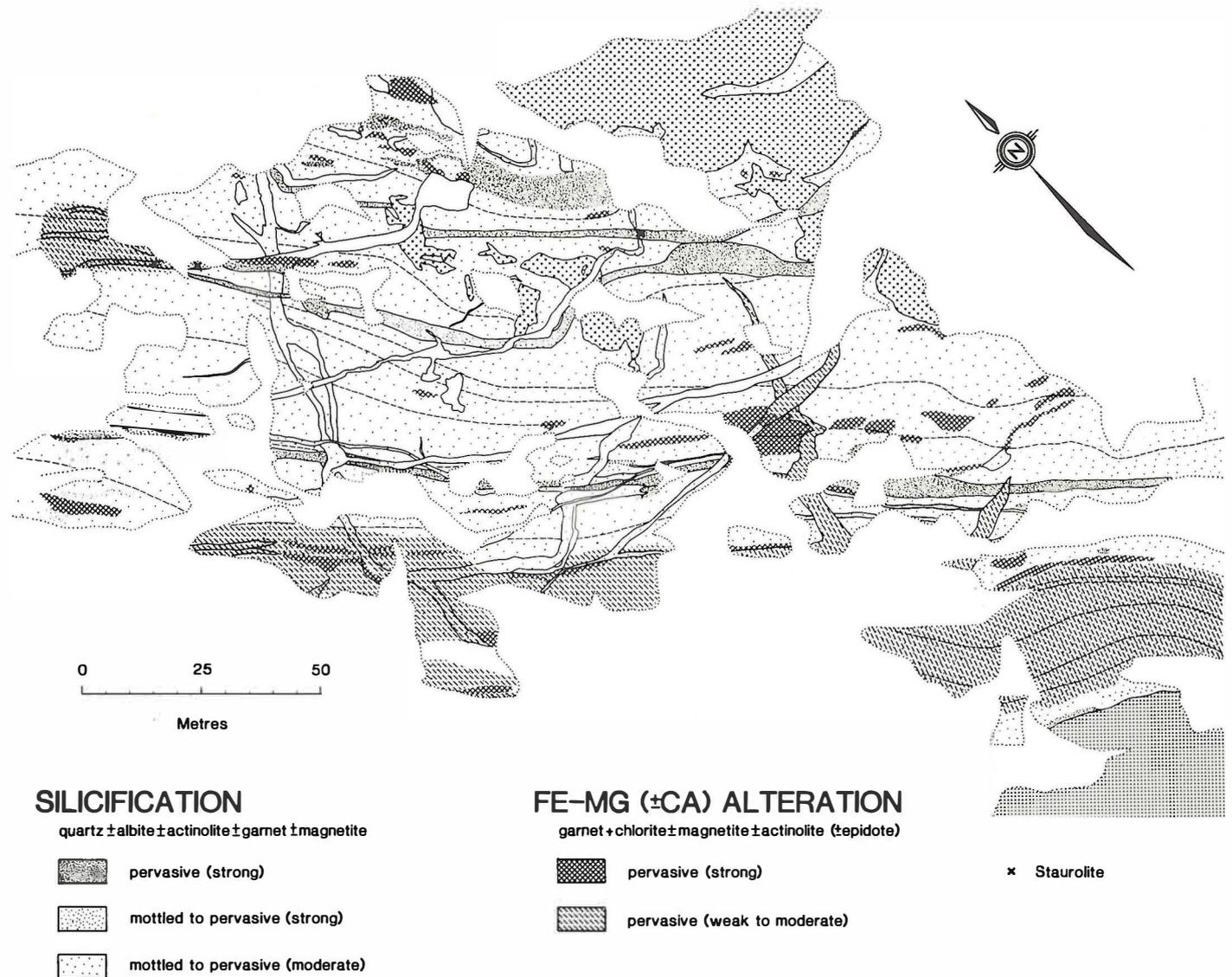
Figure GSC-1-4: Distribution of alteration in the the study area.
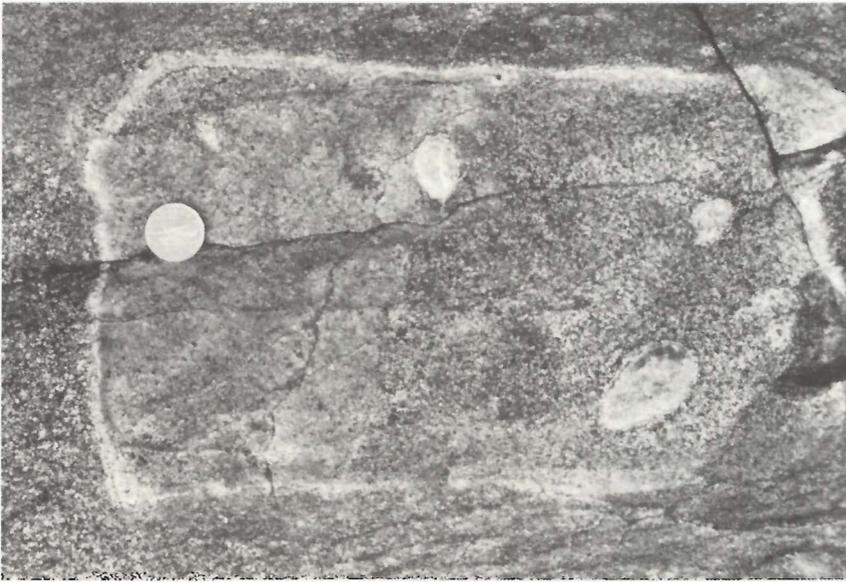
Figure GSC-1-5a: Strongly silicified rims to angular fragment. Note presence of both mottled and pervasive silicification in the core of the fragment, and the presence of epidote-rich domains (large orbicules). Loony for scale.
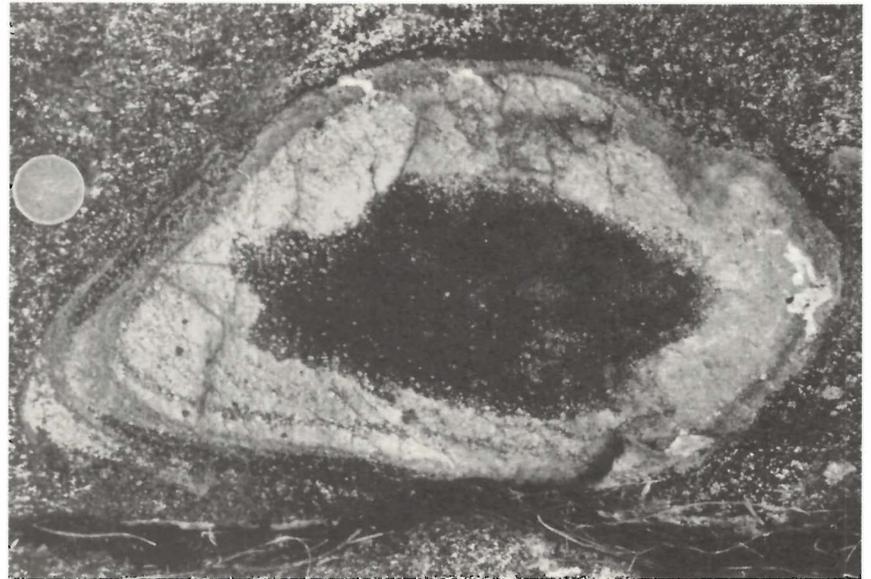
Figure GSC-1-5b: Compositional zoning within a strongly altered fragment, with an actinolite-rich core surrounded by epidote and quartz-plagioclase-rich rims.

Figure GSC-1-5c: Mottled silicification within a mafic pebble wacke. Loonie for scale.

Figure GSC-1-6a: *Silicification within a basalt dyke largely controlled by thermal contraction fractures. Lense cap for scale.*
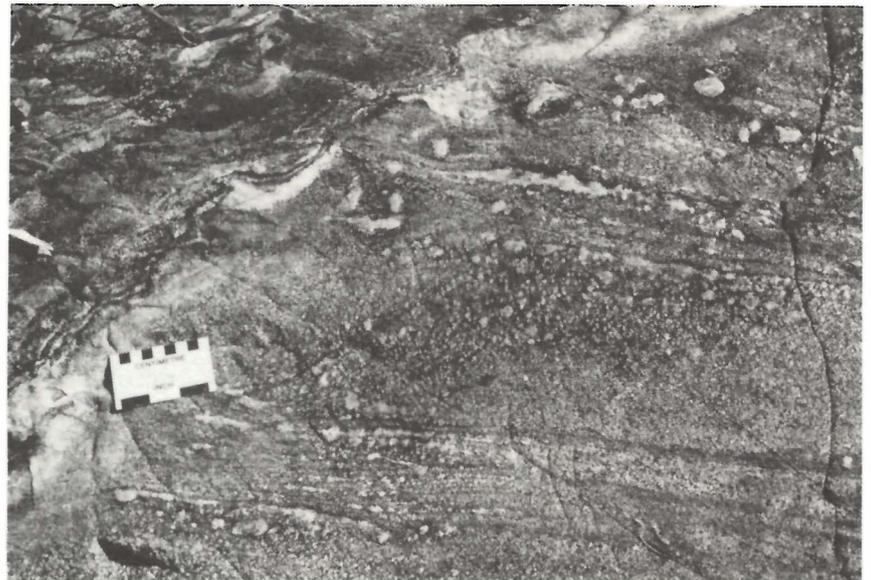
Figure GSC-1-6b: *Pervasive and bedding-controlled silicification of mafic wacke along margins of a diorite dyke.*

Iron-magnesium rich alteration is typified by pervasive actinolite-garnet alteration of the volcaniclastic matrix and clasts and by conformable to disconformable chlorite-garnet- magnetite-(sulphide) veins (Fig. GSC-1-6c). Within the coarser volcaniclastic rocks, iron-magnesium alteration is concentrated along dyke margins, and within dykes, particularly the dacite dykes (Fig. GSC-1-6d). Pervasive iron-magnesium alteration of the volcaniclastic rocks is most prominent near the junction of intersecting dacite dykes and within the layered wacke-pebble breccia sequence. In most cases the iron-magnesium alteration clearly overprints or crosscuts the silicification.

The relationship between dykes and alteration is complex. For example, near the northwest corner of the study area one can observe a strongly silicified dacite dyke crosses a basalt dyke that appears to be relatively unaltered. In another location a basalt dyke has been injected between volcanic clasts that appear to have been previously silicified.

DISCUSSION

Detailed mapping has demonstrated that the various types of dykes present within the Edwards Lake formation were emplaced into unconsolidated debris flows. The inconsistent crosscutting relationships between the different dyke lithologies suggest simultaneous injection of several magma types during volcanism. Shallow emplacement of the dykes is suggested by their semiconformable nature (ie. hydrostatic pressure exceeded lithostatic load), and by the fact that the dacite dykes feed the overlying Powderhouse dacite formation (Bailes, 1987), whose lower contact is stratigraphically 600 m above the study area.

The shallow emplacement of these dykes and their close relationship to hydrothermal alteration affecting the Edwards Lake formation has implications as to the source of the fluids involved in the alteration process. The pervasive silicification of the dacite dykes and the spatial association of the iron-magnesium alteration with these bodies suggests a close temporal relationship. The fact that alteration is largely restricted to the originally highly permeable, water-rich Edwards Lake volcaniclastic formation suggests that inter-stratal seawater played a significant role in alteration process.

Seawater trapped within the volcaniclastic sediments would equilibrate with amorphous silica glass within the volcanic clasts at elevated temperatures expected within a cooling volcanic pile (Gibson *et al.*, 1983). The regional heat gradient would be further elevated and maintained by the emplacement and cooling of the synvolcanic Richard Lake and Sneath Lake plutons. An increase in the temperature of these fluids by the injection of dykes into the aquifer is interpreted to result in the

Figure GSC-1-6c: Chlorite-garnet-magnetite vein crossing mafic cobble breccia. Lense cap in lower right corner for scale.

Figure GSC-1-6d: Small dacite dyke with silicified margins and pervasively Fe-Mg altered core.

oversaturation of silica and a decrease in silica solubility. Kennedy (1950) calculated that this alteration process would take place below 700 bars at temperatures above 350°C.

Bischoff et al. (1981) concluded from experiments on the interaction of seawater and brine with greywacke that elevated brine-rock reaction rates were initiated at temperatures exceeding 350°C; heated seawater-rock reactions at the same temperature took place at much lower rates than the brines. This would suggest that if interstratal seawater within the Edwards Lake formation was responsible for silicification of these rocks, they must have had an opportunity to evolve within a closed aquifer. This evolution would require prolonged low water-rock ratios at elevated temperatures.

The composition of the dykes is of importance with respect to the degree of their involvement in the hydrothermal process. Dacite dykes are pervasively silicified and affected by vein-controlled iron-magnesium alteration, while only the margins of the mafic dykes are strongly silicified. One possibility is that there may be a relation between the cooling rates of the dykes and their ability to react as an open chemical system with the surrounding sediments. The slower cooling rates of the dacite dykes due to their relatively initial lower liquid temperatures may have resulted in sustained, high thermal gradients. This would result in longer reaction times between interstratal fluid and the cooling rocks. Another possibility is that the higher temperatures of the intruding basalt magma would super-critically heat interstratal fluids, resulting in driving fluids away from the margins of the mafic dykes. The lower temperature dacite magma would not cause as intense a dehydration of the surrounding rocks, allowing for dyke-fluid interaction during cooling.

CONCLUSION

The emplacement of dykes into highly permeable, water-rich volcaniclastic rocks may have resulted in the focussing of an alteration process already initiated in this formation by the earlier emplacement of the Richard Lake and Sneath Lake plutons. The local increase in temperature of the sediments intruded by the dykes resulted in intense silicification of sediments and the cooling dykes. This was accompanied by fracture-controlled Fe-Mg alteration.

The close spatial relationship of the semiconformable zone of silicification and disconformable Fe-Mg alteration zones with overlying massive sulphide deposits would suggest that they were all involved in the same hydrothermal process. The ability of dykes to focus the alteration process would suggest that synvolcanic dyke swarms are prime exploration targets in the search for volcanogenic massive sulphide deposits.

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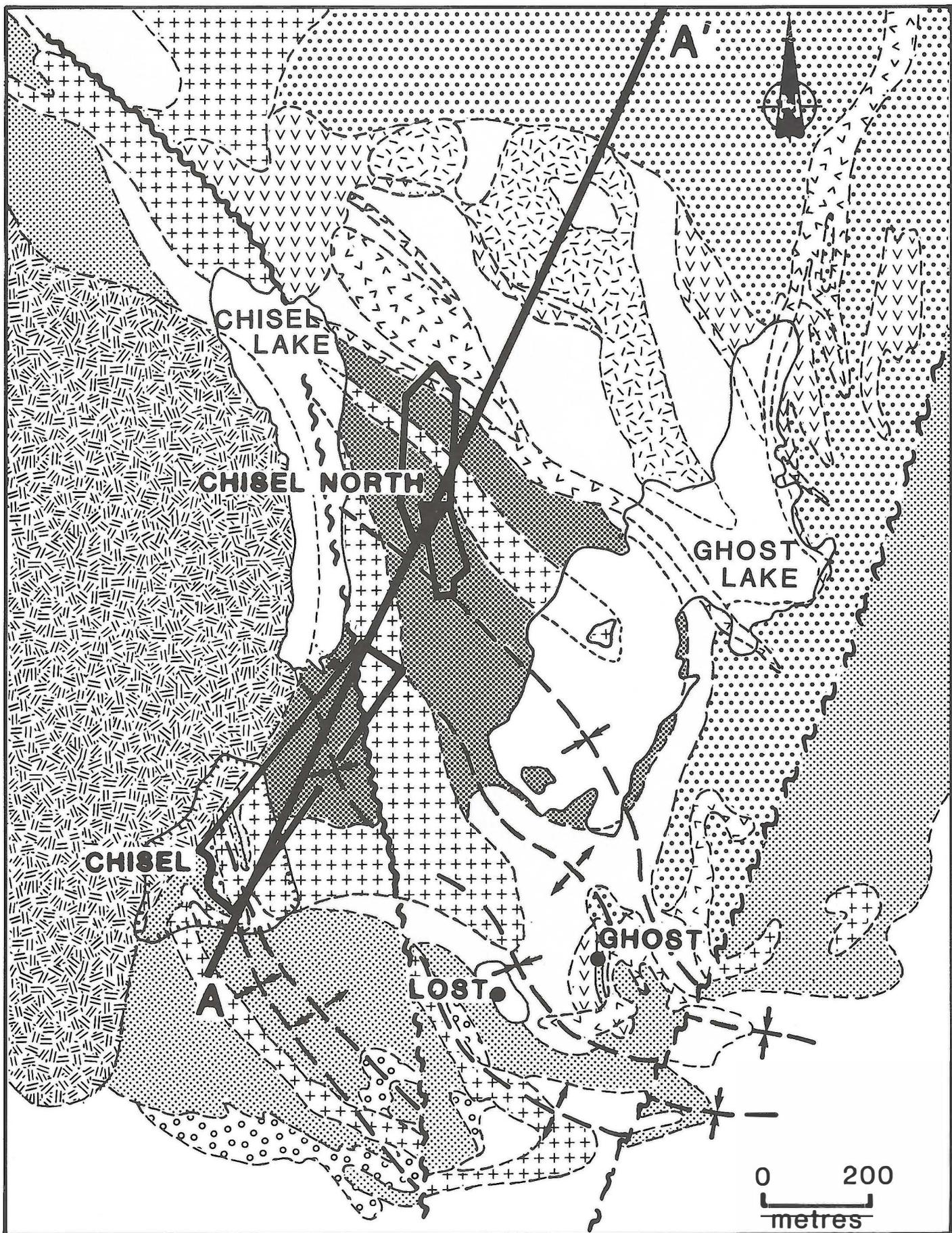
Figure GSC-2-1:   *Geology of the Chisel Lake Basin. Black lines outline the vertical projection of the orebodies. Legend for figure with Figure 2.*

GSC-2 GEOLOGY AND STRUCTURAL SETTING OF THE CHISEL NORTH DEPOSIT (NTS 63K/16)

by A.G. Galley[1] and G.H. Kitzler[2]

INTRODUCTION

In 1987 Hudson Bay Mining and Smelting Co. Ltd. intersected a new massive sulphide zone 5 km southeast of the town of Snow Lake and 300m northeast of the original Chisel Lake deposit. To date the Chisel North Zone contains in excess of 2.7 million tonnes of 9.0 per cent Zn, 0.17 per cent Cu, 0.4 per cent Pb, 0.4 g/t Au and 19 g/t Ag (diluted 15%). Tonnage and grade have been calculated from drill intersections 2000 to 2500 feet below surface. Through the EXTECH program (Exploration Science and Technology) the Geological Survey of Canada and the Manitoba Geological Services Branch have been working with the company to determine the structural setting of the new deposit, and to compare the alteration associated with the deposit to that of the original Chisel deposit. An understanding of both these factors may allow for a quicker resolution of the actual dimensions of the deposit, and possibly allow the company to 'navigate their drill holes' using facies changes in the synvolcanic, hydrothermal alteration.

GEOLOGICAL SETTING

The Chisel North deposit is hosted by a subaqueous sequence of Early Proterozoic Amisk Group volcanic strata. The Amisk Group rocks in the Snow Lake area have been mapped at 1:20 000 scale by Bailes (1989), with 1:5000 scale mapping in the immediate Chisel Lake area by Bailes and Galley (1989). In the Chisel Lake region, the Amisk Group comprises a mixed suite of volcanic strata with island arc tholeiite affinities (Bailes, 1988). The strata can be divided into four subdivisions, each initiated by basaltic volcanism. The lowermost division is composed of a thick sequence of aphyric to pyroxene porphyritic basalt and basaltic andesite (Welch Lake formation) overlain by a sequence of aphyric to coarsely quartz-phyric rhyolite volcaniclastic rocks and interlayered mafic wacke (Stroud Lake formation). The mafic wacke contains thin lenses and pods of massive sulphide, and is tentatively correlated with the Anderson-Stall-Rod massive sulphide horizon 5 km to the northeast. The second subdivision begins with the Snell Lake plagioclase porphyritic basalt, overlain by mafic wacke and heterolithic mafic breccia of the Edwards Lake formation. The third subdivision comprises a series of volcanic formations that are characterized by high LREE concentrations (Bailes, 1989); the Moore Lake aphyric to plagioclase porphyritic basalt, the Powderhouse dacite and the Ghost Lake rhyolite. The zinc-rich massive sulphide deposits composing the Chisel-Lost-Ghost horizon directly overlie the Powderhouse dacite, and are contemporaneous with the extrusion of the Ghost Lake rhyolite.

The fourth subdivision forms the hangingwall strata to the Chisel-Lost-Ghost volcanogenic massive sulphide horizon, and includes aphyric basalt, mafic tuff and associated heterolithologic breccia, aphyric rhyolite and plagioclase-phyric, pumice-rich mafic volcaniclastic rocks. These strata define a structural feature coined the Chisel Basin by the geology staff of Hudson Bay Exploration and Development Company Limited (Fig. GSC-2- 1).

The volcano-sedimentary sequence is intruded by two large, multiphase synvolcanic intrusions that have an average tonalitic composition. These intrusions have been dated at 1886 + 17/-9 Ma (Sneath Lake Pluton, Bailes et al., 1990) and 1889 + 8/-6 Ma (Richard Lake Pluton, Bailes et al., 1990). Evidence for their close temporal relationship with extruded volcanic rocks includes the fact that the intrusions have been affected by hydrothermal alteration that is restricted to the first three subdivisions described, and the composition and REE profile of the Richard Lake Pluton is identical to a swarm of dacite dykes that cross-

cut the footwall strata to the massive sulphide horizon, and are apparently feeders to the Powderhouse dacite.

The Chisel stratigraphic section is also crosscut by a series of mafic dykes and sills, most of which appear to be synvolcanic. A number of these bodies crosscut the massive sulphide horizon and extend into the hangingwall volcanic sequence. Felsic synvolcanic sills and dykes are restricted to the massive sulphide footwall stratigraphy. The only well documented synkinematic intrusion is the gabbro/pyroxenite Chisel Lake Pluton, which truncates the Chisel Lake massive sulphide deposit.

GEOLOGY OF THE NORTH CHISEL DEPOSIT

The stratigraphy hosting the North Chisel deposit is defined through correlation of lithologies examined by geologist of Hudson Bay Exploration and Development from over 60 diamond drill holes. The principal author examined and sampled in detail drill core from 12 holes. Six of these holes form a longitudinal section along the length of the deposit (Fig. GSC-2-2), and six form a section at right angles to the deposit.

Footwall Stratigraphy

The footwall strata to the deposit are strongly altered. In places, intense alteration masks the original texture of the rocks for over 225 m below the deposit. Where recognizeable, the footwall is composed of Powderhouse dacite formation plagioclase- phyric dacite. In several locations directly in contact with the massive sulphide zone there is a 2 to 5m wide zone of banded, siliceous rock similar to that observed along sections of the footwall contact of the Chisel Lake deposit. This unit could have originally been a cherty sedimentary rock. In several drill holes there is also a coarse, felsite breccia present in the immediate footwall to the sulphide zone. This may represent either a primary volcanic breccia or the in situ brecciation of the felsic footwall during hydrothermal vein formation.

Massive Sulphide Zone
STRATIFORM SULPHIDE ZONES

The stratiform massive sulphide component of the deposit consists of two, west-northwest-striking panels that are stacked and laterally offset from one another (Fig. GSC-2-1, GSC-2-2). The northwest corner of the upper panel (Green Zone) overlaps the southeast corner of the lower (Red Zone). The zones are separated by 60 m of strongly altered rock containing three small stratiform lenses of massive sulphide.

The south end of the Red Zone is separated by 300 m from the down-plunge limit of the Chisel Lake deposit (Fig. GSC-2-1, GSC-2- 2). It has been defined as a 350 m by 100 m irregular, elongate polygon. The Green Zone has a defined width of 150 m and has been traced for 500 m down plunge, where it is still open at depth. The two zones plunge and dip 20° to the north-northeast.

The stratiform sulphide zones are 4 to 20 m thick, averaging 6 m. They are composed of lenses of semi-massive to massive pyrite-sphalerite and sphalerite-pyrite that contain varying amounts of quartz, sericite, carbonate, biotite, chlorite, tremolite, pyrrhotite, chalcopyrite, galena and arsenopyrite. The sulphide body varies from massive sphalerite or pyrite-sphalerite with 30 to 50 cm of banded sulphide along the hangingwall contact to strongly foliated sericite-quartz-sulphide schist with millimetre- thick bands of pyrite and sphalerite, with close-packed, subophitic grains of pyrite and sphalerite in a white carbonate matrix.

Chalcopyrite and pyrrhotite are usually present in the stratiform lenses as coarse, anhedral blebs to 5 mm, with chlorite and biotite along the hangingwall contact of the pyrite-sphalerite lenses, or as crosscutting veins up to 10 cm wide. Pyrrhotite is also a minor constituent of the massive ores. Galena is most common as coarse crystals in veins cross-

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cutting the chalcopyrite-pyrrhotite zones, and as 1 to 2 mm scattered crystals in the semi-massive ore. Arsenopyrite is rarely observed, and usually occurs with tremolite, carbonate and galena.

Minor concentrations of garnet, kyanite, andalusite, cordierite and gahnite are present throughout the stratiform sulphide zones. The garnet and cordierite are usually associated with chlorite-rich zones, whereas gahnite is commonly present in veins with chlorite, pyrrhotite, biotite and chalcopyrite.

DISCONFORMABLE SULPHIDE ZONES

An extensive zone of footwall alteration stratigraphically below the stratiform sulphide zones contains varying concentrations of quartz-pyrite-sphalerite and chalcopyrite-pyrrhotite-chlorite-biotite veins. These veins are up to 10 cm wide; their abundance does not appear to bear any relation to the width or composition of the overlying stratiform sulphide lense. Typically, quartz-sphalerite-pyrite veins occur within 10 to 20 m of the stratiform sulphides, whereas chalcopyrite-pyrrhotite-chlorite-biotite veins have been observed up to 75 m below the sulphide horizon and up to 200 m along strike from, and below the deposit (Fig. GSC-2-4).

METAL ZONATION

Assay values from samples through the stratiform and disconformable (stringer) sulphide zones show a base-metal zonation typical of massive sulphide deposits (Large, 1977; Lydon, 1984), with the upper two thirds of the stratiform lenses having a very high zinc/copper ratio (100:1), and the base of the lenses averaging 20:1. Upper parts of the stringer zone that were included in reserve calculations average 1:2 zinc to copper. High lead values are typically, but not always, linked with high zinc concentrations. High silver and gold concentrations are invariably linked with high lead contents, although the reverse is not always true.

In the Chisel Lake deposit galena is commonly concentrated in F_1 axial planar veins that crosscut the massive sulphide and the immediate host rocks (Galley and Bailes, 1989). This mobility during deformation also appears to have affected precious metal distribution; this should be considered when attempting to relate present metal distribution to original metal zonation within the deposit.

Hangingwall Stratigraphy

FELSIC SEDIMENTARY UNIT

The immediate hangingwall to the deposit commonly consists of 10 to 20 m of felsic breccia and well foliated, siliceous rock with thin layers of biotite-pyrrhotite, and chlorite-garnet-magnetite. Thin, pyrrhotite-rich, argillaceous layers are also present in this unit. This dominantly felsic unit is strongly iron-magnesium altered, particularly in the presence of a 2 to 5m wide fine-grained, aphyric mafic sill that intrudes the unit near its contact with the massive sulphide. Where the sill is absent, silicification is the dominant alteration type. The hangingwall felsic breccia is similar in texture to that observed in the direct hangingwall to the Ghost Zn-Pb deposit along the southeast margin of the Chisel Basin.

LOWER MAFIC VOLCANICLASTIC UNIT

The felsic sedimentary unit is overlain by approximately 200 m of mafic volcaniclastic rocks with thin interlayers of mafic flows (Fig. GSC-2-2). Above the Red Zone this unit consists of well layered aphyric to feldspar-phyric mafic wacke similar to that observed on surface along the south and southeast margin of the Chisel Basin.

Near the south edge of the Green Zone the mafic wackes are overlain by a wedge of mafic breccia that increase in thickness to the north to 200 m (Fig. GSC-2-2). The fragment population of the breccia is heterolithologic, with the lower two thirds of the unit dominated by mafic aphyric amygdaloidal and plagioclase porphyritic basalt clasts with minor felsic fragments. At the north end of the Green Zone the mafic heterolithic breccia is overlain by a 25 m thick mafic breccia rich in scoria. Fragment distribution changes within the upper third of the mafic heterolithologic breccia, with an average of 40 per cent felsic clasts, 15 per cent plagioclase porphyritic basalt and 5 per cent amygdaloidal aphyric basalt in an amphibole-quartz-biotite-garnet rich matrix.

The mafic breccias are interlayered with aphyric basalt flows up to 30 m thick. These flows are highly amygdaloidal, with quartz-filled gas cavities up to 20 mm. In places the unit is overlain by a 5 to 35 m thick aphyric, amygdaloidal basalt flow, which is locally strongly silicified.

SULPHIDIC MUDSTONE UNIT

The Lower Mafic Volcaniclastic Unit is overlain by a discontinous, up to 15 m thick, well foliated, black argillaceous rock containing up to 20 per cent pyrrhotite as 5 to 10 mm bands of massive sulphide. Towards the top, this unit becomes increasingly siliceous. In places, is gradational into overlying felsic flows and flow breccia.

FELSIC FLOW UNIT

An up to 130 m thick wedge of felsic flows and flow breccia overlies the Lower Mafic Volcaniclastic Unit; it pinches out to the south and thickens to the north and east, apparently joining with the Ghost Lake Rhyolite (Fig. GSC-2-2). The felsic volcanic rock is light grey and very
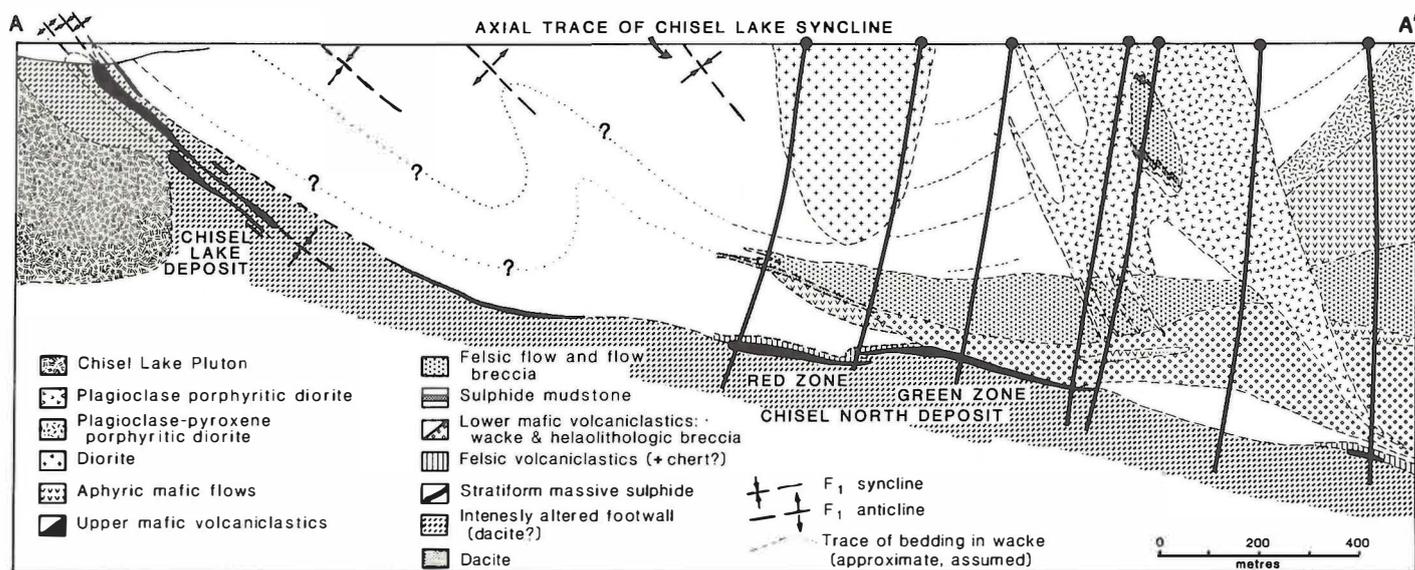

Figure GSC-2-2: Cross section looking northwest across the Chisel Basin. Drill holes shown were sampled and logged in detail for this study. Location of cross-section on Figure 1.

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fine grained, with local concentrations up to 5 per cent of 1 to 2 mm plagioclase phenocrysts. One to five metre thick units of massive rhyolite are interlayered with monolithic, felsic breccia and microbreccia. The breccia matrix is variably altered to fine grained quartz-actinolite- biotite-garnet. The southern edge of the felsic unit is interlayered with aphyric to feldspar-phyric mafic wacke.

MAFIC FLOW UNIT

The northern limit of drilling has defined a 750 m thick unit of aphyric basalt flows that directly overlies the Felsic Flow Unit to the north (Fig. GSC-2-2). These flows are truncated by a large diorite intrusion to the south and are not present south of the intrusion. Flows vary from massive to pillowed, with 5 to 10 per cent quartz, quartz-garnet and quartz-carbonate filled amygdales up to 20 mm in diameter. Basalts are strongly bleached and silicified along their lower contact with the felsic rocks. Quartz-chlorite filled amygdales are common in the silicified basalts.

UPPER MAFIC VOLCANICLASTIC UNIT

Overlying the mafic flows are well-bedded, feldspar-phyric to aphyric, fine- to coarse-grained mafic volcaniclastic rocks that display a crude, upward zonation. The lower two thirds of the section contains 4 to 6 m thick layers of scoria-rich breccias and the upper third consists of coarse, feldspar- phyric tuff and lapilli tuff. Up-section the coarse breccia and lapilli tuff disappear, and are replaced by 1 to 2m thick, graded mafic wacke with feldspar phenocryst-rich bases and finely laminated, very fine-grained, aphyric tops.

INTRUSIVE ROCKS

There are a number of mafic intrusions observed in drill hole that correlate with aphyric, plagioclase, and plagioclase-pyroxene porphyritic diorite sills and dykes that crosscut the Chisel Basin stratigraphy (Fig. GSC-2-1, GSC-2-2). Above the Flesic Flow Unit is a large plagioclase porphyry diorite intrusion 500 m by 500 m in section. A number of smaller dykes from the intrusion crosscut the mafic wackes and the felsic flows. Within the intrusion is a large pendant, at least 220 m by 150 m composed of largely massive felsic flows and flow breccia, with sulphidic mudstone along both contacts, and thin aphyric basalt flow and mafic wacke below the footwall contact. This sequence is identical to that observed directly overlaying the Red Zone stratiform sulphide lense, suggesting that intrusion of the diorite rafted a section of the basin stratigraphy towards the surface.

The second most abundant intrusive rock is a fine- to medium-grained, aphyric diorite that is up to 250 m wide and is correlatable to surface with a diorite dyke that can be traced for several kilometres across the Chisel Basin stratigraphy. Also present in the northern-most drill hole is a plagioclase-pyroxene porphyritic diorite that is correlated to surface with a +500 m thick sill that can be traced across the northern flank of the Chisel Basin.

These three types of diorite display a spatially systematic change in the composition of the mafic intrusions within the basin, with the aphyric diorite restricted to the southern part of the basin, followed to the north by the plagioclase porphyritic and the plagioclase-pyroxene porphyritic diorite. These intrusive phases have been involved in the fold history of the region, and are believed to be synvolcanic.

Alteration
FOOTWALL ALTERATION

The massive sulphide deposit is typified by extensive hydrothermal alteration of the footwall units. Where recognizeable, the primary lithology is a plagioclase-phyric dacite. Directly below the stratiform sulphide lenses intense alteration has masked original lithologies for over 250 m. Footwall stratigraphy is intensely altered from 60 to 100 m below the mineralized horizon up to 600 m west of the deposit (Fig. GSC- 2-3).

The changes in thickness of the intense footwall alteration is contoured from drill log data (Fig. GSC-2-4). The alteration zone has a keel over 225m deep and 100 m wide that strikes parallel to, but to the east side of the Chisel North deposit. This keel extends to the southeast to join with the alteration associated with the Chisel Lake deposit.

These altered rocks are now composed of a variety of mineral assemblages characteristic of the lower amphibolite grade metamorphism. The metamorphic mineral assemblages are typically coarse grained, with aluminosilicate minerals up to several centimetres in length. Quartz-biotite-chlorite-staurolite-kyanite- (garnet) is the most common footwall alteration assemblage (Fig. GSC-2-3). There is a general increase in the chlorite content towards sulphide lenses, although biotite, staurolite and kyanite remain ubiquitous. With increase in chlorite there is local cordierite and sulphide-bearing chlorite-biotite veins. Within 75 m of the sulphide lenses there are 10 to 15 per cent chalcopyrite- pyrrhotite veins.

In addition, there is a noticeable decrease in chlorite and the appearance of sericite and pyrite within 20 m of the sulphide lenses (Fig. GSC-2-3). An exception to this is where amphibole is present in the immediate footwall; here chlorite remains the principal phyllosilicate and sericite is absent. The stratiform sulphide lenses are quartz-sericite-biotite rich, with local, thin zones of chlorite-garnet-magnetite that may represent altered mafic dykes (Galley and Bailes, 1989). Gahnite and cordierite occur sporadically in both the chlorite and sericite-rich rocks. Andalusite was observed in core from several holes, generally in contact with kyanite.

HANGINGWALL ALTERATION

Alteration within hangingwall strata is ubiquitous, but patchy in both areal extent and intensity. Silicification, accompanied by actinolite-biotite-garnet alteration, either pervasive or vein-controlled, dominates. Vein-controlled quartz- epidote alteration is also present, but is principally restricted to the mafic intrusions; margins of the intrusions are commonly focii for silicification of the intruded rocks.

The siliceous, banded rocks and felsic breccia in the immediate hangwall to the sulphide lenses are commonly strongly altered to actinolite-garnet-magnetite, with some metres-thick zones of amphibole-chlorite-chalcopyrite-pyrrhotite alteration. Where the sulphide lense is overlain by mafic wacke, the wacke contains intense, patchy silicification and attendant actinolite- biotite-garnet alteration. Where overlain by heterolithologic breccias, the matrix of the breccias is commonly altered to quartz- actinolite-biotite-garnet.

Basalt flows above and below the Felsic Flow Unit are sporadically silicified and bleached; the matrix of interflow breccias are rich in actinolite, biotite and garnet. In these zones amygdales contain quartz-chlorite or quartz-garnet. At the contact between mafic flows and rhyolite the latter is commonly so bleached that they can be differentiated solely through the presence of amygdales and gas cavities that characterize the unaltered basalt.

Structure

Surface 1:20 000 scale mapping (Bailes (1988), and 1:500 scale mapping (Bailes and Galley, 1989; Galley, 1990) are combined with drill hole data to determine the structural setting of the North Chisel deposit. Surface mapping defines the Chisel Basin as a non-cylindrical, F_1 syncline whose axis and southwest limb are truncated by the post-kinematic Chisel Lake Pluton (Fig. GSC-2-1). The south-southwest limb is characterized by a series of tight to isoclinal, inclined F_1 folds that plunge moderately northwest, and dip shallowly to the northeast (Fig. GSC-2-2). This folding is particularly evident in the Chisel Lake open pit (Galley et al., 1990). The bottom of the synform, as defined by drilling, slopes shallowly to the northeast for an undetermined distance, and curves up to surface east of Ghost Lake and to the north of Chisel Lake. Basin-type mafic wackes are observed as a thin sliver to the northwest of Chisel Lake, suggesting an attenuation of the syncline in the form of a teardrop.

Minor F_1 folds, measured within the mafic volcaniclastic rocks, indicate that the syncline plunges both to the northwest and southeast and is therefore noncylindrical. The doubly-plunging nature of the structure is mimicked by an asymmetric, basin and dome structure along the southern edge of the Chisel Basin, which contains the Ghost massive sulphide deposit (Fig. GSC-2-1).

The dominant penetrative schistosity (S_1) is axial planar to the F_1 folds and varies in dip between 20 and 80° to the northeast. A second schistosity (S_2) is weaker and most commonly defined by a biotite alignment in the mafic wackes. S_2 has an averge strike of 025° and is dips
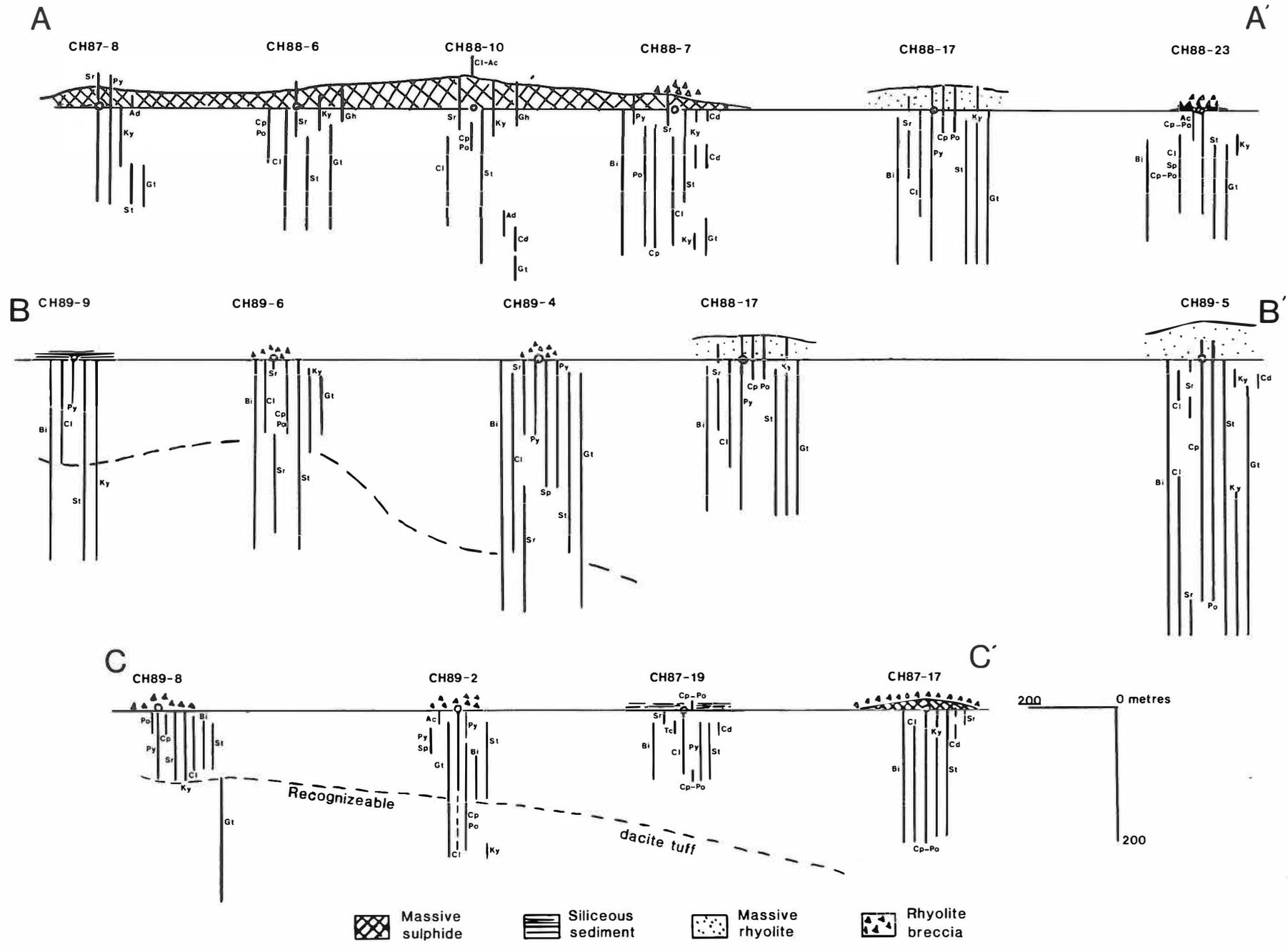
Figure GSC-2-3: *Longitudinal (A-A') and cross sections (B-B', C-C') centered on the Chisel North deposit showing the metamorphic minerals that characterize the footwall alteration zone below and along strike from the deposit. Sr - sericite, Py - pyrite, Ad - andalusite, Ky - kyanite, St - staurolite, Gt - garnet, Cp - chalcopyrite, Po - pyrrhotite, Cl - chlorite, Gh - gahnite, Cd - cordierite, Bi - biotite, Sp - sphalerite, Ac - actinolite.*
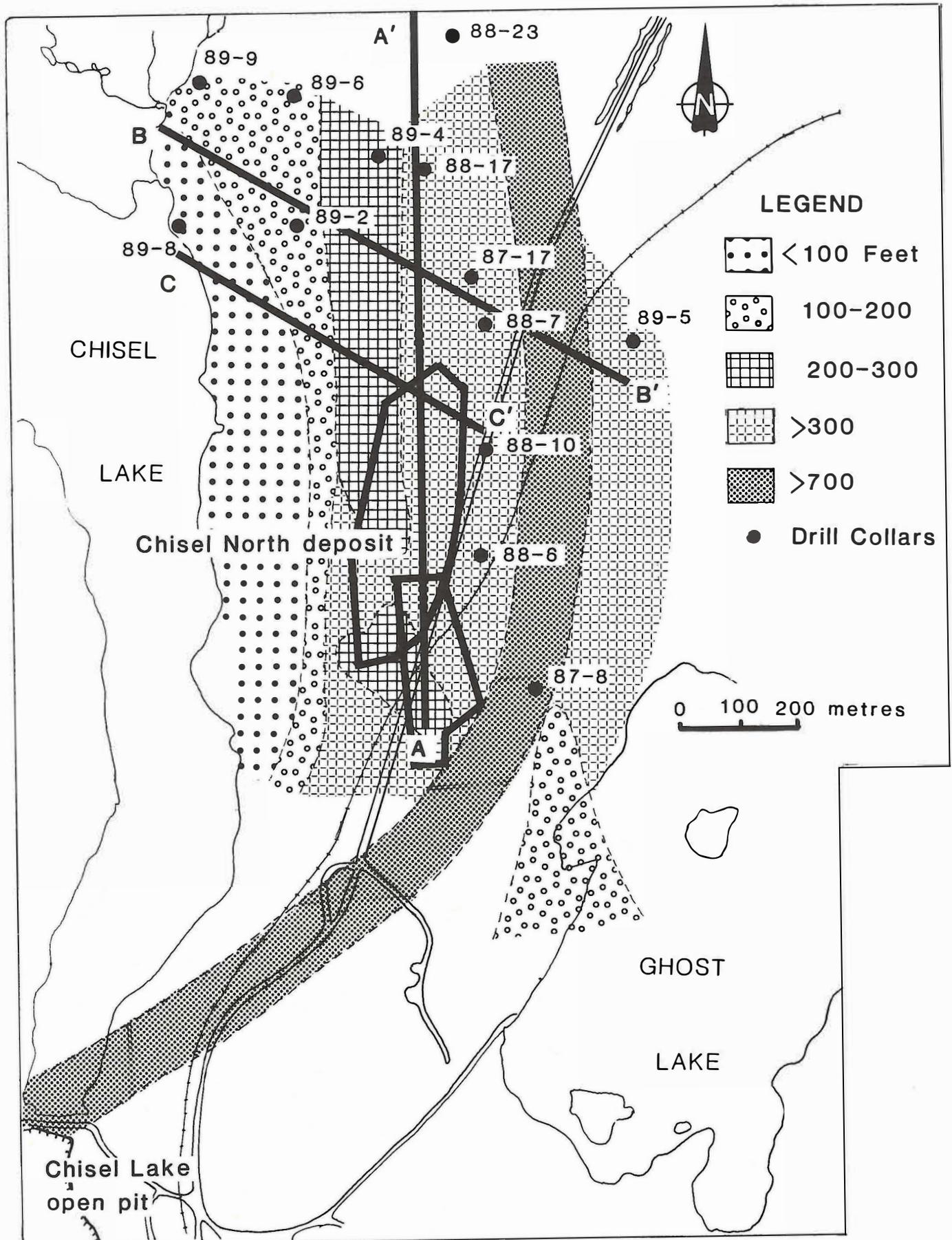
Figure GSC-2-4: *Contoured map of footwall alteration associated with the Chisel North deposit. Black lines outline the vertical projection of the two stratiform sulphide zones. Cross sections and longitudinal sections from Figure 3.*

east-southeast at 80°. The S_1/S_2 intersection lineation defines a moderately northeast-plunging F_2 fold axis. This northeast plunge is also defined by mineral lineations and fragment elongation in the S_1 plane, and by the overall plunge of the Chisel Lake orebodies (Martin, 1966; Galley and Bailes, 1989).

A cross-section of part of the Chisel Basin, looking northwest, has been constructed from surface and preliminary drill data (Fig. GSC-2-2). The orientation of units within the strata hosting the North Chisel deposit broadly conform to the configuration of the lithologies on the Chisel Basin surface map (Fig. GSC-2-1). On surface, the axial trace of the Chisel Basin syncline is situated over the south edge of the deposit. Bedding measurements from drill core were oriented with respect to the dominant S_1 penetrative foliation measured on surface. Orientation of bedding planes within the mafic volcaniclastic strata and lithological contacts in the upper two thirds of the drill holes confirm that this section of the basin rests on the northeast limb of the synform.

The North Chisel deposit may have been affected by the inclined, assymentric folding evident along the south margin of the basin. The results of the diamond drilling program have indicated the presence of two offset and stacked lenses, while examination of the core suggests that the hangingwall contact of both lenses defined the same stratigraphic horizon. This, and the presence of several small sulphide lenses, between the two main lenses at their point of overlap, would suggest that this may be the location of an inclined, asymmetric, F_1 fold nose.

DISCUSSION

The information gathered on the Chisel North deposit has generated some preliminary hypotheses as to the depositional environment of the massive sulphides in the Chisel Basin. The Powderhouse dacite foramtion appears to form a thick and continuous footwall to the massive sulphide deposits. The spatial relationship between massive sulphide and rhyolite is somewhat more complex. At the Chisel Lake deposit the massive sulphide appears to flank a discrete rhyolite flow and flow breccia structure, while at Ghost and Chisel North the massive sulphide is overlain by a thin unit of felsic breccia, although intense alteration may mask the presence of massive rhyolite in the footwall to the Chisel North deposit.

There is a radical change in the nature of the hangingwall stratigraphy between the Chisel Lake and Chisel North deposits. The former is overlain by a thick sequence of mafic turbiditic wacke and secondary, scoria-rich, pyroclastic flows, whereas the latter is almost completely covered by a thick wedge of mafic heterolithologic breccia, rhyolite flow and flow breccia and highly amygdaloidal, aphyric basalt flows. The contrasting stratigraphy would suggest that the Chisel North massive sulphides were deposited closer to the edge of a basin, or at least closer to a fault that was active during the creation of the basin. The fault itself could have controlled the extrusion of felsic and mafic flows.

The joining of the Felsic Flow Unit with the Ghost Lake Rhyolite has resulted in a re-evaluation of the relationship of the latter with felsic rocks spatially associated with the massive sulphide deposits in the basin.

It was previously thought that the massive sulphide horizon was at the contact of the Ghost Lake Rhyolite and the overlying mafic wacke and/or mafic flows. The massive sulphide horizon now appears to be below the Ghost Lake Rhyolite.

The extent and distribution of the footwall hydrothermal alteration is widespread in relation to the size of the orebody. This could be an indication that: a) a part of the alteration zone represents intake zones for seawater within a convectional hydrothermal system; b) the hydrothermal fluids responsible for the development of the alteration zone produced more than one deposit; or c) the degree of preservation of massive sulphides produced during seafloor hydrothermal alteration was minimal, as the zone of iron-magnesium alteration is at least five times the area of the Chisel North deposit.

Sulphide veins are present in all of the drill holes that intersected the footwall alteration zone. Cross-sections of the footwall alteration indicate that it forms a deep keel to the east of. but parallel to, the deposit. The presence of the keel would suggest that this was the core of the hydrothermal system. The fact that further to the southwest the keel is spatially associated with the Chisel deposit (Fig. GSC-2-4) would reinforce this supposition; the keel could represent a synvolcanic fault that has focussed hydrothermal flow. There are many examples of single fault zones controlling the location of a number of massive sulphide deposits on both the modern seafloor (Kappel and Franklin, 1989) and in the rock record (the Noranda camp; Gibson, 1990).

The areal extent of the alteration zone and the fact that its keel does not lie directly under the Chisel North deposit may be explained by diffuse fluid flow in the upper part of the hydrothermal system. Koski et al. (1988) describe massive sulphide deposits within the Escanaba Trough, Gorda Ridge, as flanking the main fluid conduit. They suggest that much of the hydrothermal fluid brought to the near-surface by a deep structure is diffused directly below the seafloor by secondary fractures, resulting in low velocity, unfocussed discharge. This could result in a funnel-shaped alteration zone as described for the Chisel Basin, and the offset of the massive sulphide accumulation from the alteration keel.

The structural configuration of the Chisel Lake area is complex, and its understanding is essential in order to locate and follow favourable mineralized horizons at depth. The Chisel area is anomalous with respect to the intensity of deformation present. Mapping of the Chisel stratigraphy south of the Chisel Basin (Bailes, 1988; Bailes and Galley, 1989) has shown the footwall stratigraphy to the Chisel-Lost-Ghost massive sulphide horizon to be monoclinal, dipping and topping consistently to the north-northeast. Tight isoclinal F_1 folding becomes apparent in the footwall dacite to the massive sulphide horizon, and within the mafic volcaniclastics and diorite intrusions within the Chisel Basin. North of the Chisel Basin, the deformation pattern continues to be complex, resulting in the reappearance of the equivalent of the Chisel Basin units (Threehouse formation) (GS-6, this volume) south of Snow Lake.

The sudden change in structural style is not understood at the present time, except that the sudden appearance of tight F_1 folding coincides with the development of intense and pervasive iron-magnesium alteration in the stratigraphic footwall to the massive sulphide horizon. It is possible that an original zone of structural weakness represented by the alteration zone became the focal point for high strain during F_1 folding. The consistent, southwest vergence of the folds would suggest a component of tectonic transport in this direction during this early fold phase.

It is hoped that detailed examination of the minor structures in the Chisel Lake area will assist in unraveling the regional deformational history, which in turn will help the mining companies define both the configuration of individual massive sulphide deposits and to locate favourable horizons in other parts of the Snow Lake area.

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LEGEND

POST-SICKLE INTRUSION

⊕ GRANODIORITE (QUARTZ DIORITE, QUARTZ MONZONITE)

PRE-SICKLE INTRUSION

⊕ DIORITE (QUARTZ MONZONITE, GRANITE)

⊕ DACITE

RUTTAN GROUP

⊕ INTERMEDIATE-MAFIC SILTSTONE WACKE/PEBBLE CONGLOMERATE, CONGLOMERATE

⊕ QUARTZ PHYRIC FELSIC TUFF, CHERT

⊖ RUTTAN Cu-Zn OREBODY

⊕ FELDSPAR, PYROXENE PHYRIC BASALT

⊕ PYROXENE PHYRIC BASALT

⬭ APHYRIC BASALT

ALTERATION

Fe-Mg

⊕ strong

⊕ weak to moderate

SILICIFICATION

⊕ pervasive

⊘ fracture controlled

SYMBOLS

⬛ STRATIGRAPHIC TOP

⁄⁄ BEDDING

⁄ᵥ FOLIATION, PRIMARY, SECONDARY

↘ LINEATION

━ SHEAR ZONE

↘• DRILL HOLE

▣ HEADFRAME

══,⋯ ROAD, TRAIL

Figure GSC-3-1:   Geology of the Ruttan Mine and area. Inset: Location Map of the Ruttan Mine, Manitoba. Note location of Figure 2.

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GSC-3 PRELIMINARY REPORT ON THE GEOLOGICAL SETTING OF THE RUTTAN BASE METAL DEPOSIT AND ASSOCIATED HYDROTHERMAL ALTERATION, RUSTY LAKE VOLCANIC BELT, MANITOBA (NTS 64B/5)

by D.E. Ames[1], J.S. Scoates[2], and J.M. Franklin[1]

INTRODUCTION

A detailed geological and geochemical study of the Ruttan Cu-Zn deposit commenced this summer as a part of the Exploration Science and Technology (EXTECH) Federal initiative. Detailed geological mapping at 1:5000 scale was undertaken within the framework of 1:50 000 mapping completed by Baldwin (1988).

The objectives of this study are to:

1. document the environment of deposition of the base metal deposit;
2. define the ore horizon and determine its relationship to the regional stratigraphy;
3. determine the mineralogical and chemical compositions of the host rocks and hydrothermal alteration zones; and
4. test the hypothesis that the Ruttan deposit is an ancient analogue of the modern day sediment-hosted massive sulphide deposits situated on the Gorda and Juan de Fuca ridges.

The Ruttan Cu-Zn massive sulphide deposit is at the western extent of the Early Proterozoic Rusty Lake volcanic belt (1878 ± 3 Ma; Baldwin et al., 1987) and is 22 km east of Leaf Rapids, Manitoba (Fig. GSC-3-1). The orebody was discovered by Sherritt Gordon Mines Limited in 1969 as a result of an airborne Input electromagnetic survey flown in 1968. The deposit consists of 72 million tonnes of sulphide with 33 million tonnes of ore mined from the open pit and underground. Presently mineable reserves are 12.6 million tonnes at 1.46 per cent Cu and 1.68 per cent Zn (A. Gottzman, pers. comm.) that include 3.6 million tonnes from the West Anomaly at 1.28 per cent Cu and 2.51 per cent Zn, which is presently under development. Ownership of the deposit was transferred to Hudson Bay Mining and Smelting Co., Limited in 1987.

FIELD RESULTS

Mapping at 1:5000 scale of an area centred on the Ruttan mine was initiated during the 1990 field season (Fig. GSC-3-1). The area, 1.5 km by 3 km, including the mine and exposures to the northeast, was mapped and 7400 m of drill core from the mine area were re-logged and sampled to study alteration, stratigraphy and structure (Fig. GSC-3-1).

As outcrops in the immediate footwall of the deposit are few and the mine exposures are intensely altered, an area northeast of the open pit, was used to define the mine stratigraphic succession (Fig. GSC-3-2). Mapping of the stratigraphic succession is further restricted by a granodiorite intrusion that truncates the footwall rocks obliquely, leaving a footwall wedge that is 250 m wide near the ore deposit and widening to 1250 m to the north.

Footwall rocks

The structural and stratigraphic footwall and hanging wall at the Ruttan mine coincide and they dip and face southeast. Basalt dominates the footwall strata. In the immediate footwall of the deposit aphyric pillowed basalt is exposed 225 m north of the open pit (Fig. GSC-3-1). This basalt contains sulphide-rich interpillow material and quartz-filled amygdales. In the northeast, the lowermost 700 to 1000 m of exposed strata consists of aphyric pillowed basalt. The pillows are poorly developed, small to medium sized (0.5-1m in diameter) with rare amygdales. Pillow cores are typically pale grey with pale, pistachio green epidotized alteration rims. Interpillow material consists of chlorite and quartz and/or sulphides. Epidote alteration comprising up to 30 per cent of the outcrop is most intense at the top of the pillowed sequence (Fig. GSC-3-3).

In the northeast, pillowed basalt is overlain to the southeast by a thick (550 m) sequence of hornblende - phyric, heterolithic basalt breccia, tuff breccia and massive flows. The mafic breccias are matrix supported; they contain basaltic clasts of different textural types and felsic clasts, but are dominated by feldspar and feldspar- hornblende-phyric mafic clasts. The basaltic rocks are locally aphyric and are crosscut by sulphide- filled fractures.

The basalt sequence contains a series of northeast-trending silicified alteration zones that weather buff grey-brown and consist of fine grained acicular hornblende and garnet (typically 2mm diameter) in a siliceous matrix. The silicified rocks contain relict feldspar crystals, 2 to 4 mm in diameter. Silicification zones are 30 to 300 m wide and are typified by irregular contacts with the less altered mafic protolith (Fig. GSC-3-4). The intensity of alteration ranges from fracture - controlled silicification through partially silicified basalt into pervasively silicified zones. Relict amygdaloidal basalt flows, black "clast-like" pods and amphibole-chorite-garnet fractures occur within the silicified zones (Fig. GSC-3-5, GSC-3-6).

Two kilometers northeast, along strike from the Ruttan orebody is a wedge-shaped disconformable zone, 75 m wide by 175 m long, of pervasively silicified rock (Fig. GSC-3-2, GSC-3-7). A series of fractures surrounded by quartz-feldspar zones that are resistant to weathering trend dominantly 100°. Adjacent to the eastern contact of the silicified area with amygdaloidal aphyric basalt the fractures trend north-south (Fig. GSC-3-8) . The contact with basalt is irregular, with fracture-controlled silicification extending into the basalt, and relict basaltic clots enclosed within the silicified zone (Fig. GSC-3-8). This zone, which is in the footwall to the mineralized horizon, coincides with a sudden change in rock type along strike, from massive aphyric amygdaloidal basalt through the silicic zone to a cross-stratal wedge of basalt breccia. The disconformable zone is overlain by a continuous unit of feldspar- hornblende-phyric amygdaloidal basalt. This latter unit forms the immediate footwall to the ore horizon (Fig. GSC-3-2). The feldspar- hornblende-phyric basalt contains fracture - controlled and mottled silicified zones with some less pervasively silicified domains (Fig. GSC-3-9). These silicified domains contain relict feldspar and hornblende and are similar to the 300 m wide footwall silicified basalt zone immediately northeast of the open pit (Fig. GSC-3-1). The wedge- shaped silicified zone and associated breccia may represent the products of a synvolcanic growth fault.

Although silicification and epidotization dominate in the footwall alteration zones to the northeast of the deposit, a series of disconformable Fe-Mg alteration zones occur in the immediate footwall. Within these, changes in alteration mineral assemblages (described below) are conformable to bedding as exposed on the eastern limit of the deposit. Below the east zone massive sulphide lenses, Fe-Mg alteration is overprinted by sericitic alteration zones. Alteration is represented by the observed assemblages in porphyroblastic schist and phyllite:

1. talc, chlorite, biotite 568 pyrrhotite, pyrite, chalcopyrite;
2. chlorite, cordierite, 568 andalusite, biotite, garnet, staurolite, magnetite;
3. staurolite, biotite, andalusite 568 garnet, chlorite;
4. staurolite, andalusite, sillimanite, plagioclase, biotite, chlorite;
5. gahnite sericite 568 sphalerite, biotite;
6. galena, sphalerite, gahnite, sericite;
7. rare anthophyllite, biotite, chlorite 568 cordierite, magnetite, pyrite, pyrrhotite; and
8. massive magnetite.

Extensive talc zones occur in footwall zones near the West and East lenses in the mine. They extend up to 75 m into the footwall of the East ore lenses and are locally 35 m wide. These talc-dominated altera-

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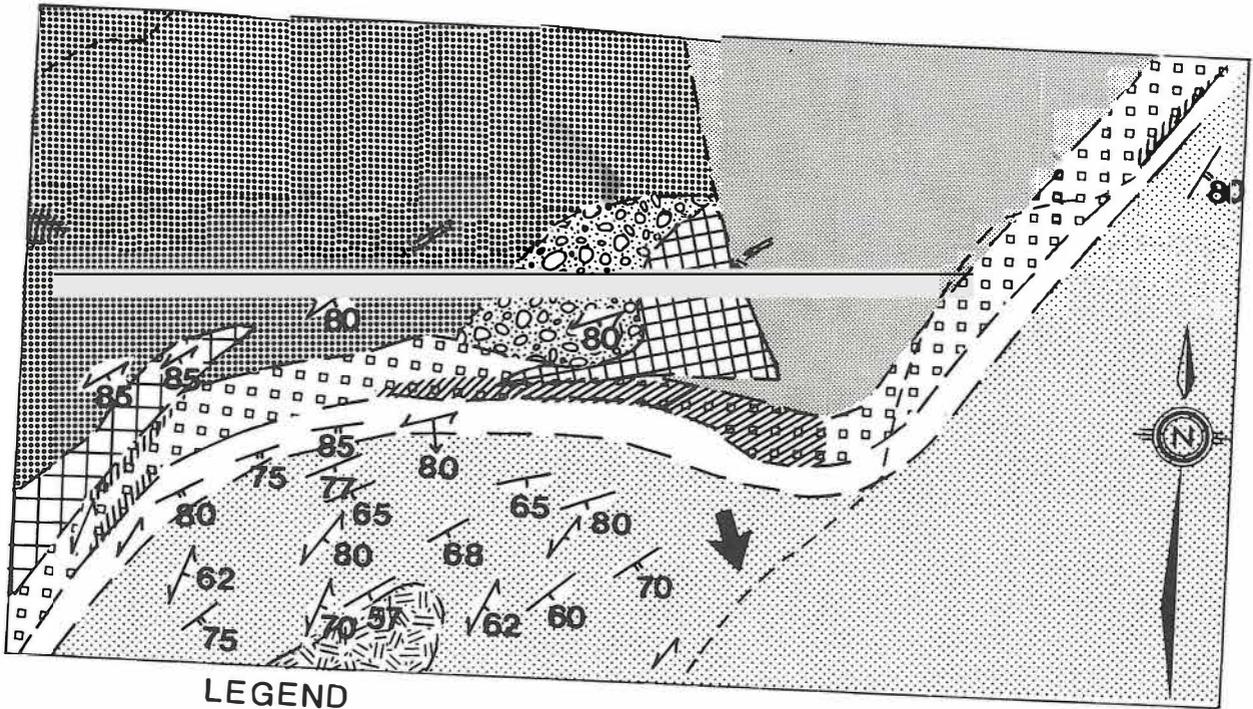
LEGEND

PRE-SICKLE INTRUSION

DACITE

RUTTAN GROUP

SYMBOLS

INTERMEDIATE-MAFIC WACKE

STRATIGRAPHIC TOP

QUARTZ PHYRIC FELSIC TUFF, CHERT

BEDDING

FELDSPAR, PYROXENE PHYRIC BASALT

FOLIATION, PRIMARY,

PYROXENE PHYRIC BASALT, BRECCIA

SECONDARY

APHYRIC BASALT

LINEATION

SILICIFICATION

TRAIL

PERVASIVE

FRACTURE CONTROLLED

0   50   100m
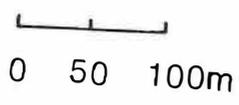
Figure GSC-3-2:   Detailed map of the northeastern extension of the mine horizon and surrounding geology.
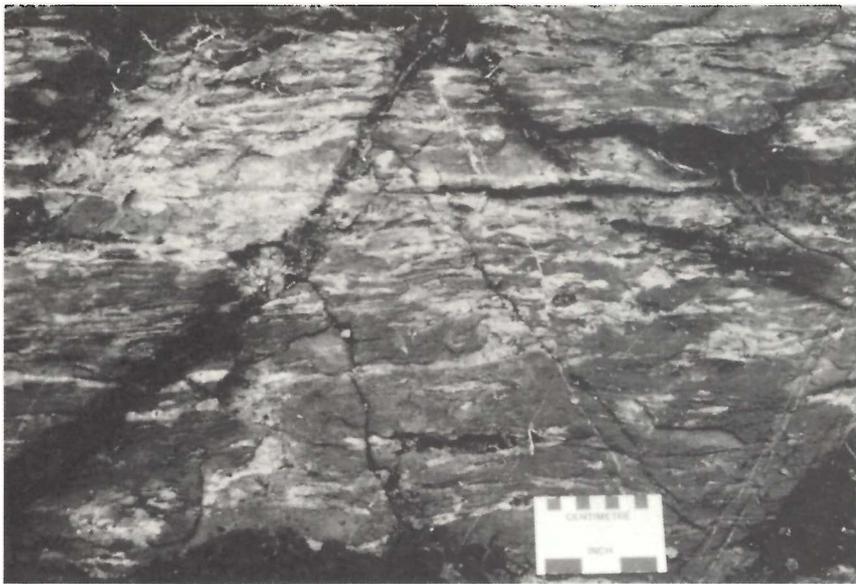
Figure GSC-3-3: Epidosite (light) alteration with relict mafic volcanic domains within a northeast trending shear zone.

Figure GSC-3-4: Irregular replacement contact of silicified zone (top) and amygdaloidal basalt (bottom). Note fracture-controlled silicification at alteration front.
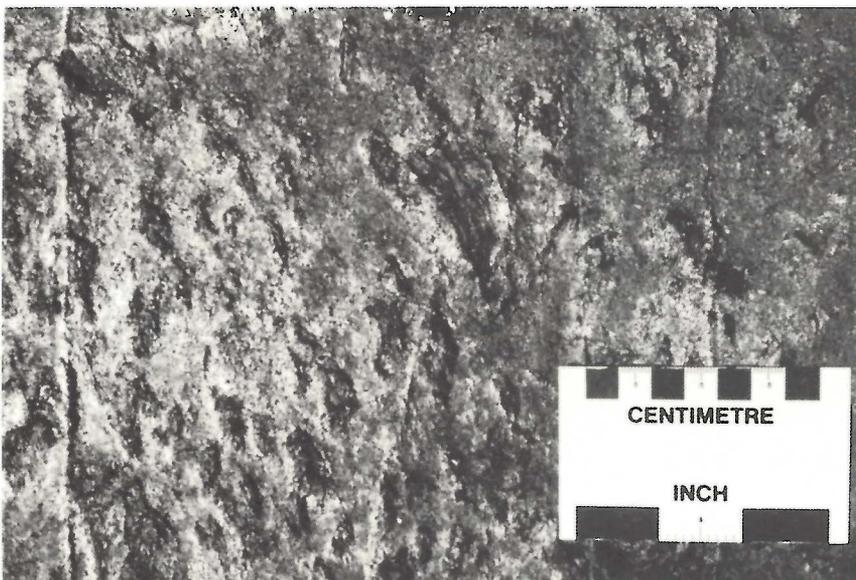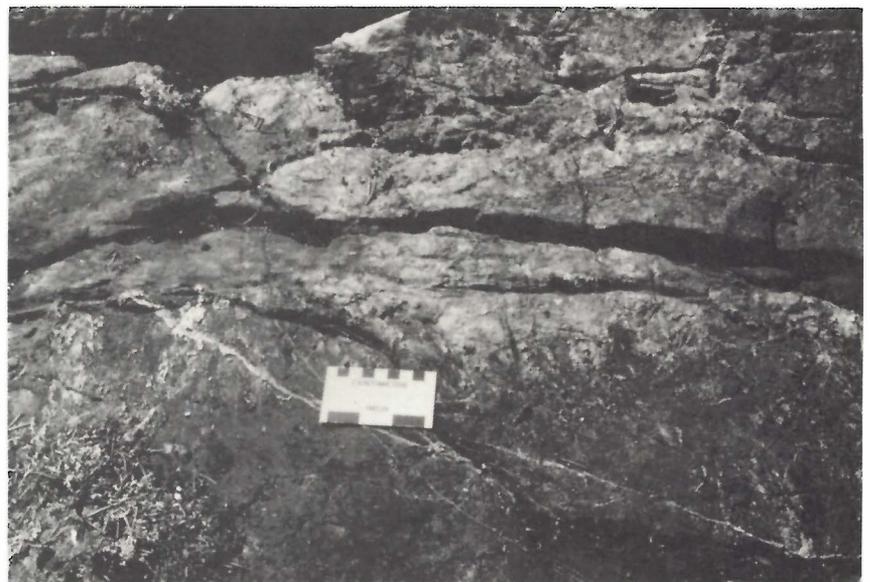
Figure GSC-3-5: Relict amphibole clots in silicified basalt produce "clastlike" appearance.
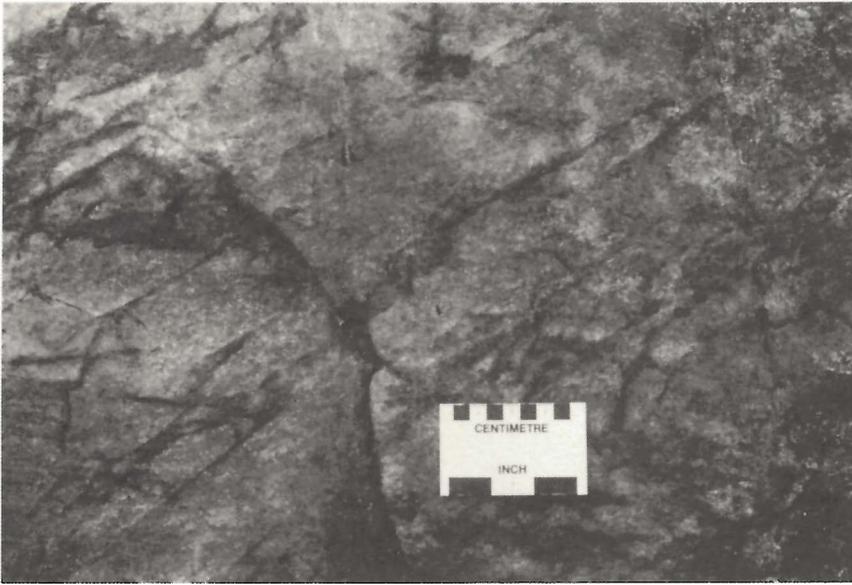
Figure GSC-3-6: Pervasively silicified basalt crosscut by chlorite-filled fractures.

Figure GSC-3-7: Pervasively silicified rock with resistant weathering silica-feldspar-bearing fractures.

Figure GSC-3-8: Contact between disconformable silicified zone and basalt with quartz-filled fractures crosscutting basalt and basaltic remnants within silicified zone. Note basalt relicts to left of scale card.

Figure GSC-3-9: Remnant of feldpar-phyric basalt within pervasively silicified basalt at top right of photo. Note replacement features at contact and relict feldspar within silicified basalt.

tion zones envelop or occur within copper- rich zones, and are situated at the base of stratigraphically higher lenses containing zinc and copper. Anhydrite occurs within the gangue of zinc-copper zones and as vug infillings near the top of the East Lenses.

Small zones of massive magnetite occur in the chalcopyrite - chlorite stringer ore of the B and C ore zones of the West Lenses. Sulphide zones with up to 8 per cent copper and 12.9 per cent zinc are associated with the massive magnetite. Anthophyllite (identified petrographically) occurs in the West Anomaly alteration zones.

At the East Lenses cordierite-chlorite alteration zones occur dominantly in the footwall (Fig. GSC-3-10). Staurolite-biotite zones occur in the hanging wall and deep in the footwall, below the chlorite-cordierite zones. Alternating lensoid zones of chlorite-cordierite and staurolite-biotite, each 10 to 35 m wide, occur in the hanging wall. At the top of the ore horizon a series of narrow sericite-galena-sphalerite-gahnite zones lie less than 10 m from the contact between altered rocks in the hanging wall to the ore and the overlying turbiditic sedimentary strata. Below the contact is 5 to 10 m of epidosite with minor garnet, magnetite and hematite.

Extension of the Ruttan Massive Sulphide Horizon

The Ruttan ore zones are situated in the upper 75 to 125 m of the volcanic stratigraphy. Overlying the ore lenses in the mine are 75 m of dominantly hornblende-biotite-garnet-bearing silicified rock.

The stratigraphic position occupied by the Ruttan deposit (the ore horizon) was identified along strike, over 2200 m northeast of the Ruttan orebody. The sulphide-bearing unit is 30 m wide at the contact between hydrothermally altered basalt and turbiditic sediments (Fig. GSC-3-2). The strata are asymmetrically folded; one limb strikes approximately east-west for 500 m and dips 85° S; the other limb strikes northeast for an additional 350 m (Fig. GSC-3-2). The strata consist of chert and finely laminated quartz-phyric and aphyric felsic tuff; both contain disseminated pyrite and chalcopyrite (Fig. GSC-3-11). This sequence is similar to a unit at the top of the East Lenses at the contact between Fe-Mg alteration and hanging wall sedimentary rocks; it is also present on the eastern edge of the open pit and was delimited for 200 m to the east in drill core.

Hanging wall Stratigraphy

A southeast-facing formation of intermediate to mafic turbiditic sedimentary strata, consisting of ABE and AE beds within the Bouma sequence stratigraphically and structurally overlies the ore horizon. Rock type varies from mudstone to conglomerate with a general increase in grain size and abundance of felsic clasts to the southeast. Numerous stratigraphic facing indicators such as graded bedding, rip-up clasts, load casts, scour and flame structures all indicate a southeast younging direction and a transport direction from the northeast.

Mappable subdivisions between siltstone/wacke- and pebbly conglomerate/conglomerate- dominated sequences were made (Fig. GSC-3-1). The lowermost unit is 150 m wide, and consists of thinly- to very thinly- interbedded wacke and mudstone/siltstone with minor, feldspar-hornblende-phyric mafic and dacite flows. This is overlain by a 100 m wide wacke- dominated sequence followed by 150 m wide pebble and cobble paraconglomerate with minor orthoconglomerate (Fig. GSC-3-1).

Two silicified zones containing garnet, acicular hornblende, and magnetite, each 5 to 25 m wide, occur at the base of the hanging wall sedimentary rocks (Fig. GSC-3-1). Fracture controlled silicification dominates, with local pervasive silicification. A large, semiconformable fracture - controlled silicification zone, 150 m by 1100 m, occurs in the wacke at the contact between the wacke- and conglomerate-dominated sequences. This silicified area is 250 m above the stratigraphic position of the ore.

Intrusive Rocks

The footwall volcanic sequence is transected by a post-Sickle granodiorite intrusion, and the hanging wall sedimentary rocks were intruded by a pre-Sickle multi-phase diorite - quartz monzonite - granite intrusion (Steeves and Lamb, 1972). Both intrusions contain inclusions of the supracrustal rocks (Fig. GSC- 3-1). Dykes associated with these plutons crosscut the strata and alteration zones.

Massive, homogeneous dacite dykes and sills containing feldspar, biotite and hornblende crosscut footwall basalt and silicification zones. They are variably silicified where they crosscut hanging wall sedimentary rocks. Fine-grained diorite dykes crosscut cordierite-chlorite and staurolite-biotite- garnet alteration zones in the footwall rocks and contain 10 cm wide pale grey magnetite-bearing alteration rims at their contacts (Fig. GSC-3-12). Diorite also occurs as boudinaged blocks in the ore zones. The mafic and dacite sills are thus interpreted to be late-synvolcanic. Mafic sills and minor dykes form approximately 30 percent of the hanging wall outcrop exposure.

Metamorphism and Structure

In the alteration zones, andalusite and sillimanite, cordierite, staurolite, garnet, anthophyllite, biotite and gahnite have been observed petrographically, indicating a middle amphibolite grade of metamorphism. Cordierite and staurolite porphyroblasts have been rotated during at least one phase of deformation.

The area contains two penetrative foliations, one subparallel to bedding (S₁) at N60°E/65 to 85 and the second (S₂) more northerly at N25°E/80 that crosscuts S₁. The vergence between these structural ele-

Figure GSC-3-10: Fe-Mg alteration in footwall of east lenses. Cordierite, chlorite, garnet, pyrite porphyroblastic schist.
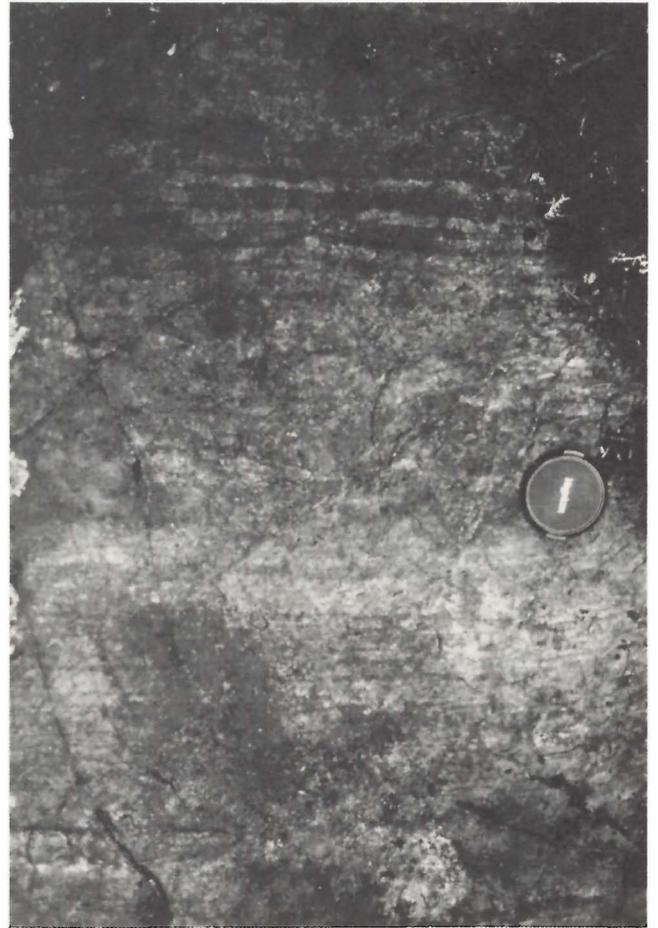
Figure GSC-3-11: Well laminated quartz-phyric felsic tuff. Colour is dark and mottled due to lichen cover.
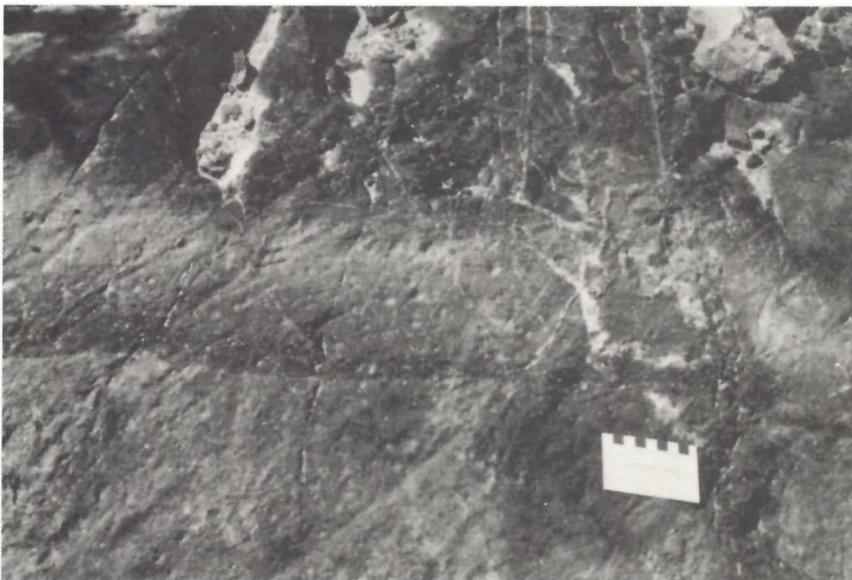
Figure GSC-3-12: Bleached alteration rim at the contact of a fine-grained diorite dyke (top) and staurolite, biotite, garnet, cordierite porphyroblastic schist (bottom).

ments is consistent, indicating that the map area is located along the western limb of an F_2 syncline. Although two foliations are present, no mesoscopic folding has been observed at the outcrop scale. Bedding changes from N70°E/60 to 85 to N30°E/75 to 85 due to F_2 folding (Fig. GSC-3-1, GSC-3-2). Mineral and intersection lineations and the ore zones trend and plunge the same direction (120/60-80°). Mineral lineations are poorly developed in the Ruttan mine area.

A series of northeasterly and easterly trending shear zones cross-cut the strata (Fig. GSC-3-1). An oblique slip normal fault, north side up, occurs 75 m into the footwall of the deposit at surface. It strikes east/west dipping 85°S with an intersection lineation at 120/80 and offsets a granitic dyke with an apparent dextral sense. The penetrative foliation is sigmoidal where it occurs between shear planes in the 0.5 m wide shear zone, indicating north side up. Numerous bedding parallel and low angle faults occur in the hanging wall metasedimentary rocks making the continuity of individual conglomerate beds difficult to establish.

SUMMARY AND DISCUSSION

1. The Ruttan base metal deposit has previously been described as an intermediate volcaniclastic sediment-hosted deposit with 400 to 450 m of sediment overlying basalt in the footwall of the deposit (Speakman et al., 1982, Baldwin 1978, 1988). Field observations indicate that the footwall rocks are dominantly variably-silicified basalt above less altered basalt and the hanging wall rocks are turbiditic sedimentary rocks.

Massive, unaltered footwall ''volcaniclastic'' rocks in the immediate mine area (Speakman et al., 1982) are similar to the dacite intrusions elsewhere in the footwall and probably are part of that sill-dyke complex. This new litho- stratigraphic information provides the basis for a re- interpretation of the environment of deposition of Ruttan deposit from a volcaniclastic sediment- sedimentary setting to a basaltic-sedimentary setting.

2. The distal extension of the ore horizon was located and identified as less than 30 m of sulphidic felsic tuff and chert. This key stratigraphic marker horizon is important for regional investigations of ore potential. It forms the base of the turbidite sequence that immediately overlies basalt. Northeast of the mine, the stratigraphic position of the ore horizon has been observed some 400 m north-westward from its position on previous maps (Jackson, 1979; Speakman et al., 1982; Baldwin, 1988). This discovery could influence future exploration in that area.

3. Four principal types of alteration were identified in the Ruttan mine area; a) epidotization: deep in the footwall, b) silicification: extensive in the footwall basalt, overlying the massive sulphide deposit and as local zones in the hanging wall turbiditic sedimentary rocks, c) Fe-Mg alteration: proximal to the deposit and overprinting silicification, and d) sericitization: present primarily in the hanging wall. In the footwall, recognition of extensive areas of pervasive silicification of basalt, previously mapped as more intermediate volcaniclastic rocks, not only affects the stratigraphic interpretation of the area, but also is of assistance in delineating areas of high base metal potential.

Similar alteration zones have been described near other Precambrian massive sulphide bodies in camps such as Noranda, (Gibson, 1983) and Snow Lake (Skirrow, 1987; Bailes and Galley, 1989; Galley and Bailes, 1989; Galley and Kitzler, 1990). Silicification, in these base metal camps occurs predominantly about 1 to 2 km stratigraphically below the deposits, and is in metal - depleted mafic rocks. This has been interpreted as a high temperature reaction zone, representing in part the paleo-reservoir for hydrothermal fluid. Silicification also occurs more locally in the alteration pipes of some massive sulphide deposits (Embley et al., 1988; Morton and Franklin, 1987), where it precipitated through conductive cooling of hydrothermal fluids (Janecky and Seyfried, 1984) in strata of low permeability. Silicification associated with alteration pipes may be differentiated from the higher-temperature analogue; the pipes are Na and Ca- depleted, and base-metal enriched. The lower ''high-temperature'' silification zones contain albite, epidote and actinolite but very little sulphide. Both types of silicification are useful exploration guides in the Ruttan area.

The Fe-Mg alteration, typical of many alteration pipes associated with massive sulphide deposits, occurs in the immediate footwall to the Ruttan deposit. It probably formed through progressive heating of downward-advecting seawater around the discharge areas for the Ruttan deposit. Under these conditions, Mg is insoluble, and formed Mg-smectite and Mg-chlorite. Fe- chlorite appears to be part of the primary hydrothermal alteration sequence in the feeder pipes (Embley et al., 1988). Talc in the footwall of Ruttan is probably the metamorphosed equivalent of Mg-smectite.

4. The recognition of a discordant alteration zone and associated breccias as a synvolcanic fault distal to the Ruttan orebody is significant for exploration for other base metal deposits. The location of synvolcanic faults may be important for focussing fluids responsible for base metal deposition (Gibson, 1990; Kappel and Franklin, 1989).

5. The Ruttan area is somewhat analagous to two modern high-temperature hydrothermal areas on the seafloor, Middle Valley on the Juan de Fuca Ridge (Kappel and Franklin, 1989) and the Escanaba Trough area of the southern Gorda Ridge (Koski et al., 1988). In these two modern examples, sulphides occur within sediments, at varying distances (tens to hundreds of meters) above a basaltic basement and locally on the basaltic basement at the Gorda Ridge. The sedimentary strata have provided a protective cap under which the sulphides are accumulating, in the modern examples. At Ruttan the main deposit is situated close to the basalt-sediment contact with the deposit below approximately 50 m of silicified rock overlain by turbiditic sediments.

The principal difference between the Ruttan Cu-Zn massive sulphide deposit and these modern occurrences may be the presence of felsic intrusions and tuff at Ruttan. The important aspects to be tested comparatively are:

1. the position of the main deposits at Middle Valley and Escanaba Trough;
2. the role that sedimentary strata and silicified zones play in providing a protective cap;
3. the mode of alteration in the hanging wall sedimentary rocks; and
4. the source of heat for the hydrothermal system. The potential for more deposits to occur within the sedimentary sequence near Ruttan will also be further investigated.

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UM-1 MINERALOGICAL EXAMINATION OF TWO SAMPLES OF A GOLD-BEARING QUARTZ VEIN FROM THE RICE LAKE GREENSTONE BELT.

by Raymond E. Healy[1] (MINORETEK)

SUMMARY

Finely disseminated, sulphide-poor, Bi- and telluride-rich mineralization containing native gold is recognized in the 'bull' quartz vein. The native gold is extremely fine grained (i.e. mean grain diameter of 10 μm), and has a mean composition of 92.0 per cent Au, 7.9 per cent Ag and 0.1 per cent Cu. The mineralization is spatially associated with a set of late, parallel planar chlorite-muscovite-calcite-albite veinlets that crosscut the quartz vein. The veinlets are possibly identifiable on the basis of their finitely spaced, strongly planar character, and the orange-brown to black colour attained during weathering.

INTRODUCTION

Two samples of a gold-bearing quartz vein, from a property near Wallace Lake in the Rice Lake greenstone belt were submitted for evaluation to Geological Services Branch, Manitoba Energy and Mines. Minoretek was contacted for detailed mineralogical analysis of the samples. Data on the location and geological setting of the vein are not available.

Assays of the samples are not available, but it has been recognized that certain veins, which on the basis of field and hand-specimen criteria were inferred to be barren, are indeed 'anomalously' gold-bearing. Furthermore, an association of gold with bismuth is apparent from assays. The objective of the study was to examine two samples of one such quartz vein using petrography and microprobe analysis in order to determine the mineralogical characteristics of the Au-bearing mineral(s) and the associated minerals. These data may provide a method of predicting the presence of gold from visual examination of hand-specimens, as has been developed for quartz veins in North Queensland, Australia by Dowling and Morrison (1988).

METHODS

A sample of the quartz vein was crushed and heavy liquid separation followed by X-ray diffraction of magnetic and non- magnetic fractions of the heavy liquid separate was done by C. McGregor of Manitoba Energy and Mines. The heavy liquid separate constitutes less than 0.01 wt per cent of the sample, indicating extremely disseminated mineralization. Magnetite and pyrrhotite were identified in the magnetic fraction, whereas tetradymite, tellurobismuthite, native bismuth, native gold, scheelite, bismutite and beyerite were identified in the non-magentic fraction.

The two handspecimen sized samples were labelled P.1 and P.2. Three polished thin sections were prepared from P.1 (i.e. P.1-A, P.1-B and P.1-C), and two from P.2 (i.e. P.2-A and P.2-B). The sections were first examined by transmitted and reflected light microscopy in order to characterize the silicate assemblage and to locate and characterize the ore minerals. It is stressed that the quality of the polish on all sections is extremely poor, such that mineral identification of less common opaque minerals in reflected light is extremely difficult. The severe plucking and scratching may have been caused by the extensive alteration of the opaques. Furthermore, substantial plucking preferentially affects soft

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[2]The electron microprobe analysis was done on the Cameca SX-50 at the University of Manitoba. All analyses were done by wavelength dispersive analysis, using a stationary point beam, 20nA beam current, and 15 and 20kV accelerating voltages for silicates and opaques, respectively. The counting scheme consisted of 20 and 10 seconds on peaks and backgrounds, respectively, for all elements. Routine data reduction including full matrix (ZAF) corrections was done using the WDSACQ software package.

minerals including native gold, and thus has a detrimental effect on related petrographic data e.g. mineral associations and grains sizes. Most minerals were identified and/or confirmed by electron microprobe analysis (EMPA)[2]. The compositions of native gold, tetradymite, gladite (?), pilsenite, pyrite, pyrrhotite, ilmenite, feldspar, chlorite and muscovite were determined by quantitative EMPA, and those of goethite, montanite, bismutite, beyerite, scheelite, molybdenite and calcite were confirmed and/or indicated by partial/semi- quantitative (in the case of montanite) or qualitative EMPA. Because H, C and O are not determinable by routine EMPA, the identifications of montanite, beyerite and bismutite are tenuous. Grain sizes were estimated petrographically.

PETROGRAPHY

The sections of P.1 consist of a substrate of massive, virtually monomineralic, coarse grained, anhedral quartz. The grains display smooth to sutured grain contacts and pronounced strain extinction. This is analogous to the anhedral 'buck' or 'bull' quartz of Dowling and Morrison (1988), which consists of milky white, interlocking, anhedral grains of variable grain size and orientation. The sections of P.2 are similar except for the minor disseminations of fine grained calcite and lesser albite. Extremely minute ($< 2 \mu$m) secondary fluid inclusions are abundant in the quartz grains, particularly in sections of P.2. Furthermore, irregular veinlets (in P.2), and sets of distinctly parallel planar veinlets (in P.1) cut the quartz vein, and are discontinuously infilled by green Fe-rich chlorite, calcite, muscovite, albite. Rare corroded grains of ilmenite with rutile are also observed. The compositions of chlorite, muscovite, ilmenite, albite and adularia are given in Tables UM-1-1 to UM-1-4.

Lateral dislocations of ≤ 1.5 mm are measurable on features on opposite sides of the fractures which are now defined by the veinlets. Where the fractures are not infilled, but rather have been re-sealed, the trace is delineated by sub-parallel, diffuse trails of minute secondary fluid inclusions oriented parallel to the fractures. The trails of inclusions are commonly accompanied by subgrain development in the dislocated and strained quartz. Scheelite is only observed in P.2B, and occurs as a large (≤ 4 mm) irregular polycrystalline mass in massive quartz, and is spatially unrelated to chlorite-calcite-muscovite-albite veinlets.

The opaques principally occur as discrete grains and polymineralic masses spatially related to chlorite-calcite- muscovite-albite veinlets. In P.2A minor pyrite altering to goethite pseudomorphs occurs discontinuously along a veinlet, whilst rare, minute grains ($< 20 \mu$m) of unaltered pyrite and pyrrhotite are disseminated in quartz adjacent to the veinlet. The composition of pyrite and pyrrhotite are given in Table UM-1-5. Furthermore, no other opaques (including native gold) are observed in sections of P.2. Importantly, this is consistent with the lack of sets of parallel planar veinlets in sections of P.2, which with the exception of one coarse mass (i.e. 1mm) of molybdenite in P.1A, are consistently the locus of opaques in sections of P.1. The minerals magnetite, tellurobismuthite and native bismuth, which had been identified by X-ray diffraction, were not petrographically observed in any section.

The opaque masses in sections of P.1 are generally < 1mm in size, and occur in, or adjacent to, the planar fractures; commonly connected by trails of fluid inclusions. With the exception of a discrete mass of tetradymite Bi_2Te_2S and gladite $CuPbBi_5S_9$ in quartz which remains fresh and unaltered, the opaque masses have undergone extensive alteration, most probably due to weathering. Gladite and tetradymite generally coexist and form the unaltered cores to most masses, which consist of montanite $Bi_2TeO_6.2H_2O$ and fine-intergrowths of beyerite $(Ca,Pb)Bi_2(CO_3)_2O_2$ and bismutite $Bi_2(CO_3)O_2$. Pilsenite Bi_4Te_3 was only observed as a remnant core in one mass of montanite and goethite $FeOOH$. In addition to Cu-bearing montanite, an unknown mineral con-

Table UM-1-1
Compositions of chlorite (ferroan chlinochlore: ripidolite)

Elem	wt%	wt% oxide P.1C.	No. of ions	wt%	wt% ˙oxide P.2A.	No. of ions	wt%	wt% oxide P.2A.	No. of ions	wt%	wt% oxide P.2A.	No. of ions
Naf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	24.86	31.98	5.91	24.14	31.05	5.70	23.35	30.04	5.46	21.76	27.99	5.09
Si	11.65	24.93	5.51	11.31	24.21	5.31	11.53	24.67	5.36	11.34	24.26	5.27
Al	10.47	19.78	5.15	11.16	21.09	5.45	11.16	21.08	5.40	11.46	21.66	5.40
Mn	0.17	0.22	0.04	0.15	0.19	0.03	0.21	0.27	0.05	0.24	0.31	0.06
Ca	0.05	0.07	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Mg	6.16	10.21	3.36	6.44	10.68	3.49	6.91	11.46	3.71	7.52	12.47	4.04
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.12	0.02	0.00	0.00	0.00
K	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.02	0.02	0.00
Ni	0.05	0.06	0.01	0.06	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00
F	0.08	0.00	0.04	0.06								
O	33.85	34.04	34.44	34.40								
Tot.		87.27			87.32			87.75			86.80	

Note:
Compositions shown water-free, and the number of ions are calculated on the basis of 20 cations per formula unit. Oxygen was calculated by stoichiometry. Because the ferric/ferrous ratio is not determinable by microprobe, the totals are low due to failure to calculate oxygen for ferric, but rather only for ferrous iron.

Table UM-1-2
Compositions of muscovite

Elem	wt%	wt% oxide P.2A.	No. of ions	wt%	wt% oxide P.2A.	No. of ions	wt%	wt% oxide P.2A.	No. of ions
Na	0.14	0.19	0.05	0.10	0.13	0.03	0.13	0.17	0.05
Fe	3.26	4.19	0.48	2.20	2.83	0.31	2.37	3.05	0.34
Si	21.20	45.36	6.24	23.40	50.07	6.44	21.80	46.64	6.24
Al	15.99	30.21	4.90	16.87	31.87	4.83	16.95	32.02	5.05
Mn	0.02	0.02	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Ca	0.03	0.04	0.01	0.02	0.02	0.00	0.00	0.00	0.00
Mg	1.02	1.70	0.35	1.26	2.09	0.40	1.05	1.74	0.35
Ti	0.09	0.16	0.02	0.09	0.15	0.01	0.13	0.22	0.02
K	7.56	9.10	1.60	4.21	5.07	0.83	6.47	7.79	1.33
Cr	0.02	0.03	0.00	0.01	0.02	0.00	0.02	0.03	0.00
Ni	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.12	0.14	0.09						
O	41.73	44.16	42.77						
Tot.		91.21			92.49			91.77	

Note:
Compositions shown water-free, and the number of ions are calculated on the basis of 12 Y and Z site cations per formula unit. Oxygen was calculated by stoichiometry. Because the ferric/ferrous ratio is not determinable by microprobe, the totals are low due to failure to calculate oxygen for ferric, but rather only for ferrous iron.

Table UM-1-3
Compositions of ilmenite

Elem	wt%	wt% oxide P.2A.	No. of ions	wt%	wt% oxide P.2A.	No. of ions
Fe	32.56	41.89	0.87	32.21	41.43	0.88
Al	0.03	0.06	0.00	0.02	0.03	0.00
Mn	2.39	3.09	0.07	2.36	3.05	0.07
Mg	0.01	0.02	0.00	0.02	0.03	0.00
Ti	34.02	56.75	1.06	33.34	55.61	1.06
Ni	0.00	0.00	0.00	0.02	0.02	0.00
O	32.81	32.20				
Tot.		101.86			100.17	

Note:
The number of ions are calculated on the basis of 2 cations per formula unit. Oxygen was calculated by stoichiometry. Assumed total iron to be ferrous iron.

Table UM-1-4
Compositions of feldspar

Elem	wt%	wt% oxide Albite P.1B.	No. of ions	wt%	wt% oxide Albite P.1B.	No. of ions	wt%	wt% oxide Adularia P.1B.	No. of ions	wt%	wt% oxide Adularia P.1B.	No. of ions
Si	31.84	8.11	2.98	31.89	68.22	2.98	29.80	63.76	2.98	30.32	64.86	3.08
Al	10.41	19.67	1.01	10.46	19.77	1.02	9.71	18.36	1.01	9.94	18.78	1.05
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00
Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Ti	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.04	0.06	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	8.74	11.78	1.00	8.70	11.72	0.99	0.00	0.00	0.00	0.00	0.00	0.00
K	0.06	0.07	0.00	0.03	0.04	0.00	14.05	16.92	1.01	11.93	14.38	0.87
F	0.00	0.00	0.04	0.08								
O	48.61	48.68	45.49	45.89								
Tot.		99.72			99.79			99.12			98.27	

Note:
Compositions shown water-free, and the number of ions are calculated on the basis of 5 cations per formula unit. Oxygen was calculated by stoichiometry.

Table UM-1-5
Compositions of pyrite and pyrrhotite

Elem	wt%	at% Pyrite	No. of ions	wt%	at% Pyrrhotite	No. of ions	wt%	at% Pyrrhotite	No. of ions	wt%	at% Pyrrhotite	No. of ions
S	53.32	66.12	1.96	40.32	53.74	1.00	40.62	54.03	1.00	39.85	53.48	1.00
Fe	47.04	33.49	0.99	60.13	46.02	0.86	59.88	45.73	0.85	60.22	46.40	0.87
Ni	0.16	0.11	0.00	0.17	0.12	0.00	0.20	0.14	0.00	0.08	0.06	0.00
Co	0.40	0.27	0.01	0.16	0.12	0.00	0.13	0.10	0.00	0.08	0.06	0.00
As	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.08
Sb	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tot.	100.95	100.78	100.84	100.24								

Note:
The number of ions are calculated on the basis of one cation per formula unit.

taining Bi, Ca, Cu and Fe forms as an alteration product after gladite in P.1-B. The compositions of gladite, tetradymite and pilsenite are given in Tables UM-1-6 to UM-1-8. The identification of gladite is tentative because of non-rational stoichiometry; 4.5 rather than 5 Bi atoms per formula unit. Gladite is one of five ordered sulfosalt minerals that were formerly considered to form a continuous solid solution between bismuthinite Bi_2S_3 and aikinite $CuPbBiS_3$ (Mumme et al., 1976). The present compositions may represent a hitherto unknown sixth phase with the stoichiometry of $Cu_2Pb_2Bi_9S_{18}$. The partial compositions given in Table UM-1-9 are most readily accounted for by montanite, whose identification is thus also tentative.

Native gold Au,Ag occurs as minute, irregular grains within masses of montanite and/or pilsenite. Only ten grains were observed in the five sections, and of which seven were observed within a single mass of montanite in P.1-B. The mean and maximum grain sizes are 10 and 28 μm, respectively. The compositional range of native gold is very restricted (See Table UM-1-10), with a mean composition of 92.0 per cent Au, 7.9 per cent Ag and 0.1 per cent Cu (i.e. fineness of 920).

Table UM-1-6
Compositions of gladite (?)

Elem	wt%	at%	No. of ions	wt%	at%	No. of ions	wt%	at%	No. of ions	wt%	at%	No. of ions
Cu	4.29	6.65	1.03	4.25	6.58	1.03	4.29	6.62	1.03	4.24	6.59	1.02
Pb	12.87	6.11	0.95	12.96	6.16	0.96	13.09	6.19	0.97	13.07	6.22	0.96
Bi	62.32	29.34	4.56	62.75	29.55	4.61	62.71	29.43	4.59	61.65	29.09	4.51
Ag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	18.83	57.77	8.98	18.76	57.59	8.98	18.82	57.57	8.97	18.83	57.92	8.97
Se	0.11	0.13	0.02	0.10	0.12	0.02	0.15	0.18	0.03	0.13	0.16	0.03
Te	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00
Tot.	98.43	98.83	99.05	97.95								

Note:
The number of ions are calculated on the basis of nine anions (S, Se and Te) per formula unit.

Table UM-1-7
Compositions of tetradymite

Elem	wt%	at% P.1B.	No. of ions	wt%	at% P.1B.	No. of ions	wt%	at% P.1A.	No. of ions	wt%	at% P.1A.	No. of ions
Bi	58.33	39.34	1.97	59.39	39.63	1.98	59.56	39.74	1.99	58.98	39.67	1.98
Pb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Te	35.35	39.05	1.95	35.57	38.88	1.94	35.29	38.56	1.93	35.35	38.94	1.95
S	4.83	21.25	1.06	4.88	21.23	1.06	4.93	21.43	1.07	4.82	21.14	1.06
Se	0.19	0.35	0.02	0.14	0.25	0.01	0.15	0.27	0.01	0.14	0.25	0.01
Tot.	98.73	99.98	99.93	99.29								

Note:
The number of ions are calculated on the basis of five ions per formula unit.

Table UM-1-8
Compositions of tetradymite and pilsenite

Elem	wt%	at% Tetradymite P.1C.	No. of ions	wt%	at% Tetradymite P.1C.	No. of ions	wt%	at% Tetradymite P.1C.	No. of ions	wt%	at% Pilsenite P.1C.	No. of ions
Bi	58.66	39.91	2.00	57.89	40.05	2.00	58.54	40.05	2.00	67.87	55.20	3.86
Pb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Te	35.43	39.47	1.97	35.06	39.73	1.99	35.33	39.59	1.98	33.21	44.24	3.10
S	4.51	20.00	1.00	4.33	19.53	0.98	4.39	19.59	0.98	0.09	0.48	0.03
Se	0.35	0.62	0.03	0.38	0.69	0.01	0.43	0.77	0.04	0.04	0.08	0.01
Tot.	98.94	97.65	98.69	101.21								

Note:
The number of ions are calculated on the basis of 5 and 7 ions per formula unit for tetradymite and pilsenite, respectively.

Table UM-1-9
Partial Compositions of Montanite (?)

Elem	wt% P.1C.	at% P.1C.	wt% P.1B.	at% P.1B.	wt% P.1B.	at% P.1B.
Bi	58.29	65.50	59.65	66.50	58.76	65.54
Pb	0.07	0.07	0.00	0.00	0.06	0.06
Cu	na.	na.	0.00	0.00	0.75	2.76
Te	18.68	34.38	18.30	33.40	17.32	31.64
S	0.00	0.00	0.00	0.00	0.00	0.00
Se	0.02	0.04	0.02	0.05	0.00	0.00
Total	77.05		78.01		76.89	

Note:
na. denotes not analyzed.

Table UM-1-10
Compositions of native gold

Elem	(Observedwt%) P.1C.	(Observedwt%) P.1C.	(Observedwt%) P.1C.	(Observedwt%) P.1B.	(Normalizedwt%) P.1C.	(Normalizedwt%) P.1C.	(Normalizedwt%) P.1C.	(Normalizedwt%) P.1B.
Au	88.60	90.62	90.72	89.27	90.14	92.33	93.26	92.43
Ag	9.67	7.42	6.48	7.27	9.84	7.56	6.66	7.53
Cu	0.02	0.11	0.08	0.04	0.02	0.11	0.08	0.04
Total	98.29	98.16	97.28	96.58	100.00	100.00	100.00	100.00

Note:
Observed compositions gave low totals due to extremely fine-grained size of native gold grains. Data were normalized to indicate 'true' compositions.

CONCLUSIONS

The native gold is intimately associated with finely disseminated mineralization consisting exclusively of a Bi-rich, telluride assemblage, and the alteration products of the latter due to weathering. No sulphides are associated with this mineralization, although pyrite and pyrrhotite are observed in P- 2A. The telluride mineralization occurs in or adjacent to thin veinlets, which define a set of parallel planar fractures. Lateral dislocations of ≤ 1.5 mm are apparent from features in the partially recrystallized strained quartz lining the fractures. The veinlets are defined by diffuse trails of minute secondary fluid inclusions, and by the discontinuous development of a chlorite- calcite-muscovite-albite assemblage. The lack of significant recrystallization of the dislocated and strained quartz adjacent to the fractures indicates post-metamorphic deformational and hydrothermal events. The quartz vein is probably characterized by a chemical signature of anomalous Au, Te, Bi, Pb, Cu, W and Mo assays, of which elevated values of Au, Bi and/or Te are likely indicative of 'kindly quartz'.

Anhedral 'buck' quartz is characteristic of the slate belt environment of Dowling and Morrison (1988). Veins from this environment are sulphide-poor, contain high fineness gold, are late orogenic, and are deposited under mesothermal (i.e. 250-350°C) fluid conditions. These authors note that gold that appears to be associated with anhedral 'buck' quartz is generally localized by features superimposed on the primary quartz (e.g. spider veinlets), and that the gold is not always associated with sulphides. Furthermore, they also note the similarity of the largely mesothermal Archean deposits with the slate belt deposits. Thus, deposition of the vein (of this study) probably occurred under similar fluid conditions, and importantly, from base metal poor fluids. Fluid conditions of low salinity, alkaline to near neutral pH, moderate to low temperature (≤ 350°C) and oxidation state (log $f(O_2)$ of -30 to -50) are thus indicated. Under these conditions gold can only be transported in significant amounts as bisulphide complexes (Romberger 1986).

Gold and telluride mineralization in the Goldlund mine, Northwestern Ontario, which is intimately associated with coeval pyrite, shows evidence of pre-existing pyrite controlling the deposition of Au and Te (Giddings and Perkins 1987), possibly through the processes of adsorption by, and coprecipitation with, sulphides. The latter mechanism however, which is common in many gold and sulphide deposits (Huston and Large 1989; Healy and Petruk 1990), is negated by the absence of an association of gold with sulphides. Furthermore, adsorption of gold by sulphides, particularly pyrite, or by semi-ordered carbon is similarly negated. The most likely mechanisms of gold deposition are oxidation and/or dilution.

Whilst tacitly recognizing the lack of comprehensive geological and petrographic control, a probable paragenetic sequence for the quartz vein is nonetheless proposed below.

Stage 1: Deposition of quartz with calcite, scheelite and molybdenite at elevated temperatures.

Stage 2: Shearing event with the formation of a set of planar veinlets, and deposition of the chlorite-calcite-muscovite-albite assemblage.

Stage 3: Deposition of pyrite and pyrrhotite along the veinlets.

Stage 4: Deposition of the tellurides and native gold at moderate to low temperatures.

Stage 5: Weathering and alteration of the sulphide and telluride mineralizations.

The presence of the veinlets with which the gold-bearing telluride mineralization is associated may be discernible without recourse to assays or petrography. On weathered outcrop surfaces the veinlets appear as black streaks. On freshly broken surfaces the (clearly linear) veinlets have a buff to orange colouration commonly with brown to black pods discontinuously developed along their length.

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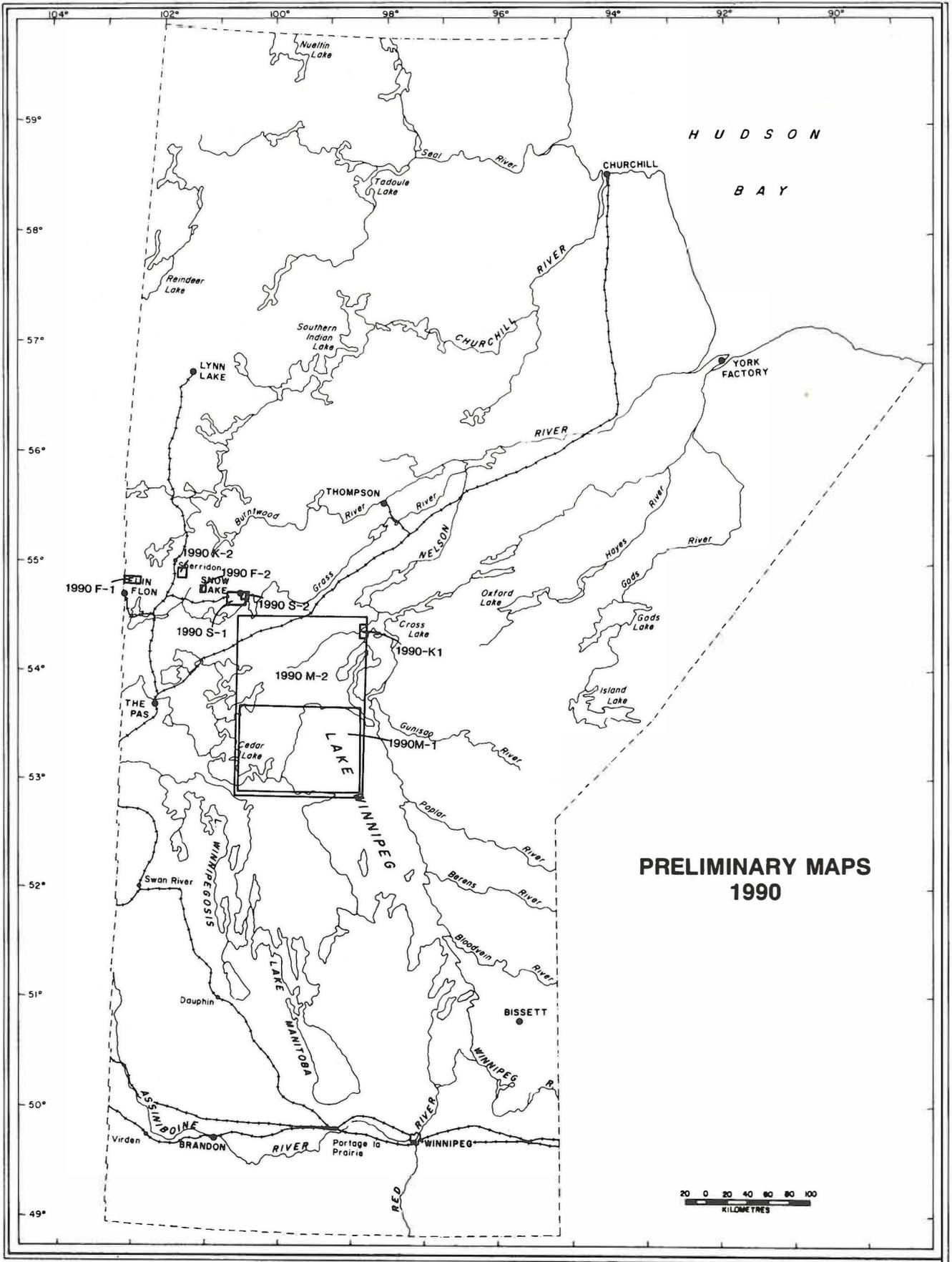
PRELIMINARY MAPS
1990

LIST OF GEOLOGICAL STAFF AND AREAS OF CURRENT INVOLVEMENT

GEOLOGICAL SERVICES

POSITION	PERSONNEL	AREA OF CURRENT INVOLVEMENT
Director	Dr. W.D. McRitchie	Manitoba
Geological Survey:		
Senior Precambrian Geologist	Dr. W. Weber	Manitoba
Precambrian Geologists	Dr. A.H. Bailes	Snow Lake
	H.D. Cameron	Cross Lake
	M.T. Corkery	Cross Lake-Northern Superior Province, Nelson and Churchill Rivers
	H.P. Gilbert	Tartan Lake
	P.G. Lenton	Cross Lake, Data Management and Analysis
	Dr. J.J. Macek	Thompson
	D.C.P. Schledewitz	Kississing Lake
	E.C. Syme	Flin Flon, Athapapuskow Lake, Elbow Lake
	Dr. H.V. Zwanzig	Churchill Province, Kisseynew belt
Mineralogist	C.R. McGregor	Mineralogy, Sub-Phanerozoic Precambrian
Geological Compiler (Atlas)	D. Lindal	1:250 000 Precambrian compilation maps
Phanerozoic Geologist	R.K. Bezys	Southwest Manitoba, Hudson Bay Lowlands, and Interlake
Mineral Investigations:		
Senior Mineral Deposit Geologist	Dr. G.H. Gale	Manitoba, specifically Flin Flon and Snow Lake
Mineral Deposit Geologists	Dr. P. Theyer	Island Lake/Southeast Manitoba: PGE investigations
	G. Ostry	File Lake-Sherridon area
	K. Ferreira	Mineral Deposit Geological Assistant
Resident Geologist (Flin Flon)	D. Parbery	Flin Flon - Snow Lake region
Industrial Minerals Geologists	W.R. Gunter	Northern Manitoba
	B.E. Schmidtke	Southern Manitoba
	J. Bamburak	Manitoba Inventory
	P. Athayde	Mineral Inventory Assistant
Computerization	G.G. Conley	Stratigraphic data files
	E. Su	Mineral deposit files
	L.E. Chackowsky	Geographic Information Systems
Geophysics, Geochemistry and Terrain Sciences:		
Section Head	I.T. Hosain	Rice Lake/Interlake
	Dr. M.A.F. Fedikow	Snow Lake/Southeast Manitoba
	Dr. E. Nielsen	Southern Manitoba
	G. Gobert	Snow Lake
Exploration Information:		
Assessment Geologist	B. Esposito	Assessment Geologist, Southern Region
Resident Geologist, The Pas	D.E. Prouse	Exploration activity, drill core program
Editorial & Cartographic Services:		
Geological Editor, Section Head	Dr. D.A. Baldwin	
Publications and Information	P.D. Leskiw	