Manitoba
Energy and Mines
Geological Services

Report of Activities 1993

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Manitoba
Energy and Mines
Geological Services

REPORT OF ACTIVITIES 1993

1993

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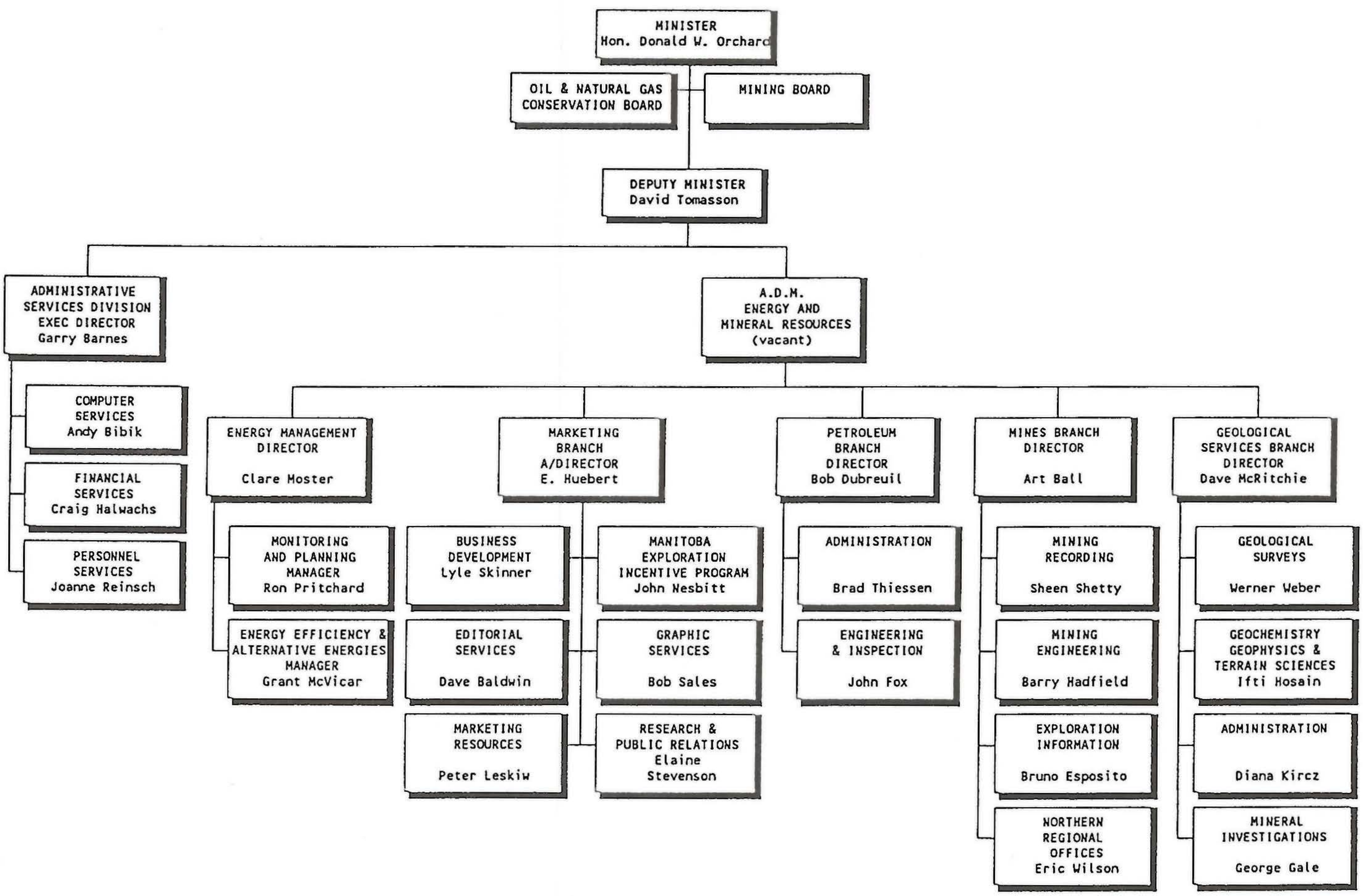
MANITOBA ENERGY AND MINES
DEPARTMENT OVERVIEW



OVERVIEW.D. October 12, 1993

Minister of
Energy and Mines
Minister responsible for Manitoba Hydro

Room 314
Legislative Building
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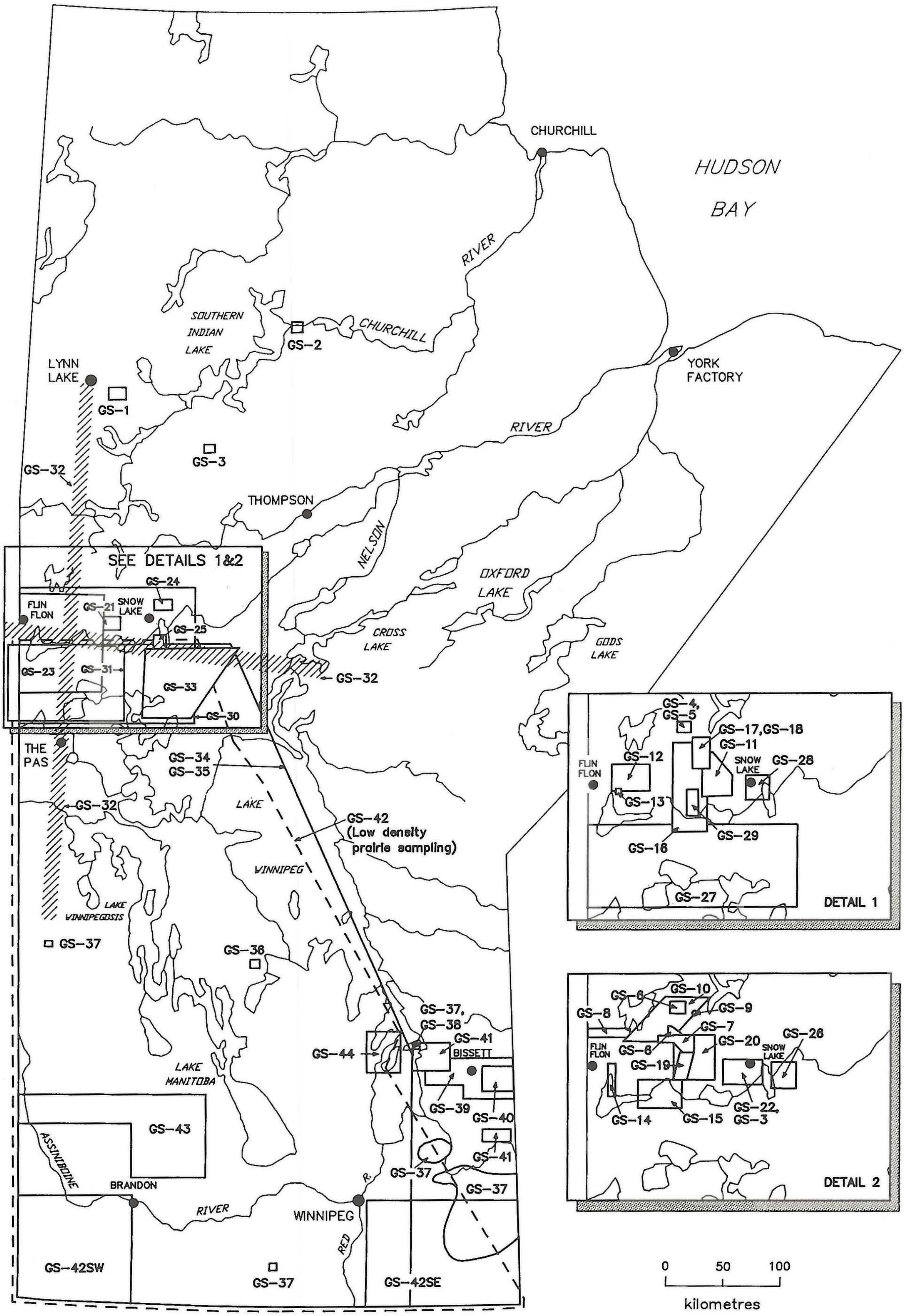
As the Minister of Energy and Mines, I am looking forward to discussing emerging mining opportunities at the Manitoba Mining, Minerals and Petroleum Convention '93. This year's convention has expanded to include the petroleum industry. Several new, and informative components, including four unique field trips, several new displays, and an outstanding list of guest speakers, will showcase Manitoba's mining industry.

Mining is the second largest primary resource industry in Manitoba and this convention provides an ideal opportunity to see how our province's innovative incentive programs offer advantages to capitalize on this industry. We have already witnessed the positive impact of these programs in the resurgence of the gold mining industry and exploration. In particular, Keystone Gold at Lynn Lake has become the first gold producer in Manitoba since 1990.

The rapid changes in sophisticated technology have added a new, challenging dimension to this competitive industry. Canada's mining industry is to be commended for taking the initiative to stay on top of new technological developments to ensure renewed growth and prosperity in this valuable industry.

On behalf of Manitoba Energy and Mines, I congratulate the individuals and companies in Canada's mining industry who are working as partners towards prosperity today and in the future. I am confident the information gathered at this convention will direct you to new ventures that are both productive and profitable.

Honourable Donald W. Orchard
Minister of Energy and Mines



Location of 1993 Projects

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by W.D. McRitchie

McRitchie, W.D., 1993: Introductory review; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 1-4.

GENERAL

The demand for information on Manitoba's geological endowment increased in 1993 as new incentives offered by the provincial government helped to maintain a healthy, and growing, level of exploration by the private sector (current estimate $30M), despite an overall downturn nationally.

The dominant thrust of the Geological Services Branch's (GSB) mapping programs and mineral investigations continues to be in support of exploration for additional reserves of copper and zinc, in the region feeding the Flin Flon smelter. Emphasis is also being given to upgrading documentation of value to nickel exploration along the southwest extension of the Thompson belt.

Development opportunities fostered and explored by the Department's Marketing Branch created a demand for new and more quantitative information on a wide range of commodities, principally for industrial minerals, and relatively nontraditional metals such as chromium, titanium, vanadium, silicon and magnesium.

In parallel with other provincial geological surveys, the GSB is also being drawn steadily into an elevated level of involvement with land access issues. In Manitoba, these are linked to the Province's Endangered Spaces commitments, and the new Natural Lands and Special Places Parks Strategy. The importance of removing the uncertainty related to land access is recognized by both levels of government, and this has precipitated a flurry of renewed interest in mineral resource assessment programs across Canada. An outline of assessments that would address Manitoba's needs is currently under development.

The Branch continued to provide information and advisory services through its central office in Winnipeg, and district offices in The Pas and Flin Flon, with expanded services scheduled for Thompson by the end of 1993. The Thompson office will house two Regional and one Staff geologists, together with a Regional Manager and support staff.

Consolidation of all Winnipeg based Energy and Mines and petroleum drill core, and GSB rock preparation operations at the Midland Street facility is well advanced, with plans to incorporate other Branch functions at this location in the upcoming year. Plans that will see new core examination facilities established in 1994, at the Centennial expediting base in Flin Flon, and in Thompson, are in the final stages of completion.

The elevated level of private sector exploration has in general triggered increased use of the provincial core storage facilities. Staff familiarity with key lithological packages, especially along the extension of the Thompson nickel belt, has proven of benefit to industry, as well as prompting a new surge in drill core collection activities.

Branch geologists continued to work closely with prospectors and industry geologists in all parts of the province where exploration is active. Field tours, property inspections, and demonstrations were given in several sectors of the Flin Flon/Snow Lake Mining District, in the northern Interlake, southeast Manitoba and in the Lynn Lake region. The latter was augmented with a two day seminar in Thompson on the geological setting and residual exploration potential of the Lynn Lake/Leaf Rapids region, and a two day workshop on geochemical and basal till sampling techniques.

Outreach activities included talks and tours given to students and groups in Whiteshell Park, and at Mafeking, as well as input to the EDGEO science teacher training program, and a Teachers Resource Package aimed at Grade 7 science students.

Provincial programs (and GSC contributions) were again partly funded under the Canada/Manitoba Partnership Agreement on Mineral Development *(MDA)*.

The Branch's task of providing benchmark geological and minerals information to the private sector and other government agencies continues to be greatly facilitated by program contributions from the Geological Survey of Canada (GSC). The highly functional cooperative federal/provincial endeavours started, and funded, under the Mineral Development Agreements have now been expanded into two, focussed and fully coordinated, multidisciplinary and multi-agency National Mapping *(NATMAP)* initiatives, the *Shield Margin* and *Southern Prairies* programs.

The *Shield Margin* program has been particularly successful in focussing the combined expertise of the federal and Manitoba and Saskatchewan Provincial Surveys (with complementary contributions from the universities of Manitoba, Calgary, Saskatchewan, New Brunswick and University of Quebec, Montreal), into an area where there is an urgent need for industry to define additional reserves of base metals. This highly timely *NATMAP* initiative has been able to build on the extensive database already generated in this area, and has triggered a sharp increase in the level and rate of information transfer to industry.

This important aspect of the work was particularly evident at the *NATMAP* field conference held in Flin Flon, June 4-6th 1993, with 150 of the 180 delegates being explorationists. Hosted by the Flin Flon CIMM, the conference featured a full day of talks followed by two days of field trips into the cross border region of Saskatchewan and Manitoba. New publication releases included a conference abstracts volume, a 1:50 000 scale cross border geological compilation of the Flin Flon area, and new gravity maps featuring the results of an extensive survey conducted in February 1993. An important fallout from the conference has been new staking throughout the area by resident and other companies.

The concerted effort being made to generate an enhanced understanding of the geology and factors controlling the distribution of base metal mineralization in the Snow Lake and Leaf Rapids regions has been boosted even further through detailed investigations conducted, primarily by the GSC, under their Exploration Science and Technology program *(EXTECH)*. The field component of this initiative is now completed, with a major outlay of preliminary results planned for the November 1993 convention in Winnipeg.

Ongoing activities related to the concurrent *LITHOPROBE* Trans-Hudson Orogen Transect included completion of a major refraction seismic survey coordinated by Z. Hajnal, University of Saskatchewan, with transects extending from Lynn Lake south to Swan River, and from Norway House west to the Primrose Weapons Range in Saskatchewan.

The explosion of diamond-related exploration currently active in the Northwest Territories, and neighbouring provinces and states, finally spilled over into Manitoba, and 1993 saw major new ground positions being taken by several companies new to the province including SouthernEra Res., Shannon Oil, Indicator Minerals, and CRA Ltd. amongst others. A spin-off of these activities was an elevated demand for information on geological attributes (indicator minerals and magnetic anomalies) targeting possible kimberlite occurrences, as well as a reevaluation of basement anomalies in the Interlake (Lake St. Martin, and Highrock Lake).

New high resolution airborne magnetic surveys conducted by the GSC (and jointly funded by the provinces and industry) in Alberta, Saskatchewan and southwest Manitoba have proven to be especially timely. The new releases in the Duck Mountain area, prompted widespread follow-up staking by industry.

In the south of the province, the *NATMAP Southern Prairies* project has provided an additional infusion of expertise and resources focussed primarily on upgrading the surficial database in southeast and southwest Manitoba. Analytical results stemming from an overburden drilling program conducted in 1992 will include new data on indicator minerals, and are expected to prompt even further interest in diamond exploration. Over 1000 claims have been staked by the private sector over the last year throughout the south of the province. Although no kimberlites have yet been confirmed, indicator minerals were identified in basal till samples from south of Winnipeg and Brandon, collected as part of a reconnaissance undertaken by the GSC in 1991. The results of a more intensive sampling program conducted by the GSC in 1992 (again with the assistance of the provincial surveys and research councils in Saskatchewan and Alberta) are to be released later this year, at the respective Government/Industry forums in each of the prairie provinces.

The expanded and highly successful format of the Department's annual meeting with industry, is to be repeated this year with a two day slate of speakers from the business community, paralleled with technical presentations and displays highlighting the results of the summer field programs. Industry will again be represented through the "Coreshack", together with talks covering exploration for sub-Paleozoic targets by Manitoba Mineral Resources on their Limestone Bay exploration project, and a feature presentation from Falconbridge on their exciting new William Lake nickel discovery. The program will also be expanded to include a full day of talks dealing with the province's petroleum potential.

A listing of all federal and provincial publications released during the year that have Manitoba subject matter, is provided at the rear of this volume.

PROGRAMS AND INVESTIGATIONS 1993/1994:

Provincial Workplans for 1993/1994 included 28 *"A-Base"* projects (8 with a field component) and 10 projects funded under the *MDA* (7 with a field component). Eleven of the 15 field projects were conducted in the region feeding the Flin Flon smelter.

The GSC mounted 33 projects in the province, with *"A-Base"* and *MDA* funding supporting 16 *Shield Margin* projects, 3 *Southern Prairies* projects, 3 *MDA* projects in southern Manitoba, and 11 under *EXTECH*. Several additional projects were supported through the *LITHOPROBE* initiative.

Lynn Lake/Leaf Rapids region:

Major advances in documenting the geology of this region were made in the previous two decades. In their Master Minerals Strategy (1992), Watts Griffis and McOuat (WGM) conducted a review of the region's residual mapping needs and exploration potential. GSB activities during 1993 were targeted to address the shortfall in geoscience documentation identified by WGM.

Mineral Deposit reports covering the region (NTS 64C/10, 11 and 12, and 64B south) are to be issued this November, and in March 1994. An update of geophysical assessment reports for the Leaf Rapids service area is to be released as an Open File in November 1993. This study was also used as a guide to planning an upgrade of 1:50 000 scale mapping of supracrustal rocks in the Partridge Breast area, conducted this summer. The mapping completed documentation of the metasedimentary and metavolcanic rocks, and demonstrated that the Southern Indian Lake area may contain more greenstones than previously suspected.

A vegetation geochemical survey, together with a ground radiometric survey, was conducted over fracture controlled zones of rare earth element-enriched britholite and allanite mineralization in the Eden Lake Aegirine-Augite Syenite, to determine whether this technique could be used to delineate extensions of the mineralization in areas of overburden. This project is a joint effort by the GSB and GSC.

An airborne inspection of areas burned in the Spring of 1993, around Barrington Lake and south of Lynn Lake, identified numerous new bedrock exposures associated with the Agassiz Metallotect, adjacent to Franklin Lake and along the Johnson Shear Zone that warrant detailed mapping in the near future.

Kisseynew Gneiss Belt:

Geological mapping and mineral deposit investigations on the south flank of the Kisseynew Gneiss belt intensified documentation in the area of the Jungle Lake and Ake Zone Cu-Zn massive sulphide deposits. New occurrences of cordierite-anthophyllite rock were found near the Ake zone. Geochemical surveys were conducted near both deposits and in the vicinity of drill-indicated VMS type mineralization 2.5 km north of the Jungle Lake siding.

A layered amphibolitic sequence on the north shore of Jungle Lake has the same stratigraphic position as amphibolites containing the Nokomis gold deposit, and Evans Lake and Lobstick Narrows gold occurrences.

In the Jungle-Puffy lakes map area, an unique volcanic formation containing mafic to ultramafic flows and intrusions was traced across the structural boundary between the Flin Flon and Kisseynew domains. Lateral stratigraphic facies changes at the base of the Missi Group range from conglomeratic, unconformably overlying Amisk Group supracrustals and intrusions, to finer grained basal meta-arenite conformably overlying the metagreywacke-turbidite sequences (now confirmed as younger than the Amisk group).

Laterally persistent marker units delineated in this years mapping confirm earlier interpretations defining major structural domains (fold-nappes) with differing exploration potential.

Numerous samples were collected from key units throughout the area as part of a geochronological study conducted by the University of Quebec, Montreal.

Further south, 1:15 840 scale mapping demonstrated that the Webb Lake plutonic complex may have a higher residual exploration potential than was previously recognized. Some phases of the complex appear to represent a subvolcanic roof zone with evidence of late magmatic hydrothermal alteration.

An M.Sc study (University of Calgary) in the Duval Lake area is using the relationship between mineral growth and fabric development to elucidate the metamorphic and deformational history of the Burntwood Suite, in a region of apparently divergent metamorphic gradients.

Flin Flon/Snow Lake:

The regional till program concentrated this year in the Naosap Lake area, where 197 samples were collected from hand dug pits. Glacier movement as interpreted from striae was toward 205.

Quaternary geological investigations in the Cormorant Lake area, by the GSC, included a systematic drift prospecting program, principally in the southern part of NTS 63K, where the basement is buried beneath Phanerozoic cover. Over 300 till samples were collected for follow-up petrological, geochemical and textural analysis, as well as trace element analysis of humus samples and a regional kimberlite indicator mineral study covering both NTS areas 63K and 63J.

1:5000 scale geological mapping of the Baker Patton felsic complex continued delineating subunits based on differences in texture and phenocryst populations. Structural observations suggest the sequence is overturned, and downward facing.

Reconnaissance mapping in the Cranberry Lakes area defined a major southwest-trending shear zone through Cranberry Lakes, separating two basalt formations that are members of the ocean-floor assemblage. On Simonhouse Lake the Berry Creek fault juxtaposes metavolcanic and plutonic rocks of the Flin Flon Belt with gneissic rocks of the sub-Paleozoic Namew Gneiss Complex. Mafic gneisses extending south from First Cranberry Lake are possibly correlative with magnetic members of the Namew Gneiss Complex.

Documentation of mineral occurrences in the Iskwasum Lake area was initiated this year, whilst similar work in the Elbow Lake and North Star Lake areas continued. Mineral Deposit reports for these areas are scheduled for completion in 1994.

In the North Star Lake area approximately 15, dominantly post tectonic breccia pipes have been documented, 9 of which are centred on an ultramafic stock. Preliminary observations suggest that there were three, diatreme-like, events separated by short intervals.

Structural studies in the North Star Lake area were completed during the 1993 season. The area has undergone polyphase deformation with four phases of ductile deformation followed by several semi-brittle to brittle events.

Detailed mapping of the Elbow Lake Shear Zone revealed a long history of deformation spanning the period prior to 1869 Ma through to post thermal climax (1830-1805 Ma). The shear zone appears to record several reversals of shear sense, which is typical for major shear zones related to readjustments of plate motion during long periods of progressive deformation, and which may help explain how supracrustal rocks of widely differing affinities are now juxtaposed.

A new GSC Open File map of NTS 63K/15 has been released as a contribution to the cooperative Elbow Lake project, initiated in 1991. Detailed descriptions are provided for each of the granitic intrusions in the region, many of which now exhibit excellent exposures generated during the 1989 forest fires. New observations suggest that the little-prospected granitic rocks may well be good hosts for epigenetic gold mineralization. Comparisons with the Phantom Lake stock west of Flin Flon, and the Star Lake pluton in the La Ronge belt suggest that the Elbow Lake plutons may also have potential for late magmatic hydrothermal gold, and porphyry type mineralization.

Detailed mapping and petrological studies of the Claw and Reed lakes mafic/ultramafic intrusions were conducted by the GSC as follow-up to earlier work by the province.

A preliminary investigation of the North Jackfish Lake Cu-Zn Deposit confirmed massive sulphide type mineralization in the Reed Lake granodiorite and granite pluton, underscoring the need to exercise caution in classifying apparently unfavourable geological host rock settings, during mineral resource assessments.

Detailed structural studies and lithological mapping in the Snow lake-Wekusko Lake area has delineated three generations of folds, and provided new insights regarding the nature of the McLeod Road, and Snow Lake faults and the Berry Creek, Anderson Bay and Bartlett shear zones. New interpretations of the relationships between metamorphic minerals and structural fabrics, coupled with isotopic age determinations, has questioned earlier observations regarding the timing of peak metamorphism.

Northwest of Chisel Lake recognition of a possible thrust fault in the VMS-hosting volcanic strata raises the possibility that mineralized horizons may be structurally repeated or truncated by these difficult to recognize structures.

Fundamental isotopic and geochemical differences between the Flin Flon and isotopically primitive Snow Lake segments suggests that the two may have evolved separately, and with different metallogenies. Further evidence of diversity comes from a new 1855 Ma age for the Wekusko Lake turbidite, showing it and the zinc-rich Bur Zone deposit to be significantly younger than the nearby 1892 Ma volcanics and VMS deposits at Snow Lake.

1:5000 mapping near the Osborne Cu-Zn deposit traced the stratigraphy hosting the mineralization 3.5 km northeast from the mine. Sillimanite grade alteration zones were also found on Long and Vince lakes in highly metamorphosed rhyolite and greywacke.

1:15 840 scale mapping of the volcanic terrane south of Goose Bay, Wekusko Lake revealed mainly mafic to felsic flows and flow breccias, with evidence of widespread silicification and carbonatization.

As part of a cooperative effort by the GSC and GSB under ***NATMAP***, several new zircon ages were obtained from volcanic and intrusive rocks in the exposed and sub-Paleozoic portions of the Flin Flon domain. A parallel geochemical program generating major, trace element and neodymium isotopic data, has documented the existence of four arc-related magma series within the Amisk Group volcanic rocks, and provided evidence that the Snow Lake and Flin Flon segments of the belt are separate arcs.

New gravity data from 1350 stations was acquired in February 1993 for NTS areas 63G, J, K, and L, to aid interpretation of the high resolution aeromagnetic data and drill core in the region south of Hanson and Snow lakes where extensions of the greenstone terranes are covered by Paleozoic rocks. Two detailed gravity profiles were also conducted over ultramafic intrusions in the Flin Flon belt.

The regional gravity data south of Hanson and Snow lakes were released at the June Field Conference in Flin Flon. That covering the southwest extension of the Thompson nickel belt will be released on October 1, 1994, following a confidential period with a consortium of exploration companies.

Twelve additional diamond-drill holes provided new information on the buried Precambrian in the Cormorant Lake region south of the main mining districts. The basement has now been subdivided into four major domains each with a distinct lithologic and aeromagnetic signature.

The GSC initiated several new structurally oriented investigations during the summer of 1993, to resolve key aspects of the tectonic evolution of the greenstones, and the adjacent more gneissic domains. Structural mapping of the Northeast Arm Shear Zone was initiated to investigate the structural setting of Archean granitoid rocks contained within the zone, as well as the zone's deformational history.

Structural studies in the transition zone between the Flin Flon and Kisseynew domains (File Lake-Limestone Point Lake area) identified a complex tectonothermal history involving early bedding-parallel faulting, two generations of tight to isoclinal folds with bedding-parallel cleavages, and two generations of upright folds with associated crenulation cleavages. The observation that prograde metamorphism peaked post F_1/S_1 but pre S_2, agrees with the timing of events recorded by earlier work by the Provincial Survey in the Burntwood migmatitic terrane to the north.

Detailed stratigraphic and structural mapping in the East Wekusko Lake area provided important new insights on the nature and relationships of the principal lithologies in the area, and the faults that generally bound them. The current work suggests that faulting, related folding and cleavage development took place during a progressive deformation event, in a possible fold and thrust belt setting.

The initial interpretations of Phase 1 ***LITHOPROBE*** seismic reflection studies of the lower crust and the lithospheric portion of the upper mantle in the Trans-Hudson Orogen, have been released in several articles (published or in press), and two manuscript submissions, as well as numerous oral and poster presentations. 20 km of combined regional and high-resolution seismic reflection data collected in 1991 (in collaboration with INCO Exploration and Technical services), is currently being processed using a customized data processing approach.

In 1993 ***LITHOPROBE*** again made considerable progress with the completion of three reversed refraction profiles totalling over 2000 line km. In the Manitoba sector, a north-south profile extended 550 km from Lynn Lake to Swan Lake, and an east-west profile from Norway House 755 km to the Primrose Weapons Range in Saskatchewan.

In order to facilitate future analysis of integrated datasets, the GSC plans to release the first CD ROM disks containing the combined provincial and federal *Shield Margin* database at the November Convention in Winnipeg. Datasets included on the CD ROM disks (in common interchange formats) will comprise bedrock geology, surficial geology, hydrography, gravity, magnetics, radiometry, mineral deposits, geochronology, Landsat and Synthetic Aperture Radar.

Nickel Belt extension:

Compilation of drillhole data and relogging of drill core continued for the region south of Wabowden in order to generate geological maps of the buried Precambrian basement along the southwest extension of the Thompson nickel belt. This years work resulted in a comprehensive catalogue of relogged core from 18 nonconfidential holes in NTS area 63J SW, as well as a 1:250 000 scale geological compilation map showing the western limits of the Churchill/Superior Boundary Zone.

Immediately to the south in NTS area 63G, five new holes, drilled principally for Paleozoic stratigraphic purposes, provided additional data on the basement in this segment of the Churchill/Superior Boundary.

Examination and logging of GSB and company core from the Grand Rapids region appears to indicate structure on the Precambrian surface, reflecting post Precambrian movement.

Southern Manitoba, and Interlake Region:

17 holes (1588.5 m) were drilled to provide additional stratigraphic information for Lower Paleozoic sequences in the Grand Rapids and Cormorant Lake areas, as well as information on the Precambrian basement. Holes in the Grand Rapids area are to be wireline logged by the Water Resources Branch or GSC to aid in correlation and provide information on groundwater aquifers. Initial results from temperature gradient profiles in two holes, suggests that aquifers in the carbonate formations are stratigraphically localized to permeable layers and migrate long distances within them.

The GSB contribution to the "Deep Petroleum" initiative has involved complete updating of all Lower Paleozoic well tops. This has now been completed and entered into the MOGWIS database. The new information has been used to generate new stratigraphic maps for the province, as well as intraformational maps for the Red River Formation.

The recent upsurge of interest in diamonds has provoked new staking in areas known to have anomalous geology. The diatreme-like meltrock associated with the Lake St. Martin structure is typical of areas undergoing re-evaluation, and the poor exposure in the area prompted a ground magnetometer survey to see whether the meltrock east of Gypsum Lake constituted a regionally extensive blanket, or a series of smaller discrete bodies. Initial results appear to favour the latter alternative.

Bulk samples of "meltrock" and granite were taken from islands in Lake St. Martin for fission track analysis by the GSC. The resultant understanding of the region's thermal history should help to resolve arguments favouring a meteoric impact or terrestrial tectonic and magmatic origin for the anomalous structure.

Field programs in southern Manitoba generated new data on a wide range of industrial minerals, including silica sand, lump silica, bentonite and building stone. Granites with dimension stone potential were identified in the Betula Lake and Lac Du Bonnet areas, other intrusions were documented and sampled as potential sources of granite aggregate.

Scanning electron microscope and image analysis studies of a composite sample of Black Island silica sand indicated contaminants in beneficiated sand were largely in the form of inclusions within the sand grains, precluding upgrading of the sand to chemical specifications. Further sampling has been undertaken to see whether the entire deposit is constrained by this limitation, or whether some stratigraphic intervals could be upgraded.

All known large quartz veins and quartzite bodies in southeast Manitoba were investigated to determine their potential as sources of high purity lump silica. Most proved to be contaminated, at least in part, with sulphides or host rock inclusions. Only a single body south of Long Lake appears to have the size and purity warranting further detailed evaluation.

Bentonite deposits in the Miami-Morden area and silica sand deposits in the Swan River area were bulk sampled for chemical and physical testing. Data will be entered into the Industrial Minerals database currently being computerized. An initial trial dataset is being established for the Hecla/Grindstone area.

In southeast Manitoba cooperative investigations between the GSC and GSB continued surficial studies as an aid to drift prospecting in the Rice Lake region and Bernic Lake areas. Samples were collected for age dating to confirm the juxtaposition of widely differing greenstone terrains in the Rice Lake belt.

Mapping of surficial deposits in southeast and southwest Manitoba continued under the aegis of the *NATMAP Southern Prairies* project. A total of 460 line km of augered transects were completed in NTS areas 62H (east half), and 52E (west half), together with complementary observations on glacial striae directions. In the Virden area 1:50 000 scale mapping of the surficial deposits has now been completed for 5 of the 16 sheets targeted by the project.

Manitoba General:

Major efforts continue in computerizing the minerals database, these being focussed into the *NATMAP Shield Margin* project, the Manitoba Oil and Gas Well Information System (MOGWIS), and the as yet embryonic Industrial Minerals database, a forerunner to a Minerals Database covering the entire province.

Computerized collection and storage of geological information and the production of maps using GIS technology has advanced rapidly in recent years. Current *NATMAP* projects include production of compilation maps at 1:50 000 for Snow Lake, and 1:100 000 scale, covering the south margin of the Kisseynew belt in Manitoba and Saskatchewan.

A computerized database containing all geochronological data relating to the Precambrian Shield in Manitoba will be released as a Open File report at the November convention.

All Lower Paleozoic tops have now been verified and entered into MOGWIS, along with UTM coordinates. This database is available in digital and hard copy formats, and is currently being used to digitally produce a series of Lower Paleozoic stratigraphic maps and isopach maps.

The first batch of seismic data stemming from petroleum exploration in southwest Manitoba was reprocessed at the University of Saskatchewan yielding two compacted seismic profiles covering 200 line km. The new cross sections are likely to be highly valuable in the ongoing stratigraphic re-interpretation of Williston basin sequences by petroleum explorationists and personnel from the GSC (ISPG), GSB and University of Saskatchewan.

S. B. Lucas and R.F.J. Scoates (GSC) are thanked for reading an early draft of this manuscript and providing comments/material that enhanced the scope of the review.

October 4, 1993

GS-1 A VEGETATION GEOCHEMICAL AND RADIOMETRIC STUDY OF A PART OF THE EDEN LAKE AEGIRINE-AUGITE SYENITE, NORTHWESTERN MANITOBA (NTS 64C/9)

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

Fedikow, M.A.F., Dunn, C.E. and Kowalyk, E, 1993: Vegetation geochemical and radiometric study of a part of the Eden Lake Aegirine-Augite Syenite, northwestern Manitoba (NTS 64C/9); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 5-10.

SUMMARY AND CONCLUSIONS

Preliminary results of this study indicate that the fracture- and pegmatite-controlled britholite and allanite mineralization in the study area are confined to a north-trending linear zone that has a characteristic radiometric response. High radiometric readings were only obtained from areas of outcrop. The absence of anomalous readings in overburden covered areas indicates the probable masking of the radiometric signature of the britholite and allanite zones. The vegetation geochemical response to these mineralized zones from outcrop to overburden covered sampling sites will be determined when vegetation analyses are complete.

INTRODUCTION

The Eden Lake syenite occurs 60 km southeast of the mining town of Lynn Lake in northwestern Manitoba (Fig. GS-1-1). This intrusion forms part of a 15 km^2 granitoid intrusive complex that is situated in the Reindeer Zone of the Trans-Hudson orogen and between the Lynn Lake and Leaf Rapids tectonic domains. The Eden Lake syenite has a marked airborne radiometric signature, has been intruded by fluorite-enriched pegmatite and contains intrusive phases with high concentrations of rare earth elements (REE), uranium and thorium. The zones of REE enrichment are associated with; (1) rusty weathered north- and west-trending fractures with pyrite, mag-

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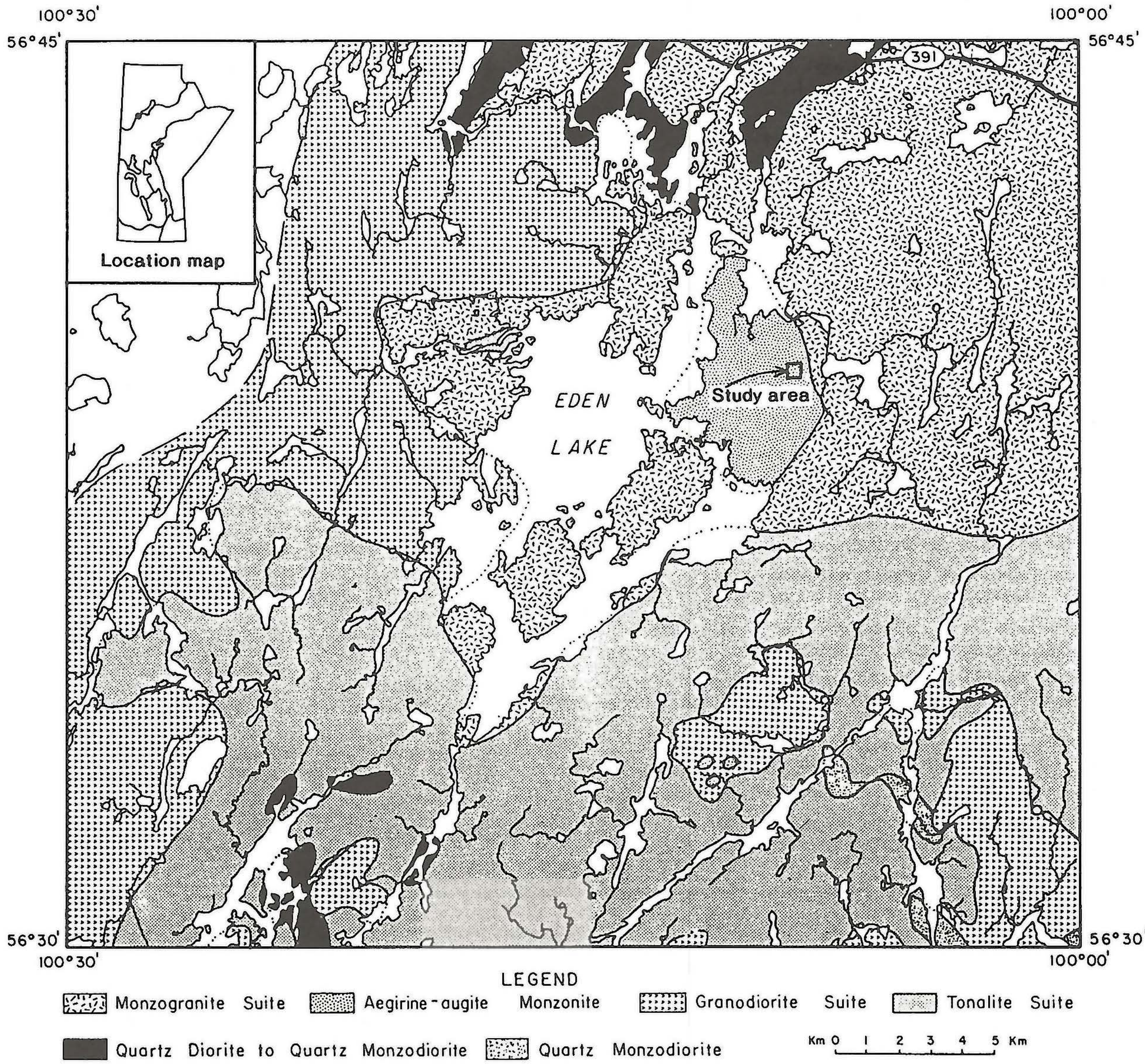

Figure GS-1-1: Location map and regional geological setting for the Eden Lake vegetation geochemical survey area.

netite, allanite and britholite, (2) red weathered aplite dykes, and (3) areas or zones of coarse grained granite and fluorite-bearing pegmatite. Despite a well developed regional airborne radiometric signature to the Eden Lake syenite ground radiometric surveys are hampered by overburden cover. McRitchie (1989) documented a moderate reduction in radiometric readings from exposed outcrop covered with a 10 to 20 cm veneer of overburden. If common species of vegetation can acquire and store REE as part of the process of nutrient acquisition then there exists potential for vegetation geochemistry to assist in the delineation of REE-enriched mineralization.

TOPOGRAPHY AND VEGETATION

The study area is characterized by mature boreal forest growing on isolated outcrop and outcrop ridges and in low-lying areas of swamp and muskeg developed upon glacial clay and sand till.

Vegetation in the survey area is characterized by ubiquitous black spruce (Picea mariana) and lesser stands of jackpine *(Pinus banksiana).* White spruce *(Picea glauca)*, birch *(Betula papyrifera)*, poplar *(Populus tremuloides)* and willow *(Salix spp.)* occur sporadically in the area. Alder *(Alnus crispa)* and labrador tea *(Ledum groenlandicum)* predominate among the shrubs. Outcrop is covered by a mixture of lichen *(Cladonia spp.)* and blueberry *(Vaccinium augustifolium).*

GEOLOGY OF THE EDEN LAKE SYENITE

The Eden lake aegirine-augite syenite is part of a post-orogenic intrusive complex that also comprises monzogranite, pegmatite, megacrystic monzodiorite and porphyritic granodiorite. The syenite typically contains several granitoid phases including a pink to cream monzosyenite phase with 15 to 30% ferromagnesian minerals that is intruded by fine grained, pink aplitic leucosyenite. The leucosyenite is subsequently intruded by pink and white granite dykes and is intruded, in turn, by pink pegmatites that contain interstitial and vug-filling purple fluorite as well as graphically intergrown quartz and potassium feldspar, plagioclase and lenses of white, nonmineralized quartz lenses.

The mineralogy of the medium grained, equigranular syenite and monzosyenite is characterized by pink potassium feldspar, aegirine-augite, hornblende, sphene, minor apatite and trace zircon. The weakly to nonfoliated syenite is marked by localized, centimetre-scale layers of ferromagnesian minerals and centimetre to millimetre wide pyroxene-rich veinlets with cores of feldspar and apatite. Local, coarse grained leucosyenite phases contain 2 to 3 mm long pyroxene crystals. Fine- to medium-grained, brecciated amphibolite fragments were observed in the syenite in the area of the vegetation geochemical survey. Pink pegmatite dykes trending 024° with almost vertical dips are present in the survey area. Veinlets, pods and lenses of britholite and allanite up to 10 cm wide are spatially associated with faults in the syenite (Fig. GS-1-2). These faults strike 014°, have been traced intermittently for up to 80 m, are generally rusty weathered and show a marked increase in radioactive response relative to the surrounding country rock (Fig. GS-1-3).

ROCK AND MINERAL GEOCHEMISTRY

Rock geochemical data from McRitchie (1989), summarizing trace element results from an allanite-britholite mineralized zone in the aegirine-augite syenite, are presented in Table GS-1-1. Mineral chemical analyses for allanite (3 analyses) and britholite (1 analysis) are given in Table GS-1-2 and are taken from Young and McRitchie (1990). These data confirm the REE-enriched nature of the aegirine-augite syenite, as well as identifying britholite and allanite as the mineralogical source of these elements, particularly the light rare earths (LREE). The lighter REE are concentrated in britholite and allanite in the order:

britholite: Ce>Nd>La>Pr>Sm

allanite: Ce>La>Nd>Pr>Sm

In addition to being highly enriched in Ce (27.06%) and Nd (17.53%) britholite also concentrates Th (3.28%). Up to 0.14% U was

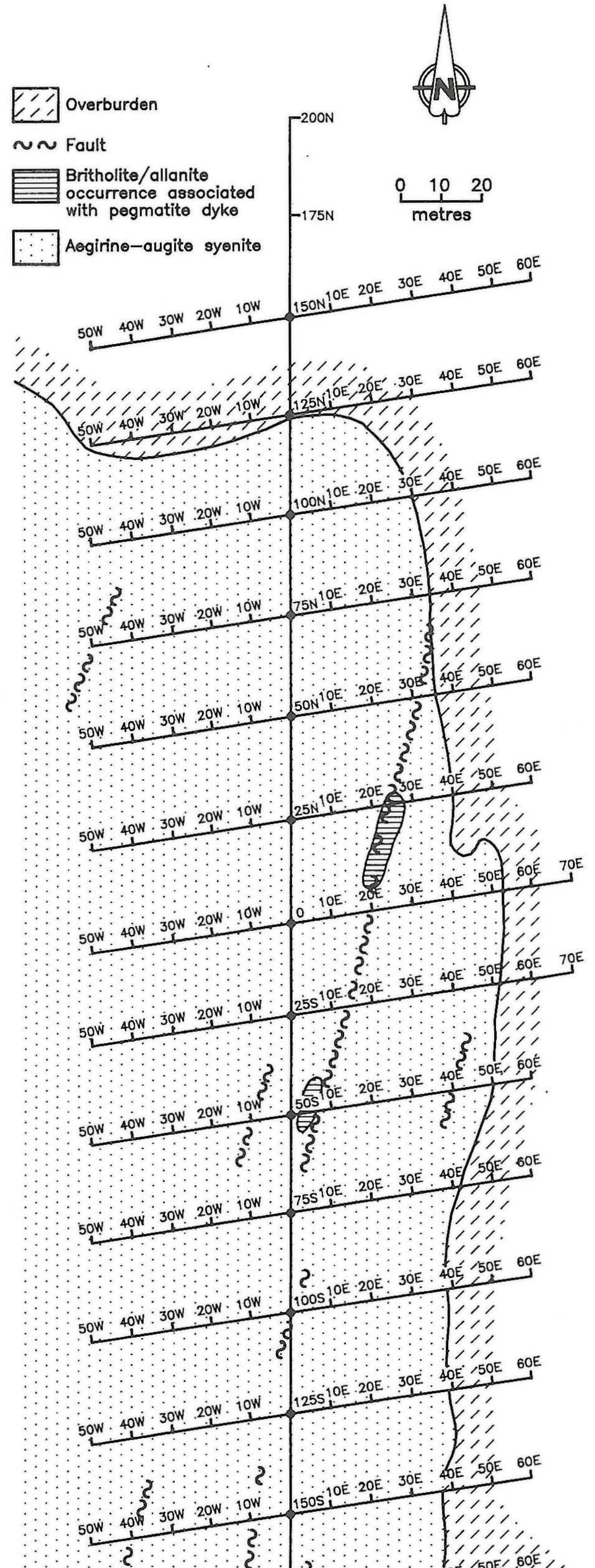

Figure GS-1-2: Geological and vegetation sampling and radiometric survey grid map for the Eden lake

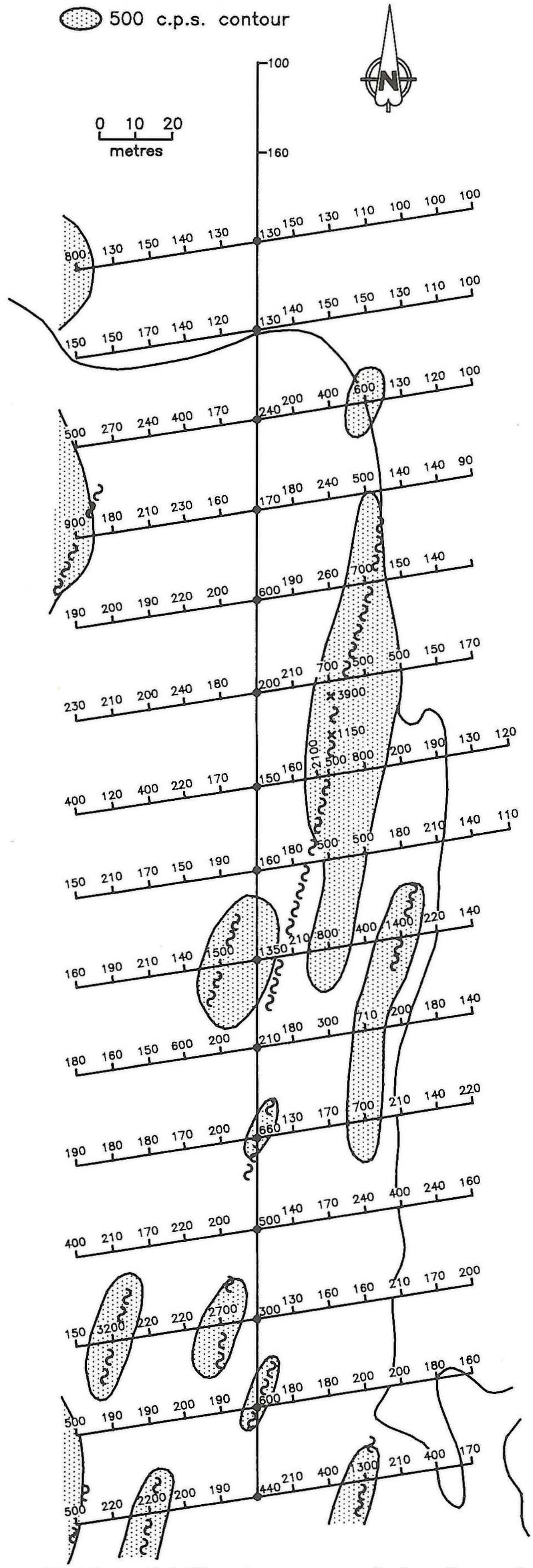

Figure GS-1-3: Scintillometer survey results from the vegetation geochemical survey grid, Eden Lake area. All radiometric measurements taken at ground level.

also detected in mineralized samples from the vegetation geochemical survey area (Table GS-1-1).

Table GS-1-1
Scintillometer readings from the Eden Lake vegetation geochemical survey grid

Scintillometer Reading (Total c.p.s.)	Grid Reference
100	200N
160	175N
300-800	150N+50W
130	150N+40W
150	150N+30W
140	150N+20W
130	150N+10W
130	150N
150	150N+10E
130	150N+20E
110	150N+30E
100	150N+40E
100	150N+50E
100	150N+60E
150	125N+50W
150	125N+40W
170	125N+30W
140	125N+20W
120	125N+10W
130	125N
140	125N+10E
150	125N+20E
150	125N+30E
130	125N+40E
110	125N+50E
100	125N+60E
220-500	100N+50W
270	100N+40W
240	100N+30W
240-400	100N+20W
170	100N+10W
240	100N
200	100N+10E
290-400	100N+20E
180-600	100N+30E
130	100N+40E
120	100N+50E
100	100N+60E
220-900	75N+50W
180	75N+40W
210	75N+30W
230	75N+20W
160	75N+10W
170	75N
180	75N+10E
300-500	75N+20E
240	75N+30E
140	75N+40E
140	75N+50E
90	75N+60E
190	50N+50W
200	50N+40W
190	50N+30W
220	50N+20W
200	50N+10W

240-600	50N
190	50N+10E
260	50N+20E
220-900	50N+30E
150	50N+40E
140	50N+50E
-	50N+60E
230	25N+50W
210	25N+40W
200	25N+30W
240	25N+20W
180	25N+10W
200	25N
210	25N+10E
220-700	25N+20E
270-500	25N+30E
220-500	25N+40E
150	25N+50E
170	25N+60E
200-400	0+50W
120	0+40W
210-400	0+30W
220	0+20W
170	0+10W
150	0
160	0+10E
230-500	0+20E
260-800	0+30E
200	0+40E
190	0+50E
130	0+60E
120	0+70E
150	25S+50W
210	25S+40W
170	25S+30W
150	25S+20W
190	25S+10W
160	25S
180	25S+10E
210-500	25S+20E
210-500	25S+30E
180	25S+40E
210	25S+50E
140	25S+60E
110	25S+70E
160	50S+50W
190	50S+40W
210	50S+30W
140	50S+20W
300-1500	50S+10W
280-1350	50S
210	50S+10E
300-800	50S+20E
280-400	50S+30E
220-1400	50S+40E
220	50S+50E
140	50S+60E
180	75S+50W
160	75S+40W
150	75S+30W
200-600	75S+20W
200	75S+10W
210	75S
180	75S+10E
240-300	75S+20E
280-710	75S+30E
200	75S+40E
180	75S+50E
140	75S+60E
180	100S+50W
180	100S+40W
180	100S+30W
170	100S+20W
200	100S+10W
220-660	100S
130	100S+10E
170	100S+20E
220-700	100S+30E
210	100S+40E
140	100S+50E
220	100S+60E
270-400	125S+50W
210	125S+40W
170	125S+30W
220	125S+20W
200	125S+10W
220-500	125S
140	125S+10E
170	125S+20E
240	125S+30E
280-400	125S+40E
240	125S+50E
160	125S+60E
150	150S+50W
300-3200	150S+40W
220	150S+30W
220	150S+20W
210-2700	150S+10W
200-300	150S
130	150S+10E
160	150S+20E
160	150S+30E
210	150S+40E
170	150S+50E
200	150S+60E
170-500	175S+50W
190	175S+40W
190	175S+30W
200	175S+20W
190	175S+10W
190-600	175S
180	175S+10E
180	175S+20E
200	175S+30E
200	175S+40E
180	175S+50E
160	175S+60E
200-500	200S+50W
220	200S+40W
500-2200	200S+30W
200	200S+20W
190	200S+10W
190-440	200S
210	200S+10E
260-400	200S+20E
290-1300	200S+30E
210	200S+40E
200-400	200S+50E
170	200S+60E
170	200S+70E

Table GS-1-2
Geochemical analyses of the Eden Lake syenite from an allanite-britholite bearing zone of pyroxene enrichment. Data from McRitchie (1989)

Sample	Sc	Th	U	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
04-89-31-1	2.90	3500	1180	13700	36500	20700	3060	600	180	54	21
04-89-08-1	2.90	1800	880	17700	45900	22900	3300	680	180	68	16
04-89-08-4C	1.90	2100	1400	13800	39600	24300	3150	670	180	27	14
04-89-06-5	2.47	775	690	12100	15000	6140	1840	247	66	56	5

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

Vegetation species and related organs collected for the orientation and grid surveys are summarized in Table GS-1-3. Approximately 350 g of eight year old black spruce twigs were collected from the north, south, east and west sides of the tree at each sampling station. For jackpine, alder and birch the most recent 45 cm of growth was sampled. One sample representing the crown of a black spruce tree was collected from the orientation sampling site. The top 45 cm of the tree was collected, dried and separated into needle, twig and cone components. For the grid survey black spruce was selected for sampling due to: (1) its ubiquitous presence on the sampling grid and throughout the Eden Lake area; (2) high contents of Sm in black spruce twigs in previous studies (Dunn, 1981, 1983) and to some extent in Dunn and Hoffman (1986); and (3) the chemical coherence of the REE.

The vegetation samples for the orientation survey were collected immediately adjacent to the britholite and allanite occurrence, whereas grid samples were collected at 10 m intervals from lines 25 m apart (Fig. GS-1-2). Since the mineralized zone outcrops on the eastern slope of the outcrop ridge sample lines were extended off of the outcrop and into the overburden covered areas. Samples were stored in brown paper bags and allowed to dry. Afterwards, needles were separated from twigs; leaves were separated from stems prior to drying.

Table GS-1-3
Summary of mineral chemical analyses for britholite and allanite from the Eden lake aegirine-augite syenite. Samples from McRitchie (1989), analyses from Young and McRitchie (1990)

Oxide (%)	Britholite		Allanite (3 analyses)	
SiO_2	11.31		30.30-30.54	
TiO_2	n.d.		0.81 -0.86	
P_2O_5	4.77		n.d.	
Al_2O_3	0.18		10.99-11.13	
MgO	n.d.		0.86 -0.98	
MnO	0.78		0.58 -0.62	
FeO	0.20		11.37-11.86	
Fe_2O_3	n.d.		6.15 -7.53	
CaO	2.08		10.31-10.47	
Y_2O_3	1.20	(9449 ppm)	n.d.	
La_2O_3	9.15	(78013 ppm)	5.96 -6.46	(50814-55077 ppm)
Ce_2O_3	27.06	(231011 ppm)	13.70-13.99	(116959-119432 ppm)
Pr_2O_3	7.26	(62029 ppm)	1.48 -1.67	(12645-14268 ppm)
Nd_2O_3	17.53	(150284 ppm)	2.85 -3.13	(24433-26833 ppm)
Sm_2O_3	2.43	(20953 ppm)	0.00 -0.27	(2328 ppm)
Gd_2O_3	0.89	(7720 ppm)	n.d.	
THO_2	3.28	(28824 ppm)	n.d.	
H_2O	0.81		1.50 -1.51	
Total	88.93		98.65-9.12	

Subsequent to drying, the samples will be ashed at 475°C, weighed into high purity, polyethylene vials and analyzed by neutron activation.

The results of vegetation geochemical analyses are unavailable at the time of writing.

RADIOMETRIC SURVEY

A Scintrex-Broadband gamma-ray scintillometer (model GSB-ISL with a 1.5" x 1.5" thallium activated sodium iodide crystal) was used to take 183 measurements at ground level from each of the vegetation sampling stations on the grid. (Fig. GS-1-2). Radiometric readings (total c.p.s. recording potassium, equivalent uranium and equivalent thorium) are summarized in Table GS-1-4 and plotted on Figure GS-1-3 with the addition of a 500 c.p.s. contour. A range in radiometric response is recorded in Table GS-1-4 if a high reading was obtained during a sweep of the immediate sampling site.

RESULTS

The 500 c.p.s. contour effectively delineates the allanite- and britholite-bearing fractures, as well as the smaller rusty-weathered, pyrite-bearing fractures in the study area. The highest responses in the survey (1150-3900 c.p.s.) correlate with known fracture-controlled and pegmatite-hosted occurrences of pods, lenses, veinlets and disseminated grains of britholite and allanite; background measurements are generally in the range of 100-220 c.p.s.; the fracture systems and their radiometric signatures trend north.

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Table GS-1-4

Summary of vegetation species and organs sampled for the orientation and grid surveys. Orientation samples collected immediately adjacent to britholite and allanite mineralization, grid reference 0+ 20E

				ORIENTATION SURVEY					
Species	Needles	Twigs	Outer Bark	Inner Bark	Trunkwood	Leaves	Crown Needles	Twigs	Cones
Black spruce *(Picea mariana)*	X	X	X	X	X		X	X	X
Jack Pine *(Pinus banksiana)*	X	X	X	X	X				
Birch *(Betula papyrifera)*		X				X			
Alder *(Alnus crispa)*		X				X			
Lichen *(Cladonia sp.)*									
GRID SURVEY - PART I - BASELINE AND LINE 0									
Black spruce *(Picea mariana)*	X	X	X						
Jack Pine *(Pinus banksiana)*	X	X							
GRID SURVEY - PART II - REMAINDER OF GRID									
Black spruce *(Picea mariana)*	X	X							

GS-2 SUPRACRUSTAL ROCKS OF THE PARTRIDGE BREAST LAKE AREA (PARTS OF NTS 64H/4, 5 AND 64G/1, 8)

by M.T. Corkery

Corkery, M.T., 1993: Supracrustal rocks of the Partridge Breast Lake area (Parts of NTS 64H/4, 5 and 64G/1, 8); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 11-12.

SUMMARY

Supracrustal rocks in the Partridge Breast Lake area represent the eastern termination of the Southern Indian Lake supracrustal belt. They consist of greywacke of the Long Point Suite, interlayered and overlain by mafic to felsic tuffaceous volcanic rocks and metasiltstone of the Partridge Breast Lake Suite. These rocks were deformed, metamorphosed and intruded by gabbro, diorite and granodiorite and subsequently eroded and overlain by conglomerate and sandstone of the Arkosic Suite. This was followed by intrusion of younger granodiorite and granite and regional metamorphism and deformation.

Volcanic rocks of the Partridge Breast Lake Suite were not previously identified in the Southern Indian Lake area; however, reconnaissance mapping in the Missi Falls area during the past field season identified several areas of Partridge Breast Lake Suite tuff and gabbro within the Long Point Suite.

INTRODUCTION

The Partridge Breast Lake area, 170 km north of Thompson, was mapped to upgrade the geologic data base in the supracrustal belt from 1:100 000 (Corkery and Lenton, 1990; Lenton and Corkery, 1981) to 1:50 000 scale. The area mapped this summer is part of the eastern extension of the supracrustal rocks of the Southern Indian Lake metasedimentary belt. Mapping, at 1:50 000 scale, covered the area south of Partridge Breast Lake in the northwest corner of NTS sheet 64H/4 and the south west portion of 64H/5, and was extended to the west into the eastern portion of 64G/1 and 64G/8 (preliminary Map 1993L-1). Bedrock exposure in the map area is sparse and restricted to a northeast-trending corridor in which much of the bush burned in 1989 and 1992.

MINERAL EXPLORATION HISTORY

Airborne geophysical surveys, as part of more regional studies, were undertaken by INCO in 1961 and in 1967.

In 1979 Troop Exploration and Development carried out airborne geophysical studies and ground follow up of numerous conductors. This program included diamond drilling near the south shore of Partridge Breast Lake, Spence Lake and in the "Cobalt" Lake area. Drilling of conductors reported iron formation in metagreywacke. A geological reconnaissance program was carried out by Hudson Bay Oil and Gas in the summer of 1979.

Manitoba Mineral Resources was active in the north Gauer Lake area and the southern portion of the map area in June of 1993.

GENERAL GEOLOGY

The area is underlain by three distinct lithological suites of supracrustal rocks.

1. The ***Partridge Breast Suite*** comprises a mixed section of metavolcanic and metasedimentary rocks. Metavolcanic rocks are chiefly tuff or reworked tuff that are hornblende porphyritic and/or biotite clot bearing. They vary in composition from basaltic to andesitic with minor interbeds of quartz-feldspar porphyritic rhyodacite and rare pillowed basalts. Dark gray metasiltstone dominates the sedimentary units; matrix-supported oligomictic and polymictic conglomerates are interbedded.
   Quartz-carbonate alteration and associated epidotization of the mafic tuff and diorite is common in Partridge Breast Lake Suite rocks, but is absent in the other suites. Small gossans and silicified zones occur in the rhyodacite .
2. The ***Long Point Suite*** comprises a section of garnetiferous graphite-bearing metagreywacke. It is distinctly different from the metasiltstone of the Partridge Breast Suite, which has less garnet, no graphite and commonly contains magnetite. Metavolcanic interlayers are absent in the Long Point section.
3. The ***Arkosic Suite*** is dominated by magnetiferous or hematitic metasedimentary rocks comprising polymictic conglomerate, meta-arkose and feldspathic metagreywacke. This suite unconformably overlies the Partridge Breast Lake and the Long Point suites..

Intrusive rocks have been divided into three groups based on their relationships with the supracrustal sequence. Layered ***pyroxenite-gabbro*** sills are probably contemporaneous with volcanism in the belt. Younger ***quartz diorite*** to ***tonalite*** dykes and sills cut the gabbros.

Tonalite to ***granodiorite*** bodies that intrude the Partridge Breast and Long Point suites are interpreted to be contemporaneous with M_1 metamorphism and D_1 deformation.

Deposition of the Arkosic Suite, which contains clasts of the older supracrustal rocks and the above mentioned intrusive rocks, was followed by intrusion of younger ***granodiorite*** and ***granite***. This was followed by a major event of regional metamorphism and deformation (M_2-D_2).

The more highly differentiated ***Thorsteinson granite*** and related ***pegmatites*** represent an even younger possible continental intrusive episode.

REGIONAL CONSIDERATIONS

In the map area, Partridge Breast Lake Suite metavolcanic and metasedimentary rocks dominate the supracrustal sequence with subordinate Long Point and Arkosic suites. However, in the region to the west, the supracrustal belt is dominated by Long Point Suite and Arkosic Suite metasedimentary rocks (Cranstone, 1972), and Partridge Breast Lake Suite rocks have not been identified.

In the Southern Indian Lake belt, metagabbro, quartz diorite and calcsilicate rocks have been identified (Cranstone, 1972, Frohlinger, 1972). As well, Frohlinger (1972) mapped mafic volcanic rocks in the Southern Indian Lake belt "Pukatawagan" Bay area that he included in the Long Point Suite. In the Partridge Breast-Gauer lakes area the mafic volcanic rocks are commonly associated with rocks of the Partridge Breast Lake Suite.

Late in the field season a short reconnaissance was carried out in the Missi Falls area to determine if earlier mapping by Cranstone (1972) had included Partridge Breast Suite rocks in the Long Point Suite. On the northeast side of Turtle Island portions of unit 1 and unit 3 (Cranstone, 1972) contain hornblende porphyritic layered gneiss similar in character to mafic tuff of the Partridge Breast Lake Suite. As well, mafic matrix conglomerates occur in these rocks. These units are intruded by gabbro and are unconformably overlain by Arkosic Suite conglomerates. Consequently, it is likely that some migmatites derived from metavolcanic rocks of the Partridge Breast Lake Suite occur in the Southern Indian Lake belt.

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GS-3 THE EXPLORATION SCIENCE AND TECHNOLOGY INITIATIVE (EXTECH), SNOW LAKE AND RUTTAN MINE AREAS, MANITOBA: AN OVERVIEW

by W.B. Coker[1]

Coker, W.B., 1993: The exploration science and technology initiative (EXTECH), Snow Lake and Ruttan Mine areas, Manitoba: An Overview; In Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 13-16.

SUMMARY

The end product of the EXTECH program will be a unified publication, scheduled to be released in 1994, in which the base metal environments of the Snow Lake and Rusty Lake regions will be characterized through the geology of the deposits, their relationship to the regional stratigraphy, the mineralogical and chemical compositions and physical properties of the ores, host rocks and alteration, the surficial geochemical dispersion patterns, and geophysical signatures.

INTRODUCTION

The aim of the Geological Survey of Canada's (GSC) initiative in Exploration Science and Technology (EXTECH) (1989-1994) is to improve concepts and technologies applicable to exploration for volcanogenic massive base metal sulphide deposits.

Through the formulation of integrated regional and deposit scale models, and the development of geophysical and geochemical methodologies and equipment, EXTECH is resulting in a range of products including:

a) enhanced regional databases for bedrock geology, airborne geophysics, regional lake sediment and water geochemistry, surficial till geochemistry and Quaternary geology;
b) detailed deposit documentation leading to integrated deposit modelling;
c) a regional mineral potential model developed using multilayering of data through a geographic information system (GIS);
d) improvements in existing exploration methods, including new ways to interpret geophysical and geochemical data; and
e) the development of new, or refined, geophysical and geochemical equipment and techniques.

The key to the program is the ability of the participants to coordinate their activities so that the flow of information will allow the knowledge from one discipline to be used to improve the conceptual approach and results of other disciplines. For example, the descriptive and genetic knowledge of base metal deposits acquired by geologists is being used by the geophysicists, geochemists and Quaternary geologists to explain phenomena within their data. On the regional scale, the success of this integration will be mirrored in the ability of the geomathematicians to effectively integrate data and concepts through a geographic information system (GIS), resulting in a widely applicable model for base metal exploration.

The Snow Lake mining camp and the Rusty Lake (Ruttan Mine) area were selected for the first EXTECH program because of:

a) the abundance of massive sulphide deposits and occurrences;
b) the presence of copper and zinc-rich deposits, and barren massive sulphides;
c) a pre-existing database to use as an effective framework, including provincial detailed geological maps and a mineral deposit inventory;
d) the presence of extensive hydrothermal alteration associated with the VMS deposits, abundant lakes for sediment and water analysis and the presence of complex Quaternary stratigraphy and ice movement history;
e) easy access to much of the region;
f) the cooperation of the provincial survey and mining and exploration companies operating in the region; and
g) the need to identify new reserves in these districts.

One of the early successes of the program is the integration of the Geological Survey of Canada (GSC) and Manitoba Energy and Mines (MEM), Geological Services Branch (GSB) geological mapping programs through which there is a continuous thread between 1:20 000, 1:5000 and deposit scale projects and a cooperative Quaternary geology and till geochemistry program. This cooperation ensures that there is no duplication of effort by federal and provincial geologists, that mapping is carried out to common standards and that the information obtained is immediately available to all parties.

The success this integrated project has experienced so far results from the development of a close and cooperative working relationship among the various members of the EXTECH working group: GSC, MEM-GSB and the exploration industry (*i.e.* Hudson Bay Mining and Smelting, Falconbridge and Minnova).

THE EXTECH PROGRAM

Following is a brief review of the work, results of which are on display in a series of posters at the Manitoba Mining, Minerals and Petroleum Convention '93, that has been carried out under the EXTECH program:

1. Integrated Deposit Models and Signatures

A. Snow Lake Area

Stratigraphic setting of early Proterozoic volcanic hosted massive sulphide deposits, Snow Lake, Manitoba (A.H. Bailes (MEM-GSB) and A.G. Galley)

The Snow Lake base metal camp is in the eastern part of the Flin Flon metavolcanic belt, a collection of accreted volcanic terranes within the Early Proterozoic Trans-Hudson Orogen. The Snow Lake area contains 10 of 24 producing and past producing massive sulphide mines within the Flin Flon metavolcanic belt, accounting for production plus reserves of 25.4 million tonnes. All of the VHMS deposits in the Snow Lake area are hosted within a tholeiitic island arc sequence (Amisk Group) consisting of a submarine basalt-rhyolite suite and associated volcaniclastic rocks (Bailes and Galley, 1991; Galley *et al.*, 1991). The Amisk group is divided into five stratigraphic cycles, with significant sulphide accumulations present at three stratigraphic intervals. Cu-rich VHMS deposits are associated with felsic extrusive piles within the thick sequence of Cycle 1 basalts. Overlying the Cycle 1 formations is an areally extensive base metal poor sulphide unit, and Zn-rich VHMS deposits lie above rhyolite lava domes along the contact between Cycle 3 felsic volcaniclastic rocks and Cycle 4 mafic lavas and volcaniclastic units. Extensive zones of alteration are associated with all three periods of hydrothermal activity, with semiconformable zones of chloritization predominating under the Cu-rich deposits, silicification under the barren sulphide horizon, and sericitization, chloritization and silicification present under the Zn-rich deposits. The results of isotopic analysis of the host volcanic pile indicates that the intervals of sulphide deposition are associated with the extrusion of the most primitive felsic lavas in the sequence whose signatures correspond to those of the underlying, high level subvolcanic intrusions.

The two base metal producing hydrothermal events are associated with the volcanic cycles in which large subvolcanic intrusions were emplaced at high levels within the volcanic pile. High geothermal gradients caused subseafloor, seawater convection, generation of base metal-rich hydrothermal fluids, and discharge of these fluids at extrusive volcanic centres. The accumulation of areally extensive base metal poor, sulphide-rich tuffite at the end of Cycle 1 was the result of regional scale, diffuse, low temperature convection during the cooling of the underlying subvolcanic intrusion.

1 Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

B. Ruttan Mine Area

Depositional environment of the large Ruttan Cu-Zn VHMS deposit, Manitoba (D.E. Ames)

The Ruttan multilensed deposit, which occurs at a major stratigraphic break, is located at the top of a dominantly volcaniclastic sequence above arc tholeiitic basaltic lava flows and is conformably overlain by mafic epiclastic rocks (Ames, 1991; Ames and Scoates, 1992). Stratigraphically below the distal (2 km) mine horizon, the Trail basaltic andesite comprises amygdaloidal, massive to pillowed lavas and related lensoid volcaniclastic deposits. Towards the deposit are a thick sequence of pervasively silicified intermediate fragmental rocks intercalated with minor basaltic flows. The conformable felsic host to the ore lenses is a semicontinuous unit of finely bedded and massive, sulphidic quartz phyric rhyolite tuff whose distal expression is enriched in Ba, Hg, Zn, Cu. The geochemical signature of adjacent, barren, subaerial Karsakuwigamak rhyolite flows is distinctive from those in the productive Ruttan environment. Proximal mine alteration is typified by silicification, sericitization and Fe-Mg metasomatism. Regional epidotization, silicification and sulphidation occur at distinct intervals. Visible microcline-quartz alteration occurs at the eastern fringe of the deposit and 2 km away within the host felsic tuff and also as a disconformable (425 X 100 m) plug in the Trail andesite. The orthogonal microcline veins and quartz stockwork with amoeboid microcline patches predate deformation and are cut by arsenopyrite-gold veins.

A shallow water environment for deposition of the Ruttan deposit is inferred from the combined presence of, abundant large vesicles in proximal volcanic strata, microcline alteration and the dominance of volcaniclastic rocks.

2. Enhanced Geophysical Methods

A. Airborne Geophysics

Gamma ray, magnetometer, VLF-EM surveys in the Snow Lake and Rusty Lake areas, Manitoba (R.B.K. Shives)

Airborne gamma ray spectrometric-magnetometer-VLF-EM surveys flown over the Snow Lake and Rusty Lake areas, Manitoba, were released April 1991, as GSC Open Files 2300 and 2301 (Hetu, 1991a,b).

Follow-up ground spectrometry and sampling were conducted in July 1991, to relate the airborne patterns to known VMS deposits and regional and detailed surficial and bedrock geology. Additional follow-up in 1992 included ground spectrometry and magnetic susceptibility measurements through the Chisel and Anderson stratigraphic sections.

Results of this component of the EXTECH project demonstrate that airborne and ground radiometric and magnetic measurements can be used to aid regional and local geological mapping. As a practical aid to VMS deposit exploration, these techniques can be used to identify and correlate volcanic stratigraphy (chemostratigraphy); to distinguish and subdivide subvolcanic intrusions acting as hydrothermal system heat engines and correlate them with specific volcanic cycles; and to identify felsic eruptive centres.

B. Borehole Logging

Development of an oriented 3-component borehole magnetometer. (P.G. Killeen, C.J. Mwenifumbo, D. Blohm, S. Balch (IFG Corp); and W. Morris (Morris Magnetics Inc.))

As fundamental as the geophysical measurement in a borehole is the location of the measurement. A GSC/industry cooperative effort in the EXTECH project has resulted in the development of a new borehole surveying tool that combines three component fluxgate magnetometers with solid state electronic tiltmeters. The device not only produces a continuous record of the dip and azimuth of the borehole but also does a vector magnetic survey while traversing the borehole.

The tiltmeters track the dip of the hole and rotation of the probe in the hole. The azimuth of the hole is determined from the total field vector computed from the three magnetic components. Logging at 6m/min with measurements every 0.5 seconds yields a data set at 5 cm intervals. This high data density makes it possible to separate the slow changes in the magnetic azimuth of the hole from anomalies caused by magnetic bodies in the vicinity of the hole. These magnetic bodies are of geologic interest and the vector displays of the data in vertical planes in North-South or East-West directions can help to visualize the location of the body. Both aspects (borehole orientation surveys and magnetic surveys) will be illustrated with examples from several mining areas.

C. HLEM-VLF-IP and Other Geophysical Techniques

Application of ground electromagnetic, VLF-EM and magnetic surveys in the Snow Lake area, Manitoba (A.K. Sinha and G.J. Palacky)

Ground electromagnetic and magnetic investigations were conducted over four sulphide deposits (Cook Lake North, Linda 2, Joannie Option and Copper-Man) in the Snow Lake area, Manitoba (Palacky and Sinha, 1992a,b; Sinha, 1992; Sinha and Palacky, 1992). The purpose of the surveys was to obtain and examine typical geophysical signatures over mineralized sulphide bodies, and to acquire geophysical properties of the sulphides and the host rocks in the area, which could be used in modelling. Multifrequency, multiseparation horizontal loop E.M. (MaxMin 1) was used at the first three sites to determine the resistivity characteristics of the sulphide bodies and host rocks. Ground total field magnetics and gradiometer surveys were also used at the first three sites to obtain the distribution of magnetic minerals in the area. Ground VLF-EM surveys using three VLF stations simultaneously, along with total field magnetics and magnetic gradiometer surveys, were made at the fourth site (Copper-Man) to obtain the distribution of conductive and magnetic materials at shallow depths.

Despite some differences in geological setting and mineralogical compositions, the investigation has shown that all four sulphide bodies are poorly conductive (conductance values range from 0.1 to 2.0 Siemens). Some conductors are distinctly magnetic, although the magnetic trend is not coincident with the EM anomalies at several places.

Recently, a few drill core and hand samples of the sulphide bodies from the Snow Lake area have been studied in the Rock Properties Laboratory of the GSC, and five of the seven samples showed unusually high resistivity. Such characteristics are quite unlike those observed in other greenstone belts, where the sulphides are highly conductive. The results of this study have important implications for mineral exploration in the Snow lake area, since potentially economic sulphide deposits may remain undetected, as standard EM systems are not sufficiently sensitive to detect poorly conductive targets.

3. Enhanced Geochemical Methods

A. Surficial Geochemistry

Regional and Detailed Till Geochemistry Studies, Snow Lake and Ruttan Mine Areas, Manitoba (C.A. Kaszycki, E. Nielsen, (MEM-GSB) and G.E.M. Hall)

A primary objective of the regional till geochemistry program of the EXTECH working group, is to identify regional geochemic patterns that may be related to zones of enhanced mineral potential. A variety of surficial materials were collected, including C-horizon till and humus. Geochemical trends for each type of sample media were identified and contrasted, in an effort to evaluate the relative utility of various types of material in regional geochemical exploration programs. In addition to standard trace element analysis, samples are presently being analyzed for major element distribution. By recasting major element data as standard indices of alteration, it is hoped that alteration zones associated with base metal mineralization within the area can be delineated. This ability would significantly increase target areas in geochemical exploration programs and more effectively delineate areas of economic interest.

Detailed studies have been carried out at three sites characterized by volcanogenic massive sulphide mineralization. These studies have been designed to identify and develop new analytical approaches to resolve the surficial geochemical expression of VMS deposits and associated alteration zones, using a variety of surficial materials. In addition, these serve as orientation studies, helping to guide the interpretation of regional surveys. Multimedia sampling, including B and C-horizon till, and humus was carried out at the Chisel and Linda 2 deposits, in an effort to evaluate the scale and form of geochemical anomalies produced by each. The geochemical expression of mineralization was found to vary dramatically with sample type, ranging from patterns reflecting glacial transport and erosion, to hydromorphic and biogenic dispersion, and anthropogenic contamination. C-horizon till samples produce the largest and most predictable anomalies, being elongate in the direction of ice flow. B-horizon anomalies are more diffuse, exhibit a lower background to anomaly ratio, and provide a smaller exploration target. Humus samples produce diffuse anomalies, that may reflect various anthropogenic and hydromorphic inputs.

Phase selective and sequential extraction techniques have been used to identify the residence sites of metals in a variety of surficial materials and to characterize the different types of geochemical anomalies observed in samples collected over the Chisel Lake volcanogenic massive sulphide deposit (Hall *et al.,* 1993). The extraction scheme employed enables differentiation of metals held at exchange sites and within carbonate minerals, metals associated with hydrous Fe and Mn oxides, metals associated with crystalline Fe and Mn oxides, metals associated with sulphide and insoluble organic matter, and metals held in resistate silicate minerals. Based on the analysis of C-horizon till, B-horizon till and humus collected at each of approximately 65 sites, three different types of geochemical anomalies have been characterized: those associated with glacial dispersal (mineralogenic anomalies); those associated with hydromorphic/biogenic dispersion; and those associated with surface contamination (anthropogenic anomalies).

Preliminary results of a detailed lake sediment survey, Snow Lake Manitoba: Implications for mineral exploration (P.W.B. Friske, M.W. McCurdy and D.F. Wright)

A detailed lake sediment and water survey near Snow Lake, Manitoba was completed as part of the EXTECH program. One hundred samples were collected from the western two-thirds of 63J/13 (600 km^2) and 246 samples from 63K/16 (900 km^2). Overall sampling density is 1 site per 4.3 km^2.

The samples have been analyzed by a combination of techniques including atomic absorption spectroscopy (AAS), instrumental neutron activation (INA) analysis and other specific techniques. Variables determined on the sediment samples include: Zn, Cu, Pb, Ni, Co, Ag, Mn, As, Mo, Fe, Hg, LOI, U, F, V, Cd, Sb Au, Ba, Br, Cr, Cs, Hf, Na, Rb, Sb, Sc, Ta, Th, U, W, La, Ce, Nd, Sm, Eu, Tb, Yb and Lu. Waters were analyzed for U, pH and F.

Initial evaluation of the data indicates bedrock and mineralization are strong factors affecting the trace element distributions of the area (*e.g.* anomalous base metal values immediately south and east of Snow Lake, reflecting known mineralization; elevated concentrations of Pb associated with felsic igneous rocks).

Sedimentological and geochemical effects of liming sulphide tailings on lacustrine systems, Ruttan mine, Manitoba (W.W. Shilts, W.B. Coker, G. Hall, and A. MacDonald)

Waters were collected from the surface and bottom of four lakes as well as from the Churchill River and approximately 20 small ponds beside the Leaf Rapids-Ruttan Mine-South Bay road to determine geochemical variations related to tailings and waste rock disposal from the Ruttan Cu-Zn VHMS deposit. Using sonar profiling as a guide, grab samples and cores of sediments were also collected in Ruttan, Brehaut, Rusty, and Alto Lakes to investigate the geochemical and sedimentological effects of liming the acid (pH = 2.5) outflow from Ruttan Lake. Preliminary results indicate that metal anthropogenically enriched in Ruttan Lake (Zn, Cd, and Hg, in particular) is scavenged and precipitated at the inflow end of Brehaut Lake as a result of adding lime solutions to the Vermillion River, midway through the 500 m reach that connects the Ruttan and Brehaut Lakes. Zinc in Ruttan Lake water (up to 17 ppm) is precipitated in the limy sediment that contains 3 to 5% Zn. Zinc is not enriched in waters of the next lake downstream from Brehaut Lake, Rusty Lake, which has Zn concentrations comparable to background water from Alto Lake (<< ppb Zn). Liming presently appears to be controlling metal migration effectively, but a huge body (500 000-1 000 000 m^3) of Zn-Cd-Hg-rich carbonate precipitate occupies the south end of Brehaut Lake that, without liming, would be receiving water of pH 2.5 from Ruttan Lake. The related study showed that zinc concentrations are elevated in water in contact with waste rock used to upgrade sections of the Leaf Rapids-Ruttan Mine-South Bay road as well as the road into Brehaut Lake.

B. Analytical Chemistry

Development of cost-effective phase-selective leaches for exploration geochemistry (G.E.M. Hall, J.E. Vaive and M. Hoashi)

There has been much renewed interest in the past several years in the application of phase selective leaches for (1) metals bound as humate and fulvate complexes in humus, and (2) metals adsorbed by the highly scavenging properties of amorphous Fe and Mn oxides and hydroxides present in soils and tills. This allows the geochemist to identify that portion of element that has been emplaced in the surficial environment in a relatively free or labile form (*e.g.,* through hydromorphic or gaseous transport), and subsequently fixed on preferential sites in a humus or soil, from the 'total' amount present that may represent a number of different sources (Hall *et al.,* 1993). The Analytical Method Development Section at the GSC has refined these two leaches to improve selectivity and continued to develop a sequential procedure to also identify those metals/metalloids held in the following phases: (1) carbonate/exchangeable/adsorbed; (2) crystalline Fe oxides; (3) sulphides and 'insoluble' organics; and (4) silicates.

4. GIS-Based Data Integration

Evaluating VMS potential using integration modelling in a GIS, Snow Lake, Manitoba (G.F. Bonham-Carter and D.F. Wright)

Geoscience data, collected through the EXTECH program, from provincial and federal governments and industry, were built into a spatial digital data base. This included bedrock mapping at 1:20 000 scale, lake sediment, till and lithological geochemistry, alteration, airborne radiometric, gravity and magnetic data, mineral deposits and structure.

Using both expert driven (Fuzzy Logic) and data driven (Weights of Evidence) type methods, these data were used in a Geographic Information System (GIS) to evaluate volcanic massive sulphide potential for the area including the Chisel, Lost, Ghost, Rod, Stall and Anderson mines (Reddy and Bonham-Carter, 1991; Reddy *et al.,* 1991, 1992). A key element of the data selection, analysis and modelling was the development of a conceptual deposit model established by geologists working in the area. These methods were successful in predicting the larger known deposits in the area. Of particular interest were several other areas showing high potential but containing no known deposits. These methods for mineral potential evaluation implemented on in a GIS provide a flexible, interactive approach to testing exploration strategies.

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GS-4 GEOLOGICAL INVESTIGATIONS IN THE VICINITY OF THE AKE ZONE Cu-Zn MASSIVE SULPHIDE DEPOSIT AND IN THE JUNGLE LAKE AREA, KISSEYNEW GNEISS BELT, MANITOBA (NTS 63N/2)

by G. Ostry and T. Tuba

Ostry, G. and Tuba, T., 1993: Geological investigations in the vicinity of the Ake Zone Cu-Zn massive sulphide deposit and in the Jungle Lake area, Kisseynew gneiss belt, Manitoba (NTS 63N/2); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 17-21.

SUMMARY

During 1993 a 1:5000 geological mapping project and geochemical sampling program was undertaken in the vicinity of the Ake Zone Cu-Zn deposit (Ostry and Trembath, 1992). The Ake zone mineralization occurs at a stratigraphic break between fine grained to aphanitic felsic quartzofeldspathic gneiss and medium- to coarse-grained, ridgy weathered, felsic, quartzofeldspathic gneiss. Cordierite-anthophyllite ± garnet rock was identified adjacent to the location of the surface projection of the Ake zone. In addition, a geological section through stratigraphy was mapped and geochemical samples collected in the vicinity of drill indicated pyrite, pyrrhotite and sphalerite mineralization approximately 2.5 km north of the Jungle Lake railway siding (Location 37, MDS Report 19, Ostry and Trembath, 1992). A stratigraphy similar to that identified in the vicinity of the Ake is exposed in this area. A follow up geochemical sampling program was also undertaken in the vicinity of the Jungle Lake Cu-Zn massive sulphide type deposit (*cf.* Ostry, 1992).

AKE ZONE CU-ZN DEPOSIT

The Ake zone (Fig. GS-4-1) was discovered by Hudson Bay Exploration and Development Limited during a 1971 diamond drill program. Surface exposures in the area comprise a northwest-dipping sequence of Sherridon Metamorphic Suite layered, pink to cream weathered, fine grained, predominantly felsic quartzofeldspathic gneiss (Unit 1; Fig. GS-4-2) that is structurally underlain by medium- to coarse-grained, felsic quartz-feldspar-biotite-garnet gneiss (Unit 2). The Ake zone contains well mineralized to near solid pyrrhotite and pyrite layers with blebs and stringers of chalcopyrite and subordinate sphalerite (A.T. Baumgartner, Hudson Bay Exploration and Development Limited, written communication, 1990). The zone occurs near, or at the contact between, Units 1 and 2 and is up to 4.6 m thick with an average thickness of approximately 1.5 m. At surface the zone strikes 210°, dips approximately 50° to the west and has a strike length of 183 m. At the 305 m (1000 foot) level the strike is 270° and the dip is less than 10° north. The mineralized zone plunges for at least 915 m at 345° with a variable dip.

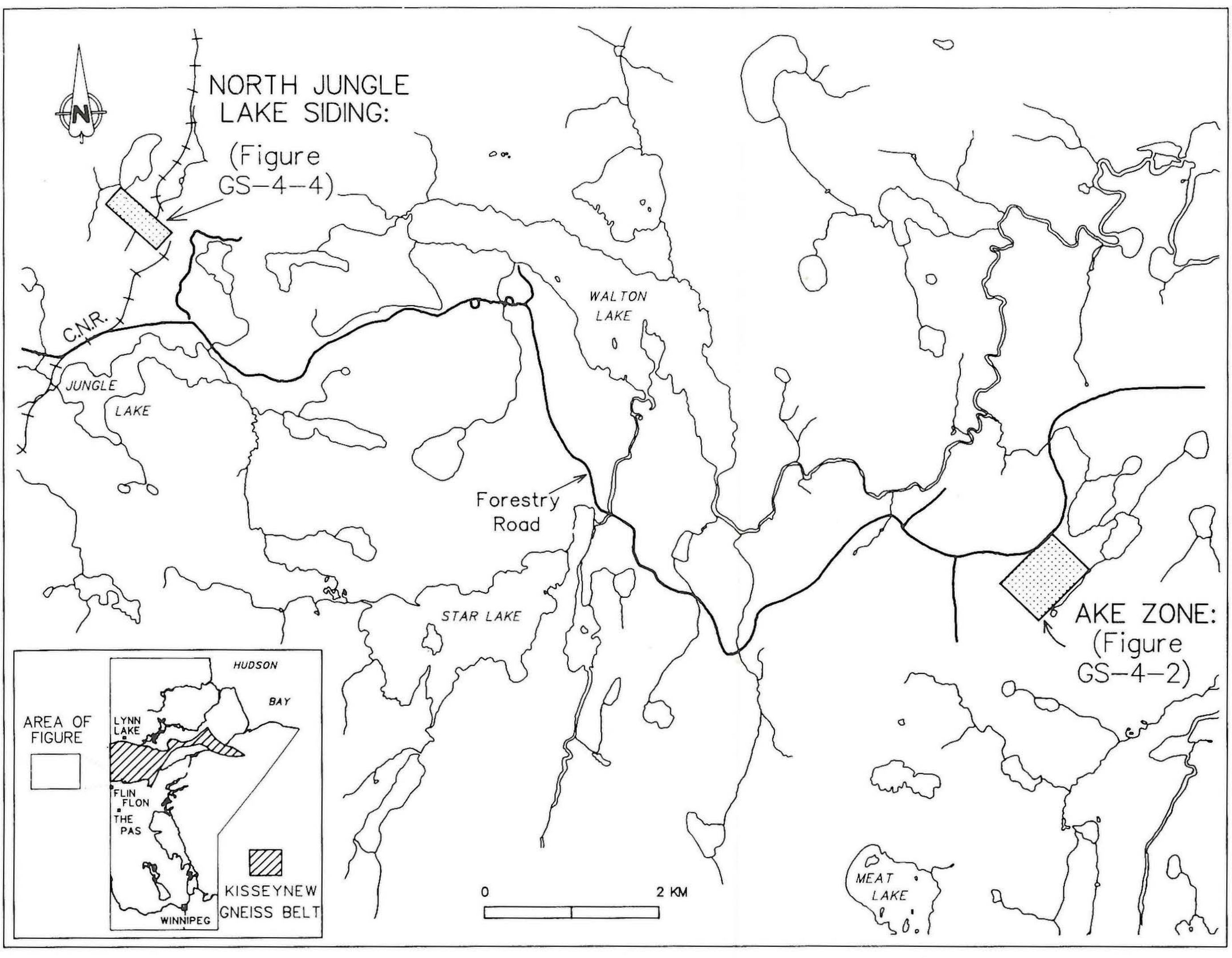

Figure GS-4-1: Location of the 'Ake Zone' and 'North Jungle Lake Siding' project areas (NTS 63N/2).

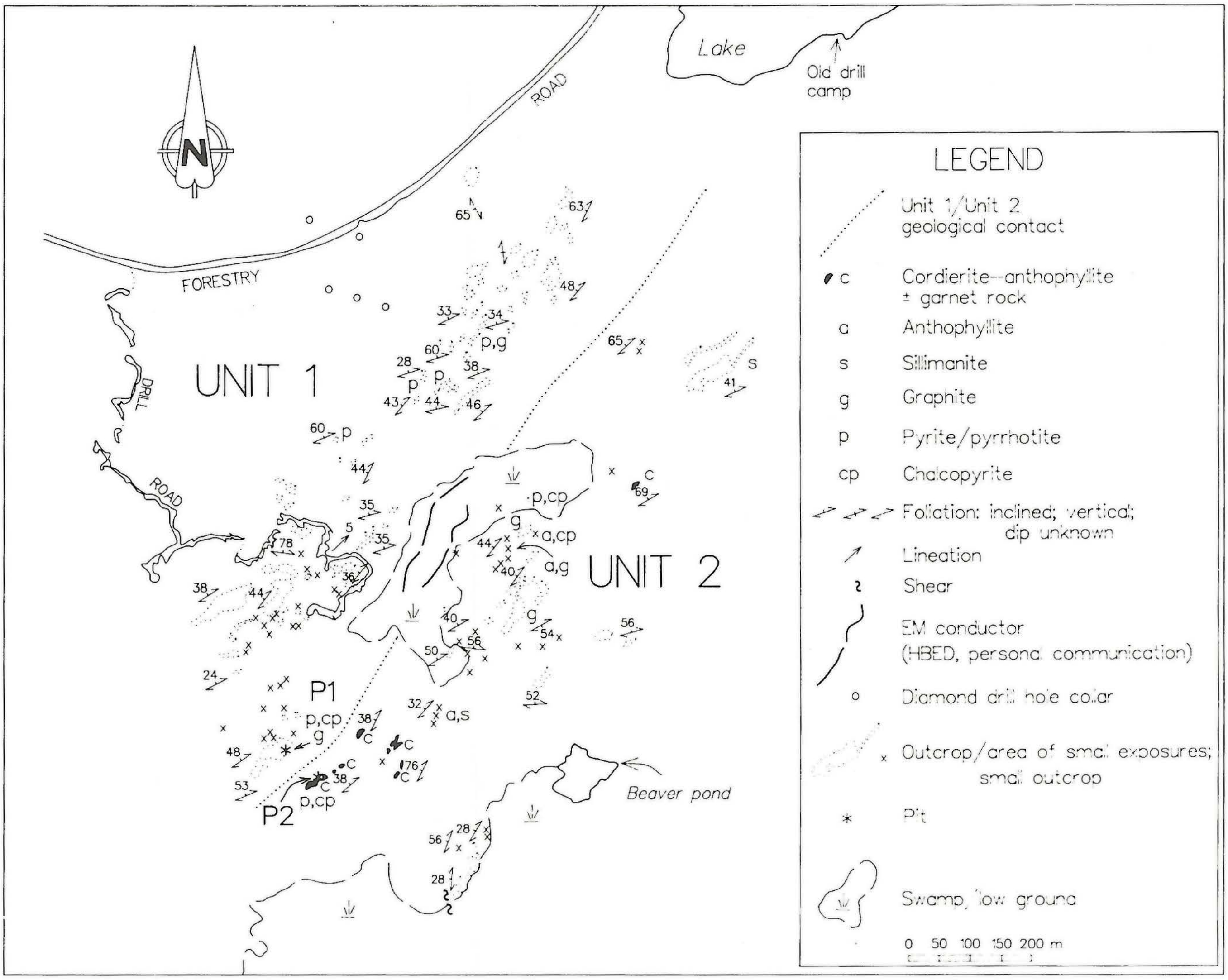

Figure GS-4-2: ***Geology in the vicinity of the Ake Zone Cu-Zn massive sulphide type deposit (NTS 63N/2).***

Unit 1

Unit 1 is predominantly a pink to pale orange weathered, fine grained, locally aphanitic, granoblastic, massive to laminated quartz-feldspar-biotite gneiss with rare garnet and magnetite. Locally, subhedral garnet is present, but it rarely exceeds 2 to 3 mm in diameter. Layers are on the order of 1 cm to tens of cm thick and are defined by variations in the mafic mineral content. Similar rock with hornblende instead of, or in addition to, biotite is also present, but is less abundant. A ridgy textured weathered surface that is delineated by numerous closely spaced 1 to 2 mm thick quartz-rich segregations is characteristic of the Unit 2 felsic rock, but is only developed locally. Pink, pegmatitic quartzofeldspathic segregations and quartz veins, that typically constitute up to 15%, can compose 60% of an individual exposure. Layers of slightly more mafic (pelitic?) quartz-feldspar-biotite-garnet gneiss that contain up to 30% mafic minerals and slightly larger garnets (up to 2 cm) form approximately 5% of Unit 1. Calc-silicate layers comprising quartz-rich quartz-feldspar-diopside gneiss ± garnet also occur within Unit 1, but are not common. Near the north limit of the map area amphibolite ± garnet is interlayered with the felsic gneiss. Rusty weathered areas that contain up to 1% fine grained disseminated pyrite and rare graphite are erratically distributed throughout Unit 1, but are more prolific in areas adjacent to the surface projection of the Ake zone. A recent (1993) pit blasted in a rusty weathered patch (P1; Fig. GS-4-2) exposes felsic (silicified?) gneiss with minor amounts of diopside and fine grained disseminated 1 to 3% pyrrhotite ± chalcopyrite, pyrite, and graphite.

Unit 2

Unit 2 consists predominantly of medium- to coarse-grained, felsic quartz-feldspar-garnet-biotite and/or hornblende gneiss; sillimanite occurs locally. Most rock exposures display a distinctive ridgy weathered surface and, up to 5 cm, but more commonly 2 cm, subhedral, sieve textured garnets and/or lensoid fine grained granular masses of garnet. The ridgy texture reflects numerous closely spaced (mm scale) quartz-rich segregations that form discontinuous, parallel to subparallel, 1 to 3 mm wide quartz ribbons throughout the rock. The quartz ribbons either deflect around and/or pass through the garnet. Layers within the felsic gneiss are defined by variations in the percentage of mafic minerals and range from 1 cm to 1 m in thickness. Quartzofeldspathic segregations ordinarily constitute 5 to 15% of an outcrop, but locally can form up to 50% of a rock exposure. Quartz-rich, diopside-bearing calc-silicate layers form a minor component of Unit 2. Near the south limit of the map area a thin 5 to 10 cm thick fine grained, pink weathered, granoblastic, massive quartz - feldspar - hornblende ± biotite ± garnet gneiss, which is lithologically similar to Unit 1, forms a 5 to 10 cm thick layer within the ridgy weathered gneiss.

Anthophyllite-bearing rocks are important local constituents of Unit 2. A layered anthophyllite-bearing zone is exposed over approximately 10 m (true thickness) near the surface projection of the Ake zone at the south limit of the map area (Fig. GS-4-2). A rock with coarse grained anthophyllite (up to 20 cm long crystals) and cordierite (up to 5 cm long crystals) ± garnet (Fig. GS-4-3) forms the thickest layer within this zone. Coarse grained garnet-anthophyllite ±

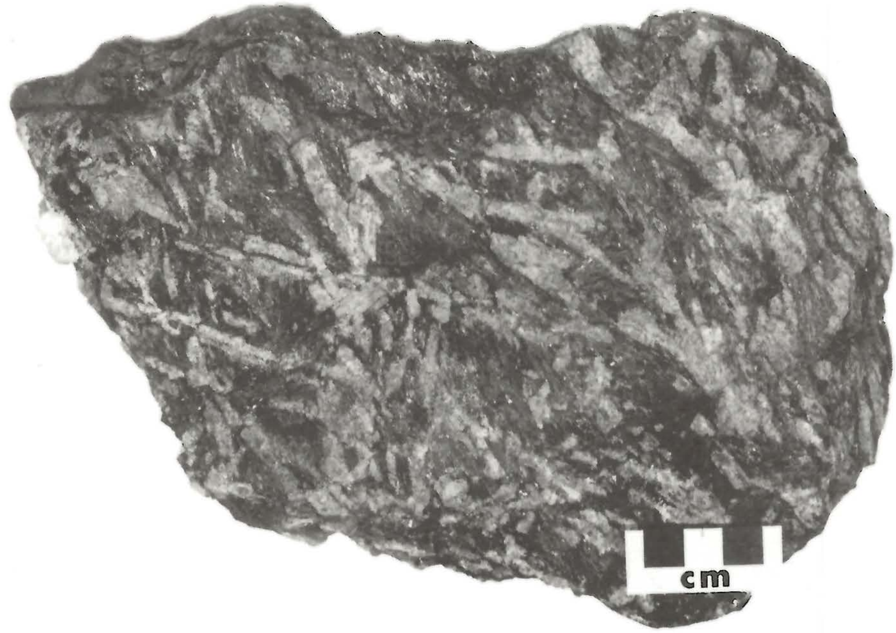

Figure GS-4-3: Coarse grained cordierite-anthophyllite rock.

cordierite rock, and felsic quartz-feldspar-garnet-biotite gneiss that contains up to 20% anthophyllite also are interlayered within this zone. Approximately 50 m along strike to the northeast, layered, ridgy weathered, quartz-rich, sillimanite-bearing felsic gneiss ± magnetite is interlayered with ridgy weathered, quartz-rich felsic gneiss that contains 5 to 10% anthophyllite. Similarly, further to the northeast, anthophyllite- and garnet-rich rock form thin (cm) interlayers within felsic quartz-rich gneiss. Locally, anthophyllite also constitutes a minor constituent of the mafic mineral component within felsic quartz-rich gneiss. A rock with coarse grained garnet and anthophyllite with up to 10% feldspar is exposed near the northeast limit of the map area, approximately 550 m along strike to the northeast from the coarse grained anthophyllite-cordierite rock exposures (Fig. GS-4-2).

Massive, medium grained amphibolite and garnetiferous amphibolite probably form conformable units within the felsic gneiss, but due to a paucity of outcrop the relative thickness of these layers/sills(?) could not be determined.

Mineralization

Rusty weathered areas on outcrops are common, notably in proximity to the surface projection of the Ake zone mineralization, but are erratically distributed. Most rusty weathered rocks contain 1% or less fine grained disseminated pyrite and/or pyrrhotite with rare fine grained disseminated graphite or chalcopyrite (Fig. GS-4-2). Another recent (1993) pit blasted in a rusty weathered area (approximately 1 x 2 m) within the coarse grained anthophyllite-cordierite rock (P2; Fig. GS-4-2) exposes 1 to 3% fine grained disseminated pyrrhotite ± chalcopyrite and pyrite mineralization.

Structure

Three, possibly four periods of deformation have affected the rocks in this area. The earliest deformation (D_1) produced a well developed foliation (S_1) defined by biotite or hornblende alignment parallel to compositional layering. The second deformation (D_2) produced small scale recumbent predominantly tight to open 'S' asymmetry folds that fold the S_1 foliation. A later deformational event (D_3) has produced open folds with axes that have shallow plunges to the north and close to vertical axial planes that have northwest and northeast axial traces. Locally, quartzofeldspathic mobilizate forms veins that are deformed on the limbs of F_3 folds and are axial planar within their hinges. An approximately 3 to 4 m wide, northerly striking and steep dipping shear zone has deflected S_1 at the south limit of the map area (Fig. GS-4-2) indicating a sinistral strike slip movement.

Discussion

The Ake zone massive sulphide type deposit occupies a stratigraphic position between a sequence of fine grained, massive to laminated, pink weathered, felsic quartzofeldspathic gneiss (Unit 1) and a sequence of coarser grained ridgy weathered felsic quartzofeldspathic gneiss that contains large porphyroblastic garnet (Unit 2). Host rocks to the 'Cu-sulphide' massive sulphide type mineralization (Location 5, Ostry and Trembath, 1992) located north of Molly Lake and documented in Ostry and Bieri (1990) are comparable to the fine grained massive rocks prevalent within Unit 1. Host rocks to the Jungle Lake massive sulphide type deposit, documented in Ostry (1992) are analogous to the coarser grained ridgy weathered Unit 2 rocks and are similar to Sherridon Group ridgy weathered quartz-rich quartzofeldspathic gneisses described by Bateman and Harrison (1946) in the vicinity of the Sherritt Gordon massive sulphide deposit at Sherridon, Manitoba and Robertson (1953) in the NTS 63N/2 area.

The cordierite-anthophyllite rocks may represent the alteration zone or feeder pipe to the Ake zone deposit, but crosscutting features with respect to stratigraphy were not identified. Where observed the anthophyllite ± cordierite ± garnet rock appears as conformable layers within the Unit 2 felsic gneiss, but in this area does not appear to be laterally continuous. The discontinuous nature of this layer may be generated tectonically or alternatively, may reflect the distribution of geographic depressions on the paleodepositional surface. The thicker sections of anthophyllite-bearing rock may indicate the accumulation of chemical precipitates within subbasins, whereas the thin layers of anthophyllite-bearing rock intermixed with quartz-bearing gneisses (that also may contain anthophyllite) identified along strike may represent a mixed depositional regime away from the subbasin.

NORTH JUNGLE LAKE SIDING

Near solid pyrrhotite with disseminated pyrite and sphalerite mineralization was intersected in diamond drill core in 1958 by Hudson Bay Exploration and Development Limited (Fig. GS-4-1). DDH F17 intersected an approximately 15 m thick zone of sulphide mineralization hosted by 'sheared' quartz-feldspar ± biotite ± sericite rock that comprises 3.5 m of moderate pyrite and disseminated sphalerite mineralization underlain by 11.5 m of moderate to near solid pyrrhotite with disseminated pyrite and sphalerite.

A northwest to southeast geological section was examined in the vicinity of the 1958 diamond drill holes (Fig. GS-4-4). This section comprises, from structurally highest to lowest: 1) Missi Metamorphic Suite felsic quartzofeldspathic gneiss; 2) Sherridon Metamorphic Suite felsic - intermediate quartzofeldspathic gneiss; 3) probable Burntwood River Metamorphic Suite gneiss; and, 4) Missi Metamorphic Suite felsic quartzofeldspathic gneiss.

Unit 1 is a predominantly layered (cm-m), fine grained, massive to laminated, felsic-intermediate quartz - feldspar - biotite and/or hornblende ± garnet ± magnetite gneiss. Quartz-bearing amphibolite layers occur locally. Fine grained amphibolite that contains lenses of calc-silicate rich rock is the lowermost unit exposed within Unit 1.

Unit 2 is a layered sequence of Sherridon Metamorphic Suite gneisses. Two major rock units were identified in this area: a) predominantly medium- to coarse-grained, felsic-intermediate quartz-feldspar-biotite-garnetcordierite gneiss that characteristically exhibits a ridgy weathered surface and contains coarse porphyroblastic garnet (*cf.* Unit 1 at the Ake Zone, above); medium grained, variably rusty weathered, diopside-bearing, calc-silicate layers form approximately 20% of this rock sequence; and b) pink to white weathered, massive to laminated, fine grained, predominantly felsic quartzofeldspathic gneiss ± sillimanite ± cordierite (Fig. GS-4-4) that also contains abundant interlayered calc-silicate rock (*cf.* Unit 2 at the Ake Zone, above), that structurally underlies a). Garnet is a minor constituent of these rocks and cordierite, where observed, forms coarse grained euhedral to subhedral crystals within quartz segregations (Fig. GS-4-5). A fine-grained intermediate, quartz - feldspar - biotite ± sillimanite ± cordierite gneiss layer, approximately 5 m in thickness immediately underlies the pink to white gneiss. This intermediate rock is, in turn, underlain by fine- to medium-grained, layered (cm), felsic to intermediate quartz - feldspar - hornblende ± biotite ± garnet gneiss

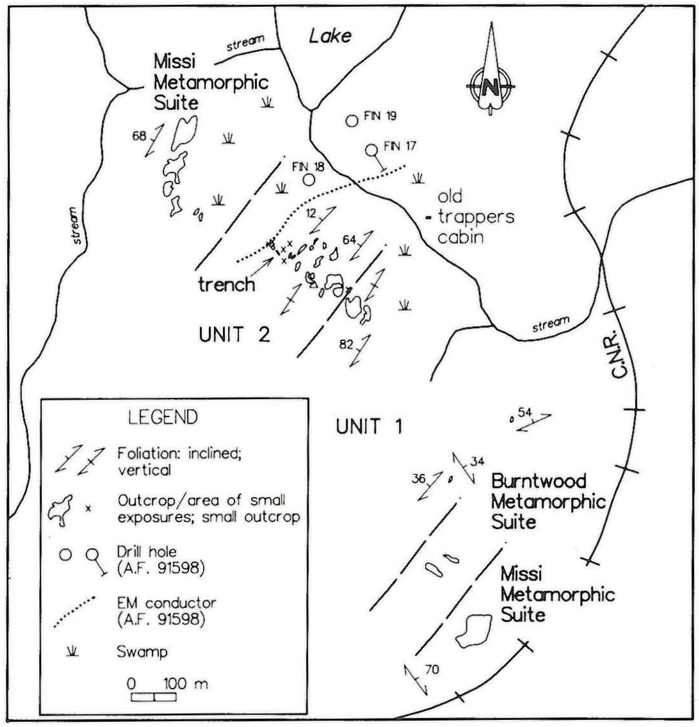

Figure GS-4-4: *Geology north of the Jungle Lake railway siding (NTS 63N/2).*

Figure GS-4-5: ***Euhedral to subhedral blue cordierite crystals in quartz-rich segregation from Unit B pelite(?).***

Unit 3 is a variably rusty weathered sequence of fine grained, intermediate quartz - feldspar - biotite - garnet ± sillimanite ± graphite gneiss.

Unit 4 is a layered (tens of cm or less) sequence of fine- to medium-grained felsic - intermediate quartz - feldspar - hornblende ± magnetite gneiss and felsic - intermediate quartz - feldspar - biotite ± sillimanite gneiss. Calc-silicate layers occur locally. Garnet is rare to absent in this sequence.

Mineralization

Minor amounts of fine grained disseminated pyrite or pyrrhotite occur locally within the Sherridon Metamorphic Suite quartzofeldspathic gneisses. The calc-silicate rock is variably rusty weathered and typically contains <1% fine grained disseminated pyrite. At the north limit of the Sherridon Metamorphic Suite gneiss sequence a 3.5 m long, 2m deep and 1m wide trench (Fig. GS-4-4) exposes fine grained siliceous (silicified?) quartzofeldspathic rock that, locally, contains sericite and sillimanite. The siliceous rock usually contains 1 to 2% fine grained disseminated pyrrhotite and, locally, medium- to coarse-grained pyrite mobilizate that occurs as veins/fracture fillings.

ACKNOWLEDGMENTS

Ed Kowalyk is thanked for his assistance during the latter part of the field season.

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GS-5 THE KISSEYNEW METALLOTECT NEAR JUNGLE LAKE, MANITOBA (NTS 63N/2)

by G. Ostry

Ostry, G., 1993: The Kisseynew metallotect near Jungle Lake, Manitoba (NTS 63N/2); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 22-23.

SUMMARY

A layered amphibolitic sequence that occurs between Burntwood Metamorphic Suite Gneiss and Missi Metamorphic Suite Gneiss and is exposed on the north shore of Jungle Lake (Fig. GS-5-1; Zwanzig, 1993, personal communication) was documented and sampled. This rock sequence occurs at the same stratigraphic position as the amphibolite sequences, collectively designated the 'Kisseynew metallotect' by Gale and Ostry (1984), that host the Nokomis Lake gold deposit (*cf.* Gale and Ostry, 1984; Ostry and Trembath, 1992), the Evans Lake gold occurrence (*cf.* Peloquin *et al.*, 1985; Ostry and Trembath, 1992), and the Lobstick Narrows gold occurrence (Parbery, 1990). Mineralization comprises minor amounts of disseminated pyrite. Analyses of selected chip samples are provided.

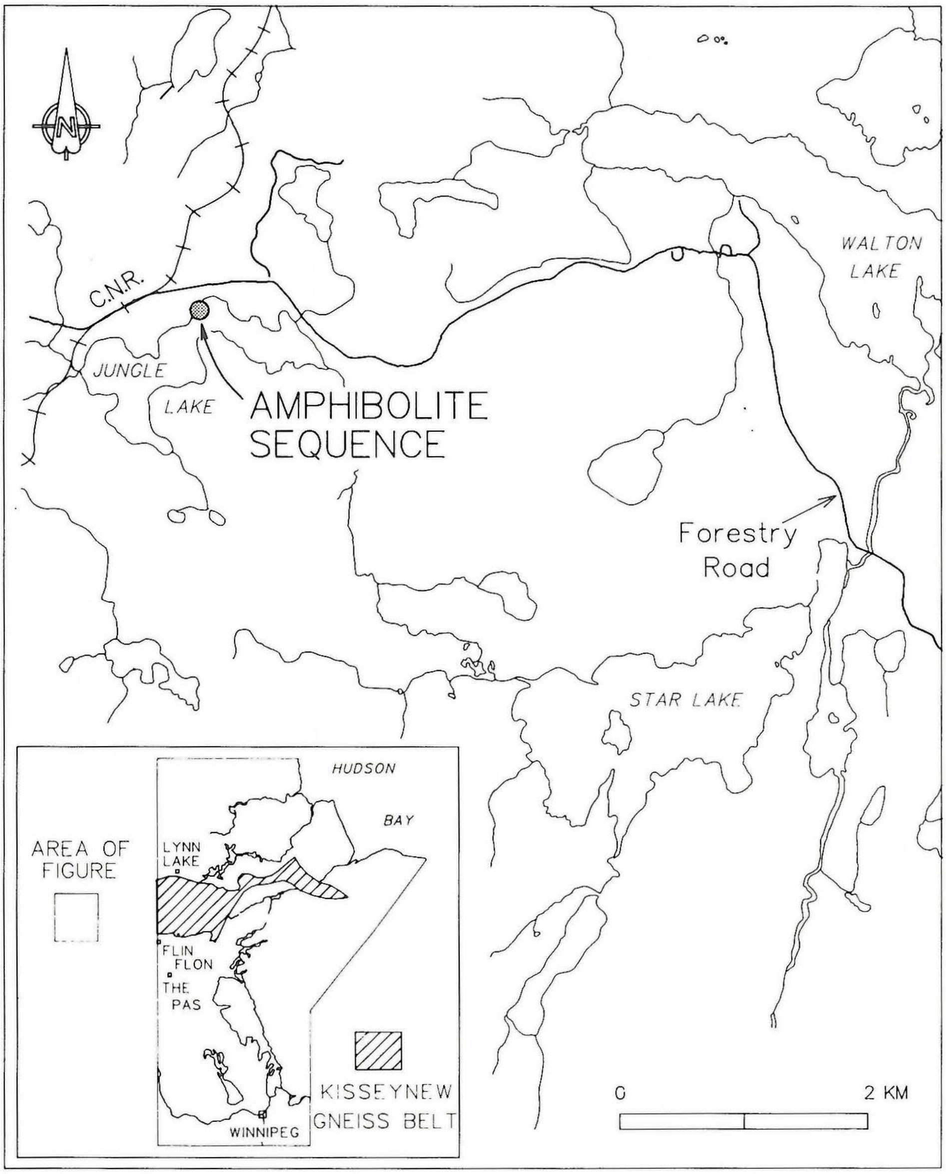

Figure GS-5-1: Location of the Kisseynew metallotect at Jungle Lake, Manitoba (NTS 63N/2).

NORTH SHORE JUNGLE LAKE

Approximately 9 m (true thickness) of the amphibolitic sequence (Fig. GS-5-2) is exposed on the north shore of Jungle Lake. The amphibolitic sequence is structurally underlain by Missi Metamorphic Suite rocks and overlain by Burntwood Metamorphic Suite rocks, but the contacts with these units are not exposed. The exposed amphibolitic sequence comprises from structurally lowermost to highest: 1) approximately 5 m of massive, medium grained amphibolite ± garnet; 2) 2.5 to 3.0 m of variable rusty weathered, medium grained, felsic, quartz-rich, quartz-feldspar- hornblende-diopside-garnet gneiss that contains up to 1% fine grained disseminated pyrite; 3) approximately 1.5 m of intermediate to mafic, medium- to coarse-grained hornblende-feldspar-garnet-quartz gneiss that contains up to 20% rusty weathered garnet-hornblende ± feldspar pods/lenses; these pods are aligned in the foliation direction and are up to 15 cm by 2 m on the weathered surface; and, 4) approximately 1 m of banded or layered gneiss; bands/layers are from 1 cm to 10 cm thick and are composed of hornblendite (segregation?), amphibolite, felsic fine grained quartz-feldspar-biotitegarnet gneiss, felsic fine grained quartz-feldspar-hornblende-diopside gneiss and quartz-rich gneiss similar to 2). Continuous chip samples were taken every 0.5 m through the section. Several of the chip samples were analyzed for Au, Ag, Cu, Pb and Zn. Table GS-5-1 presents the results of these analyses.

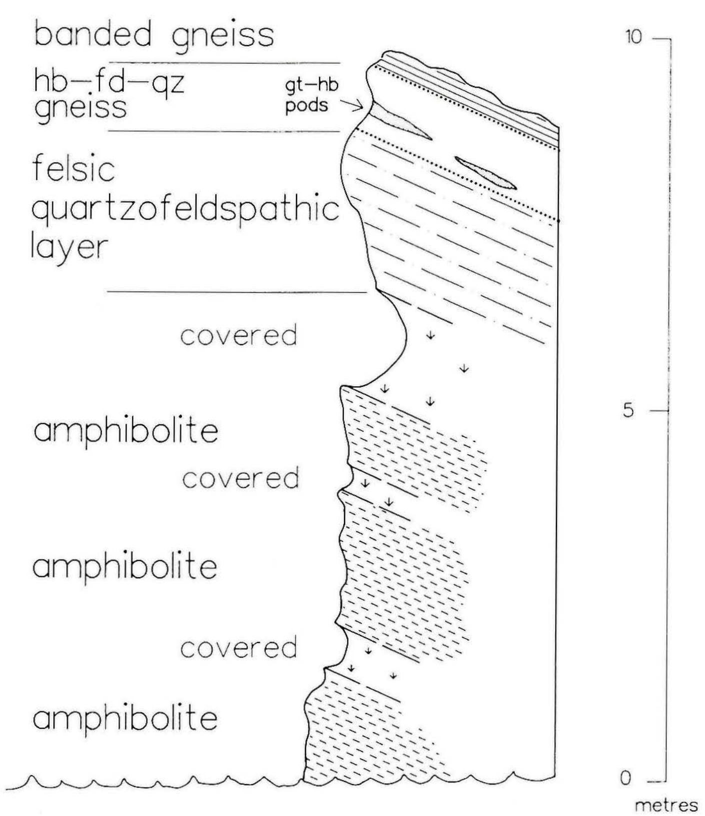

Figure GS-5-2: Geological section through metallotect sequence on north shore of Jungle Lake.

Table GS-5-1
Analyses of Selected Chip Samples

Chip Sample (metres)	Rock Type	Au (ppb)	Ag (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)
0.0-0.5	Amphibolite	28	<1	70	45	<2
0.5-1.0		<12	<1	49	46	<2
1.0-1.5		<12	<1	56	58	<2
6.5-7.0	Felsic quartzofeldspathic layer	25	<1	57	15	<2
7.0-7.5		12	<1	26	40	<2
7.5-8.0		12	<1	24	16	<2
8.0-8.5		<12	<1	19	19	<2

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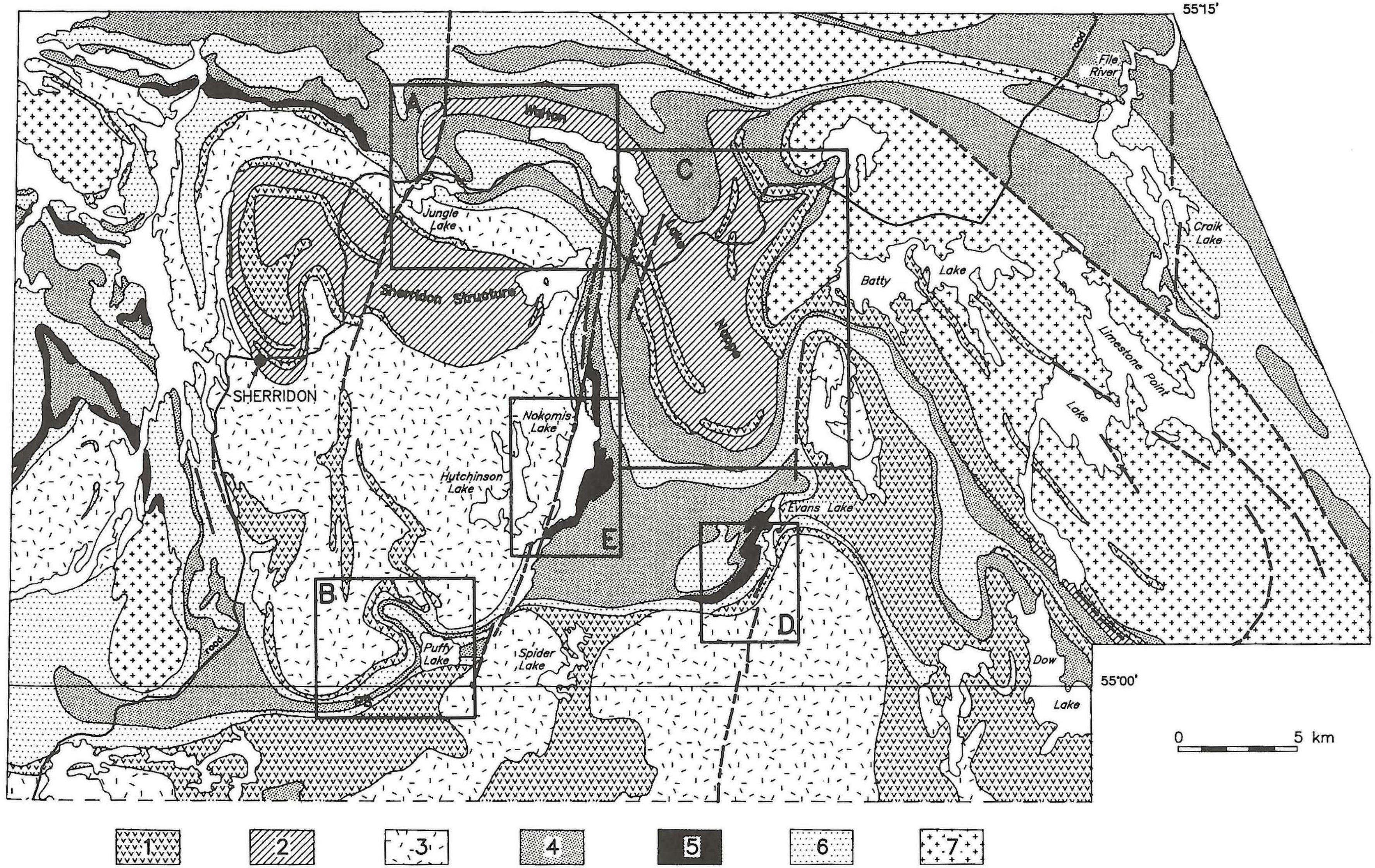

Figure GS-6-1: Simplified geology of the Sherridon - Batty Lake region showing outlines of the 1993 preliminary maps: A = 1993K-1, B = 1993K-2; 1992 preliminary maps: C = 1992K-1, C = 1992K-2; and planned map area: D. Units are given from oldest to youngest where the age is known: Amisk Group and equivalents = 1 - metavolcanics / sediments, 2 - felsic gneiss; tonalite = 3; Burntwood Group = 4 - metagreywacke, 5 - amphibolite; Missi Group = 6; Granitoid gneiss = 7; Ponton Lake Synform = PS.

GS-6 GEOLOGY OF THE JUNGLE LAKE-PUFFY LAKE AREAS (PARTS OF NTS 63N/2, 3 AND 63K/14, 15)

by H.V. Zwanzig

Zwanzig, H.V., 1993: Geology of the Jungle Lake-Puffy Lake areas (Parts of NTS 63N/2, 3 and 63K/14, 15); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 24-28.

SUMMARY

The main part of this report provides a stratigraphic framework with a catalogue of units shown on Preliminary Maps 1993K-1 and 1993K-2. Tectonostratigraphic and structural implications are discussed at the end. The major findings of the geological field work are summarized below.

1. A unique volcanic formation in the Amisk Group was traced across the structural boundary between the Flin Flon and Kisseynew belts indicating that parts of these areas belonged to a single volcanic subdomain. This formation contains mafic to ultramafic flows and intrusions with a geochemical signature of komatiitic basalt.
2. In the Kisseynew belt the mafic to ultramafic formation occurs as roof pendants in tonalite gneiss that may be as old as 1892 Ma (Hunt and Zwanzig, 1990), whereas in the Jungle Lake area, felsic gneiss (Sherridon Group of Robertson, 1953) is intruded by the same tonalite gneiss. This relationship is consistent with the interpretation that the felsic gneiss is part of a volcanic arc assemblage in the Amisk Group.
3. Mafic to felsic volcanic units in the Missi Group can be traced across the Kisseynew south flank and show the regional importance of post-Amisk subaerial volcanism.
4. Laterally persistent marker units in each sequence are delineated on the preliminary maps and confirm the importance of three regional fold-nappes (Zwanzig and Schledewitz, 1992) in tracing out volcanic and economically important units.
5. Lateral stratigraphic facies changes at the base of the Missi Group define a south to north transition from conglomerate and meta-arkose to finer grained metasedimentary rocks. The conglomerate unconformably overlies the Amisk Group and early intrusive rocks, whereas the finer grained basal sandstone conformably overlies Burntwood River Group metaturbidite that is younger than the Amisk Group.

INTRODUCTION

Geological mapping and geochemical sampling were carried out in the structural and stratigraphic transition zone between the Kisseynew gneiss belt and the Flin Flon volcanic belt (Fig. GS-6-1) to upgrade and extend the existing 1:50 000 scale coverage (Zwanzig 1984, 1988; Zwanzig and Schledewitz, 1992). About 80 km^2 were remapped at 1:20 000 scale in the vicinity of Jungle Lake, and 45 km^2 were mapped at 1:10 000 scale at Puffy Lake (Preliminary Map 1993K-1 and 1993K-2). Both areas have excellent exposure produced by the forest fire of 1989.

Two new projects of U-Pb geochronology were started on the Kisseynew south flank, to be carried out at GEOTOP, Université du Québec à Montréal under the auspices of LITHOPROBE. The field work for an M.Sc. thesis relating geochronology and structure was completed by M. Parent; sampling for magmatic, depositional and deformational ages was completed by J. David and N. Machado (David *et al.*, GS-10, this volume).

LITHOSTRATIGRAPHY

Lichen free outcrops have allowed primary lithologies to be identified and stratigraphic relationships to be determined despite the upper amphibolite grade of metamorphism. The units shown on Preliminary Maps 1993K-1 and 1993K-2 are given below in groups that follow stratigraphic order, a departure from earlier maps. The inferred age of the Burntwood River Group (previously mapped as a metamorphic suite) is based on a correlation with rocks that contain detrital zircons younger than the Amisk Group and slightly older than the Missi Group (David *et al.*, 1993). Units within the groups and intrusive rocks are generally listed from mafic to felsic compositions without chronological order.

The Missi Group in the Jungle and Puffy lakes areas is an assemblage of gneisses derived from argillaceous to pebbly sandstone and mafic to felsic volcanic rocks. Map units commonly consist of several lithologies that are interlayered on a scale of several metres to tens of metres. Important thin marker units are shown on the maps as ornamented lines.

Amisk Group and related rocks

Unit 1 comprises dark mafic to ultramafic flows, dykes and sills. The mafic flows weather dark grey reen and are predominantly aphyric, pillowed and amygdaloidal with lighter grey-green diopside-epidote alteration. Preliminary geochemistry shows that komatiitic basalt is common. The intrusions range from weakly differentiated mafic sills to microdiorite dykes. Green to brown weathering ultramafic rocks include a well-preserved pillowed flow and numerous dykes and sills. Unit 1 forms a northwest-facing sediment-free succession south of Ponton and Puffy lakes. More foliated, but otherwise identical rocks form the roof to the gneissic tonalite between Archie Lake and Puffy Lake Mine, and rocks with similar chemistry under Burntwood River metagreywacke southeast of Walton Lake.

Unit 1a resembles unit 1, but weathers medium grey and contains 15 to 25% leucosome, 0 to 20% garnet and 0 to 10% biotite. These rocks occur north of Puffy Lake Mine above an interlayered succession of unit 1 and metadacite (unit 4b).

Unit 2 is more heterogeneous fine grained amphibolite with rare pillow structure and associated intermediate to felsic clastic rocks. It underlies unit 1 south of Puffy Lake.

Unit 3 is interlayered amphibolite and felsic gneiss (units 1 or 2 and 4b) interpreted as part of a bimodal volcanic sequence. It overlies unit 1 north of the mine.

Unit 3a is like unit 3, but partly altered to calc-silicate gneiss. It is a discontinuous marker along the outer contact of the felsic gneiss in the Sherridon structure south of Jungle Lake and in the Walton Lake nappe. The unit suggests a correlation between the gneisses in the two structures. The felsic component contains remnants of quartz phenocrysts of possible volcanic origin.

Unit 4 is light grey to pink weathering felsic gneiss exposed southeast of Jungle Lake where evidence exists for a rhyolite protolith (Zwanzig, 1992).

Unit 4a is a light grey-green variety of unit 4 partly altered to calc-silicate gneiss such as north of Walton Lake. Its patchy distribution and gradational contacts with units 4, 5 and 7 suggest carbonatization of unit 4.

Unit 4b is light grey to buff weathering metadacite with 0 to 5% garnet and local patches of pegmatitic leucosome. It occurs as dykes, sills and thicker units with rare layering that indicate an origin as flows or tuff.

Unit 4c, medium grey intermediate gneiss, was derived from supracrustal and intrusive rocks associated with unit 4b.

Unit 5, the most common variety of felsic gneiss in the Sherridon structure and Walton Lake nappe, weathers light grey to pink and has a characteristic quartz lamination. On average, 10% (7 mm) sieve-textured garnet porphyroblasts reside in a medium grained (1 - 5 mm) felsic, granoblastic matrix that is about 45% quartz. Locally 2 to 5 mm long quartz phenocrysts are preserved where the matrix is exceptionally fine grained. Hornblende or sillimanite and rare cordierite have a patchy distribution. Quartz-rich mobilizate constitutes up to 25% of the rock. The rock was called unit 7 in the Meat Lake area (Zwanzig, 1992). It is presumed to be metavolcanic, but near Jungle Lake it lacks reliable indications of a protolith.

Unit 6 is medium grey quartzofeldspathic gneiss with 15% large (<20 mm) garnet porphyroblasts and widespread cordierite and sillimanite. Variable amounts of amphibole and biotite have a patchy distribution and rusty weathered zones with traces of iron sulphide minerals are abundant. The rock forms belts northwest of Walton Lake where it grades into units 4, 5 and 7. It is interpreted as the result of low grade regional hydrothermal Mg-Fe alteration of felsic volcanic and clastic rocks.

Unit 7 is similar to unit 6, but contains less cordierite and more biotite. The rock is locally layered and has up to 30% quartz-rich leucosome. It grades into units 4 and 5. Some of the rock closely resembles unit 9 (metagreywacke).

Unit 8, volcanogenic metagreywacke occurs as mappable units near Evans Lake (Zwanzig, 1992) and as thin members elsewhere within unit 2 and rarely unit 1.

Burntwood River Group

Unit 9 is grey to brown weathering biotite gneiss (metagreywacke-turbidite) that generally contains 15% (2.5 mm) subhedral garnet porphyroblasts and traces of graphite. The rock has layering (2 - 50 cm thick) that represents bedding and generally contains less than 10% parallel quartzofeldspathic veins.

Unit 9a is grey and brown to reddish weathering and contains members (several metres thick) with small amphibole porphyroblasts, and with less garnet and more graphite than unit 9. This rock is most common near the stratigraphic bottom and top of the Burntwood River Group.

Unit 9c contains white weathering veins of pegmatitic leucosome (commonly less than 20 cm thick) that average 25% of the rock. The veins are parallel to grey layers of unit 9 (<15 cm thick). Sillimanite and cordierite are more abundant than in unit 9.

Unit 10 comprises dark green, black and brown weathering amphibolite lenses (up to 4 km long and up to 80 m thick) at the top of the Burntwood River Group, directly below Missi Group basal conglomerate. On Jungle Lake there is a complete section with uniform to patchy amphibolite of igneous origin overlain by a layer (*ca.* 4 m) of mottled felsic to intermediate gneiss, and this is overlain by diopsidic and garnetiferous amphibolite interlayered at 1 to 30 cm (probably silicate iron formation and calcium-rich mudstone). Elsewhere the mottled gneiss can host gold mineralization.

Missi Group

Unit 11 is a basal conglomerate (2 to 20 m thick, commonly 4 m), that lies on the Amisk Group and its intrusions, locally on unit 10 and rarely on unit 9. Clasts, though highly flattened, are recognizable as pink and light grey felsic igneous and sedimentary lithologies, vein quartz, and magnetiferous quartzite. Amphibolite clasts are most abundant at the base. Very flattened pale pink clast or "ribbons" locally mark the base. The clasts can have rapid reverse grading above the unconformity, followed by weak normal grading. The matrix commonly grades from mafic at the base to quartzofeldspathic higher up. Metasandstone beds (5 - 30 cm) become common upward. In areas of high strain the whole formation is a ribbon gneiss.

Unit 11a, a massive white, pale pink to buff weathering formation of protoquartzite to arkose (30 m thick) extends for 2 km along the base of the Missi Group northwest of Puffy Lake. One or 2 m of the rock occurs at the base in other places.

Unit 11b comprises polymictic metaconglomerate and metasandstone that is locally pebbly. The conglomerate has the same clasts as unit 11, but fewer mafic clasts. The matrix is generally quartzofeldspathic. Metasandstone constitutes up to 50% of exposures. It has local biotite-rich parting, probably structurally transposed crossbedding. Lenses and layers rich in epidote are interpreted as recrystallized concretions and beds with calcareous cement. The lithology occurs at Puffy Lake witin the Missi Group and locally at the base.

Unit 11c is the lateral facies of unit 11 with a greater proportion of metasandstone. The conglomerate members are 30 to 150 cm thick, and their composition is mafic to successively more felsic upwards. Three to 30 m thick sections may have 80% metasandstone. The unit directly overlies Burntwood River Group metagreywacke (unit 9) and locally contains garnetiferous metasandstone beds near the base.

Unit 12, is light- to medium-grey quartzofeldspathic gneiss in the Missi Group. It was probably derived from lithic and arkosic sandstone. Field estimates suggest that the rock commonly contains 10 to 15% biotite, traces of magnetite, and an average of 8% hornblende on about two thirds of the exposures. Epidote or muscovite are local accessories. Layering is thin (<10 cm) and millimetre-scale biotite or hornblende lamination is common. Pink granitic leucosome, where present, rarely constitutes more than 10% of the rock.

Unit 12a consists of quartzofeldspathic gneiss (unit 12) and about 20% intercalated amphibolite (unit 13) in members that are, on average, 4 m thick. This type of formation constitutes the greater part of the Missi Group at Puffy Lake. Grey-green hornblende-biotite-bearing metasediments are closely associated with the amphibolite.

Unit 12b comprises unit 12 interlayered with thin beds of protoquartzite and rare grey-green pelite. Locally the metasandstone and pelite contain scattered pale pink garnet. This is the basal formation (<60 m thick) in the Missi Group, and grades conformably downward into the metagreywacke of the Burntwood River Group.

Unit 12c grades into unit 12b along strike and has the same components with the addition of various thin members comprising amphibolite to hornblende-biotite gneiss (unit 13), felsic metatuff, traces of conglomerate and a marker bed of light green epidote-bearing quartzite, commonly with scattered pink felsic pebbles and well rounded white quartz pebbles. Some of the members can be traced along strike for 5 km and across strike for 20 km from Ponton Lake to the road north of Jungle Lake. They indicate deposition over >100 km^2 and help track the overturned limb of one of the nappes.

Unit 12d is light grey to pink quartz-rich gneiss (meta-arkose) with muscovite and biotite-sillimanite, or less commonly, with hornblende-epidote. It contains local felsic and quartz pebbles, and rare conglomerate. The unit has scattered members of felsic gneiss (rhyolite tuff, breccia and reworked tuff). This association suggests a felsic volcanic source for some of the detritus.

Unit 12e is grey green weathering paragneiss with abundant epidote, variable amounts of microcline, hornblende and up to 15% pink microcline-hornblende-blastic segregations. The unit extends along the north shore of Ponton Lake and grades laterally into unit 12a. Farther north it is discontinuous and grades into unit 12d. The abundance of epidote is ascribed to recrystallized calcareous cement in the original sandstone.

Unit 13 contains mafic to intermediate, mixed volcanic, sedimentary and intrusive rocks. Dark grey-green amphibolite (50% of unit 13) with an average hornblende content of 40% comprises mafic flows and tuff with interlayered sandstone. Many flows have amygdaloidal margins and are aphyric (subunit 13a). Porphyritic tuff and flows (subunit 13b) contain pseudomorphs of plagioclase (3 - 25 mm long) and/or hornblende after pyroxene (3 - 8 mm long). Composite mafic units are up to 20 m thick, but individual flows are as thin as 10 cm in the present deformed state. Some units are massive and may be high-level sills.

Grey-green intermediate gneiss (20% of unit 13) has 10% biotite and 30% hornblende. It is interpreted as intermediate flows and tuff, possibly of trachyandesite. Epidote alteration and up to 30 mm long amygdales mark some flow contacts. Variations in phenocryst populations characterize different flows.

Medium grey hornblende (15%) -biotite (15%) gneiss, and dark grey biotite (12%) -hornblende (25%) gneiss are thinly layered (commonly <7 cm). They are interpreted as sandstone, mudstone and tuff.

Unit 14 is pink felsic gneiss derived from aphyric and rare quartz phyric rhyolitic ash-flow tuff and minor sediments. The rock forms distinctive marker units 20 cm to 5 m thick (2 m average). Local gradational contacts at the top suggest reworking of tuff by the overlying sandstone.

Unit 14a is a bimodal formation of fragmental felsic gneiss (one or more layers, up to 15 m thick) and various thinner mafic flows. The felsic rocks include pale grey ribbon gneiss, possible rhyodacite and dacite breccia, and darker matrix-supported conglomerate or mass flows.

Unit 14b, layered pink granite gneiss, which grades laterally into unit 14, is restricted to northern areas of highly mobilized rocks.

Intrusive Rocks

Unit 15 is dark green to brown weathering ultramafic rock that occurs as lenses (up to 10 m thick) intruding the top of the Burntwood River Group (unit 10) and the contact zones of felsic gneiss (units 4 - 7) in the Sherridon structure and Walton Lake nappe.

Unit 16 is coarse grained amphibolite derived from gabbro that intruded unit 7.

Unit 16c is a porphyritic mafic intrusion breccia along the margin of the pluton southeast of Puffy Lake.

Unit 17a varies from quartz gabbro to gneissic hornblende tonalite as part of the Sherridon - Hutchinson Lake complex.

Unit 18 is the main phase tonalite that intrudes units 1 and 2 southeast of Puffy Lake.

Unit 18a comprises light grey gneissic tonalite with 10 to 15% hornblende-biotite aggregates, and local grey to pink granodiorite with 5 to 15% biotite. This unit is the main phase in several intrusions in the Sherridon - Hutchinson Lake complex. Granitic and pegmatitic dykes and local migmatitic leucosome are present. Subunit 18b is a fine- to medium-grained phase (average 2 mm) present in dykes and along some pluton margins.

Unit 19 is foliated medium grained biotite granite from the pluton west of Archie Lake.

Unit 19a is the main phase gneissic granite of the Ragged Lake pluton. Where the foliation is crenulated there is commonly diffuse granitic mobilizate along the crenulation surface.

Unit 21 is synkynematic granite pegmatite.

TECTONOSTRATIGRAPHY AND STRUCTURE

The mapping carried out in 1993 has provided details for a qualitative reconstruction of tectonostratigraphic sequences proposed for the Kisseynew belt south flank (Zwanzig and Schledewitz, 1992). The work supports the model that the older parts of the sequences represent; (1) a volcanic terrain, (2) a basin margin, and (3) a turbidite basin. They occur on top of each other in a stack of foldnappes, each with 20 km overlap between Jungle and Puffy lakes. Changes in the pre-Missi substrate are abrupt between folds and suggest that early tectonic contacts exist. Systematic facies changes in the lowest formation in the Missi Group may allow a reconstruction of early Missi paleogeography if a direction for unfolding is chosen.

The structure is dominated by early foldnappes; numerous units in the Missi Group are symmetrically disposed about the axial surfaces of the synclinal nappes. The pile of nappes (1, 2, 3) is reversed (3, 2, 1) in the Ponton Lake synform (a younger upright fold crossing Ponton and Puffy lakes). The nappes extend north across the inclined dome that has the Sherridon structure in its core. A somewhat different structural pile is folded over the Walton Lake nappe. The large S-shaped fold pairs, which dominate the map pattern, further complicate the structural geometry.

Sequence 1: Volcanic substrate - proximal Missi Group

The Amisk Group in the remapped areas consists of three assemblages, each restricted to a different volcanic subdomain. Unit 2, the mafic and mixed composition assemblage south of Puffy Lake is probably contiguous with the volcanic arc rocks northeast of Elbow Lake (Schledewitz, GS-7, this volume). Unit 1 is a mafic to ultramafic assemblage, which is interpreted to extend underneath the Ponton Lake synform, thus connecting the Flin Flon and Kisseynew belts. At Sherridon and Walton Lake units 4 to 7 comprise another assemblage. All these assemblages are part of sequence 1 and form a volcanic composite terrane intruded by units 15 to 19a.

The Missi Group overlies the volcanoplutonic substate with profound unconformity. Massive conglomerate (unit 11) or quartzite overlain by mainly conglomerate (units 11a and 11b) form its base. Pebbly arkose (unit 12d) and more conglomerate occur higher up, although sandstone and volcanic rocks (units 13 and 14) predominate.

Sequence 2: Basin margin substrate - transitional Missi Group

The oldest rocks in the core of the lowermost anticlinal nappe are the Burntwood River Group metaturbidites (units 9 and 9a). These are overlain by lenses of mafic and ultramafic igneous rocks, locally gold-bearing felsic rock, and silicate iron formation (unit 10).

The Missi Group overlies these rocks with little or no unconformity. The basal conglomerate (unit 11) is thinner and becomes interleaved with sandstone. Clast types are similar to proximal facies conglomerate derived from the distant volcanic substrate, with no representation from the Burntwood River Group.

Sequence 3: Basin substrate - distal Missi Group

Only uniform Burntwood River Group metaturbidite (unit 9) and its migmatitic equivalent (unit 9c) form the core of the higher nappe. Turbidite is gradationally overlain by the basal Missi formation (unit 12b or 12c) that contains thinly interbedded fine grained clastic rocks and tuff, deposited in shallow water, possibly in an alluvial plane.

Walton Lake Nappe: Mixed substrate - distal Missi Group

The gneisses in the core of the Walton Lake nappe are the same as in the Sherridon structure (a regional culmination) and are interpreted to represent the deepest structural member in the volcanic substrate. The core gneisses are structurally overlain by the Burntwood River Group turbidites that grade upward into the distal facies basal Missi Group (lenses of unit 12b). The entire Walton Lake nappe is probably not distal because it is part of the volcanic composite terrane. Most likely, the Burntwood River and Missi groups were structurally emplaced on the volcanic rocks as the earliest nappes. Then the Walton Lake nappe and its Missi Group mantle may have been emplaced out of sequence over the lower nappes with little more displacement than the 10 km overlap exposed in the Meat Lake synform (Zwanzig, 1992).

Structural restoration: a discussion

The basal Missi Group changes from units 11 to 11c and then 12b to 12c as it climbs through 500 m of structural section containing the first three nappes. With the late folding removed, these facies changes appear to represent a relatively simple trend ranging from proximal to distal clastic deposits. The base of the Missi Group fines north in the upright limbs, and south in the inverted limbs of the nappes. Unfolding the nappes across regional strike produces a N - S section that is in the order of 100 km long. The basal Missi Group fines north and its substrate changes from a volcanic belt in the south to a turbidite basin in the north. Unfolding the Walton lake nappe would extend the volcanoplutonic substrate, but not necessarily under the original turbidite basin.

Notably, unit 10 mottled gneiss, which hosts the gold deposit at Nokomis Lake, was found in sequence 2 on Jungle Lake, as the structural model predicts. Delineating volcanic domains in the pre-Missi substrate and separating the assemblages within them should provide further guides for targeting mineral exploration.

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GS-7 GEOLOGY OF THE WEBB LAKE-FAY LAKE AREA (NTS 63K/14NE AND 63K/15NW)

by D.C.P. Schledewitz

Schledewitz, D.C.P., 1993: Geology of the Webb Lake-Fay Lake area (NTS 63K/14NE and 63K/15NW); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 29-32.

SUMMARY

Plutonic rocks of diverse age and composition make up more than 50% of the map area. Enclaves of Amisk Group metavolcanic rocks comprise large volumes of mafic flows of unknown tectonic affinity in the northwest part of the map area. To the south they structurally overly intermediate volcaniclastic rocks. The intermediate volcaniclastic rocks, which contain abundant felsic and intermediate dykes and sills, extend south to the Sexton Lake-Elbow Lake region, where they overlie either arc tholeiite mafic flows or back-arc/ocean floor mafic flows. In the northwest part of the map area the Amisk Group is unconformably overlain by Missi Group metasedimentary rocks. Missi Group rocks are also tectonically interleaved with gneisses of the Burntwood Group. Structural data along the unconformity indicate after the interleaving the rocks were deformed by ductile conjugate shear with coincident amphibolite grade metamorphism. The axis of bulk stretching has a northeasterly/southwesterly trend.

INTRODUCTION

The 225 km² Webb Lake-Fay Lake map area straddles the boundary zone between the Proterozoic Flin Flon belt and the south flank of the Kisseynew gneiss belt, 65 km northeast of Flin Flon (Fig. GS-7-1). Mapping in 1993 was conducted in the west corner of the project area from Fay Lake to Ponton Lake, in the central part around Carter Lake and the east portion around and north of Sexton Lake. The east half of the project area adjoins the northern boundary of the Elbow Lake project area (Syme, 1992a).

The project entails detailed (1:15 480) geological mapping of supracrustal and plutonic rocks in the Webb Lake-Fay Lake map area. Mapping is in part split between Manitoba Energy and Mines and the Geological Survey of Canada. J. Whalen (GSC) mapped the intrusive rocks, whereas Schledewitz (GSB) concentrated on the supracrustal assemblages.

The area was previously mapped at 1:63 360 (McGlynn, 1959). Webb Lake was examined briefly by Syme (1978). Limited mapping and detailed examination of mineral occurrences was carried out by Parbery (1986) at Fay Lake.

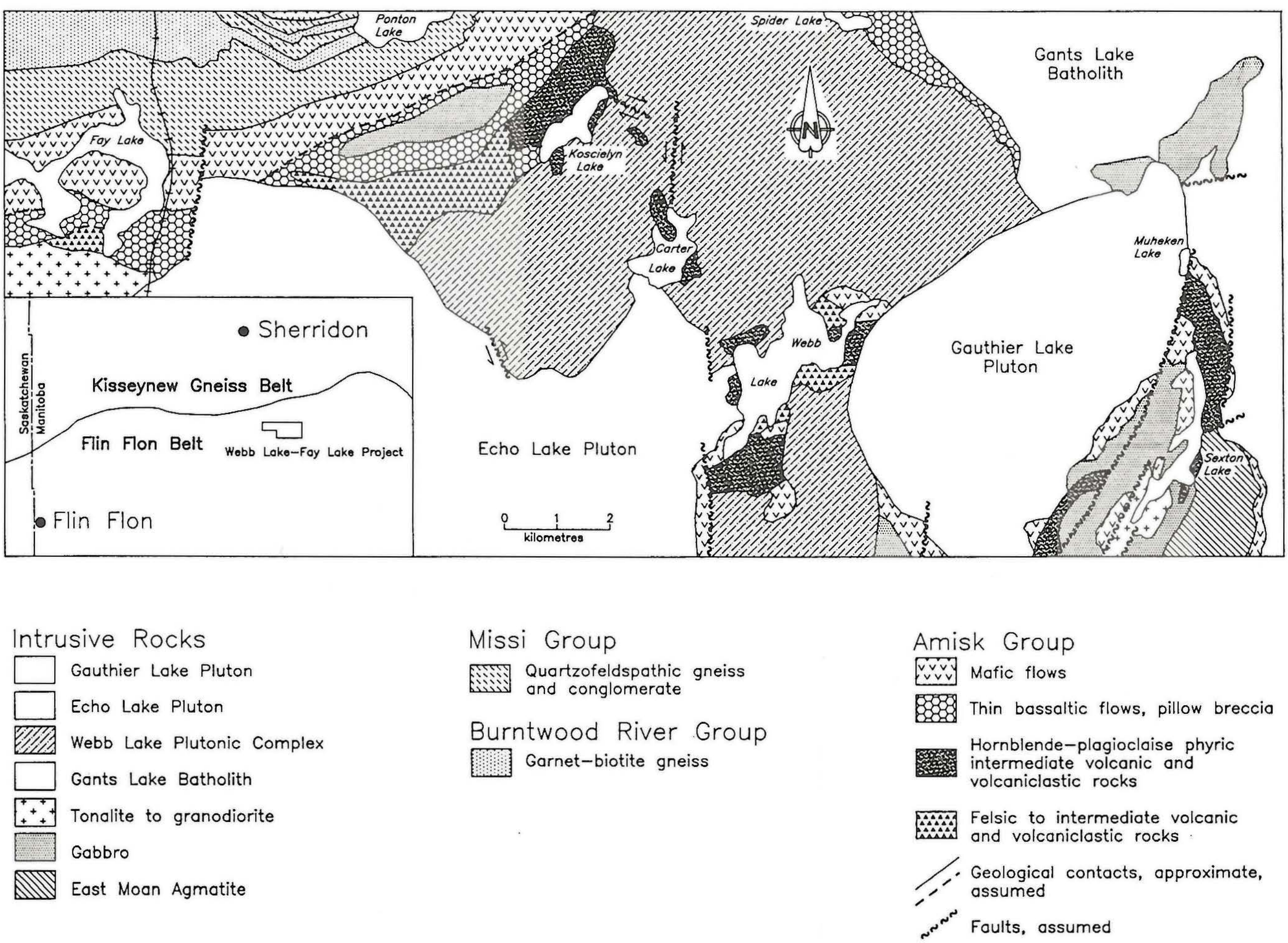

Figure GS-7-1: Simplified geology of the Webb Lake-Fay Lake area.

GENERAL GEOLOGY

Supracrustal rocks between Fay and Ponton lakes comprise Amisk Group metavolcanic rocks and related high level intrusions unconformably overlain by Missi Group basal conglomerate and quartzofeldspathic paragneiss. Greywacke derived paragneisses of the Burntwood River Group are tectonically interleaved with rocks of the Missi Group.

Amisk Group metavolcanic rocks are centered on the Fay Lake-Koscielny Lake , Webb Lake, Spider Lake, Carter Lake and the Sexton Lake areas (Fig. GS-7-1). Mafic volcanic rocks of unknown tectonic affinity occur in parts of the Fay Lake-Koscielny Lake region. The remaining areas of Webb Lake, Spider Lake, Carter Lake, the south edge of the Fay Lake-Koscielny Lake area and the Sexton Lake area contain pillowed mafic flows, intermediate tuff and breccia, felsic volcanic rocks, and subvolcanic intrusive rocks. Similar volcaniclastic lithologies occur in the northwest part of the Elbow Lake Project area northwest of Webb Island (Syme, 1991; unit 12, Syme and Whalen, 1992b). The intermediate tuff, breccia and felsic rocks in the Elbow Lake area, (tentatively interpreted to be of calc-alkaline affinity), are considered to be unrelated to the underlying Webb Island arc tholeiite (unit 5). The distribution of these calc-alkaline volcaniclastic rocks indicate that they extend over a large area. In the Sexton Lake area these volcaniclastic rocks appear to overlie mafic volcanic rocks, tentatively identified as equivalent to back-arc/ocean floor flows that occur on Moan Bay, Elbow Lake (unit 3, Syme, 1992).

The regions between the centres of preserved supracrustal rocks are occupied by large intrusive bodies, the Webb Lake plutonic complex, the Gauthier Lake pluton, the Echo Lake pluton and the Gants Lake batholith (Fig GS-7-1) (Whalen 1992; GS-20 this volume). The Webb Lake plutonic complex appears to preserve a high structural level with some phases representing a subvolcanic roof zone. Sulphide-bearing quartz veins and disseminated sulphides, as well as late magmatic hydrothermal alteration in phases of the Webb Lake plutonic complex, suggest the plutonic rocks of the region have potential for mineralization.

STRUCTURAL GEOLOGY

The Webb Lake-Fay Lake area has undergone a lengthy history of deformation and intrusive events. These processes involved;

1. assembly of the Flin Flon belt arc terrane,
2. deposition of the Missi and Burntwood River groups with,
3. contemporaneous emplacement of intrusions into the Flin Flon belt infrastructure, and
4. polyphase (post-Missi/Burntwood) deformation that variably overprinted the Flin Flon belt infrastructure.

The unconformity between Missi and Amisk groups in the Fay Lake-Ponton Lake region provides a reliable stratigraphic horizon for analysis of post-Missi deformation. This unconformity has now been traced, almost continuously, for a distance of 15 km from the east end of Fay Lake to the southeast shore of Ponton Lake. The eastward continuation has been mapped for another 4 km by Zwanzig (1992). The unconformity is interpreted to lie on the most southerly limb of a series of upright easterly-trending folds that refolded an earlier post- Missi nappe and/or thrust belt (Zwanzig and Schledewitz, 1992).

This segment of the unconformity lies in a zone between regions of apparently contrasting structural behavior. To the north the region is one of southwest vergent ductile flow that deformed post-Missi nappes and the underlying Amisk granitoid rocks (Zwanzig and Schledewitz, 1992). To the south, post-Missi deformation appears to have involved mainly upright structures and steep shear zones. The variably foliated plutons acted as rigid bodies in contrast to the behavior of the plutons in the region of ductile flow in the north.

The unconformity has been deformed by a phase of ductile conjugate shear with the axis of bulk stretching oriented to the northeast and the axis of bulk shortening to the northwest (Fig. GS-7-2). The orientation of this strain field is based on minor structures, in Missi Group rocks along the trend of the unconformity, that indicate a conjugate set of east trending right lateral and north trending left lateral shear zones. Recrystallization of hornblende during the early stages of ductile shear deformation indicates a minimum of middle amphibolite facies of metamorphism. This phase of deformation was post-nappe and post peak of metamorphism and related to northwest crustal shortening. The northwest crustal shortening was accommodated by southwesterly ductile flow in layered gneisses and strain-softened granitoid rocks to the north, while at the same time more rigid crust to the south responded along localized planar shears zones. By developing a conjugate set of shears it is possible to build up an overall bulk strain in rocks by forming localized planar shear zones with abnormally high finite strains separating regions that are not strained or have lower finite strain than that of the bulk deformation (Fig. GS-7-2).

Younger, north-trending brittle faults with apparent left lateral movement postdate the ductile shear event.

Mapping in the area of Sexton Lake and north to Muhekun Lake identified northwest trending, predominantly south dipping layering intersected by north to northeast trending semi-brittle shears. Displacement of the contacts of a suite of distinctive felsic to intermediate volcaniclastic rocks (intersected by the Elbow Lake shear zone) indicates an apparent left lateral displacement of three kilometres. Lineations in the shear zone plunge steeply to the southeast.

The principal results of mapping during 1993 are described in the following section. Lithologies and structure in the area of Webb Lake were reported in Schledewitz (1991, 1992).

FAY LAKE-PONTON LAKE-KOSCIELNY LAKE

Amisk Group Rocks

The structurally highest unit of the volcanic sequence is a compositionally uniform, fine grained, dark green weathering, well foliated mafic volcanic rock. This unit is 1200 m thick at Fay Lake, thinning to 500 m north of Saddle Lake. It appears to pinch out along a northeasterly trend. Alternatively this apparent pinch out may relate to an angular unconformity with the overlying Missi Group. These volcanic rocks have been intruded by numerous diorite, gabbro and diabase sills. The mafic volcanic rocks consist of massive and pillowed flows and rare flow top breccia.

These mafic flows are underlain by a thin unit of grey weathering, plagioclase phyric, pillowed mafic flows that appears to be in fault contact with a plagioclase-hornblende phyric suit of intermediate to mafic pillowed flows, volcaniclastic rocks, interflow sediment and rare iron formation. Felsic volcanic and volcaniclastic rocks occur at the southeast end of Fay Lake, and between the northeastern shore of Rodwalsh Lake and King Lake.

Missi Group

Missi Group basal conglomerate is 1 to 30 m thick and extends almost continuously from the west end of Fay Lake east to Ponton Lake. Basal conglomerate is clast supported and has a variably hornblende bearing, biotite-feldspar matrix with abundant epidote and quartz. The clasts are mafic volcanic, minor quartz porphyry, diorite, tonalite, rare granite, vein quartz and grey quartz that contains disseminated magnetite. The clasts are flattened, elongated down dip in the plane of a steep foliation, and have aspect ratios of 1:4.5:18. The conglomerate is absent on the north-trending short limb of a large Z-fold at the east end of Fay Lake. At this locality the conglomerate is attenuated, and has been intruded by granite.

The conglomerate is overlain by 100 to 400 m of variably crossbedded meta-arkose with isolated pebble beds, cobbles and thin lenses of conglomerate. The arkose is intruded by mafic dykes and sills that predate the peak of metamorphism and subsequent deformation. A 200 to 300 m thick suite of interlayered hornblende-epidote bearing, quartzofeldspathic and grey biotite-feldspar-quartz paragneiss overlies the meta-arkose. The average thickness of the

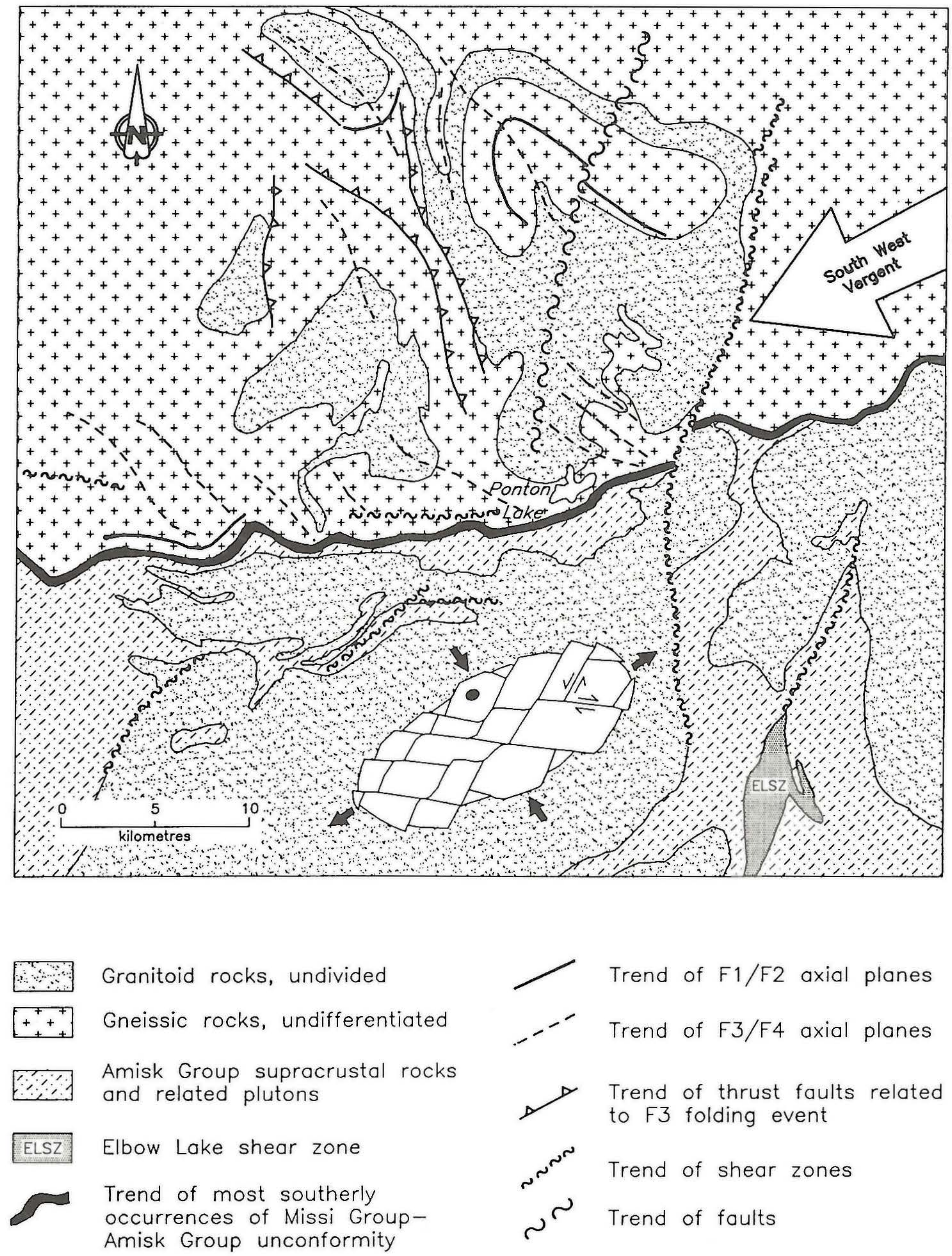

Figure GS-7-2: Trend of the Missi Group-Amisk Group unconformity (most southerly occurrences) with more mobile gneissic terrane to the north with evidence of southwest vergent flow and less mobile terrane to the south of the unconformity interpreted to have been deformed by ductile conjugate shear. Both styles of deformation are consistent with the axis of maximum bulk shortening oriented northwest.

Missi Group appears to be 700 m. A 1600 m thick sequence of Missi Group in the large Z-fold at the east end of Fay Lake suggests that considerable thickening has taken place in the north-trending short limb of this structure during deformation.

Burntwood River Group

Burntwood River Group garnet-biotite-quartz paragneiss structurally overlies the Missi Group north of Fay Lake to Ponton Lake. Three layers of Burntwood paragneiss are interleaved with quartzofeldspathic rocks of the Missi Group. Early F_1 fold nappes are interpreted to account for these repetitions (Zwanzig and Schledewitz, 1992). North of the east end of Fay Lake the most southerly layer of garnet-biotite gneiss has been folded into a series of tight S-folds about northwesterly axial planes. These folds post-date the F_1 nappes.

SEXTON LAKE-MUHEKUN LAKE REGION

Mapping in the Sexton Lake area and north to Muhekun Lake concentrated on the supracrustal rocks and related intrusions that trend northward from Elbow Lake.

Amisk Group

Mapping indicates a northerly continuity of some units of the Amisk Group (metavolcanic rocks, gabbros and diabase intrusions) from Moan Bay on Elbow Lake (Syme 1991, 1992). Amisk Group metavolcanic rocks can be traced as far north as Muhekun Lake.

A complex unit of intermediate and felsic volcaniclastic rocks (tuff and breccia), intruded by synvolcanic dykes, is exposed west of the Elbow Lake shear zone west of Sexton Lake. The intermediate tuff and breccia contain a variety of angular, intermediate and felsic fragments: plagioclase phyric and aphyric andesite, aphyric and quartz phyric rhyolite, and pumice. These volcanic rocks are extensively intruded by dykes and sills of gabbro and diabase. The intermediate volcaniclastic rocks trend NNE, subparallel to the more north striking, steep-dipping, foliation and are truncated by the Elbow Lake shear zone. The same intermediate volcaniclastic rocks occur on the east side of the Elbow Lake shear zone with an apparent left lateral displacement of 3 km. Pillowed mafic flows lie south of the intermediate volcaniclastic unit and are probably equivalent to the back-arc/ocean floor Moan Bay Basalt. Tonalite, gabbro and diabase dykes and sills are abundant in the mafic volcanic rocks along the west shore of Sexton Lake. At its north end layering trends southeasterly and is overprinted by a northerly foliation. The contact between the Moan Bay Basalt and the intermediate volcaniclastic rocks, although not exposed, parallels this trend. Several zones of sulphide mineralization occur in the pillowed mafic volcanic rocks along the trend of the contact. A large pyritic quartz vein (2 m wide and 50 m long), with intense sericite alteration of the country rocks along its margins, occurs where the contact is truncated by a north-trending shear zone. To the north the volcaniclastic rocks are in contact with an amphibolite, possibly equivalent to the mafic tectonite (unit 2f, Syme and Whalen, 1992b) that occurs in the Elbow Lake map area.

MUHEKUN LAKE GABBRO COMPLEX

This gabbro complex lies immediately north of Muhekun Lake and is noteworthy because of its similarity with the Elbow Lake gabbro complex (unit 26a, Syme and Whalen, 1992b). It is a medium- to coarse-grained, mesocratic, gabbro with sporadic white layers of leucogabbro to anorthosite. The gabbro contains olive green weathering peridotite and rusty, green brown, coarse grained pyroxenite lenses that range in size from 5 cm to 100 m in length. The south and west margins of the gabbro are intruded by quartz monzonite and granodiorite of the Gauthier Lake pluton. These contacts are a complex tectonic interleaving of gabbro and the younger granitoid rocks suggesting that the Gauthier Lake pluton had not completely crystallized before it was affected by a deformational event. To the north and east the gabbro is in contact with a plagioclase porphyritic granodiorite, of the Gants Lake batholith, that contains inclusions of the gabbro.

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GS-8 METAMORPHISM IN THE DUVAL LAKE AREA (NTS 63N/4)

by T.L. Jungwirth[1] and T.M. Gordon[1]

Jungwirth, T.L. and Gordon, T.M., 1993: Metamorphism in the Duval Lake area (NTS 63N/4); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 33.

SUMMARY

In the Duval Lake area metamorphic grade increases possibly as the result of post metamorphic folding. The occurrence of sillimanite+biotite+garnet rather than staurolite+garnet+biotite to the south and in the core of a major fold suggest that metamorphic grade is not uniform within the schists.

INTRODUCTION

Parts of the Duval Lake area (NTS 63N/4), located in the south flank of the Kisseynew gneiss belt, were mapped by T.L. Jungwirth, as part of an M.Sc. thesis, during the summer of 1993 using 1:15 840 and 1:4000 airphotos. The Duval Lake area contains staurolite-bearing and sillimanite-bearing metagreywackes named the Duval Lake Schists by Pollock (1964). This map unit is bounded to the north by migmatites and to the south by the Kississing River Shear Zone and Missi Group rocks. Both the Duval Lake Schists and migmatite have been assigned to the Burntwood Suite by Zwanzig and Schledewitz (1992). Within the map area, the metamorphic grade increases to the north. South of the area, in the Missi Group, metamorphic grade increases to the south (Zwanzig and Schledewitz, 1992).

The objective of the study is to elucidate the metamorphic and deformational history of the Duval Lake area by determining peak metamorphic conditions of the metasedimentary rocks and by examining the relationship of metamorphic mineral growth to fabric development.

The following is a summary of the preliminary results and conclusions from the summer.

GENERAL GEOLOGY

Lithology

Metagreywackes dominate the Duval Lake area. These quartz-plagioclase-biotite metasedimentary rocks have been divided into four units based on the presence or absence of compositional layering and on the type and percentage of porphyroblasts. The psammitic-pelitic layering varies from a few cm to 50 cm in thickness. Staurolite and sillimanite are restricted to the more pelitic layers, whereas garnet is omnipresent.

North of the Duval Lake Schists, the Burntwood Group comprises varying proportion of metagreywacke, leucogranitic intrusions and granitic pegmatites. Migmatites are located in the northeast portion of the area. At one locality, sillimanite and garnet occur in a pink coarse grained granitoid gneiss.

Structure and Metamorphism

The southern third of the Duval Lake area is dominated by a southward verging, east plunging antiform. The nose of the fold is interpreted to underlie the southeastern part of the area. Along the southern limb, Missi Group rocks are tectonically juxtaposed by the Kississing River shear zone. The northern limb is adjacent to the migmatite from (Zwanzig and Schledewitz, 1992).

The Kississing River shear zone is 500 metre wide extending from the Manitoba-Saskatchewan border to the north of Kisseynew Lake (Norman and Williams, 1992). Local occurrences of rotated staurolite indicate that some deformation in the shear zone post dates porphyroblast growth. Elsewhere in the map area, staurolite is parallel to foliation defined by compositional layering. Associated with the shear zone are quartz-feldspar veins and segregations that crosscut compositional layering.

The metamorphic grade increases to the north, as indicated by an increase in mineral grain size, appearance of sillimanite+biotite+garnet and the formation of migmatites. The occurrence of sillimanite+biotite+garnet rather than staurolite+garnet+biotite to the south and in the core of the fold suggest that metamorphic grade is not uniform within the schists.

PRELIMINARY CONCLUSIONS

The eratic distribution of the metamorphic grade increase may be explained by post metamorphic folding that has affected the area. In general, the metagreywackes near leucogranites are devoid of porphyroblasts. The porphyroblasts may have been destroyed by metasomatism associated with the leucogranites, though in two areas outside of the main map area, sillimanite-garnet metagreywackes are found adjacent to intrusions.

Future work will include detailed petrographic and petrologic studies to examine mineral equilibria, metamorphic textures and tectonic fabrics. Metamorphic P-T values will be obtained using the data base of Berman (1989) and method of Gordon (1992).

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GS-9 U-Pb AGES OF INTRUSION, METAMORPHISM AND DEFORMATION IN THE BATTY LAKE AREA, KISSEYNEW GNEISS BELT, MANITOBA

by P.A. Hunt[1] and H.V. Zwanzig[2]

Hunt, P.A. and Zwanzig, H.V., 1993: U-Pb ages of intrusion, metamorphism and deformation in the Batty Lake area, Kisseynew gneiss belt, Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 34-37.

SUMMARY

Tonalite gneiss in the Batty Lake area has yielded an U-Pb crystalliztion age of 1859+14/-7 Ma (upper intercept) from a population of elongate dark zircons, and what is interpreted as the age of peak metamorphism of 1810 ± 8 Ma from a concordant fraction of a population of clear rounded zircons. A late kinematic (syn-D_4) granitic pegmatite yielded an average $^{207}Pb/^{206}Pb$ zircon age of 1803±1 Ma. Concordant $^{207}Pb/^{206}Pb$ monazite ages of these rocks are respectively 1804±8 and 1796±1 Ma. The data also suggests time limits for D_3, which occurred between peak metamorphism and pegmatite intrusion.

INTRODUCTION

The Batty Lake area, chosen for this U-Pb geochronological study, is 90 km northeast of Flin Flon on the south flank of the Kisseynew gneiss belt. Recent interest in this area is supported by provincial mapping (Zwanzig and Schledewitz, 1992), Mineral deposits compilation (Ostry and Trembath, 1992), NATMAP, LITHOPROBE, and new staking. Accurate correlation of the gneisses with rock units in the Flin Flon belt supported by U-Pb geochronology is vital to this work.

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GEOLOGY AND SAMPLING

The Batty Lake area is underlain by various types of quartzofeldspathic gneiss and amphibolite derived from volcanic, sedimentary and intrusive rocks (Fig. GS-9-1). Correlation of these gneisses with lower metamorphic grade rocks in the Flin Flon belt (Zwanzig and Schledewitz, 1992; Zwanzig, 1992), and published U-Pb zircon ages in the Flin Flon belt (Syme *et al.*, 1993) suggest that amphibolite (1) and felsic gneiss (2) may be *ca.* 1.9 Ga volcanic arc deposits of the Amisk Group. The overlying garnet-biotite gneiss of the Burntwood River Group is correlated with metagreywacke-mudstone turbidites (File Lake Formation), in which the youngest detrital zircons in the Flin Flon belt are 1850 to 1857 Ma (David *et al.*, 1993). Gneissic intrusive rock yielded ages of 1892 and 1874 Ma (Hunt and Zwanzig, 1990). All these units are unconformably to conformably overlain by quartzofeldspathic gneiss and amphibolite of the Missi Group (Zwanzig, GS-6 this volume). The rocks have under gone upper amphibolite grade metamorphism and polyphase deformation (Zwanzig and Schledewitz, 1992).

One sample for U-Pb zircon analysis was collected from the Batty Lake intrusive complex, an oval structure (25 km long) in a

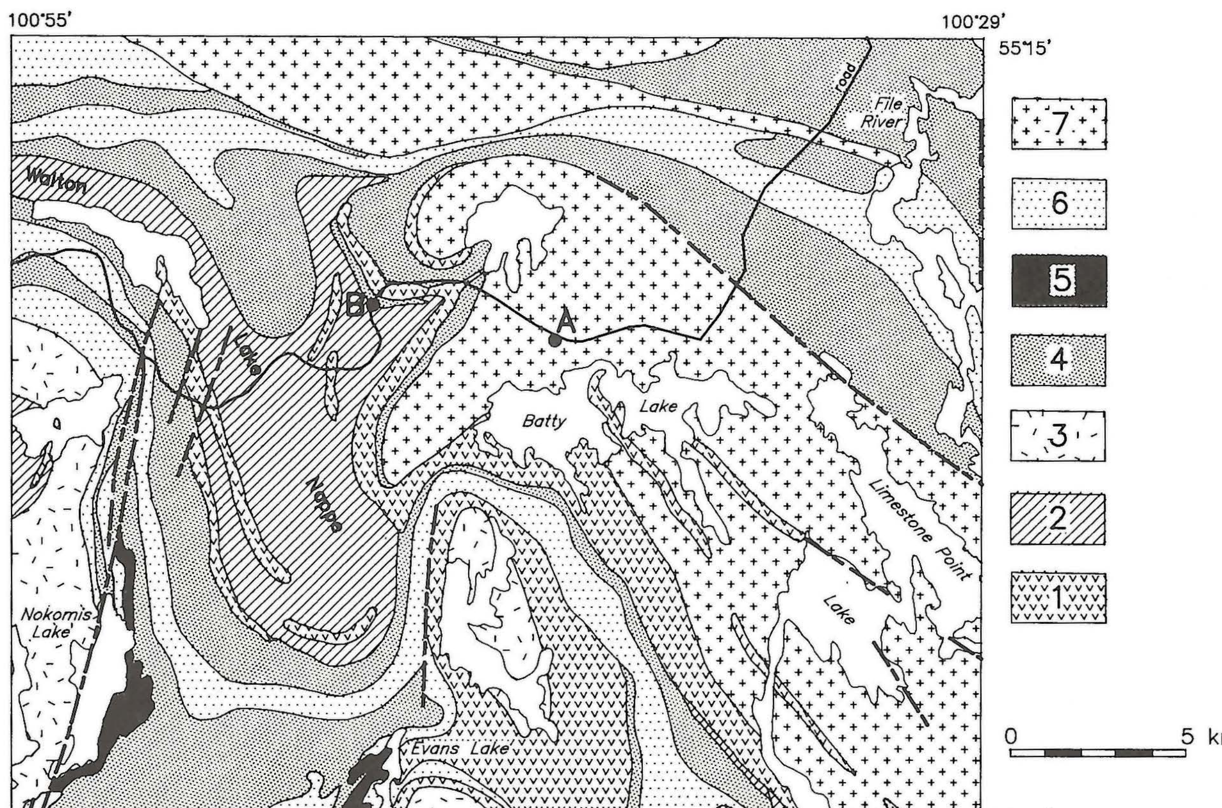

Figure GS-9-1: *Simplified geology of the Batty Lake area showing location of U-Pb zircon sample sites A (12-91-2) and B (12-91-1A). Units are given from oldest to youngest where the age is known: Amisk Group and equivalents = 1 - metavolcanics / sediments, 2 - felsic gneiss; tonalite = 3; Burntwood River Group = 4 - metagreywacke, 5 - amphibolite; Missi Group = 6; Granitoid gneiss = 7.*

chain that extends from Herblet Lake to the northwest end of Kississing Lake. The sample was chosen to provide a comparison with plutons in the Flin Flon belt. It is a medium grained, quartz-rich tonalitic gneiss locally with granitoid leucosome. Much of the rock has a granoblastic texture interpreted to be a high strain fabric that was largely annealed. A typical mode is 40% quartz, 50% plagioclase and 10% hornbende-biotite, but the quartz content is variable; garnet occurs in some samples. The Batty Lake complex is probably part of the late D_2 Walton Lake nappe (Zwanzig, GS-6 this volume). High temperature mineral assemblages in synkinematic mobilizate in adjacent rocks suggest that the deformation took place during peak metamorphism.

The other sample for this geochronology study was collected from a northerly-trending pegmatite dyke (50 cm wide) that intruded the axial plane of a late upright fold on the east side of the Walton Lake nappe. The dyke has weakly sheared vertical contacts and is part of a swarm that is interpreted to be synkinematic with F_4 structures (in particular, the Meat Lake synform), which postdate emplacement of the nappe. The sample was chosen to provide the age of the upright folding and a minimum age for the nappe emplacement. Regional mapping indicated that these dykes were emplaced during the waning stages of metamorphism (Zwanzig and Schledewitz, 1992).

ANALYTICAL TECHNIQUES AND RESULTS

U-Pb analytical methods used for zircon and monazite are outlined in Parrish *et al.*, (1987). All zircon fractions were strongly air abraded (Krogh, 1982). U and Pb blanks were approximately 1 and 15 picograms, respectively. The U-Pb data are presented in Table GS-9-1. In all concordia plots, errors are shown at the 2σ level.

Tonalite Gneiss

Zircons separated from the tonalite gneiss show two very distinct morphological populations consisting of; 1) rounded, anhedral, very clear zircons, and 2) subhedral, elongate grains with rounded terminations and a L:B ratio of 3:1 to 2:1. The grains of the second population have very poor clarity, are dark grey, and have extensive fractures and inclusions.

Two fractions were analyzed from the rounded population (Fig. GS-9-2). Fraction Ar, the smaller of these at -74μ, has a lower U concentration of 143 ppm, and is concordant at 1810 ± 8 Ma. Fraction Br was +74μ in size, had less clarity than Ar, a higher U concentration of 350 ppm and is 2.0% discordant.

The elongate population has U ranges from 381 to 1033 ppm. When plotted, all fractions are fairly discordant, ranging from 1.6 to 2.5%, with fraction D the most discordant at 7% (Fig. GS-9-2). A York regression of this population of elongate grains yields a upper intersect of 1859 +14/-7 Ma with a lower intercept of 355 Ma.

Table GS-9-1
U-Pb zircon and monazite analytical data

Fraction¹	Wt. μg²	U ppm	Pb* ppm	$^{206}Pb/^{204}Pb$ ³	Pb⁴ (pg)	^{208}Pb ⁵ (%)	$^{206}Pb/^{238}U$ ⁵	$^{207}Pb/^{235}U$ ⁵	Corr.⁶ Coeff.	$^{207}Pb/^{206}Pb$ ⁵	$^{207}Pb/^{206}Pb$ Age (Ma)
Tonalite	12-91-2		Z2895	55°10'25"N, 100°40'20"W							
Ar	8	143	46	400	55	3.1	0.3252±.12%	4.962±.27%	.61	0.11066±.22%	1810.3 ± 8.0
Br	14	350	110	1064	86	3.1	0.3173±.09%	4.834±.15%	.75	0.11051±.10%	1807.9 ± 3.6
C	15	434	139	1624	74	3.6	0.3230±.10%	5.025±.13%	.80	0.11281±.08%	1845.2 ± 3.0
D	10	381	118	571	124	4.0	0.3095±.11%	4.829±.22%	.69	0.11317±.17%	1851.0 ± 6.1
E	4	1033	337	510	145	4.1	0.3267±.17%	5.091±.28%	.60	0.11304±.23%	1848.8 ± 8.2
F	5	674	221	2937	24	5.0	0.3255±.10%	5.092±.11%	.92	0.11345±.04%	1855.4 ± 1.6
G	9	459	148	3885	21	4.1	0.3237±.09%	5.051±.10%	.93	0.11319±.04%	1851.3 ± 1.4
H	6	637	209	6737	12	4.6	0.3267±.09%	5.110±.10%	.94	0.11342±.03%	1854.9 ± 1.2
MA monazite	6	139	45	384	47	3.9	0.3228±.17%	4.908±.28%	.58	0.11027±.23%	1803.9 ± 8.2
MB monazite	11	81	27	269	65	6.4	0.3234±.18%	4.917±.37%	.57	0.11028±.31%	1804.0 ± 11.3
Pegmatite	12-91-1A		Z2894	55°11'02"N, 100°45'08"W							
A	13	998	308	10150	24	.8	0.3210±.08%	4.874±.10%	.96	0.11013±.03%	1801.5 ± 1.1
B	17	2972	908	26590	35	.5	0.3187±.09%	4.844±.10%	.96	0.11025±.03%	1803.5 ± 1.0
C	10	2619	802	38583	13	.7	0.3188±.08%	4.849±.10%	.96	0.11031±.03%	1804.5 ± 1.0
D	20	2844	869	35479	30	.7	0.3179±.09%	4.828±.10%	.96	0.11013±.03%	1801.6 ± 1.0
E	16	2510	772	108621	7	.7	0.3202±.09%	4.875±.10%	.96	0.11042±.03%	1806.3 ± 1.0
F	7	2261	696	10437	30	.7	0.3205±.09%	4.868±.10%	.96	0.11017±.03%	1802.2 ± 1.1
MA monazite	15	12241	9455	81518	45	60.1	0.3210±.10%	4.859±.11%	.97	0.10980±.03%	1796.1 ± 1.0
MB monazite	19	3904	3335	20915	66	65.2	0.3103±.09%	4.691±.10%	.97	0.10966±.03%	1793.8 ± 1.0

Errors are 1 std. error of mean in % except $^{207}Pb/^{206}Pb$ age errors which are 2σ in million years.

Pb* = radiogenic Pb

¹All fractions are zircon except where monazite is indicated; lower case letters refer to morphology: r- rounded

² Sample weight error of ± 1 μg in concentration uncertainty

³ Corrected for fractionation and spike Pb

⁴ Total common Pb in analysis in picograms

⁵ Corrected for blank Pb and U, and common Pb

⁶ Correlation Coefficient of errors in $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$.

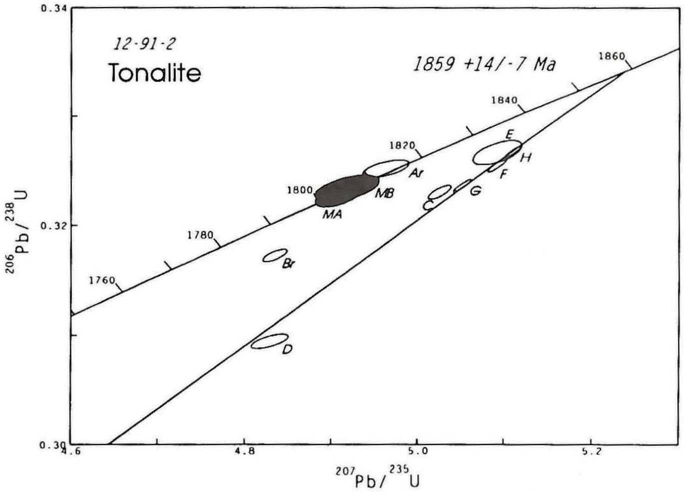

Figure GS-9-2: *Concordia diagram for the tonalite gneiss. Ar and Br are -74 and +74 fractions of rounded zircons. D - H are fractions from elongate zircons. Solid ellipses are monazite data from fractions MA and MB.*

Of the two monazite fractions analyzed, MA is concordant and has a $^{207}Pb/^{206}Pb$ age of 1804±8 Ma. Fraction MB is slightly above concordia (0.1%) and has a $^{207}Pb/^{206}Pb$ age of 1804±11 Ma.

The two distinct morphological populations from this tonalite give two different ages. The elongate population of zircon with an upper intercept age of 1859 Ma most likely dates the crystallization and emplacement age of this tonalite. The concordant zircon age of 1810 ± 8 Ma for the rounded, clear population, most likely of metamorphic origin, agrees within error with the slightly younger monazite age of 1804 ± 8 Ma, and dates the time of upper amphibolite facies metamorphism.

Granitoid Pegmatite

Zircons separated from this rock are euhedral prismatic grains with slightly rounded tips and a L:B ratio of 3:1. Fractions vary from colourless to cloudy with poor clarity; fractures, and inclusions are abundant. There is no evidence of cores and uranium concentrations range from 998 to 2972 ppm.

The six analyzed fractions form a none linear array and range from 0.4 to 1.4% discordant (Fig. GS-9-3). The $^{207}Pb/^{206}Pb$ ages range from 1802 to 1806 Ma. The zircons are too loosely clustered to give a reasonable York regression. The average $^{207}Pb/^{206}Pb$ age of 1803±1 Ma is at least a minimum emplacement age for this pegmatite.

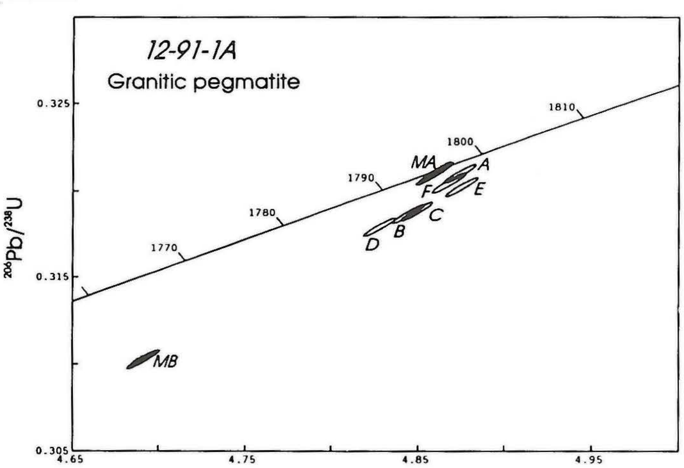

Figure GS-9-3: *Concordia diagram for the granitoid pegmatite (zircon fractions A - F); solid ellipses are monazite data from fractions MA and MB.*

Two monazite fractions yield a concordant $^{207}Pb/^{206}Pb$ age of 1796 ± 1 Ma and a 3.3% discordant $^{207}Pb/^{206}Pb$ age of 1796 Ma (Fig. GS-9-3). The concordant monazite (MA) of 1796 Ma is the time a which the pegmatite cooled past the closure temperature for monazite.

DISCUSSION

The crystallization age of the quartz tonalite gneiss falls into the range of voluminous volcanic-arc plutonism in the Flin Flon belt (Syme *et al.*, 1993) and adds evidence that the Kisseynew belt south flank had a similar intrusive history. However, the large uncertainty precludes for the distinction whether the body is pre- or post-Missi Group in age. Rocks previously interpreted as products of syn-Amisk volcanic alteration along the margin of the Batty Lake complex (Zwanzig, 1992) have been re-examined because the tonalite gneiss is significantly younger than the *ca.* 1.9 Ga Amisk Group. Apparently the Batty Lake complex has a thin supracrustal mantle and partly assimilated xenoliths containing altered felsic volcanic rocks.

The younger U-Pb ages, ranging from 1810 ± 8 Ma for metamorphic zircon to 1796±1 Ma for monazite in late-kinematic pegmatite (with *ca.* 1802-1806 Ma zircons), place some constraints on the timing and duration of orogenies affecting the Batty Lake area. Peak metamorphism, generation of granitoid leucosome and emplacement of hot fold nappes occurred in the order of 10 Myr before the last major folding and the ductile-brittle transition. The timing of deformation at Batty Lake corresponds with that all along the Kisseynew-Flin Flon margin in Manitoba (*e.g.* Ansdell and Norman, in prep.) Improved precision in dating is required to correlate separate phases of deformation.

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GS-10 U-Pb GEOCHRONOLOGY OF THE SOUTH FLANK OF THE KISSEYNEW GNEISS BELT, KISSISSING-BATTY LAKES AREA

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David, J., Machado, N. and Zwanzig, H.V., 1993: U-Pb geochronology of the south flank of the Kisseynew gneiss belt; Kississing-Batty lakes area; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 38-41.

SUMMARY

Samples for geochronology were collected during 1993 field work to address several important aspects of the igneous and tectonic history of the southern flank of the Kisseynew gneiss belt, for which timing is presently poorly known. Results of U-Pb geochronology of the supracrustal rocks may help to provide a stratigraphic framework for the Kisseynew belt and answer long-standing questions of correlation with the Flin Flon belt. Dating of the different intrusive lithologies will place more limits on the timing of magmatic activity, whereas dating anatectic materials may provide ages of metamorphic and deformational episodes.

To date, 19 samples have been crushed and heavy minerals separated; more than 70% have uranium-bearing minerals. Monazite and titanite fractions from 8 samples, mainly pegmatitic and tonalitic gneisses, are presently being analyzed.

INTRODUCTION

This report discusses a U-Pb geochronology sampling program (27 samples from 20 localities) conducted during late May 1993 on the southern flank of the Kisseynew gneiss belt, in the Kississing-Batty lakes area. This study is an extension of our geochronological work carried out in the vicinities of Flin Flon and Snow Lake, and which has already resulted in major revisions in concepts of the tectonic evolution of the Flin Flon volcanic belt (David *et al.*, 1993; Lucas, GS-14 this volume).

The timing of events is presently less well understood in the Kisseynew belt than it was in the Flin Flon belt a few years ago. The Kisseynew belt south flank consists of metamorphic rocks, interpreted to be derived from rocks that occur in the Flin Flon belt (Zwanzig and Schledewitz, 1992). Supracrustal rocks comprise, in tentative chronological order: (1) gneisses interpreted to be derived from the Amisk Group, dominated by metavolcanic rocks, and including the 'Unnamed' gneisses of Zwanzig and Schledewitz (1992) and the Sherridon Group of Robertson (1953); (2) the Burntwood River Group, containing mainly metasedimentary rocks; and (3) the Missi Group, containing both classes of rocks. (See Zwanzig, GS-6 this volume for stratigraphic relationships, recent nomenclature and a rock catalogue, and Fig. GS-10-1 for simplified geology.) Recent work suggests that the volcanic rocks are more extensive than previously recognized and these were tentatively assigned to the Amisk Group based on lithology, intrusive and stratigraphic relationships (Ashton and Froese, 1988; Zwanzig, 1992 and GS-6 this volume). Little supporting geochronology and no primary crystallization ages of the volcanic-derived gneisses exist at the present time.

Intrusive rocks occur primarily as large complexes of ultramafic to felsic gneisses that show strong deformational structures. A network of veins, dykes and sills show mainly syntectonic structure or are massive. The few U-Pb ages obtained from the intrusive rocks on a reconnaissance basis generally have low precision.

The contact between the Kisseynew and Flin Flon belts is transitional along most of its length. It represents a series of changes in structural style, proportion of exposed lithologies and increasing metamorphic grade (*e.g.* Zwanzig and Schledewitz, 1992). Specific units can be traced across the transition (Bailes, 1980; Ashton and Leclair, 1991; Zwanzig, GS-6 this volume). The contact acts primarily as the southern limit of fold nappes and possible thrust sheets dominated by the Burntwood River and Missi groups. These are interleaved with gneisses interpreted to be derived from the Amisk Group and its intrusions. The importance of this "contact" is a matter of debate, which can be partly resolved by geochronology.

The main objective of our research is to investigate the temporal relationship between rock units and between events in the two belts, in order to improve our understanding of the processes and mechanisms responsible for the juxtaposition of their various components. The U-Pb geochronological program is being conducted with this focus along LITHOPROBE Trans-Hudson Orogen Transect 7, an accessible corridor of intense past and present geological and geophysical work and with a rising interest shown by the mineral exploration industry. The program builds on the existing geochronological database (Gordon *et al.*, 1990; Hunt and Zwanzig, 1990, GS-9 this volume; Ansdell and Norman, in prep. and see Syme *et al.*, 1993 for a compilation). Sampling undertaken in the present study is intended to address the specific problems, discussed below.

SUPRACRUSTAL ASSEMBLAGES

Gneisses interpreted as Amisk Group are fine- to coarse-grained amphibolite and felsic rocks, which probably represent the high grade metamorphic equivalents of predominantly volcanic rocks. Three felsic gneiss samples were collected in order to attempt to determine their primary crystallization ages and thus test their proposed stratigraphic correlation. The samples were collected from the Walton Lake nappe, close to the axis of the Meat Lake synform: sample K93-12 is characterized by the presence of small quartz phenocrysts and was taken from a sequence interpreted as thinly bedded, aphanitic metarhyolites; sample K93-14 is similar to K93-12, whereas K93-15 is from a breccia layer. (Sample sites are shown in Fig. GS-10-1 and UTM coordinates are listed in Table GS-10-1).

A white pegmatite, sample K93-11, occurring in an amphibolite of the Amisk related gneiss, was collected to the northeast of the Batty Lake intrusive complex. The pegmatite, a mobilizate from the amphibolite, is interpreted as an early melt for which the age of crystallization should represent the age of an early metamorphism.

Sample K93-9, a phenocryst-rich, fine grained, felsic gneiss from the ***Sherridon Group,*** originally interpreted as a meta-arkose (*e.g.* Froese and Goetz, 1981), may represent a felsic tuff (Ashton and Froese, 1988). If the interpretation is correct, we may be able to determine the primary age of the Sherridon Group and know whether it is indeed equivalent to the Amisk Group. Unpublished work by Hunt and Froese suggests that only relatively young, possibly metamorphic zircons have been found to date.

The Burntwood River Group, which consists mainly of graphite bearing, garnet-biotite gneisses, is thought to be the equivalent to greywacke-mudstone turbidites of the File Lake formation in the Snow Lake area. Metagreywacke samples of this group have been collected from two localities: K93-7, on the NE limb of the Meat Lake synform, and K93-16 immediately north of the Kississing River Shear Zone. Samples from two metagreywacke beds of different composition and a sample of calcsilicate composition were collected at site 7. Beds of interstratified coarse- and fine-grained material characterize sample location 16, where a single homogeneous coarse grained metagreywacke sample was collected. Detrital zircons from this metagreywacke will be analyzed to determine provenance ages and the maximum age of sedimentation. Comparison will be made to the data available from the File Lake formation (David *et al.*, 1993) and the metasedimentary rocks on Athapapuskow Lake.

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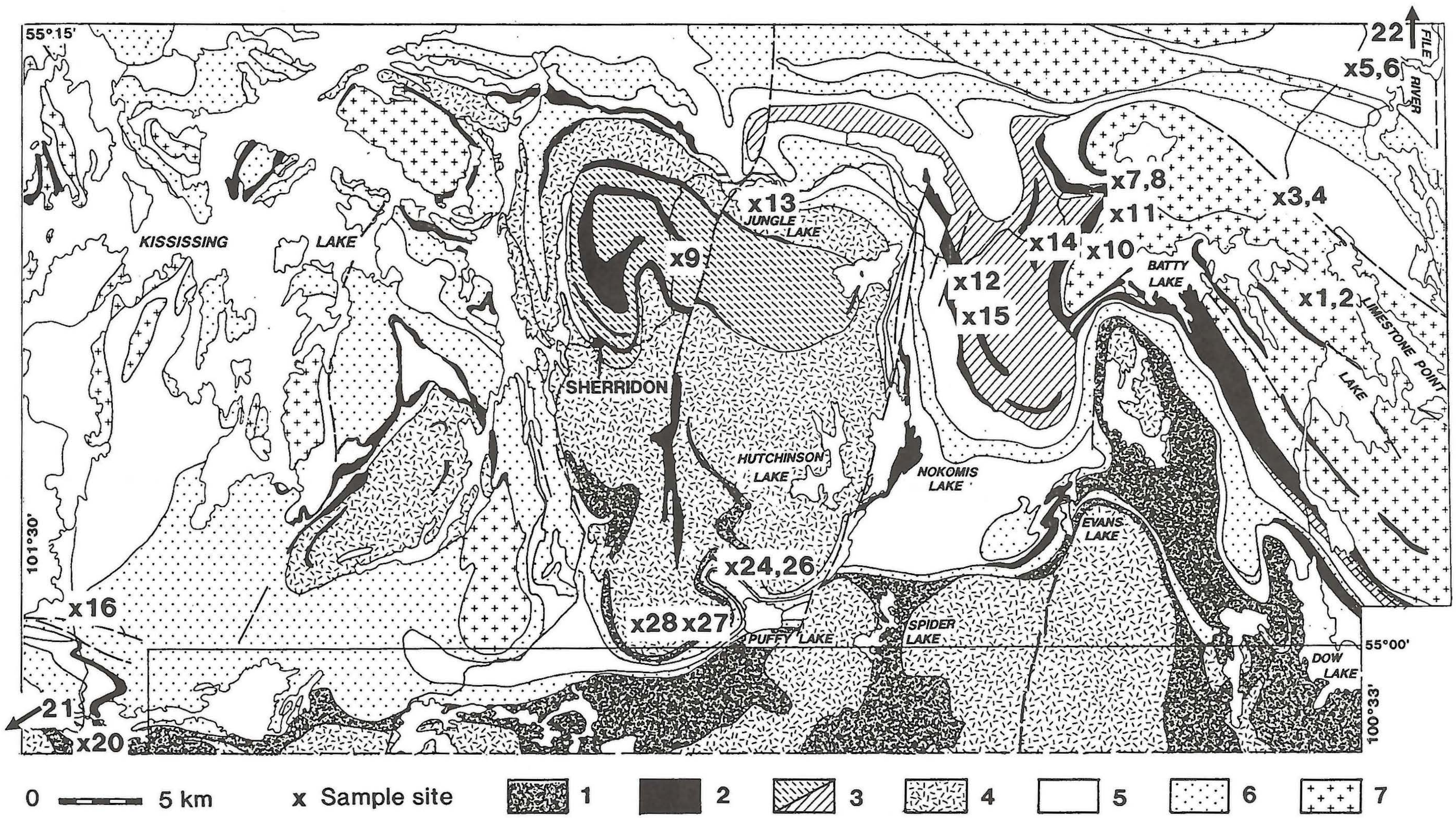

Figure GS-10-1: *Simplified geology of the Kissississing-Batty lakes area showing location of samples for U-Pb ages. Units are given from oldest to youngest where the age is known: Amisk Group and equivalents = 1 - metavolcanics, 2 - amphibolite, 3 - felsic gneiss (Sherridon/unnamed); Tonalite = 4; Burntwood River Group = 5; Missi Group = 6; Granitoid gneiss = 7.*

Table GS-10-1
List of Samples, Rock Types and UTM Coordinates

Site	Sample	Group/Complex	Rock Type	UTM-N	UTM-E
1, 2	K93-1	Batty Lake	tonalitic gneiss	6110925	399150
1, 2	K93-2	Batty Lake	pegmatite	6110925	399150
3, 4	K93-3	Batty Lake	tonalitic gneiss	6116050	398225
3, 4	K93-4	Batty Lake	pegmatite	6116050	398225
5, 6	K93-5	Core Zone gneiss	tonalitic gneiss	6121700	401750
5, 6	K93-6	Core Zone gneiss	pegmatite	6121700	401750
7, 8	K93-7a	Burntwood River	metagreywacke	6116675	390650
7, 8	K93-7b	Burntwood River	metagreywacke	6116675	390650
7, 8	K93-7c	Burntwood River	calc-silicate	6116675	390650
7, 8	K93-8	Burntwood River	pegmatite	6116675	390650
9	K93-9	Sherridon/Amisk(?)	felsic gneiss	6115350	370300
10	K93-10	BattyLake	pegmatite-mylonite	6115250	390900
11	K93-11	Amisk(?)	pegmatite	6115975	390900
12	K93-12	Amisk(?)	felsic volcanic	6112750	383100
13	K93-13a	Sherridon-Hutchinson	tonalitic gneiss	6116600	374075
13	K93-13b	Sherridon-Hutchinson	pegmatite	6116600	374075
14	K93-14	Amisk(?)	felsic volcanic	6114475	386950
15	K93-15	Amisk(?)	felsic breccia	6111650	383175
16	K93-16	Burntwood River	metagreywacke	6098900	343125
20	K93-20	Missi	felsic volcanic	6092825	342950
21	K93-21	Defender Lake	granitic gneiss	6094850	338400
22	K93-22	Core Zone gneiss	tonalitic gneiss	6130650	404200
24	K93-24	Missi	metarhyolite	6100100	372150
26	K93-26	Missi	metadacite	6100100	372150
27	K93-27	Sherridon-Hutchinson	tonalite	6099500	370150
28	K93-28	Sherridon-Hutchinson	granite	6098825	367975

The age of crystallization of a pegmatite (K93-8) intrusive into the metagreywacke (K93-7) that, in turn, contains the cleavage associated with F_3 should provide the minimum age of the sedimentation and also date the development of the D_3 deformation episode (Zwanzig and Schledewitz, 1992).

The Missi Group, an assemblage of quartzofeldspathic gneisses and amphibolite, is the youngest sequence; it unconformably overlies rocks of the Amisk Group and conformably overlies the Burntwood River Group (*cf.* Zwanzig, GS-6 this volume). A unit of pink felsic gneiss occurs near the base of the sequence close to the unconformity. The protolith of the pink gneiss is recognized to be a felsic volcanic rock interpreted to be the equivalent to the Chickadee rhyolitic ash-flow tuff that has been dated at 1832 ± 2 Ma (Gordon *et al.,* 1990) in the Wekusko Lake area. The objective of sampling the present metarhyolite is to test, by establishing its crystallization age, the hypothesis that the unit represents a synchronous marker above the angular unconformity as has been reported from several locations in the south flank of the Kisseynew belt, and also the Flin Flon belt. Samples K93-24 and K93-26 are respectively a pink felsic gneiss and a fine grained gneiss of dacitic composition from the Puffy Lake area. Sample K93-20, a fine grained, quartzofeldspathic pink gneiss with quartz phenocrysts was collected on the southern limb of the Lobstick Narrows anticline. A similar, but slightly remobilized, gneiss in the Missi Group at Cleunion Lake has yielded 1818± 5 Ma zircons (Ansdell and Norman, in prep.).

INTRUSIVE ROCKS

The Batty Lake Complex is one of the largest intrusive complexes in the area and occurs at the eastern limit of the study region. Preliminary U-Pb geochronology has produced ages of ca. 1859 Ma and 1810 Ma, interpreted as the ages of crystallization and metamorphism (Hunt and Zwanzig, GS-9 this volume). Samples selected to determine the range of ages of intrusions in the complex were collected at two locations; K93-1 and -2 are from the central part of the complex (close to Limestone Point Lake), and K93-3, and -4 from the northeastern edge of the complex (close to the Limestone Creek high strain zone). Samples 1 and 3 are strongly foliated leucotonalitic orthogneisses with highly elongated amphibolitic xenoliths. Samples 2 and 4 are pink granitic pegmatites that postdate formation of the gneissosity at both locations. The pegmatites are, however, weakly sheared, interpreted as a result of D_3 deformation. The crystallization ages for the pegmatites may therefore identify a melting event prior to D_3. The northwestern contact of the complex is a D_4 shear zone (Zwanzig and Schledewitz, 1992). The crystallization age for a pegmatitic mylonite, K93-10, should place some limits on the minimum age of this latest phase of deformation.

The Sherridon-Hutchinson Lake Complex occupies the central part of the area and appears to be the of result of multiple tectonomagmatic events. Preliminary U-Pb geochronology for the complex has produced ages of *ca.* 1892 Ma and 1873 ± 4 Ma (Hunt and Zwanzig, 1990), interpreted as the age of crystallization of tonalitic and granitic intrusions respectively, near Puffy Lake. The tonalitic gneiss and a younger granite pegmatite, K93-13a, -b respectively, from Jungle Lake at the northern limit of the complex, have a relationship similar to the gneiss/pegmatite samples from the Batty Lake Complex. Successful analysis of the Sherridon-Hutchinson Complex samples should facilitate comparing the timing of intrusion, deformation and metamorphism of both complexes and of the Herblet Lake Gneiss Dome in the Snow Lake Area (David *et al.,* 1993), and the Defender Dome (below). Two other samples were collected west of Puffy Lake at the southern limit of the complex; a homogeneous grey tonalite K93-27 and a later granite K93-28, that intruded the tonalite and provides evidence for multiple intrusive events.

The Core Zone of the Kisseynew belt has as yet provided only four U-Pb ages (Gordon *et al.,* 1990). Samples K93-5 and -6, at the northeastern limit of the study region, are a homogeneous tonalitic gneiss and a pink granitic pegmatite respectively. The pegmatite is generally parallel to the regional fabric in the tonalite, but it is locally discordant. These two lithologies are developed as lenses within metatexite derived from the metagreywacke of the Burntwood River Group, and are of uncertain origin. Approximately 11 km north of sample location 5 (Fig. GS-10-1) an orthopyroxene-bearing tonalite (K93-22) has been sampled to be compared with a similar enderbite sill on Burntwood Lake that has been dated at 1830 +11/-5 Ma (Gordon *et al.,* 1990).

The Defender Lake dome appears to be mainly a tonalitic complex, the northern margin of which is strongly foliated (Zwanzig and Schledewitz, 1992). It lies close to the transition between the Kisseynew and the Flin Flon belts. The crystallization age of a granitic gneiss (K93-21) from the northern margin of the dome, collected on the shore of Kisseynew Lake, should provide information about the age of a high strain zone that developed in relation to the southwestward transport of the gneiss belt.

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GS-11 TRANSITION BETWEEN THE FLIN FLON AND KISSEYNEW DOMAINS, FILE LAKE-LIMESTONE POINT LAKE AREA, NORTHERN MANITOBA

by K.A. Connors[1] and K.M. Ansdell[2]

Connors, K. A. and Ansdell, K.M., 1993: Transition between the Flin Flon and Kisseynew domains, File Lake-Limestone Point Lake area, northern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 42-46.

SUMMARY

The tectonothermal evolution of the File Lake-Limestone Point Lake area involved early bedding-parallel faulting, two generations of tight to isoclinal folds (F_1, F_2) with bedding-parallel cleavages (S_1, S_2) and two generations of upright folds (F_3, F_4) with associated crenulation cleavages (S_3, S_4). Prograde metamorphism peaked post-F_1/S_1 but pre-S_2, although metamorphic conditions remained sufficient for sillimanite recrystallization during F_3 and biotite recrystallization during F_4. The actual "boundary" between the Flin Flon and Kisseynew domains corresponds to the Loonhead Lake fault, an early bedding-parallel structure that places the Burntwood River Group (File Lake formation) on top of the Amisk Group over a substantial strike length (>80 km). The orientation of the early structures (F_1/S_1, S_2) changes progressively from near vertical in the File Lake area (greenschist to amphibolite grade) to gently-dipping in upper amphibolite grade gneisses to the north of Loonhead Lake.

INTRODUCTION

The Kisseynew and Flin Flon domains are locally separated by faults, which are generally considered late, although, elsewhere the "boundary" is marked by a rapid increase in metamorphic grade and/or a change in dominant rock type (Zwanzig, 1990). For convenience, the boundary is commonly defined as the biotite-sillimanite-garnet isograd (*e.g.* Froese and Moore, 1980; Zwanzig, 1990). Recent studies in the File Lake-Limestone Point Lake area have documented the northward increase in metamorphic grade, correlated the principal map units (Amisk, Burntwood River and Missi Groups) between the low grade rocks and the high grade gneisses, and examined the structural history (Bailes, 1980; Zwanzig and Schledewitz, 1992). However, the detailed maps of Bailes (1980) and Zwanzig and Schledewitz (1992) are separated by a 3 to 4 km wide strip passing along the northern edge of Loonhead Lake (Fig. GS-11-1), which was mapped only as undifferentiated gneiss by Harrison (1949).

The principal aims of this project are to: i) document the detailed structural history in the File Lake area; ii) determine the nature of the contacts between the Missi, Burntwood River and Amisk Groups; and iii) evaluate the significance of the structural and metamorphic transition between the Flin Flon and Kisseynew domains. Note that although all rocks in this area have been metamorphosed, the prefix meta has been omitted.

ROCK UNITS AND CONTACTS

In the File Lake area the Amisk Group consists of subalkaline basalt to rhyolite (<20%) flows and fragmental rocks (Bailes 1980) that are metamorphosed to form amphibolitic gneisses on the southern flank of the Kisseynew Domain. The Amisk Group rocks are structurally overlain (see below) by the File Lake formation greywacke turbidites and paragneisses of the Burntwood River Group, which are in turn overlain (structurally or stratigraphically?) by the Missi Group quartzofeldspathic gneisses. The interpreted continuity of Missi Group gneisses from File Lake to Dow Lake as depicted in Figure GS-11-1 is based on magnetic and limited mapping data. The magnetite-bearing Missi Group stands out against the File Lake Formation on magnetic maps, and a fairly consistent magnetic high joins the known outcrops of Missi Group north of File Lake to the known outcrops of Missi Group at Dow Lake.

The rock units within the study area have been described in detail by Bailes (1980) and Zwanzig and Schledewitz (1992), therefore the following section focuses on evidence regarding the nature of the contact relationships and the significance of the mafic volcanic rocks within the File Lake Formation.

Amisk Group-File Lake formation contact

Although the File Lake Formation turbidites have previously been interpreted as being part of the Amisk Group (Bailes, 1980), recent U-Pb geochronology of detrital zircons indicates that the turbidites are younger than 1850 Ma (David and Machado, 1993) and therefore postdate volcanism by at least 35 Myr. This age difference between Amisk Group and File Lake formation has prompted re-evaluation of the contact between these two units. In the File Lake area, there is evidence of intense cleavage development, boudinage, disruption of units and alteration along most of this contact (Bailes, 1980; this study). Furthermore, this contact has been traced northwards (Harrison 1949) to where Zwanzig and Schledewitz (1992) interpreted it as a fault. Based on this combination of regional and local evidence, the File Lake formation-Amisk Group contact in the File Lake area is interpreted as a fault, and is referred to here as the Loonhead Lake Fault. In the Kisseynew Domain, Zwanzig and Schledewitz (1992) suggested that this faulted contact is truncated at the Missi Group basal unconformity.

Alternatively, the Loonhead Lake Fault may be cut by a younger fault at the base of the Missi Group. Regardless of whether the Loonhead Lake Fault predates Missi Group deposition, this structure appears to be truncated by, and therefore predates, the 1830 Ma (Gordon *et al.*, 1990) Ham Lake Pluton (Fig. GS-11-1). East of the Ham Lake Pluton, the same File Lake formation-Amisk Group contact is interpreted as the Snow Lake Fault (Bailes and Galley, 1992). If the Loonhead Lake and Snow Lake faults represent the same structure, this implies a strike length of >80 km and thus possibly substantial displacement. Regional distribution of units and kinematic analyses in the Kisseynew Domain suggest that the File Lake formation was deposited farther north and was transported S or SW toward Amisk Group rocks (Zwanzig, 1990; Norman and Williams, 1993).

Missi Group-File Lake formation contact

The nature of the contact between the Missi Group and File Lake formation is uncertain due to lack of outcrop in the File Lake area, but Zwanzig and Schledewitz (1992) reported evidence of a 3 to 10 m thick deformed conglomerate between Lobstick Narrows and Martell Lake and interpreted the contact as an unconformity. Farther east toward Snow Lake, this contact occurs lower in the File Lake Formation stratigraphy, closer to the Corley Lake member (Bailes, pers. comm. 1993), suggesting that it may either be a low angle fault or an unconformity. It is interesting to note that the only contact between these two units in the east Wekusko Lake area is interpreted as an early fault (Ansdell and Connors, in prep.).

Significance of the mafic gneiss

An unnamed unit of mafic to intermediate gneisses occurs within the File Lake formation along the southern edge of the Batty Lake complex and within the NNE-trending File Lake synform (Fig. GS-11-1). In the former area, Zwanzig and Schledewitz (1992) have

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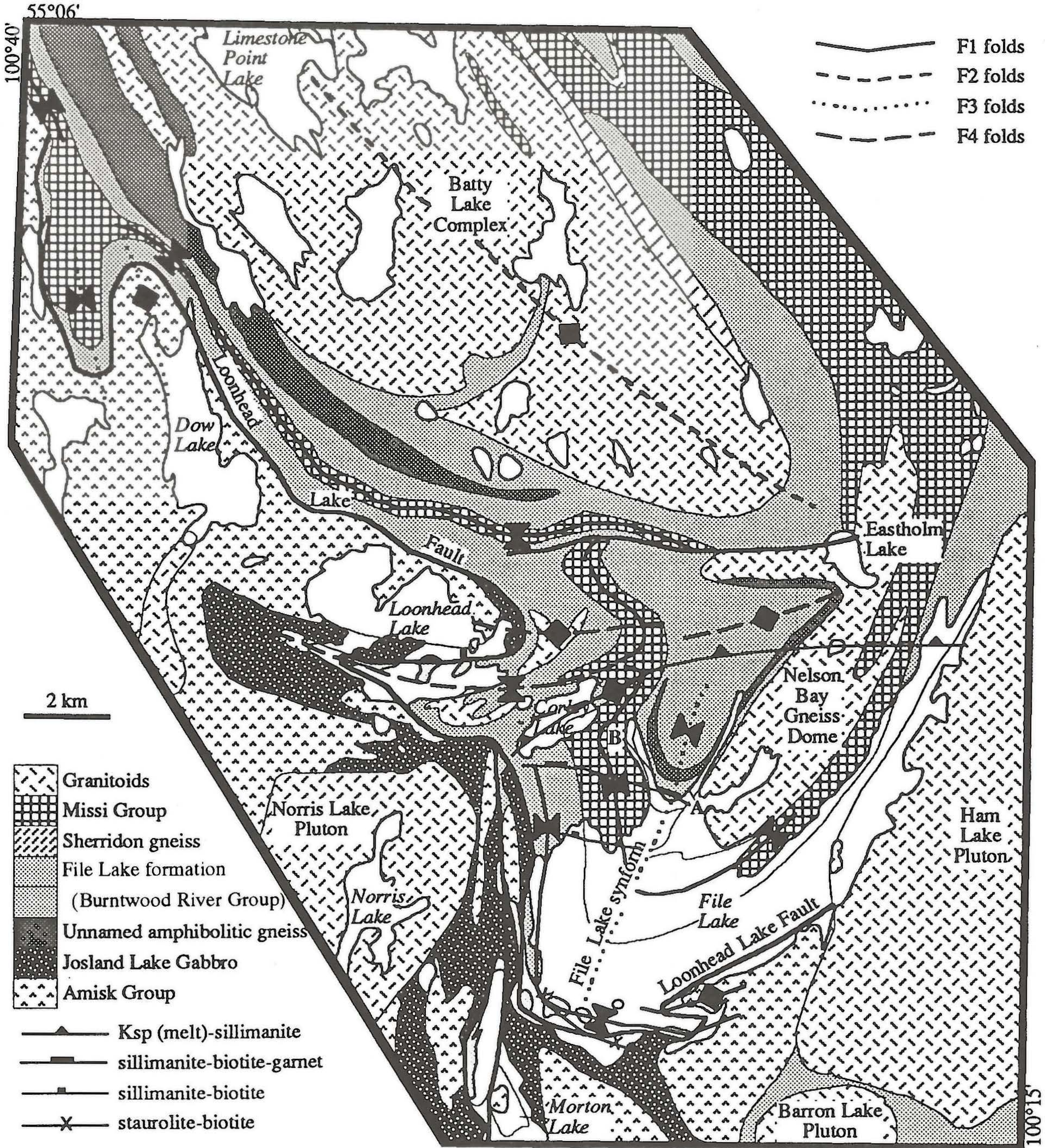

Figure GS-11-1: Simplified geology of the File Lake-Limestone Point Lake area (modified from Zwanzig and Schledewitz (1992) and from Bailes (1980)).

suggested that this unit includes metamorphosed gabbro, basalt, and locally, silicate iron formation. In the latter area, the unit consists largely of fine grained banded gneisses containing thin discontinuous felsic bands within a mafic host, which may represent tuffaceous units. This unit also includes mafic flows with deformed pillow selvages.

It is uncertain whether these mafic gneisses represent a fault-bounded package or part of the File Lake formation stratigraphy. The former interpretation supports early, low angle faulting, and although the latter interpretation accounts for the mafic rocks by contemporaneous sedimentation and volcanism, it also supports early faulting. These mafic gneisses occur only in the File Lake formation north of the Missi Group and are absent in the southern band of File Lake Formation, which is juxtaposed with the Amisk Group (Fig. GS-11-1). The latter hypothesis would therefore suggest: i) that the two bands of File Lake formation may represent two distinct lithological packages; and ii) the presence of a fault somewhere between these two packages (*i.e.* on either side of the Missi Group; Fig. GS-11-1).

FOLD/CLEAVAGE GENERATIONS AND THEIR TIMING WITH RESPECT TO METAMORPHISM

Early structures (F_1-F_2 folds)

The oldest generation of structures recognized in the File Lake area are F_1 isoclinal folds. The hinges are rarely exposed and the folds are identified by changes in younging. The pervasive S_1 cleavage is parallel to layering and vergence generally cannot be determined. Staurolite, garnet and sillimanite overgrow S_1 indicating that peak metamorphism postdates F_1/S_1. Regional metamorphism resulted in extensive anatexis within the paragneisses north of File Lake.

A stretching lineation, defined by aligned minerals and stretched clasts, is developed on the S_1 cleavage. The steep, SSW-plunging stretching lineation is subparallel to the S_1/S_0 intersection lineation. The F_1 axial planes, however, can be traced over 10 km, suggesting that the fold hinges are subhorizontal on a regional scale. This suggests that F_1 folds are doubly plunging and/or that the steep stretching lineation postdates F_1 folding (see below).

Numerous mesoscopic faults at a low angle to bedding were identified along the northwest shore of File Lake. Some of these structures truncate F_1 folds, whereas other faults are folded and overprinted by the S_1 cleavage especially where ramps are developed. Development of these low angle faults pre-, post- and possibly syn-F_1/S_1 suggests that the folds and faults formed during the same phase of deformation. These small scale faults may be the same generation as large scale faults such as the Loonhead Lake Fault.

The F_1 folds, S_1 cleavage and peak metamorphic assemblages are overprinted by the S_2 cleavage, which is developed at a small angle to bedding and S_1 throughout the File Lake area. Staurolite and garnet generally contain straight inclusion trails despite development of S_2 crenulations in the matrix, suggesting that S_2 postdates peak metamorphism. Along the north shore of File Lake the S_2 cleavage consistently verges to the east, and on the south shore in the hinge of the F_3 File Lake synform (Fig. GS-11-1) S_2 indicates northward vergence toward the core of the F_3 synform. Although no F_2 folds have been identified in the File Lake area, folds of this generation occur in the Kisseynew gneisses (see below).

On the north shore of File Lake, the S_2/S_1 and S_2/S_0 intersection lineations plunge steeply SSW parallel to the L_1 stretching lineation, as well as the S_1/S_0 intersection lineation. This suggests several possible interpretations.

1. F_1/S_1 and F_2/S_2 structural generations developed during progressive deformation and the stretching lineation is related to both generations of structures.
2. Development of the stretching lineation and S_1/S_0 intersection lineation may have influenced the orientation of the younger S_2/S_1 intersection lineation, although the older lineations may not be sufficiently intense to have influenced the orientation of later structures.
3. The stretching lineation developed during F_2/S_2 and overprints F_1/S_1 structures.

Although studies in the Kisseynew favor the first hypothesis (*e.g.* Norman and Williams, 1993), F_1/S_1 may substantially predate F_2/S_2 in this area (see below).

It is difficult to trace the cleavages from the low grade rocks into the Kisseynew gneisses. However, the dominant foliation within the Missi Group and File Lake formation gneisses north of Loonhead Lake (Fig. GS-11-1), is a crenulation cleavage suggesting that it is at least the second cleavage in these rocks. In addition, this cleavage contains flattened faserkiesels (sillimanite-quartz nodules) and is axial planar to folded leucosome suggesting that it postdates the metamorphic peak and associated anatexis. The dominant fabric in the gneisses is therefore correlated with S_2 in the lower grade rocks.

Late folds (F_3-F_4)

The F_1 isoclinal folds and S_2 cleavage are overprinted by the large scale NNE-trending File Lake synform (Fig. GS-11-1). Mesoscopic structures are dominated by steeply plunging, asymmetrical folds and by crenulations in mica-rich rocks. The steep axial planar S_3 crenulation cleavage is only developed in micaceous layers within F_3 hinge zones. In thin section, S_3 crenulations deform sillimanite bundles and therefore postdate the peak of metamorphism. Nevertheless biotite, and locally sillimanite, in the hinges of S_3 crenulations are recrystallized and largely strain free, indicating that conditions were close to the sillimanite stability field during S_3.

Tight to open F_4 folds plunge moderately E to ENE and are best developed north of File Lake (Fig. GS-11-1). The steep S_4 cleavage is only developed within hinge zones of F_4 folds and is defined by crenulations in micaceous units and/or alignment of biotite and muscovite in quartzofeldspathic gneisses. Biotite laths in the F_4 folds and S_4 crenulations are recrystallized, and S_4 is locally defined by a biotite foliation. A generation of centimetre to metre thick pegmatites are associated with F_4/S_4. Some pegmatites crosscut F_4 folds, some are folded by F_4, and some are associated with offset along F_4 axial planes, indicating emplacement during F_4 folding.

DISCUSSION AND PRELIMINARY CONCLUSIONS

Timing of low angle faulting

Truncation of the Loonhead Lake Fault by the 1830 Ma Ham Lake Pluton suggests that the fault may substantially predate peak metamorphism, which is estimated at 1810 to 1815 (Gordon *et al.*, 1990; David and Machado, 1993), and therefore also predate S_2, F_3/S_3, and F_4/S_4. Although the mesoscopic overprinting relationships between F_1/S_1 and outcrop scale faults suggest that faulting may have occurred in association with folding, it is uncertain whether map scale F_1 folds formed at approximately the same time as large scale faults, such as the Loonhead Lake Fault, and therefore also predate peak metamorphism by 15 to 20 Myr. Any of the potential faults within the File Lake Formation (*i.e.* adjacent to the mafic gneisses) or between the File Lake Formation and the Missi Group (as discussed above), must predate the S_2 cleavage, which has a consistent orientation and vergence across all of these contacts along the north shore of File Lake. It is therefore likely that any faults within these units are approximately the same age as the Loonhead Lake Fault.

Timing of metamorphism

The field and limited thin section observations indicate that although several stages of deformation in the File Lake area occurred during regional metamorphism, low angle faulting, and possibly F_1/S_1, substantially predate metamorphism. The metamorphic peak occurred post-F_1/S_1, and this generation of structures may have developed 15 to 20 Myr before, or any time up to peak metamorphism. Conditions peaked pre-S_2 within the sillimanite-garnet-biotite field, and remained near the sillimanite stability field through to F_3/S_3. In addition, S_4 microstructures indicate that temperature was sufficient for recrystallization of biotite during F_4 upright folding.

Correlation of structural generations

The Missi Group rocks at File Lake and at Dow Lake are both folded by large scale, isoclinal synclines (Fig. GS-11-1), therefore correlation of map units leads to correlation of structural generations (Fig. GS-11-2). The SW-verging D_2 syncline (Zwanzig and Schledewitz, 1992) of Missi Group gneisses at Dow Lake correlates with the F_1 syncline at File Lake where the asymmetry and vergence are unknown (Fig. GS-11-2). Although we did not identify map scale folds in the File Lake area that correlate with Zwanzig and Schledewitz's (1992) D_3 folds, we did identify a cleavage (S_2) that postdates F_1 isoclinal folds and is folded by NNE-trending, upright folds, and therefore is tentatively interpreted as equivalent in age. The S_2 cleavage in the File Lake area consistently verges toward the core of the overprinting F_3 File Lake synform, indicating roughly northward vergence prior to F_3 folding. This suggests that the File Lake area occurs on the southern limb of a F_2 antiform that may correlate with the antiform of the Batty Lake Complex (one of Zwanzig and Schledewitz's D_3 folds; Fig. GS-11-1). NE- to NNE-trending, upright folds that overprint the early structures have been identified by Bailes (1980), Zwanzig and Schledewitz (1992) and this study (Fig. GS-11-2). The E-W F3 folds of Bailes (1980) represent the F_4 folds of this study.

Further support for the interpreted correlation of structural generations between the low grade rocks and high grade gneisses is provided by the timing of metamorphism. Zwanzig and Schledewitz (1992) concluded that the metamorphic peak in the Kisseynew Domain occurred after their D_2 folds (equivalent to F_1 folds at File Lake), and before D_3 folds (which correlate with S_2; Fig. GS-11-1). The same post-F_1/S_1, pre-S_2 timing for peak metamorphism has been determined for the File Lake area (see above). Bailes (1980), however, suggested peak metamorphism postdated the NNE-trending folds (F_3 of this study) apparently due to differences in correlation of cleavage generations.

The structural correlations outlined in Figure GS-11-2 highlight variations in structural style from the low grade Flin Flon Domain into the high grade Kisseynew gneisses. The isoclinal F_1 folds and S_2 cleavage of the File Lake area are consistently steep, whereas the equivalent age structures in the Kisseynew dip gently northeast (30° or less). This change occurs in pre- to syn-metamorphic structures, therefore suggesting that the transition to gently dipping structures occurred with paleodepth. No late structures that could account for the change in orientation by overprinting have been identified.

There are several factors that may have been partly responsible for this structural transition. These include: i) differences in rheology at higher temperature; ii) increasing shear strain with depth (*cf.* Sanderson 1982); and iii) a buttress effect at the northern margin of the Flin Flon Domain, which is dominated by more competent arc-related volcanic and intrusive rocks. It is likely that all three factors influenced the structural transition along the Kisseynew-Flin Flon boundary.

ACKNOWLEDGMENTS

We would like to thank Sue Schaan and Ian Russell for pleasant and efficient assistance in the field; Al Bailes for providing thin sections and location maps, and for showing us around the File Lake area; Steve Lucas, Terry Gordon, and Al Bailes for numerous geological discussions.

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Bailes (1980)	Zwanzig and Schledewitz (1992)	This study
	D1 faulting (pre-Missi)	early faulting
F1 isoclinal folds	D2 fold nappes	F1 isoclinal folds
	M	M
	D3 fold nappes	S2 cleavage
F2 NNE upright folds	D4 NE upright folds	F3 NNE upright folds
M		
F3 E-W folds		F4 E-W folds

Figure GS-11-2: Correlation of structural generations and peak metamorphism.

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GS-12 SURFICIAL GEOLOGY AND TILL GEOCHEMICAL SAMPLING IN THE NAOSAP LAKE AREA (NTS 63K/14)

by E. Nielsen

Nielsen, E., 1993: Surficial geology and till geochemical sampling in the Naosap Lake area (NTS 63K/14); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 47-49.

SUMMARY

This report briefly describes till sampling and surficial geological mapping undertaken to aid in the search for base metals in the Naosap Lake area. Lee-side till, which is widespread and variable in texture and thickness constitutes the main sampling medium. The results of the geochemical analyses on 197 till samples are forthcoming.

INTRODUCTION

Regional till sampling at one sample per 4 or 5 km² initiated in the Flin Flon-Snow Lake area in 1989 continued in the Naosap Lake area (Gobert and Nielsen, 1991). In the present survey a total of 197 till samples and 156 humus samples were collected from 157 hand-dug pits (Fig. GS-12-1). Sampling was concentrated in the western, northwestern and northern part of the area underlain primarily by volcanic and related rocks. The extensive and relatively inaccessible areas of intrusive rocks in the southeast were largely ignored during the present survey.

SURFICIAL GEOLOGY

The surficial geology of the Naosap Lake area is similar to that described previously for the Elbow Lake area to the east (Nielsen, 1992). Till is generally thin and patchy in its distribution in areas above 320 m in elevation. Below 320 m glaciolacustrine clay is pervasive and a hindrance to till sampling from hand-dug pits. A long beaded esker or series of subaqueous outwash fans (Groom, 1989) occurs near the western edge of the map area and forms a natural roadbed for much of the Sherridon road. During the regression of glacial Lake Agassiz, till and other previously deposited sediments were eroded and reworked into littoral sediments that now flank many of the hills in the area.

Figure GS-12-2 summarizes striation measurements and shows the dominant ice flow was toward 200-210°, similar to the Elbow Lake area.

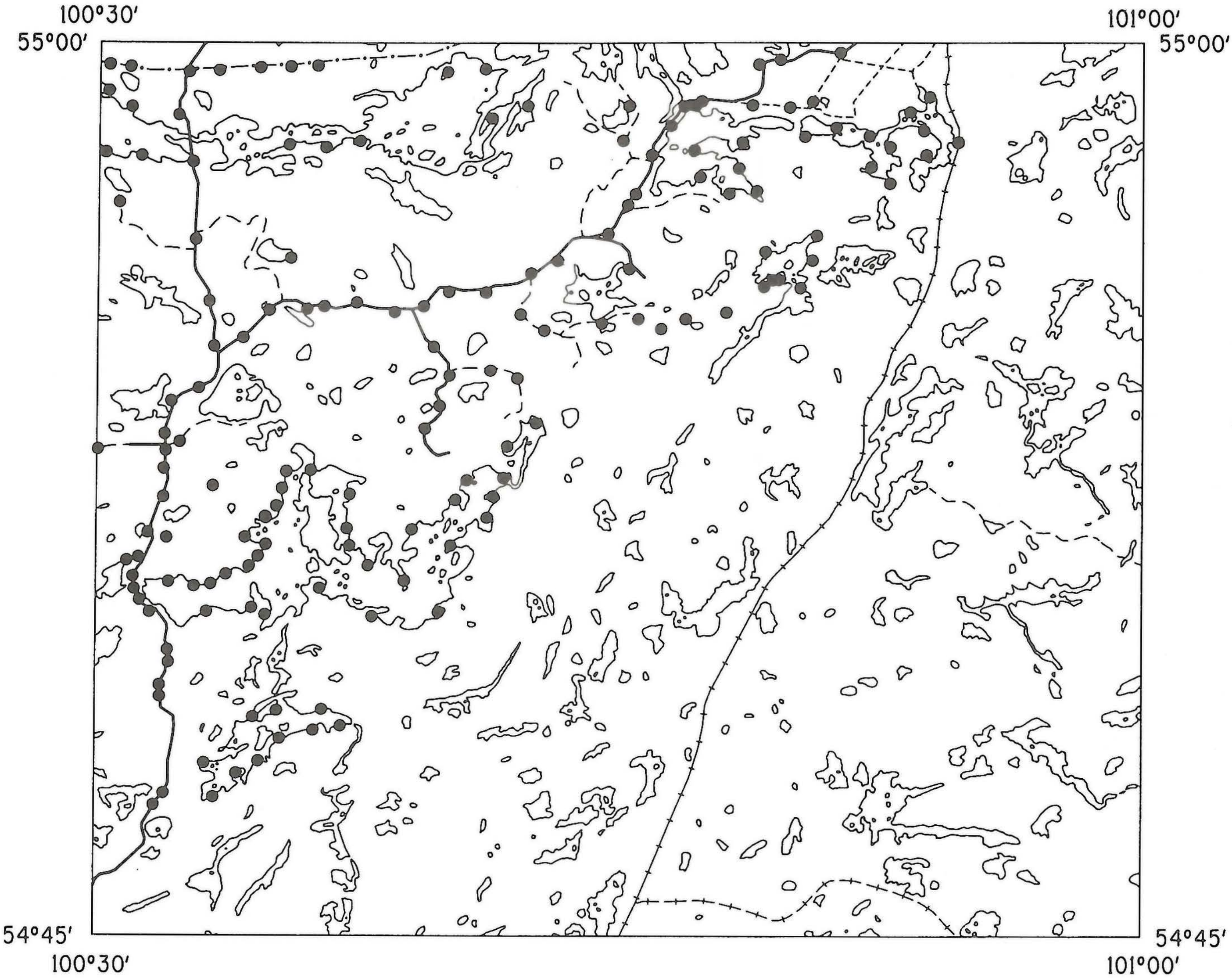

Figure GS-12-1: Till and humus sampling sites in the Naosap Lake area.

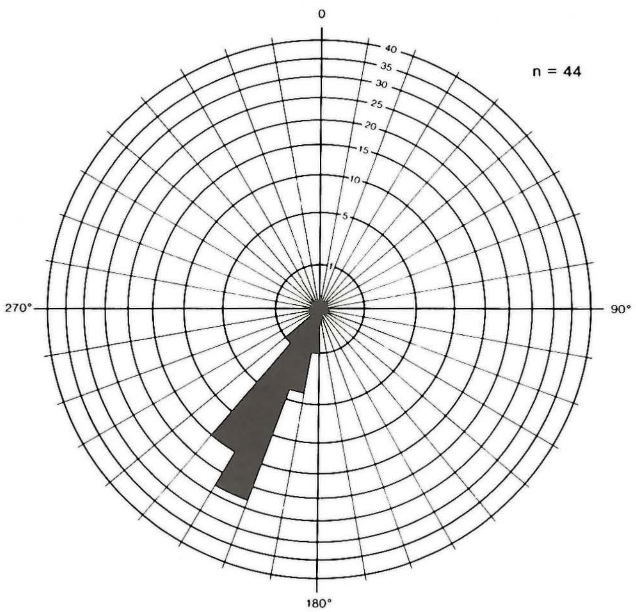

Figure GS-12-2: Striation directions for the Naosap Lake area plotted on a frequency net.

Till is generally thin, and where present it is easily sampled in hand-dug pits. The only thick accumulations of till appears to be lee-side till, which occurs on the down-ice side of bedrock hills that formed obstructions to ice flow. Lee-side till accumulated in tunnel-caves that formed under the ice as the glacier slid over a series of rock steps. Observations under modern glaciers indicate that the basal layers of a glacier may separate from the rock floor for a distance of up to 10 m and possibly more forming a temporary cave (Kamb and LaChapelle, 1964). Water-borne debris, drop stones and diamicton commonly associated with glaciofluvial sediments accumulate in the cave forming lee-side deposits (Hillefors, 1975). Figure GS-12-3 shows a cross section through a lee-side till deposit in a small gravel pit just south of Nekik Lake. This exposure shows that lee-side till is in places characterized by the presence of bedding, flow structures, a wide range of particle sizes and marked differences in the degree of sorting in addition to the presence of sediment with the more normal characteristics of till (Fig. GS-12-4). Till, reminiscent of ablation till caps the section.

Littoral sediments deposited in glacial Lake Agassiz may be confused with lee-side till as both sediments commonly consist of well sorted, thinly bedded sands and fine pebble gravels. Caution is therefore required when sampling till for geochemical surveys or mineral tracing in the Snow Lake-Flin Flon area as these sediments may have significant different provenances.

GEOCHEMISTRY

The less than 2 micron fraction of the till samples and the 10 mesh fraction of the humus samples will be analysed by ICP-atomic emission spectroscopy for 28 elements. The less than 63 micron fraction will be analysed for "Gold+33" elements by neutron activation. These analytical schemes are consistent with those used for other till geochemical projects in the Shield Margin NATMAP area (Henderson and Campbell, 1992).

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Figure GS-12-3: ***Large bedrock obstruction and lee-side till deposit south of Nekik Lake. Ice flow was from right to left.***

Figure GS-12-4: ***Details of the internal composition of the lee-side till deposit shown in figure GS-12-3.***

GS-13 GEOLOGICAL INVESTIGATIONS OF THE BAKER PATTON FELSIC COMPLEX (NTS 63K/12 AND 63K/13)

by G.H. Gale, J. Underhill[1] and L. Dabeck[1]

Gale, G.H., Underhill, J. and Dabeck, L., 1993: Geological investigations of the Baker Patton felsic complex (NTS 63K/12 and 63K/13); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 50-53.

ABSTRACT

The Baker Patton Felsic Complex east and south of Thompson Lake consists predominantly of thick sequences of aphyric and quartz phyric composite rhyolite flows. A volcaniclastic breccia, which can be traced across the map area, confirms a faulted east-west striking strata in the eastern part of the area.

1 Brandon University

INTRODUCTION

Geological mapping of the Baker Patton Felsic Complex (NTS 63K/12 and 63K/13) was continued in the areas east and south of Thompson Lake and in the area immediately northwest of the Pine Bay copper deposit (Fig. GS-13-1). This thirteen week program, undertaken mainly by the two junior authors, was designed to delineate lithologic units at 1:5000 scale within the predominantly rhyolitic extrusive rocks of the complex utilizing differences in phenocryst populations and textures. Portions of the complex have been

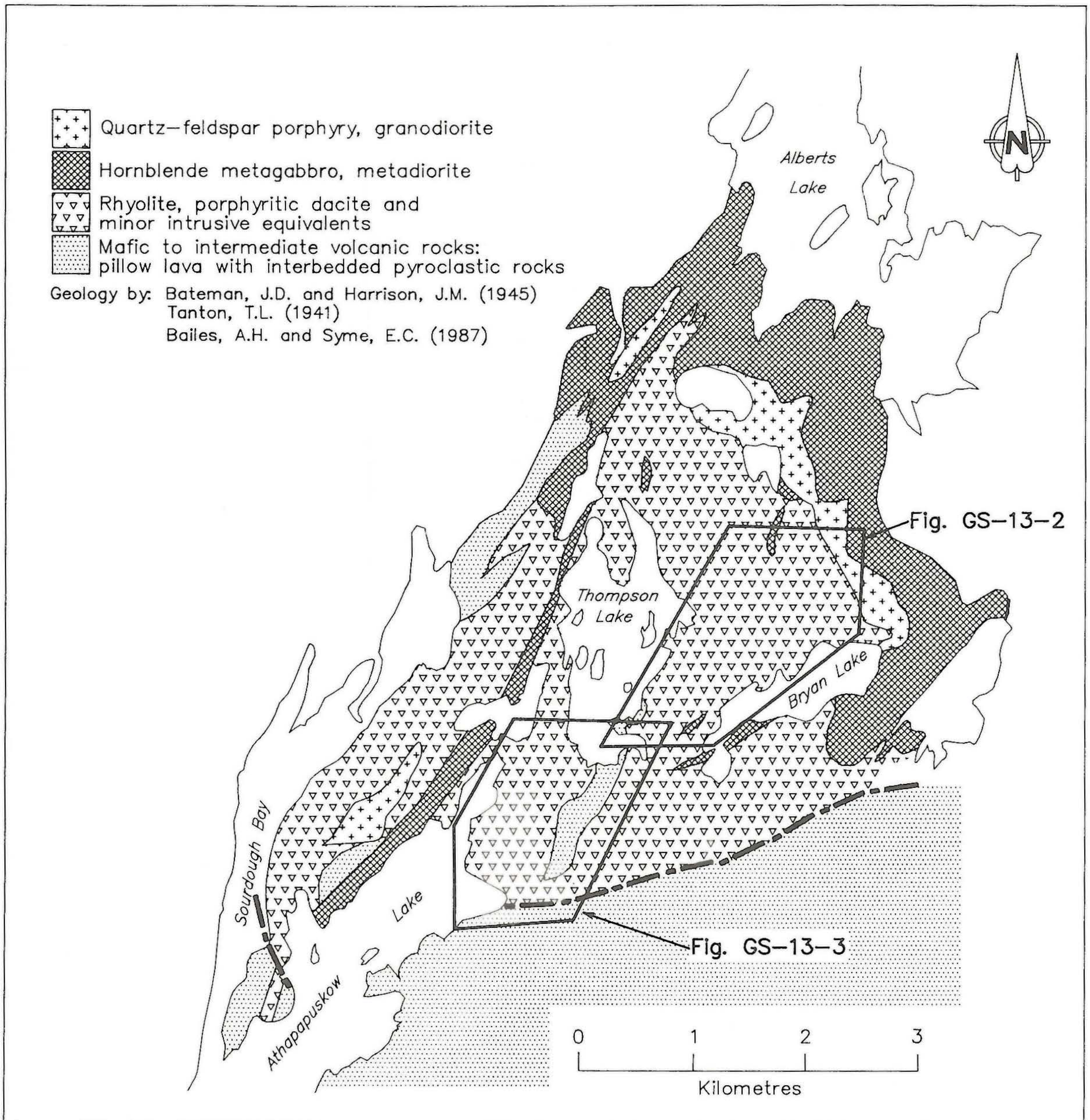

Figure GS-13-1: General geology of the Baker Patton Complex.

mapped previously at 1:5000 and larger scales by Gale and Foote (1988), Norquay and Gale (1990), Ferreira (1991) and Gale *et al.* (1992).

Cut grid lines and outcrop outline maps were provided by Placer Dome Ltd., Minnova Ltd. and Hudson Bay Exploration and Development exploration staff. 1:5000 scale airphotos were used for control in areas without outcrop maps. The main geological subdivisions are illustrated in Figure GS-13-2 and Figure GS-13-3 and are included on preliminary map 1993F-1. The geological data are digitized and are available upon request in either digital, mylar or paper copy from Manitoba Energy and Mines.

THOMPSON LAKE AREA

The area east of Thompson Lake and northwest of Bryan Lake (Fig. GS-13-2) consists dominantly of aphyric and quartz phyric rhyolite flows that have been intruded by felsic subvolcanic(?) intrusions and younger gabbroic intrusions.

A unit of dominantly felsic heterolithologic angular breccia occurs in the central portion of this area (Fig. GS-13-2) and similar rocks have been recognized at several localities south of Thompson Lake (Fig. GS-13-3). The unit varies in apparent thickness from several tens of metres to upwards of 100 m. Although the easternmost exposures of this unit appear to be at the same stratigraphic position as those at the shoreline of Thompson Lake, it is not certain whether they are connected via a folded or faulted surface. Locally, especially near the southern margin of the unit, the matrix supported heterolithologic breccia consists of 10 to 30 cm, white weathered, massive to flow banded, angular fragments in a matrix of pale green to brown felsic lapilli tuff and tuff. Elsewhere the fragments are brown to beige coloured, weakly to highly (>30%) amygdaloidal, massive to banded and subrounded to angular. It has not been possible to establish and trace individual layers within the breccia unit, but this is considered to be a composite unit composed of a number of different layers or beds because the dominant fragment types vary from outcrop to outcrop. In several exposures, reddish outer rims on white subrounded rhyolite fragments are probably weathered rinds produced during weathering in a subaerial environment. Although definitive layer boundaries were not established for these breccias, a debris flow origin is favoured for some, if not all, of these breccias.

Rhyolitic flows north of the breccia unit are aphyric, sparsely quartz phyric or contain up to 3% angular 1 to 2 mm quartz phenocrysts, but flows south of the breccia are predominantly aphyric. Pinkish subhedral to anhedral feldspar crystals vary from <1% in the massive portions to 10% in flow banded and hyaloclastic portions of flows. In the absence of thin section studies the feldspars are considered to be the products of metasomatism and/or metamorphism. Consequently, the feldspar contents were not useful in delineating flows.

A 1 to 2 m thick layer of clastic rocks with graded beds of siltstones and sandstones occurs locally between two rhyolite flows north of the breccia and confirms the overall northeastern strike of the flows in this area.

The flow(s) east and south of the heterolithic breccia is aphyric to sparsely quartz phyric, but locally contains up to 10% pink feldspar crystals and aggregates in microbreccia and hyaloclastite.

The flows south of the breccia are distinct from those to the north in that they do not contain rafts or layers of the quartz-bearing lapilli tuff that are common in the area southeast of Leo Lake (Gale *et al.*, 1992). Correlation of the aphyric to sparsely phyric flows south and east of the breccia is tenuous without clean exposures and in the absence of thin sections and geochemical data.

Felsic intrusions in the area of Figure GS-13-2 include massive aphyric, fine- to medium-grained and a coarse grained porphyry. Fine- to medium-grained and medium- to coarse-grained gabbro are the only mafic rocks identified in this area; some fine grained mafic rocks contained within the fine- to medium-grained felsic intrusion in the northeast corner of the map area, may be dykes.

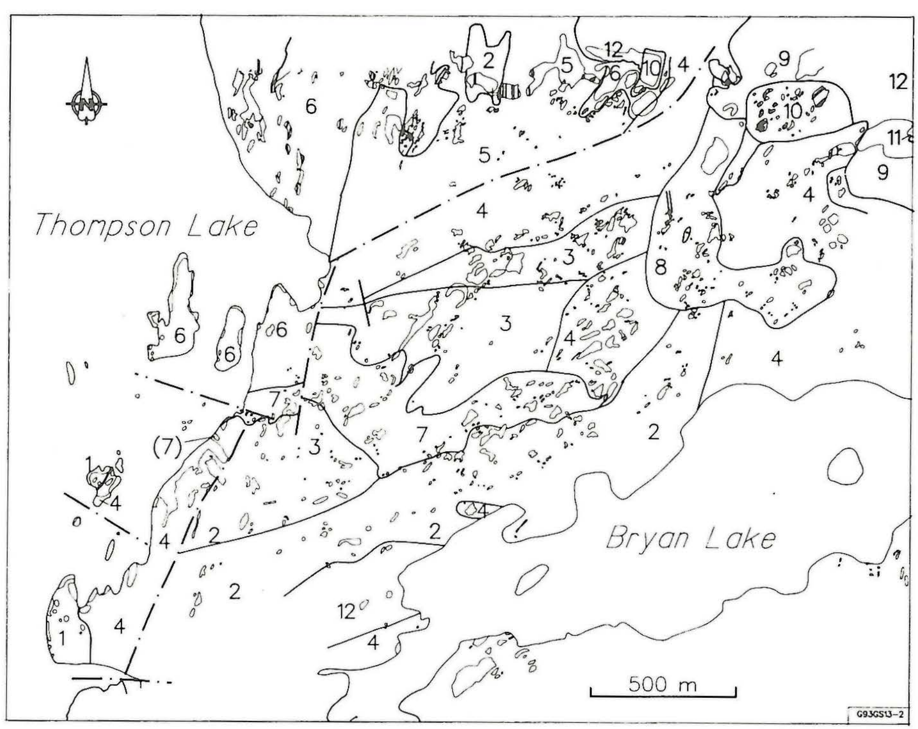

Figure GS-13-2: Geology of the Bryan Lake area.

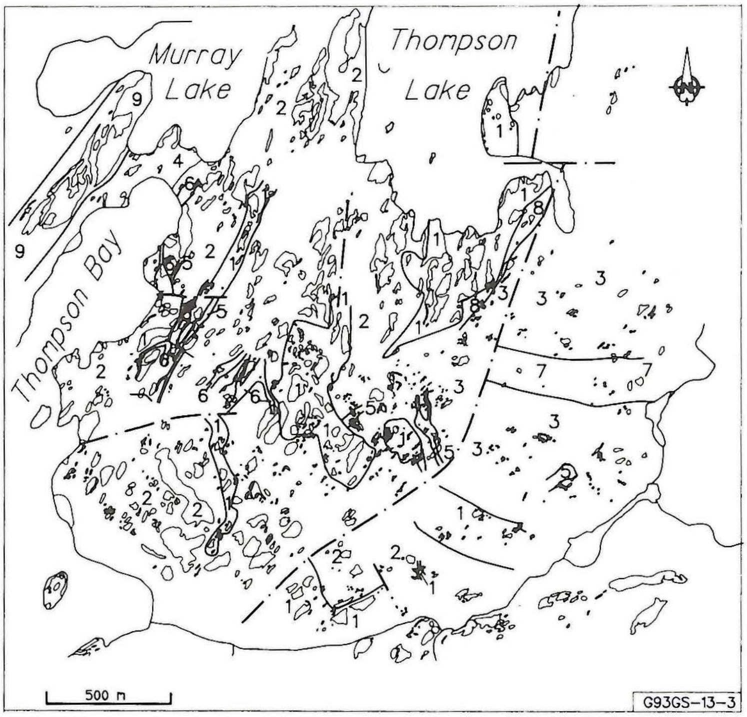

Figure GS-13-3: Geology of the Thompson Bay area.

Aphyric rhyolitic intrusions cut most of the rhyolite flows and probably represent feeders to overlying aphyric flows, but there is no evidence to link flows and dykes. Felsic intrusions include a massive rhyodacite quartz-bearing rock that has been variably chloritized and varies in texture from aphanitic to fine grained (Fig. GS-13-2). It cuts across several rhyolite flows and probably represents a late subvolcanic intrusion.

Massive quartz-feldspar porphyry with 0.5 to 1.0 cm quartz phenocrysts and 3 to 4 mm feldspar crystals occurs as a large mass and as dykes cutting the extrusive rocks. This rock is comparable to unit 2 of Ferreira (1991) and unit 9 of Gale *et al.* (1992).

A fine- to medium-grained felsic intrusion in the northeastern part of the map area contains blocks of felsic and mafic volcanic rocks that range in size from several, to several tens of, metres in size; its relative age is not certain, but it appears to be younger than the quartz-feldspar porphyry intrusion.

Medium-to coarse-grained gabbro appears to be the youngest intrusion in the area (*cf.* Ferreira, 1991). The fine- to medium-grained gabbroic rock at the southwest end of Bryan Lake may be related to this magmatic event.

It is suggested that the intrusions in the northeast portion of Figure GS-13-2 represent the central or vent area of the felsic volcano.

THOMPSON BAY AREA

Rhyolitic rocks in the Thompson Bay area (Fig. GS-13-3) are predominantly flows. Although single flows were distinguished locally, in general, only one contact of a flow could be exposed and consequently the units as outlined here are composite flows. Both aphyric and quartz phyric (1-3%) flows are present; feldspar contents are variable and in hand specimen appear to be mostly potassic feldspar. Individual flows vary from >75% massive rhyolite as lobes and tongues of lava with <25% fine grained schistose interlobe matrix (hyaloclastite) to flows with >90% hyaloclastite and microbreccia. The massive parts of flows are commonly white or beige to pale green, whereas the hyaloclastite and microbrecciated portions are brown to green. Amygdules are common (<10%) in massive flow material, but abundant (>30%) in some hyaloclastic and microbrecciated portions.

Rhyolitic dykes in this area include aphyric and quartz phyric clastic varieties.

Mafic volcanic rocks in the area of Figure GS-13-3 consist of massive, pillowed and brecciated lava. Preliminary studies suggest that these are predominantly single rather than composite flows and flow organization varies both vertically and laterally within flow units. However, a composite flow unit was exposed by stripping outcrops along the powerline in the southeastern portion of the map area (Fig. GS-13-3).

A massive, vesicular (up to 1 cm) andesitic rock that occurs in the southeastern corner of the area mapped in Figure GS-13-3 is probably a dyke, but a paucity of exposure in this area precludes a definite interpretation.

A fine grained dark green massive andesitic flow is exposed in a number of outcrops on the shores of Thompson Lake. This flow contains fragments of scoriaceous andesite that contain up to 30% vesicles. Its relationship to the highly amygdaloidal (>50%) and jasper-bearing andesitic rocks to the immediate east is not certain, but it is probably the massive part of the same flow.

Several exposures of clastic sedimentary rocks, fine and coarse grained sandstone, siltstones and minor black shales with abundant sedimentary structures indicate an overall east-west strike for units in the eastern part of this area.

PINE BAY MINE AREA

Mapping was initiated in the Pine Bay Mine area, but only several days work were completed. A quartz-feldspar porphyry in this area has up to 20% distinctive 1 cm quartz phenocrysts and up to 10%, 3 to 5 mm plagioclase crystals in its massive portions. Locally, it has large amygdules (1 cm), tongues of massive lava in a chloritic and amygdaloidal matrix that contains variable quartz and feldspar contents. The easternmost 2 to 3 m of this unit contains 10 to 15% feldspar and may represent tuff from the same magma. This rock resembles the quartz-feldspar porphyritic intrusive and extrusive rocks at Leo Lake (unit 2 of Ferreira, 1991).

Correlation of units across fault boundaries and between previously mapped areas within the Baker Patton Felsic Complex is tentative. There is a direct relationship between the bimodal sized quartz lapilli tuff at the Baker Patton shaft area (Gale and Foote, 1988), the Leo Lake area (Gale *et al.,* 1992) and the occurrences mapped in the northern part of Figure GS-13-2. In addition, a tentative correlation is drawn between the flow with grey and white weathered massive rhyolite lobes in the Thompson Bay area (Fig.

GS-13-3) and the lobes and tongues of grey and white weathered massive rhyolite in the brown weathered composite dominantly hyaloclastite flows (unit 2, Figure GS-4-2 of Gale *et al.*, 1992).

STRUCTURE

Top indicators include graded beds, scour channels, pillows and flow organization. In general, these criteria indicate an overall southwards-younging sequence that appears from limited structural observations to indicate an overturned and downward facing sequence. Early folds associated with the regional schistosity have not been positively delineated. Several events of semi-brittle shear and faults have been observed in outcrop and several faults have been inferred from outcrop distribution.

The distribution of rhyolite breccia along the east shore of Thompson Lake, and south of Thompson Lake, is probably a combination of a large scale fold and faults with northerly and easterly strikes. A north-trending fault or shear zone in the vicinity of the Don Juan deposit may explain that atypical deposit as a lense of mobilized sulphide.

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GS-14 STRUCTURAL STUDIES OF THE NORTHEAST ARM SHEAR ZONE (SCHIST LAKE), FLIN FLON BELT

by S.B. Lucas[1]

Lucas, S.B., 1993: Structural studies of the Northeast Arm shear zone (Schist Lake), Flin Flon Belt; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 54-60.

SUMMARY

Structural mapping of the Northeast Arm shear zone (Northeast Arm of Schist Lake, Beaverhouse Lake) was initiated in the summer of 1993 with the aim of describing the structural setting of U-Pb dated Archean rocks and the deformation history of the shear zone. In addition, study of this structure is part of a larger project focused on understanding the geometry, kinematics and age of faults/shear zones identified through both interpretation of LITHOPROBE seismic reflection data and subdivision of the Amisk Group volcanic sequences into distinct lithogeochemical assemblages.

Highly foliated to mylonitic mafic to intermediate rocks (tectonites derived from the arc assemblage) and felsic plutonic rocks occur along the Northeast Arm of Schist Lake, and project along strike to the north at least as far as Beaverhouse Lake. The Archean zircons occur in deformed tonalite-granodiorite bodies that are concordant with the mafic tectonites along the zone. These units, together with rare pyroxenites and sedimentary rocks and a variety of syntectonic felsic sheets, compose the Northeast Arm shear zone. The zone is characterized by a moderate to steeply, east or west dipping foliation that locally contains a north or south-plunging extension lineation. These penetrative fabrics are "reworked" by heterogeneously distributed ductile (folds, shears) and brittle (fractures) structures that appear to be related to shortening across the shear zone, possibly contributing to its present steep attitude.

INTRODUCTION

Structural mapping of the Northeast Arm shear zone (Flin Flon Belt; Syme, 1986) was initiated in the summer of 1993 on Schist Lake and Beaverhouse Lake (63K/15; Fig. GS-14-1). The project aims to determine the structural setting of recently discovered Archean rocks within the shear zone (*cf.* David and Machado, 1993; David *et al.*, GS-10 this volume) as well as describing the deformation history of the shear zone and adjacent block-bounding faults (Syme, 1988; Bailes and Syme, 1989). In addition, study of this structure is part of a larger project focused on understanding the geometry, kinematics and age of faults/shear zones identified through both interpretation of LITHOPROBE Trans-Hudson Orogen (THO) seismic reflection data (Lewry *et al.*, 1993; Lucas, 1993a, b; White *et al.*, 1993) and subdivision of the Amisk Group volcanic sequences into distinct lithogeochemical assemblages (Stern *et al.*, 1992; 1993a; Syme *et al.*, 1993a, b). A parallel study is underway in Saskatchewan to investigate the Meridian Creek-West Arm shear zone (Reilly, 1992; Thomas, 1992), a long-lived structure that juxtaposed major Amisk Group assemblages (arc, ocean floor/Mystic Lake; Lucas *et al.*, 1993c; Fig. GS-14-1). The following report first presents a brief overview of the tectonic history of the Flin Flon-Athapapuskow area and the geology of Schist Lake area, and then summarizes preliminary structural observations from two detailed transects across the Northeast Arm shear zone (Fig. GS-14-1).

TECTONIC HISTORY OF THE FLIN FLON-ATHAPAPUSKOW AREA

The Flin Flon Belt comprises (1) 1.91-1.88 Ga island arc and *ca.* 1.9 Ga ocean floor volcanic sequences (Amisk Group: Bailes and Syme, 1989; Gordon *et al.*, 1990; Syme *et al.*, 1993a; Stern *et al.*, 1992, 1993a); (2) *ca.* 1.85-1.83 Ga alluvial-fluvial sedimentary rocks deposited unconformably on previously deformed arc assemblages (Missi Group: Bailes and Syme, 1989; Gordon *et al.*, 1990; Stauffer, 1990; Ansdell *et al.*, 1992; Ansdell, 1993); and (3) felsic to ultramafic intrusive rocks predominantly ranging in age from 1.89-1.83 Ga (Gordon *et al.*, 1990; David and Machado, 1993; Stern *et al.*, 1993b). The protracted deformation history of the Flin Flon Belt is marked by a transition from an oceanic to a continental tectonic setting (Lucas *et al.*, 1993c). The age of ductile deformation along the Meridian Creek-West Arm shear zone (D_1) is indicated by syntectonic felsic dykes (minimum age ca. 1869 Ma) and by stitching plutons (Reynard Lake pluton: 1850±1 Ma; Stern *et al.*, 1993b). Missi Group continental sedimentation (minimum age 1847-1842 Ma for the Flin Flon-Athapapuskow area; Ansdell, 1993) may reflect unroofing of early accretionary complexes built during amalgamation of Amisk Group arc and oceanic assemblages. Alternatively, the Missi Group may be been deposited syntectonically during a fold-thrust deformation event (D_2) involving both the Amisk and Missi groups, now constrained to have occurred at *ca.* 1.85 Ga (Fedorowich *et al.*, 1993). The Amisk and Missi groups were subsequently deformed during collisional (D_3; *ca.* 1.83-1.80 Ga) and post collisional (D_4, D_5; *ca.* 1.80-1.70? Ga) transpression of the orogen associated with oblique convergence between the Reindeer zone (THO internides) and Superior craton (Green *et al.*, 1985; Bickford *et al.*, 1990; Bleeker, 1990).

In the Flin Flon area, the post-Missi Group deformation history can be viewed in terms of four principal "events" (after Stauffer and Mukherjee, 1971; Bailes and Syme, 1989; Ashton, 1992; Thomas, 1992; Fedorowich *et al.*, 1993). The *ca.* 1.85 Ga event (D_2) is thought to involve north-directed thrusting (*e.g.* Club Lake fault, Railway fault; Bailes and Syme, 1989) and relating folding and cleavage development involving both the older Amisk assemblages and the unconformably overlying Missi Group sedimentary rocks. Structures associated with the "collisional" or peak metamorphic event (D_3; *ca.* 1.83-1.80 Ga; Gordon *et al.*, 1990) include steep north-trending faults with sinistral reverse kinematics (*e.g.* Embury Lake fault (ELF, Fig. GS-14-1)), N trending, west-verging folds, and a steep east-dipping foliation and fold axis-parallel extension lineation. Structures related to the D_4 event are principally found in the northern part of the Flin Flon Belt and include W trending, sinistral-reverse shear zones (*e.g.* Tartan-Annabel shear zone (TASZ, Fig. GS-14-1); Wilcox, 1990; Fedorowich *et al.*, 1991) and the large scale Embury Lake antiform. Ashton and Wilcox (1988; *cf.* Ashton, 1992) suggest that this event marks a change to NNE-SSW transpression of the Flin Flon Belt.

The NNW- to NNE-trending, block-bounding faults (Fig. GS-14-1) initiated at least in part as thermal peak sinistral-reverse structures (*i.e.* D_3) but were necessarily active post metamorphic peak in that they offset mineral isograds (Bailes and Syme, 1989; Digel and Gordon, 1993). However, these structures are deformed by the Embury Lake fold and transposed into the Tartan-Annabel shear zone to the northwest. A set of NE trending, ductile and brittle faults also occurs in the Athapapuskow area and appear to have dextral map separations (Syme, 1988; Syme *et al.*, 1993b). Some of these structures may also have initiated during D_3 and stayed active (or were reactivated) at post-thermal peak conditions (D_4, D_5), similar to some of the block-bounding structures to the northwest. The final deformation event (D_5), marked by brittle faulting, occurred along conjugate NNW and NE-trending structures (*e.g.* Ross Lake Fault (RLF, Fig. GS-14-1)) that show predominantly strike-slip displacements consistent with NW-SE shortening (Stauffer and Mukherjee, 1971; Bailes and Syme, 1989; Syme, 1988).

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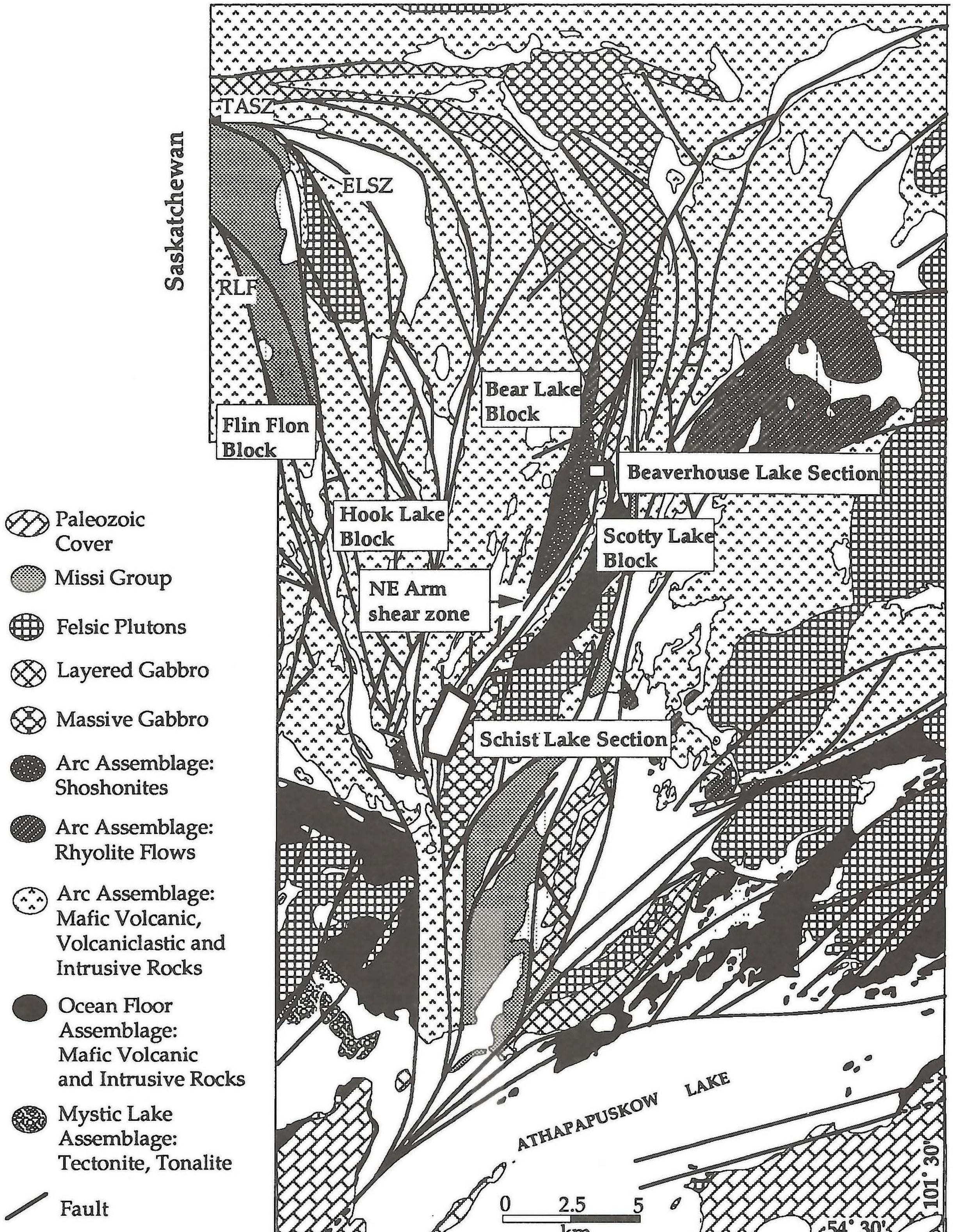

Figure GS-14-1: Simplified geological map of the Flin Flon-Athapapuskow Lake area (after Syme, 1988; Bailes and Syme, 1989; Syme et al., 1993b). ELF: Embury Lake fault; RLF: Ross Lake fault; TASZ: Tartan-Annabel shear zone.

GEOLOGIC SETTING OF THE NORTHEAST ARM SHEAR ZONE

The Northeast Arm shear zone occurs between the Bear Lake Block and the Scotty Lake Block, and appears to be derived in part from rocks belonging to each block. The actual boundary between the two blocks was mapped by Bailes and Syme (1989) and Syme (1986) as the Northeast Arm fault (Fig. GS-14-2), a relatively discrete brittle structure (steeply west dipping) that represents one of the block-bounding faults in the Flin Flon-Athapapuskow area. The Northeast Arm shear zone, mapped as a distinct corridor of highly deformed rocks by Syme (1986), is truncated along with the Northeast Arm fault against the Inlet Arm fault (Fig. GS-14-2). The Inlet Arm fault, interpreted as another of the post-thermal peak (D_3-D_5?) block-bounding faults, forms the western boundary to the Bear Lake Block (Fig. GS-14-1; Bailes and Syme, 1989; Syme, 1986). However, it should be noted that a broad zone of penetrative ductile strain occurs adjacent to the Inlet Arm fault in the Bear Lake Block (in contrast to the Hook Lake Block to the west; Syme, 1986; Bailes and Syme, 1989), which may not be related to the actual "block-bounding fault. The Bear Lake Block contains a complex lithogeochemical stratigraphy that contains, in stratigraphic order, a thick arc assemblage sequence, Ocean Floor Assemblage ferrobasalt and rhyolite tuff (1886 Ma; Gordon *et al.*, 1990), and an 1885 Ma (Stern *et al.*, 1993b) Arc assemblage shoshonite tuff (Syme *et al.*, 1993a,b; Stern *et al.*, 1993a). The top of the Bear Lake Block is folded about NNE-plunging D_3 synform that is cut off against the Northeast Arm fault. The Scotty Lake Block to the east of the shear zone contains a thick, westward-younging sequence of ocean floor assemblage ferrobasalts intruded by tonalite and gabbro sills and capped (along the NE Arm of Schist Lake) by arc assemblage volcaniclastic rocks (Syme, 1986; Bailes and Syme, 1989; Syme *et al.*, 1993). The southern part of the Scotty Lake Block is dominated by tonalitic and gabbroic intrusive rocks and is separated from the northern ocean floor volcanic sequence by a fault (Syme, 1986, 1987; Syme *et al.*, 1993b).

The islands and shorelines of the NE Arm of Schist Lake, and the northward continuation of this zone to at least Beaverhouse Lake (Fig. GS-14-1), contain highly deformed rocks that are related to both the Bear Lake Block (west side) and the Scotty Lake Block (east side). On the west side of the NE Arm fault (Fig. GS-14-2), units examined in this study include Bear Lake basaltic andesite, units of the White Lake differentiated mafic sill (gabbro, ferrogabbro, quartz ferrodiorite), the White Lake dacite tuff and the Little Spruce Lake sediments and tuff (Syme, 1986). Whereas these units can be correlated with less deformed rocks of the Bear Lake Block, units to the east have no obvious stratigraphic affinity to either the Bear Lake Block or the Scotty Lake Block. NE Arm shear zone units in the Schist Lake section (Fig. GS-14-1) include fine grained sedimentary and volcaniclastic rocks of presumed arc assemblage affinity (Syme *et al.*, 1993b), largely transformed into mafic to intermediate S ± L tectonites and locally chlorite-Fe carbonate schist (see below; Bailes and Syme, 1989). The fine grained tectonites are intruded by several generations of mafic and felsic sheets, including diorite, tonalite-granodiorite, pyroxenite and aplite (Syme, 1986). At Beaverhouse Lake (Fig. GS-14-1), mafic tectonites form the predominant shear zone unit, and are at least in part derived from a mafic volcanic sequence in that they contain epidosite domains and boudined sill/flow units. The trace of the NE Arm fault forms the western boundary to the mafic tectonites and separates them from the east facing, Mikanagan layered mafic sill (Bailes and Syme, 1989).

Felsic intrusive rocks within the Northeast Arm shear zone include the Beaverhouse Lake tonalite-granodiorite, NE Arm tonalite-granodiorite sheets, and a series of felsic dykes that appear to have been syntectonically emplaced in tectonites throughout the zone. Both the Beaverhouse and a NE Arm tonalite-granodiorite (hereafter referred to as tonalite) yield late Archean discordia ages based on the regression of numerous zircon fractions (David and Machado, 1993). These foliated to mylonitized rocks occur in metre- to tens of metre-wide bodies that are concordant with the mafic tectonites along the zone and are cut by distinct chlorite-carbonate mylonite-ultramylonite bands (see below). Another equigranular, medium grained tonalite, in part forming the eastern shore of the NE Arm of Schist Lake (Syme, 1986; Syme *et al.*, 1993b), was sampled for U-Pb geochronology. This body, possibly related to Syme's "Airport Pluton" (southern Scotty Lake Block, Fig. GS-14-1; Syme, 1987), locally contains mafic layers (tectonite and gabbroic enclaves?), is well foliated to mylonitic, and has a moderately NE-plunging extension lineation defined by elongate quartz±feldspar aggregates. Dykes of similar texture and composition are found in the supracrustal sequence immediately to the west of the principal tonalite body. The tonalite is intruded by foliation-parallel pegmatite veins (cm scale) that are themselves foliated and show pinch-and-swell structures and boudinage.

The syntectonic felsic dykes (aplites of Syme, 1986) are broadly parallel to the foliation/compositional layering in the country rock tectonites, although low angle (~10°) discordance can often be observed or inferred. They vary in width from mm to 10's of cm and in deformation state from mylonites to foliated. Several such dykes were sampled for U-Pb geochronology and include a well foliated, fine- to medium-grained, equigranular tonalite-granodiorite dyke emplaced in and deformed with mafic tectonites (Beaverhouse Lake section, Fig. GS-14-1). This dyke contains cm scale enclaves of mafic tectonite that are clearly misoriented with respect to the enveloping tectonite foliation, although misorientation can not simply be attributed to post crystallization strain-induced rotation. Two dykes that intrude mafic to intermediate tuffaceous rocks of the Bear Lake Block (*i.e.* west side of NE Arm fault) were also sampled for geochronological study. One is a narrow quartz phyric felsic dyke that includes xenoliths of high foliated country rock. The dyke and the country rock foliation are folded into cm (country rock) to m scale (dyke) folds with moderate to steeply SSE-plunging axes. The other dyke is aphyric and has a penetrative foliation that is subparallel to the country rock foliation and contiguous with it at the dyke margins, and appears to be pinched and swollen along its length. In general, the felsic (aplitic) dykes appear to be "late" syntectonic with respect to the tectonite-forming deformation but predate development of overprinting structures (*e.g.* folds and shear bands; see below).

NORTHEAST ARM SHEAR ZONE: STRUCTURAL HISTORY

Early ductile structures

Well foliated to mylonitic mafic to intermediate rocks (tectonites) and felsic plutonic rocks (*e.g.* Beaverhouse tonalite) occur along the Northeast Arm of Schist Lake, and project along strike to the north at least as far as Beaverhouse Lake. These units, together with rare pyroxenites and sedimentary rocks and a variety of syntectonic felsic sheets, comprise the Northeast Arm shear zone (Syme, 1986). The eastern boundary to the shear zone is a well defined, relatively abrupt transition to little deformed rocks (quartz diorite) and may correspond to a late discrete fault (D_5?; Syme, 1988; Syme *et al.*, 1993b). The western boundary of strongly sheared rocks does not correspond to the trace of the NE Arm fault (Fig. GS-14-2) but may occur within the Bear Lake Block to the west. At the latitude of the Schist Lake section, rocks of the Bear Lake Block are in general well foliated, with the intensity of ductile deformation increasing towards the Inlet Arm fault (Syme, 1986; Bailes and Syme, 1989). The relationship between penetrative ductile deformation along the NE Arm shear zone and Inlet Arm zone is little known at this time, but may well be coeval and thus predate "block-bounding" faulting.

The oldest deformation structures observed in the Schist Lake and Beaverhouse Lake sections are a moderate to steeply east or west dipping foliation and, locally, a north or south-plunging extension lineation (S_1, L_1; Fig. GS-14-2). Depending on lithology and bulk deformation state, foliation can be defined by the alignment of greenschist grade metamorphic minerals (*e.g.* biotite, actinolite, chlorite) and/or by a quartz-feldspar±biotite grain shape fabric. In more intensely foliated (*i.e.* tectonite) to mylonitized units, the grain-scale fabric parallels a cm- to m-scale layering defined by aligned (transposed) primary features (*e.g.* bedding, pillow margins?, epidosite domains), quartz veins and felsic (tonalite, "aplite", pegmatite) veins and sheets. Intense flattening strain is suggested by boudi-

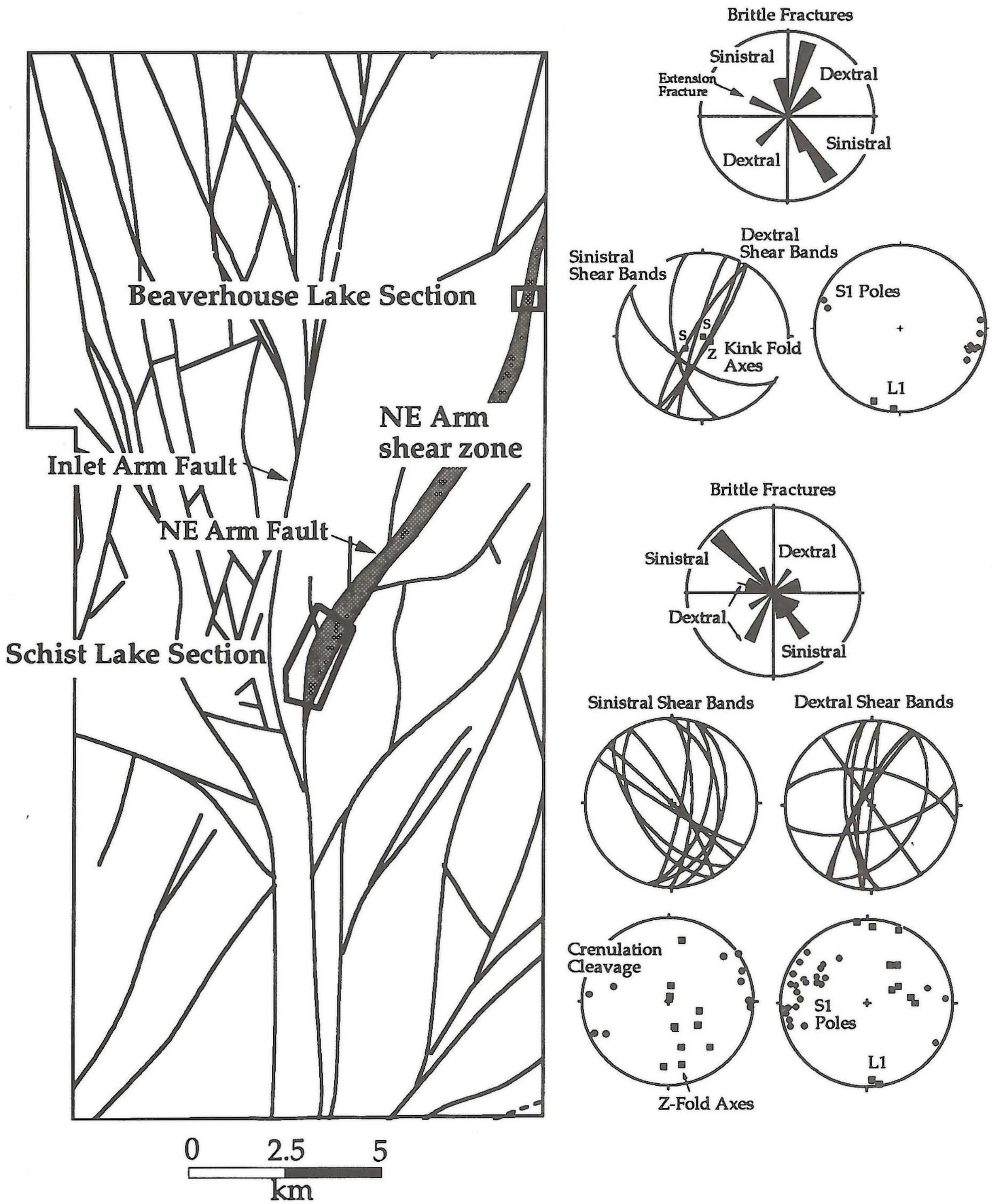

Figure GS-14-2: Synthesis of structural observations from the Beaverhouse Lake (upper 3 stereonets) and Schist Lake (lower 5 stereonets) sections of the NE Arm shear zone (outlined in stipple). Note that the NE Arm fault forms the western boundary to the NE Arm shear zone and the eastern boundary to the Bear Lake Block (shown in Fig. GS-14-1).

nage of veins and compositional layers in both horizontal and vertical planes. As discussed above, many of the felsic veins (tonalite, aplite, pegmatite) appear to have been emplaced during the foliation forming, ductile deformation event, although relatively late in that they are not as intensely foliated as their wall rocks. True mylonites form narrow (cm scale) bands in intrusive rocks (felsic and mafic) where grain size reduction via an apparent "ductile" process can be documented. These bands are distinct from the dark, chlorite, Fe carbonate ultramylonite seams that crosscut and rework the preexisting S_1 fabric (see below). Rare F_1 mesoscopic folds are observed in the fine grained sedimentary and tuffaceous rocks; these structures are isoclinal folds of compositional layering (bedding?) with S_1 forming an axial planar foliation. The L_1 lineation can generally be described as a smearing or rodding of quartz and feldspar aggregates. L_1 forms a great circle distribution (Fig. GS-14-2) that suggests dispersion of the lineations from a moderately east plunging attitude (*i.e.* transverse to foliation) during subsequent deformation. Kinematic indicators associated with the mylonites are infrequently observed but include both sinistral and dextral C/S fabrics developed in the margins of the mylonite bands preserving strain gradients. Further work is required to unambiguously identify asymmetric structures in the fine grained tectonites that are associated with the early deformation event, although dextral folds and boudinage appear to be the most common.

Overprinting ductile structures

The penetrative early ductile fabrics are "reworked" by heterogeneously distributed ductile structures that appear to be related to shortening across the shear zone, possibly contributing to its present steep attitude. Two types of overprinting structures dominate the outcrops of the shear zone: shear bands and folds. Shear bands (*cf.* Williams and Price, 1990) are narrow (mm- to cm-width) zones of ductile deformation that reorient the S_1 foliation and produce further grain size reduction and grain alignment at chlorite-grade conditions. The shear bands generally form an angle of ±10-30° to S_1, with the strike of dextral shear bands clockwise (east) of S_1 and that of sinistral shear bands counterclockwise of S_1 (west; Fig. GS-14-2). Locally, shear bands form an almost penetrative S_2 cleavage, and are associated with crenulation-like folds. These folds have the opposite sense of asymmetry to the adjacent shear bands (*i.e.* S-microfolds adjacent to dextral shear bands), suggesting that they be the result of local antithetic shear within volumes of rock bounded by shear bands (spin-induced vorticity; Lister and Williams, 1983). Both sinistral and dextral shear bands are present on many outcrops and appear to be coeval in that overprinting relations are almost absent even though the structures can be developed in close proximity to one another. These relations, coupled with the steeply west dipping (NNW- to NNE-trending) symmetry plane for the shear band sets (Fig. GS-14-2), suggest that the shear bands were generated during an episode of subhorizontal ± east-west shortening across the preexisting shear zone.

Post-S_1 mylonite/ultramylonite/cataclasite seams (cm- to m-scale) are locally developed along the NE Arm shear zone, and are in general marked by pervasive chlorite±Fe-carbonate (ankerite?) ± Fe (hematite?) assemblages. These zones are in part associated with the shear band-forming event, although more than one age of localized high strain is suggested by the occurrence of both ductile and cataclastic (semi-brittle) shear zones. The high strain zones are broadly north trending and are subparallel to the S_1 foliation. Both dextral and sinistral kinematic indicators are associated with ductile mylonite/ultramylonite seams, consistent with the prevalence of conjugate sinistral and dextral shear bands. The ductile, chlorite-rich zones are principally developed in the tonalite bodies (including the Beaverhouse tonalite) and generally contain cm scale lozenges of less "altered" tonalite and/or pin-head sized plagioclase (and quartz?) porphyroclasts, indicating that they are derived from the tonalite. These zones grade both along and across strike into the tonalite and display feather like, longitudinal terminations but often more abrupt lateral terminations (*i.e.* sharp lateral strain gradients). Some of the abrupt lateral terminations may result from subsequent brittle faulting and possibly from development of narrow pseudotachylyte bands.

Mesoscopic (mm- to m-scale) folds of the S_1 foliation/compositional layering, veins and the ultramylonite bands occur along the entire length of the NE Arm shear zone. The folds vary in morphology from rounded to chevron depending on the material being deformed, and occur as both isolated structures and in multiple-wavelength trains. The asymmetry of measured folds is consistently dextral (*i.e.* Z) in the Schist Lake section (Fig. GS-14-2); sinistral (*i.e.* S) microfolds are locally present in the Schist Lake section but are directly associated with dextral shear bands or are unrelated kinkbands. The measured fold axes show a great circle dispersion similar to L_1 (Fig. GS-14-2) that suggests rotation of linear elements about a west-plunging axis. The Beaverhouse Lake section has both dextral and sinistral folds but most appear to have a kinkband morphology and may not be associated with the principal folding event (see below; Fig. GS-14-2). Spaced axial planar crenulation cleavages to the folds are locally developed in the hinge regions. The crenulation cleavages to the dextral folds are similar to the sinistral shear bands in both asymmetry and orientation (Fig. GS-14-2). This suggests that this folding may have occurred contemporaneously with shear band development during a period of strong east-west shortening. The Schist Lake section folds are interpreted to be of the same generation as Bailes and Syme's (1989) NE Arm synform (fold axis: 36°>>008°) and associated minor fold and axial planar cleavage. This suggests that folding and shear band development along the NE Arm shear zone occurred during the D_3 event associated with the regional metamorphic peak.

Deformation of both syn- and post-S_1 veins is another hallmark of the post-S_1 ductile deformation event(s). As discussed above, syn-S_1 veins are usually subparallel to S_1 and are both folded (Z-asymmetry) and extended. Boudinage of these veins is often asymmetric and associated with sinistral and/or dextral shear bands, resulting in local back rotation of boudins (*cf.* Hanmer and Passchier, 1991). Post-S_1 quartz-feldspar veins that are ductilely deformed commonly strike NW and form en echelon arrays, although NE-striking veins are also present. NW veins tend to show evidence for sinistral shearing (*i.e.* along shear bands) or extension, whereas NE veins are generally associated with dextral shear and/or extension. Complex strain histories are locally observed, with dextrally folded sinistrally extended veins, being the most common. Ductile deformation of post-S_1 veins can be explained by a number of deformation paths but the simplest coincides with the model developed for the shear bands and folds in which the NE Arm shear zone experiences east-west shortening and north-south extension during D_3.

Several lines of evidence suggest that the NE Arm shear zone may have been shortened at a low angle to the S_1 foliation subsequent to ductile shearing and shear band development/folding. First, L_1 and post-S_1 Z-fold axes are dispersed about north trending, steeply dipping, great circles (Fig. GS-14-2), indicating shallowly west-plunging axes of rotation. Second, imbrication of both boudins and S_1 foliation/layering is locally documented, often in a dextral sense. Third, steeply-plunging kinkbands and boxfolds (defined by conjugate kinks; Fig. GS-14-2) have geometries consistent with shortening at a low angle to the S_1 foliation. Together, these observations suggest that D_3 ductile shortening across the shear zone was succeeded by approximately north-south shortening along the shear zone, perhaps correlative with the D_4 event principally recognized to the northeast.

Overprinting brittle structures

The youngest structures observed in the Schist and Beaverhouse Lake sections are a conjugate set of brittle ("hairline") fractures. Rose diagrams displaying the azimuths of the steep to vertical fractures (Fig. GS-14-2) indicate NW-SE strikes for ones with sinistral separations, on horizontal outcrop surfaces, and NE-SW strikes for dextral ones. Extension fractures (*i.e.* with quartz veins) generally have azimuths that are within ±20° of east-west, although some of these show evidence for either sinistral or dextral rotation (which correlates well with their azimuthal quadrant in Fig. GS-14-2). This structural data suggests that the brittle structures developed in response to WNW-ESE subhorizontal shortening. This event probably corresponds to the D_5 late, brittle faulting episode. Final movement on some of the block-bounding faults (*e.g.* Ross Lake Fault) may have occurred at this time, resulting in further offset on metamorphic isograds (Bailes and Syme, 1989; Digel and Gordon, 1993).

DISCUSSION

The structural history of the NE Arm shear zone parallels, at outcrop scale, the overall history for the Flin Flon-Athapapuskow area derived from geologic mapping, structural study and geochronology. The early, high strain event responsible for S_1-L_1 development probably correlates with the *ca.* 1.87 Ga D_1 event documented along such structures as the Meridian Creek-West Arm shear zone (Reilly, 1992; Thomas, 1992; Lucas *et al.*, 1993c; Stern *et al.*, 1993b). Juxtaposition of the Amisk group volcanic assemblages (*e.g.* arc, ocean floor), along with possible slices of Archean crust (*e.g.* Beaverhouse tonalite), is thought to have occurred during this event. Evaluation of this hypothesis for the NE Arm shear zone requires U-Pb geochronological study of the syn-S_1 felsic dykes described above. The suite of overprinting ductile structures (shear bands, folds) along the NE Arm shear zone are consistent with a regional D_3 age in that they can be attributed to east-west shortening and north-south extension. Movement on the NE Arm fault and the complementary fault on the east side of the shear zone, as well as the Inlet Arm fault, may have been initiated during D_3. Whereas the symmetry of the D_3 structures suggests that the S_1 fabric may have been relatively steep during D_3, it is interesting to speculate as to whether the D_3 event was responsible for steepening of S_1 or whether the S_1 fabric developed in a relatively steep attitude. The sparsely distributed folds and faults suggesting shortening at a high angle to the zone, and probably associated with D_4 and the development of structures such as the Embury Lake fold and the Tartan-Annabel shear zone. Finally, conjugate dextral and sinistral brittle fractures found throughout the NE Arm area are consistent with the D_5 post-collisional faulting event (*e.g.* Ross Lake fault).

The results of this study illuminate a fundamental problem for further interpretation of Flin Flon Belt structures: how can one distinguish (1) important volcanic assemblage "sutures" or structural boundaries (*i.e.* D_1, D_2?) from (2) long-lived fault/shear zones (*i.e.* D_3-D_5) from (3) late high angle faults that may form important boundaries between tectonostratigraphic blocks (as distinct from assemblages; D_5). In other words, were all of the early (*i.e.* D_1) faults subsequently reactivated in relatively steep attitudes during D_3-D_5, or are some cryptically preserved with block interiors? This problem gains further importance in that the seismic reflection profiles of the Flin Flon Belt appear to contain evidence for high-angle faulting (Lucas *et al.*, 1993b; White *et al.*, submitted ms). These faults, defined by either diffractions on unmigrated sections or by the truncation of reflections, appear to closely correlate with the block-bounding faults (D_3-D_5) and can be traced to about 3 to 5 seconds (two-way travel time) depth, below which laterally-continuous reflections are the dominant seismic signature (Lucas, 1993b). The challenge for further detailed structural studies will be to determine the kinematics, age and tectonic significance of the high-angle structures and thus infer the significance of the underlying low-angle reflections. Finally, given that the size, character and distribution of Cu-Zn VMS deposits are now known to be directly related to distribution of Amisk Group volcanic assemblages (Syme *et al.*, 1993a, b; Stern *et al.*, 1993a), the regional identification of early (D_1) sutures/structural boundaries and the characterization of subsequent structural histories should be of critical importance to the hunt for further ore deposits.

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GS-15 CRANBERRY-SIMONHOUSE RECONNAISSANCE

by E.C. Syme

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SUMMARY

Metavolcanic rocks in the Cranberry lakes area (NTS 63K/11) were examined during a two week reconnaissance study. The area is part of the Paleoproterozoic Flin Flon metavolcanic belt, and lies between the recently mapped Athapapuskow Lake area (Syme, 1988; Syme *et al.*, 1993) and Elbow Lake area (Syme, 1990, 1991, 1992; Fig. GS-15-1). The goals of the reconnaissance were to: 1) evaluate existing geological maps (Podolsky, 1951, 1958; Hunt, 1970); 2) trace structures from the Elbow Lake area through the Cranberry lakes; 3) identify the volcanic lithologies for possible correlation with rock types in adjoining map areas; and 4) evaluate the massive sulphide potential of the area by comparing lithologies to those at Flin Flon.

Mapping was conducted on First Cranberry, Second Cranberry, Third Cranberry and Simonhouse lakes, as well as part of the Grass River. Only well-exposed shoreline outcrops were examined, to take advantage of unusually low, early summer water levels on the Cranberry chain. Coverage extended from Cranberry Portage to within 1.5 km of the southern boundary of the Elbow Lake project. The key geological observations include:

1. A major shear zone up to 2.2 km wide trends southwest through the Cranberry lakes chain. This structure appears to map into the Grass River fault (Syme, 1992) at Elbow Lake. Minor structures in the shear zone suggest that it has a long and complex movement history.
2. Lithologic units defined at Athapapuskow Lake and Elbow Lake were identified on Cranberry lakes, for the first time providing a link between the two areas. The main units are Athapapuskow basalt (extending from the Athapapuskow area) and McDougalls Point basalt (extending from the Elbow Lake area); they are tectonically juxtaposed by the Cranberry shear zone. The units are both members of the Ocean Floor assemblage (Stern *et al.*, 1993). Members of the Ocean Floor assemblage have, to date, provided only a very small proportion of the massive sulphide production from the Flin Flon belt.
3. The Berry Creek fault was mapped in northern Simonhouse Lake. This fault extends for at least 150 km, from Wekusko Lake to Athapapuskow Lake, generally at or just south of the Paleozoic edge. Identifiable structures related to the fault include shearing, carbonatization and brittle deformation in the supracrustal rocks, and mylonitization in plutonic rocks. Mapped relationships and minor structures suggest that the Berry Creek fault is a sinistral oblique-slip structure with a large component of dip-slip movement.
4. Folded, compositionally layered mafic gneisses extending south from First Cranberry Lake can be correlated with magnetic units in the sub-Paleozoic Namew Gneiss Complex.

The results from this brief reconnaissance indicate that there is a need to upgrade existing maps in the western Flin Flon belt for the NATMAP 1:100 000 compilation.

GENERAL SETTING

The Flin Flon metavolcanic belt consists of a predominantly low grade, polydeformed assemblage of supracrustal and intrusive rocks. Detailed geochemical, isotopic and geochronological studies indicate that the volcanic rocks in the belt were derived from 1.91 to 1.88 Ga arc and ocean floor magmatism (Bailes and Syme, 1989; Syme, 1990; Gordon *et al.*, 1990; David and Machado, 1993; Stern *et al.*, 1993). The volcanic rocks are subdivided into two major assemblages reflecting these different tectonic settings: Arc assemblage (dominating at Flin Flon and Snow Lake) and Ocean Floor assemblage (dominating at Athapapuskow and Elbow lakes). A third, minor assemblage with Ocean Island Basalt affinity occurs on Elbow Lake (Stern *et al.*, 1993). One of the goals of this study was to determine the lithologic/tectonic affinity of basalts on the Cranberry lakes chain.

Ductile shear zones occur between and within the major volcanic assemblages and are the major structural elements within the metavolcanic belt. The larger shear zones have a long and complex history (see Ryan and Williams, GS-19 this volume). At least some of these structures are imaged in the recent LITHOPROBE seismic reflection survey across the Trans-Hudson Orogen (Lucas *et al.*, 1993a,b; White *et al.*, in prep.). Although many of the major shear zones in the Flin Flon belt have been identified in recent mapping, areas that have not been remapped since the 1950s require revision. The Cranberry lakes area is particularly important because LITHOPROBE seismic reflection line 5 passes through Cranberry Portage.

ROCK TYPES

The metavolcanic belt in the Cranberry lakes area is only 2.6 to 6.4 km wide. Lakes cover much the belt, following a zone of recessive phyllonites and mylonites up to 2 km wide. Consequently, there is limited shoreline exposure of nonsheared metavolcanic rock. Basalt flows predominate, as would be expected in an ocean floor (as opposed to island arc) environment. Other rock types include: 1) a small unit of rhyolite on Third Cranberry Lake; 2) pebbly mafic wackes and conglomerates (occurring mostly as fault-bounded slivers within shear zones); 3) fine grained, laminated, folded mafic gneisses extending south from First Cranberry Lake; 4) a large body of gabbro south of the Cranberry shear zone on First Cranberry Lake, probably correlative with a large gabbro on the south shore of East Arm (Athapapuskow Lake); and 5) a previously unmapped layered ultramafic intrusion in the narrow septum of supracrustal rocks extending from Second Cranberry Lake to Simonhouse Lake.

Basalts

Most of the nonsheared metavolcanic rocks are exposed at the margins of the belt, where they are within the thermal aureoles of adjacent granitoid plutons. Despite this metamorphic overprint basaltic units in the Cranberry lakes area can be correlated with two major units (Athapapuskow basalt and McDougalls Point basalt) along strike in the Athapapuskow and Elbow Lake areas, respectively. These two units have regional significance in the Flin Flon belt, and are tectonically juxtaposed along the Cranberry shear zone.

Athapapuskow and McDougalls Point basalts have ocean floor basalt geochemical characteristics (Syme, 1990, 1992; Stern *et al.*, 1993), and are thus distinct from the island arc rocks that characterize the Flin Flon and Snow Lake areas (Syme, 1990; Stern *et al.*, 1993; Syme and Bailes, 1993). They are tholeiitic, subalkaline, and have MORB-like compositions. The ocean floor basalts have higher abundances of Ti, Zr, Nb, Y and REEs than the arc assemblage. The geochemistry suggests that they were erupted in an immature oceanic rift setting, such as a back-arc basin (Stern *et al.*, 1993).

Athapapuskow basalt

Athapapuskow basalt (Syme, 1987, 1988) occurs along the north shores of the Cranberry lakes (Fig. GS-15-2). The unit consists of dark green massive and pillowed basalt, intruded by common diabase dykes and sills. The unit tops to the north, away from the Cranberry shear zone. Basalt flows contain quartz- and epidote-filled amygdales up to 1 cm in size, and contain abundant epidote veins and epidosite domains. The abundance of epidote alteration serves to distinguish this unit from McDougalls Point basalt.

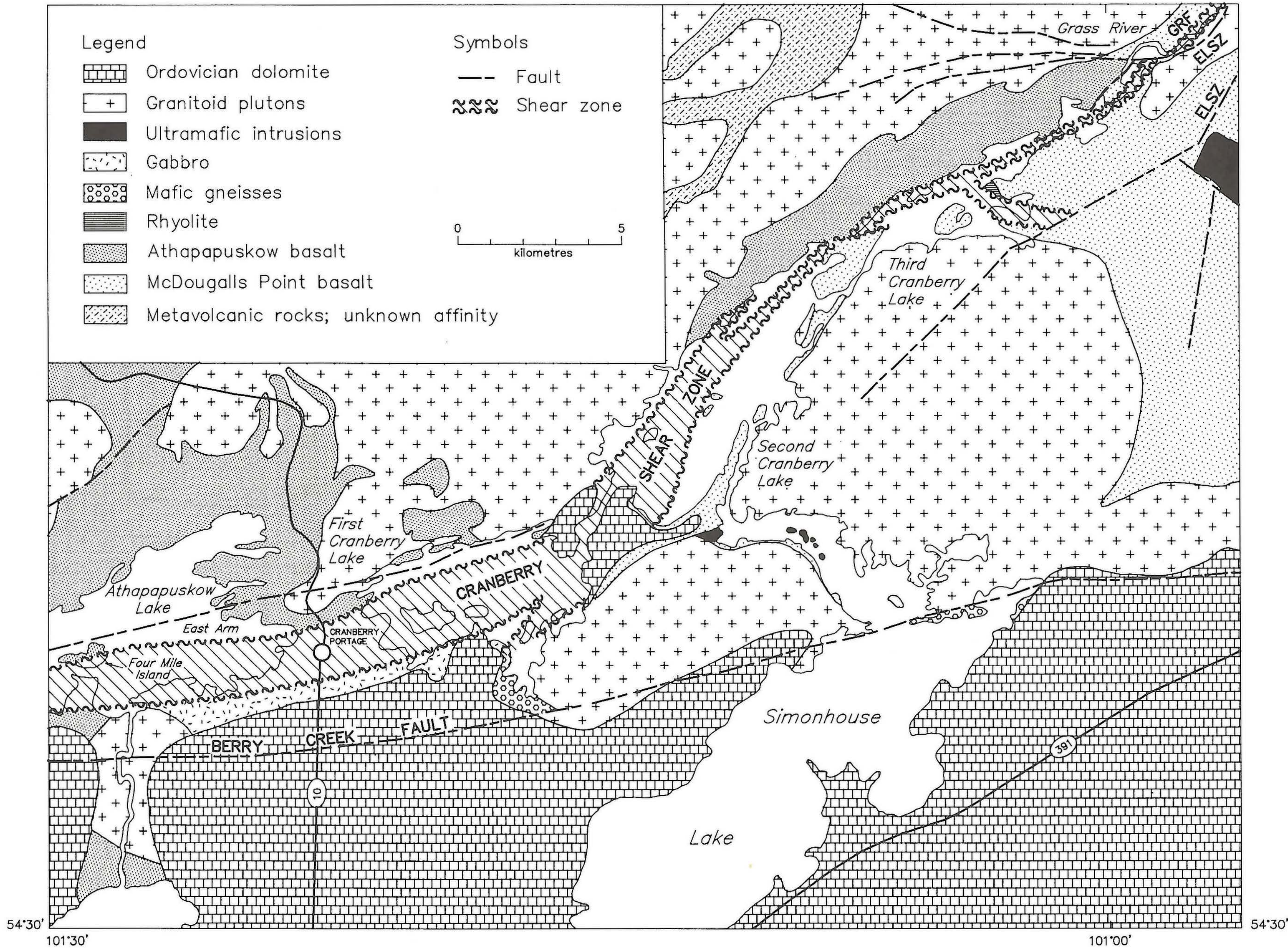

Figure GS-15-1: ***Simplified geological map of the Flin Flon belt with location of the Athapapuskow Lake area ("A"; Syme, 1988), Elbow Lake area ("B"; Syme, 1992) and Cranberry - Simonhouse area ("C"; this report). ELSZ: Elbow Lake shear zone; CSZ: Cranberry - Grass River shear zone; BCF: Berry Creek fault; SASZ: South Athapapuskow shear zone.***

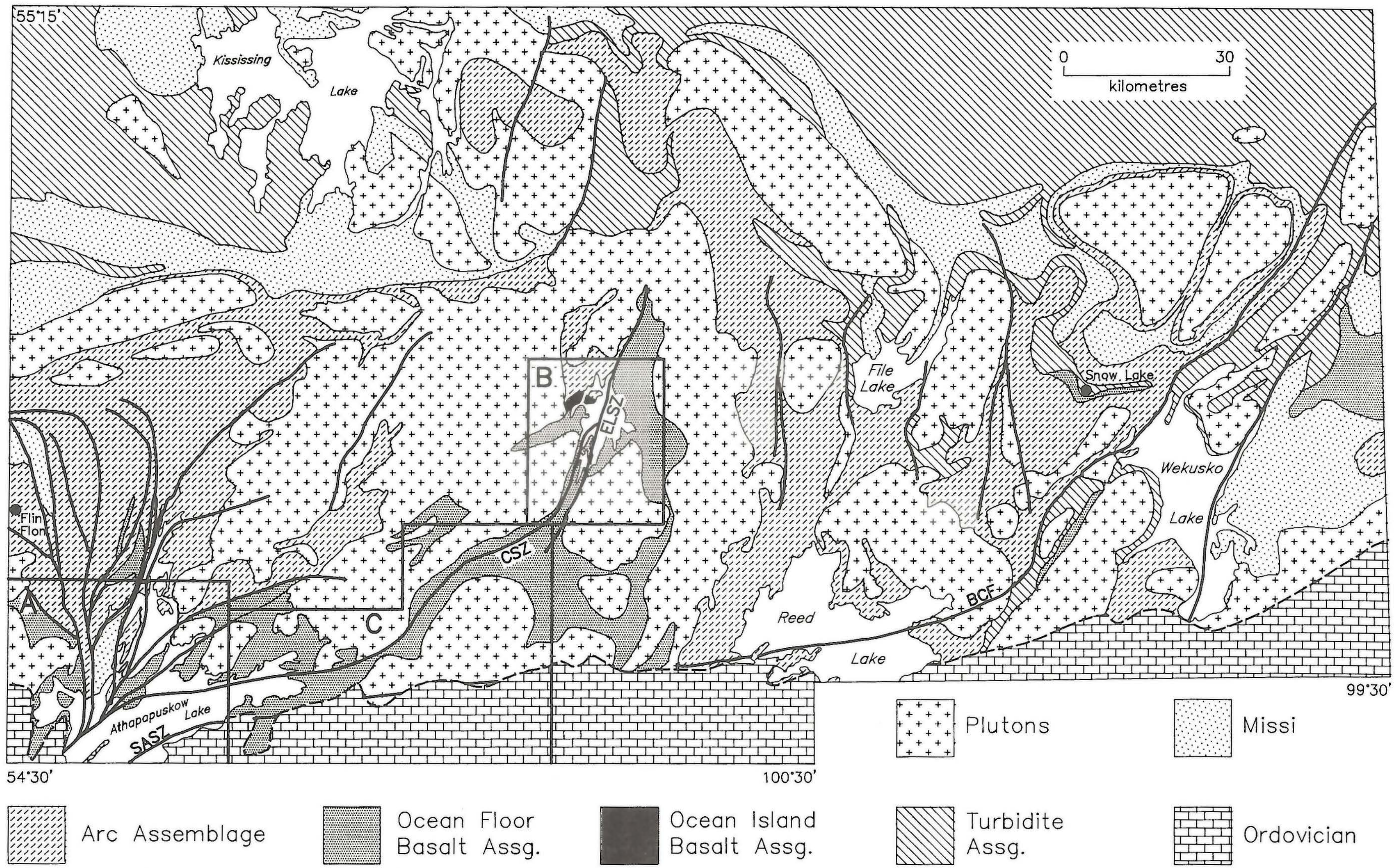

Figure GS-15-2: ***Simplified geological map of the Cranberry - Simonhouse area, modified from Podolsky (1951, 1958) and Hunt (1970). Reconnaissance work in 1993 was confined to the Cranberry lakes chain, Simonhouse Lake and the Grass River. ELSZ: strands of the Elbow Lake shear zone; GRF: Grass River fault.***

McDougalls Point basalt

McDougalls Point basalt (Syme, 1991, 1992) occurs southeast of the Cranberry shear zone, and is exposed on the southeast shores of Second and Third Cranberry lakes (Fig. GS-15-2). The outcrop distribution on Third Cranberry Lake and southern Elbow Lake (Syme, 1992) suggests that much of the large part of the belt southeast of Third Cranberry Lake is also McDougalls Point basalt.

McDougalls Point basalt has a typical brownish buff colour where it occurs more than 1 km from granitoid plutons (*e.g.* on islands in Second Cranberry Lake). Flows are predominantly pillowed; pillows are medium to small in size, have narrow selvages, and are characterized by the presence of white interpillow chert. Infrequent amygdales up to 4 mm are filled with quartz. The conspicuous epidosite domains that characterize Athapapuskow basalt are generally absent.

Within about 1 km of pluton contacts McDougalls Point basalt is contact metamorphosed. The normally buff-coloured pillowed flows weather dark grey-green to black, and the rocks have a strong, platy fabric. Pillows are flattened, and tops are generally impossible to determine. The characteristic presence of interpillow chert, and low abundance of epidosite domains, serves to identify this unit within the contact aureoles.

Rhyolite

Felsic volcanic rocks are extremely rare in the Cranberry lakes area, consistent with the ocean floor geochemical nature of the basalts. The only rhyolite observed during this reconnaissance mapping was a small body that occurs within McDougalls Point basalt on Third Cranberry Lake. The rhyolite is strongly foliated, lineated, aphyric and spherulitic. It is bounded on the southwest and northwest sides by shear zones.

Sedimentary rocks

Bedded polymictic pebble conglomerate and pebbly wacke occur in a number of locations within the Cranberry shear zone and associated structures. They represent the structural remnants of what was presumably originally a much more extensive formation.

On the southeast part of First Cranberry Lake these rocks consist of well preserved pebble conglomerates. Clasts are predominantly mafic in composition, but also include rhyolite, epidosite, quartz diorite, diabase, and medium grained granodiorite. Clasts (up to 10 cm long) are flattened into the plane of foliation. Granitoid clasts comprise 2% of the conglomerate. With increasing strain the conglomerate locally grades into mylonite.

Mafic gneiss

Mafic gneisses are exposed in the southernmost bay of First Cranberry Lake. These rocks are laminated to thinly banded and are invariably folded (Fig. GS-15-3). Although they are distinct from any other rock types in the Cranberry area, they appear to be higher metamorphic grade equivalents of mylonitic rocks in the Cranberry shear zone.

Compositional bands in the gneiss are generally 1 to 100 mm thick. They include grey-green mafic material, dark green hornblendite, white felsic material, and yellow-green epidote-rich material. Foliation is parallel to compositional banding. Foliation and banding are folded by medium-amplitude, east-trending upright folds that plunge steeply to the east. Locally there is a weak axial planar crenulation cleavage developed in the hinge areas of the folds.

The mafic gneisses exposed on First Cranberry Lake correlate along strike with zones of high magnetization in the sub-Paleozoic, zones that are interpreted as gneissic Amisk Group metavolcanic rocks (Manitoba Energy and Mines, 1992). These narrow, curvilinear zones are part of the Namew Gneiss Complex, a high grade gneissic domain dominated by amphibolite grade tonalite gneisses. The Namew Gneiss complex is interpreted to represent a deeper crustal segment of the Flin Flon magmatic arc (Leclair *et al.,* 1993).

Gabbro

Gabbroic rocks exposed on the south side of the Cranberry shear zone on First Cranberry Lake include mesocratic, light green rocks with 1 to 2 mm grain size, and a coarser variety with larger, equant plagioclase. Gabbro pegmatite pods and veins are locally common. In some localities the mesocratic gabbro contains weak modal layering.

The gabbros on First Cranberry Lake are almost certainly equivalent to gabbros mapped by Podolsky (1958) on the south shore of East Arm (Athapapuskow Lake). They thus form a body at 11 km long and at least 1 km thick (Fig. GS-15-2). Lithologically the gabbro is similar to layered gabbros at Elbow Lake.

Layered ultramafic intrusion

Part of the narrow supracrustal septum that extends southeast from Second Cranberry Lake to Simonhouse Lake is composed of peridotite, pyroxenite and gabbro. The ultramafic is at least 3 km long, and is bordered on the southern margin by mafic gneiss derived from basalt (Fig. GS-15-2).

Peridotite weathers dark brown and is composed of 60 to 70% serpentinized oval olivine crystals (to 2 mm) in a matrix of hematite,

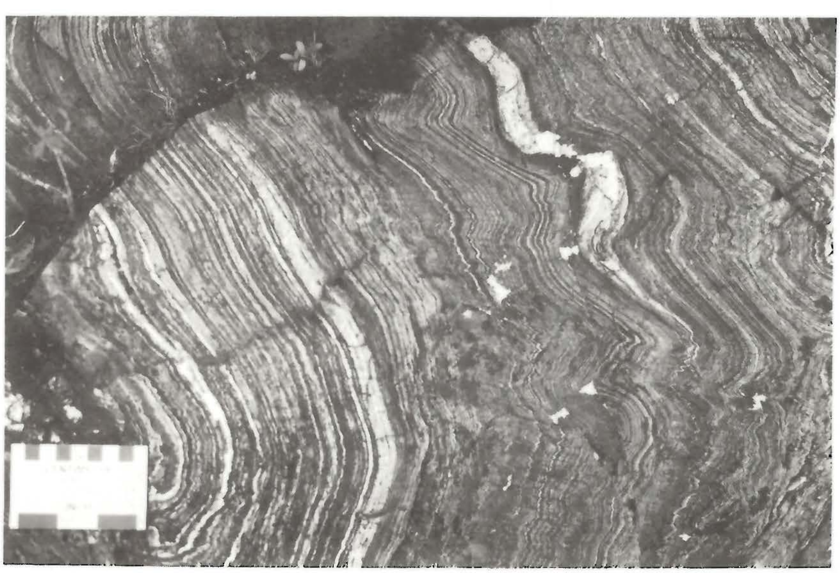

Figure GS-15-3: Folded, laminated mafic gneiss from southern First Cranberry Lake.

amphibole and talc. Some peridotite is completely recrystallized and schistose. Pyroxenite weathers green and is massive, medium grained and contains equant amphibole pseudomorphs after primary pyroxene. Gabbro weathers light green and is medium grained, with gabbro pegmatite pods and veins.

FAULTS AND SHEAR ZONES

Cranberry shear zone

The Cranberry shear zone is a major feature that extends 30 km from the Grass River in the northeast to at least Cranberry Portage in the southwest (Fig. GS-15-2). The shear zone decreases in width to the northeast; it is 2200 m wide on First and Second Cranberry lakes, and is 100 to 400 m wide on Third Cranberry Lake. Like the Elbow Lake shear zone (Syme, 1990, 1991, 1992), the Cranberry shear zone not only changes in width but bifurcates to form subparallel splays. The shear zone is offset by later, east trending, dextral, brittle structures on Third Cranberry Lake.

The Cranberry shear zone may be the along strike equivalent of the Grass River fault (GRF; Fig. GS-15-2; Syme, 1992) northeast of Third Cranberry Lake. The two structures cannot be traced directly into one another. A west-trending dextral splay from the Elbow Lake shear zone apparently offsets the northeast-trending Grass River fault/Cranberry shear zone by some 1200 m (Fig. GS-15-2). The Grass River fault is a narrower structure (up to 230 m wide) characterized by felsic mylonites and associated brittle deformation structures; while these also occur in the Cranberry shear zone, most of the zone is composed of schistose rocks similar to those in the Elbow Lake shear zone (Syme, 1991, 1992).

The western extent of the shear zone is presently unknown. The zone likely extends through the East Arm of Athapapuskow Lake, and is probably represented by sheared rocks on, and south of, Four Mile Island (Fig. GS-15-2).

The strong schistosity within the Cranberry shear zone dips steeply northwest or southeast. Lineations lie within the foliation plane and plunge steeply (50-80°) northeast. The few kinematic indicators observed suggest that early dextral movement on the zone was followed by subsequent sinistral and dextral movement.

Rocks within the Cranberry shear zone vary considerably in both lithology and state of strain. Most of the shear zone is composed of schistose mafic phyllonites derived from basalt, but sheared quartz diorite, diabase, gabbro and conglomerate are locally prominent. Low-strain zones containing rocks with relict primary structures occur within the widest part of the zone. Intrafolial carbonate, boudinaged quartz-carbonate veins and boudinaged pods of iron carbonate characterize the phyllonitic portions of the zone. Pseudotachylyte veins were observed in sedimentary rocks.

Mylonites form part of the shear zone on southwestern Second Cranberry Lake and on parts of third Cranberry Lake. At the southwestern end of Second Cranberry a 500 m wide zone of mafic and felsic mylonites forms the northwest side of the shear zone. The felsic mylonites are buff to white, flinty, and banded, whereas the mafic mylonites consist of alternating laminae of epidote-rich and amphibole-rich material. These mafic mylonites lack the intrafolial carbonate that characterizes the phyllonitic portions of the shear zone. At the northeast end of Third Cranberry Lake the entire shear zone is only about 100 m wide, and is composed predominantly of finely laminated mafic mylonites.

Berry Creek fault

The Berry Creek fault is an arcuate structure that extends at least 150 km from Wekusko Lake, southwest through Tramping Lake, then west through Reed and Simonhouse lakes to Athapapuskow Lake (Manitoba Energy and Mines, 1992). West of Reed Lake the fault is rarely exposed because it typically occurs at, or just south of, the Paleozoic edge. However, during this study the fault was found to be exposed for 8 km in northern Simonhouse Lake (Fig. GS-15-2).

The Berry Creek fault is probably responsible for the abrupt truncation of upper crustal reflections imaged in LITHOPROBE line 5 (Lucas *et al.*, in press; referred to as "Athapapuskow Lake shear zone"). The fault appears to contain a component of north-side-down normal slip, resulting in down-faulting of the low grade Flin Flon belt against mid-crustal gneisses of the Namew Gneiss complex (White *et al.*, in prep.).

At Simonhouse Lake a dominantly plutonic portion of the Flin Flon belt lies north of the fault, and a narrow (1 km wide) supracrustal panel bordered by plutons is on the south side. The straight boundary between the supracrustal and plutonic rocks is taken to represent the fault plane. Fabrics in the plutonic rocks north of the fault trend southeast, but rotate into a more easterly orientation near the fault, consistent with a sinistral component of shear. Fabrics in the mafic tectonites south of the fault trend west-southwest, parallel to the trace of the fault. The wall-rock foliation dips 75 to 80° north, consistent with the steep dip imaged on LITHOPROBE line 5 (White *et al.*, in prep.). Lineations in the mafic tectonite plunge moderately (45-60°) to the west.

The supracrustal rocks south of the Berry Creek fault are dominated by strongly flattened, locally compositionally banded, fine grained mafic gneisses and tectonites derived from pillow basalt and diabase. The ductile deformation recorded in these rocks may reflect an early phase of deformation in the Berry Creek structure. The tectonites are locally overprinted by zones of buff-brown carbonatization and associated tectonic brecciation, likely reflecting late brittle deformation along the fault.

Plutonic rocks north of the fault trace generally show limited evidence of shearing. The granodiorites contain a plane of foliation and flattening parallel to the fault trace, and locally contain a weak gneissic layering. Mylonitic granodiorite was found at one location.

CONCLUSIONS

Reconnaissance mapping in the Cranberry lakes area indicates that existing maps do not adequately depict the structural and lithologic complexity in the metavolcanic belt. A major shear zone (Cranberry shear zone), 100 m to 2.2 km wide, trends southwest through the Cranberry lakes, separating Athapapuskow basalt in the northwest from McDougalls Point basalt in the southeast. Both basalt formations are members of the Ocean Floor assemblage.

The Berry Creek fault exposed on northern Simonhouse Lake separates metavolcanic and plutonic rocks of the Flin Flon belt from gneissic rocks of the sub-Paleozoic Namew Gneiss Complex. On Simonhouse Lake the Berry Creek fault is a sharply defined, sinistral oblique-slip, brittle structure with associated carbonatization, brecciation, shearing and mylonitization in the wall rocks.

Mafic gneisses extending south from First Cranberry Lake are possibly correlative with members of the Namew Gneiss Complex in the sub-Paleozoic. These higher grade rocks are structurally and lithologically unlike metavolcanic rock types elsewhere on the Cranberry lakes.

The potential for volcanogenic massive sulphide deposits in the Cranberry lakes area is probably low, based on the fact that relative to the Arc assemblage, Ocean Floor assemblage rocks elsewhere in the Flin Flon belt host few deposits (Syme and Bailes, 1993). There may be potential for gold deposits hosted within the Cranberry shear zone and related structures; a number of gold showings are known in the Cranberry lakes area.

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GS-16 MINERAL OCCURRENCES IN THE ISKWASUM LAKE (NTS 63K/10), ELBOW LAKE AND NORTH STAR LAKE (NTS 63K/15) AREAS

by T.H. Heine

Heine, T.H., 1993: Mineral occurrences in the Iskwasum Lake (NTS 63K/10), Elbow Lake and North Star Lake (NTS 63K/15) areas; in Manitoba Energy and Mines, Geological Services, Report of Activities, 1993, p. 67-72.

SUMMARY

The Iskwasum Lake and Elbow Lake map areas contain numerous mineral occurrences that have been evaluated since the early 1920's. Descriptions for many of these have been provided by a number of workers including Armstrong (1922), Stockwell (1935), Harrison (1949), McGlynn (1959), Hunt (1970), Rousell (1970), Stewart (1977), Ostry (1985, 1987), Galley *et al.* (1987, 1989), Pippert and Gale (1990) and Heine and Prouse (1992). A review of cancelled assessment files of projects undertaken in the map areas has also indicated several additional mineral occurrences that were evaluated by mining and exploration companies.

Field investigations of mineral occurrences were undertaken in NTS map areas 63K/10 (Iskwasum Lake) and 63K/15 (Elbow Lake). Activities consisted of accurately locating mineral occurrences and associated workings (trenches, strippings, shafts, etc.) on 1:5 000 scale aerial photographs and mapping the geology at each locality, generally at a scale of 1:200. Occurrence locations were determined using a chain and compass from known topographic reference points. Individual occurrence descriptions will be incorporated into the forthcoming Mineral Deposits Series publications for the respective topographic areas.

The Iskwasum Lake map area (NTS 63K/10) contains occurrences of gold, asbestos, talc and sulphides, some of which have been evaluated in exploration programs. The investigations by Hunt (1970) and Rousell (1970) provide an outline of the regional geology, but the work undertaken during the 1993 field season suggests that much additional work is still required to establish an accurate geological description for this area. Several areas appear to have been completely ignored with respect to their mineral potential. For example, the Reed Lake gabbro, along the west side of Reed Lake, represents a differentiated mafic intrusion (Williamson, 1992) that has unknown potential for hosting base metal and platinum-group element reserves. Felsic volcanic and/or volcaniclastic rocks and associated sulphides are present in the area, but their extent, distribution and economic mineral potential remain essentially unknown.

The auriferous quartz veins east and southeast of North Star Lake (NTS 63K/15) are early structures (pre-D_3 features; see Norquay *et al.*, GS-18 this volume, for a discussion of the structural history of the area). At a number of locations the veins have been thickened within Z-asymmetry shear folds. Such areas may have enhanced gold values and thus should be considered as important exploration targets.

The Snow and Eva sulphide occurrences (NTS 63K/15) south of North Star Lake occur at the same stratigraphic position within mafic and felsic tuff (Norquay *et al.*, GS-18 this volume). The layered sulphide mineralization occurs in felsic to intermediate, fine grained, light- to medium-grey and grey-green banded tuff and/or volcaniclastic metasedimentary rocks. Conformable amphibolite layers and lenses 1 cm to 4 m thick are common. These occurrences represent a conformable sulphide-rich layer that has a strike length of at least several kilometres.

ISKWASUM LAKE MAP AREA (NTS 63K/10)

The investigations by Stockwell (1935) of the gold deposits in the Elbow-Morton Lakes area included the northern part of NTS map area 63K/10. His results were published in a 1:126 270 geological map. Fourmile Island was included in the mapping by Harrison (1949) of NTS 63K/9. More detailed geological investigations by Hunt (1970) and Rousell (1970) covered the Iskwasum Lake sheet, and their results were presented as 1:63 360 scale geological maps.

The fire that affected a large part of NTS area 63K/15 extended only a short distance into NTS 63K/10. Trenches are generally overgrown and caved, and bedrock is poorly exposed.

GOLD

The gold occurrences on Fourmile Island in Reed Lake were first staked in 1928 (Mineral Inventory File 735). In the 1930's numerous trenches and a shaft were excavated. Gold values were obtained from several of the veins and small quantities of free-milling gold were recovered as late as the early 1950's (Corky Peterson, pers. comm., 1993), but no commercial production has been recorded. Harrison (1949), Rousell (1970) and Stewart (1977) examined and briefly described some of the occurrences.

Four areas on Fourmile Island have gold occurrences (Fig. GS-16-1). Rousell (1970) and Stewart (1977) indicate that gold-bearing quartz veins occur in a tonalite intrusion. At the occurrences, the host rocks are massive and quartz bearing, and show little evidence for being other than an intrusion. Mafic rock fragments occur as xenoliths (?) up to several metres and possibly tens of metres in size within the tonalite. The lithologic sequence along the northwest shoreline of the island, previously mapped as chlorite schist and tonalite (Rousell, 1970), consists of massive, felsic, quartz crystal tuff intercalated with uncommon thin finer-grained metasedimentary units. The metasedimentary rocks show graded bedding and soft sediment deformation features such as load casts and flame structures. It remains unclear whether the tonalite represents an intrusion, an accumulation of tuff that shows only subtle depositional forms or a hybrid.

The gold is hosted by quartz-ankerite veins that trend north-northwesterly to north-northeasterly. Iron carbonate occurs as selvages and rusty-weathering masses throughout the quartz, and can make up to 25% of the vein material. Pyrite is the most common sulphide mineral present, but it generally occurs in only trace quantities. In limited areas it can make up to 10% of the vein material. Pyrite occurs as euhedral disseminated grains and aggregates to 10 mm distributed throughout the quartz and at the wallrock-vein contact. Trace amounts of chalcopyrite are present in the material excavated from the shaft (Locality 1a, Fig. GS-16-1). Dark green chlorite is present both as inclusions in, and as selvages to, the quartz veins. The quartz veins commonly contain angular fragments of the enclosing rock, some of which have been variably chloritized and carbonatized. No visible gold was noted at any of the occurrences.

Tonalite away from the gold occurrences is commonly extensively ankeritized as indicated by distinctive chocolate-brown weathering. The limits, distribution and significance of these altered areas remain to be determined.

The Big A and Little A occurrences are located along the west side of the Grass River at the foot of the first rapid below the railway bridge (Locality 2, Fig. GS-16-2). A quartz vein up to 7 m thick and trending 225°/75° is exposed along the shoreline. The vein is hosted by calcareous mafic schist that is probably part of the Elbow Lake Shear Zone (Galley *et al.*, 1987, 1989; Syme, 1990), and by a weakly foliated, fine grained pink felsic intrusion. The intrusion is made up of approximately 50% quartz and 50% pink feldspar. Contacts of the intrusion with the enclosing schist are not exposed. Two trenches, now completely overgrown, were excavated a few metres north of the quartz vein outcrop. No sulphides were noted in the quartz, but the pink intrusion contains up to 0.5%, disseminated, 1 mm pyrite cubes.

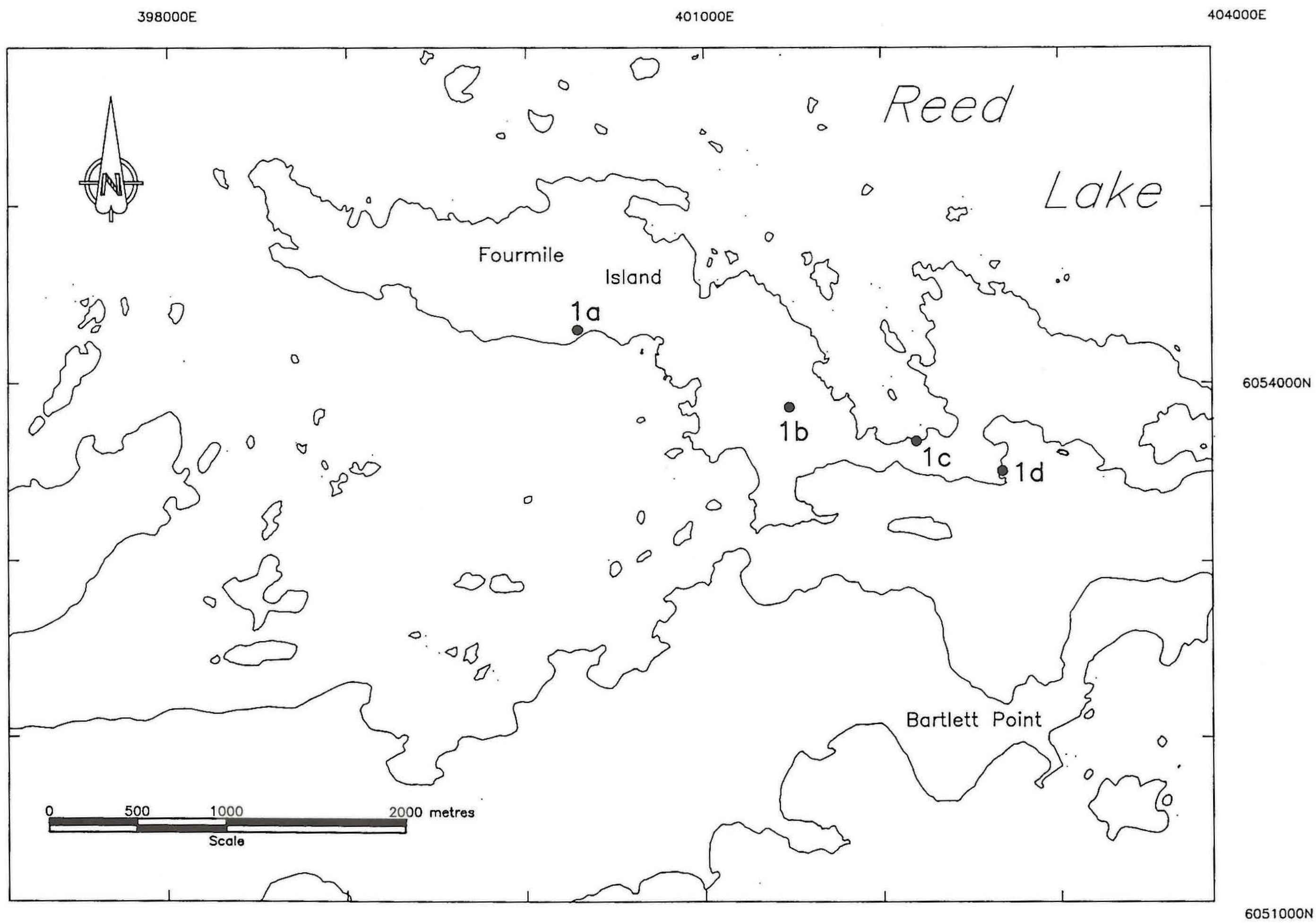

Figure GS-16-1: Gold occurrences on Four mile Island.

The R.G. occurrence is located approximately 1500 m southwest of a large bay on the Grass River and approximately 3300 m northwest of the north end of Iskwasum Lake (Locality 3, Fig. GS-16-2). R. Daniel Studer (pers. comm., 1993) indicated that a number of trenches had been excavated on this gold occurrence, possibly in the 1940's. In 1949 and 1951 several holes were drilled on the property, and assays returned up to 8.4 g Au/tonne (0.28 oz. Au/ton) (Mineral Inventory File No. 734). Fifteen trenches are located in the area of the main occurrence; most are water filled and/or overgrown.

Hunt (1970) indicated that the area is underlain by the Grass River pillowed flows and associated pyroclastic rocks, with minor derived schists and metasedimentary rocks. The occurrence is hosted by fine grained layered oxide facies (magnetite) iron formation. The rock is magnetic and contains up to 5% disseminated pyrite cubes. Massive nonfoliated tonalite outcrops approximately 10 m east of the southern part of the main occurrence. The areal extent of this intrusion and its relationship to the enclosing units are not known. A network of irregular quartz veins that are up to 10 cm thick and contain up to 10% pyrite as cubes to 20 mm, cut the iron formation. No visible gold was noted in either the quartz or the enclosing rocks.

A number of trenches have been excavated into quartz veins to the southeast of the main part of the R.G. occurrence. The veins occur within tonalite or metasedimentary rocks in close proximity to the intrusion. Up to 5% disseminated pyrite occurs in some of the quartz veins and in the tonalite exposed in the excavations.

A quartz mass, at least 20 m in size, is located approximately 1500 m north of the south end of Iskwasum Lake along the west shoreline (Locality 4, Fig. GS-16-2). This occurrence, which was located by Hunt (1970), is exposed in outcrop and six trenches. Discrete quartz veins up to 50 cm thick occur in fine grained mafic rock peripheral to the quartz mass that composes the main part of the occurrence. The mafic rock is in part fragmental and shows complex folds and crenulations; primary textures have been mostly obliterated. The folds postdate the formation of the quartz veins, but it is not clear whether the main quartz mass is located in the hinge area of the structure. The calcareous nature of the rock is reflected by its pitted weathered surface. Folded fine-grained feldspar porphyry dykes 3 to 75 cm thick crosscut the mafic rocks.

Most of the quartz vein is barren, but some restricted areas contain up to 60% pyrite. A bright green phyllosilicate, possibly fuchsite, is a common accessory mineral and locally composes 10% of the vein material. Minor schorl is also present.

SULPHIDES

Gossanous outcrop at the south end of Loucks Lake (Locality 5, Fig. GS-16-2) occurs in fine grained, laminated cherty metasedimentary rocks just to the north of a feldspar porphyritic granodiorite intrusion. Two conformable, limonitic, arenaceous layers, 30 and 15 cm thick, occur along the shoreline. These recessive layers are too deeply weathered to obtain fresh samples. Barren quartz veins up to 10 cm thick, which contain dark green chlorite inclusions, cut layering at a shallow angle. No trenches have been excavated at this occurrence.

A sulphide occurrence is located along the northwest shore of a small island in the north end near the east side of Iskwasum Lake (Locality 6, Fig. GS-16-2). No trenches have been excavated at this locality. The host to the mineralization is a folded fine grained dark

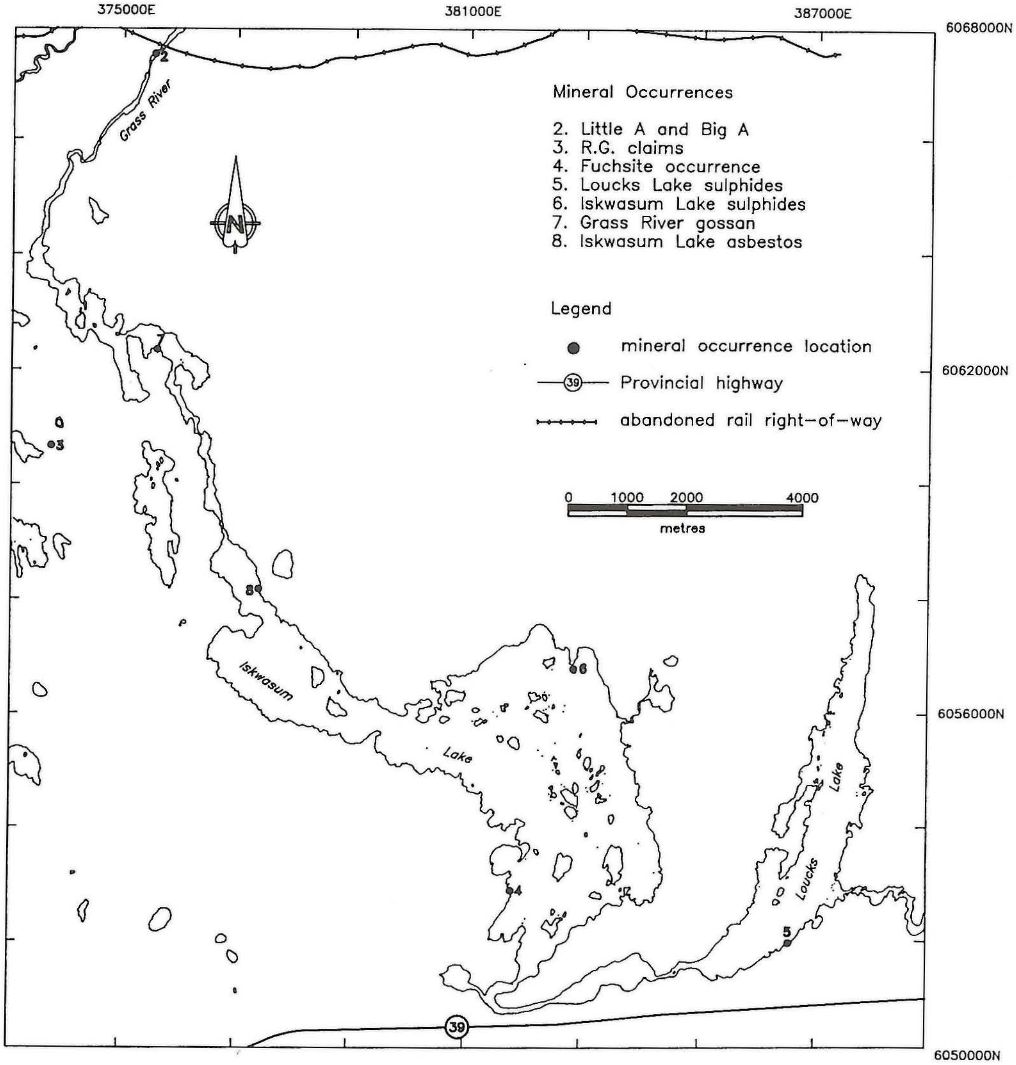

Figure GS-16-2: Mineral occurrences in the Iskwasum Lake area.

grey mafic rock. The unit is calcareous and commonly has pits, greater than 15 cm deep. Sulphides occur as discrete layers up to 30 cm thick and containing 70% pyrite. Up to 5% pyrite also occurs as disseminated grains in the mafic rock. Some of the grains have been stretched. No base metal mineralization was noted.

Four trenches have been excavated along the south shoreline of the Grass River approximately 3500 m north of the north end of Iskwasum Lake (Locality 7, Fig. GS-16-2). Two of the trenches are cut into the side of a hill and provide good bedrock exposures, but the other two are completely overgrown. The hillside trenches expose limonitic and barren felsic fragmental rocks. The sulphide-bearing rock exposed in the trenches is deeply weathered, and no sulphides were noted. The fragments, which consist of rounded, white to mottled white and green, fine-grained felsic material, are equant to elongate and range from 5 to 40 mm. The matrix consists of medium green chlorite. The rocks show a prominent foliation/layering that strikes 125° and dips 70° SW. The contact between the barren and limonitic rocks is sharp and conformable with the foliation.

ASBESTOS AND TALC

Hunt (1970) indicated an asbestos occurrence along the east shore of Iskwasum Lake at its north end (Locality 8, Fig. GS-16-2). The asbestos is hosted by an nonfoliated, intensely altered, weakly magnetic, talcose ultramafic rock. It is pale light green on weathered surface and shows irregular red and brown ferruginous patches. The ultramafic rock contains approximately 10% irregularly distributed brittle to semiflexible fibrous aggregates of asbestos (picrolite?) up to 30 mm long. The fibres are oriented both normal and at an angle to the walls of an irregular fracture network, and are commonly deformed. Outcrops containing asbestos were noted in the woods to the southeast of the shoreline exposures, but the size and distribution of the mineralized unit remains unknown.

The ultramafic body is bounded to the west by well layered, medium grained, brown-weathering arkosic metasedimentary rocks. The contact with the ultramafic unit is sharp, but its character could not be ascertained because of lichen cover. The metasedimentary rocks contain up to 1% disseminated magnetite; red spots of hematite after magnetite are ubiquitous. Conglomeratic layers containing fine grained, light grey weathering, rounded pebbles 5 to 20 mm long are present. Hematite forms laminae parallel to the layering, which trends 310° to 340° and dips vertically. Moss-covered outcrops to the south-southeast of the shoreline exposures are made up of similar ferruginous arenites.

The area contains a number of talc occurrences within serpentinite. These have been delineated along, and to the east of, the Grass River and extend into Iskwasum Lake. Hunt (1970) tabulated 11 occurrences, and further investigations were undertaken by

Gunter and Yamada (1986) and Gunter (1988).

Hunt (1970) suggested that the ultramafic bodies in the Iskwasum Lake area could be delineated on the basis of their magnetic response. The presence of magnetite-bearing metasedimentary rocks, possibly a red-bed sequence, suggests that areas of higher magnetic response may reflect the presence of such rocks, and that they could be widely distributed in the Iskwasum Lake area. The use of magnetic surveys in delineating altered magnetite-poor ultramafic bodies in the area should thus be viewed with caution.

ELBOW LAKE MAP AREA (NTS 63K/15)

Most of the mineral occurrences in the Elbow Lake and North Star Lake areas had been examined and described by the end of the 1992 field season. Observations by previous workers left a number a questions unanswered, that required several of the mineral occurrences in both the Elbow Lake and North Star Lake areas to be re-examined. The locations of properties examined in 1993 are shown on Figures GS-16-3 and -4.

ELBOW LAKE AREA

The Murray occurrence has been investigated by extensive trenches, a shaft and an adit. The description provided by Stockwell (1935) indicated that widely-spaced quartz stringers cut a body of fine grained, foliated quartz diorite. Some quartz stringers were reportedly very rich in gold (Armstrong, 1922). The diorite contains common fine grained, dark grey sericitic inclusions a few centimetres to several metres in size. Both the quartz diorite and the mafic rock inclusions are cut by nonfoliated tonalite dykes, most likely originating from a large intrusion to the southeast. Disseminated pyrite and pyrrhotite, ≤2%, are common accessory minerals. Very minor chalcopyrite is also present. Native gold was found in a few pieces of white quartz south of the adit.

Six areas were trenched on Smith Island in the south part of Elbow Lake (Localities 10a to f, Fig. GS-16-3). These are part of the Smith Island Claim #1 occurrence of Stockwell (1935). At Locality 10a two trenches expose 20 cm thick quartz veins hosted by calcareous sericite schist of the Elbow Lake Shear Zone. The quartz veins contain areas of orange carbonate. Up to 5% pyrite as 2 mm, disseminated, euhedral grains occur within the quartz.

Occurrences 10b, 10c and 10d are located in a 1.5 to 4.5 m thick chert unit within schist of the Elbow Lake Shear Zone. The chert is massive, aphanitic and varies from brown to olive green, pink and off-white on fresh surface. It contains up to 0.1%, 1 mm, disseminated euhedral pyrite grains. Minor arsenopyrite was noted as a fracture coating at locality 10b.

At locality 10e a now-flooded trench was excavated into a quartz-carbonate vein at least 40 cm thick. The vein is hosted by mafic phyllonite and contains minor disseminated pyrite. Fe-carbonate makes up to 10% of the vein.

At locality 10f a trench has been excavated into a light brown, sheared quartz porphyry dyke within a mafic phyllonite of the Elbow Lake Shear Zone. Quartz grains make up approximately 5% of the dyke, which also contains up to 0.5% disseminated pyrite. Minor arsenopyrite occurs with pyrite in a quartz vein in rubble.

The Hanna occurrence (locality 11, Fig. GS-16-3) of Stockwell (1935) is located within mafic phyllonites at the junction of the Elbow Lake and Claw Bay Shear Zones (Syme and Whalen, 1992). Several trenches at this gold occurrence expose quartz and ankerite veins in close proximity to a magnetite-bearing chert that contains disseminated pyrite.

NORTH STAR LAKE

Gold Occurrences

Several gold occurrences in basaltic rocks east and southeast of North Star Lake previously investigated by Pippert and Gale (1990) and Heine and Prouse (1992) were re-examined in order to establish the structural setting of the auriferous quartz veins and to attempt to relate this to the deformation history of the area (Norquay *et al.*; GS-18, this volume).

The quartz veins are discontinuous and broken up, and can show abrupt thickening along strike, from less than 0.5 m to several metres. At several locations large trenches have been excavated at such thickened portions of the quartz veins, including the Jupiter No. 2, Winnipeg, Jupiter No. 7, North Star No. 1 and 2, and Gold Rock occurrences. The quartz vein in the northeastern trenches of the North Star 1 and 2 occurrence (locality 44a of Stockwell, 1935) is well exposed and illustrates the mechanism by which veins undergo tectonic thickening. The large mass of quartz represents the central portion of a shear fold with Z-asymmetry. The limbs of the fold contain a quartz vein with an average thickness of 30 cm. Within the central part of the fold the vein has been thickened to 160 cm. Relative to the structural history established by Norquay *et al.* (GS-18 this volume) for the rocks west of the Eastern Basalts, the quartz veins represent pre-D_3 features.

Sulphide Occurrences

The Snow and Eva occurrences are located approximately 800 m apart at the same stratigraphic position within mafic to felsic, fine grained, light- to medium-grey and grey-green, banded tuff/volcaniclastic rocks (Norquay *et al.*, GS-18 this volume). This unit trends approximately 020° and dips steeply to the east. Garnet+quartz porphyroblasts, 0.1 to 0.3 mm, make up 1 to 5% of the unit. Conformable dark green amphibolite layers and lenses 1 cm to 4 m thick are common. The amphibolite layers contain up to 20% garnet porphyroblasts 0.5 to 1.0 mm in diameter. Locally, barren white quartz segregations are present in the grey metasedimentary rocks and along the contacts with amphibolite.

The material excavated from the trenches at both the Snow and Eva occurrences is limonitic and decrepitated; no fresh sulphides were noted. The grey metasedimentary rocks in the vicinity of the trenches average 0.5% disseminated pyrrhotite, but in some areas the sulphide content can reach 5%. Stockwell (1935) indicated that the quartz veins are well mineralized with pyrite and a few stringers of sphalerite. Minor chalcopyrite has also been noted at these occurrences (Ostry, 1985).

The rock sequence at the Snow occurrence has been folded. The folds show Z-asymmetry, with fold axes trending 340° to 005°, dipping steeply to the east and plunging 65° SSE. It is not clear to what extent the folding has affected the distribution and concentration of sulphides in the area of the occurrence: in one area a rusty layer shows open folds with no attendant mobilization of sulphide.

The lithologic sequence at the Eva occurrence is identical to that at the Snow. The sequence is essentially planar with several minor S folds. A well-defined 2 m thick limonitic band forms a unit with a higher sulphide content than the surrounding metasedimentary rocks. Parts of the lithologic assemblage are moderately calcareous as shown by deeply weathered pits in some of the outcrops. The trenches described by Stockwell (1935) were excavated into an interval that contains numerous quartz veins.

ACKNOWLEDGMENTS

Mr. Zerai Andegeorgs provided capable and enthusiastic assistance throughout the field program. Dr. George Gale provided invaluable assistance in sorting out some of the structural influences on the auriferous quartz veins in the North Star Lake area.

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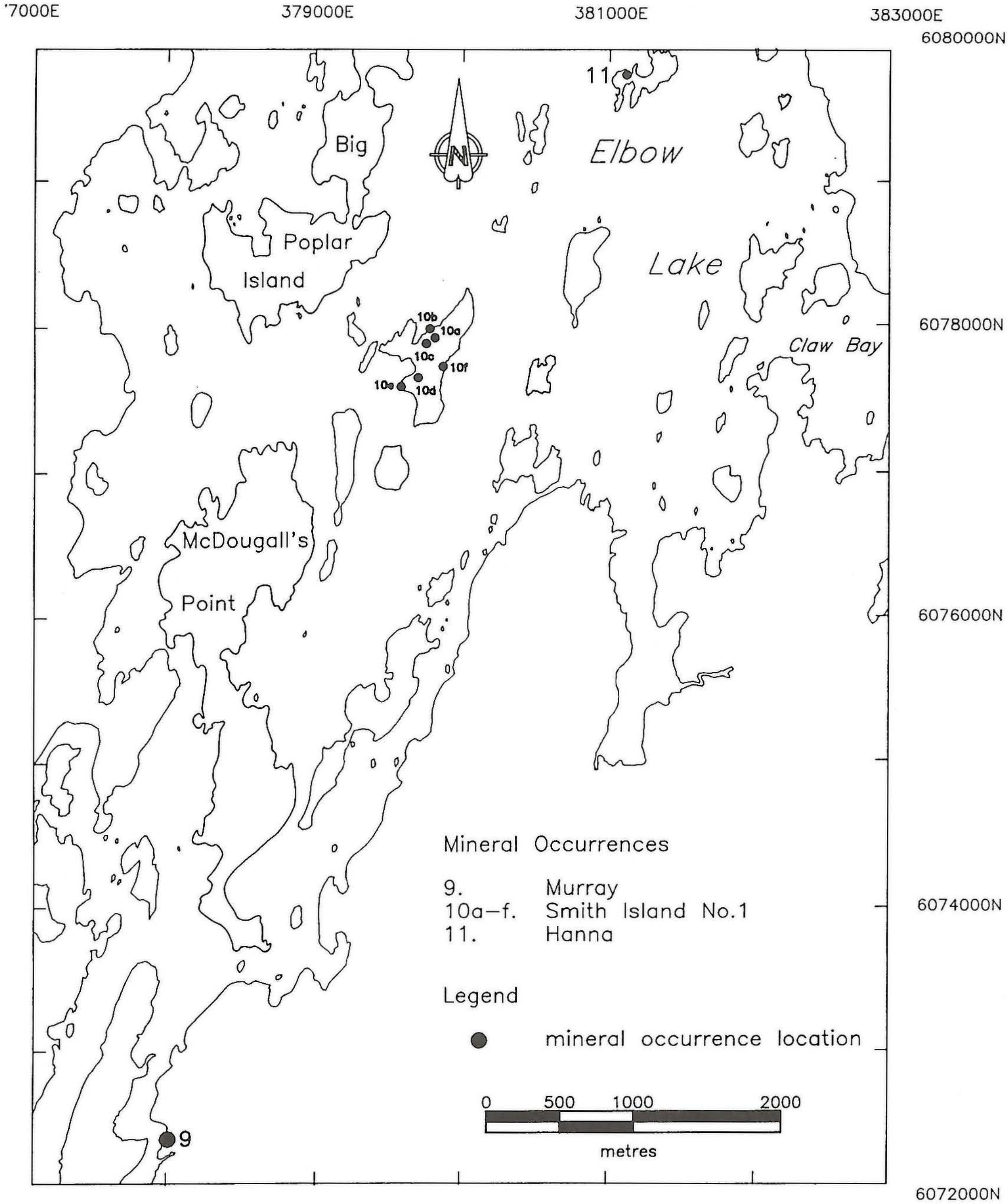

Figure GS-16-3: Mineral occurrences examined during the 1993 field program in the Elbow Lake area.

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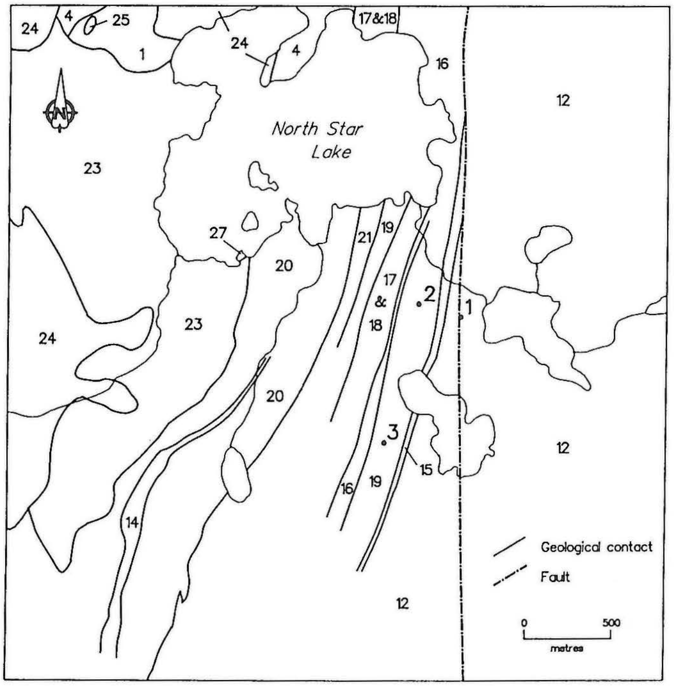

Figure GS-16-4: *Mineral occurrences examined during the 1993 field program in the North Star Lake area.*

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GS-17 NORTH STAR LAKE BRECCIA PIPES (NTS 63K/15)

by A.E. Ayed[1] and N.M. Halden[1]

Ayed, A.E. and Halden, N.M., 1993: North Star Lake breccia pipes (NTS 63K/15); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 73-77.

SUMMARY

At North Star Lake three types of breccia pipes appear to be spatially associated with ultramafic magmatism. Emplacement of these breccia pipes took place over a relatively short period of time, after the main regional metamorphism and deformation; their intrusion postdated the fourth phase of ductile deformation in the area, but predated brittle deformation. Many intrusive breccias may have acted as conduits for successive magma pulses. Many of the pipes lie within the hinge area of a major D_4 fold, indicating that there may be a spatial association with a tensional regime imposed within a 3 km wide area after folding.

INTRODUCTION

The objective of this project was to produce detailed field maps of breccia pipes in the vicinity of North Star Lake. North Star Lake is located in the middle of the Snow Lake- Flin Flon domain, Manitoba. The area was burned in 1989 and regional mapping was initiated in 1990 (Trembath *et al.,* 1990), and extended in 1991 (Norquay *et al.,* 1991a, b, c) and 1992 (Norquay *et al.,* 1992). Volcanic rocks are present in the area and sulphides are the subject of active exploration. Breccia pipes were first noted in the area during the 1991 field season (Norquay *et al.,* 1991). Consequently, during a portion of the 1993 field season, the first author concentrated on the detailed mapping and characterization of some of these breccias. This investigation will be undertaken as part of honours B.Sc. thesis work by the first author.

In the North Star Lake area 15 breccia pipes have been identified, 8 of which surround an intrusion of ultramafic rocks underlying North Star Lake (Fig. GS-17-1; Norquay *et. al.,* 1991b, c). Details of breccia pipes 1, 2, 5, and 6 will be discussed. Other breccia pipes shown on Figure GS-17-2 will be referred to in general terms.

GENERAL CHARACTERISTICS OF THE BRECCIA PIPES

The breccia pipes range in size from several metres to in excess of 100 m. They occur as dyke like forms, up to 35 cm wide and tens of metres long, trending at approximately 300°. Most commonly the breccia pipes are larger than the dykes, but have no regular geometrical shape (Fig. GS-17-1, -2, -3, and -4).

Rock fragments and matrix are visible in most breccia pipes giving them a fragment-supported texture. Fragments are most commonly angular to subrounded. They include various felsic and mafic intrusive rocks, felsic volcanic, and metasedimentary rocks; fragments range in size from <1 cm up to several metres. Most fragments appear to have been derived from the country rocks immediately surrounding a breccia pipe. However, fragments of rocks not found in surrounding country rocks are present and indicate some transport of material from depth.

The matrix to the fragments, where present, varies in composition from ultramafic to felsic (Norquay *et al.,* 1991). The felsic matrix is aphanitic to fine grained and is composed mostly of quartz and feldspar. This matrix could be rock flour derived from the milling of country rock. The second matrix, (associated with a later pulse of magma in breccia pipes proximal to the ultramafic intrusion) is an aphanitic to fine grained norite gabbro. Finally, the third matrix, also associated with a later magmatic pulse, is found in breccia pipes that are more distal to the ultramafic intrusion. It is a medium grained diorite with minor sulphide and magnetite. This matrix might have formed by syntexis or it may be a hybrid rock formed by the mixing of the silicic and the ultramafic matrix types. Most breccia pipes have two matrix types. Breccia pipes 1 to 4 and 6 to 12 have a dominantly silicic matrix. Breccia pipes 3, 5, 6, 7, and 8 have some ultramafic matrix material.

1 University of Manitoba

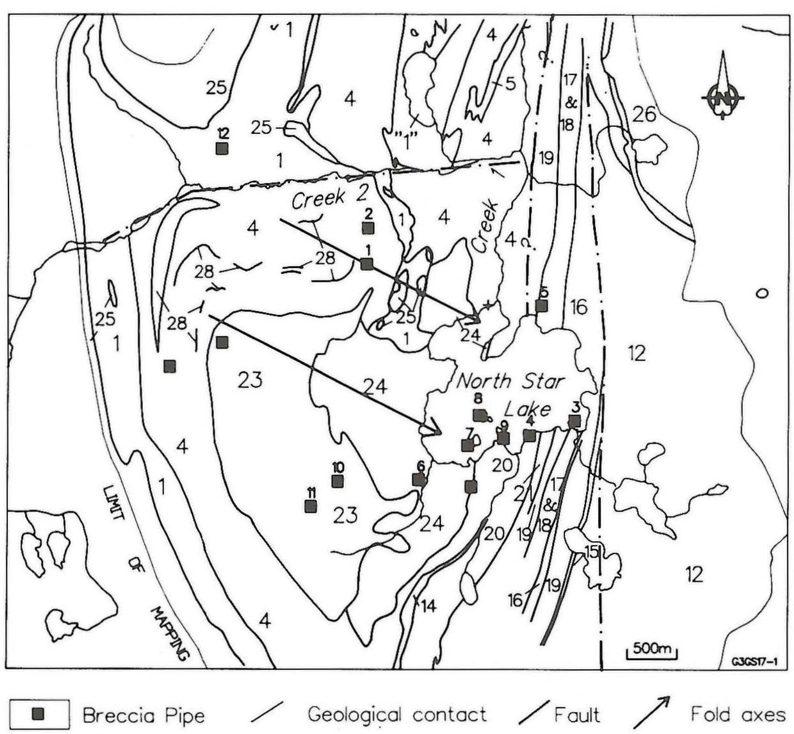

Figure GS-17-1: General geology of the North Star Lake area (after Norquay et al., 1993). For explanation of geological units see Figure GS-18-1, this volume.

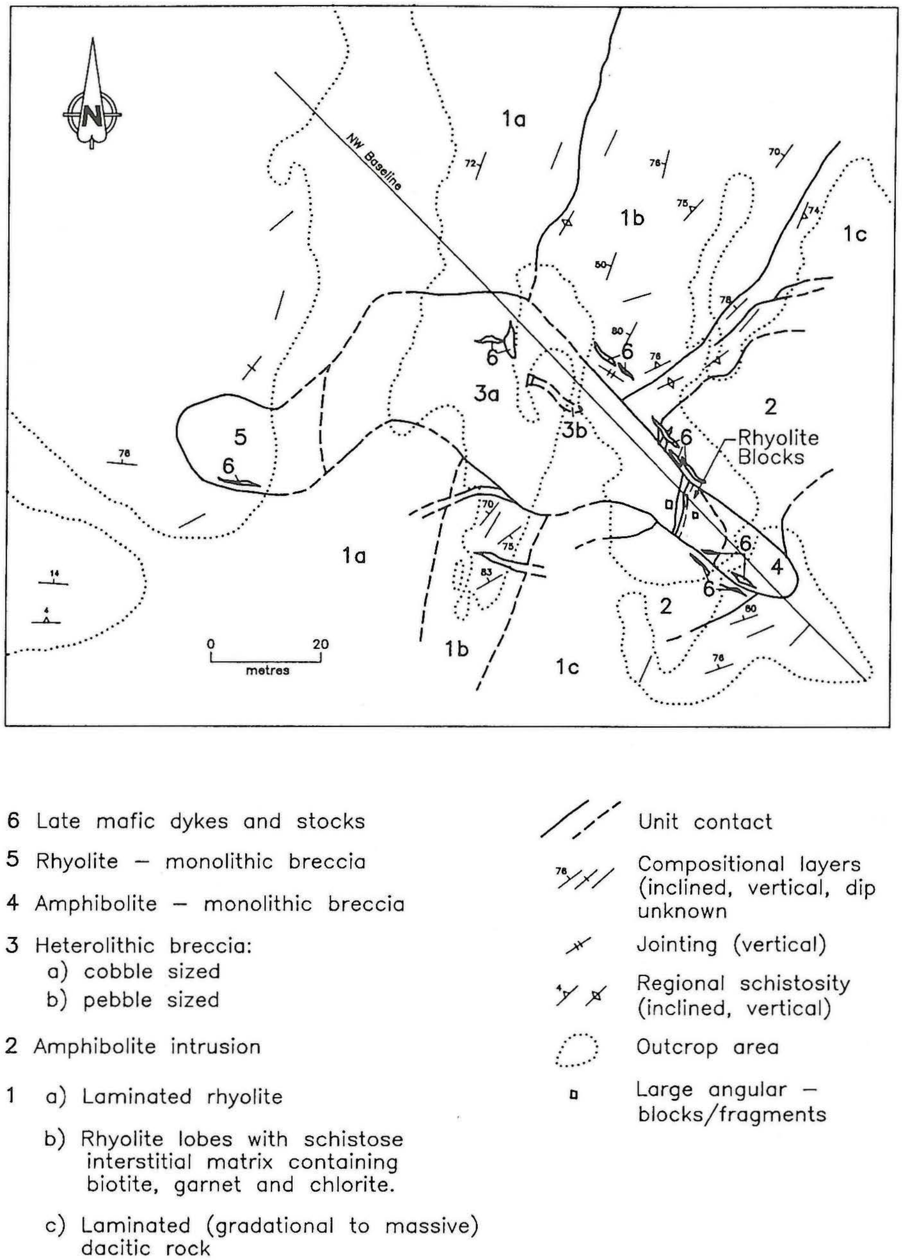

Figure GS-17-2: Geology of breccia pipe 1.

BRECCIA PIPES

Breccia pipe 1

Figure GS-17-2 shows a 1:1000 scale map of breccia pipe 1. The matrix is exclusively silicic. This breccia pipe is heterolithic in its central portions (unit 3a) grading to monolithologic at its extreme edges (units 4 and 5). Rounded fragments of exotic rock types (those not found in the immediate country rocks) are found towards the centre of the breccia pipe suggesting that transportation in the breccia pipe increased towards its central portions. Fragments preserving crenulation folds typical of those formed during the fourth phase of ductile deformation (D_4) are found within the breccia pipe indicating that the breccia pipe emplacement postdated the bulk of the deformation in the area. Unit 6 is a late mafic intrusion that postdated the breccia pipe. The stock in the central part of the breccia pipe is a zoned gabbroic intrusion containing a small amount of sulphide minerals.

Breccia pipe 2

Figure GS-17-3 is a map of breccia pipe 2. Both silicic and dioritic matrix types are present. The dioritic matrix has intruded the silicic matrix, infilling brittle fractures. Field evidence shows that this later phase also consisted of 2 pulses. The portion of the breccia pipe with the dioritic matrix has been subdivided into 2 units. The contact is gradational. Unit 4b has up to 5% fragments in some areas, but for the most part it is devoid of fragments. Unit 4a is a typical heterolithic breccia with a dioritic matrix.

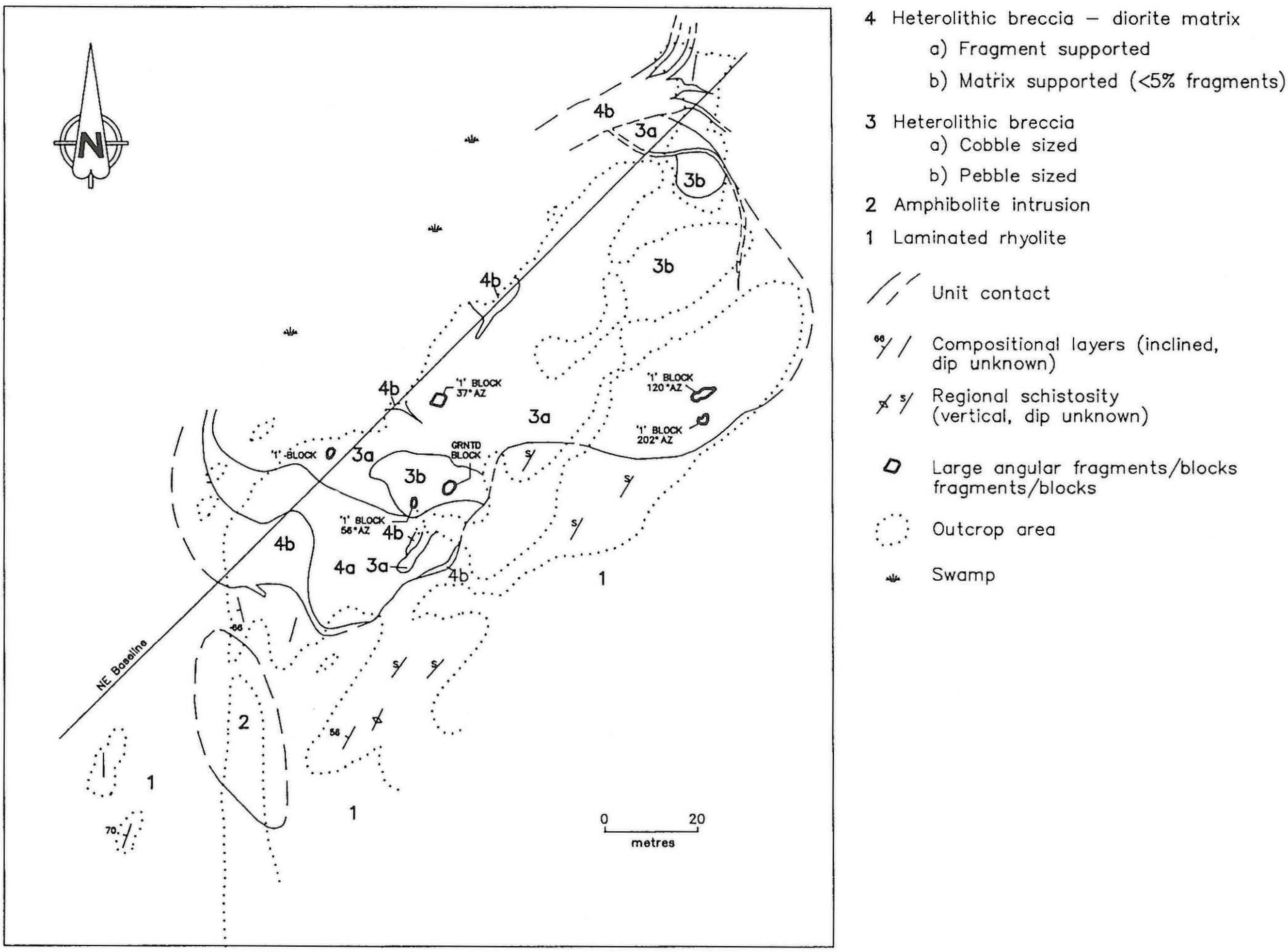

Figure GS-17-3: Geology of breccia pipe 2

Breccia pipe 5

Breccia pipe 5 is shown in Figure GS-17-4. The matrix is exclusively fine grained norite gabbro. Unit 3a is a heterolithic breccia with an ultramafic matrix. Unit 3b is composed of large (>0.5 m) rotated blocks of rhyodacitic country rock with no visible matrix.

The pyroxenite dykes that occur throughout, and along edges of, the breccia pipe are consanguineous with the pipe. Unit 4 is a zoned pyroxenite stock, the intrusion of which postdated the breccia pipe.

Breccia pipe 6

Figure GS-17-5 shows a 1:500 scale map of breccia pipe 6. The fine grained silicic and aphanitic ultramafic matrix types are present. The latter has intruded the former. Field evidence shows that the later phase consisted of 2 pulses that were intruded in a ductile fashion.

Fragments within this breccia pipe are angular to subangular and derived mostly from the adjacent fine grained granitic intrusion (unit 1). There is no sorting of the fragments, which suggests a chaotic nature of emplacement. Brittle fractures (160°) related to brittle deformation in the area (L. Norquay, pers. comm.) crosscut the breccia pipe.

Breccia pipe 7

Breccia pipe 7 (Fig. GS-17-1) was the only breccia pipe that has fragments of the surrounding ultramafic (pyroxenite) stock. This suggests an even later breccia pipe pulse that postdated the ultramafic intrusion.

CONCLUSIONS

It is apparent from field studies that there are 3 types of breccia pipes. They appear to be spatially associated with the ultramafic magmatism at North Star Lake. The emplacement of these breccia pipes took place over a relatively short period of time, after the main regional metamorphism and deformation. The emplacement of the breccia pipes and the ultramafic stock postdated the fourth phase of ductile deformation in the area, but predates brittle deformation. Most breccia pipes may have acted as conduits for successive magmatic pulses. These pulses were in the form of either breccia pipes or as dykes and stocks crosscutting the earlier breccia pipes. This is dependant upon the degree of cooling of the previously emplaced breccia pipe and the force of the intrusion of the later pulse. A number of breccia pipes lie within the hinge zone of a major D_4 fold in the North Star Lake area; this suggests that there may be a spatial association with a tensional regime imposed within this 3 km wide area of folded rocks.

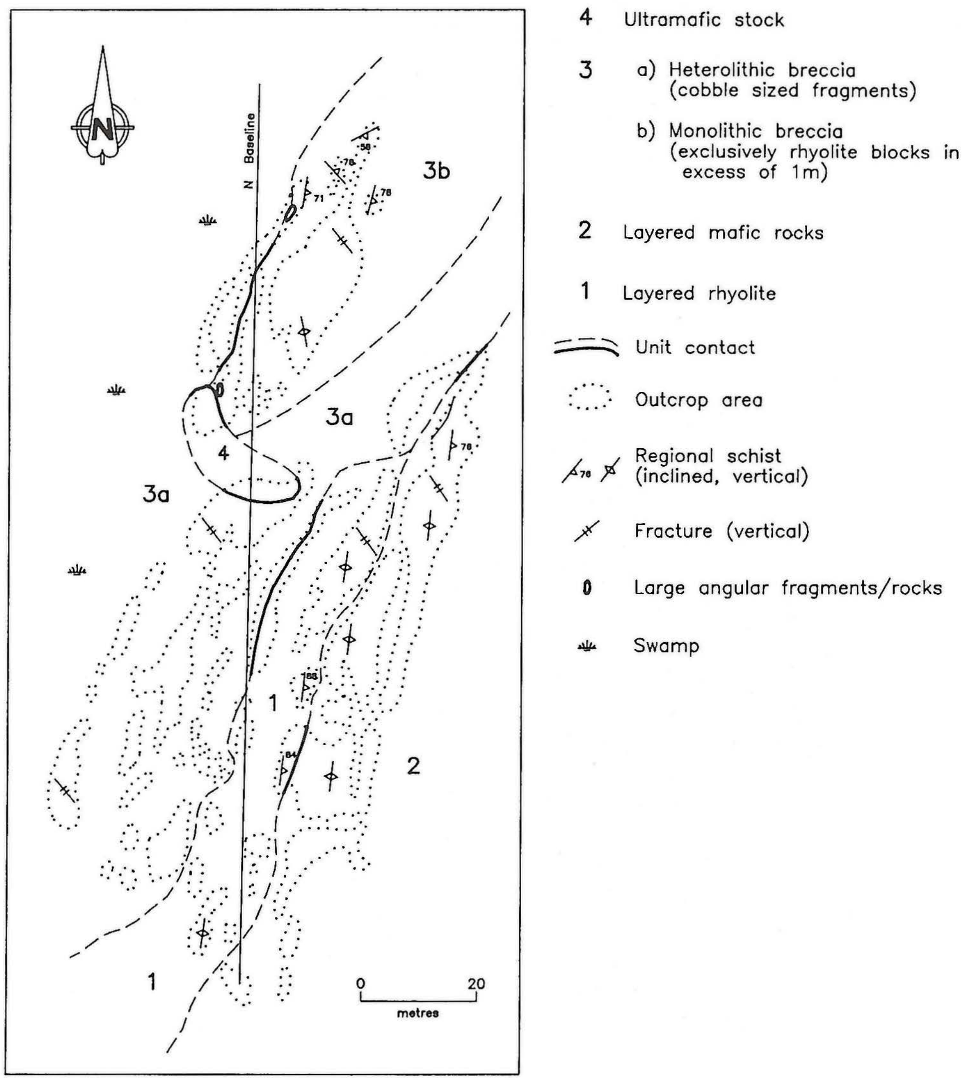

Figure GS-17-4: Geology of breccia pipe 5

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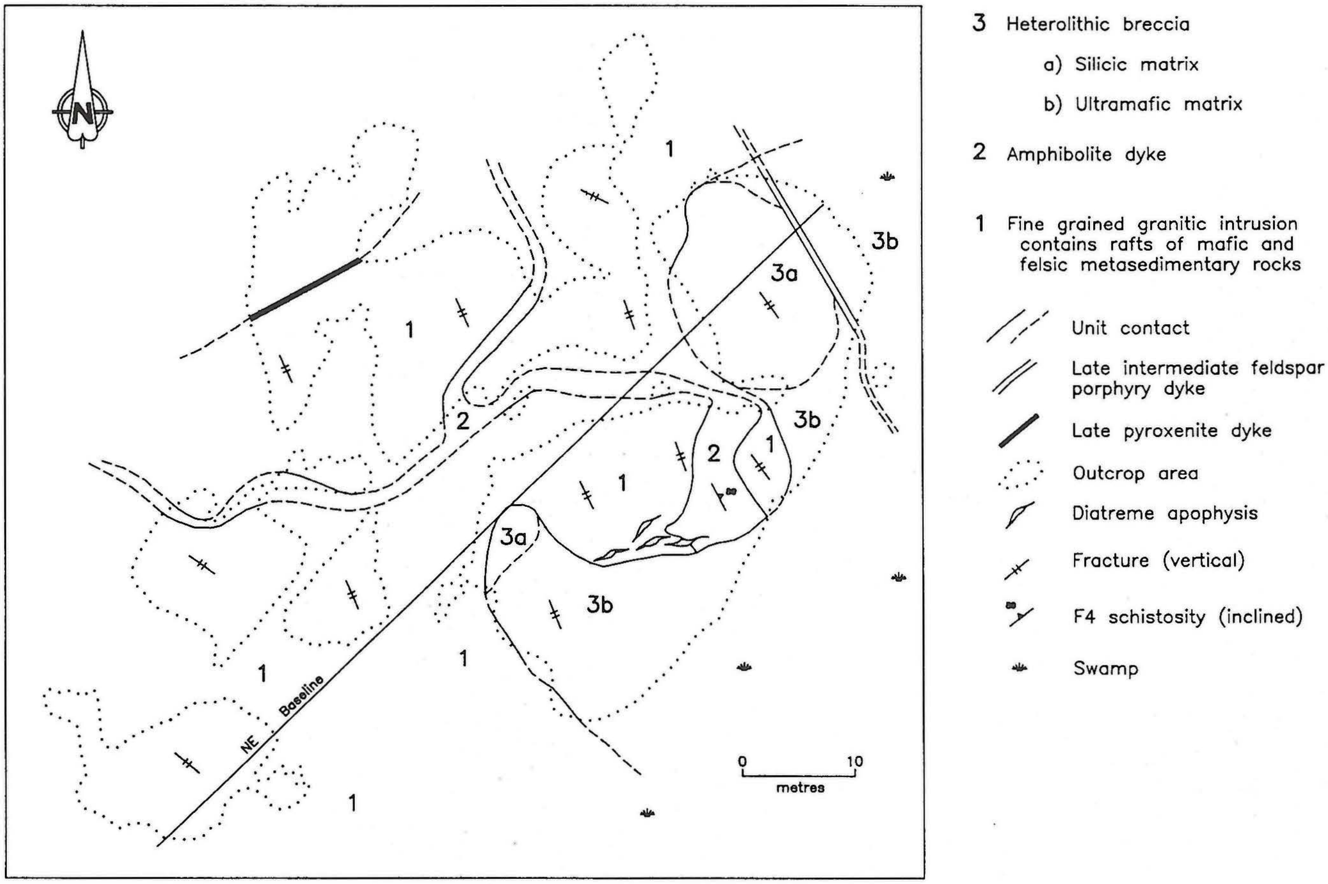

Figure GS-17-5: Geology of breccia pipe 6

GS-18 GEOLOGICAL INVESTIGATIONS IN THE NORTH STAR LAKE AREA (NTS 63K/15)

by L.I. Norquay, D.E. Prouse and G.H. Gale

Norquay, L.I., Prouse, D.E. and Gale, G.H., 1993: Geological investigations in the North Star Lake area (NTS 63K/15); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 78-83.

SUMMARY

1:5 000 scale systematic mapping of the southern portion of the North Star Lake area was completed. The central portion of the map area consists predominantly of well layered volcaniclastic rocks. The distribution of lithologies in the map area is largely the result of the large scale S-asymmetry folds.

INTRODUCTION

Current geological investigations of the North Star Lake area commenced when Trembath *et al.*, (1990) undertook 1:5000 scale mapping of a portion of a newly burnt area that reportedly contained abundant chemical sedimentary rocks (A.F. 92828). Based on the results of Trembath *et al.* (1990) detailed mapping was extended to the remainder of the supracrustal rocks exposed during the 1989 forest fire (Norquay *et al.*, 1991a, 1992,). Preliminary maps (Norquay *et al.*, 1991b, 1991c) defined the major lithologic units in the western part of the area, but structural analysis of this structurally complex area was postponed in order to permit an in-depth analysis of the area as part of a M.Sc. thesis (Norquay and Halden, 1992; Norquay, in prep.).

Previous exploration in the project area (A.F. 90488, 90489, 91607, 91608) indicated that the supracrustal rocks had the potential to contain massive sulphide type deposits. In addition, Stockwell (1935) documented gold occurrences east and southeast of North Star Lake. A detailed investigation of mineral occurrences in the project area started in 1992 (Heine and Prouse, 1992) and was continued in 1993 (Heine, GS-16 this volume).

Fieldwork during the 1993 season has been devoted mainly to: 1) completion of map coverage of supracrustal rocks in the southern part of the map area; 2) revision and definition of subunits within several previously defined map units; and 3) structural studies southwest of North Star Lake and eastwards to a regional fault (Zak's fault, Fig. GS-18-1). A geochemical sampling program initiated in 1990 was extended to determine the magmatic affinities of felsic and mafic rock units in order to establish their lithotectonic paleoenvironments of deposition. Geochemical studies to establish zones of hydrothermal alteration were discontinued after 1990 because exploration programs by Granges Inc. included an extensive geochemical sampling program (Todd Keast, pers. comm. 1992).

Several of the 1993 project objectives were not attained due to inclement weather, namely: 1) completion of the structural and petrographic studies of the Lon Zone area in the northern extremity of the project area; and 2) structural analysis of the mafic rocks in the eastern part of the area (Fig. GS-18-1).

GENERAL GEOLOGY

Physiographically and geologically the area has been loosely subdivided for discussion purposes into the Eastern zone, the Central zone and the Western zone (Fig. GS-18-1). The Eastern zone consists predominantly of basaltic flows and fine- to medium-grained mafic intrusions. The Central zone consists mainly of layered volcaniclastic rocks and minor felsic and mafic volcanic rocks. The Western zone contains mafic and felsic volcanic and volcaniclastic rocks, and fine- to coarse- grained felsic intrusions.

The oldest rocks in the North Star Lake area appear to be the mafic volcanic rocks of the Eastern zone. They consist predominantly of flows that comprise massive, pillowed and brecciated lava. The pillows are commonly flattened and typically show length to width ratios of 10:1. Deformed quartz-filled amygdules are common in some flows. Some flows are sparsely feldspar phyric, but individual flows or composite flows with a distinctive phenocryst mineralogy have not been recognized. Locally, especially in the eastern and central parts of the Eastern zone, aphanitic to fine grained massive and/or pillowed lava pass into amoeboid pillows and subrounded breccia with variable amounts of <1 cm sized hyaloclastite matrix. Although single flow units are preserved within the Eastern zone, they have not been delineated (Norquay *et al.*, 1993; Prouse and Gale, 1993).

Throughout the Eastern zone there are fine grained mafic dykes several metres to several tens of metres thick; these rocks are considered to be related to the basaltic flows and probably represent lava conduits. The most abundant intrusive mafic rocks have medium- to coarse- grained centres and texturally resemble gabbroic or dioritic intrusions. These intrusions, which probably represent local magma chambers for basaltic flows, were not discriminated from the fine grained intrusions during the current mapping program.

Throughout the Eastern zone there are zones or layers of aphanitic to fine grained rocks that have a pronounced schistosity and discontinuous thin (<1 cm thick) layers that probably represent deformed layered tuffs or sedimentary rocks.

The mafic rocks of the Eastern zone are also intruded by a variety of younger rocks that include:

a) nonfoliated, light grey weathering mafic to intermediate feldspar phyric dykes;
b) weakly foliated, light brown to white weathering biotite-garnet ± quartz phyric felsic dykes;
c) granitic stocks and associated dykes
d) fine grained mafic dykes with abundant angular host-rock fragments; and
e) fine grained rhyolitic dykes.

The rocks of the Central zone comprise layered amphibolite, quartz-rich amphibolite, psammitic and psammopelitic rocks, layered rhyolitic tuff, lapilli tuff and tuff breccia, mafic flows and chemical sedimentary rocks (Norquay *et al.*, 1993). The rocks in this zone were identified as a major tectonic zone (Bailes, 1990) and as a major shear zone by E.C. Syme (written comm., 1992). The individual units exhibit remarkable continuity from the southernmost part of the area mapped, and can be traced northwards until they are intersected and displaced by Zak's fault (Norquay *et al.*, 1993). Biotitic and amphibolitic rocks in this zone generally have a well-developed schistosity and dislocated fold hinges are common in the pelitic bands, but (<10 cm) deformed beds can be traced from exposure to exposure. In addition, although pillows are flattened, massive, pillowed and pyroclastic portions of flows can be easily distinguished, and tops determined from pillows. Locally, minor splays off Zak's fault both parallel and crosscut layering in the rocks, but provide only minor offset to individual lithologies. Mylonitic rocks are rare, but 1 to 2 cm thick discontinuous lenses are locally common in several lithologies. In general, the pillows have been flattened with long to short axis ratios of 5:1; although rock fragments are rare in most units, they appear to have similar ratios or to be less deformed.

The brown weathered psammitic to pelitic rocks in this zone are felsic to intermediate in composition. In general the psammitic rocks have 5 to 10% biotite and/or hornblende and variable garnet contents. Layers vary from a few cm to 10 m thick. White-weathered (rhyolitic) layers (<10 cm thick) are locally interlayered with psammopelitic layers.

Fine grained, aphanitic, quartz crystal-bearing, white-weathered layers within several of the felsic units are considered to be tuff deposits.

A unit of clastic rhyolite with white weathered, angular, blocks in a pale brown lapilli and tuff matrix is cut by Zak's fault, immediately east of North Star Lake. In the vicinity of North Star Lake this

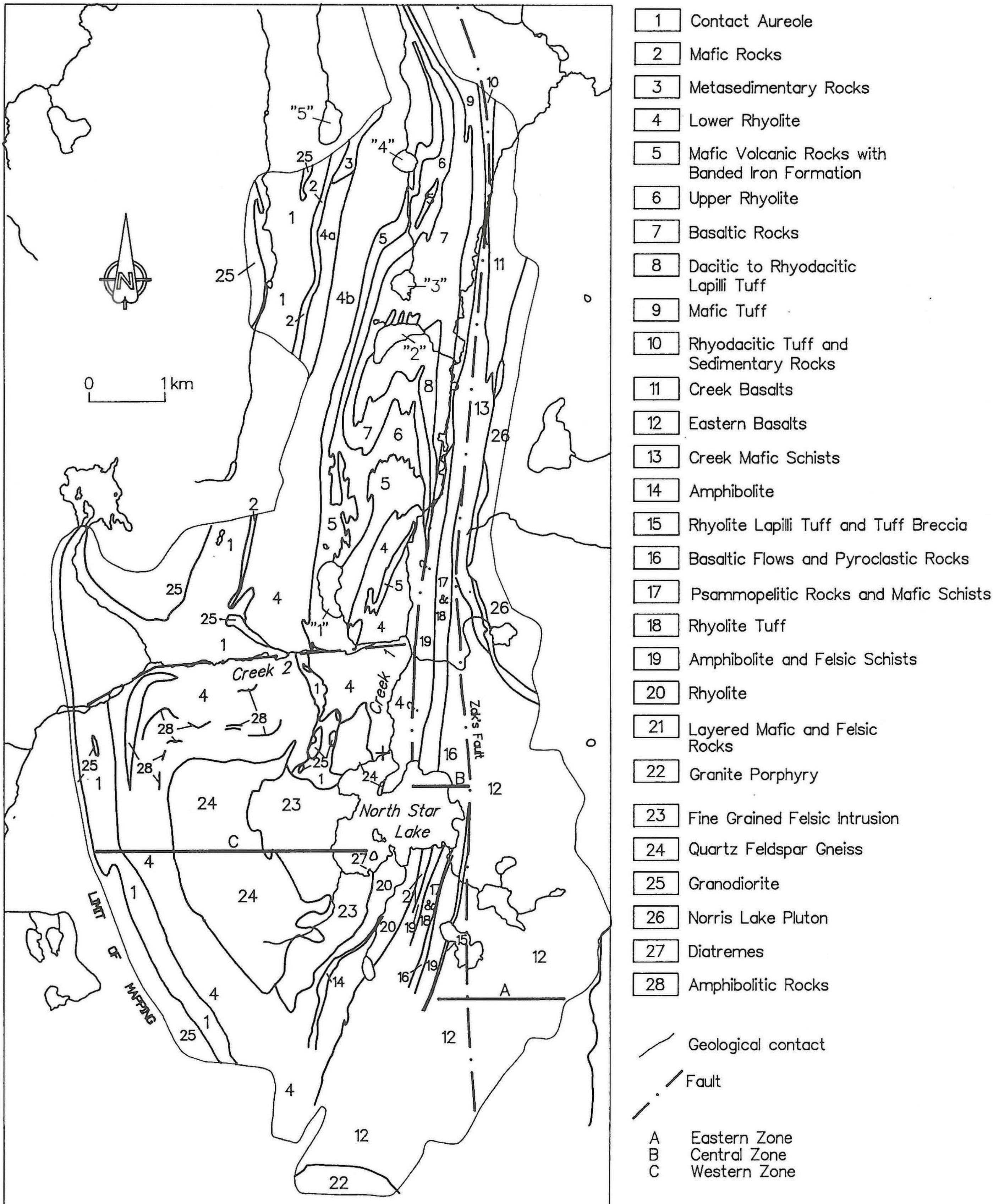

Figure GS-18-1: General geology of the North Star Lake area.

unit is crudely layered with a tuff breccia eastern layer and a lapilli tuff western layer. Fragment size decreases southwards in this unit and the southernmost outcrops of this rock do not contain any fragments greater than 5 mm in length and the rock is well layered (30-50 cm thick). Although a primary volcanic origin for this unit cannot be ruled out, it is probably a reworked volcaniclastic deposit.

Two units of white weathered, fine grained, rhyolitic rocks occur towards the western boundary of the Central zone (Norquay *et al.*, 1993; Fig. GS-18-1). In general, these rocks are poorly layered to massive, but locally have well-defined layers with variable quartz crystal (2-4 mm) contents. These rocks are considered to be rhyolite tuffs.

The amphibolitic rocks in the central zone include a fine grained, quartz-rich (estimated 50% quartz) poorly-layered amphibolite, layered amphibolites, a thin unit of mafic schist and chemical sedimentary rocks and several units of interlayered mafic and felsic rocks in the south eastern part of the zone that are associated with sulphide iron formation.

The quartz-rich amphibolite is an indistinctly layered, dark green to black rock that consists of approximately 50% quartz (estimated) and hornblende. The rock is texturally similar to some of the rocks in unit 5 of Norquay *et al.* (1991b, c).

The layered amphibolite has well-defined layers that are generally several cm to several tens of cm thick, but range up to 1 m thick. The layers contain variable amounts of porphyroblastic feldspar in a dark green matrix that consists predominantly of amphibole. North of North Star Lake there are several 1 to 1.5 m thick zones with abundant deformed lenses and veins of white quartz; these zones are generally parallel to layers and contained within amphibolite units.. These quartz-rich zones probably represent mobilization of silica into early high strain zones rather than compositionally different layers.

The mafic schist is a 2 to 4 m thick unit that has an overall light green colour, is well layered and contains calc silicate-bearing and sulphide layers. It occurs at the contact between rhyolite tuff and psammitic felsic rocks.

The interlayered amphibolite and felsic rocks exposed southeast of North Star Lake occur between mafic volcanic rocks and several mappable units of felsic rocks (Fig. GS-18-2). Layer thickness varies from several cm to several tens of cm, but are rarely more than 50 cm thick. The amphibolites are pale green to dark green and are interlayered with felsic volcaniclastic (?) rocks. Several layers of sulphide facies iron formation are interlayered with these rocks.

Mafic volcanic rocks include two distinctive basaltic units that have been traced the length of the zone and a dark green to black basaltic unit that could only be followed for several hundred metres. The westernmost of the two distinctive flow units contains green weathering massive, pillowed and brecciated amygdular lava and minor amounts of mafic schist north of North Star Lake that changes to minor amounts of massive lava and mostly mafic schist in the

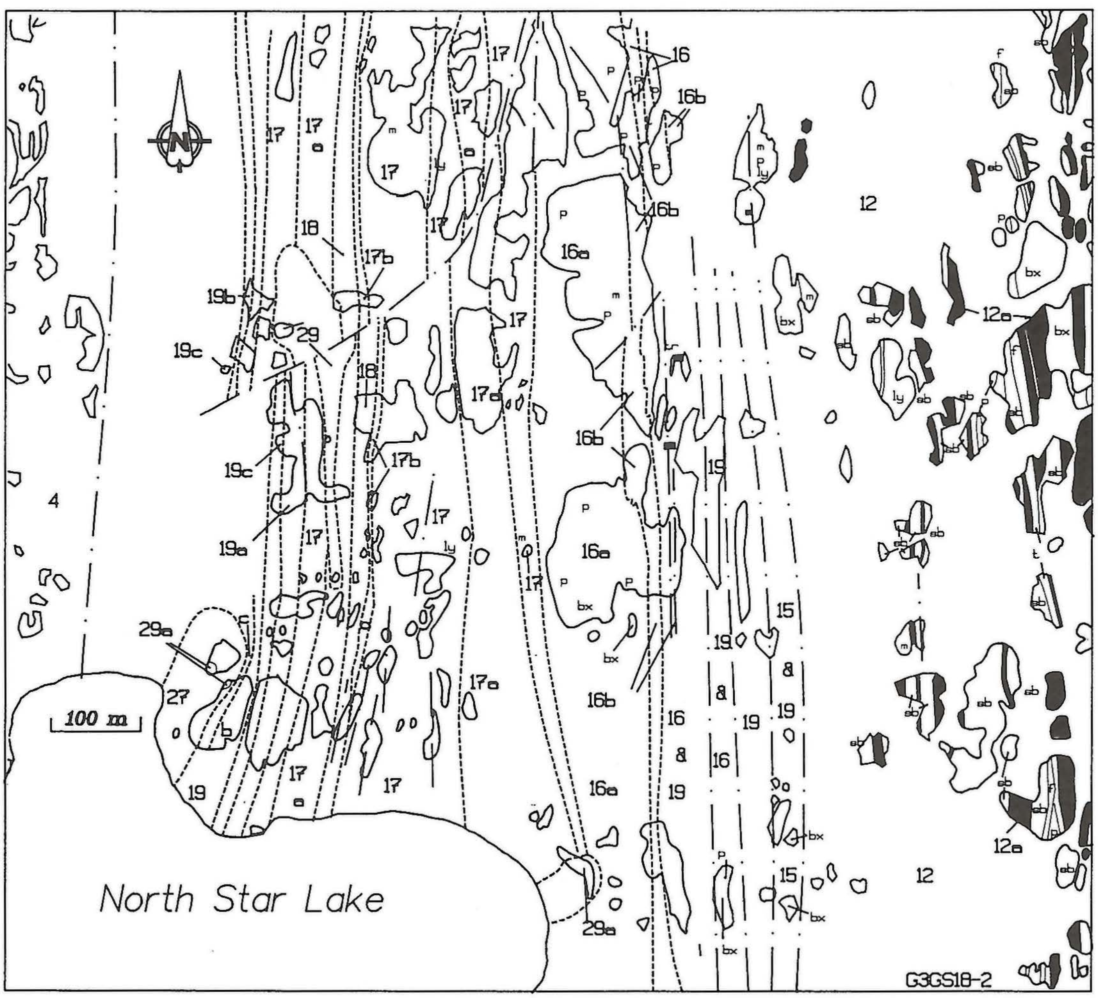

Figure GS-18-2: General geology of a portion of the Central Zone; units numbered as in Figure GS-18-1: 4 Rhyolitic rocks; 12 Basaltic flows and related rocks, a) fine- to coarse-grained gabbroic and dioritic intrusions; 15 Rhyolite volcaniclastic rocks; 16 Mafic volcanic rocks, a) green basaltic flows and pyroclastic rocks, b) brown hornblende- and plagioclase-bearing flows and pyroclastic rocks; 17 Psammopelitic rocks, a) amphibolite, b) calcsilicate and/or sulphide-bearing amphibolite; 18 Rhyolite; 19a amphibolite, b) quartz-rich amphibolite, c) rhyolite; 27 Diatreme; 29 Gabbro, medium- to coarse-grained, a) ultramafic rocks; bx-breccia; f-felsic dyke; ly-layered; m-massive; p-pillowed; sb-schistose basalt; t-tuff; tb-tuff breccia; tr-trench.

southernmost exposures. The other distinctive basaltic unit consists of brown weathered massive and amygdular pillowed lava and variable (<30%) amounts of brown weathered mafic schist in the north to more than 60% mafic schist and distinct to vaguely defined pillowed lava in the south. This unit contains up to 10% black amphibole (2 x 5 mm) and up to 10% white, 2-4 mm, feldspar porphyroblasts in both the lava and the schists. The dark green to black basaltic unit includes aphanitic to fine grained massive, pillowed and brecciated lava and minor mafic schist. Amygdules and flow lines are visible in some of the pillows in this unit, which cannot visually be distinguished from the adjacent Eastern zone basaltic flows.

The only reliable top indicators in this zone are derived from pillow lavas and these indicate tops are towards the west; facing directions are unknown because the relationships between the earliest schistosity and strata could not be established.

Outcrops of ultramafic to gabbroic rocks and associated diatremes occur on the islands and along the shores of North Star Lake. These correspond with the margins of a large circular magnetically high area underlying North Star Lake (Magnetic Anomaly Map, 1990). A small body of gabbro has been outlined immediately north of North Star Lake (Norquay *et al.*, 1993). Although the younger east-trending intrusions that cut the Eastern zone volcanic rocks are present in this zone there does not appear to be any of the north-trending fine- to coarse-grained gabbroic and dioritic intrusions that are abundant in the Eastern zone.

The Western zone comprises several sequences of felsic and mafic volcanic rocks, associated volcaniclastic rocks, felsic intrusions, and diatremes associated with mafic intrusions (Ayed and Halden, GS-17, this volume). These rocks have been intruded and locally partially melted by younger granodioritic intrusions. These rocks have been described in some detail (Norquay *et al.*, 1991).

Additional observations in the area between Lake 1 and Lake 2 indicate that there is less identifiable mafic flow rocks and more quartz-rich amphibolite in the area than previously indicated (units 5 and 7 of Norquay *et al.*, 1991b,c).

The felsic and mafic rocks southwest of North Star Lake have been separated into extrusive and intrusive rhyolites and intrusive and layered mafic rocks. A newly recognized unit, which comprises fine grained recrystallized anastomosing dykes of rhyolite with abundant rafts of mafic sedimentary rocks, that commonly contain coarse grained feldspar porphyroblasts, has been delineated in the area southwest of North Star Lake (Norquay *et al.*, 1993). The thinly (1-2 cm) layered amphibolites that occur east of this rhyolite dyke complex contain anastomosing white rhyolite dykes/flows and intrusion breccia. These mafic rocks are overlain to the east by pale brown weathered, layered rhyolite that is mostly tuff, but locally contains lapilli tuff and tuff breccia. Eastwards these rhyolites are interlayered with layered fine grained and feldspar porphyroblastic amphibolites. These rhyolitic rocks are considered to represent a local(?) rhyolite dome with intrusion of rhyolite lava into a sequence of unconsolidated mafic sediments followed by extrusion of rhyolite on top of the mafic sediment sequence; subsequent to the extrusion of the rhyolite, both rhyolite and mafic detritus were added to the basin. If this interpretation is valid, then the rocks in this part of the map area have tops towards the east.

Volcaniclastic rocks derived from felsic and mafic source rocks overlie the volcanic sequences in the northern part of the area (south and north of Lake 2); it is not certain if an unconformity exists, or if they were derived from these particular volcanic sequences.

The relationships between the fine- to medium-grained intrusions, which are exposed west of North Star Lake, and the rhyolitic rocks north of the lake were re-examined. The contact zone of the intrusion is characterized by abundant xenoliths of supracrustal rocks. The felsic rocks northeast of the intrusion as defined by Norquay *et al.* (1991) do not contain any inclusions and are texturally and mineralogically diverse. Consequently, the most northern protrusion of this intrusion as shown by Manitoba Energy and Mines (1992) is incorrect and the intrusion has a more circular shape as shown on Norquay *et al.* (1991b, 1993).

DEFORMATION AND METAMORPHISM

Four phases of ductile deformation have been identified in the North Star Lake area. Several episodes of late semi-brittle to brittle faults have also been recognized.

Two phases of regional metamorphism have been identified. A regional metamorphism (M_1) associated with the first phase of deformation produced abundant phyllosilicates in psammopelitic and aluminous felsic rocks. These phyllosilicates define a well-developed schistosity (S_1). Peak regional metamorphism (M_2), which produced garnet, hornblende, staurolite, and sillimanite or kyanite, is associated with the second phase of deformation. Mineral assemblages associated with a retrograde metamorphism occur locally in brittle faults.

The first phase of deformation (D_1) folded the primary layering (S_0) and produced tight to isoclinal, intrafolial folds (F_1) with a well-developed axial planar schistosity or spaced cleavage (S_1).

The S_1 schistosity, defined by a preferred orientation of phyllosilicates, is well developed in micaceous felsic rocks and is less developed in biotitic amphibolite. Quartzofeldspathic rocks commonly have a spaced cleavage (S_1) that is axial planar to large F_1 structures. This spaced cleavage is expressed by thin (<5 mm) biotite-rich domains that separate quartzofeldspathic microlithons ($\leq$1 cm). Although this cleavage is axial planar on a mesoscopic scale, in detail the biotite-rich domains commonly undulate along both the horizontal and vertical axes. S_1 is generally only well preserved, or definitely recognizable, in the hinge areas of younger folds.

F_1 minor folds, which occur throughout the map area, have amplitudes of 10 cm to several metres and are easily recognized in rocks that were laminated to thinly bedded . Thinly bedded primary layers have commonly undergone transposition in the hinge areas of D_1 folds to produce pseudoconglomerate. A large F_1 structure, with S-asymmetry, has been defined in the area between Lake 1 and Lake 2 (Fig. GS-18-1).

The second phase of deformation (D_2) produced open to tight folds (F_2) that fold S_1. These folds generally have north-trending axial traces and axial planes that dip steeply to the east. The most commonly recognized F_2 structures are minor folds, with amplitudes of less than 1 metre, that have predominantly Z-asymmetry and vertical to near vertical axial planar fracture cleavages (S_2). The S_2 fracture cleavage is commonly well developed in quartzofeldspathic rocks and less developed in quartz-rich amphibolite. Locally, F_1 minor structures have been observed refolded by F_2. On the limbs of F_2 structures the S_1 foliation is coplanar to near coplanar with the S1 foliation, *i.e.* it is an S_1/S_2 fabric.

A distinctive feature of D_2 is a well-developed lineation (L_2). In amphibolite this lineation is expressed as a preferred alignment of amphibole crystals, as well as an alignment of quartz-plagioclase aggregates. In quartzofeldspathic rocks L_2 is defined macroscopically by lenses of quartz aggregates. L_2 generally has a 10° to 20° northerly plunge in the southern portion of the mapped area, and a 25° to 45° northerly to northwesterly plunge in the northern portion.

Pillows, lithic fragments, and mineral aggregates define a *l>s* fabric. Primary features such as pillows and lithic fragments have been flattened in D_1 and stretched in D_2. These linear fabrics are coaxial to F_2 minor fold axes and therefore considered to be of D_2 age.

Fabrics and minerals assemblages indicate that peak metamorphism occurred during D_2. In amphibolite amphibole crystals and aggregates of quartz and plagioclase appear to have developed with an L_2 fabric. In felsic rocks metamorphic segregations composed of garnet, biotite and quartz define the L_2 fabric. Some psammopelitic rocks have developed a prominent gneissosity (S_2). This gneissosity incorporates the L_2 fabric and the distribution of the gneissosity appears to have been controlled by compositional variations in the original lithological package. Locally, some psammopelitic rocks are partially melted. The neosome in these partially melted rocks defines and crosscuts D_2 fabrics and was folded during later deformational events.

Further evidence of the timing of the peak metamorphism is preserved in the hinge areas of small F_2 parasitic folds. In some of these hinges subhedral to euhedral garnet and amphibole porphyroblasts overgrow the folded S_1 fabric. These porphyroblasts are flattened in later fold hinges.

In the Central zone thin lithologic units generally strike north-south (Fig. GS-18-2). In this zone the third phase of deformation (D_3) has produced minor tight shear folds (F_3) that fold a schistosity (S_1) and a mineral lineation (L_2), and commonly fold intrafolial quartz veins. The axial planes of these folds have an orientation similar to those of F_2, but their plunges are moderate to steep to the south. In the hinge areas of these folds the earlier schistosity is commonly folded to produce crenulate folds with wavelengths of up to 0.5 cm. These D_3 structures have commonly undergone semi-brittle failure along their axial planes or short limbs.

Outside F_3 hinge areas porphyroblasts and fabrics that developed during M_2 and D_2 are locally flattened. This flattening occurs as discrete planes parallel to the long limb of the D_3 minor folds. Younger quartz veins lie in, and crosscut, this D_3 fabric (S_3).

S_1 and S_2, and in the Central Zone S_3, were refolded during the fourth deformational event (D_4), which produced a new fabric (S_4) that developed locally in micaceous or lineated rocks. This deformational event produced flexure folds (F_4) that exhibit a variety of styles, but have similar orientations. The variations in fold styles resulted from deformation of different lithologies and nonuniform orientations of earlier fabrics.

In the southern portion of the map area the axial planes of F_4 structures are generally oriented between 120° and 160° and are near vertical; fold hinges have steep plunges. In the western portion of this area plunge on F_4 structures are to the northwest, whereas in the eastern portion plunges are to the southeast. In the northern portion of the map area F_4 structures are oriented between 090° and 12°, have near vertical axial planes and plunge steeply to the southeast.

On the long limbs of F_1 structures the S_1/S_2 fabrics have a northerly trend and are steeply dipping. In these areas the F_4 structures are commonly preserved as gentle to open folds, with wavelengths that range from 1 m to several metres, that fold the S_1/S_2 foliation and rotate the L_2 fabric.

Well developed examples of the S_4 fabric appear to be restricted to amphibolite characterized by a well developed earlier foliation. In these rocks S_4 is preserved as a near vertical crenulation cleavage that overprints the older foliation, and F_4 is preserved as crenulate folds approximately 1 cm in wavelength.

Chevron folds with an orientation similar to the F_4 crenulate folds have developed in micaceous quartzofeldspathic rocks that have a well developed earlier schistosity. These chevron folds (F_4) commonly have a weak axial planar schistosity (S_4). Locally, quartz veins, pegmatitic or felsite dykes are axial planar to the (F_4) chevron folds.

Cuspate and lobate folds have developed at the contacts between amphibolite dykes and the quartzofeldspathic country rocks. This response to stress indicates a moderate competency difference between the quartzofeldspathic country rock and the relatively incompetent amphibolite dykes. These cuspate and lobate folds, which have an orientation similar to the F_4 chevron and crenulate folds, are considered to be F_4 in age.

The fifth phase of deformation (D_5) produced semi-brittle shear folds (F_5) and semi-brittle to brittle faults. The F_5 structures are open folds with S-asymmetry and steeply-dipping axial planes oriented at 035° to 055°. Semi-brittle to brittle failure has commonly occurred in the F_5 structures along planes parallel to the F_5 short limbs.

Semi-brittle to brittle faults associated with D_5 become common in the eastern portion of the Central Zone. A major fault (Zak's fault) occurs along the contact between the Central Zone and the Eastern Basalt in the area northeast of North Star Lake (Fig. GS-18-1). This zone of faults is up to 50 m wide, and consists of faults that are brittle, steep dipping, predominantly sinistral, have a predominantly north-south orientation (but can range from 340° to 035°) and commonly contain fault gouge, crush breccia and rare pseudotachylyte that is locally vesicular.

Minor east-west oriented brittle faults occur throughout the area. These commonly contain fault gouge, as well as quartz, carbonate and epidote.

DISCUSSION

Rocks of the Eastern zone are in direct contact with the Central zone rocks in the area south of North Star Lake (Norquay *et al.*, 1993). The exact position and nature of this contact is not certain, because there is no obvious lithological or structural break. Although there are minor north-trending faults in the area, where the boundary should be placed, there is no obvious late structural dislocation such as Zak's fault, that forms the boundary between the two zones north and east of North Star Lake (Fig. GS-18-1). Volcanic and clastic rocks are interlayered near the southeastern boundary between the Eastern and Central zones; the western boundary of the Eastern zone is tentatively placed immediately west of the last appearance of mafic intrusive rocks. It is possible that an early structural discordancy exists between the two units, but a more detailed examination is required to resolve the nature of this contact.

Relationships between the Central zone and Western zone rocks are not certain. Immediately north of North Star Lake the contact is hidden under a linear swamp and is probably a fault, but further north, where 'creek 2' intersects the boundary, several units of rocks similar to those of the Western zone, occur on the eastern side of the fault and within the Central zone. In addition, studies in the area south of the Lon Zone (Norquay *et al.*, 1991a) indicate that, although there are late minor faults, there does not appear to be a major tectonic break between the Central zone and the Western zone.

Although clastic rocks derived from felsic and mafic source rocks overlie the volcanic sequences in the northern part of the area (south of Lake 2), it is not certain if an unconformity exists, or even if the clasts were derived from these particular volcanic sequences. The western boundary of the Western zone is a zone of migmatization and felsic intrusions.

If the top criteria are valid, then the Western zone and the Central zone form a major syncline in the southern portion of the area.

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GS-19 STRUCTURAL MAPPING IN THE ELBOW LAKE AREA, FLIN FLON-SNOW LAKE BELT, CENTRAL MANITOBA

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Ryan, J.J. and Williams, P.F., 1993: Structural mapping in the Elbow Lake area, Flin Flon-Snow Lake belt, central Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 84-85.

SUMMARY

Shear zones in the Elbow Lake area record a long history of deformation that began prior to 1869 Ma and continued through to post-peak metamorphic conditions (between 1830 Ma and 1805 Ma). The shear zone has a vertical plane of symmetry indicating a transcurrent shear sense. Several reversals of shear sense are recorded in overprinting relationships.

INTRODUCTION

Detailed structural mapping was undertaken in the Elbow Lake area during the summer of 1993 as part of the first year of graduate studies at the University of New Brunswick. The primary focus of this project is to establish the kinematic history of the Elbow Lake shear zone (ELSZ: Galley *et al.*, 1987; Syme, 1991) and its relation to the structural evolution of the larger Flin Flon-Snow Lake greenstone belt. Previous work in the Elbow Lake area includes Stockwell (1935), McGlynn (1959), Galley *et al.* (1987), Syme (1990, 1991, 1992) and Whalen (1992).

Mapping at a scale of both 1:15 840 and 1:5 000 was concentrated on islands around the centre of Elbow Lake and on the mainland south of Elbow Lake. Most of the islands escaped the pervasive burn of 1989, hence the best outcrops for detailed structural mapping are low-lying shoreline exposures. Outcrop exposure south of the lake, particularly between the inflow and outflow of the Grass River, was greatly improved by the 1989 fire. Field mapping will be followed up by detailed microstructural and metamorphic analyses. Several samples have been collected for U/Pb zircon geochronology to bracket the timing of deformation, metamorphism and magmatism in the area.

Part of this year's mapping included the use of an experimental Geographical Information System (GIS) data acquisition program called AC-GEMM, with which the geology was digitized in the field. A Global Positioning System (GPS) was used briefly in an attempt to establish ground control on aerial photographs for the transfer of data to GIS.

GENERAL GEOLOGY

The Elbow Lake area hosts a variety of supracrustal rocks and large granitoid plutons. Supracrustal rocks are Amisk Group metavolcanics and related intrusions (Syme, 1990; 1991; 1992). Granitoid rocks vary in composition from gabbro to granite and range in age from 1869 Ma to 1845 Ma (Whalen, 1992).

The Elbow Lake area is transected by a NNE-trending zone of intense ductile shear deformation referred to as the Elbow Lake shear zone (ELSZ: Galley *et al.*, 1987; Syme, 1991). Rocks on the eastern side of the lake have a prominent vertical, NNW-trending shear foliation which marks the Claw Bay shear zone (CBSZ: Syme, 1991). Geochemical investigations by Syme (1992) indicate that mafic volcanic rocks to the east of the ELSZ have ocean floor affinity, whereas those west of the ELSZ have ocean floor, ocean island and island arc characteristics (Stern *et al.*, 1993). The regional metamorphic grade appears to increase from lower to middle greenschist facies on the west side of the ELSZ to upper greenschist to lower amphibolite on the east side (Syme, 1992). The timing of peak metamorphism in this part of the Flin Flon-Snow Lake belt is not well bracketed, but is likely between approximately 1830 Ma and 1805 Ma (Machado and David, 1992; Heaman *et al.*, 1992). The supracrustal rocks surrounding some of the large granitoid intrusions are hornfelsed to lower amphibolite facies in 1 km wide contact aureoles (Syme, 1991).

STRUCTURAL OBSERVATIONS

The ELSZ and the CBSZ comprise a system of anastomosing shear zones with complex deformational histories. Several generations of structures (F_1 to F_5) occur within, and adjacent to, the shear zones. The prominent shear foliation within the ELSZ is generally vertical and strikes 020°, and is the most regionally consistent fabric in the area. Locally the foliation anastomoses around low strain domains that vary in scale from centimetres to hundreds of metres.

Shear zone rocks are marked by the flattening, stretching, or obliteration of primary features such as pillow selvages, amygdales, phenocrysts, breccia clasts, veins and dykes. Shear zone boundaries are sharp to gradational. The degree of flattening is highly variable throughout the shear zone but appears to increase inward. The ELSZ reaches a maximum width of about 2000 m in the centre of the lake between Big Poplar Island and Leaping Moose Island. The shear zone contains an elongation lineation that is consistently vertical. The intersection of C/S fabrics, the orientation of shear bands, the plunge of drag fold axes, the orientation of tension gashes, and the long axes of boudins, define a plane of symmetry indicative of transcurrent movement within shear zone. Overprinting relationships indicate shear sense reversals during the deformation history, for example dextral over sinistral over dextral. Sinistral kinematic indicators are the most abundant, indicating that this may have been the dominant shear sense.

The intense flattening of primary features, as well as fold style in some dykes and layers, indicates a large component of shortening across the shear zone. Shortening across the shear zone and vertical elongation lineations are most easily explained by invoking a transpressional model.

Central and eastern portions of Elbow Lake

Overprinting relationships of folds and cleavages are best preserved in the central and eastern parts of Elbow Lake. Fabrics related to both the ELSZ and the CBSZ coalesce NNW of Claw Bay. Within a low strain area on the north side of Leaping Moose Island, two cleavages (S_1 and S_2) and an F_2 fold are refolded about an F_3 fold, axial planar to the ELSZ fabric (S_3). Locally on Leaping Moose Island, the ELSZ fabric is intensely folded with an axial planar crenulation cleavage parallel to the CBSZ (S_4). The CBSZ fabric is then folded about consistently sinistrally verging minor and major F_5 folds with a locally well developed axial planar crenulation cleavage (S_5). S_5 is vertical and strikes 010°. All fold axes (F_1 to F_5) in the Claw Bay area plunge vertically. F_4 folding of the ELSZ fabric (S_3) in this area can be explained by shortening related to dextral movement along the CBSZ. F_5 folding of the CBSZ can be explained by a shear sense reversal along the ELSZ, shortening the CBSZ.

Late deformational structures recognized throughout the central and eastern portions of the lake are thin ductile to brittle shear zones, kink bands, and brittle faults. The ductile to brittle shear zones are typically 2 to 5 cm wide, and cut the main shear foliation at a low angle. The foliation and quartz veins are dragged into brittle shear planes. Brittle faults crosscut the thin shear zones and appear to be the latest structures developed. Displacement along both types of structures varies from a few centimetres to tens of metres. The faults are consistently NNW, NNE or N-striking with both sinistral and dextral displacement and may be related to a larger set of faults mapped by Syme (1991). A conjugate set of WNW-ESE and ENE-WSW trending kink bands is present in the central Elbow Lake area and post date ductile to brittle shear deformation, but the age of kink bands relative to the brittle faults is unclear.

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Southern Elbow Lake

The ELSZ narrows significantly in the southern Elbow Lake area, locally being only a few tens of metres wide along the outflow of the Grass River. In this area, the shear zone coincides with the western margin of the Elbow Lake tonalite, which yielded a U/Pb zircon age of 1869 +20/-7 Ma (Whalen, 1992). The tonalite has a foliation defined by flattened quartz that appears to run parallel to the margin of the batholith. Mafic country rocks contain a well developed shear foliation that is cut by tonalite dyke offshoots from the batholith. The dykes are themselves intensely deformed within the shear zone.

A domain rich in mafic xenoliths occurs a couple hundred meters into the Elbow Lake tonalite batholith. The most common xenoliths include basalt, gabbro, diorite, pyroxenite and grey chert, and vary in size from a few centimetres to tens of meters, with some areas being almost xenolith supported. About 20% of the xenoliths were deformed prior to being incorporated into the batholith. Evidence for deformation within the inclusions includes a strong foliation, boudinaged quartz veins and isoclinal folds. The crosscutting relationship of the tonalite dykes coupled with the occurrence of deformed xenoliths within the batholith indicate that the ELSZ had a pre-1869 Ma deformation history. This is the oldest recorded deformation within the Flin Flon-Snow Lake belt.

The kinematic history in the southern portion of the lake is also very complicated. Vertically plunging isoclinal F_3 folds within flattened rhyolite fragments have a dextral asymmetry. A tonalite dyke in an outcrop at the contact between the batholith and the sheared mafic schist crosscuts a shear foliation and is itself sinistrally sheared and boudinaged. Within the same outcrop, subvertically plunging isoclinally folded quartz veins have a dextral asymmetry. The wings of the sheared dyke are overprinted by younger dextral shear bands. C/S fabrics within the tonalite indicate a sinistral sense of shear. Excluding the late dextral shear bands, the relative timing of the different senses of shear is unclear. In this section of the shear zone a lineation best defined by elongate quartz in mylonitized porphyritic tonalite varies from moderately south to moderately north plunging. The entire shear zone in the southern portion of the map is cut by dextral ductile to brittle shear bands at an angle consistently between 20° and 40° to the main shear foliation.

Three different localities exhibit the ELSZ fabric folded about sinistrally verging tight folds, plunging moderately toward 025°. These folds have a weak to moderately developed axial planar crenulation cleavage. It is not possible to correlate the post-F_3 structures in the southern portion of the lake to structures in the central portion of the lake, but continued mapping may resolve this problem.

CONCLUSIONS

The shear zones in the Elbow Lake area record a long history of deformation that began prior to emplacement of the Elbow Lake tonalite (1869 Ma) and continued through to post-peak metamorphic conditions (sometime between 1830 Ma and 1805 Ma). The shear zone has a vertical plane of symmetry indicating a transcurrent shear sense.

Several reversals of shear sense are recorded in overprinting relationships, and help explain large scale overprinting of the ELSZ fabric and the CBSZ fabric. Shear sense reversals are typical of major shear zones due to readjustments of plate motion during a long progressive deformation. The long complex history of shear deformation in the Elbow Lake area may help explain how supracrustal rocks of different affinities are juxtaposed by the shear zone.

The increase in metamorphic grade eastward across the ELSZ is difficult to explain by a transcurrent shear zone. The moderately plunging folds in the southern portion of the map area indicate an east side up element of dip-slip movement late in the shear history. The higher grade rocks may have been carried up during this deformation event. It is also possible that rocks on the eastern side of the shear zone were brought up by a late stage brittle fault parallel to the shear zone.

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GS-20 GRANITOID ROCKS OF THE ELBOW LAKE SHEET (NTS 63K/15)

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Whalen, J.B., 1993a: Granitoid rocks of the Elbow Lake sheet (NTS 63K/15); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 86-89.

SUMMARY

A diverse compositional and age spectrum of granitoid rocks are present in the Elbow Lake map area. Granitoid rocks have been grouped in composite bodies, the Gants Lake batholith and the smaller Echo Lake pluton. Compositionally and mineralogically uniform bodies of tonalite have been grouped as early plutons based on two U/Pb zircon ages. The tonalites locally exhibit features of high level to subvolcanic intrusive zones and hydrothermal alteration. A third grouping is younger composite, compositionally zoned plutons (Gauthier Lake, Norris Lake and Big Rat Lake). The Gauthier Lake and the Norris Lake plutons contain areas of fracture-related hydrothermal alteration with associated sulphides.

INTRODUCTION

The Elbow Lake map area (NTS 63K/15) lies within the Early Proterozoic Flin Flon metavolcanic belt, 65 km east of Flin Flon and 40 km west of Snow Lake. It is bounded by latitudes 54° 45' and 55° 00' and longitudes 101° 00' and 100° 30'.

This project is a follow-up to the cooperative Elbow Lake project (1991 to 1992) in which detailed (1:15 840) geological mapping was divided between Manitoba Energy and Mines (supracrustal rocks: Syme, 1992) and the Geological Survey of Canada (granitoid rocks: Whalen, 1992) (Syme and Whalen, 1992). During 1992 and 1993, geological mapping at 1:50 000 scale of granitoid rocks within the remainder of NTS 63K/15 was carried out. Only an area in the northeast corner of the map area remains to be covered.

This year a preliminary 1:50 0000 geological map of NTS 63K/15 with extensive descriptive notes has been produced (Whalen, 1993b). Map unit numbers used in the text below refer to those used on this map. The geology of the area covered in the cooperative Elbow Lake project (Syme and Whalen, 1992), has been greatly simplified in this open file map, in particular the supracrustal rocks, major mafic intrusions and minor intrusions. This report briefly summarizes some features of the major granitoid intrusions in the map area. Amisk Group supracrustal rocks and major mafic intrusions have been described previously by Syme (1990, 1991, 1992) and Schledewitz (1991, 1992).

DESCRIPTIONS OF PLUTONS

Early Tonalite Suite

The East Elbow Lake, Elbow Lake, Webb Lake, and Rail Lake intrusions (units 5 through 8) (Fig. GS-20-1) are quartz phyric to quartz megacrystic biotite-hornblende tonalitic intrusive rocks that may belong to an early (>1860 Ma), potassium-poor felsic intrusive suite. Lithologically similar plutons near Flin Flon (Cliff Lake) and Snow Lake (Sneath Lake and Richard Lake) have been interpreted as being subvolcanic bodies that are genetically related to massive sulphide mineralization (Gordon *et al.*, 1990).

The East Elbow Lake stock (unit 5a) is an oval quartz megacrystic (1-2.5 cm) intrusion that covers an area of 10 km² just east of the northeast corner of Elbow Lake. Preliminary U-Pb results from this body indicate it is pre-Missi in age (1864±3 Ma; Whalen and Hunt, unpublished data). Similar quartz megacrystic to quartz phyric tonalite sills (units 5b and 5c) occur within and northwest of Claw Lake.

The Elbow Lake tonalite (unit 6) covers an area of 250 km², about 25% of which is located within the map-area. Unit 6 is generally quartz phyric rather than quartz megacrystic and remarkably homogeneous in texture and composition for such a large intrusion. Preliminary U-Pb zircon results from this pluton suggest that it is pre-Missi in age (1869+20/-7 Ma; Hunt and Whalen, unpublished data).

The name Webb Lake plutonic complex (unit 7) is used to refer to a texturally diverse group of mainly tonalitic plutonic rocks covering an area of about 35 km² near Webb Lake. Phases resemble the Elbow Lake tonalite (unit 6), in being quartz phyric or biotite phyric rather than quartz megacrystic and in being affected by hydrothermal alteration. In general, this complex appears to preserve a higher structural level than exposed in the Elbow Lake tonalite, with some phases probably representing a subvolcanic roof zone.

The Rail Lake pluton (unit 8) is a small, 18 km², ovoid body in the southeastern portion of the map area. It includes quartz megacrystic (1 to 2.5 cm), biotite megacrystic (1 to 3 cm) and quartz phyric phases.

Gants Lake Batholith

The Gants Lake batholith (unit 9) is an elongate, north-south trending body that extends for over 54 km from beneath the Shield margin to within the Kisseynew belt. Of the 550 km² it occupies, over 60% is located in the map area. McGlynn (1959) described this batholith as consisting simply of gneissic biotite granodiorite. However, remapping, indicates this to be a composite batholith that contains the oldest (>1870 Ma) granitoid rocks in the map area and intrusive phases equivalent in age to the younger (<1850 Ma) zoned plutons (units 12 to 14). A sharp difference in metamorphic grade and penetrative deformation exists across this batholith. In the northeast it consists of orthogneisses bounded further east by heterogeneous paragneisses and amphibolites. In contrast, on its western side, slightly to moderately foliated homogeneous plutonic phases intrude easily recognizable metavolcanic lithologies. Further work, in particular U-Pb dating, is required to resolve whether this batholith stitches a major tectonic boundary, or whether it may juxtapose equivalent rocks of contrasting erosional levels.

The northeastern portion of the Gants Lake batholith contains a variety of compositionally banded to migmatitic gneisses (units 9a to 9d), including grey tonalitic to quartz dioritic gneiss that contain abundant sheets of earlier deformed tonalitic to mafic orthogneisses, and K-feldspar phyric migmatitic granodioritic gneiss. These orthogneisses grade westward into a mixed zone where they contain abundant foliation-parallel sheets of younger biotite granodiorite and granite and subsequently into an area where outcrop scale rafts of orthogneiss are included within less deformed granodiorite to granite.

The central portion of the Gants Lake batholith consists of several fine- to coarse-grained, biotite amphibole granodioritic phases (units 9f to 9h). More northern exposures of these units are gneissic and include compositionally banded areas. It is assumed that this reflects a progressive northward metamorphic and local tectonic overprinting rather than the presence of different ages of granodiorites.

The northwestern portion of the Gants Lake batholith consists of a group of probably comagmatic phases (units 9i to 9m). The main unit, a slightly to well foliated, buff, coarse-grained, plagioclase porphyritic (1-2 cm), biotite-hornblende granodiorite has yielded a U-Pb age of 1871±3 Ma (Hunt and Whalen, unpublished data). Where the dated granodiorite abuts the Amisk Group or the central portion of the batholith, it grades to feldspar augen schist or ribbon mylonites, indicating these contacts are faults.

The southern end of the Gants Lake batholith consists of an ovoid, bimodal intrusion (units 9n to 9s), only the northern half of which lies within the map area. The eastern part of this body consists

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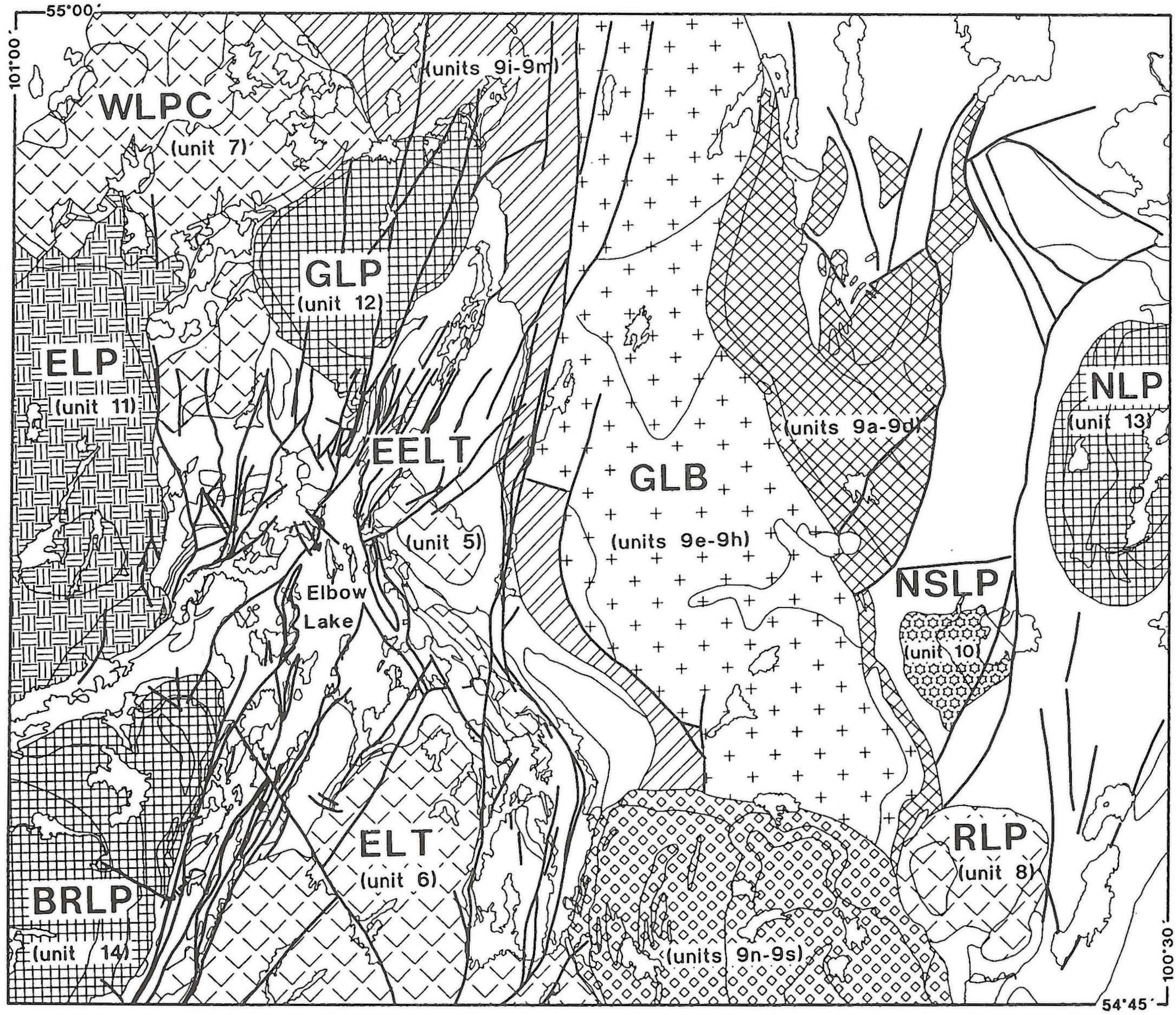

Figure GS-20-1: Simplified geological map of the Elbow Lake area (NTS 63K/15) showing major granitoid intrusions. Abbreviations are as follows; EELT - East Elbow Lake tonalite and related sills (unit 5); ELT - Elbow Lake tonalite (unit 6); WLPC - Webb Lake plutonic complex (unit 7); RLP - Rail Lake pluton (unit 8); GLB - Gants Lake batholith (unit 9); NSLP - North Star Lake pluton (unit 10); ELP - Echo Lake pluton (unit 11); GLP - Gauthier Lake pluton (unit 12); NLP - Norris Lake pluton (unit 13); BRLP - Big Rat Lake pluton (BRLP). Minor intrusions, supracrustal rocks and major mafic intrusions are not patterned. For details see GSC open file map 2709 (Whalen, 1993b).

of poorly exposed fine- to coarse-grained gabbroic to dioritic rocks. On its west side, adjacent to Claw Lake, there is a heterogeneous mixture of gneissic to massive, fine- to medium-grained, gabbroic to tonalitic intrusive and basaltic volcanic rocks. To the east, similar mafic intrusive rocks, without the volcanic lithologies, form irregularly spaced, north-south orientated screens within a granodiorite to granite phase. The northern end of the intrusion consists of quartz diorite to tonalite. Contact relationships suggest comagmatic intrusion of mafic and felsic magmas with hybridization to produce intermediate compositions. The granodiorite yielded a poorly defined U-Pb zircon age of 1845+27/-12 Ma, compatible with all phases at this end of the batholith being contemporaneous with the various zoned plutons in the map area (units 12 to 14).

North Star Lake Pluton

The North Star Lake pluton (unit 10), a small, 10 km^2, intrusion exposed on the west side of North Star Lake, has been mapped by Norquay *et al.* (1991). It contains, a strongly foliated, medium- to coarse-grained quartz and plagioclase phyric biotite granodiorite to tonalite phase, and a very fine- to fine-grained biotite felsic aplite phase. These units may be metamorphosed equivalents of phases within the central portion of the Gants Lake batholith.

Echo Lake Pluton

The composite Echo Lake pluton (unit 11) covers an area of about 48 km^2 on the northwest side of the map area. In the northwestern portion of this pluton, there is a massive and apparently undeformed oval plug, that may be equivalent in age (1847 Ma; Gordon *et al.*, 1990) to plutons such as the Lynx Lake pluton south of Flin Flon, which postdate regional D_2 deformation. Sharp contacts have been observed between this massive, feldspar-amphibole porphyritic granodiorite and well foliated, coarse grained, hornblende-biotite granodiorite. Textures exhibited by the massive granodiorite, together with the presence of crosscutting amygdaloidal mafic dykes, suggest that it was intruded at a relatively high level. The older, tectonically foliated portion of the Echo Lake pluton has been subdivided into a number of compositional variants that become more felsic and more lithologically homogeneous toward the interior of the pluton. The most eastern phase exhibits textural variation from fine- to coarse-grained and compositional variation from melagabbro to diorite and quartz diorite. Included in this unit are areas of diorite which contain a high portion (10 to 40%) of pyroxenitic inclusions. Coarse grained pyroxenite occurs both as bands or schlieren and as massive zones. The two western interior phases are a diorite to quartz diorite unit, which commonly contains mafic (basaltic or gabbroic) inclusions, and a quartz diorite to granodiorite unit.

Younger Zoned Plutons

The Gauthier Lake, Norris Lake and Big Rat Lake plutons (units 12 through 14) are composite, compositionally zoned, generally unaltered and only slightly deformed. This relatively late suite of intrusions is probably of similar age to the Big Rat Lake pluton from which a U-Pb age of 1845±3 Ma was obtained (Whalen and Hunt, unpublished data).

The Gauthier Lake pluton (unit 12), an ovoid body covering an area of about 30 km^2 in the north central portion of the map area, is zoned from a monzodiorite or quartz monzonite rim, through granodiorite to a granite core. All internal contacts appear to be gradational. Contacts are displaced by late north-south trending, narrow, fault zones.

The oval Norris Lake pluton (unit 13), covers an area of 24 km^2 at the east-central edge of the map area. The western half of this intrusion, which lies in the map area, is zoned from a mafic inclusion-rich dioritic rim, through quartz diorite and granodiorite to minor areas of late granite. Gradational contacts exist between diorite to granodiorite, whereas the granite phase is intrusive into the granodiorite phase.

The Big Rat Lake pluton (unit 14) covers an area of about 32 km^2 on the southwest side of the map-area. Granitic units cut more mafic phases and appear not to be cut by dykes that intrude the more mafic phases. This suggests that there could be an age difference between granitic and dioritic to granodioritic phases. The medium to dark pink, foliated biotite granite is remarkably uniform in composition, lacks mafic enclaves and is only cut by some probably comagmatic granitic aplite dykes. Sharp intrusive contacts were observed between granite and older units to the northeast. Two granodiorite units, an outer equigranular and an inner subporphyritic to porphyritic phase, form the outer zones of this part of the pluton. Other subunits vary from more felsic (quartz diorite to granodiorite) to more mafic (quartz diorite to diorite) towards the core. Mapped boundaries, based on field estimates of quartz and mafic mineral content, are gradational over short distances rather than intrusive. Small areas of hybrid intrusive rocks contain mainly rounded mafic igneous inclusions (5 cm to >3 m) in a matrix of diorite to quartz diorite. Inclusions form about 40 to 60% of this subunit and include mafic metavolcanic rocks, which were deformed prior to their incorporation, and cognate mafic intrusive rocks.

ECONOMIC GEOLOGY

In general, the vastly improved quality of outcrop resulting from the 1989 burn greatly facilitates prospecting for mineral deposits in the Elbow Lake sheet. The setting of gold mineralization and potential for VMS deposits in the map area has been reviewed by Syme (1991, 1992) and Schledewitz (1991). Known gold occurrences in the Elbow Lake area are epigenetic and localized within intense deformation zones within, and adjacent to, the Elbow Lake shear zone. Though these gold showings occur mainly within supracrustal units, granitoid units may be equally good hosts. The burn has provided extensive new exposures of plutonic rocks cut by quartz and sulphide-bearing veins, major faults and shear zones. In contrast to the supracrustal rocks, which have been intensely prospected since the early 1930's, the granitoid rocks generally bear no evidence of having been prospected. Though major deformation zones in granitoid intrusions are frequently not exposed, mapped displacements of, or juxtapositioning of, plutonic phases on the new Elbow Lake map (Whalen, 1993b) indicate the location of such zones.

Comparisons with the Phantom Lake stock, west of Flin Flon (Galley and Franklin, 1989; Thomas, 1990) and the Star Lake pluton in the La Ronge belt (Poulsen *et al.*, 1986), suggest that Elbow Lake area plutons have also have potential for late magmatic hydrothermal gold and porphyry type mineralization. Portions of the Webb Lake complex probably represent a subvolcanic roof zone. Texturally diverse, very fine to fine grained intrusive phases in these units are cut by sulphide-bearing quartz vein systems which have potential for gold mineralization (Schledewitz, 1993 pers. com.). The presence of late magmatic, fracture controlled, potassic alteration in portions of the Elbow Lake tonalite (unit 6) make it a possible target for gold prospecting. Two of the younger zoned plutons contain areas of fracture-related alteration with associated sulphides. The larger fault-bounded block on the east side of the granite core to the Gauthier Lake pluton has outcrop scale areas of quartz vein-related sericitic alteration. This block exhibits porphyritic textures, absent in adjacent portions of this phase, suggesting that it may represent a down faulted higher level zone of the pluton. Within the core of the Norris Lake pluton (unit 13) there are a number of small late bodies of granite. Exposures of granodiorite adjacent to granite are cut by stockworks of sulphide-bearing veins that die out within the granite, suggesting a genetic tie between veins and granite.

The map area contains a number of both early and late mafic to ultramafic intrusions. The potential of these bodies for nickel and platinum group metals merits evaluation. For example, at the northeast edge of the Gants Lake batholith (unit 9), an extensive gossan zone was noted within a 5 km^2 body of gabbro at its contact with granodioritic gneisses.

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GS-21 THE NORTH JACKFISH LAKE Cu-Zn DEPOSIT: MASSIVE SULPHIDE TYPE MINERALIZATION IN THE REED LAKE PLUTON, SNOW LAKE AREA (NTS 63K/9)

by M.A.F. Fedikow and E. Kowalyk

Fedikow, M.A.F. and Kowalyk, E., 1993: The North Jackfish Lake Cu-Zn deposit: Massive sulphide type mineralization in the Reed Lake pluton, Snow Lake area (NTS 63K/9); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 90-92.

SUMMARY AND CONCLUSIONS

The North Jackfish Lake Cu-Zn deposit occurs within the Reed Lake pluton along a medium to strong airborne EM anomaly. The geophysical expression of this mineralized "horizon" suggests a depositional surface that extends from North Jackfish Lake to the west shore of Deep Lake. The west shore of Deep Lake is characterized by a small greenstone belt of predominantly mafic flows with arc tholeiite affinities. This gives some support to the possibility that the mafic fragments or rafts observed in the intrusive rocks at North Jackfish Lake, as well as the JN-1 and JN-6 mineralized zones, may be remnants of the Deep Lake greenstone belt.

The North Jackfish Lake Cu-Zn deposit contains copper- and zinc-enriched near solid zones of iron sulphide spatially associated with vein and disseminated sulphide, as well as a silicate facies alteration zone. These features are characteristic of massive sulphide type deposits. Intrusion of the Reed Lake Pluton has disrupted, deformed, altered and generally disguised North Jackfish Lake deposit host rocks.

The presence of base metal massive sulphide type mineralization in areas of granodiorite and granite (Reed Lake Pluton) underscores the need for careful evaluation of terrane during planning stages for; (1) possible base and precious metal exploration programs, and (2) resource potential assessments in areas that may subsequently be removed from consideration for exploration due to apparently unfavourable geology.

INTRODUCTION

The North Jackfish Lake area occurs 27 km southwest of Snow Lake midway between Deep Lake and Jackfish Lake, north of Reed Lake and entirely within granodiorite and granite of the Reed Lake pluton (Manitoba Energy and Mines, 1992; Fig. GS-21-1). North Jackfish Lake trends northwest-southeast and access to the area of the deposit is achieved by float plane or by traversing off of the Canadian National Railway rail bed that runs between Snow Lake and Flin Flon.

One day was spent traversing and examining outcrop along the lake shore and in the immediate vicinity of the surface projections of the mineralized zones that represent the North Jackfish Lake deposit. Geological mapping in the area of the deposit had been undertaken by Falconbridge Ltd. in the early 1980's. However, moss and lichen-cover makes observations difficult. Outcrop stripping was undertaken in areas considered critical to preliminary assessment of the geological environment of these mineralized zones. A summary of mineralized localities in NTS 63K/9, which includes the general area of North Jackfish Lake, is provided by Ferreira and Fedikow (1990).

GEOLOGICAL SETTING

The North Jackfish Lake deposit occurs within the granodiorite-granite Reed Lake pluton (Fig. GS-21-1). Narrow and short greenstone belts comprising sequences of pillowed mafic flows, volcaniclastic rocks and related intrusions with arc tholeiite affinities also occur in the pluton (Manitoba Energy and Mines, 1992) and represent vestiges of supracrustal rocks that were subsequently intruded by the pluton.

In the general area of the North Jackfish Lake deposit the predominant rock types are granite and granodiorite, each of which has been variably altered. Multiple north-trending faults crosscut the

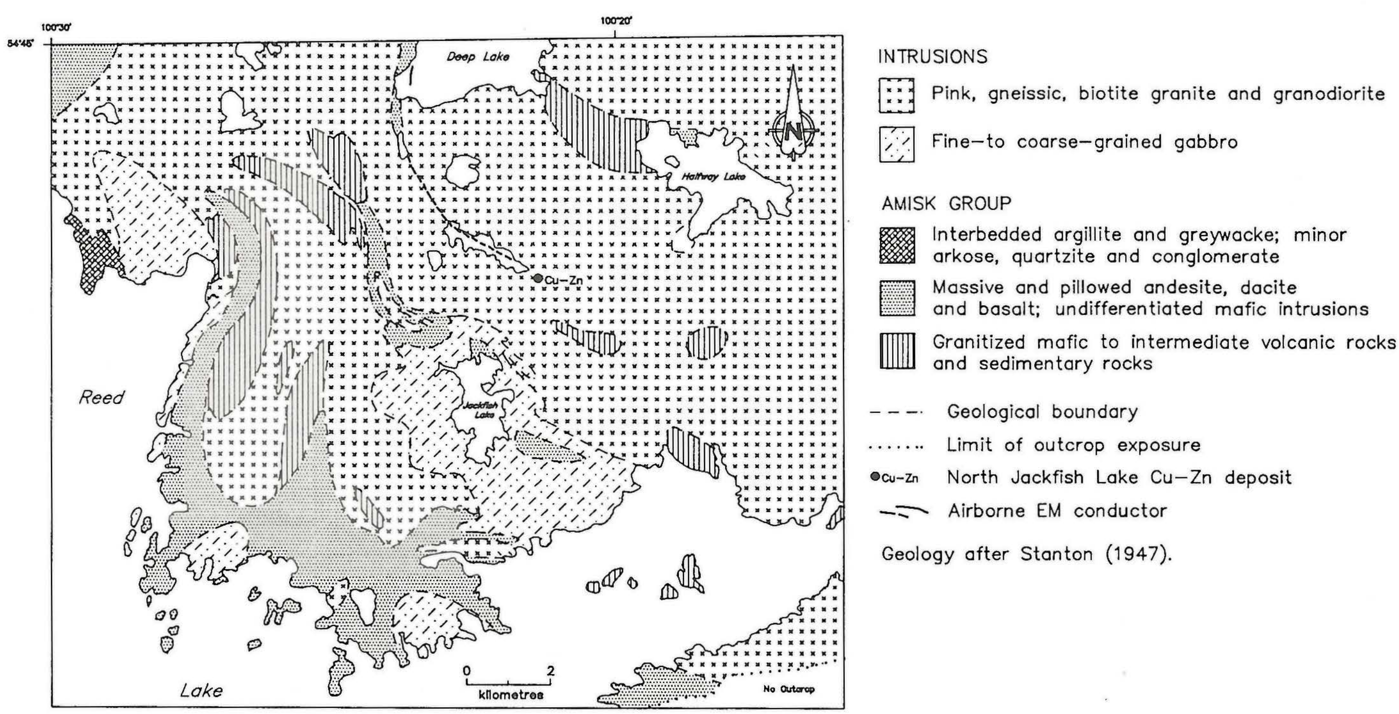

Figure GS—21—1: Location and regional geological setting of the North Jackfish Lake Cu—Zn deposit.

Figure GS-21-1: Location and regional geological setting of the North Jackfish Lake Cu-Zn deposit.

area (Fig. GS-21-2) and appear to have facilitated silicification of some of the intrusions. The granite appears cherty at the faulted localities. Elsewhere, particularly in proximity to the deposit, the granites contain variable amounts of fine- to coarse-grained biotite and chlorite, a maximum of 5% pyrite and significant variations in colour from grey to brown. Locally, the granites and granodiorite contain angular to subrounded, fine grained, magnetite-bearing inclusions that may represent quartzite (chert?) or felsic volcanic remnants. Predominant among the inclusions or rafts observed in the intrusive rocks is a population of fine- to medium-grained, poorly sorted and locally elongate mafic fragments also interpreted to represent portions of the former supracrustal sequence. A medium grained, grey intrusive (?) rock with 2 to 5 mm rounded blue quartz eyes occurs on the north shore of the lake and may represent a rhyolite.

Near the east end of the lake intermediate to mafic rocks containing 1 to 2% pyrite, chlorite, cordierite and anthophyllite are exposed. These rocks occur at the edge of a granodiorite and represent either altered mafic volcanic rocks or an altered granodiorite. The contact between altered and unaltered counterparts at this locality is obscured.

North Jackfish Lake Deposit

The deposit comprises two spatially separated base metal-enriched iron sulphide zones. These are designated the JN-1 and JN-6 mineralized zones (Fig. GS-21-2). Both zones contain near solid mineralization with associated alteration zones characterized by vein and disseminated sulphide mineralization and variable silicate alteration facies. Surface projections of the mineralized zones correlate with fine- to medium-grained, brown-grey and pink-grey granitic gneiss with a maximum of 5% pyrite and fine- to coarse grained-biotite, chlorite, garnet and magnetite. Each of these two zones are described below.

JN-1 Mineralized Zone

The JN-1 zone may be considered typical, in many respects, of the North Jackfish Lake Cu-Zn deposit. Diamond drill core logs indicate near solid sulphide mineralization characterized by 50 to 75% pyrite, 2 to 3% sphalerite, and 0.5 to 2% chalcopyrite over 1.2 m underlain in the drill core (DDH JN-1) by hornblende granodiorite and strongly altered granodiorite with a 1.1 m interval of disseminated and vein type sulphide mineralization. This possible alteration zone contains 15 to 40% pyrrhotite and pyrite, trace to 2% chalcopyrite and trace sphalerite. Weakly altered granodiorite that overlies the near solid sulphide zone contains patchy chlorite, minor magnetite and muscovite, whereas strongly altered granodiorite is characterized by 60% biotite, phlogopite and muscovite, 5% cordierite and chlorite, minor magnetite and up to 5% disseminated pyrite developed in a quartz-feldspar-hornblende matrix.

Assay results from the near solid sulphide and stringer sulphide mineralization, respectively, are 0.94% Cu, 1.77% Zn, 11.3 g/tonne Ag and 0.07 g/tonne Au over a 1.2 m assay interval and 0.33% Cu, 1.04% Zn, 2.4 g/tonne Ag and 0.1 g/tonne Au over a 1.1 m assay interval.

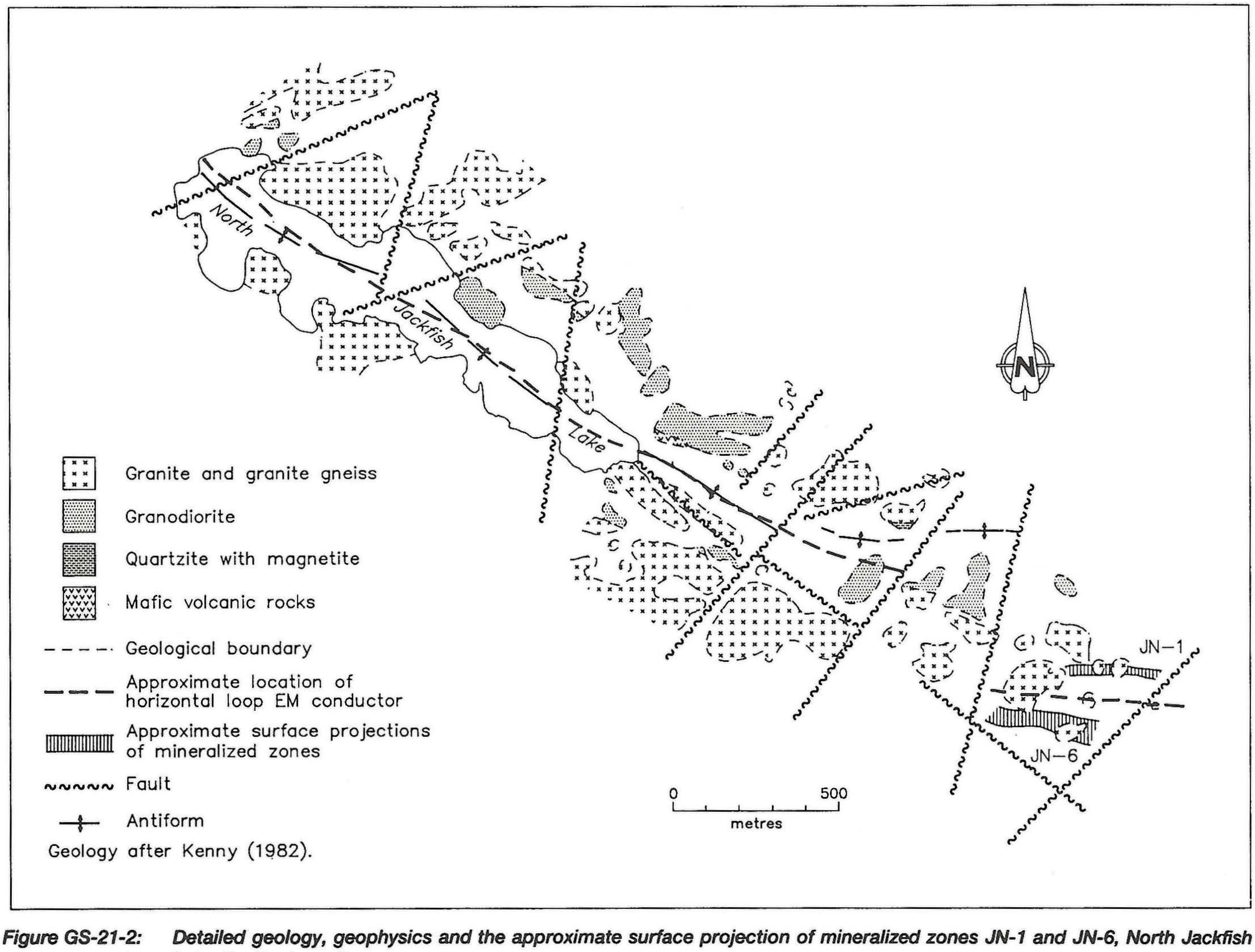

Figure GS-21-2: Detailed geology, geophysics and the approximate surface projection of mineralized zones JN-1 and JN-6, North Jackfish Lake Cu-Zn deposit.

JN-6 Mineralized Zone

The JN-6 zone is represented by near solid and solid sulphides overlain in the drill core (DDH JN-6) by a stringer sulphide zone. Host rocks to the mineralization are granodiorite and biotite-hornblende granite. The near solid sulphide zone is approximately 10 m thick and contains 20 to 95% pyrite and pyrrhotite, 1 to 4% chalcopyrite and 2 to 4% sphalerite. Sulphides are fine- to coarse-grained and poorly foliated; rafts of relatively unaltered granodiorite are present in the sulphide mineralized zone. This zone is overlain in core from drill hole JN-6 by 14.6 m of 5 to 75% disseminated, near solid and vein pyrite and pyrrhotite with trace chalcopyrite and sphalerite. The stringer zone is overlain by biotite and hornblende-bearing granite and granodiorite. An increase in layers of amphibolite in the host rocks is noted with proximity to the stringer sulphide zone. Assay results for the near solid sulphides range from 0.04 to 3.3% Cu, 0.36 to 2.8% Zn, 2.7 to 25 g/tonne Ag, and nil to 1.0 g/tonne Au over 0.4 m to 1.8 m assay intervals. Stringer zone sulphides contain 0.03 to 0.52% Cu, 0.04 to 1.20% Zn, trace to 7.5 g/tonne Ag and nil to 2.4 g/tonne Au.

GEOPHYSICAL AND GEOCHEMICAL SIGNATURES

Geophysics

An airborne EM conductor was delineated in the North Jackfish Lake area by Hudson Bay Exploration Co. Ltd. in 1968 (Hosain, 1978). This strong- to medium-strength conductor extends from the west side of Deep Lake through the center of North Jackfish Lake and corresponds to the position of subsequent ground EM surveys by HBED that defined the mineralized layer, as well as the position of mineralized zones JN-1 and JN-6 (Fig. GS-21-1 and 21-2).

Geochemistry

A rock geochemical survey based on the analysis of 226 lithogeochemical samples for the elements and compounds SiO_2, Al_2O_3, CaO, Na_2O, K_2O, MgO, Fe_2O_3, TiO_2, P_2O_5, Cr_2O_3, Zr, Sr and Rb (x-ray fluorescence) and for Cu and Zn (atomic absorption) was undertaken by Falconbridge Ltd. in 1982. The survey failed to identify mineralization-related alteration zones characterized by enrichment or depletion in the area of the deposit.

ACKNOWLEDGEMENTS

W. Bruce Dunlop is thanked for permission to use information from the area of the North Jackfish Lake deposit for this preliminary investigation. Liberal use was made of outcrop and geology maps, diamond drill logs with assay results and geophysical survey results.

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GS-22 SNOW LAKE MAPPING PROJECTS (NTS 63K/6SE AND 63J/13SW)

by A.H. Bailes

Bailes, A.H., 1993: Snow Lake mapping projects (NTS 63K/16SE and 63J/13SW); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p.93-95 .

SUMMARY

A two week field program in 1993 checked problem areas on Snow Lake Preliminary Maps 1992S-1, 2 and 3. This completes field work begun in 1986. Changes to the maps are minor, but some are significant to interpretation of geology in the Snow Lake area. Findings this year include:

1. identification of a structural repetition, possibly by a thrust fault, of strata northwest of Chisel Lake.
2. changes to location of the basal contact of the Snow Creek basalt northwest of Anderson Lake and east of Sock Lake showing that the N-MORB Snow Creek basalt overlies, rather than interfingers with, arc facies rhyolite and heterolithologic mafic breccias.
3. more complete breakdown of units in a northeast-trending tectonite zone that follows the northwest shore of Wekusko Lake.

Ongoing programs of U-Pb geochronology in conjunction with GEOTOP (Machado and David, 1991; David *et al.*, 1993), Nd isotopic studies with the GSC (Stern *et al.*, 1992) and structural analysis (Krause and Williams, 1993 and pers.com.) have important implications for Snow Lake geology as follows: 1) turbidite deposits of greywacke, siltstone and mudstone on Wekusko Lake were likely shed from a deformed emergent arc terrane rather than by direct input from the active 1892 Ma arc system as previously hypothesized; 2) the Snow Lake and Flin Flon arc segments probably evolved separately; and 3) peak regional metamorphism at Snow Lake may be syn-F_1 rather than syn F_3 (Threehouse folds).

RESULTS OF 1993 FIELD WORK

Geology Northwest Of Chisel Lake

The area north and northwest of Chisel Lake is of economic interest as the exposed strata correlate with massive sulphide-hosting units south of Chisel Lake. Tracing the Chisel Lake mine horizon in this area is complicated because original lithologies are obscured by a combination of synvolcanic alteration and metamorphic recrystallization, and by generally poor quality of outcrop exposures. Revisions to the geological map stemming from new mapping in 1993 are shown in Figure GS-22-1 along with the interpreted location of the mine horizon.

Structural repetition of units northwest of Chisel Lake, in a continuously southwest-facing sequence, is interpreted to have been produced by a conformable fault (Figure GS-22-1). The fault, which is not exposed, is important as it repeats the mine horizon. The largely conformable character of the fault and placement of older over younger strata suggests that this structure is a thrust.

Thrust faults, most notably the McLeod Road thrust, have been identified previously along the contact between the older (1892 Ma) arc volcanic assemblage and the younger >1855 Ma) turbidite greywacke assemblage (Russell, 1958; Froese and Moore, 1980). The fault northwest of Chisel Lake is the first example of a thrust within the VMS-hosting arc volcanic assemblage at Snow Lake. The implication is that VMS-hosting stratigraphy and contained ore deposits could be repeated within otherwise homoclinal arc volcanic assemblages.

Snow Creek Basalt

The Snow Creek basalt, which displays N-MORB geochemical affinities, is the stratigraphically highest member in the VMS-hosting volcanic section at Snow Lake. Previous mapping (Preliminary Map 1992S-1) suggested that the Snow Creek basalt is intercalated with the underlying arc volcanic assemblage, an unlikely scenario considering their very different tectonic setting.

Mapping in 1993 clearly demonstrates that the Snow Creek basalt does not interfinger with the arc volcanic assemblage. Snow Creek basalt overlies, rather than underlies, rhyolite units at the southwest corner of Snow Lake, and aphyric basalt on Sock Lake, previously included as part of the Snow Creek sequence, is demonstratably a separate and stratigraphically lower unit.

The absence of interfingering of the N-MORB Snow Creek basalt with underlying arc assemblage volcanic rocks implies that this basalt is either a younger unit deposited on a rifted arc terrane or a structurally emplaced fault-bounded segment. At a map scale the basal contact of the Snow Creek basalt is broadly conformable, although it does overlie older units towards the west. At an outcrop scale the basal contact has been observed for only a couple of metres in one locality, where it is marked by a less that one centimetre thick zone of slightly foliated rocks and by a downward decrease in grain size of the Snow Creek basalt flow above the contact. Although this information is inconclusive, it suggests that the contact is depositional.

Tectonite Zone, Northwest Wekusko Lake

Strongly foliated rocks outcrop in an up to 100 m wide northeast-trending zone that follows the northwest shore of Wekusko Lake. Rocks in this zone are typically fragmental, with individual fragments strongly flattened to paper thin elongate discs. At the northeast end of this zone many of these rocks are difficult to distinguish from silicified and strongly deformed heterolithologic mafic breccias. One interpretation of these rocks is that they may represent the highly attenuated southeast limb of an early "F_1" fold. An alternative interpretation is that they represent an early ductile phase of movement on the Berry Creek fault. Preliminary Map 1993S-1 defines lithologies within this tectonite zone more clearly than they were previously.

NEW INTERPRETATIONS OF SNOW LAKE GEOLOGY

Results of U-Pb geochronolgy, Nd isotopic analyses, geochemical analysis and structural studies undertaken over the past two years have some important implications for the interpretation of Snow Lake geology.

U-Pb geochronology demonstrates that arc assemblage rocks at Snow Lake were extruded at 1892 Ma (Machado and David, 1991) whereas the turbidite greywacke assemblage at Wekusko Lake contains 1855 Ma detrital zircons (David *et al.*, 1993). This indicates that the turbidite assemblage was not deposited until at least 30 million years after extrusion of the arc assemblage, and implies that the greywacke was likely derived from a deformed emergent arc terrane rather than by direct input from the active 1886 Ma arc system as previously hypothesized by Bailes (1980). A corollary to this is that contacts between the turbidite greywacke domain and the arc volcanic assemblage at Snow Lake are probably tectonic.

Examination of initial epsilon Nd values for the arc assemblage at Snow Lake and Flin Flon shows that the Snow Lake rocks have higher overall initial epsilon Nd values and thus the two arc segments probably evolved independently (Stern *et al.*, 1992). Other features that suggest independent evolution of the Snow Lake and Flin Flon arc segments are the presence of inherited Archean zircons in samples from Snow Lake and none in the Flin Flon samples (Machado and David, 1991), and the absence of felsic plutons between 1885 and 1840 Ma at Snow Lake (Gordon *et al.*, 1990: Bailes *et al.*, 1991; Machado and David, 1991); the Flin Flon segment contains abundant felsic plutons emplaced between 1845 and 1870 Ma. This suggests that the primary regional structural grain in the Flin Flon volcanic belt is north-northeast and that the Snow Lake arc segment continues to the southwest, as proposed by Green *et al.* (1985) from interpretation of aeromagnetic data.

LEGEND

INTRUSIONS

- 7 — Chisel Lake pluton (pyroxenite, gabbro, diorite)
- 6 — Gabbro
  - a) equigranular
  - b) porphyritic
- 5 — Quartz-feldspar porphyry

SUPRACRUSTAL ROCKS (in stratigraphic order)

- 4a, 4b — Threehouse mafic volcaniclastics
  - a) mafic wacke
  - b) heterolithologic mafic breccia
- 3 — Aphyric basalt
- 2 — Felsic metavolcanic rocks
  - a) plagioclase phyric
- 1 — Powderhouse dacite

SYMBOLS

- Geological boundary
- Chisel mine horizon
- Stretch lineation
- Bedding, tops known
- Fault (possible thrust)

Figure GS-22-1: Revised geology of the area north of Chisel Mine, showing the possible trace of the mine horizon.

New structural studies in the Snow Lake area by Kraus and Williams (1993; GS-28, this volume) and in the File Lake area by Conners and Ansdell (GS-11, this volume) indicate that peak regional metamorphism occurred earlier than previous studies have indicated, possibly coincident with $F_{1,2}$ at Snow Lake and F_2 at File Lake. The timing of the peak regional metamorphic event is important because it provides key information on the tectonometamorphic evolution of the Kisseynew and Flin Flon belts.

IMPLICATIONS FOR VMS EXPLORATION

Mapping in 1993 combined with new interpretation of Snow Lake geology have important implications for exploration for base metal mineralization. For example, recognition of a possible thrust fault in the VMS-hosting volcanic strata northwest of Chisel Lake indicates that mineralized horizons in the Snow Lake area may be structurally repeated or truncated by these difficult to recognize structures. In addition, fundamental differences between the Snow Lake and Flin Flon arc segments suggests that the two may have evolved separately with different metallogenies, and that the trend of the Snow Lake base metal district is likely to follow the regional trend of the Snow Lake arc segment to the south southwest under the Phanerozoic cover.

The young age (*ca.* 1855 Ma) of the Wekusko Lake turbidite greywacke assemblage is important as this unit hosts the Zn-rich BUR zone (Fedikow, 1991). This implies that the BUR zone is unrelated to the 1892 Ma arc volcanic-hosted episode of base metal mineralization at Snow Lake, and that it represents a completely new deposit type for Snow Lake. Exploration for the Zn-rich sediment-hosted mineralization is likely to require a different approach to exploration than has been used for the 1892 Ma VHMS deposits.

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GS-23 GEOCHRONOLOGICAL AND GEOCHEMICAL STUDIES IN THE FLIN FLON DOMAIN, MANITOBA, NATMAP SHIELD MARGIN PROJECT

by R.A. Stern[1] and E.C. Syme[2]

Stern, R.A. and Syme, E.C., 1993: Geochronological and geochemical studies in the Flin Flon Domain, Manitoba, NATMAP shield margin project; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 96.

The primary emphasis of the 1992-1993 geochronology program related to the NATMAP Shield Margin Project (Lucas, 1992) was the determination of U-Pb zircon crystallization ages of volcanic and intrusive rocks within the exposed and sub-Paleozoic portions of the Flin Flon domain. Detailed results for samples collected during the 1992 field season are presented by Stern *et al.* (1993a), and the results relevant to Manitoba are summarized below.

Vick Lake andesite tuff from the Bear Lake block gave a minimum crystallization age 1885 ± 3 Ma, dating a phase of arc-related shoshonitic volcanism in the Flin Flon domain. Intrusive diabase from Athapapuskow Lake yielded an imprecise age of *ca.* 1.9 Ga, the first attempt to directly date mafic rocks of the Ocean Floor Assemblage. Foliated tonalite from the West Arm of Athapapuskow Lake crystallized at 1903 +6/-4 Ma, an age that supports a correlation with the similar rocks in the Mystic Lake area of Saskatchewan, and provides a minimum age for the mafic and felsic rocks that it intrudes. Quartz diorite from drill core of the sub-Paleozoic Namew Gneiss Complex gave a possible crystallization age of 1880 ±2 Ma. An improved age of 1831 +5/-4 Ma was derived for the sub-Paleozoic Cormorant batholith, the intrusion of which marks the last major phase of plutonism in the Flin Flon domain.

Geochronological sampling with E. Syme during the 1993 field season focussed upon mafic and felsic volcanic rocks within the Elbow Lake area.

As part of the geochemistry program, new major element, trace element, and Nd-isotopic data (Stern *et al.,* 1992) were obtained on Amisk Group volcanic rocks, and a synthesis and analysis of new and existing data on volcanic rocks was initiated. The data have aided the delineation of three distinct "lithogeochemical assemblages" within the Amisk Group volcanic rocks, (1) Arc Assemblage, (2) Ocean Floor Assemblage, and (3) Ocean Island Basalt Assemblage (Syme *et al.,* 1993). These volcanic assemblages erupted in fundamentally different tectonic settings, and the mineral potential differs in each. Publication of results is currently in progress, and has commenced with a detailed analysis of the geochemistry and tectonic setting of the most important Arc Assemblage (Stern *et al.,* in prep.). This latter work documents the existence of four arc-related magma "series" within the Amisk Group volcanic rocks, tholeiitic, calc-alkaline, shoshonitic, and boninitic (Stern *et al.,* 1993b). Based on these data and published Nd-isotopic data (Stern *et al.,* 1992), Snow Lake and Flin Flon segments are interpreted as separate arcs.

It is hoped that a comprehensive synthesis of the volcanic assemblages will provide the geochemical framework necessary to interpret the origin and tectonic setting of the volcanic rocks, and thus provide a sound basis for understanding the context of volcanic massive sulphide deposits within the Flin Flon domain.

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GS-24 THE OSBORNE Cu-Zn DEPOSIT PROJECT

by M.A.F. Fedikow and E. Kowalyk

Fedikow, M.A.F. and Kowalyk, E., 1993: The Osborne Cu-Zn deposit project; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 97-99.

SUMMARY AND CONCLUSIONS

Felsic volcanic rocks and their altered equivalents have now been documented for a distance of 3.5 km northeast of the Osborne deposit. This stratigraphic sequence is overprinted by a strongly developed foliation attributed to the formation of the Berry Creek fault. Locally, zones of quartz-garnet-amphibole-biotite have been produced in the rhyolites as a result of fluid flow associated with this major structure. These distinctive alteration mineral assemblages are not considered to represent mineralization-related alteration that is so commonly developed in proximity to base metal massive sulphide deposits of the Snow Lake area.

INTRODUCTION

The 1:5000 scale mapping of the Osborne deposit host rocks initiated in 1992 (Fedikow and Kowalyk, 1992) was continued this year. Progress was hampered by lichen- and moss-covered outcrop, however, characteristic rock units from the Osborne stratigraphic sequence have been traced for a distance of 3.5 km northeast and along strike from the Osborne deposit (Fig. GS-24-1). In addition to extrapolating rock units typical of the Osborne stratigraphic sequence, alteration zones were delineated on the southwest shore of Long Lake and on the southeast shore of Vince Lake (Fig. GS-24-2). The Vince Lake zone was examined during reconnaissance traverses undertaken in this area to examine; (i) the contact between Amisk and Missi Group sedimentary rocks, (ii) the presence or absence of felsic volcanic rocks, and (iii) alteration, recrystallization and mineralogy of the greywacke adjacent to the Barry Creek Fault.

RESULTS

Fragmental, massive aphyric and quartz phyric rhyolite were mapped for an additional 2000 m east of the limits of 1992 mapping. These rock units occur on the southwest shore of Long Lake and are essentially along strike equivalents to rhyolites mapped last year. The results of mapping and rock geochemical surveys undertaken to date are summarized by Fedikow and Kowalyk (in prep.).

Outcrop exposures in the area are controlled by a series of linear ridges that abut a northeast-trending linear swamp. This swamp represents the topographic expression of the Berry Creek Fault as delineated by Quinn (1955). Rhyolite outcrops on ridges adjacent to this pronounced linear are strongly foliated and altered along foliation parallel to slightly foliation-discordant linear fracture/fault systems. Fluid flow along these fractures has altered the rhyolite protolith and produced a rock with a quartz-garnet-amphibole-biotite mineralogy and local very fine grained pyrite and rare chalcopyrite. Despite this intense alteration and recrystallization, primary features such as quartz phyric felsic fragments, can be recognized in the rhy-

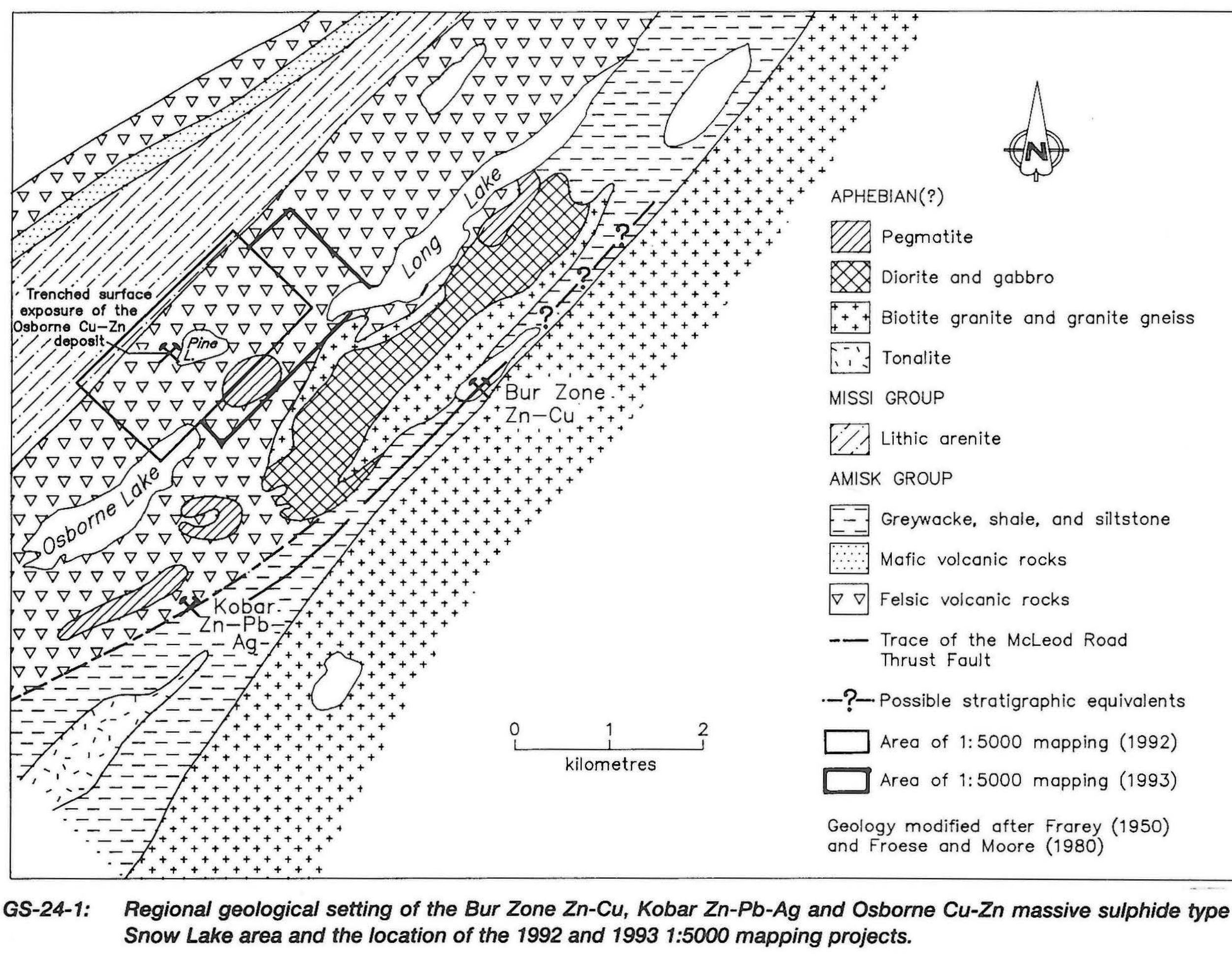

Figure GS-24-1: Regional geological setting of the Bur Zone Zn-Cu, Kobar Zn-Pb-Ag and Osborne Cu-Zn massive sulphide type deposits, Snow Lake area and the location of the 1992 and 1993 1:5000 mapping projects.

olites (Fig. GS-24-3). The linear fractures form a persistent system that trends northeast and was observed, complete with the above-mentioned silicate alteration mineralogy, in Amisk Group greywacke at Vince lake (Fig. GS-24-2). As such, these linear fractures are considered to represent subsidiary en echelon faults produced in association with the Berry Creek Fault.

The massive, medium grained and aphyric rhyolitic units, as well as the fragmental rhyolites in the 1993 map area, are characterized by abundant sillimanite knots and laths of variable sizes. Sillimanite, and local garnet occur as bed specific 2 x 1 mm (10-25%) flattened sillimanite laths and occasionally 1 to 3 x 1 to 2 cm sillimanite knots. Locally, 8 x 4 cm sillimanite knots accompanied by 4 cm garnets are developed in the rhyolitic rocks.

Rusty weathering beds of massive aphyric and fine grained rhyolite that are most commonly <1 m in width are not uncommon on the southwest shore of Long Lake. Visible sulphide is rare in these units, but pyrite and chalcopyrite are observed locally. Coarse grained mineralization-related alteration mineralogies are documented from rusty weathered rhyolite along the southeast shore of Long Lake and in Amisk Group greywacke on the southeast shore of Vince Lake. These occurrences are described below.

Long Lake Alteration Zone

A zone of rusty weathered rhyolite with discordant and partially transposed veinlets of anthophyllite with disseminated chalcopyrite, is exposed on the southwest shore of Long Lake (Fig. GS-24-2). The host rocks are massive and quartz porphyritic rhyolite locally altered to a quartz-garnet-anthophyllite-chalcopyrite-pyrite mineralogy. The zone is traced intermittently along strike for approximately 100 m and appears to represent the along strike extension of a rusty weathered zone exposed on the northwest shore of a small lake to the southwest (Fig. GS-24-2). A bed of medium grained rhyolite with 2 x 1 cm sillimanite knots is in conformable contact with the altered rhyolites on the northwest side of the zone. Southwest of this alteration zone to the shore of Long Lake the rocks are silicified, rusty weathered to rotten aphyric rhyolite and amphibolite. The amphibolite contains boudined quartz-carbonate veins. Steep cliffs truncate strongly foliated rhyolite further to the east and are suggestive of a fault controlled topography. The Long Lake alteration zone may be part of a mineralized system characterized by ground EM conductors in the northeast end of Long Lake (Fedikow *et al.*, in prep.).

Vince Lake Alteration Zone

A 7 m wide, rusty weathered to rotten zone of Amisk Group greywacke containing 4 x 1 cm sillimanite knots and finer grained sillimanite laths occurs on the southeast shore of Vince Lake (Fig. GS-24-2). This zone is described as a chemical sediment type deposit, sulphide facies iron formation in Fedikow and Trembath (1991) (*cf.* Fig. 42-1) based on a compilation of cancelled assessment files using diamond drill logs. The greywacke is fine grained, weakly garnetiferous, nonmagnetic and contains very fine grained pyrite and possibly chalcopyrite. Muscovite is abundant in the altered greywacke. Diamond drill results from this locality (D.D.H. OZ-6; C.A.F. 90080) indicate the zone consists of graphitic, sericitic and talcose gneiss with disseminated pyrite, pyrrhotite and sphalerite (*cf.* Location 43, Fedikow and Trembath, 1991). Further to the northeast the nonmineralized greywacke becomes medium grained and altered to a quartz-garnet-amphibole mineralogy along linear fractures that parallel the Berry Creek Fault. This alteration appears to be identical to that produced along linear fractures developed in felsic volcanic rocks further to the southeast near the Osborne deposit.

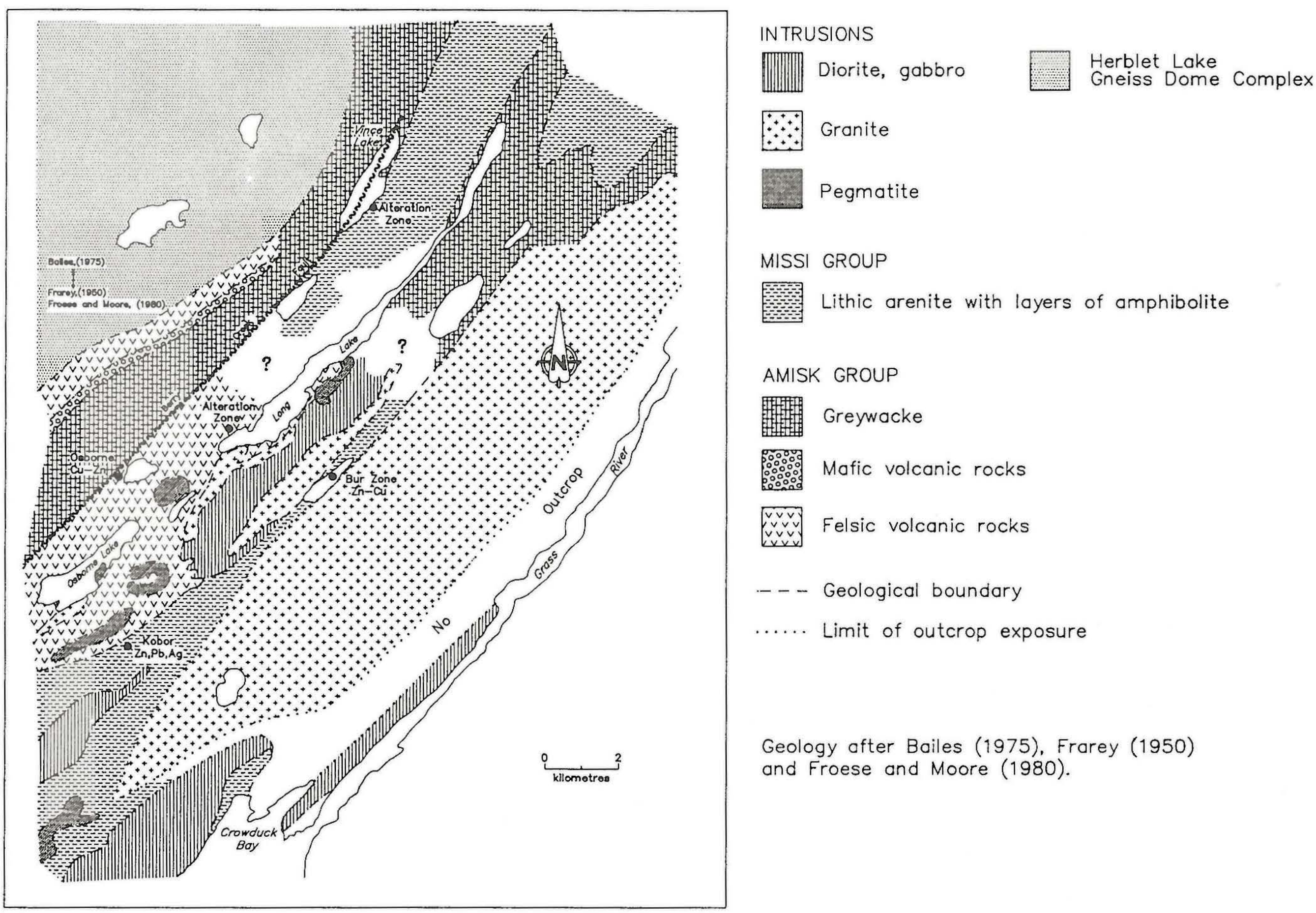

Figure GS-24-2: Location of alteration zones in the 1992 and 1993 mapping areas.

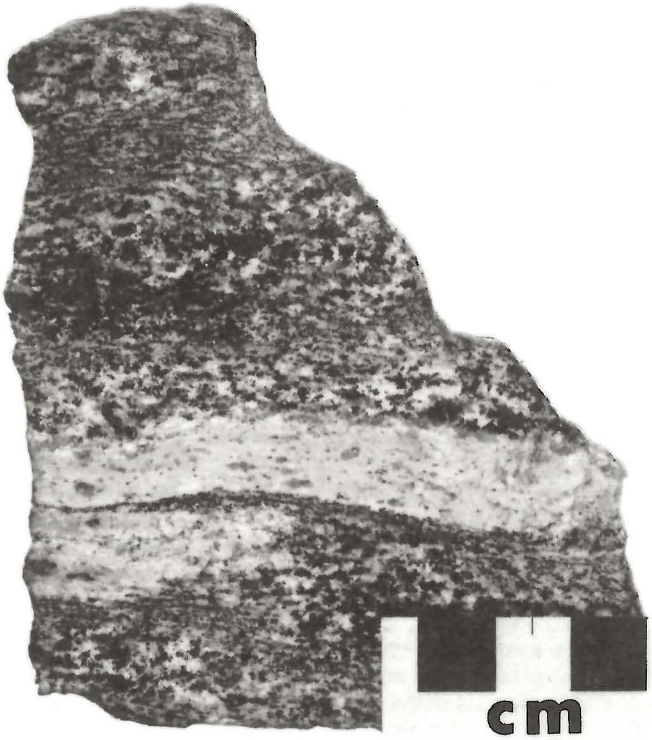

Figure GS-24-3: Strongly foliated altered and recrystallized felsic fragmental rock, Osborne deposit area. Matrix is medium grained quartz-amphibole-garnet. Fragment has a fine grained quartz-rich matrix and rounded to sub-angular 1-3 mm quartz eyes. Sample represents the style of alteration and recrystallization of rhyolite adjacent to the Berry Creek Fault.

East of the northern shoreline of Vince Lake the greywacke is intruded by abundant white pegmatite. Patchy rusty weathered zones are observed in the greywacke and in the pegmatite at this locality and the iron stain in the greywacke may represent the surface expression of pyrite-graphite layers intersected by diamond drilling (Fedikow and Trembath, 1991).

The contact between Missi Group and Amisk Group sedimentary rocks is obscured by the recrystallization and alteration of the rocks that accompanied the development of the Berry Creek Fault. Felsic volcanic rocks were not positively identified at Vince Lake.

GEOCHEMISTRY

A total of 63 outcrop chip samples were collected from the 1993 map area. These samples will be analyzed for major and trace elements and utilized to identify mineralization-related alteration, as well as to geochemically characterize the felsic volcanic rocks in this area. Sample locations are plotted on a geological base in Fedikow and Kowalyk (in prep.).

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GS-25 GEOLOGICAL INVESTIGATIONS IN THE SOUTHWEST WEKUSKO LAKE AREA (NTS 63J/12)

by H.P. Gilbert

Gilbert, H.P., 1993: Geological investigations in the southwest Wekusko Lake area (NTS 63J/12); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 100-107.

SUMMARY

Geological mapping of the volcanic terrane in the north part of the project area was completed in 1993. This terrane consists mainly of Amisk Group mafic to felsic volcanic flows and related flow breccia that have been partly reworked and deposited by subaqueous debris flows. Intercalations of mafic tuff and lapilli tuff occur within the debris flows. Greywacke and siltstone north and northeast of the volcanic terrane may be post-Amisk Group volcanism; a major fault is locally inferred between the greywacke and the volcanic rocks.

Volcanic rocks east of Goose Bay were deformed by a major F_1 anticlinorium that was subsequently deformed by a northeast plunging F_2 antiform. F_3 resulted in southeast plunging folds and stretching lineations.

Mafic and felsic synvolcanic intrusive rocks occur as dykes and as fragments within volcaniclastic debris flows. At least two phases of felsic volcanism are indicated by the occurrence of felsic porphyry fragments in breccia that is overlain by younger rhyolite. Postvolcanic intrusions include diabase and minor gabbro, and younger quartz diorite, diorite and felsic porphyry. A SE-trending mafic dyke swarm southeast of Goose Bay contains several coarsely plagioclase±hornblende phyric diabase phases.

Minor sulphide mineralization has been documented at the margins of the volcanic terrane adjacent to felsic porphyry or quartz diorite intrusions. Mineralization may also occur in association with felsic volcanic rocks or adjacent to alteration zones that are widespread in mafic volcanic rocks. Exploration is currently underway for kimberlite and base metal mineralization close to the south end of Wekusko Lake.

INTRODUCTION

The Wekusko Lake (southwest) project was established in 1992 to conduct 1:20 000 mapping in the area that extends from the south extremity of Wekusko Lake north to latitude 54° 45', and west to longitude 100° 00' (Preliminary Map 1993S-2). Preliminary Map 1992S-2 adjoins the project area directly to the north. The main purpose of the project is to provide a detailed geological map, with concurrent investigations of the geochemistry of volcanic rocks and the structural and metamorphic history of the area. Surficial mineralization and alteration are also documented to evaluate the economic potential of the area.

Mapping in 1993 focused on the mainly volcaniclastic Amisk Group rocks in the north central part of the project area (Fig. GS-25-1). This volcanic terrane has been mapped from Goose Bay at the north margin, south to where the volcanic rocks are intruded by Early Proterozoic granitoid rocks and are overlain, in part, by Ordovician dolomite and swamp-covered glacial clay.

STRUCTURE

Three ages of folding have been recognized. The rocks have been folded in an F_1 anticlinorium that contains at least seven major folds. These are defined by a variety of facing criteria (reverse- to normal-grading and rare scoured surfaces in volcaniclastic debris flows; graded bedding, scour, load structures and Bouma zonation in turbidites). F_1 folds and the associated regional S_1 foliation are deformed by a major NE-trending F_2 open fold that is roughly outlined by the lakeshore east of Goose Bay (Fig. GS-25-1). Small flexures and large open to closed folds of the S_1 foliation are attributed to F_3. The relative ages of F_2 and F_3 cannot be firmly established in the southwest Wekusko Lake area, but the interpretation described here is corroborated by the structural history in the north part of Wekusko Lake (Bailes, 1992).

F_1 minor folds in greywacke in the north part of Wekusko Lake are isoclinal, and locally display axial planar S_1 foliation (Bailes, 1992). In the southwest Wekusko Lake area, minor F_1 folds have not been observed, possibly due to the scarcity of well layered, incompetent rocks that would respond to stress by folding. S_1 foliation is generally coincident with the primary layering (S_0), but S_0/S_1 discordance occurs locally in mafic tuff, and has been utilized (together with facing criteria) to accurately locate F_1 fold hinges at several localities. The configuration of map units (Fig. GS-25-1) is, in part, consistent with the pattern of F_1 folds, and locally indicates reversals of plunge along the hinge lines of the folds.

A major NE-trending F_2 antiform is well defined by the arcuate felsic volcanic unit that extends around the lakeshore east of Goose Bay. Variation of primary layering in the axial zone of the fold indicates an upright structure with subvertical axis plunging approximately 036°/80° (Fig. GS-25-2). This fold is analogous to the upright, open F_2 antiform that trends northeast across the north part of Wekusko Lake (Bailes, 1992). S_2 foliation, which occurs at north Wekusko Lake, has not so far been recognized in the southwest Wekusko Lake area.

F3 folds with steep, E- to SSE-plunging axes deform the S_1 foliation; the amplitudes of these folds range from 0.5 to 25 m. Fold axis plunges of large (5-25 m) F_3 folds at three localities in the north, central and east parts of the mapped area are shown in Fig. GS-25-3. The orientations of these folds are derived from stereographic plots of deformed S_1 foliations at the three localities; their orientations are similar to F_3 fold axes measured directly from small (<1 m) F_3 folds (Fig. GS-25-3). F_3 fold axial planes are roughly vertical and trend W to NNW, consistent with the orientation of small F_3 chevron folds and associated crenulation cleavage observed in the north Wekusko Lake area, and throughout the Snow Lake area (Bailes, 1992).

Moderate to steep, SE-plunging stretching lineations that were previously designated L_1 (Gilbert, 1992) are re-interpreted as L_3 (Fig. GS-25-3), because their orientation is not conformable with major F_1 folds defined by mapping this year, and they are subparallel to F_3 fold axes. The approximate average of 90 lineations is 140°/55° (Fig. GS-25-3); F_3 folds have similar orientation, but slightly steeper plunge. The moderately dispersed pattern of L_3 lineations may be due to a minor change in the direction of stress during F_3. If the plunge of folds had become steeper during the course of F_3, late F_3 folds would have been oblique to early L_3 lineations; this could have resulted in dispersion of the lineations by late F_3 folds.

Minor faults, locally associated with topographic lineaments, are steeply dipping to vertical, and strike mostly north to northeast (Fig. GS-25-4). These structures are commonly associated with ankeritic and/or quartz veining, and chloritic alteration. Faults and sheared zones are typically 20 to 50 cm thick, but range up to 6 m. Many faults are concordant with major structural trends; others are discordant and truncate lithologic units, or juxtapose rock units of markedly different strain character. A major fault parallel to the NW-trending shoreline of Wekusko Lake is inferred at the contact between unit 3 and units 1 and 2 (Fig. GS-25-1). Most faulting is interpreted to be late, possibly post F_3; however, earlier phases of brittle deformation are also inferred.

STRATIGRAPHY

The volcanic terrane southeast of Goose Bay consists mainly of Amisk Group mafic to felsic volcanic flows and related flow breccia that have been partly reworked and deposited by subaqueous debris flows. Intercalations of mafic tuff and lapilli tuff within the volcaniclastic debris flows are locally well bedded and graded. Greywacke and siltstone at the north flank of the mapped area (unit 3, Fig. GS-25-1) are analogous to turbidites described in the north

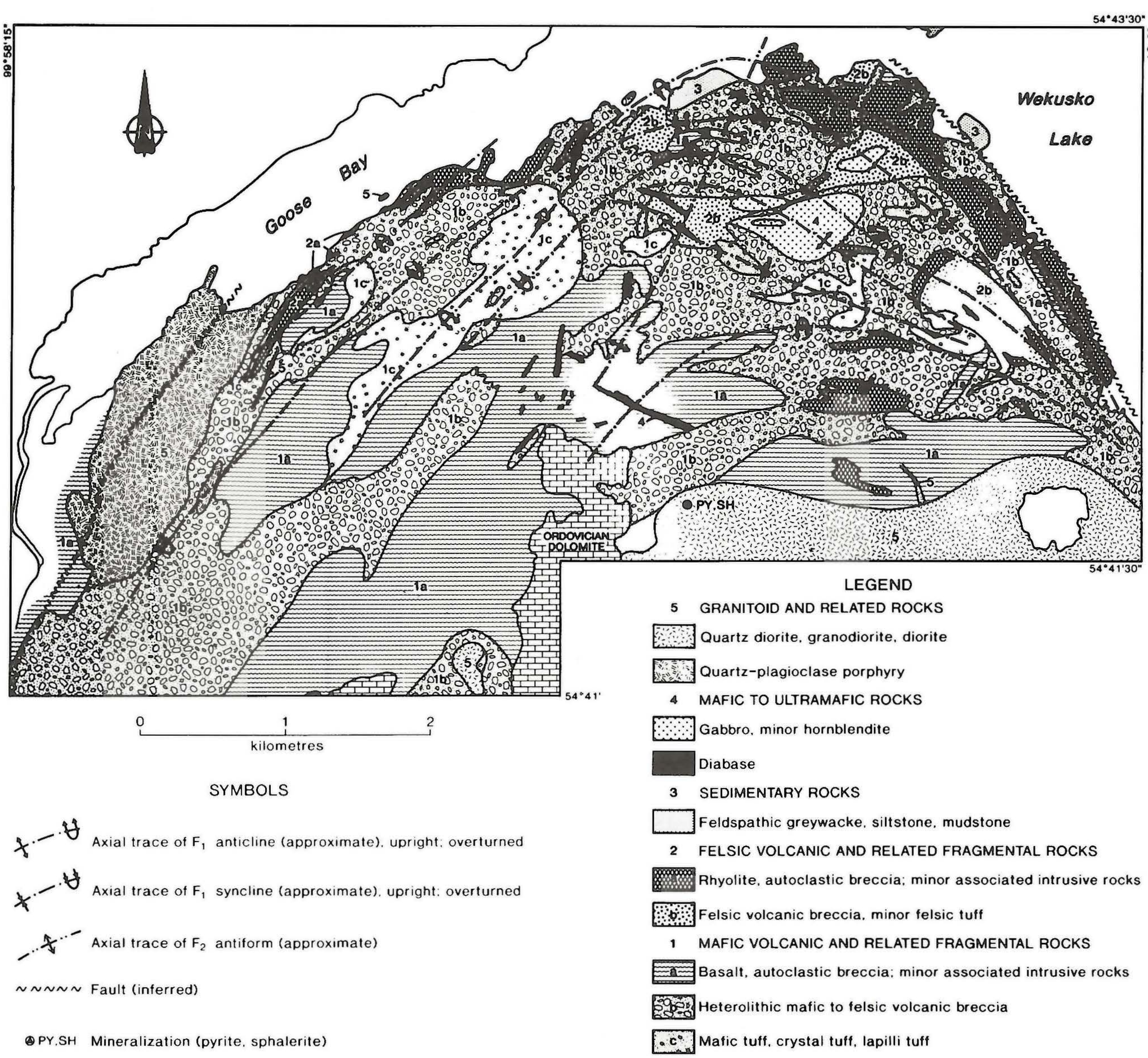

Figure GS-25-1: Geological map of the north-central part of the southwest Wekusko Lake project area.

Wekusko Lake area (unit 17 in Bailes, 1992), which may be syn- or post-Amisk Group volcanism. No outcrops of unit 3 were examined in 1993; a description of this unit has been provided (unit 5 in Gilbert, 1992).

Basalt, autoclastic breccia; minor associated intrusive rocks (1a)

Mafic volcanic flows and flow breccia are most extensive in the southwest part of the mapped area (Fig. GS-25-1). Autoclastic breccia is locally gradational with derived heterolithic debris flow breccia. Basalt (1) displays a variety of features that include: phenocrysts (plagioclase and hornblende after pyroxene); amygdales (quartz, plagioclase, carbonate, or less common hornblende); and varioles (plagioclase or epidote). Pillow selvage remnants occur sporadically; well-formed pillows occur at several localities, but do not afford reliable tops. Flow directions are indicated by fine (1-6 mm) primary lamination or trails of aligned autoclasts entrained within the flows. Thermal contraction cracks occur locally in massive basalt and consist of fine (1-3 mm) subparallel fractures filled with plagioclase (and/or epidote), spaced at 1 to 6 cm.

Flow breccia consists of a monolithic assemblage of ovoid, amoeboid or crescentic fragments derived by fragmentation of the chilled flow margin or pillow selvages. Some densely quartz-amygdaloidal fragments (up to 80% amygdales) may be derived from the highly vesicular upper marginal zone of the basalt flow. Large ovoid quartz-filled vugs (up to 8 cm) occur in several flows.

Alteration is widespread in mafic volcanic flows. Silicification and carbonatization are the main types, and lead to a variety of weathering colours (unaltered dark to medium green basalt grades to paler tones of green, gray, or beige). Amphibolitization is characterized by diffuse zones of hornblende porphyroblasts that grade into medium grained diorite developed by recrystallization of basalt. This type of alteration occurs near the south margin of the volcanic terrane, near the contact with quartz diorite and diorite (unit 5, Fig. GS-25-1). Epidote is widely developed in unit 1 as irregular pods, stringers, or ovoid porphyroblastic aggregates; diffuse epidotized zones are also common. Fine garnet porphyroblasts are related to alteration in a flow at the southwest extremity of Goose Bay, close to the contact with a quartz-plagioclase porphyry intrusion (5). In the southwest part of the project area (Preliminary Map 1993S-2), basalt

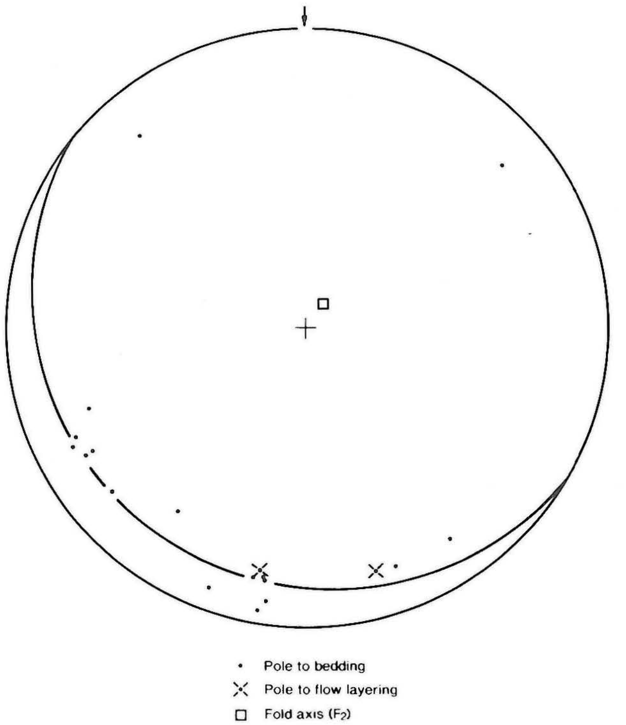

Figure GS-25-2: ***Lower hemisphere stereographic plot of bedding and flow layering in the axial zone of the F_2 antiform east of Goose Bay.***

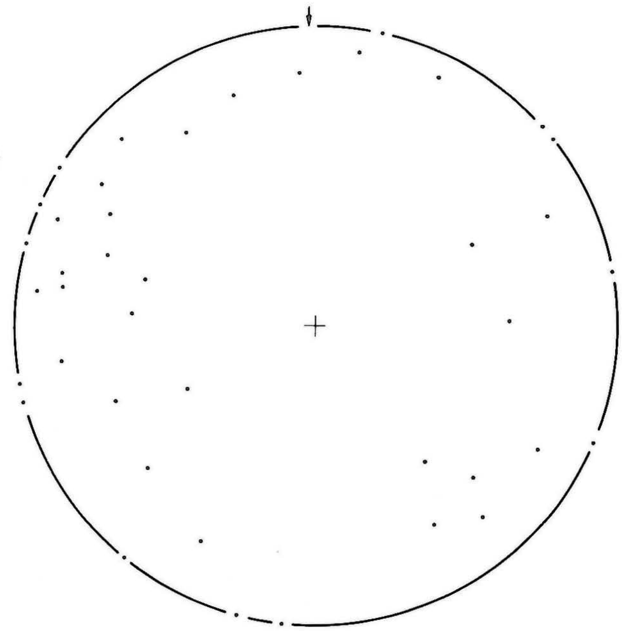

Figure GS-25-4: ***Lower hemisphere stereographic plot of faults in the in the area east of Goose Bay.***

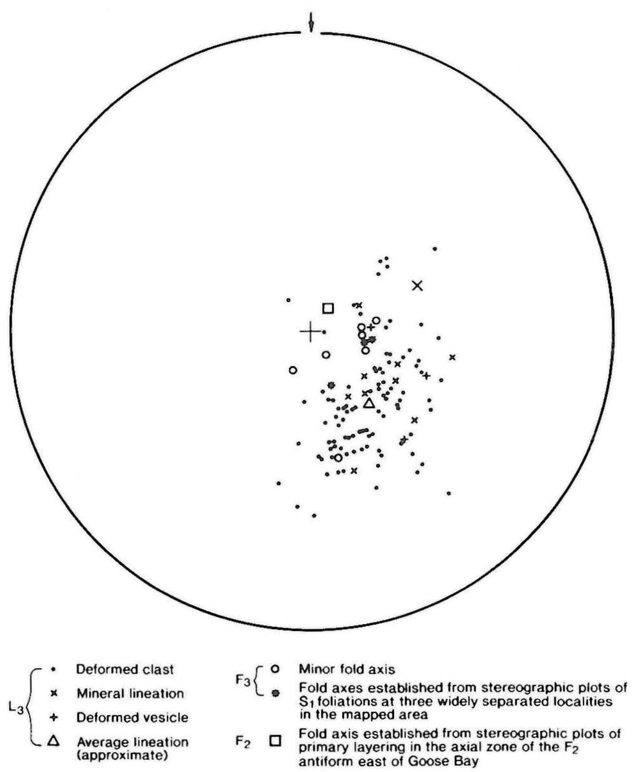

Figure GS-25-3: ***Lower hemisphere stereographic plot of fold axes and linear structures in the area east of Goose Bay.***

displays only minor alteration, but primary structures are less well preserved than further north due to slightly coarser recrystallization.

Heterolithic mafic to felsic volcanic breccia (1b)

Heterolithic volcanic breccia (1b) is the most abundant rock type in the volcanic terrane southeast of Goose Bay. The fragmental rocks range from lapilli grade to very coarse breccia that contains large blocks (>60 cm); fragment assemblages range from highly diverse to near monolithic (mafic or felsic types predominant). These rock units (0.5 to over 30 m thick) have been interpreted as subaqueous debris flows derived mainly from mafic and felsic volcanic flows and related flow breccia.

Fragment types in breccia (1b) include the following main categories: (1) mafic volcanic (aphyric to porphyritic, vesicular, amygdaloidal, variolitic); (2) felsic volcanic (variously porphyritic, massive to flow laminated, locally with early chlorite-filled fractures); (3) hypabyssal rocks of inferred synvolcanic origin (quartz-plagioclase porphyry, leucotonalite to quartz diorite, diabase); (4) altered mafic to intermediate volcanic rocks (mainly partly silicified basalt); and (5) rare tabular or angular blocks of reworked volcanic fragmental rocks (laminated mafic tuff, unsorted lapilli tuff).

Fragment shapes are highly variable; most are subangular to angular (Fig. GS-25-5); a minority is subrounded. Zoned amygdaloidal basalt fragments derived from autoclastic or pillow fragment breccia are locally common. Heterolithic breccia (1b) is matrix- to clast-supported; fragments typically constitute 45 to 70% of the rock. The matrix is intermediate to mafic and consists of comminuted detritus (granules and small lapilli) equivalent to the larger fragments in the breccia. Vague sorting based on minor variations in fragment size and abundance occurs at several localities. Diffuse layering occurs where breccia is intercalated with tuff (Fig. GS-25-6), and reverse- to normal-grading is typical of some debris flows (1b). However, sorting is generally poor or absent. Several scoured contacts between debris flows indicate the stratigraphic facing direction.

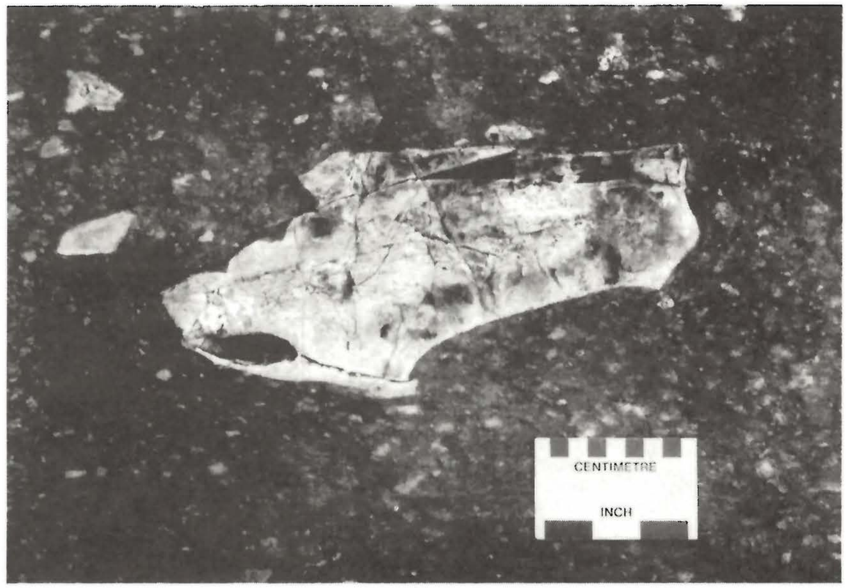

Figure GS-25-5: Rhyolite boulder in heterolithic volcanic breccia (1b) with predepositional veining and highly irregular shape. Note the concavity at the lower side suggesting fragmentation was in part controlled by thermal contraction jointing at the margin of a massive flow.

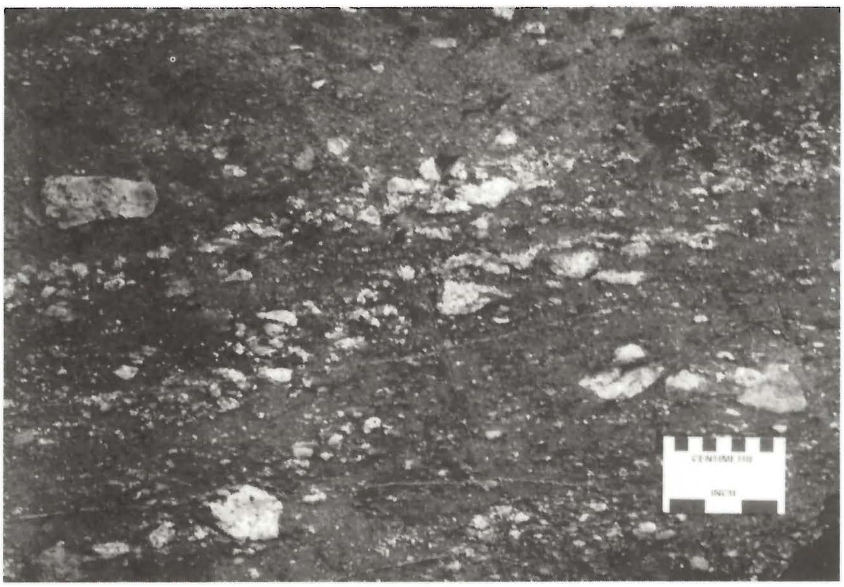

Figure GS-25-6: Diffuse layering in heterolithic volcanic breccia (1b) that contains mainly felsic fragments, alternating with lapilli tuff (1c).

Mafic tuff, crystal tuff, lapilli tuff (1c)

Lensoid to irregular formations of mafic tuff and lapilli tuff (1c) occur throughout the volcanic terrane southeast of Goose Bay. Tuff units are commonly intercalated with heterolithic breccia (1b), and are characterized by conspicuous layering, grading and scoured contacts consistent with deposition by turbulent density currents.

Layering in mafic tuff includes fine lamination (1 to 5 mm) and thicker bedding (5 to 50 cm) defined by variable grain size, colour (green to brown gray) or the presence/absence of lapilli. Graded, cyclic units of tuff/lapilli tuff (20 to 50 cm thick), locally with scoured basal contacts, occur in some formations (Fig. GS-25-7). In reverse- to normally-graded sequences, the top of the bed is locally laminated and generally very fine grained. Sporadic occurrences of load structure, disrupted sedimentary folds and rare tabular rip-ups of laminated tuff occur in unit 1c.

Lapilli tuff (1c) is generally matrix supported and contains predominantly mafic lapilli that constitute up to 50% of the rock, and subordinate felsic lapilli (up to 20%). Fragments are mainly angular to subangular. The mafic matrix consists of finely comminuted grains that are gradational to lithic granules and small lapilli. Some tuff units contain plagioclase phenoclasts and hornblende pseudomorphs after pyroxene.

Thick (5-20 m) mafic tuff units that are relatively massive and homogeneous are similar to basalt, but are distinguished by the presence of detrital lithic grains and granules, and by rare zones showing fine bedding lamination. These rocks are possibly the result of reworking by debris flows.

A conspicuous porphyroblastic formation interpreted as altered mafic tuff extends laterally for at least 0.8 km along the southeast side of Goose Bay parallel to, and within 100 m of, the NE-trending margin of a quartz-plagioclase porphyry intrusion (Fig GS-25-1). The unit (5 to >30 m thick) contains ovoid to subhedral andalusite (?) porphyroblasts up to 3 cm long (Fig. GS-25-8).

Rhyolite, autoclastic breccia; minor associated intrusive rocks (2a)

Rhyolite and related flow breccia (2a) occur in a major unit up to 350 m wide that extends from Goose Bay around the lakeshore to the east, and in several smaller formations in the central and southeast parts of the mapped area (Fig. GS-25-1). At least two phases of felsic volcanism are indicated by the occurrence of rhyolite fragments within debris flows (1b, 2b) that are overlain by the major rhyolite unit parallel to the lakeshore east of Goose Bay.

Figure GS-25-7: Vertical section through a 20 cm lapilli tuff unit (1c) deposited by mass flow. Note the scoured basal contact and sporadic lapilli in the graded lower part of the unit, and laminated zones in central to upper parts.

Rhyolite is typically plagioclase- and/or quartz-phyric (phenocrysts 0.5-2 mm); flow contacts are locally inferred from abrupt changes in phenocryst type and abundance. Rhyolite flows and related sills are generally more finely and sparsely porphyritic than younger felsic porphyries (5). Diffuse grey streaks attributed to contamination are generally conformable with the trend of the felsic units. Fine primary flow lamination occurs at the margins of massive rhyolite flows, and at the margins of rhyolite lobes within flow breccia.

Subvertical flow laminae (1-10 mm) extend around a lobe at the front of a rhyolite flow in the northeast part of the mapped area (Fig. GS-25-9). The same flow is locally characterized by pervasive, chlorite-filled polygonal fractures (Fig. GS-25-10) interpreted as a result of contraction stress during cooling of the flow. Subparallel to anastomosing sericitic fractures are more widely developed in rhyolite flows. Sericitic alteration is locally conspicuous at the margins of some flows, where they are in contact with related flow breccias.

Massive rhyolite flows are commonly associated with a contiguous breccia facies that contains angular felsic blocks in a rhyolite microbreccia matrix derived by fragmentation of chilled flow margins. Sporadic ovoid to irregular felsic lobes in the breccia are interpreted as partially cooled, plastic masses of rhyolite extruded through the chilled flow margin into the breccia facies. Rhyolite flow breccia (2a) has been variously reworked and deposited as volcaniclastic breccia (2b) by debris flows.

A fragmental rhyolite unit up to 10 m thick extends laterally for over 1 km close to the southeast shore of Goose Bay. The fragmental rhyolite is overlain by porphyroblastic mafic tuff (1c) to the northwest, and is locally underlain by heterolithic breccia (1b) or massive rhyolite (2a) to the southeast. The unit contains massive to vesicular, locally silicified rhyolite lobes (up to 1 x 5m) that were apparently extruded onto soft sediment, represented by the siltstone matrix of the unit.

Felsic volcanic breccia, minor felsic tuff (2b)

Several formations of felsic volcanic breccia (2b) occur in the north and southeast parts of the mapped area (Fig GS-25-1). Similar breccia occurs elsewhere as minor intercalations within heterolithic mafic to felsic volcanic breccia (1b). The volcaniclastic breccias (2b, 1b) were emplaced by debris flows and vary in composition according to variations in the source terrane; thus these rock units are lithologically gradational. Unit 2b is also similar to rhyolite flow breccia (2a), from which it is partly derived; features that distinguish these units are described in Table GS-25-1.

Felsic volcanic breccia (2b) consists of an assemblage of angular to subangular rhyolite blocks and lapilli that are commonly accompanied by subordinate mafic to intermediate fragments. Textural features of felsic breccia (*e.g.* sorting and grading) are similar to those described for unit 1b. Quartz and/or plagioclase phenocrysts occur in the fragments and equivalent phenoclasts occur in

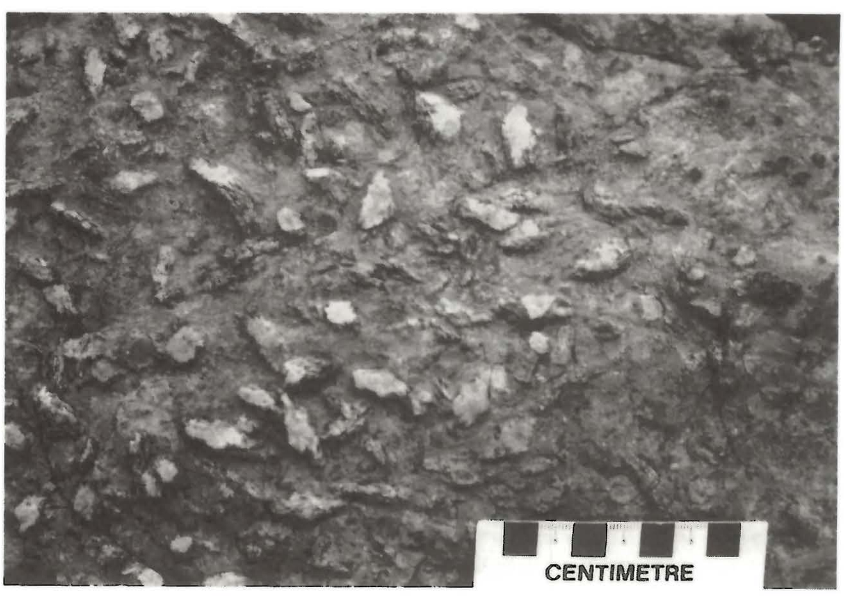

Figure GS-25-8: Randomly distributed andalusite (?) porphyroblasts in altered mafic tuff (1c) close to the southeast shore of Goose Bay.

Figure GS-25-9: Flow lamination in rhyolite (2a) in the northeast part of the mapped area. The subvertical laminae wrap around a 1.5 m wide lobe at the front of the flow.

the comminuted breccia matrix.

An unusually coarse, thick formation (at least 0.75 x 0.2 km) of monolithic felsic volcanic breccia (2b) occurs within heterolithic breccia (debris flows) in the central part of the mapped area. The felsic breccia, which is interpreted as a debris flow deposit, contains angular rhyolite blocks (10-40 cm) and subordinate ovoid lobes (0.2 to 1 m; up to 7 m long) in a comminuted rhyolite matrix. Rhyolite flow breccia (2a) occurs locally within the formation and at one locality several large mafic volcanic enclaves (1 to 5 m long) have been incorporated in the debris flow deposit.

The stratigraphic relationships of a felsic breccia unit close to the southeast shore of Goose Bay are illustrated in Figure GS-25-11. Monolithic and heterolithic felsic breccias are locally graded and are intercalated with relatively more mafic heterolithic breccia (debris flows), massive rhyolite and flow breccia, and minor mafic tuff. The main felsic breccia unit (35 m thick) is possibly derived from an underlying felsic volcanic flow.

Table GS-25-1
Comparative features of rhyolite flow breccia (2a) and felsic volcanic breccia emplaced by debris flows (2b).

Rhyolite Flow Breccia (2a)	Felsic Volcanic Breccia (2b) (Debris flow)
(1) Monolithic	Heterolithic to monolithic
(2) Angular blocks and ovoid to irregular lobes of rhyolite (up to several metres long)	Coarse detritus generally angular to subangular blocks. Sporadic rhyolite lobes are locally incorporated directly from flow breccia source
(3) Rhyolite microbeccia matrix (± quartz and plagioclase phenoclasts)	Felsic to intermediate matrix; locally mafic, in contrast to felsic fragment composition
(4) Stratigraphically associated with massive rhyolite flows. Massive rhyolite with *in situ* fractures grades into flow breccia	Intercalated with more diverse heterolithic breccia and mafic tuffs deposited by mass flow

INTRUSIVE ROCKS

Gabbro, diabase, minor hornblendite (4)
Quartz diorite, granodiorite, diorite, quartz-plagioclase porphyry (5)

The earliest recognized intrusions are synvolcanic mafic dykes and felsic porphyries. The former include aphyric and porphyritic diabase (with hornblende pseudomorphs after pyroxene, ± plagioclase phenocrysts) and related minor gabbro. Synvolcanic felsic porphyries with quartz and plagioclase phenocrysts (0.5-1.5 mm, 7% each) are spatially associated with rhyolite flows (2a). Coarser grained porphyry dykes (phenocrysts 2-8 mm, 10-15%) have no extrusive counterparts. Both porphyry types also occur as angular

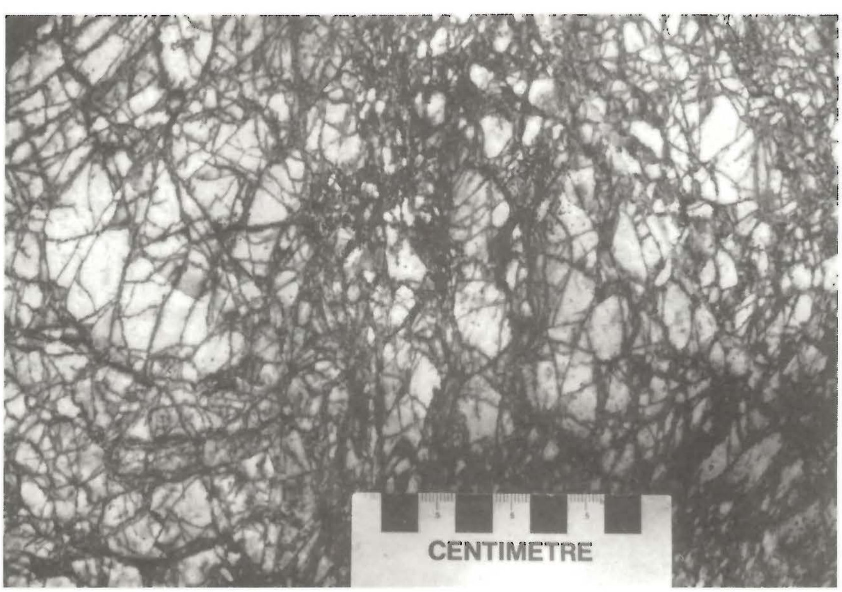

Figure GS-25-10: Rhyolite (2a) with pervasive chloritic fractures and altered zones. The occurrence of fragments of similar altered rhyolite in breccia (1b) suggests fracturing was penecontemporaneous with volcanism.

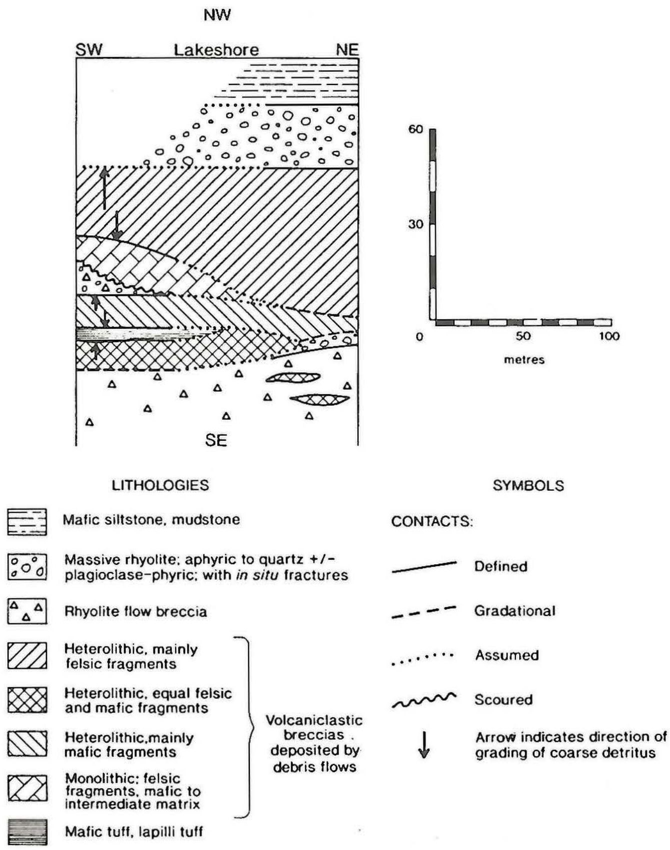

Figure GS-25-11: ***Stratigraphic section at the southeast shore of Goose Bay showing the relationship between massive and fragmental rhyolite flows (2a) and intercalated volcaniclastic debris flows (1b, 2b); the section faces northwest.***

blocks in volcaniclastic breccia (1b, 2b). A NE-trending quartz-plagioclase porphyry sill (at least 2 x 0.6 km) at the southwest end of Goose Bay (Gilbert, 1992) is spatially related to a rhyolite unit (2a) that extends along the lakeshore to the east. The sill is characterized by tectonically brecciated margins, and is bisected by a strongly sheared to mylonitic zone (Fig. GS-25-1).

A variety of massive gabbroic (4) and granitoid intrusions (5) postdate the volcanic rocks. Previous mapping defined a gabbro stock (1.2 x 0.6 km) in the northeast part of the mapped area (Fig. GS-25-1), and minor coarsely plagioclase phyric gabbro and hornblendite intrusions in the southwest part of the project area (Gilbert, 1992). Current mapping has identified an ESE- to SE-trending dyke swarm of plagioclase(±hornblende) phyric diabase that extends through the south central part of the mapped area. Several por-

Figure GS-25-12: ***Thermal contraction fractures in a wide (25 m) hornblende phyric diabase dyke (4).***

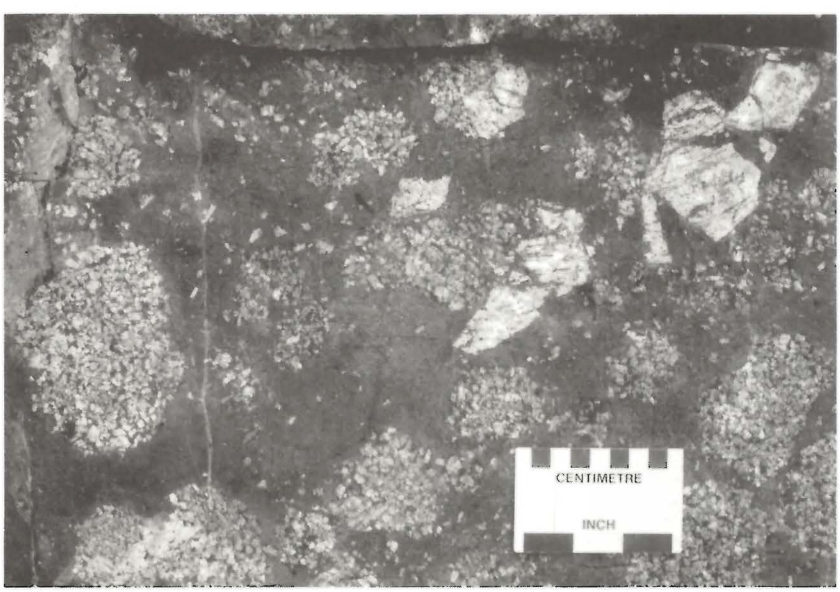

Figure GS-25-13: ***Megaphyric, cumulophyric diabase (4). Two phases of plagioclase are distinguished by size (2-15 mm; and 2-8 cm). The larger plagioclases display synneusis texture; smaller feldspars are aggregated in ovoid clusters up to 10 cm across. The diabase also contains pyroxene phenocrysts altered to hornblende.***

phyritic diabase phases have been distinguished; these commonly occur as contiguous dykes and are considered to be contemporaneous. Trachytic diabase dykes (1-15 m thick) contain subparallel plagioclase laths (3-30 mm x 1-3 mm; 15-45% of the rock), locally accompanied by equant pyroxene phenocrysts altered to hornblende (1-4 mm; 8-20%). The feldspars are aligned roughly parallel to dyke margins; swirling flow patterns of feldspars in the cores of several dykes indicate localized turbulent flow. Related hornblende phyric dykes without plagioclase phenocrysts locally display prominent thermal contraction fractures filled with plagioclase (Fig. GS-25-12). Hornblende phyric diabase is invariably slightly older than trachytic and related megaphyric diabase dykes. Megaphyric dykes contain equant to tabular plagioclase phenocrysts (2-15 mm) and large (2-8 cm) prisms that are locally aggregated in clusters (synneusis texture). The smaller equant plagioclase phenocrysts locally display cumulophyric texture (Fig. GS-25-13). Quartz phyric felsic dykes (5) locally truncate the megaphyric diabase.

Xenoliths of trachytic diabase (4) in quartz diorite (5) at the south margin of the volcanic terrane southeast of Goose Bay suggest granitoid plutonism is younger than the mafic dykes. The medium- to coarse-grained, homogeneous quartz diorite is locally characterized by ragged hornblendic aggregates (2-8 mm) and minor mafic xenoliths and schlieren. Irregular "net veining" by diorite or hornblendite occurs at a few localities; sporadic occurrences of igneous layering consist of alternating feldspathic/hornblendic laminae (1-3 cm thick). Minor intrusions of leucotonalite, felsic porphyry, diorite and hornblendite occur in the contact zone between units 1 and 5. Contamination and metasomatism (by volcanic and intrusive rocks respectively) are characteristic of the contact zone.

Massive very coarse grained quartz gabbro (>60 m thick) occurs at several localities within quartz diorite (5), approximately 100 m south of the margin of the volcanic terrane southeast of Goose Bay. The rock is subophitic and consists mainly of subhedral plagioclase (0.5-2 cm), with altered pyroxene, interstitial quartz aggregates (5-8 mm, 5%) and irregular magnetite aggregates (1-4 mm, 3%). The gabbro, and minor pegmatite and aplite dykes that occur sporadically in the quartz diorite pluton, are the youngest intrusive rocks recognized in the project area.

ECONOMIC GEOLOGY

Mineralization examined this year includes:

a) pyrite-sphalerite stringers over a 2 m zone in leucotonalite (5) and disseminated pyrite (10%) in hornblendite (4); the dyke host rocks occur in the contact zone between basalt (1) and quartz diorite (5) at the south margin of the volcanic terrane southeast of Goose Bay; and
b) disseminated pyrite (4%) over a 17 m section in basalt (1) adjacent to the quartz-plagioclase porphyry intrusion (5) at the southwest end of Goose Bay. Minor gossan zones occur elsewhere in basalt that contains disseminated pyrite.

Potential sites for base metal mineralization include: contact zones between volcanic and granitoid rocks, as in (a), (b); within or marginal to the numerous felsic volcanic units; and at zones of alteration that are widely developed in the project area.

A subeconomic Cu/Zn sulphide deposit (estimated at 250 000 tons) with minor Au, Ag and Cd is located close to the south end of Wekusko Lake (Corporation Files; Mineral Inventory Card 63J/12 Cu1; Manitoba Energy and Mines, Minerals Division)

Kimberlite that contains garnets of diamond affiliation (one G10 and several G9 types) has been intersected by diamond drilling in volcanic rocks close to the sulphide deposit (European Ventures Inc., July 26 1993 news release). The kimberlite is interpreted as a dyke related to an inferred larger kimberlite intrusion that is the subject of continuing exploration (M. Muzylowski, pers. comm.).

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GS-26 LITHOLOGICAL AND STRUCTURAL RELATIONSHIPS IN THE EAST WEKUSKO LAKE AREA, FLIN FLON DOMAIN, MANITOBA

by K.M. Ansdell[1] and K.A. Connors[2]

Ansdell, K.M. and Connors, K.A., 1993: Lithological and structural relationships in the east Wekusko Lake area, Flin Flon Domain, Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 108-111.

SUMMARY

The intimate relationship between folding and faulting suggests that they developed in a fold and thrust belt. The timing of porphyroblast growth indicates that metamorphism occurred during this period of shortening/thickening. The relationship between F_2, S_2 and metamorphism suggests substantial thickening occurred prior to this phase of deformation. It is likely that pervasive deformation during folding and thrusting obliterated early structures.

INTRODUCTION

The East Wekusko Lake area occurs in the eastern portion of the Flin Flon Domain (parts of NTS 63J/12 and 13) (Fig. GS-26-1), one of the lithotectonic elements of the Paleoproterozoic Trans-Hudson Orogen. Within the Flin Flon Domain, the supracrustal rocks have been subdivided into island-arc and ocean floor volcanic rocks (Amisk Group), turbidites (File Lake formation), and fluvial sedimentary rocks and rare volcanic rocks (Missi Group). Previous mapping in the east Wekusko Lake area identified volcanic and sedimentary rocks that have been assigned to all three supracrustal groups (Stockwell, 1937; Armstrong, 1941; Frarey, 1950). The geological setting and structural characteristics of gold mineralization in the area have been summarized by Galley *et al.* (1986); however, the contact relationships between the supracrustal packages are unclear and, at present, lead to complex structural interpretations. To alleviate this problem, an integrated lithological, structural and geochronological study has been initiated, the objectives of which include:

1. interpretation of the depositional environment of volcanic and sedimentary rocks;
2. improving the constraints on the timing of igneous and sedimentary events using U-Pb zircon geochronology;
3. determining the metamorphic and structural history of the area using detailed structural mapping and microstructural observations. This will concentrate particularly on the contact relationships between the main packages of rocks to determine whether there is evidence of early structural juxtaposition of units (*e.g.* Gordon and Gall, 1982); and
4. provision of constraints on the metamorphic and uplift history of these rocks using Ar-Ar thermochronology.

Better definition of the depositional and structural history of this area, which straddles the defined boundary between the Flin Flon and Kisseynew domains, will increase confidence in the extrapolation of geological events from the low grade upper crustal rocks into possible equivalents in the high-grade, mid- to lower-crustal rocks in the Kisseynew Domain.

In this report, lithological and structural observations and preliminary interpretations are summarized. The description of rock types and structures are based on mapping performed in selected areas by the authors. All rocks are deformed and metamorphosed, and rock type names should bear the prefix meta-.

LITHOLOGICAL OBSERVATIONS

The sedimentary and volcanic rocks have been subdivided into a number of generally fault-bounded lithological packages (Fig. GS-26-1). The identification of these packages simplifies structural reinterpretations. The supracrustal rocks east of the Crowduck Bay Fault are cut by numerous small coarse grained gabbro and diorite bodies, banded aphyric and sometimes plagioclase phyric mafic dykes, feldspar porphyritic felsic dykes, and three larger intrusions, namely the Lostfrog Lake quartz porphyritic granite (1, Fig. GS-26-1), the Stuart Lake granodiorite (2, Fig. GS-26-1), and the Puella Bay porphyry (3, Fig. GS-26-1).

File Lake formation

Sedimentary rocks west of the Crowduck Bay Fault (Fig. GS-26-1) consist of graded beds of fine grained sandstones, siltstones and mudstones, which were likely deposited by turbidity currents. These rocks are considered to be equivalent to the File Lake Formation (*e.g.* Bailes, 1980), and form part of a distinct package of sedimentary rocks between the Crowduck Bay Fault and the Berry Creek Fault at Snow Lake (Bailes, 1992).

Missi Group

Sedimentary rocks east of the Crowduck Bay Fault consist of conglomerate and sandstone that outcrop in two main packages, the eastern and western packages (Fig. GS-26-1). Although rock types are similar and are interpreted as Missi Group (Frarey, 1950), there are no unambiguous marker horizons and no direct correlation can be made.

The rocks of the eastern package have been described previously in Shanks and Bailes (1977). Conglomerates in the eastern package can be divided into the lower, middle and upper conglomerates (Fig. GS-26-1), and are typically massive, clast supported, polymictic pebble to boulder conglomerate with similar clast types. The base of the lower conglomerate is not exposed, but is interpreted as a fault. The top of the sedimentary sequence is also not observed, and so the thickness of the sedimentary pile is unknown.

The sandstones vary from medium- to coarse-grained, tabular and trough crossbedded sandstone overlying the lower conglomerate to shallow crossbedded to parallel laminated, magnetite-rich sandstone between the middle and upper conglomerates. The upper sandstones are generally featureless, but do contain rare scours, graded beds and rip-up clasts. The consistent dip direction of crossbedding suggests a unidirectional paleocurrent and supports the interpretation of a fluvial environment, although the sandstones higher in the sequence may represent a quieter, more distal fluvial environment.

The base of the western package of Missi Group sedimentary rocks is exposed at A (Fig. GS-26-1) where bedding strikes perpendicular to the regional orientation. At this outcrop conglomerate unconformably overlies a package of rhyolite and felsic tuff. The basal sedimentary rocks consist of polymictic clast-supported conglomerate, gravel and coarse sandstone lenses; in places crossbedded and scoured surfaces indicate younging to the north away from the underlying volcanic rocks.

The sedimentary rocks farther north along the shoreline have a faulted base. Crossbedded sandstone consists of trough and tabular sets of gently-dipping foresets with intermittent mm to cm thick mud seams, and these rocks grade upwards into coarse sandstone, grit and conglomerate. The outcrop of western package rocks widens northward where it includes a conglomerate band within a thick sequence of sandstone (Fig. GS-26-1), which locally contain low angle crossbeds. These rocks are similar to the Missi Group sandstone east of the Roberts Lake Fault (Fig. GS-26-1).

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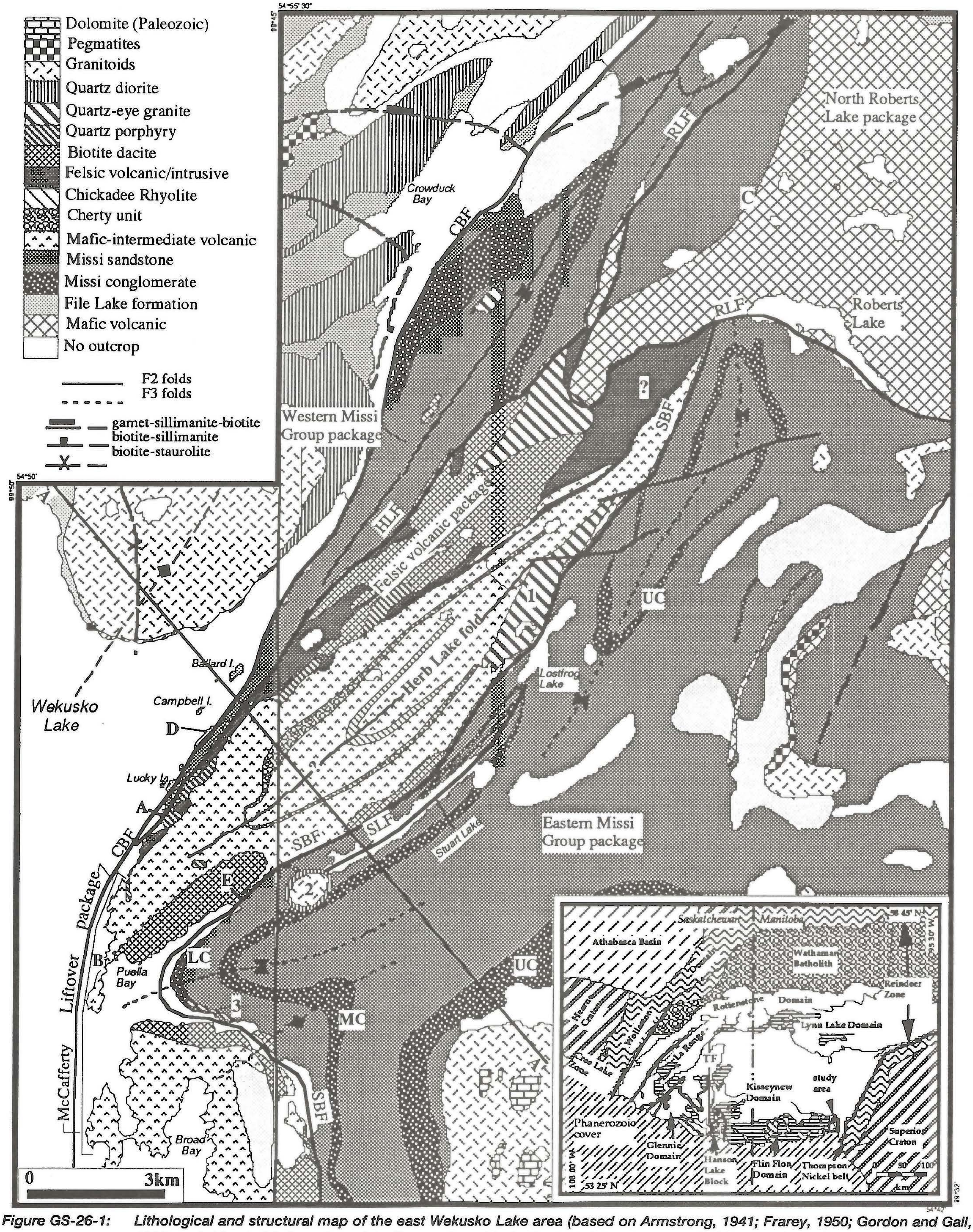

Figure GS-26-1: Lithological and structural map of the east Wekusko Lake area (based on Armstrong, 1941; Frarey, 1950; Gordon and Gall, 1982, and this study). Locations A to E are referred to in the text. Intrusions sampled for geochronology are labelled (1, 2, 3). Abbreviations: CBF-Crowduck Bay Fault, HLF-Herb Lake Fault, SBF-Stuart Bay Fault, SLF-Stuart Lake Fault, RLF-Roberts Lake Fault, LC-Lower conglomerate, MC-Middle conglomerate, UC-Upper conglomerate. Inset shows the location of the study area within the Trans-Hudson Orogen.

Volcanic rocks

The volcanic rocks have been subdivided into four lithological packages (Fig. GS-26-1), although the temporal and structural relationship between some of them are still unclear.

The **North Roberts Lake package** (Fig. GS-26-1) consists of amphibolite, that was originally pillowed and massive mafic flows, tuff, dykes and sills (Gordon and Gall, 1982). They are interpreted as Amisk in age, because they stratigraphically underlie Missi Group rocks to the west (Fig. GS-26-1).

The **Herb Lake fold package** (Fig. GS-26-1) is a complex sequence of volcanic rocks that includes the Chickadee Rhyolite, which has been dated at 1832 ± 2 Ma (Gordon *et al.*, 1990). The lack of pillowed mafic volcanic rocks, the presence of welded felsic rocks, and their apparent stratigraphic and temporal association with fluvial sedimentary rocks has been used to suggest that these volcanic rocks were dominantly subaerial and Missi in age (Shanks and Bailes, 1977; Gordon and Gall, 1982). However, results of this study suggest that contacts between the volcanic and sedimentary rocks are faulted and the structural character of the Herb Lake fold is unclear (see below).

On the western edge of the Herb Lake fold package is a heterogeneous package of feldspar phyric rhyolitic flows, quartz-feldspar porphyritic intrusions, felsic tuff and heterolithic debris flows, termed the **felsic volcanic package** (Fig. GS-26-1). Many of these rocks were originally identified as sedimentary rocks by Stockwell (1938) and Frarey (1950). At A (Fig. GS-26-1) felsic volcanic rocks consist of spherulitic rhyolite, overlain by graded-bedded ash and lapilli tuff that are unconformably overlain by polymictic conglomerate inferred to be Missi in age.

The **McCafferty Liftover package** comprises a succession of mafic and intermediate volcanic and volcaniclastic rocks that are well exposed along the east shore of Wekusko Lake (Fig. GS-26-1). Rock types include; 1) aphyric, plagioclase phyric, and amygdaloidal basaltic rocks that are commonly pillowed, 2) a sequence of intermediate agglomerates and graded turbiditic crystal tuffs indicating younging to the east (location B, Fig. GS-26-1), and 3) a heterogeneous package of dacitic flows or intrusions, heterolithic debris flows and volcanic breccia (Armstrong, 1941). Overall, shoreline outcrops suggest that a compositionally evolving package of mafic to intermediate volcanic and volcaniclastic rocks were deposited in a submarine environment. This contrast in depositional environment with that inferred for the volcanic rocks in the **Herb Lake fold package** (Fig. GS-26-1) and the apparently underlying Missi Group fluvial sedimentary rocks indicates either a complex volcanic paleogeography, and/or significant variations in the age of the volcanic rocks.

STRUCTURAL OBSERVATIONS

Fold and cleavage generations

Disharmonic, noncylindrical synsedimentary folds occur within the sandstones of the Missi Group at the north end of Stuart Lake (Fig. GS-26-1).

Early deformation in the form of S_1 cleavage has been identified at a few localities, but no F_1 folds have been recognized. In the core of the F_2 syncline at location A (Fig. GS-26-1) some pebbles in the Missi conglomerate preserve an E-W, bedding parallel fabric that is overprinted by S_2. In the File Lake formation, S_1 has been locally observed subparallel to bedding and S_2 and F_2 overprint boudinaged gabbro sills and quartz veins. The dominant northeast-striking S_2 foliation is largely parallel to layering and is axial planar to tight to isoclinal folds. Isoclinal folds with thickened hinges and thinned limbs occur throughout the File Lake Formation and F_2 fold hinges are commonly truncated by cleavage parallel faults. Several map scale folds within the Missi Group are interpreted as F_2 based on correlation of S_2 from the File Lake formation to the Missi Group. The Herb Lake fold (Fig. GS-26-1) is also interpreted as F_2 although it is uncertain, however, whether this structure is synformal or antiformal because the limbs are subparallel and the hinge is poorly exposed. Outcrop scale matrix-porphyroblast relationships suggest that metamorphism was contemporaneous with F_2/S_2 deformation. In biotite grade rocks, S_2 is defined by phyllosilicates that have crystallized/recrystallized syn- to post-S_2. In the staurolite-garnet zone, S_2 is deflected around staurolite porphyroblasts and the biotite is aligned, although the garnets overgrow the cleavage. Locally developed quartz-sillimanite nodules in the Missi Group rocks are flattened in S_2. The L_2 stretching lineation is developed in all units and is defined by elongate minerals in the S_2 cleavage, and by stretched clasts in conglomerate, agglomerate and breccia. In the south, the lineation plunges steeply (70-80°) north-northeast, but shallows to approximately 30° near the garnet-biotite-sillimanite isograd east of the Crowduck Bay Fault (Fig. GS-26-1).

F_3 folds and a weak S_3 phyllosilicate cleavage are developed within the eastern package of Missi Group rocks (Fig. GS-26-1). The map scale antiform within the granitic rocks west of the Crowduck Bay Fault (Fig. GS-26-1) is also interpreted as F_3 because it overprints isoclinal folds (F_2) on the west shore of Wekusko Lake (Bailes 1992). A well developed, northerly-striking S_4 phyllosilicate cleavage overprints F_3 folds at Puella Bay, although its origin is unknown.

Faulting

Although previous workers interpreted most contacts between lithological packages as stratigraphic, new observations suggest that these packages are fault bounded. These faults are described from west to east.

Crowduck Bay Fault:

The contact between the File Lake formation and the western Missi Group package was interpreted as sedimentary by Frarey (1950), but was interpreted as a fault by Gordon and Gall (1982). Faulting is suggested by truncation of the Missi conglomerate east of Crowduck Bay (Fig. GS-26-1), and the consistent orientation of S_2 and L_2 at D (Fig. GS-26-1) suggests that the fault formed pre- to syn-S_2/F_2.

Herb Lake Fault:

The eastern contact of the western package of Missi Group with the felsic volcanic rocks has been interpreted as stratigraphic (Armstrong 1941; Frarey 1950). However, at location A (Fig. GS-26-1) where Missi conglomerate unconformably overlie felsic volcanic rocks, these rocks are folded by a F_2 syncline and the hinge is truncated against the felsic volcanic package to the east. This fault is interpreted as syn- to post-F_2.

Stuart Bay Fault:

The eastern contact of the Herb Lake fold package of volcanic rocks with the eastern Missi Group package has similarly been interpreted as stratigraphic (Frarey 1950). Along the shore of Lostfrog Lake (Fig. GS-26-1) sandstone and mafic tuff are intensely silicified and there is evidence of mm scale brecciation, and at E (Fig. GS-26-1) a felsic igneous rock is brecciated near the contact with Missi sandstone. The breccias and alteration are overprinted by S_2/L_2. The absence of the lower Missi conglomerate (LC) and part of the overlying sandstone at Puella Bay also indicates a faulted contact.

Stuart Lake Fault:

The Stuart Lake Fault occurs within Missi Group sedimentary rocks and disrupts the hinge of the F_2 anticline between Stuart and Lostfrog lakes (Fig. GS-26-1). This fault likely merges with the Stuart Bay Fault to the north and/or the south.

Roberts Lake Fault:

The Roberts Lake Fault (Frarey, 1950; Bailes, 1985) juxtaposes the North Roberts Lake mafic volcanic package with Missi Group rocks of the eastern package, and truncates the Stuart Bay and Herb Lake faults before changing orientation and continuing north (Fig. GS-26-1). The N-striking section of the contact between the mafic volcanic rocks and Missi Group sedimentary rocks has been interpreted as a fault (Gordon and Gall, 1982), although is interpreted here as a stratigraphic contact. The Roberts Lake Fault is therefore interpreted to cut up section into the Missi Group sedimentary rocks and juxtapose this sequence of mafic volcanic and Missi Group sedimentary rocks with the western Missi Group package (Fig. GS-26-1). The apparent "folding" of this fault (Fig. GS-26-1) appears to result from topography and/or a frontal or lateral ramp.

PRELIMINARY STRUCTURAL INTERPRETATION

Overprinting relationships indicate that the Crowduck Bay and Stuart Bay faults formed pre- to syn-S_2, the Herb Lake and Stuart Lake faults syn- to post-S_2, and the Roberts Lake fault, that cross-cuts the Stuart Bay and Herb Lake faults, at a later stage during the same progressive deformational event. The intimate relationship between folding and faulting, and the attitude of the Stuart Bay fault prior to being folded by steep F_3 folds suggest development in a fold and thrust belt. Unfortunately, the original orientation and movement direction of the folds and faults is uncertain.

Pre- to syn-S_2 porphyroblast growth indicates that metamorphism occurred during this stage of shortening/thickening. This also suggests that, in order to account for syn-F_2/S_2 metamorphism, substantial thickening must have occurred prior to this phase of deformation. It is likely that pervasive deformation during folding (F_2/S_2) and thrusting may have obliterated any early structures.

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GS-27 NATMAP DIAMOND DRILLING PROGRAM: ADDITIONAL INSIGHTS ON THE SUB-PHANEROZOIC GEOLOGY SOUTH OF THE FLIN FLON-SNOW LAKE BELT

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SUMMARY

The NATMAP diamond drilling program is an important aspect of the coordinated efforts by the federal and provincial surveys to map and understand the geology of the sub-Phanerozoic continuation of the economically prospective Flin Flon-Snow Lake Belt.

So far, this program has been successful in providing crucial drill core data, and thus better ground control, in areas that have no or relatively few industry drillholes. As well, the presence of structures proposed from previous geophysical interpretation have been tested through carefully positioned drillsites, contributing to a regional framework for the overall structure of the buried Precambrian basement. The new drill core data have been incorporated into the digital GIS geoscience database of the NATMAP Shield Margin Project, and are being used in ongoing sub-Phanerozoic interpretation studies. The ultimate goal is to release a 1:100,000 scale compilation map of the sub-Phanerozoic basement geology at the conclusion of the NATMAP Shield Margin Project.

INTRODUCTION

Regional geological mapping of the sub-Phanerozoic segment of the Flin Flon-Snow Lake Belt represents one of two main components of the NATMAP Shield Margin Project (Lucas, 1992). This task is being undertaken principally by the Geological Survey of Canada with the collaboration of the Manitoba Geological Services Branch and Saskatchewan Geological Survey, and involves the integration of extensive regional drill core mapping with high resolution aeromagnetic (residual total field and vertical gradient) and gravity data (see Leclair *et al.*, 1993a).

Although mineral exploration industry drill core provides the most important sampling source of Precambrian basement rocks, the majority of the industry targets are highly magnetic or electromagnetically conductive zones. Therefore, the NATMAP project is supported by a diamond drilling program in order to; (1) obtain maximum regional coverage and a reconnaissance collection of all major subsurface Precambrian rock units, and (2) provide critical ground control in selected problematic areas identified through potential fields interpretation. Under this program, a total of 286.50 m of sub-Phanerozoic Precambrian core has been retrieved from twenty diamond drillholes during the summers of 1992 and 1993 by the Manitoba Geological Services Drilling Crew. The results of the 1992 drilling (Weber, 1992) were incorporated into the new 1:250,000 scale compilation map of both exposed and sub-Phanerozoic Precambrian geology for the Cormorant Lake sheet (NTS 63K) (see Manitoba Energy and Mines, 1992; Lucas and the NATMAP Shield Margin Project Working Group, 1993).

In this report, we focus on the second set of 12 diamond drillholes completed during the summer of 1993. Following a brief description of the core recovered from each hole, the results of the NATMAP diamond drilling program are placed in a regional geological context. Detailed logs of this years drill core are included in Table GS-34-1 (Bezys, GS-34, this volume).

GENERAL GEOLOGY AND GEOPHYSICS

The regional structural grain of the sub-Phanerozoic Precambrian rocks trends south-southwest, as indicated by the prominent aeromagnetic anomaly patterns (see Fig. 5 in Leclair *et al.*, 1993a). In general, this mimics structural trends on the exposed shield and suggests that some of the geological elements of the Flin Flon-Snow Lake Belt extend beneath the Phanerozoic sedimentary cover.

The sub-Phanerozoic Precambrian basement in the Cormorant Lake area (NTS 63K) has been subdivided into the Athapapuskow Domain, Clearwater Domain, Namew Gneiss Complex and Cormorant Batholith (Fig. GS-27-1) based on their distinct lithostructural characters and aeromagnetic anomaly patterns (Leclair *et al.*, 1993a, 1993b, 1993c). Six main rock units and three subunits have been delineated within these geological-geophysical entities (Fig. GS-27-1).

The Athapapuskow Domain is an arcuate, concave to the east, fault-bounded belt of foliated metavolcanic/volcaniclastic rocks (unit Av; Fig. GS-27-1) with a striped (striated) magnetic anomaly pattern. It extends southward from the shield margin to, at least, the southern edge of the map area. The rocks are predominantly greenschist grade, but the grade increases to amphibolite facies near granitoid plutons in the south. They are separated from orthogneisses of the Namew Gneiss Complex by the inferred sub-Phanerozoic continuation of the South Athapapuskow Lake Fault (SALF, Fig. GS-27-1). Near the shield margin, the contact between these two lithotectonic elements is defined by E-W trending fault zones that appear to accommodate a component of north-side-down displacement as implied by an abrupt change in metamorphic grade. To the west, the Athapapuskow Domain is bounded by the Namew Lake Structure. The continuity of the striped magnetic anomaly patterns from the back-arc Athapapuskow Assemblage, exposed at the shield margin, toward the south-southwest suggests that metavolcanic rocks of the Athapapuskow Domain are correlative with this assemblage (Leclair *et al.*, 1993c).

The Clearwater Domain is a broad, south-southwest trending volcanoplutonic domain (Fig. GS-27-1) with a generally corrugated aeromagnetic pattern. It is represented by layered sequences of intercalated, dominantly amphibolite facies, mafic metavolcanic and metasedimentary rocks (unit Aa) that are intruded by felsic and mafic plutons (units T, Ta, G, Ga and Um). This domain extends southward from the edge of the Precambrian Shield to the bottom of 63K and is intruded by the Cormorant Batholith. The overall structure has a predominant east-southeast dip and appears to be mainly homoclinal (Leclair *et al.*, 1993b). The Clearwater Domain is interpreted to represent the subsurface extension of the Flin Flon Assemblage as exposed in the File Lake-Snow Lake area (Leclair *et al.*, 1993a). This interpretation is supported by the unbroken continuity of linear aeromagnetic and gravity anomalies across the shield margin south of Snow Lake.

The Namew Gneiss Complex is a heterogeneous domain of variably-deformed granitoid rocks (subunit Ta) with metre to kilometre scale enclaves of mafic, psammitic and pelitic gneisses (subunit Aag). It displays curvilinear, cusp-shaped aeromagnetic highs that outline a generally north- to northwest-dipping structural pattern. In the southeastern part of the complex, interlayered orthogneiss and paragneiss delineate a series of tight northeast-trending folds that are overturned to the east (Leclair *et al.*, 1993b). Initial epsilon Nd values (Stern, unpublished data) and tentative crystallization ages for the Namew Gneiss Complex (U-Pb zircon age of 1880±2 Ma, Stern *et al.*, 1993; see also Cumming and Krstic, 1991) are similar to those obtained in the Flin Flon-Snow Lake Belt. This implies that initial magmatism in the Namew Gneiss Complex may have occurred at an early stage in the development of the volcanic arc. The highly deformed nature and upper amphibolite grade of the metaplutonic complex further suggests that it may have been built up from multiple intrusions of tonalite-diorite sheets at midcrustal levels, and pos-

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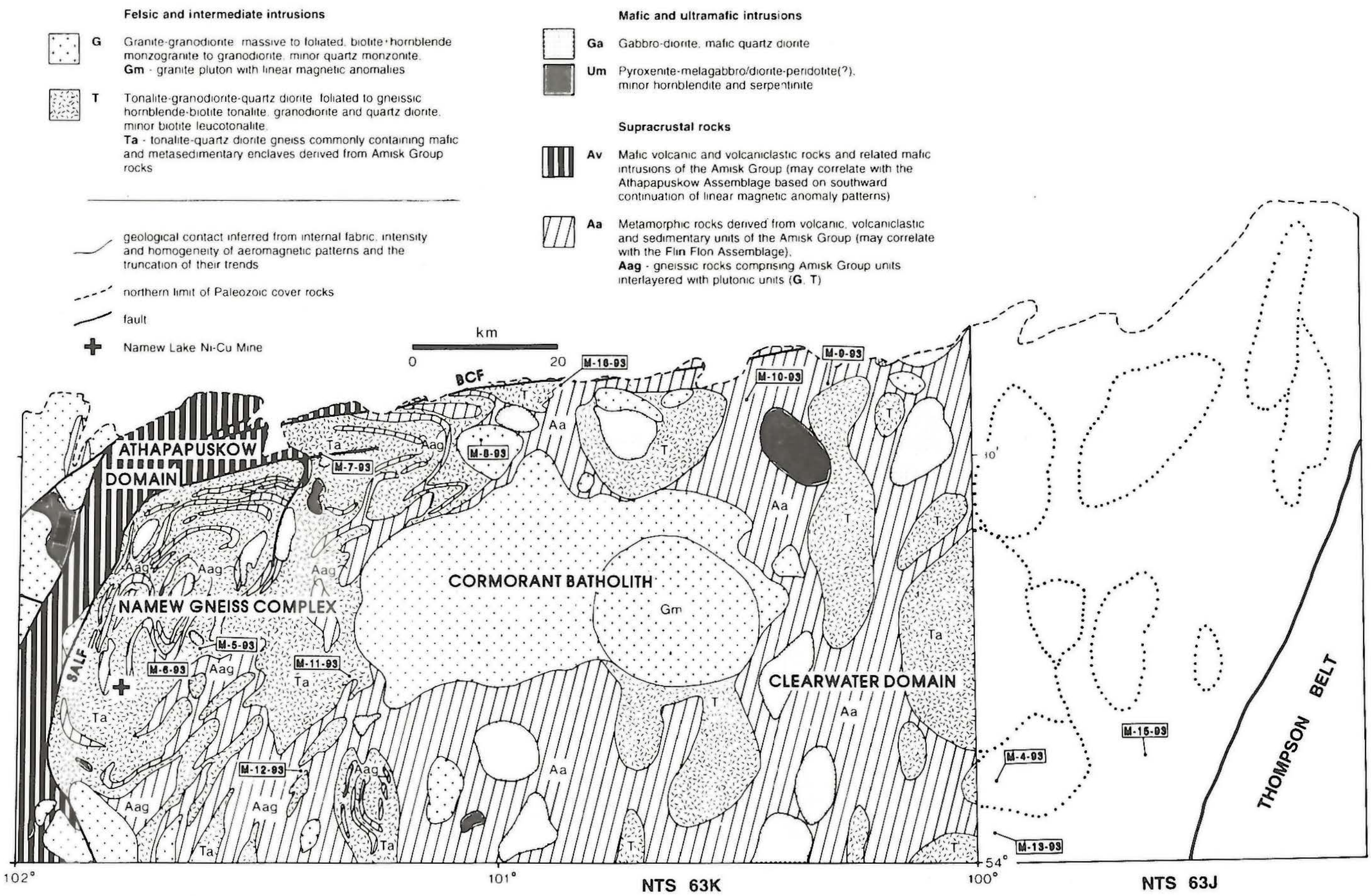

Figure GS-27-1: ***Simplified geological compilation map showing the location of drillholes of the 1993 NATMAP diamond drilling program. The subPhanerozoic basement geology of the Cormorant Lake sheet, NTS 63K, is modified from Leclair et al. (1993a). The outlines of some granitoid intrusions inferred from aeromagnetic anomaly patterns are shown by the dotted lines on the preliminary subPhanerozoic interpretive map for the Wekusko Lake (west half) sheet, NTS 63J. The western limit of the Thompson belt is approximate. BCF-Berry Creek fault; NLS-Namew Lake structure; SALF-South Athapapuskow Lake fault.***

sibly represents a deeper portion of the Flin Flon magmatic arc that formed during a crustal thickening event (Leclair *et al.*, 1993c).

The south central part of NTS 63K contains the 60 x 25 km Cormorant Batholith, characterized by an aeromagnetically neutral pattern and locally subtle semiconcentric and linear anomalies (unit G and subunit Gm; Fig. GS-27-1). On the Bouguer gravity map (Broome *et al.*, 1993), a regional low is centred over the northeastern half of the batholith and decreases in intensity to the southwest and over the Namew Gneiss Complex. The Cormorant Batholith clearly crosscuts the structural trend of the Clearwater Domain, indicating that its emplacement was late tectonic (Leclair *et al.*, 1993a). A biotite monzogranite core sample from the central part of the batholith yielded a U-Pb zircon age of 1845+10/-8 Ma (Blair *et al.*, 1988). An improved age of 1831+5/-4 Ma was obtained for this sample (Stern *et al.*, 1993), coinciding with the latest major phase of plutonism in the Flin Flon-Snow Lake Belt.

DESCRIPTION AND INTERPRETATION OF PRECAMBRIAN DRILL-CORE DATA

The NATMAP diamond drillholes that are intended to complement the industry drill core database were carefully positioned over selected aeromagnetic anomalies that either lack "ground truthing" or mark the locus of inferred major sub-Phanerozoic basement structures (Fig. GS-27-1). In order to aid in the interpretation of the new 1993 drill core data, some results from the earlier Manitoba "scout" drilling program are incorporated in the following discussion. Note that the core axis (inclination) of the drillholes is vertical.

M-4-93 (NTS 63J-southwest corner)

A diamond drillhole was completed at this location (Fig. GS-27-1) to ground truth a subcircular, moderate- to high-intensity positive aeromagnetic anomaly that appears on the new high resolution vertical gradient and residual total field maps (Geological Survey of Canada, 1993). About four metres of foliated homogeneous granodiorite was retrieved at that locality; the depth to Precambrian basement is 113.70 m. The rock is light pink and medium grained, containing 25 to 35% combined hornblende, biotite and epidote. At present, we interpret the granodiorite to be part of a pluton with variable magnetic susceptibility, in turn resulting in the aeromagnetic anomaly. This pluton may represent the southeastern part of a large multi-intrusion granitoid complex including unit Ta, which straddles the map boundary of 63K and 63J (Fig. GS-27-1).

M-5-93 (NTS 63K-Namew Gneiss Complex)

This drillsite was positioned over a northeast-trending aeromagnetic lineament to test the hypothesis that this structure may represent the locus of a major fault zone within the Namew Gneiss Complex (Leclair *et al.*, 1993b). The Precambrian basement rocks retrieved below the Precambrian-Phanerozoic unconformity (depth of 63.20m) are mixed amphibolite and granitoid rocks. The amphibolite (60% of the core) is medium grained and contains some epidote. It is injected by light grey to pink, fine- to medium-grained, leucocratic hornblende-biotite-epidote tonalite and/or granodiorite. The presence of minor late brittle faults in the drill core may be interpreted as indicating proximity to a fault, but whether it is part of a suspected major fault zone is uncertain.

M-6-93 (NTS 63K-Namew Gneiss Complex)

This drillhole also lies within the Namew Gneiss Complex, and was targeted to examine the geological nature of the northern extension of a prominent north- to north-northeast trending aeromagnetic low that arches around and south of the Namew Lake Mine (Fig. GS-27-1). The Precambrian basement rocks, 63.15 m below the erosion surface, consist of strongly layered, heterogeneous orthogneisses. The dominant rock type is a grey, leucocratic to mesocratic, hornblende-biotite-epidote-titanite tonalite gneiss. It is complexly interlayered with minor mafic (hornblende-biotite) diorite gneiss and rare clinopyroxene-rich layers. These rocks are typical of the upper amphibolite grade sequence of tonalite-diorite gneisses (unit Ta; Fig. GS-27-1) that make up most of the Namew Gneiss Complex (Leclair *et al.*, 1993a). The strong gneissic foliation, with a dip of 40 to 45°, is also observed in the same orthogneiss sequence at the Namew Lake Mine (D. Price, pers. comm. 1993).

M-7-93 (NTS 63K-Namew Gneiss Complex)

Located on Highway 10, about 5 km from the edge of the Precambrian Shield, this drillsite was selected to ground truth the extension of an easterly-trending fault zone interpreted from a steep, linear aeromagnetic gradient to the west and from truncations of reflections on LITHOPROBE seismic profiles (Lucas *et al.*, in press). The Precambrian is overlain by approximately 3.90 m of overburden; Phanerozoic cover rocks are missing. The drill core comprises medium grained, mesocratic hornblende-biotite-epidote-titanite quartz diorite with minor crosscutting pegmatite veins. These rocks are massive and homogeneous and lack any evidence of fault-related deformation. However, such evidence can be found at drillsite M-15-86, just 1 km further south. There, the subsurface Precambrian rock is a leucocratic hornblende monzogranite cut by discrete fractures and millimetre thick cataclastic zones (McRitchie and Hosain, 1986; Leclair, unpublished data).

Furthermore, the different lithology between these two drillsites is consistent with the presence of a intervening fault zone.

M-8-93 (NTS 63K-Satellite intrusion of Cormorant Batholith)

A massive, leucocratic hornblende-biotite-epidote-titanite granodiorite injected by minor pink aplite dykes was cored at this site. It was recovered from below 23.55 m of Phanerozoic cover rocks near the centre of a circular aeromagnetically low domain (unit G, Fig. GS-27-1). Leclair *et al.* (1993a) had interpreted this domain to be a satellite granite-granodiorite intrusion of the Cormorant Batholith on the basis of comparable intensity and internal fabric of the magnetic anomaly patterns. Previous drilling into the northern margin of the unit yielded a similar rock type (see drillsite M-12-84 in McRitchie and Hosain, 1984). Both core samples show strong mineralogical and textural affinities to those of the Cormorant Batholith, supporting the above interpretation.

M-9-93 (NTS 63K-Clearwater Domain)

This drillsite (Fig. GS-27-1) was selected to verify the interpretation of an elongate gradiometer anomaly as a granitoid pluton (unit T, Leclair *et al.*, 1993a). On the Bouguer gravity map (Broome *et al.*, 1993), the northern half of this inferred pluton is situated in the "saddle" of two flanking gravity highs associated with mafic (unit Ga) and ultramafic (unit Um) intrusions to the east and west, respectively. Beneath the Precambrian-Phanerozoic unconformity (25.60 m deep), the drilling yielded 35 m of low grade, thinly laminated, graphitic mudstone, locally interbedded with siltstone. This drill core data indicate that the northern contact of the inferred granitoid pluton is further to the south than previously mapped. Reevaluation of high resolution aeromagnetic data in light of these new results suggests that the curvilinear magnetic high in the same area is probably caused by a sequence of supracrustal rocks belonging to unit Aa.

M-10-93 (NTS 63K-Clearwater Domain)

Diamond drilling at this site was targeted to intersect one of a series of irregular north-northeast trending aeromagnetic anomalies (high and low intensities) interpreted to be associated with a sequence of metavolcanic and metasedimentary rocks contiguous with the Amisk Group in the exposed shield. Below a small section of unconsolidated Paleozoic sandstone (<14.40 m) over 24 m of strongly sheared melagabbro/diorite was encountered. The mafic rock is intersected by numerous cataclastic zones and fractures and includes some highly altered sections of chlorite schist. A well-developed shear foliation has a dip of 60 to 65°. The drill core data suggest the presence of a previously unrecognized fault zone with no observable aeromagnetic expression. Drilling less than 5 km to the west of the present drillsite yielded 40 m of highly chloritized and cataclastically deformed granite-granodiorite (hole GSC-A12; unpublished data), which may represent an across strike extension of the same fault zone. The lack of apparent truncation of the magnetic anomalies in this area may imply that faults parallel the north-northeast trending lithostructural grain inferred from the aeromagnetic fabric.

M-11-93 (NTS 63K-Namew Gneiss Complex)

This drillsite was selected to determine the source of a high amplitude positive aeromagnetic anomaly, and at the same time verify the interpreted southwestern limit of the Cormorant Batholith. Previous drilling at the edge of the anomaly (hole M-13-87; Weber and Hosain, 1987) yielded mainly hornblende-biotite-plagioclase-quartz gneisses that were derived probably from mafic quartz diorite-tonalite (Leclair, unpublished data).

These gneisses are moderately to strongly magnetic and are cut by biotite-magnetite leucogranite. Further to the east, two drillholes from the 1992 NATMAP drilling program (*i.e.* M-18-92 and M-19-92; Weber, 1992), and one from the earlier "scout" program (*i.e.* M-17-85; McRitchie and Hosain, 1985) penetrated granitic rocks and associated pegmatite of the Cormorant Batholith. At the present site (hole M-11-93, Fig. GS-27-1), the basement rocks, which are buried beneath 66.75 m of overburden and Phanerozoic sediments, are mainly heterogeneous biotite-magnetite-hornblende tonalite gneisses with a near vertical gneissic foliation. The gneisses include coarse grained tonalitic veins and are cut by magnetite-bearing pegmatite dykes. The large positive anomaly in the area can be attributed to the relatively strong magnetic susceptibility of these granitoid rocks.

Cross-cutting pegmatites such as those observed in this core are common in tonalitic gneisses of the Namew Gneiss Complex.

M-12-93 (NTS 63K-Clearwater Domain)

The neighbouring drillholes, more than 5 km from the present site (Fig. GS-27-1), indicate that the Precambrian basement consists of mixed metasedimentary and mafic gneisses and variably-deformed granitoid rocks (Leclair *et al.*, 1993a, unpublished data). The structure of the basement is characterized by an alternating series of slightly arcuate northeast-trending aeromagnetic highs and lows, which have been inferred to represent tight to isoclinal folds that developed in a complexly interlayered sequence of orthogneiss and paragneiss (Leclair *et al.*, 1993b). Hole M-12-93 penetrated one of these magnetic lows, where the Precambrian basement rocks (>90.60 m below the erosion surface) are well layered mesocratic biotite-hornblende orthogneisses with local disseminated sulfides and quartzofeldspathic veins. The foliation dips 30 to 45°. These rocks are, in part, oxidized and retrogressed where narrow cataclastic zones and brittle fractures are present. The limited extent (<4 m wide) of these structures suggests only minor faulting. Similar rock types in the area display a wide range of magnetic susceptibilities. However, the commonly applicable correlation of granitoid rocks with low intensity aeromagnetic anomalies (Leclair *et al.*, 1993a) is favored in this case.

M-13-93 (NTS 63J-southwest corner)

Some parts of the sub-Phanerozoic Precambrian basement have moderate magnetic relief with a striated to corrugated texture. These magnetic anomaly patterns are most commonly associated with metavolcanic and metasedimentary sequences of the Amisk Group (Leclair *et al.*, 1993a). In the southwestern corner of NTS 63J, drillsite M-13-93 (Fig. GS-27-1) is situated over such a magnetic pattern displaying a slightly curvilinear east-west fabric. At this locality, the 10 m of Precambrian core acquired beneath 112.80 m of Phanerozoic cover rocks comprise fine- to medium-grained psammitic metasedimentary rocks containing biotite and garnet porphyroblasts. The metasedimentary rocks are homogeneous with a weak foliation (dipping 50°) and contain isolated coarser grained leucocratic pods that may represent an *in situ* partial melt phase. Based on their magnetic characteristics these rocks are most likely part of a metasedimentary-metavolcanic belt that skirts the eastern margin of the granitoid complex (unit Ta, Fig. GS-27-1) and other inferred granitoid plutons, and extends northward to the shield margin where it joins the Snow Lake portion of the greenstone belt.

M-15-93 (NTS 63J-southwest corner)

Hole M-15-93 (Fig. GS-27-1) penetrates the inferred extension of the same striated magnetic anomaly pattern as examined in the previous drillhole. The Precambrian basement, overlain by about 112.40 m of Phanerozoic rocks, is made up of massive, fine- to medium-grained biotite-bearing amphibolite with minor thin (<20 cm) pegmatite veins.

Locally, a weak foliation defined by the preferred alignment of hornblende dips 60 to 80°. In the exposed Flin Flon-Snow Lake Belt, similar rock types at subgreenschist facies and low strain states are associated with mafic volcanic/volcaniclastic sequences. This result supports the above interpretation of a metasedimentary-metavolcanic belt that extends north-northeastward from drillsite M-13-93 to at least M-15-93.

M-16-93 (NTS 63K-Clearwater Domain)

The Berry Creek Fault can be traced for approximately 150 km on aeromagnetic maps, from the exposed shield northeast of Snow Lake to the southwest and west along the shield margin. In the Snow Lake area, it separates two geological domains of disparate geology (Bailes, 1992). The core samples of four "scout" drillholes located within <3 km of the presumed fault trace did not provide definite proof for the existence of a fault, except for rare near vertical fractures (*i.e.* M-8-84, M-11-84, M-8-85 and M-22-86; McRitchie and Hosain, 1984, 1985, 1986; Leclair, unpublished data). Drillsite M-16-93 is located approximately 1 km from the shield edge, where north-trending aeromagnetic anomalies are abruptly truncated against and/or swing, with a dextral shear sense, into the inferred western extension of the Berry Creek Fault (Fig. GS-27-1). The drilling intersected deformed granitoid rocks with a mylonitic laminated layering that are structurally overlain by a highly sheared to mylonitic supracrustal sequence consisting of mafic metavolcanic rocks (chlorite-epidote schist) and felsic dykes. These sheared rocks are in turn largely carbonitized and cataclastically brecciated. The mylonitic foliation dips 70 to 90°, and locally is tightly folded. The drill core is identical to surface exposures of the Berry Creek fault in northern Simonhouse Lake (E. Syme, pers. comm., 1993; *cf.* Syme, GS-15, this volume). These data establish the cause of aeromagnetic anomaly truncations near the Phanerozoic-Precambrian boundary to be brittle/ductile faulting associated with the Berry Creek Fault.

It should be noted that M-16-93 is located on the boundary between the Namew Gneiss Complex and Clearwater Domain delineated by Leclair *et al.* (1993a). On the LITHOPROBE seismic reflection profile of highway 39 (line 3), this boundary coincides with a moderately east-dipping reflective zone that separates contrasting reflectivity patterns attributed to these two lithostructural domains. This boundary has been interpreted as a major décollement that floors upper crustal arc rocks of the Flin Flon-Snow Lake Belt (Lucas *et al.*, in press), separating them from the footwall orthogneisses of the Namew Gneiss Complex.

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GS-28 STRUCTURAL STUDIES ALONG THE NORTHERN MARGIN OF THE FLIN FLON-SNOW LAKE GREENSTONE BELT, SNOW LAKE

by J. Kraus[1] and P.F. Williams[1]

Kraus, J. and Williams, P.F., 1993: Structural studies along the northern margin of the Flin Flon-Snow Lake greenstone belt, Snow Lake; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 117-118.

SUMMARY

The relationship of metamorphic minerals and structural fabrics suggests that peak metamorphism in the Snow Lake area occurred during F_2 between 1850 Ma (youngest detrital zircon in the File Lake formation) and 1834 Ma (the age of the post-F_3 Wekusko Lake pluton). Peak metamorphic grade in the Snow Lake area decreases from amphibolite facies in the vicinity of the McLeod Road fault to upper greenschist facies south of the Berry Creek shear zone.

INTRODUCTION

Detailed structural analysis with localized lithological mapping was conducted in the Snow Lake-Wekusko Lake area during the 1992 and 1993 field seasons. The field work is part of a PhD study currently underway at the University of New Brunswick in conjunction with the NATMAP project. Although much attention has been paid to the area over the last two decades (*e.g.* Froese and Moore, 1975; Froese and Moore, 1980; Bailes *et al.*, 1991), little emphasis was placed on structure. The objective of this study is to delineate the structural and metamorphic evolution of this eastern segment of the Flin Flon-Snow Lake greenstone belt.

The northern limit of the study area extends from the northwest end of Snow Lake eastward along the McLeod Road fault to Bart Lake (east of Kormans Lake). The southern limit extends from Wedge Point on Wekusko Lake to the contact of the Wekusko granite on the west shore of Wekusko Lake (*cf.* Bailes, 1992).

GEOLOGICAL SETTING

The study area is located in the Flin Flon-Snow Lake greenstone belt within the Early Proterozoic Trans-Hudson orogenic belt. In the Snow Lake area, the greenstone belt comprises both arc and back-arc volcanic assemblages (Amisk Group), which are in structural contact with a younger metaturbidite sequence (File Lake formation). The arc volcanic sequence is composed of bimodal mafic and felsic volcanic flows, volcaniclastic rocks and minor intercalated metasediments (Bailes, 1990, 1992; Bailes and Galley, 1990, 1992). A U-Pb zircon age of 1892±4 Ma is interpreted as the crystallization age for Amisk volcanic rocks (Machado and David, 1992; David *et al.*, 1993). An 1886 ± 2 U-Pb zircon age is interpreted as the crystallization age for a synvolcanic tonalite pluton intruding the Amisk Group (Gordon *et al.*, 1990; Bailes *et al.*, 1991). U-Pb detrital zircon ages from the File Lake formation indicate deposition between 1857 and 1850 Ma (David pers. comm. 1993). The late- to post-tectonic Wekusko Lake pluton gives a U-Pb zircon age of 1834 +8/-6 Ma (Gordon *et al.*, 1990) and titanite age of 1841± 4 (David pers. com., 1993). Geochronology samples from the adjoining Tramping Lake Pluton are currently being processed.

STRUCTURE

Deformation in the Snow Lake area is predated by intrusion of layer-parallel mafic sills. The sills are abundant in Amisk Group rocks north of the McLeod Road fault, but only a few sills appear in rocks south of the fault (*e.g.* at Anderson Lake).

F_1 and F_2 folds

Three generations of folds (F_1, F_2 and F_3) have been recognized in the Snow Lake area. F_1 and F_2 folds, interpreted to be coeval with prograde metamorphism, are tight to isoclinal and occur in File Lake formation metaturbidites both at the town of Snow Lake and at Wekusko Lake. Although F_1 and F_2 folds are indistinguishable in terms of their style or orientation, two fold events are indicated by the presence of both S- and Z-shaped minor folds on the same limb of macroscopic F_1 structures (there is no evidence that these folds are doubly plunging F_1 fold pairs parasitic to macroscopic F_1 sheath folds). F_1 and F_2 folds are locally dismembered by shearing parallel to their limbs or their axial planes. In the latter case, the presence of folds is indicated only by bed facing reversals across the axial planar shears. Axial plane shears are commonly identified by thin quartz veins intruded along them. F_1 and F_2 fold axes have a moderate to steep plunge mainly to the northeast. F_1 and F_2 axial planes are inclined at moderate to steep angles towards the north at Snow Lake and are subvertical on islands in north Wekusko Lake.

An S_1 foliation, defined by alignment of biotite and amphibole, is well developed axial planar to F_1 folds in Amisk rocks. North of the Berry Creek shear zone, this S_1 foliation is overgrown by porphyroblasts. Quartz stretching lineation and elongation of amphibole and clasts, L_1, are sub-parallel to the F_1 fold axes. S_1 and L_1 are rare in the metaturbidites.

The most prominent macroscopic F_1 structure is the northeast closing Anderson Bay anticline (Jeffery, 1982). The axial trace of this fold trends northeast of Anderson Bay through Kormans Lake. The Amisk Group succession is structurally thinned on the overturned southern limb of the Anderson Bay anticline along Wekusko Lake. This structural thinning is interpreted to be a consequence of shearing of the overturned limb.

F_2 folds overprint F_1 structures. They occur only at cm to m scale in contrast to F_1 folds, which are developed from microscopic to macroscopic scale. F_2 folds exclusively have S-asymmetry and must have resulted from sinistral layer parallel shear. In overturned strata, F_2 folds are downward facing. In the metaturbidites along Snow Lake a penetrative S_2 foliation is the dominant fabric. It is defined by the alignment of coarse biotite and up to 14 cm long pulled-apart staurolite porphyroblasts. In some micaceous units, S_2 is a spaced cleavage, resulting from microfolding of a bedding cleavage (S_0). In muddy Bouma E horizons S_2 is refracted due to sinistral F_2 shear and thus exhibits a lower angle to bedding (Ss). Locally, S_2 is parallel to Ss. In Amisk Group rocks, no F_2 folds have been found and S_2 is only locally developed in hornblendic mafic lithologies.

McLeod Road fault and Snow Lake fault

F_1 structures and lithological units are cut at low angles by a parallel fault pair, the McLeod Road fault and the Snow Lake fault. An isoclinally folded File Lake formation metaturbidite sequence is sandwiched between these faults.

The steep north dipping McLeod Road fault has a listric geometry (level plans of the Nor Acme mine, Hudson Bay Mining and Smelting, unpubl. data). It cuts up section to the west into younger Missi Group rocks and therefore dips steeper than the lithological contacts near the surface. The McLeod Road fault is only exposed at one location. At this locality, in the town of Snow Lake, it is a greater than 15 m wide east-trending zone of intensely deformed rocks containing massive quartz pods. A mylonitic foliation dips steeply to the north subparallel to Ss, and contains an amphibole elongation lineation that plunges steeply to the east-southeast. The McLeod Road fault preserves no evidence of brittle or brittle-ductile deformation.

The Snow Lake fault is not exposed. It is inferred from regional mapping (Bailes, 1990; Ziehlke pers. comm., 1993) as Amisk Group stratigraphy is cut off at a low angle to the north. The vicinity of the inferred fault is characterized by an increase in quartz-carbonate veining. The McLeod Road fault and Snow Lake fault are folded by F_3. They coalesce east of Snow Lake along Snow Creek.

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Deformation along the faults is interpreted as syn-F_2 with a superimposed sinistral strike slip component that brought Amisk Group rocks to a shallower crustal level. F_2 faulting/shearing is accompanied by sinistral tension gashes and minor F_2 S-asymmetric folds in the fault-bounded metaturbidite slice at Snow Lake. A microstructural study of the McLeod Road fault is in progress.

F_3 folds

Open to tight F_3 folds refold F_1/F_2 axial planes, F_2 shears and deform F_2 porphyroblasts. F_1, F_2 and F_3 folds are coaxial. F_3 axial-planes are oblique to F_1/F_2 axial-planes and have a steep east-southeast dip. Major F_3 structures have Z-asymmetry indicating reversal to dextral shear after F_2 folding. Mesoscopic F_3 folds typically show zigzag to kink-like geometries in thinly layered metaturbidites and layered Amisk Group rocks.

On the eastern limb of the F_3 Threehouse synform at Snow Lake, dextral, layer-parallel F_3 shear is prominently recorded by microfolded S_2 in Bouma E (mudstone) horizons. Limbs of these kink-like F_3 microfolds are transposed into a dominant S_3 fabric, which is parallel to major F_3 axial-planes. In competent Bouma A (greywacke) horizons S_2 is well preserved and S_3 is only poorly developed. Locally, the dominant fabric in competent beds is a composite S_2/S_3 foliation. Accentuation of S_2 and S_3 in competent and incompetent metaturbidite layers, respectively, gives them a herringbone-like appearance.

Berry Creek shear zone, Anderson Bay shear zone and Bartlett shear zone

The northeast-trending Berry Creek shear zone truncates F_3 structures and the undeformed northern margin of the Tramping Lake pluton. At the shear zone boundary, the transition from undeformed to ultramylonitic Tramping Lake granite is gradational over a width of a few centimetres. A stretching lineation in the mylonitic foliation plunges moderately to steeply towards the northeast/north-northeast. Stretching lineation and microfabrics, such as S/C-fabrics and shear bands, indicate sinistral southside-down movement. Within the Tramping Lake pluton, subsidiary centimetre wide shears, parallel to the main structure, are developed. The Bartlett and Anderson Bay shear zones probably represent splays from the Berry Creek shear zone. These three structures coalesce to the southwest at Berry Bay and to the northeast at Bart Lake. Boudinage of the mylonitic foliation and the presence of shear bands at microscopic to mesoscopic scale suggest the shear zones were narrowing in a dextral transpression.

Late structures

Brittle-ductile to brittle conjugate shear fractures and minor faults are present throughout the Snow Lake area, but are most intense in the vicinity of the shear zones at Wekusko Lake. Brittle fault gouge and, locally, S_3 are deformed by kink bands.

TIMING OF METAMORPHISM

North of the Berry Creek shear zone, S_1 in Amisk Group rocks is overgrown by subhedral to euhedral garnet, staurolite and kyanite porphyroblasts. The porphyroblasts contain S_1 inclusion trails. Garnet locally has a tabular shape that is interpreted to result from crystallization mimetic after S_1 differentiated layering (Zaleski and Halden, 1988). In some F_3 folds, the porphyroblasts are re-oriented parallel to the S_3 axial plane foliation.

In rocks of the File Lake formation, north of the Snow Lake fault, S_2 wraps around pulled-apart staurolite porphyroblasts. In thick, more competent beds, S_2 and porphyroblasts are re-oriented toward parallelism with F_3 axial-planes. In thin, pelitic horizons, where S_2 is subparallel to Ss, the original F_2 stretching direction, at a high angle to S_3, is preserved. Staurolite pull-aparts are folded by F_3 folds. Open mesoscopic folds along the west shore of Wekusko Lake are interpreted as F_3 structures based on style and asymmetry. These folds are cut by the 1841-1834 Ma Wekusko Lake pluton.

These observations imply that timing of the regional metamorphic peak, previously suggested as being coeval with F_3 (Threehouse synform generation; Froese & Moore, 1980; Bailes, 1992) at 1815 Ma (Gordon *et al.*, 1990) to 1810 (Machado and David, 1992), needs to be re-evaluated.

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GS-29 PETROLOGIC STUDIES OF THE REED LAKE GABBRO AND CLAW LAKE GABBROIC COMPLEX

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Williamson, B.L., 1993: Petrologic studies of the Reed Lake gabbro and Claw Lake gabbroic complex; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 119.

SUMMARY

Gravity surveys have been successful in confirming strike continuity of the Reed Lake Gabbro. The lower portion of this intrusion has weakly enriched PGE levels. Local rusty patches in the Claw Lake Gabbroic Complex have not been correlated with sulphide.

INTRODUCTION

Following field work undertaken in 1992 (Williamson, 1992; Syme, 1992), it was recognized that: 1) although rocks of the Reed Lake Gabbro outcrop extensively, heavy bush and lichen growth on the bedrock make a detailed study of the intrusion difficult; and 2) a previously unrecognized layered mafic-ultramafic intrusion is well exposed at Claw Lake due to 1989 forest fires. As a result, it was decided to curtail the intended work on the Reed Lake Gabbro (limiting it to completion of a cross section through its south end, along the Grass River), and refocus on the Claw Lake intrusion.

REED LAKE GABBRO

Additional gravity stations were established at the north and south ends of the Reed Lake Gabbro during the winter of 1993, under the NATMAP Shield Margin Project, and the results released as part of GSC Open File 2657 (Broome *et al*, 1993). At the north end, an additional cross section confirmed strike continuity of the previously recognized 15 mgal gravity anomaly, in contrast to aeromagnetic patterns (Konings, 1988) that suggest termination of the magnetic lenses into a variable magnetic pattern similar to the volcanic host rocks. This discrepancy between aeromagnetic and gravity data is unresolved.

Three weeks of further field investigation at Reed Lake succeeded in filling sampling gaps in the cross section along the Grass River. Several additional thin, fine grained melagabbro dikes or sills in leucogabbro underlying the western (uppermost) aeromagnetic anomaly were recognized and sampled. Intrusive breccia observed in outcrop along the Grass River shoreline (just above the lower rapids) in 1992 was traced further inland (for 150 m). An attempt was made to correlate rock variations with magnetic striping that occurs in the lower part of the intrusion, where last year's efforts succeeded in defining one of the magnetic lenses on the ground. This year's efforts to locate additional lenses were unsuccessful. Although distinct magnetic anomalies occur (175 nT, 50 x 1000 m, striking approximately N-S; Konings, 1988), all of the rock observed in a traverse across the area is nonmagnetic gabbro. Quartz-bearing, zirconium enriched rocks from the centre and roof of the intrusion were sampled for U-Pb zircon geochronological analysis to be conducted during next year.

Analyzed samples collected during the 1992 field season indicate weakly enriched levels of PGE, virtually all from the lower portion of the intrusion. Results from 124 samples are:

24 analyses: > 20 ppb Pt
32 analyses: > 20 ppb Pd
5 samples: > 100 ppb (Pt + Pd)

Two samples with the highest levels contain 117 ppb Pt + 134 ppb Pd and 89 ppb Pt + 176 ppb Pd. This corroborates enriched PGE levels reported by Gittings (1986) for samples from the same area.

CLAW LAKE GABBRO COMPLEX

Field mapping by Manitoba Geological Services Branch during 1992 in the Claw Lake area defined a previously unrecognized layered gabbroic intrusion (Syme, 1992). Syme divided the intrusion into two principal units: 1) an older Layered Series consisting of interlayered peridotite, pyroxenite, anorthosite and predominant gabbro (commonly altered variably or completely to amphibolite); and 2) a Younger Gabbro, consisting of massive, homogeneous gabbro with ultramafic lenses. The current work consisted of three weeks of field investigations focused principally on documenting and sampling the stratigraphy of ultramafic layers in the Layered Series, with limited reconnaissance in the Younger Gabbro.

In the Layered Series, two of the layered ultramafic horizons were investigated. They are well layered on decimetre scale, and in the field were described as peridotite (serpentine green or orange to rusty brown weathering), orthopyroxenite (weathering resistantly to grey), clinopyroxenite (weathering recessively to dark green), websterite (principally green clinopyroxenite containing pods of grey orthopyroxenite, centimetres thick x decimetres long), and gabbro or amphibolitized gabbro. Ultramafic layers have characteristic textures and consistent stratigraphic thicknesses and relationships that make them distinguishable over tens to a hundred metres strike length, and provide potentially good marker horizons. Chemical analysis to be undertaken over the ensuing year may allow recognition of differentiation trends within or between individual ultramafic units; field work next year is intended to describe and compare the remaining ultramafic units of the Layered Series.

In the Younger Gabbro, two of the ultramafic lenses investigated were found to be massive, serpentinzed peridotite with no internal layering and few distinguishing features. The host massive gabbro was prospected along parts of the shoreline of Claw Lake. Varitextured gabbro described by Syme (personal communication) suggests potential for Lac des Iles type PGE mineralization, but rusty patches observed in a few locales could not be correlated with sulphide. Field work next year is intended to investigate and sample the remaining ultramafic lenses in the Younger gabbro.

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GS-30 NATMAP SHIELD MARGIN PROJECT: PROGRESS REPORT ON GEOPHYSICAL STUDIES (WITH LITHOPROBE) AND THE DIGITAL GEOSCIENCE DATABASE

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Lucas, S.B., Broome, J., Viljoen, D., Thomas, M., Tanczyk, E., White, D. and Garson, D., 1993: NATMAP shield margin project: progress report on geophysical studies (with lithoprobe) and the digital geoscience database; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 120-122.

SUMMARY

Interpretation and publication of preliminary results from the first phase of LITHOPROBE seismic reflection data acquisition (1991) in the Trans-Hudson Orogen (THO) has occurred over the past year, resulting in 3 journal articles published or in press and two submitted as well as numerous oral and poster presentations.

The three-dimensional structure of the eastern THO is revealed through a network of LITHOPROBE seismic reflection profiles that cross the Flin Flon-Sherridon-Snow Lake area and continuing onto the Superior craton. The seismic reflection data provide striking images of juvenile Paleoproterozoic arc rocks dipping beneath the northwestern margin of the Archean Superior craton, probably reflecting late-or post-collisional convergence as opposed to earlier oceanic subduction. Crustal imbrication on a scale imaged in few other orogens is observed beneath the Flin Flon belt where a package of shallowly east-dipping reflections extends from the surface to 14 s (~42 km). These reflections are attributed to middle to lower crustal arc rocks (Namew gneiss complex) that appear to have been stacked below a major detachment that carries the upper crustal rocks of the Flin Flon Belt.

LITHOPROBE, in collaboration with INCO Exploration and Technical Services, acquired 20 km of combined regional and high-resolution seismic reflection data across INCO property near Thompson in 1991. The geological complexity of the Thompson camp, marked by high grade, multiply-deformed Archean and Proterozoic rocks with moderate to steep dips, represents a significant seismic processing and interpretation challenge. A customized data processing approach has been designed to meet this challenge, including cross-dip analysis and dip-moveout (DMO) to successfully handle the crooked nature of the survey line and the steep attitudes of the surface structures.

To both meet the current demand for geoscience data from the NATMAP Shield Margin Project area, and free would-be users from the time-consuming task of building integrated digital databases, an integrated collection of geoscience data is being released on CD-ROM in November 1993. In order to meet the different needs of end-users, the data contained on the CD-ROM are provided in common interchange formats that are both compatible with a commercial data visualization package and GIS systems. The data contained on the CD were extracted from the geoscience database generated for the NATMAP Shield Margin Project. The following data sets are included on the CD-ROM: (1) bedrock geology, (2) surficial geology, (3) hydrographic data, (4) gravity imagery, (5) magnetic imagery, (6) radiometric data, (7) mineral deposit occurrence data, (8) geochronological data, (9) Landsat data, and (10) synthetic aperture radar (SAR) data.

INTRODUCTION

The Shield Margin Project of the Geological Survey of Canada's (GSC) National Mapping Program (NATMAP) represents an intensive, multidisciplinary and multi-institutional geoscience project focussed on the Flin Flon-Snow Lake-Hanson Lake Belt and its sub-Phanerozoic continuation in Manitoba and Saskatchewan. The project was initiated in March 1991 with the development of a joint proposal involving the GSC and the geological surveys of Manitoba and Saskatchewan, and now involves over 50 participants from these organizations, the Saskatchewan Research Council and the universities of New Brunswick, Québec (à Montréal), Manitoba, Regina, Saskatchewan and Calgary. The Shield Margin Project is integrated with the Partnership Agreements on Mineral Development (1991-96) in Manitoba and Saskatchewan, the GSC's Exploration Technology (EXTECH) program, the Trans-Hudson Orogen Transect of the LITHOPROBE program and the international Metamorphic Map program.

Three fundamental objectives for the project were defined at its onset, to be completed by March 31, 1996: (1) bedrock and surficial deposit mapping of the Flin Flon-Snow Lake-Hanson Lake Belt and the adjacent southern flank of the Kisseynew domain, supported by thematic geological, geochronological and geophysical studies; (2) development of an interpretive map of sub-Phanerozoic geology immediately south of the shield margin; and (3) development of a digital geoscience database housing an extensive set of both existing and new data, including regional compilation maps, for the project area. This progress report presents an update on GSC activities related to all three objectives. It complements more detailed reports contained within this volume on specific GSC subprojects of the overall NATMAP Shield Margin Project (Ansdell and Connors, GS-26; Connors and Ansdell, GS-11; Leclair and Weber, GS-27; Lucas, GS-14; McMartin, GS-31; Stern and Syme, GS-23 and Whalen, GS-20).

FLIN FLON CIM MEETING, JUNE 4-6 (1993)

A highly successful special meeting of the Flin Flon-Creighton CIM Branch was held on June 4-6 (1993) in Flin Flon (Manitoba) and attracted over 180 registrants from the mineral exploration industry, government and academia. The meeting, entitled "New Perspectives on the Flin Flon-Snow Lake-Hanson Lake Belt from the NATMAP Shield Margin Project" was sponsored by the Flin Flon-Creighton CIM Branch, the "Friends of the Reindeer", "Friends of the Nickel Belt" and the NATMAP Shield Margin Project Working Group (including the Manitoba Geological Services Branch (MGSB), Saskatchewan Geological Survey, Geological Survey of Canada and participants of the LITHOPROBE Trans-Hudson Orogen Transect). The meeting was co-organized by the MGSB and GSC, and involved a day of oral and poster presentations in Flin Flon followed by two days of fieldtrips in the NATMAP project area. Highlights of the meeting included: (1) the release of two new NATMAP products (a new 1:50 000 scale bedrock geology map of the Flin Flon-Amisk-Athapapuskow area in Manitoba and Saskatchewan (Syme *et al.*, 1993); and new 1:250 000 scale Bouguer gravity map of the sub-Phanerozoic portion of the NATMAP area (Broome *et al.*, 1993a)); (2) a demonstration of the forthcoming CD-ROM digital geoscientific data release for the NATMAP area (Broome *et al.*, 1993b); and (3) the overwhelming support of the Flin Flon-Creighton area exploration industry and community for the CIM meeting and the NATMAP project.

CD-ROM RELEASE

Today, effective geoscientific mapping and mineral exploration require an integrated approach where all available geoscience data are utilized. The recent availability of cost effective geographic information system (GIS) software and hardware capable of registering, managing, analyzing, and plotting the entire spectrum of geoscience data can greatly facilitate the process. Unfortunately, most geoscience data sets are available only in analog (*i.e.*, hard copy) form and must be digitized before they can be entered into a GIS. In cases where the data are available in digital form, data sets are often obtained form different sources, in different formats, and registered to different cartographic projections. The net result of these problems is that in a typical GIS analysis project, the interpreter spends 80% of his/hers time loading the required data and 20% of the time analysing them. To both meet the current demand for geoscience

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data from the NATMAP Shield Margin Project area, and free would-be users from the time-consuming task of building integrated digital databases, an integrated collection of geoscience data is being released on CD-ROM in November 1993 (Broome *et al.*, 1993b).

The CD-ROM represents a tangible demonstration of the progress that has been made to date towards achieving the third major goal for the Shield Margin Project, the development of a comprehensive, integrated digital geoscience database. This data release is designed to test distribution of an integrated data set to the public. Some groups within the geoscience community have already embraced the use of digital data and GIS software while other groups are just developing expertise with these methods. In order to meet the different needs of both of these groups, the data contained on the CD-ROM are provided in common interchange formats that are both compatible with a commercial data visualization package and GIS systems.

The data contained on the CD were extracted from the geoscience database generated for the NATMAP Shield Margin Project. The methodology used to accomplish this goal includes multiparameter synthesis of geoscience information, and development of digital information management and processing systems and standards for geoscientific maps and compilations (Broome *et al.*, 1993c). It is important to recognize that the data contained on this CD represent the results of the data collection and analysis activities of innumerable scientists and technicians from federal and provincial departments and academia. The following data sets are included on the CD-ROM: (1) bedrock geology, (2) surficial geology, (3) hydrographic data, (4) gravity imagery, (5) magnetic imagery, (6) radiometric data, (7) mineral deposit occurrence data, (8) geochronological data, (9) Landsat data, and (10) synthetic aperture radar (SAR) data.

ROCK PROPERTIES AND POTENTIAL FIELDS STUDIES

In February 1992, 1350 new gravity stations were acquired in NTS 63G, J, K, L (Manitoba and Saskatchewan) to enhance the density of stations on top of the Phanerozoic cover south of the Flin Flon-Snow Lake-Hanson Lake Belt and the Thompson Belt. Within the NATMAP project area, these data will enhance the interpretation of the high resolution aeromagnetic data and drill core . In addition, gravity data were acquired in support of two detailed projects centered on ultramafic intrusions in the Flin Flon belt. The regional gravity data for stations acquired south of the Flin Flon-Snow Lake-Hanson Lake belt in Manitoba and Saskatchewan was released at the Flin Flon CIM meeting in June 1993 (Broome *et al.*, 1993a). The gravity data for stations acquired along the sub-Phanerozoic extension of the Thompson belt in Manitoba will be released on October 1, 1994 following a confidential period with a consortium of mineral exploration companies.

During the summer of 1993, fieldwork was undertaken to collect samples for rock properties studies in support of NATMAP and LITHOPROBE potential fields modelling projects. *In situ* magnetic susceptibility measurements (~250) and sampling for density determination were completed for most rock units along the LITHOPROBE lines that traverse the Kisseynew domain-Thompson belt-Superior craton, Snow Lake area, Flin Flon belt (Saskatchewan) and Hanson Block-Pelican Narrows area. In addition, detailed susceptibility measurement and sampling was carried out on the Reed Lake granite and Reed Lake ultramafic rocks within the previously acquired detailed gravity measurement grid. Gravity stations were acquired this summer in the Missi Group Flin Flon basin in order to complete a detailed study aimed at modelling the structure of the basin. The initial focus of potential fields studies this fall/winter will be on density measurements of samples collected this summer and updating the rock properties component of the NATMAP digital database. Magnetic and gravity modelling and geophysical image analysis will continue to be an integral part of the NATMAP sub-Phanerozoic basement interpretation project and the LITHOPROBE program. The LITHOPROBE-related modelling projects in Manitoba are focused on areas where significant gradients in either gravity or magnetics occur (Kisseynew "magnetic boundary", Churchill-Superior boundary zone, Pikwitonei belt, Missi Group Flin Flon basin).

A complementary potential fields program associated with both the NATMAP and LITHOPROBE projects is examining the nature of magnetic remanence and magnetic anisotropy in the Flin Flon belt, Kisseynew domain, Thompson belt and Pikwitonei belt. Over 250 oriented cores were collected from 40 sites in these areas for NRM and anisotropy measurement, including sites of previous paleomagnetic determinations in the Amisk Group. These data will add to the existing rock properties database and will continue to form an integral part of detailed magnetic anomaly analysis and modelling projects, such as the current study of the Kisseynew "magnetic boundary".

MINERAL DEPOSITS DATABASE

An essential component of the NATMAP Shield Margin Project GIS/database will be up-to-date information on all aspects of mineral deposits within the project area. The rationale for producing such a database is to enhance the value of the overall geoscientific database being developed by the NATMAP Shield Margin Project, particularly for the mineral exploration industry. A joint GSC-MGSB proposal for the development of a comprehensive mineral deposits digital database is being negotiated at present. However, work is underway to update existing index-level digital data sets (CANMINDEX and MINSYS) in order to provide a digital index to mineral deposits in the NATMAP Shield Margin Project area for the CD-ROM preliminary digital release in November 1993.

LITHOPROBE TRANS-HUDSON OROGEN TRANSECT

Interpretation and publication of preliminary results from the first phase of LITHOPROBE seismic reflection data acquisition (1991) in the Trans-Hudson Orogen (THO) has occurred over the past year, resulting in 3 journal articles published (Lucas, 1993a) or in press (Lewry, 1993; Lucas, 1993b) and two submitted manuscripts (Hajnal *et al.*; White *et al.*) as well as numerous oral and poster presentations. Discussions are underway concerning the 1994 seismic reflection acquisition program for the Trans-Hudson Orogen Transect. A brief summary of the major results of the seismic reflection interpretation program in Manitoba follows below.

The >1000 km of vertical incidence seismic reflection profiles acquired in LITHOPROBE's THO transect image highly reflective Early Proterozoic and Archean crust and a laterally continuous Moho. Principal results of integrated interpretation of the reflection data in eastern THO (Lewry *et al.*, 1993; Lucas *et al.*, 1993a) are: (1) strong, east-dipping reflections extend throughout the crust as either discrete crustal-scale structures or broad zones of layered, middle to lower crustal arc (Flin Flon belt) and marginal basin (Kisseynew domain) rocks; (2) reflections dipping beneath the Superior craton project updip to surface exposures of continental margin, marginal basin and "juvenile" arc rocks of the Thompson, Kisseynew and Flin Flon belts; and (3) crustal architecture of the orogen was largely shaped during *ca.* 1.83 to 1.79 Ga terminal (Superior-Hearne) collision and intracontinental deformation.

The three-dimensional structure of the eastern THO is revealed through a network of LITHOPROBE seismic reflection profiles that cross the Flin Flon-Sherridon-Snow Lake area and continuing onto the Superior craton (Lucas *et al.*, 1993b; White *et al.*, 1993). Crustal imbrication on a scale imaged in few other orogens is observed beneath the Flin Flon belt where a package of shallowly east-dipping reflections extends from the surface to 14 s (~42 km). These reflections are attributed to middle to lower crustal arc rocks (Namew gneiss complex; Leclair *et al.*, 1993) appear to have been stacked below a major detachment that carries the upper crustal rocks of the Flin Flon belt. The detachment and hanging wall Flin Flon belt appear to be offset by steep faults near the shield margin, such as the Athapapuskow Lake shear zone (Syme, 1988) and Berry Creek fault (*cf.* Syme, GS-15, this volume).

The southern flank of the Kisseynew domain structurally overlies the Flin Flon belt. The boundary zone between the Kisseynew south flank and the Flin Flon belt is interpreted as a series of thrust faults (Lucas *et al.*, 1993b) and/or highly strained ductile fold nappes (*cf.* Zwanzig and Schledewitz, 1992). Field studies have suggested a south to southwest sense of transport for the recumbent folds (nappes) and shear zones in the southern flank area (Norman and Williams, 1992; Zwanzig and Schledewitz, 1992).

LITHOPROBE, in collaboration with INCO Exploration and Technical Services, acquired 20 km of combined regional and high-resolution seismic reflection data across INCO property near Thompson in 1991. The geological complexity of the Thompson camp, marked by high grade, multiply deformed Archean and Proterozoic rocks with moderate to steep dips, represents a significant seismic processing and interpretation challenge. A customized data processing approach has been designed to meet this challenge, including cross-dip analysis and dip-moveout (DMO) to successfully handle the crooked nature of the survey line and the steep attitudes of the surface structures.

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GS-31 HIGHLIGHTS OF QUATERNARY GEOLOGY INVESTIGATIONS IN THE CORMORANT LAKE AREA (NTS 63K)

by I. McMartin[1]

McMartin, I., 1993: Highlights of quaternary geology investigations in the Cormorant Lake area (NTS 63K); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 123-124.

SUMMARY

During the summer of 1993, fieldwork was carried out in the central part of the NATMAP Shield Margin Project area (NTS 63K), mostly within the Phanerozoic bedrock portion of the area. A complex ice flow record was documented in the area, resulting from its location at the confluence of two major Late Wisconsinan ice lobes (both northern and eastern ice provenance) and also the effects of a major north-south trending moraine (The Pas moraine). Drift cover is highly variable, ranging from <2 m on the shield to 0 to 80 m on the Phanerozoic cover. A systematic drift prospecting program was initiated in the study area and comprises textural, petrological and geochemical analysis of >300 till samples, as well as trace element analysis of humus samples and a regional kimberlite indicator mineral study (NTS 63J and 63K).

INTRODUCTION

Quaternary geology investigations were initiated in 1991 under the NATMAP Shield Margin Project. The objectives are: (1) mapping the surficial deposits and compiling digital surficial geology maps (1:100 000); (2) establishing the Quaternary stratigraphic framework and paleoenvironmental history of the area; and (3) undertaking systematic drift sampling. These objectives are designed to provide a basic database to aid in mineral exploration (mainly base metals, gold, and diamonds), environmental protection and land use planning.

During the summer of 1993, field work was carried out in the central part of the Shield Margin Project area (NTS 63K), mostly within the Phanerozoic portion of the study area. Additional detailed studies focussing on drift prospecting were also carried out in the Naosap Lake area to the north (Nielsen, GS-12, this volume) and in the Annabel Lake-Amisk Lake area in Saskatchewan (Henderson and Campbell, 1992). This summary outlines the Quaternary history and describes the sediments of the Cormorant Lake area.

PREVIOUS WORK

Surficial geology mapping was completed in the Cormorant Lake area at a scale of 1:250 000 as part of the 1984-1989 Canada-Manitoba Development Agreement (Clarke, 1989). The Saskatchewan part was mapped on a reconnaissance scale (1:250 000) by Schreiner (1984). More detailed preliminary surficial geology and aggregate resources maps are available for different parts of NTS 63K, primarily at a scale of 1:50 000 (Groom, 1989; Mihychuk, 1988; Singhroy, 1977; Singhroy and Werstler, 1980).

Several reports comment on the history of deglaciation and the nature of the surficial sediments in the study area. Most of these studies were aimed at providing information for use in aggregate resources and land use planning activities (Groom, 1989; Pedersen, 1973: Singhroy and Werstler, 1980). Nielsen and Groom (1987, 1989) provide the most comprehensive study of the Quaternary history of The Pas-Flin Flon area, by documenting ice flow events and till provenance. More recent work within the NATMAP Project area (Gobert and Nielsen, 1991; Henderson and Campbell, 1992; McMartin *et al.*, 1993; Nielsen, 1992) have focussed on drift prospecting and till provenance.

ICE FLOW RECORD

The study area is located at the confluence of two major Late Wisconsinan ice lobes, where ice flowing from the Keewatin Sector (northern provenance) interacted with ice flowing out of Hudson Bay (more eastern provenance) (Dyke and Prest, 1987). On the Paleozoic platform, the ice flow events are recorded by striations, grooves, crescentic marks, chattermarks, drumlins and flutes. Erosional features are abundant but variable on flat dolomitic outcrops, particularly where polished surfaces have been recently exposed in burrow pits. On the Shield, ice flow directions are numerous but more unidirectional, as recorded by striations and roches moutonnées.

South of the Shield margin, ice flow directions differ on either side of The Pas moraine, which trends approximately north-south. West of the moraine, the oldest ice flow recorded was towards the west and west-southwest (254°-272°), and is related to ice flowing out of Hudson Bay. Ice flow directional indicators related to this early event is commonly preserved on protected outcrop surfaces, truncated by the dominant southerly ice flow direction for that area. The dominant flow varies from 210° immediately south of the Shield margin to 179° at the southern edge of the study area. A late glacial advance towards the southwest (228°-235°) was also recorded in the same area.

East of The Pas moraine, old and deep striae trending 135° to 144° were found sporadically, recording the early southeasterly flow documented throughout north central Manitoba (Nielsen and Groom, 1987). Westerly striae and the orientation of drumlins and flutings, indicate ice flow was from Hudson Bay. Directly on top of The Pas moraine and along the Shield margin south of Reed Lake, a minor glacial re-advance occurred towards the west-northwest, with flutings and fine striae trending 270° to 285°. This late re-advance, resulting in glacial overriding of The Pas moraine, was first noted by Craig (1965) and Klassen (1967), and documented by Nielsen and Groom (1987). No evidence for the extension of this re-advance west of The Pas moraine was found. Along the Shield margin, the record of ice flow is complex. Ice flow directions at 210°, 230°, 250° and 280°, with variable age relationships and associated with a large east-west trending ice contact zone mark the contact between Keewatin ice and Hudson Bay ice.

On the Shield, dominant striae and roche moutonnées trend 190° to 210°, indicating ice flow toward the south-southwest. The late southwesterly re-advance observed on the Paleozoic rocks west of the moraine is also recorded on the Shield west of Reed Lake by striae trending 218° to 224°. In the Elbow Lake area, a late event towards the southeast was recorded by striae trending 156° (Nielsen, 1992).

GLACIAL GEOLOGY

Within the study area, drift cover is generally thin (<2 m) on the Shield and thicker (<5 m, but up to 80 m) on the Paleozoic cover. On the Shield, the thickest till accumulations occur on the lee-side of bedrock outcrops particularly above elevations of 300 m a.s.l. (Nielsen, 1992). Below this elevation, glaciolacustrine sediments dominate and are concentrated in topographic lows. Till sheets related to the complex ice flow history recorded by the striations have not been recognized in hand dug pits or natural sections in the area (Nielsen, 1992). Calcareous till found on the Shield at one site in the Naosap Lake area (Nielsen, per com., 1993) and east of the study area near Wekusko Lake indicate ice flow towards the west and debris transported either from local Paleozoic outcrops north of Ponton (Gobert and Nielsen, 1991) or from the Paleozoic terrane of the Hudson Bay Lowland.

South of the Shield margin, the drift cover is very thick in places, *e.g.* up to 80 m thick on The Pas moraine (Pedersen, 1973), and commonly forms flutes up to 15 m high east of the moraine.

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Five till units are recognized in the Cormorant Lake area overlying the Paleozoic rocks.

1. A thin pink-brown (8/3, 10YR to 7.5YR) till sheet is widespread west of The Pas moraine as far north as Atik Lake. This unit was found overlying bedrock with southerly-trending striae, indicating a northern provenance. The till is highly compact, pebble rich, and calcareous (87 to 99% carbonate pebbles). A similar red till unit was also found overlying bedrock at a few sites east of the moraine. This unit has also been recorded at depth along The Pas moraine (Singhroy and Werstler, 1980), and has been associated with ice flow toward the southeast from the Keewatin Ice Sector (Nielsen and Groom, 1987). These two units are probably closely related in time and provenance.
2. A Precambrian-derived, sandy/silty calcareous till unit commonly overlies bedrock for at least 25 km south of the Shield margin. This unit is related to ice flow events from the Keewatin Sector that occurred throughout most of the study area. It is commonly found directly on top of bedrock with striae trending 206° to 214°.
3. A younger till commonly overlies glaciolacustrine sediments at several sites west of The Pas moraine. The composition and texture of this unit vary from a calcareous, clayey, clast-poor diamicton where it overlies laminated sediments, to a weakly calcareous sandy Precambrian derived till (Wanless till of Nielsen and Groom, 1987) overlying striated bedrock (228°-235°). This till was deposited by a major late glacial re-advance of the Keewatin ice lobe toward the southwest. This re-advance occurred north of Wanless and on the Shield throughout most of the study area.
4. Within, and east of, The Pas moraine (Singhroy and Werstler, 1980) the surface till consists of a grey to white (7/2 to 8/2, 10YR) calcareous till of eastern provenance (Clearwater till of Nielsen and Groom, 1987). This till is silty to silty/sandy and variably enriched in carbonate pebbles (65 to 95%). This unit is related to ice flow events from Hudson Bay, that formed the core of The Pas moraine and the widely distributed till sheet east of the moraine. This till unit cannot be distinguished from till found in the numerous drumlins and flutings located on top and east of the moraine.
5. A large westerly-trending ice contact zone south of Reed Lake is characterized by a hummocky topography, composed of boulders, pebbly gravels and cobbly calcareous till. This hummocky moraine was deposited by stagnating Hudsonian ice.

DRIFT PROSPECTING

A systematic drift prospecting program was initiated in the study area. It consists of sampling and analyzing over 300 till samples (3 to 4 samples per 100 km^2) for textural, petrological and geochemical parameters. Humus samples were also collected and will be analyzed for trace element content. A regional kimberlite indicator mineral study is being carried out in the Wekusko Lake area, and part of the Cormorant Lake area. The results from all drift prospecting programs undertaken in the NATMAP Shield margin area will form part of the final compilation.

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GS-32 LITHOPROBE 1993 SEISMIC REFRACTION PROGRAM

by Z. Hajnal[1]

Hajnal, Z., 1993: Lithoprobe 1993 seismic refraction program; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 125.

The 1993 refraction seismic survey program of the LITHOPROBE Trans-Hudson Orogen Transect (THOT) extended over significant portions of northern Manitoba and Saskatchewan (Fig. GS-32-1). The objective of the investigation was to study the lower crust and the lithospheric portion of the upper mantle in all major tectonic domains of THOT. The final results will include structural depth sections and acoustic property presentations of the lithospheric segment of THOT.

The data acquisition included three reversed refraction profiles (Fig. GS-32-1). An east-west 755 km long line followed the highways system from near Norway House to the Primrose Weapons Range in Saskatchewan. This line crosses the entire orogen and the margins of the bounding Superior and Rae-Hearn cratons. The north-south profile in Manitoba extended for 550 km from Lynn Lake to Swan River. This survey was designed to examine the deep tectonic signatures of the Lynn Lake, Kisseynew and Flin Flon domains, as well as the continental margin of the Superior Province underneath the Paleozoic cover. The north-south profile in Saskatchewan spanned 750 km between Wollaston Lake and Mozart. This survey traversed the Rottenstone, La Ronge, Glennie domains and was intended to examine both regional and depth configurations of the buried Archean crustal block discovered by the 1991 reflection seismic program (Lucas *et al.*, 1993).

To secure better control of upper crustal structural settings and lateral variations of density properties, energy sources were placed at 50 km intervals on all survey profiles. Instrumentation included 525 portable digital refraction recorders that were distributed along the survey lines at intervals of 1.1 to 1.4 km.

Early evaluations indicate that the data quality of the survey is exceptional. Preliminary results will be available in 1994.

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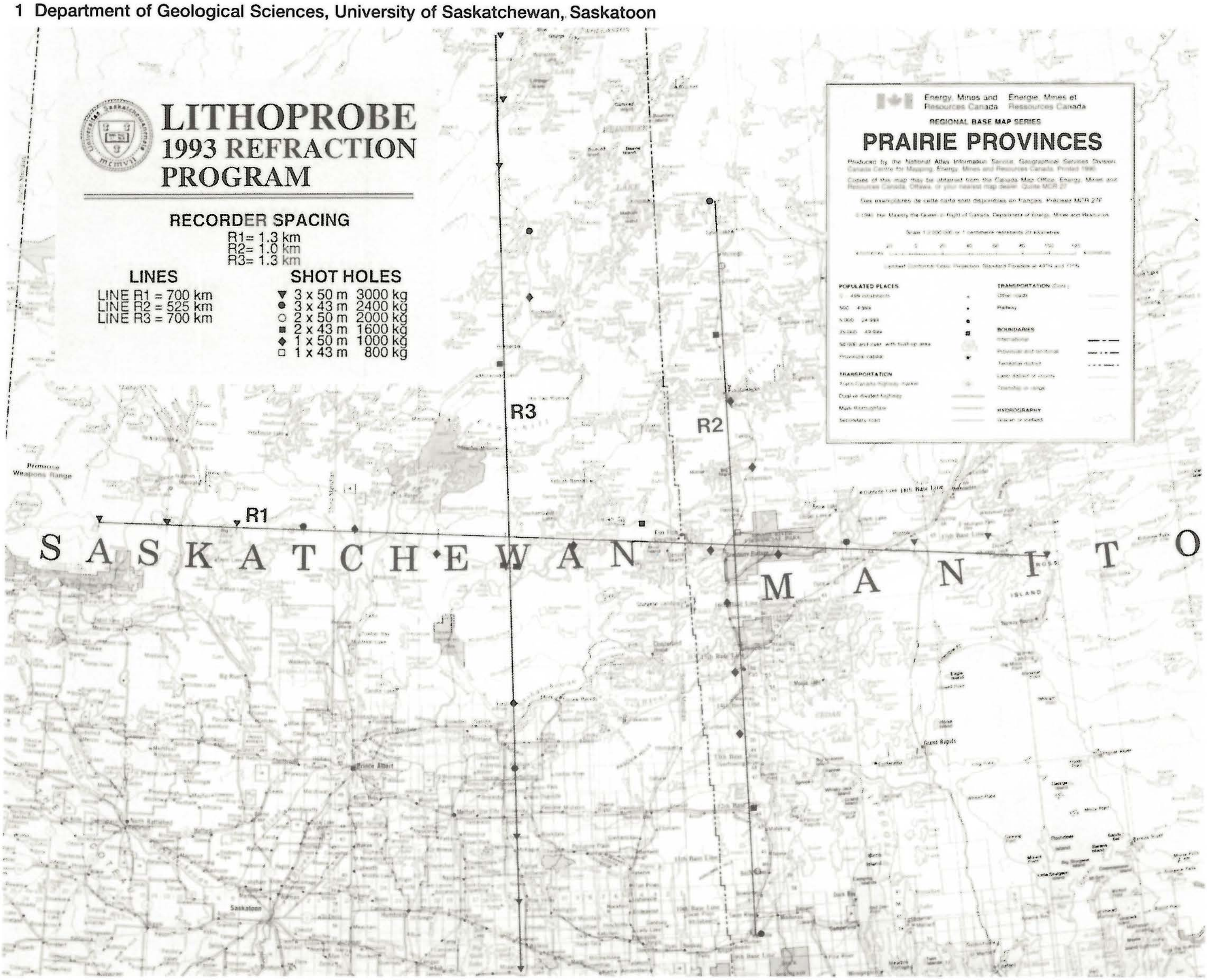

Figure GS-32-1: Map showing profile lines of refraction seismic survey completed in the summer 1993 along the LITHOPROBE Trans-Hudson Orogen transect.

GS-33 RELOGGED DRILL CORE FROM THE SUB-PHANEROZOIC PRECAMBRIAN BASEMENT IN NTS 63J

by C.R. McGregor and J.J. Macek

McGregor, C.R. and Macek, J.J., 1993: Relogged drill core from sub-Phanerozoic precambrian basement in NTS 63J; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 126.

INTRODUCTION

Eighteen nonconfidential drill holes intersecting sub-Phanerozoic Precambrian rocks in NTS 63J (Fig. GS-33-1) were relogged in 1993 (McGregor and Macek, 1993) in order to identify major lithologic units within the projected southern extension of the Thompson Nickel Belt and within the eastern Churchill Province.

All of the relogged holes were drilled by Manitoba Minerals Resources Ltd., between 1974 and 1991 as part of its regional drilling programs in which a total of approximately 115 holes were drilled. About half of the core (approximately 56 holes) is stored in the provincial Core Library in The Pas.

The results of the relogging have been plotted on a 1:250 000 scale map (NTS 63J) that records the location of the drill holes and intersected host and target lithologies (Mc Gregor and Macek, 1993), in addition to those done in 1992 (McGregor and Macek, 1992). Similarly, a catalog containing a summative log, a cross section and a colour photograph documentation for each drill hole, is available to the public for viewing. This catalog is also available for reproduction at cost. A detailed evaluation and further interpretation of the lithologies intersected is in progress.

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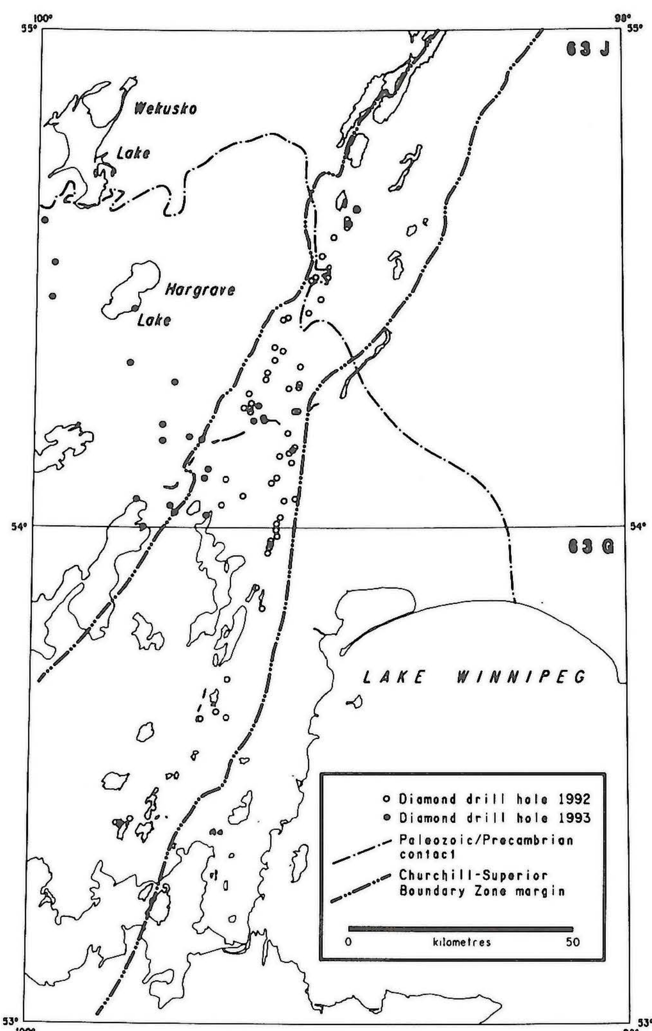

Figure GS-33-1: Location of subPhanerozoic Precambrian holes in NTS 63J

GS-34 STRATIGRAPHIC MAPPING AND CORE HOLE LOGGING 1993

by R.K. Bezys

Bezys, R.K., 1993: Stratigraphic mapping and core hole logging 1993; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 127-133.

SUMMARY

The Geological Services Branch's drilling program completed a total of 17 holes with a total of 1588.35 m of core. Five of these holes were drilled and cored for Paleozoic stratigraphic purposes and open holes will be used for down-hole wire line measurements.

This drill core data and recently logged mineral exploration Paleozoic drill core, is being used to help identify possible Precambrian structure along the CSBZ, as well as correlation of Ordovician and Silurian stratigraphy in the Grand Rapids area. All data is to be added to MOGWIS, which includes all Lower Paleozoic well tops verified and corrected by the Geological Services Branch. All information is available in digital format to allow for its rapid retrieval. The Lower Paleozoic database has been used to generate new stratigraphic maps for the Province and intraformational maps for the Red River Formation study.

INTRODUCTION

Stratigraphic activities were carried out on three separate projects in 1993. They include: 1) continued drilling in the Grand Rapids area; 2) detailed inventory of mineral exploration Paleozoic drill core; and 3) continued work on the Ordovician Red River Formation study.

The Geological Services Branch's drilling program completed 17 holes with a total of 1588.35 m of core. Locations of the drill holes are shown in Figure GS-34-1 and summary core hole data are presented in Table GS-34-1.

Holes M-1-93, M-2-93, M-3-93, M-4-93, and M-14-93 were drilled specifically for the Grand Rapids (Northern Interlake) drilling project. All other holes were drilled for NATMAP and are discussed in Leclair and Weber (GS-27, this volume).

GRAND RAPIDS DRILLING

Five core holes (M-1-93, M-2-93, M-3-93, M-4-93, and M-14-93) were drilled north of Grand Rapids to obtain detailed Paleozoic and Precambrian stratigraphic information. Four of the holes were located within the Churchill-Superior Boundary Zone (CSBZ) to intersect the Precambrian and determine its lithology and to better define the eastern edge of the boundary zone. Core hole M-4-93 was drilled west of Talbot Lake (and west of the CSBZ) to obtain a deep stratigraphic core hole (to Precambrian) for future geophysical logging purposes.

These five holes were drilled in areas with sparse Paleozoic well control. Core logging of the Paleozoic intervals will be followed-up by downhole geophysical logging of the same holes (by Water Resources Branch and Geological Survey of Canada). These data, as well as previously drilled and geophysically logged holes, are to be stored digitally in MOGWIS (Manitoba Oil and Gas Well Information System) (*cf.* Conley, GS-35, this volume).

Presently, two holes, M-6-91 and M-3-93, have had temperature gradient profiles performed (see Figures GS-34-1 and 2). Unfortunately, the isothermal conditions found in the subsurface at these sites indicate that ground water is flowing downward at a velocity sufficient to "wash out" the upper crustal heat flow signal (W.Gosnold, personal communication, 1993). In Figure GS-34-3, an attempt to calculate possible gradient curves for the hole is shown.

Comparison of the temperature profiles between M-6-91 and M-3-93 indicate a stratigraphic correlation where temperature increases occur. The two holes are approximately 25 km apart. The correlation is as follows:

M-3-93 (HONEYMOON LAKE)
5-24-52-13WPM
Ground Elevation: 268.8 m

Temperature Change Depth (m)	Structural Elevation (below sea level)	Stratigraphic Formation
12.4	256.4	Moose Lake Fm
73.3	195.5	basal Stony Mountain Fm
128.0	140.8	lowermost Red River Fm

M-6-91 (COOK'S CAVE SE)
15-18-51-14WPM
Ground Elevation: 266.7 m

Temperature Change Depth (m)	Structural Elevation (below sea level)	Stratigraphic Formation
26.5	240.2	Moose Lake Fm
83.0	183.7	Lower Stony Mountain Fm
125.0	141.7	Lowermost Red River Fm
132.0	134.7	IBID

The fact that these correlations extend over a distance of 25 km, may indicate that aquifers in the Grand Rapids karst terrane are stratigraphically bound within permeable layers and migrate long distances within them. This applies especially for the Moose Lake Formation (Silurian), which rests directly on a significant aquiclude, the U_1-marker, a persistent dolomitic shale-mudstone horizon. The zones within the Red River and Stony Mountain formations are more difficult to resolve. The lithologies indicate a slight increase in formational porosity, but permeability is the governing component for aquifer movement and cannot be easily measured with visual inspection of the core. Fracture patterns within these zones may also be a factor, but no distinct patterns have yet been identified.

PALEOZOIC DRILL CORE INVENTORY

In the last five years, considerable amounts of Paleozoic drill core have been inventoried from mineral exploration drilling, especially in the Grand Rapids area. Drilling targets were primarily Precambrian ultramafic rocks within the CSBZ. Concurrent with the retrieval of Precambrian core, a considerable amount of Paleozoic core has also been retrieved and is available for logging.

Detailed logging of the drill core (at a regional and detailed scale) has allowed for the stratigraphic evaluation of possible Precambrian structure along the CSBZ. Locally, in the area north of Grand Rapids, the boundary zone is called the Moose Lake Syncline (McCabe, 1967) and in southwest Manitoba it is termed the Birdtail-Waskada Axis.

This summer, 42 mineral exploration holes were added to the Paleozoic stratigraphic database inventory. Presently, the drillhole data are confidential, but detailed core logs and a report will be available next year. This recent data has outlined the complexity of the Precambrian surface, as well as its effects on the overlying Paleozoic strata. Up to now it has been assumed that the surface of the Precambrian beneath the Williston Basin is essentially flat-lying. Evidence, to the contrary, indicates relief differences as much as 30 m (on top of the Precambrian) between holes spaced less than 1 km apart. Some of these structures may be aligned with unique topographic lineaments that are evident on airphotos and radar images.

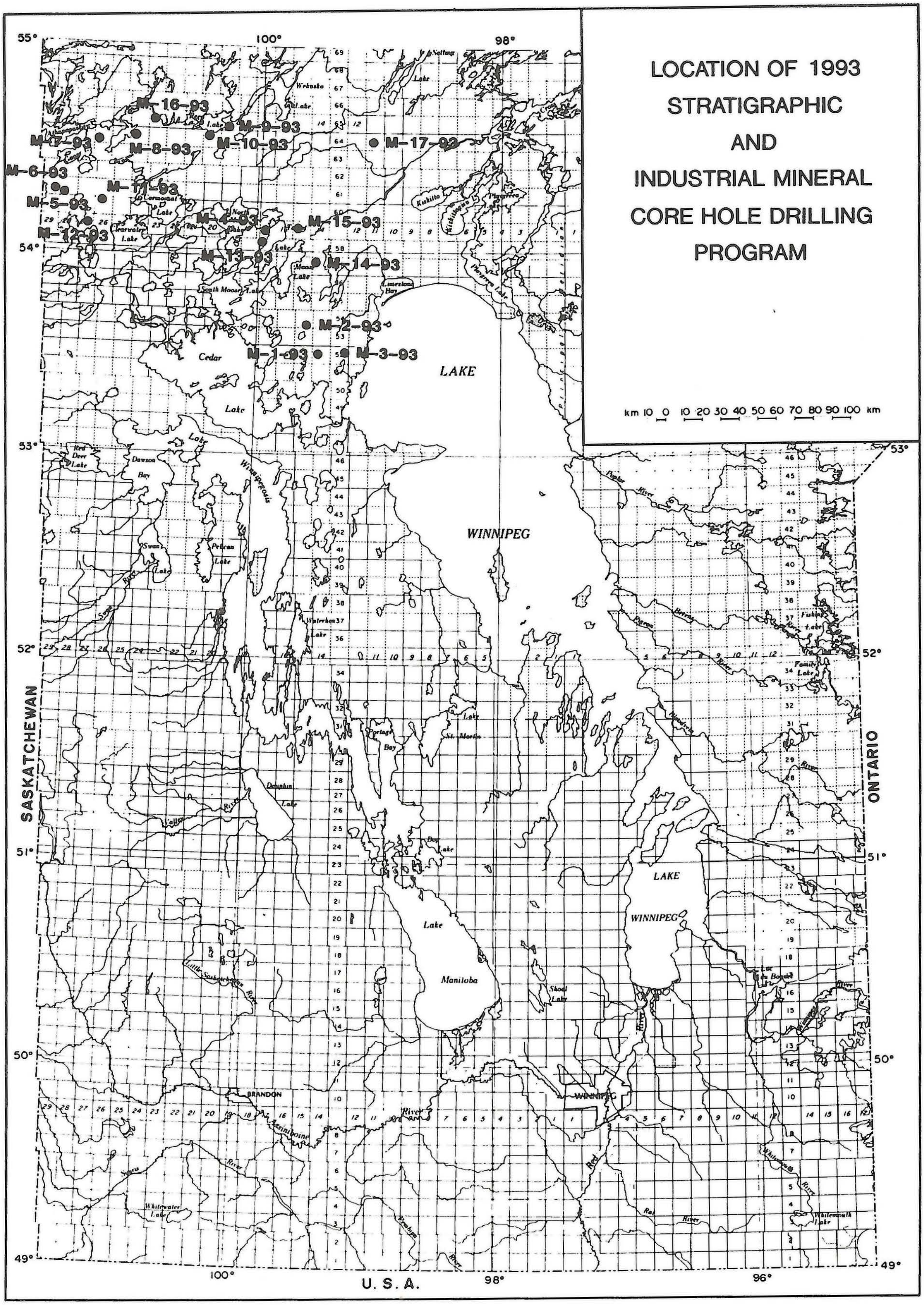

Figure GS-34-1: Location of 1993 stratigraphic and industrial mineral core hole drilling program in Manitoba.

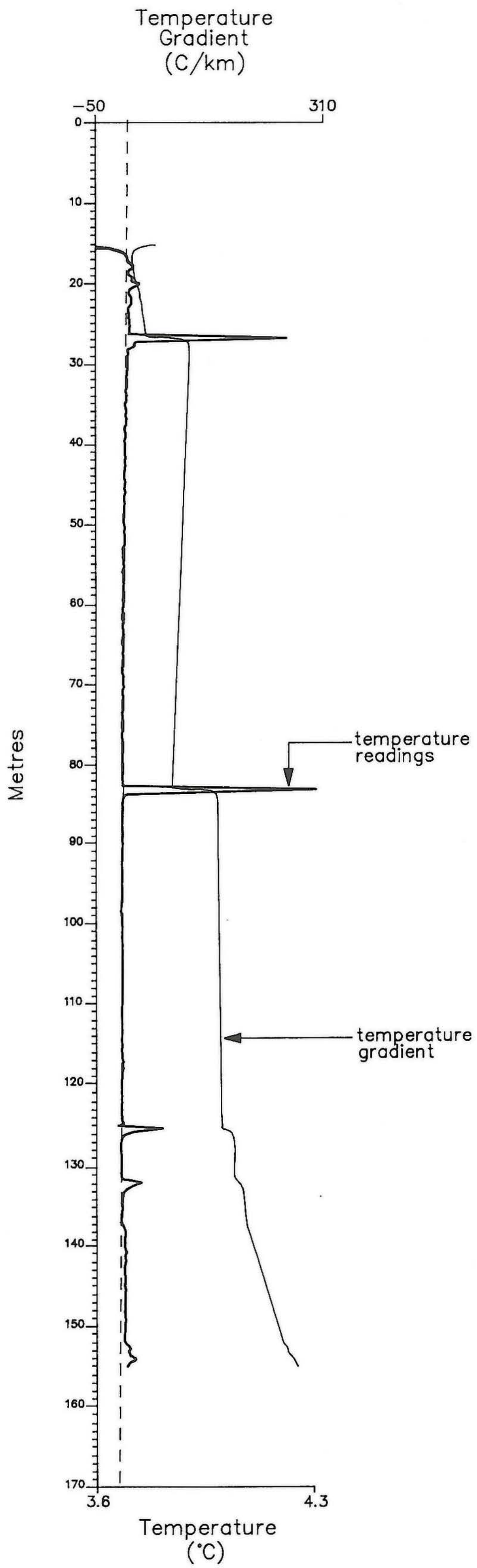

Figure GS-34-2: ***Temperature gradient profile of core hole M-6-91 (Cook's Cave SE) (depth in metres versus C). Courtesy of J. Mwenifumbo, Geological Survey of Canada, Ottawa, 1992.***

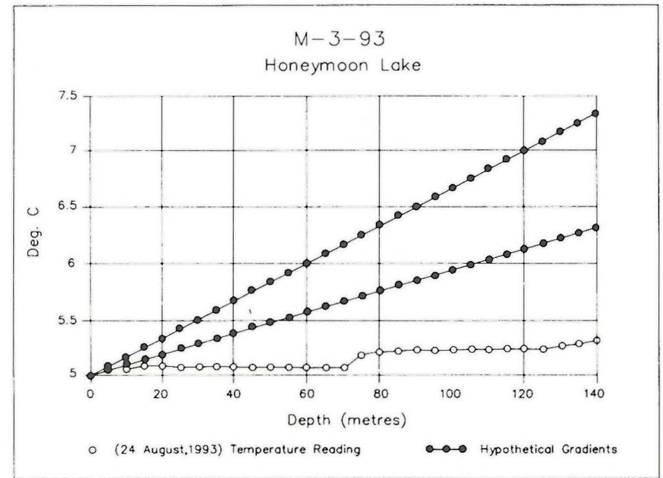

Figure GS-34-3: ***Temperature vs depth profile (+) of core hole M-3-93 (Honeymoon Lake) and two hypothetical curves that would be expected for the region (*). These curves were determined using heat flow measurements from nearby sites (Flin Flon, Whiteshell and Winnipeg) and using the thermal conductivity of Ordovician and Silurian carbonates. Therefore, the geothermal gradient at the site probably lies between 16.7C°/km and 9.4C°/km. Plot and calculations courtesy of W.Gosnold, University of North Dakota, 1993.***

The identification of these structural deviations and their extent could be beneficial to the mineral and petroleum industries. Mineral exploration drilling would benefit from precursory knowledge of anomalous structures on top of the Precambrian surface that may help in establishing drill targets and drilling depths, as well as future mine shafts. The petroleum industry could benefit from the identification of similar structures in southwest Manitoba where the possibility of deep oil reservoirs may exist.

Additional mineral exploration drilling will increase our knowledge of these structures in the future.

RED RIVER FORMATION STUDY

Last year, Manitoba Energy and Mines initiated a major basin analysis study with the intent of examining all Paleozoic formations within the Manitoba portion of the Williston Basin. Since hydrocarbons from deep Paleozoic formations have been found in Saskatchewan, North Dakota and Montana, it is feasible that they may also be present in Manitoba's subsurface. The Ordovician Red River Formation study was implemented in 1992 to present stratigraphic and sedimentologic information on the formation by means of cross sections, structure contour and isopach maps, and detailed lithologic descriptions (*cf.* Bezys, 1992). Presently, all data are entered digitally into MOGWIS and are undergoing a verification process. Once the final maps for all intraformational units have been prepared and finalized, preparation of the final report will begin.

Table GS-34-1

Core hole logs, locations and elevations for 1993 stratigraphic and industrial mineral drilling

Hole No.	Location and Elevation (m)	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
M-1-93	5927654N	SILURIAN - Cedar Lake	0.00-10.35	Packstones, grainstones and mudstones.
Cook's Cave	467039E	East Arm (and V-marker)	10.35-23.13	Wackestones and mudstones; good paleofavositids fragment.
North	4-20-52-14W			
	274.3	(U_2-marker)	23.13-25.10	Mudstone (some sand).
		Atikameg	25.10-30.55	Packstone to mudstone; vuggy.
		Moose Lake	30.55-37.20	Grainstone to mudstone; medial marker at 34.14-34.44 m.
		(U_1-marker)	37.20-38.50	Mudstone (some sand).
		Fisher Branch	38.50-49.74	Wackestone; *Virgiana decussata* present.
		Stonewall (marker)	49.74-51.50	Mudstone; minor conglomerate.
			51.50-53.55	Mudstone to wackestone.
		(T-marker)	53.55-55.76	Mudstone; slightly brecciated
		ORDOVICIAN-Stonewall	55.76-61.60	Wackestone; fossiliferous.
		(lower T-marker)	61.60-62.20	Mudstone; laminated.
			62.20-68.30	Wackestone; cherty.
		(Williams Member)	68.30-71.67	Mudstone; laminated.
		Stony Mountain	71.67-101.67	Wackestone; nodular.
		Red River (Fort Garry)	101.67-115.00	Mudstone; laminated; minor brecciation; cherty.
		Lower Red River	115.00-158.20	Wackestone; mottled; cherty.
		Winnipeg	158.20-166.32	Sandstone; minor siltstone; quartzose.
		PRECAMBRIAN-Weathered	166.32-168.09	Weathered ultramafic.
		Unweathered	168.09-176.00	Unaltered ultramafic with "minifex" texture.
M-2-93	5942822N	SILURIAN-Cedar Lake	0.00-23.60(?)	Wackestone to mudstone; minor conglomerate.
Road End	461252E	(V-marker)	23.60-28.65	Mudstone; laminated; conglomeratic.
Lake	7-3-54-15W	East Arm	28.65-30.50	Mudstone; arenaceous.
	285.6	(U_2-marker)	30.50-32.28	Mudstone; laminated; conglomeratic.
		Atikameg	32.28-37.45	Grainstone to mudstone.
		Moose Lake	37.45-44.03	Grainstone to mudstone; no medial marker.
		(U_1-marker)	44.03-44.55	Mudstone; laminated; conglomeratic.
		Fisher Branch	44.55-53.62	Wackestone; minor fossils.
		Stonewall (marker)	53.62-54.52	Mudstone.
			54.52-57.11	Mudstone; mottled.
		(T-marker)	57.11-58.29	Mudstone; burrow mottled.
		ORDOVICIAN-Stonewall	58.29-66.10	Wackestone to mudstone.
		(lower T-marker)	66.10-66.70	Mudstone.
			66.70-72.20	Wackestone; cherty.
		(Williams Member)	72.20-76.15	Mudstone; laminated.
		Stony Mountain	76.15-105.75	Wackestone; mottled and nodular.
		Red River (Fort Garry)	105.75-117.94	Mudstone; brecciated; cherty.
		Lower Red River	117.94-159.39	Wackestone; fossiliferous; cherty.
		Winnipeg	159.39-166.95	Sandstone; quartzose; burrow mottled; minor shale.
		PRECAMBRIAN	166.95-176.10	Strongly weathered, foliated rock; altered ultramafic (?) in garnet-biotite-muscovite siliceous gneiss; crosscut by granitic pegmatite.
M-3-93	5931025N	SILURIAN-(U_2-marker)	0.00-3.20	Mudstone; arenaceous; conglomeratic.
Honeymoon	480525E	Atikameg	3.20-8.90	Grainstone/packstone; marker bed at base.
Lake	5-24-52-13W	Moose Lake	8.90-16.13	Mudstone to wackestone; medial marker bed at 12.58-13.09 m.
	268.8 m			
		(U_1-marker)	16.13-17.10	Mudstone; slight brecciation; minor sand.
		Fisher Branch	17.10-28.30	Packstone to grainstone (minor wackestone); minor *Virgiana decussata* at base.
		Stonewall (marker)	28.30-28.98	Mudstone; conglomeratic.
			28.98-31.44	Mudstone.
		(T-marker)	31.44-32.70	Mudstone; minor sand.
		ORDOVICIAN-Stonewall	32.70-41.78	Wackestone to mudstone.
		(lower T-marker)	41.78-43.13	Mudstone; laminated.
			43.13-46.63	Wackestone (some mudstone).
		(Williams Member)	46.63-50.79	Mudstone; laminated; burrowed.
		Stony Mountain	50.79-79.81	Wackestone; nodular.
		Red River (Fort Garry)	79.81-94.50	Mudstone; laminated; brecciated.
		Lower Red River	94.50-138.60	Wackestone; cherty; fossiliferous.
		Winnipeg	138.60-146.21	Sandstone; quartzose; minor shale with bioturbation.
		PRECAMBRIAN	146.21-161.80	Plagioclase-pyroxene gabbro; locally foliated; weak hydrothermal alteration; biotite granodiorite (?) or granitic pegmatite inclusion present at 153.7-158.9.

M-4-93	5994260N	SILURIAN-Atikameg	0.00-5.57	Packstone to grainstone; rare fossils; marker bed at base.
John's Lake	437300E	Moose Lake	5.57-10.70	Mudstone to grainstone; medial marker bed at 8.85-9.05 m; rare fossils.
	4-16-59-17W			
	283.5	(U_1-marker)	10.70-12.30	Mudstone; arenaceous.
		Fisher Branch	12.30-19.72	Wackestone to grainstone; scattered paleofavositids.
		Stonewall (marker)	19.72-19.91	Mudstone; slightly brecciated.
			19.91-22.31	Mudstone.
		(T-marker)	22.31-22.84	Mudstone; brecciated; bioturbated.
		ORDOVICIAN-Stonewall	22.84-30.00	Wackestone to mudstone.
		(lower T-marker)	30.00-31.15	Mudstone; conglomerate/brecciated.
			31.15-33.93	Wackestone (minor mudstone)
		(Williams Member)	33.93-36.93	Mudstone; laminated.
		Stony Mountain	36.93-63.15	Wackestone (minor mudstone); cherty; mottled.
		Red River (Fort Garry)	63.15-75.35	Mudstone; brecciated; cherty.
		Lower Red River	75.35-107.13	Wackestone; fossiliferous.
		Winnipeg	107.13-113.85	Sandstone; quartzose.
		PRECAMBRIAN	113.85-117.55	Light pink; mesocratic; foliated; hornblende-biotite-epidote granodiorite.
M-5-93	6016050N	ORDOVICIAN-Stony Mountain	0.00-15.05	Wackestone.
Atik Road	329200E	Red River (Fort Garry)	15.05-21.93	Mudstone; brecciated.
	15-8-61-28W	Lower Red River	21.93-61.07	Wackestone; pyrite mineralization; cherty.
	291.0	Winnipeg	61.07-63.20	Sandstone (dolomitic at top); quartzose, mottled.
		PRECAMBRIAN	63.20-75.35	Green amphibolite with or without epidote; injected by leucocratic hornblende-biotite-epidote tonalite/ granodiorite; minor faults.
M-6-93	6016250N	ORDOVICIAN-Stony Mountain	0.00-14.60	Wackestone.
Atik Road	323100E	Red River (Fort Garry)	14.60-27.75	Mudstone; cherty; minor breccia.
	16-10-61-29W	Lower Red River	27.75-60.38	Wackestone; minor chert.
	295.0	Winnipeg	60.38-63.15	Sandstone; quartzose; kaolinitic at base.
		PRECAMBRIAN-Weathered	63.15-66.50	
		Unweathered	66.50-84.45	Grey leucocratic to mesocratic, hornblende-biotite-epidote-titanite tonalite gneiss; with amphibolitic-dioritic layers; well-layered tonalitic gneisses with mixed amphibolite; rare clinopyroxene-titanite-rich layers.
M-7-93	6041625N	OVERBURDEN	0.00-3.90	
East Goose	345950E	PRECAMBRIAN	3.90-20.45	Grey massive mesocratic hornblende-biotite-epidote-titanite quartz diorite; with cross-cutting pegmatite.
Lake	2-6-64-26W			
	281.1			
M-8-93	6043425N	ORDOVICIAN-Lower Red River	0.00-23.10	Wackestone.
Petryk	368450E			
	11-9-64-24W	Winnipeg (?)	23.10-23.75	Arenaceous dolomite; very pyritic at top.
	304.5	PRECAMBRIAN	23.75-38.55	Grey to pink leucocratic hornblende-biotite-epidote-titanite granodiorite; minor pink aplite dykes.
M-9-93	6049750N	OVERBURDEN	0.00-11.00	Boulder till and beach sand?
East Spruce	416250E	ORDOVICIAN-Lower Red River	11.00-24.55	Wackestone; mottled; minor fossils.
Point	2-5-65-19W	Winnipeg	24.55-25.96	Siltstone to mudstone; quartzose; abundant pyrite mineralization; dolomitic sand at top.
	295.7			
		PRECAMBRIAN	25.96-60.15	Black graphitic mudstone with minor silty beds; laminated, locally; brecciated, local quartz veins.
M-10-93	6047900N	ORDOVICIAN-Lower Red River	0.00-11.35	Wackestone.
Highway 39	405050E			
Sand	16-30-64-20W	Winnipeg	11.35-14.60	Unconsolidated sand with some Quaternary/Recent(?) infill.
	289.3			
		PRECAMBRIAN-Weathered	14.60-18.00	Hematized and chloritized sheared diorite/gabbro.
		Unweathered	18.00-38.80	Green, strongly sheared and cataclastic (numerous brittle faults) diorite/gabbro; some altered to chlorite schist.
M-11-93	6011750N	OVERBURDEN	0.00-7.80	Boulder till (?).
Mitchell Lake	349750E	ORDOVICIAN-Stony Mountain	7.80-19.60	Wackestone; minor silt; infilled fractures.
Road	11-33-60-26W	Red River (Fort Garry)	19.60-26.83	Mudstone; minor breccia.
	285.0	Lower Red River	26.83-60.62	Wackestone; cherty.
		Winnipeg	60.62-66.75	Sandstone; quartzose; dolomitic sand at top.

		PRECAMBRIAN	66.75-84.55	Tonalitic gneisses; grey, foliated to gneissic; leucocratic to mesocratic; biotite-hornblende-magnetite tonalitic gneiss with coarse grained *in situ* leucocratic tonalitic melt; magnetite bearing pegmatite dykes.
M-12-93	5998750N	ORDOVICIAN-Stonewall	0.00-5.48	Wackestone.
Rocky Lake	342400E	(lower T-marker)	5.48-6.05	Mudstone.
	14-23-59-27W		6.05-9.20	Wackestone.
	284.0	(Williams Member)	9.20-12.50	Mudstone; laminated.
		Stony Mountain	12.50-37.40	Wackestone; nodular.
		Red River (Fort Garry)	37.40-44.50	Mudstone; minor breccia and conglomerate.
		Lower Red River	44.50-84.50	Wackestone; cherty; fossiliferous; burrowed.
		Winnipeg	84.50-90.60	Sandstone; quartzose; dolomitic sand at top.
		PRECAMBRIAN-Weathered	90.60-91.10	
		Unweathered	91.10-92.70	Mesocratic biotite hornblende gneiss, locally disseminated sulphides, granitoid *lits;* gneissosity 30-45°.
			92.70-97.00	Same as above but oxidized; cataclastic and faulted._
			97.00-101.70	Mesocratic biotite hornblende gneiss.
M-13-93	5987950N	SILURIAN-Moose Lake	0.00-5.63	Mudstone; medial marker bed at 3.7-3.9 m.
High Ridge	436550E	(U_1-Marker)	5.63-7.20	Mudstone; laminated; slightly arenaceous.
	1-30-58-17W	Fisher Branch	7.20-15.51	Wackestone to packstone; abundant paleofavosites at base.
	266.7			
		Stonewall (marker)	15.51-16.20	Mudstone; conglomeratic.
			16.20-18.05	Mudstone.
		(T-marker)	18.05-18.60	Mudstone; laminated; conglomeratic.
		ORDOVICIAN-Stonewall	18.60-19.51	Wackestone to mudstone.
		(lower T-marker)	19.51-20.65	Mudstone.
			20.65-30.62	Wackestone to packstone; minor fossils.
		(Williams Member)	30.62-34.50	Mudstone; brecciated; laminated.
		Stony Mountain	34.50-60.85	Wackestone; nodular.
		Red River (Fort Garry)	60.85-70.50	Mudstone; minor breccia and conglomeratic.
		Lower Red River	70.50-104.85	Wackestone; cherty; fossiliferous.
		Winnipeg	104.85-112.71	Sandstone; quartzose; arenaceous dolomite at top; brachiopods at top.
		PECAMBRIAN-Weathered	112.71-113.40	
		Unweathered	113.40-121.10	Homogeneous, weakly foliated, fine- to medium-grained mesocratic psammitic biotite gneiss; with pinhead-size garnets; isolated coarse grained portions with 2 cm garnets; metamorphic layering 50°.
M-14-93	5978071N	SILURIAN-East Arm	0.00-2.80	Mudstone.
West William	464574E	(U_2-marker)	2.80-5.00	Mudstone; laminated; some sand.
Lake	4-30-57-14W	Atikameg	5.00-9.40	Grainstone to floatstone.
	283.5	Moose Lake	9.40-15.15	Mudstone; medial marker at 12.80-13.70 m.
		(U_1-marker)	15.15-16.50	Mudstone; arenaceous.
		Fisher Branch	16.50-23.95	Wackestone to packstone.
		Stonewall (marker)	23.95-24.95	Mudstone; slightly conglomeratic.
			24.95-26.55	Mudstone.
		(T-marker)	26.55-27.84	Mudstone; slightly conglomeratic.
		ORDOVICIAN-Stonewall	27.84-35.70	Wackestone to packstone; minor corals.
		(lower T-marker)	35.70-36.24	Mudstone.
			36.24-38.97	Wackestone to packstone.
		(Williams Member)	38.97-43.06	Mudstone.
		Stony Mountain	43.06-71.70	Wackestone; nodular; mud infilled fracture at 55.62 m.
		Red River (Fort Garry)	71.70-81.90	Mudstone; minor breccia and conglomerate.
		Lower Red River	81.90-113.61	Wackestone; cherty; fossiliferous; mud infilled fracture from 111.50-113.61 m.
		Winnipeg	113.61-123.90	Sandstone; quartzose.
		PRECAMBRIAN-Weathered	123.90-125.50	
		Unweathered	125.50-133.00	Ultramafic/mafic rocks with hornblende, biotite, garnet, pyroxene, phlogopite, tremolite; layering 40-70°.
M-15-93	5998000N	SILURIAN-Atikameg	0.00-1.35	Grainstone to floatstone; vuggy.
East Talbot	457500E	Moose Lake	1.35-9.50	Mudstone; medial marker at 7.40-7.80 m.
Lake	11-28-59-15W	(U_1-marker)	9.50-10.30	Mudstone; arenaceous.
	281.6	Fisher Branch	10.30-18.03	Wackestone to packstone.
		Stonewall (marker)	18.03-18.70	Mudstone; conglomeratic.
			18.70-20.65	Mudstone.
		(T-marker)	20.65-22.70	Mudstone; slightly conglomeratic.
			22.70-28.05	Wackestone to mudstone.

		(lower T-marker)	28.05-28.70	Mudstone.
			28.70-32.20	Wackestone to packstone.
		(Williams Member)	32.20-38.50	Mudstone; laminated.
		Stony Mountain	38.50-63.30	Wackestone; nodular.
		Red River (Fort Garry)	63.30-73.80	Mudstone; minor breccia and conglomerate.
		Lower Red River	73.80-103.15	Wackestone; cherty; fossiliferous.
		Winnipeg	103.15-112.05	Sandstone; quartzose.
		PRECAMBRIAN-Weathered	112.05-118.00	
		Unweathered	118.00-127.30	Fine- to medium-grained biotite amphibolite with leucocratic feldspathic layers at 60-80° dip and thin pink pegmatite.
M-16-93	6050500N	ORDOVICIAN-Lower Red River	0.00-17.90	Wackestone; mottled.
Lucas Hole	379700E	Winnipeg	17.90-18.54	Dolomitic sandstone; quartzose.
	4-3-65-23W	PRECAMBRIAN-Weathered	18.54-21.90	Weathered greenstone.
	310.9	Unweathered	21.90-27.10	In part weathered greenstone (fault gouge?); in part mylonitic metavolcanic rocks.
			27.10-35.75	Strongly sheared to mylonitic metavolcanic rocks locally tightly folded.
M-17-93	6045000N	OVERBURDEN	0.00-6.37	
Ponton South	495600E	ORDOVICIAN-Lower Red River	6.37-18.95	Wackestone; mottled.
	11-21-64-11W	Winnipeg	18.95-20.50	Sandstone; quartzose.
	247.8	PRECAMBRIAN-Weathered	20.50-23.70	
		Unweathered	23.70-35.75	Coarse grained, foliated biotite amphibolite (metagabbro?); foliation 70°.

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GS-35 STATUS OF MANITOBA'S STRATIGRAPHIC DATABASE (MOGWIS), GEOLOGICAL SERVICES' COMPONENT

by G.G. Conley

Conley, G.G., 1993: Status of Manitoba's stratigraphic database (MOGWIS), Geological Services' component; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 134.

BACKGROUND AND OBJECTIVES

Since 1988, the Petroleum Branch and the Geological Services Branch have been actively developing a computerized approach for the storage and retrieval of all Oil and Gas well data for Manitoba. Petroleum is responsible for the development and maintenance of the general well data, production, and engineering components, as well as petroleum related stratigraphic data. Geological Services is responsible for development and maintenance of the Paleozoic stratigraphic picks data and core storage data and has extended the database to include all relevant Phanerozoic wells in Manitoba.

The Manitoba Oil and Gas Well Information System (MOGWIS) will eventually incorporate existing paper and computer databases into one centralized integrated system that will provide rapid access to all well records for internal users and external clients. The goal of MOGWIS is to assist clients in the exploration and development of the mineral resource and oil and natural gas potential of Manitoba.

CURRENT STATUS OF THE PROJECT

The schema (Public Petroleum Data Model - PPDM) that was adopted in principle, is a relational model developed by a consortium now comprising major corporations involved in petroleum exploration, data acquisition and distribution. The PPDM Association has been established to oversee modifications and extensions to the model, as well as its distribution, and has recently released Version 3.2. In recent months, PPDM, the Petrotechnical Open Software Corporation (POSC) and International Business Machines Corporation (IBM) have agreed in concept to work together to create a single, comprehensive data model for the petroleum industry and to place this industry standard model in the public domain. As a result, the database structure may not be finalized for a year or more.

Geological Services Branch has concentrated on computerizing the subsurface stratigraphic picks data and core storage for all Phanerozoic wells in Manitoba. In 1988, data for oil and gas wells, license numbers 1 to 4200, was purchased from Digitech. Since that time, picks for the Lower Paleozoic wells have been checked and modified by R. Bezys to conform to stratigraphic nomenclature established by the Western Canada Sedimentary Basin Atlas Project. Wireline logs and cores were used in the verification process. This involved the relogging of some Lower Paleozoic oil and gas cores, and the addition of 294 wells drilled under the Geological Services Branch stratigraphic drilling program, 107 Mineral Exploration wells and 10 miscellaneous wells (*i.e.*, water wells, Manitoba Hydro, etc.). In addition, detailed descriptions of old logs and new re-logs of all wells are being entered in MS Word and will be merged into the database. Isopachs of selected stratigraphic units have been calculated and stored in the database and subsea elevations are generated at report time.

To generate coordinates for digital mapping, wells were plotted on 1:50 000 topographic maps according to the original land survey descriptions. The 1:50 000 maps were then registered in AutoCad and the well locations were digitized. The UTM coordinates were then extracted and imported into MOGWIS.

The data for each well includes stratigraphic picks, isopach values, subseas elevations, geologist responsible for the pick, and the date the pick was made or revised. Also included is well header information including UWI (Unique Well Indicator), well location (both NTS and UTM), map sheet reference, well name, license number, assessment file number, Kelly Bushing elevation, ground elevation, well type indicator (oil & gas, stratigraphic, mineral exploration, water well), source of the data, and date of last update. The well header data also includes a field indicating detailed core log descriptions that are currently available in digital format.

Core storage location data is being maintained by D. Berk as a separate stand-alone dBase IV database at the Midland core storage facility. The core storage locations are merged into MOGWIS following all major updates. Drill chip sample storage will be added as soon as practical.

In total, 3164 well records with tops data reside in the formation tops database and all nonconfidential wells are available to the public. At present, all historical picks maintained by Geological Services and core descriptions are also being entered into the database on an as-is basis. The historical data includes wells primarily picked by H.R. McCabe and other Manitoba geologists. The picks will cover the entire stratigraphic column in Manitoba and will serve as a valuable permanent reference.

R. Bezys is presently using the formation tops database to digitally produce a series of Lower Paleozoic stratigraphic structural maps and isopach maps. This data is available in digital form or as printed listings.

FUTURE DEVELOPMENTS

As funding becomes available, MOGWIS will be moved onto a centralized database server so that Petroleum and Geological Services users can simultaneously access the system. It is hoped that dial-up access can be made available to clients. Until remote access becomes a possibility, Geological Services will make the data available to clients in the form of printouts, or digitally in the form of ASCII text or dBase III or IV database files.

GS-36 GROUND MAGNETOMETER SURVEY OF "MELTROCK" EAST OF GYPSUM LAKE, MANITOBA

W.D. McRitchie and D. Wright

McRitchie, W.D. and Wright, D., 1993: Ground magnetometer survey of "Meltrock" east of Gypsum Lake, Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 135-140.

SUMMARY

A ground magnetometer survey was conducted in the region east of Gypsum Lake to aid in the delineation of "meltrock" in order to provide additional data to assist interpretation of the Lake St. Martin structure.

The "meltrock's" highly variable magnetic signature is in marked contrast to a relatively flat response over gypsum bedrock. This contrast in variability can be used as a guide to mapping the distribution of the two lithologies on the ground, but is too localized to be detected by airborne surveys.

INTRODUCTION

Recent geological mapping in the Gypsumville area (McRitchie, 1991) has improved definition of near-surface gypsum and "meltrock", in a region noted for having sparse and widely spaced bedrock exposures (Fig. GS-36-1). The unique and complex geology of the area has led previous authors (McCabe and Bannatyne, 1970, Dence, 1970) to propose a meteoric impact origin for the apparently circular, 24 km diameter structure. Alternatively, Currie (1970) suggested that the features observed in the structure could be attributed to a cryptovolcanic origin. These unique features

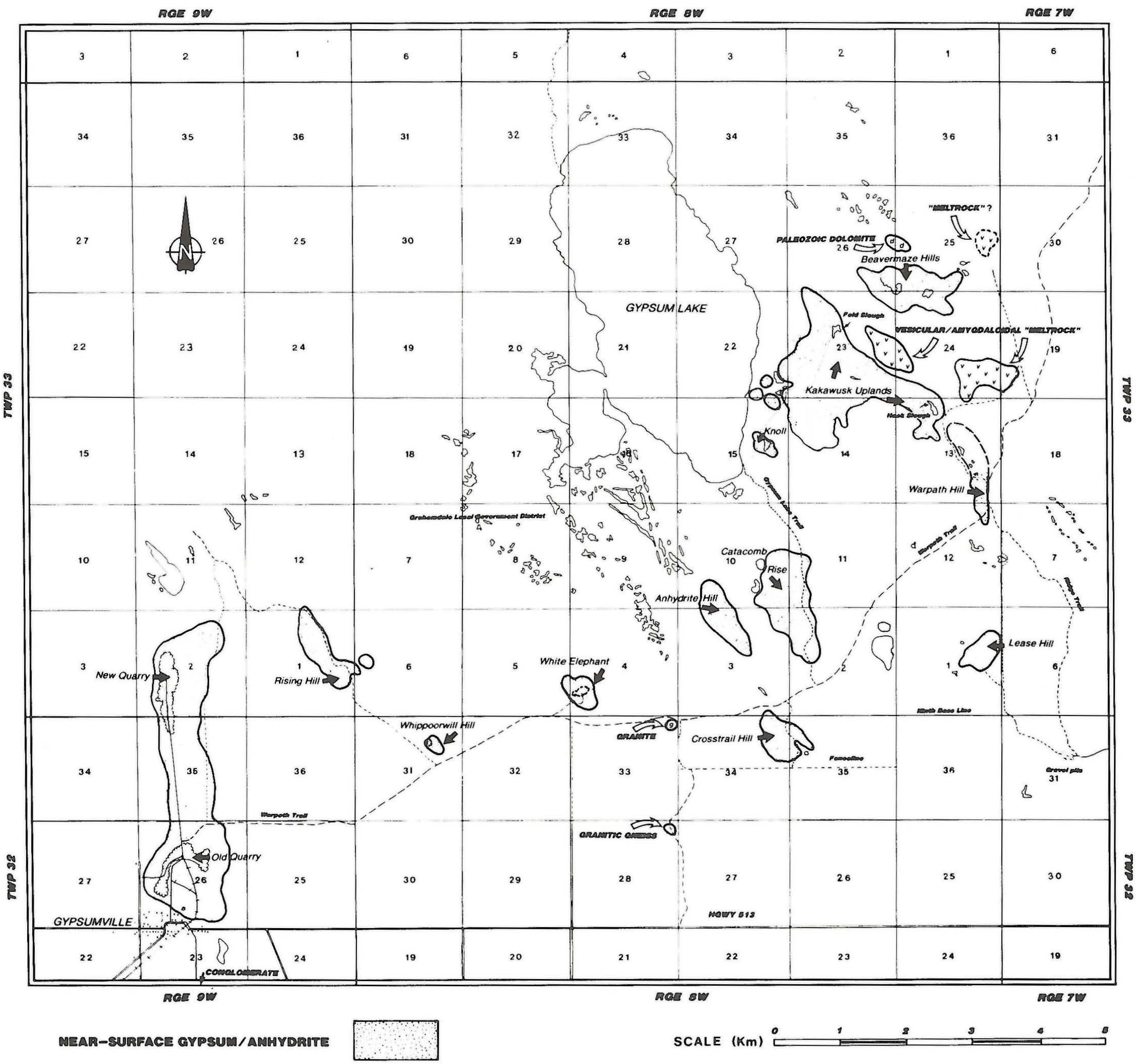


Figure GS-36-1: Near surface gypsum/anhydrite deposits, Gypsumville, and Gypsum Lake area, Manitoba.

include shock metamorphosed granite in the "central uplift", anomalous distribution of gypsum, anhydrite and redbeds east of the main Jurassic outcrop belt, drill core intersections of disoriented carbonates, trachyandesitic "meltrock", diatreme-like "meltrock" breccias, and on the east side of the structure, an uplifted "granite rim".

CURRENT WORK

The current study focussed on the area east of Gypsum Lake where gypsum, anhydrite and "meltrock" are well exposed in an area informally referred to as the Kakawusk Uplands (the old name for Gypsum Lake was Kakawusk Sikahigan or Mica Lake). The gypsum occurs in the outcrop belts to the north and south of two separate tracts of "meltrock" exposures (Fig. GS-36-1). The east and west extensions of the gypsum and "meltrock" are concealed beneath overburden, although potentially diagnostic vegetation cover (aspen and hazelnut), suggests that the evaporites link up around the western end of the "meltrock" occurrences.

Because of the paucity of outcrops, a magnetometer survey was implemented to determine whether the "meltrock" had a diagnostic magnetic signature, and if so to use this to enhance delineation of the "meltrock" distribution. The underlying questions to be resolved were;

1. What were the contact relationships between the gypsum and "meltrock" (exposures of both units occur within 200 m of each other at the same topographic level, and yet south of Gypsum Lake and gypsum sequence is underlain by 60 m of redbeds)?, and
2. Were the two isolated tracts of "meltrock" exposures linked at depth beneath the overburden, or did they constitute two separate and distinct "pipes"?

A rectangular grid (comprising 12, 1.6 km long, traverse lines spaced at 200 m intervals, with a 020° azimuth) was drawn up on 1:5000 scale aerial photographs of the area, flown in November 1991. [The absence of leaf cover, complemented by a light dusting of snow at the time the aerial photography were taken, enhanced the visibility of all surface features and improved the reliability of positioning on the ground.] The grid was positioned to provide overlap onto both the northern and southern areas of gypsum and to cover both tracts of "meltrock" exposures (Fig. GS-36-2).

The survey was conducted using a Scintrex MP2 precession magnetometer. Base stations were established at the end of every two traverse legs and repeat readings taken every two hours. Diurnal variations over longer periods were monitored by taking repeat readings at the beginning and end of each day at a control base station on Hook Sleugh.

Navigation was by compass and pace, augmented by inspection of aerial photographs to detect off-line excursions. Accuracy was within 5 m, although this may have been less in tamarack swamps where distinctive features were hard to locate on the photographs. Start and end points for each traverse leg were determined exactly on the photographs, and UTM coordinates defined at several locations using a GARMIN GPS unit (with software conversion from latitude/longitude readings taken in the field).

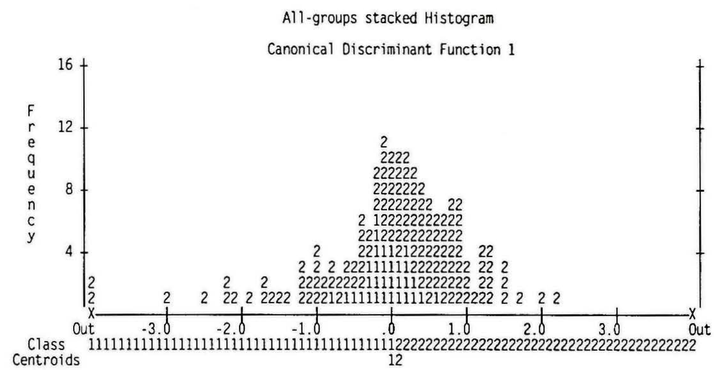
Initially, (legs 12-8), readings were taken every 100 m along the traverse lines. However, as the survey progressed these were closed up to 50 m spacings, and ultimately 25 m spacing along legs 1 to 3. Dramatic local variations of up to 1000 gammas were detected in some "meltrock" areas by taking additional, within station, readings at 10, 20 and 30 m east and west of the on-line stations. The length of traverse lines 1 to 6 was reduced to 1 km to meet time constraints.

RESULTS

The survey demonstrated that "meltrock" was characterized by a highly variable magnetic signature, with readings ranging over 1000 gammas within less than 100 m. Gamma readings ranged from a high of 60494 to a low of 59476, with a mean of 60174 (Table GS-36-1). In contrast readings over areas underlain by gypsum display a smaller range from a high of 60262 and a low of 60045 and a mean of 60162 (Table GS-36-1). This dramatic contrast in variability (see lines 1-5, Fig. GS-36-3) may be used to extrapolate the distribution of the two principal rock types from their surface exposures, and to infer the location of the contacts between areas underlain by gypsum or "meltrock" respectively, (Fig. GS-36-2). The interpretation is further supported through correlation with diagnostic vegetation, the gypsum being covered by aspen and hazelnut, the "meltrock" occurring in open glades and clearings with scattered jackpine and light underbrush.

Table GS-36-1
G>round magnetometer survey, east of Gypsum Lake, Statistical Summary

	Gypsum	Meltrock
No. readings	32	132
Mean	60163	60175
Median	60159	60205
Variance	1853.797	26493.65
Std. Dev.	43.0557	162.7687
Skewness	-.1126	-1.4497
Kurtosis	.5152	3.7077
Highest reading	60262	60494
Lowest reading	60056	59476



Classification Results

Actual Group		No. of Cases	Predicted Group Membership 1	2
Group Gypsum	1	32	19 59.4%	13 40.6%
Group Meltrock	2	132	52 39.4%	80 60.6%

Percent of "grouped" cases correctly classified: 60.37%

The results indicate that the east and west areas of "meltrock" exposure are discrete entities separated by 500 m (of buried gypsum?), with a third body at the south end of line 6. The easternmost body is open to the north, whereas the highly vesicular and amygdaloidal western body appears fully constrained with a surface area of 48.25 hectares. The high variability in magnetic response precludes modelling the shape and thickness of the "meltrock" bodies at depth. The extreme local variability in the magnetic response of the "meltrock" presumably reflects the heterogeneous nature of this inclusion-filled lithology, and is a feature that would not readily be detectable using airborne magnetic sensors.

Although the survey proved functional in defining the approximate location of the contacts between gypsum and "meltrock", no new information was obtained about the nature of the contact. Drilling or hammer seismic surveys will be necessary to determine the contact (and age) relationships, and the extent of the redbeds underlying the gypsum.

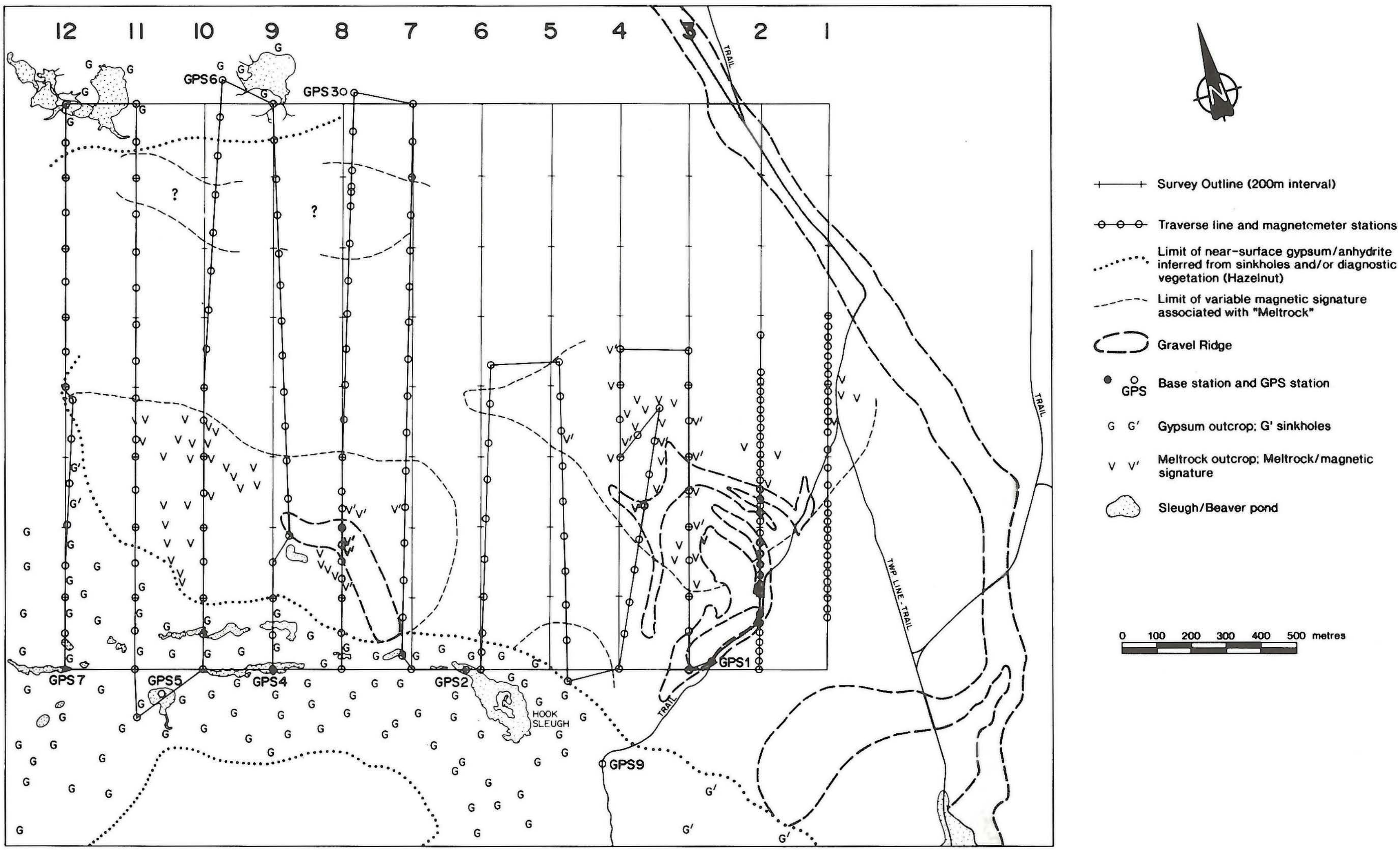


Figure GS-36-2: ***Ground magnetometer survey of "meltrock" east of Gypsum Lake area, Manitoba.***

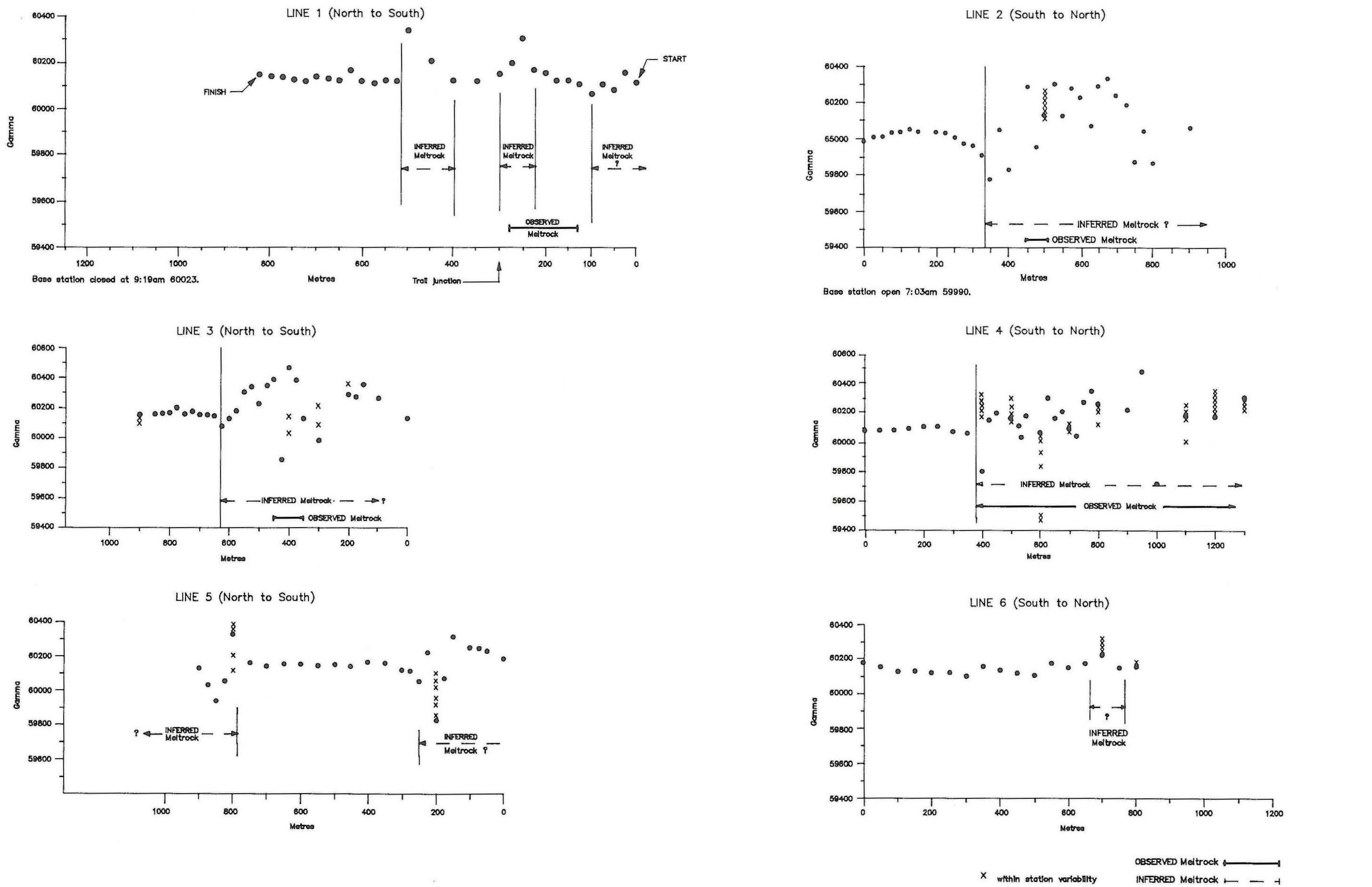


Figure GS-36-3: ***Ground magnetometer profiles, east of Gypsum Lake.***

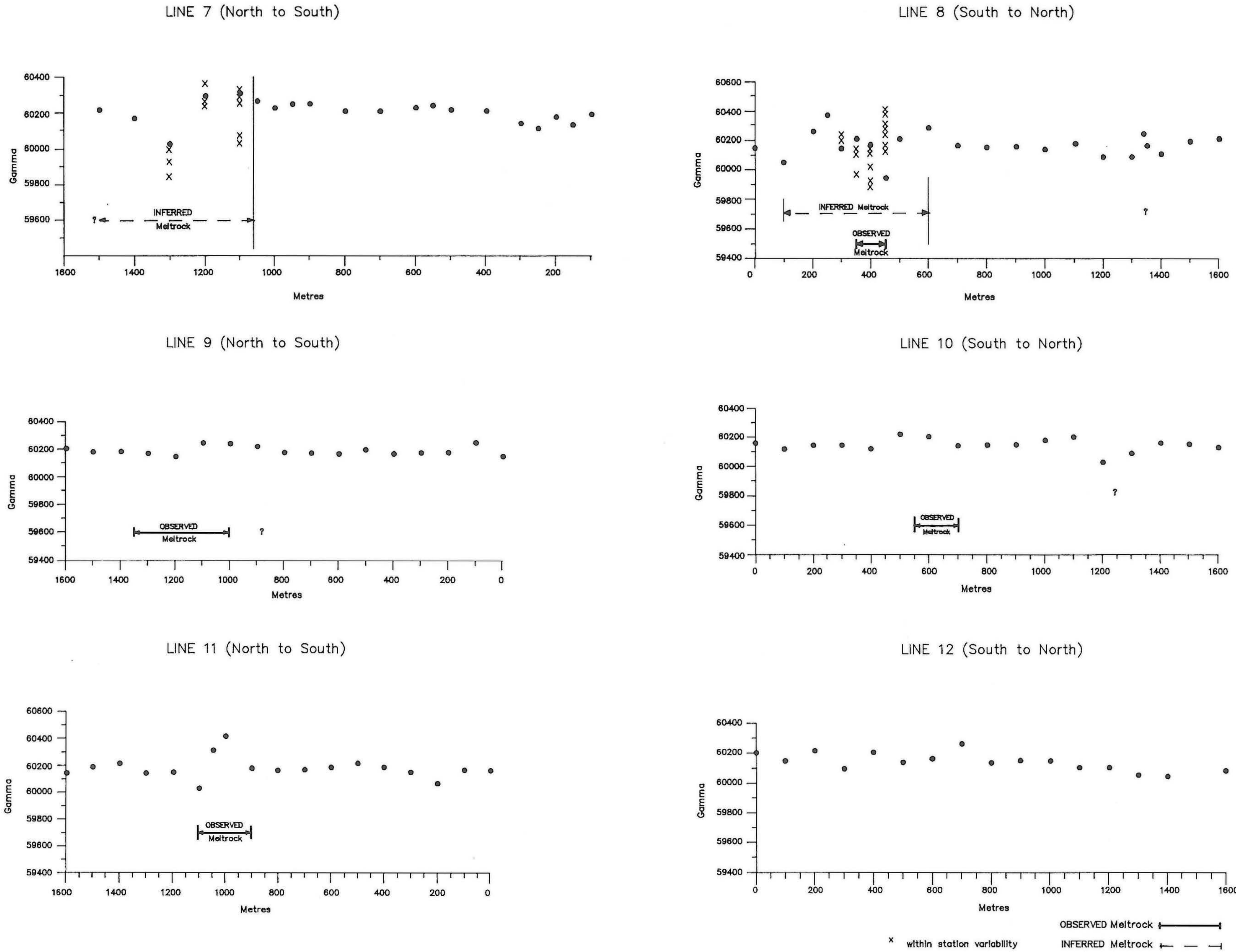


Figure GS-36-3: Ground magnetometer profiles, east of Gypsum Lake.

Future work will extend the existing grid to the north and south and introduce additional traverses closing the line spacing up to 100 m, with readings every 25 m. The regional coverage will be augmented by a 10 to 25 m grid over a smaller "meltrock" area to determine whether the variability in magnetic response is systematic at a larger scale, or whether the response is random and related to individual inclusions or matrix inhomogeneity.

Addendum

The highly variable magnetometer responses over the "meltrock" were investigated further by mounting a more detailed survey over "meltrock" outcrops in the western sector, and by taking susceptibility measurements on bedrock exposures. Magnetometer readings were taken at 25 m intervals on lines (azimuth 20°) spaced at 50 m. The highly variable magnetic signature of the heterogeneous "meltrock" was confirmed with little indication of a systematic distribution of the magnetic responses. Apparent susceptibility measurements were taken at three principal outcrop groupings using a Geofyzika Brno model KT-5 microkappameter. Although extreme measurements ranged from 0 to 18.7 ($X10^{-3}$ SI units), 92% of the 125 readings were between 1.5-9.0, with a population mean at 5.2 (Fig. GS-36-4).

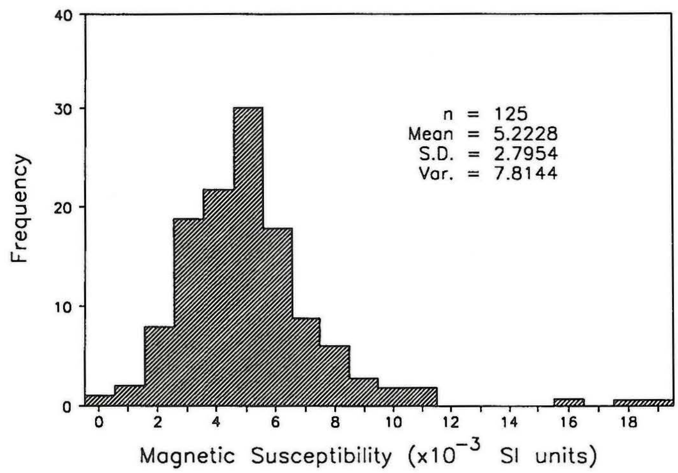


Figure GS-36-4: Susceptibility measurements, "meltrock" east of Gypsum Lake, Manitoba (western outcrop area).

No correlation was noted between apparent susceptibility of the "meltrock", and clast/matrix type/abundance. 12 apparent susceptibility measurements on nearby gypsum exposures yielded dominantly zero responses, with two readings at 0.02.

The follow-up survey confirmed the extreme, localized, and apparently non-systematic variation in magnetic response of the "meltrock" in the western outcrop grouping. Apparent, on-rock, magnetic susceptibility measurements show a unimodal distribution similar to that determined from the magnetometer surveys (Table GS-36-1).

Elevated, relatively flat magnetometer responses over areas of magnetically transparent gypsum bedrock, are interpreted to represent a muted signature originating in more magnetic "meltrock"? sources buried at depth. Contrasting variabilities in magnetic signature can be used to discriminate between near-surface occurrences of "meltrock" and gypsum (and thick overburden?), but should not be used to infer the geometry of "meltrock" distribution at depth.

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GS-37 INDUSTRIAL MINERALS INVESTIGATIONS IN SOUTHERN MANITOBA (NTS 52E, 52L, 62G, 62I, 62P, 63C)

by B.E. Schmidtke and J.D. Bamburak

Schmidtke, B.E. and Bamburak, J.D., 1993: Industrial minerals investigations in southern Manitoba (NTS 52E, 52L, 62G, 62I, 62P, 63C); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 141-145.

SUMMARY

During the 1993 summer field season an outcrop of grey Lac du Bonnet Batholith granite was mapped and sampled as a potential source of dimension stone. A new high potential mineral resource zone was delineated in the Whiteshell Provincial Park and several sites on four granitic intrusions were sampled as potential sources of granitic aggregate. Limited investigations of bentonite and silica sand were also conducted.

INTRODUCTION

Industrial Minerals Investigations fieldwork concentrated on deposits of dimension stone, granitic aggregate, bentonite and silica sand.

Investigations of granitic intrusions in southeast Manitoba, as potential sources of dimension stone production, concentrated on an outcrop of the Lac du Bonnet Batholith northwest of the Town of Lac du Bonnet, and on outcrops of the Betula Lake Pluton in the Whiteshell Provincial Park (Fig. GS-37-1).

A reconnaissance project to identify potential sources of granitic aggregate in southeast Manitoba (Fig. GS-37-1) concentrated on intrusions that have homogeneous textures and colours and an areal extent of at least 1 km^2 (Leathers, 1985).

Bentonite beds in the Miami-Morden area and silica sand-bearing formations in the Swan River and Black Island areas were sampled (Fig. GS-37-1).

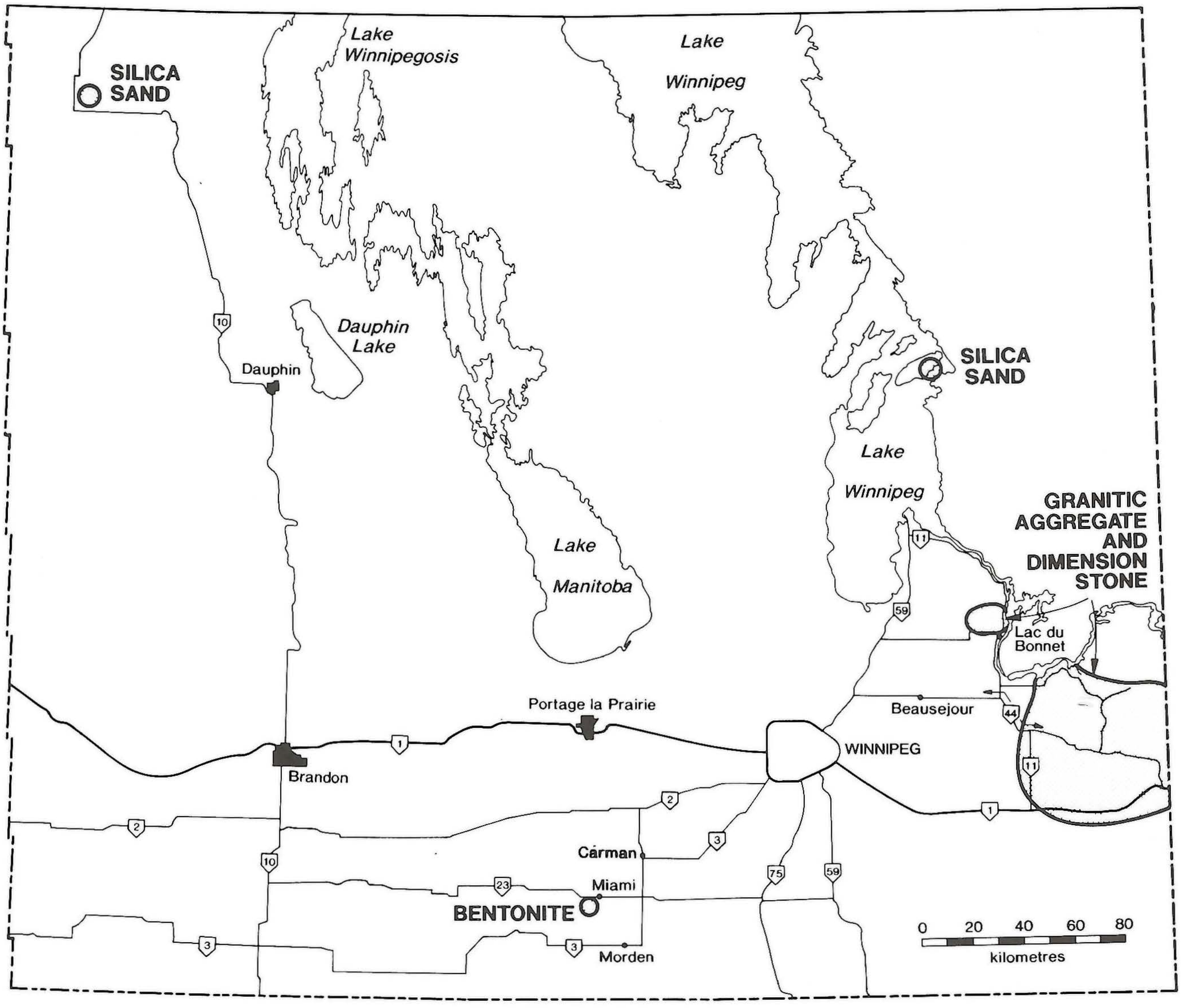

Figure GS-37-1: Location of 1993 industrial minerals investigations.

DIMENSION STONE

Lac du Bonnet Batholith

The Lac du Bonnet Batholith (LDBB), shown on Figure GS-37-2, is a predominantly pink, medium grained granite. The pink granite structurally overlies grey granite that is mineralogically identical to the pink granite (Tammemagi, 1980). The grey granite has widely spaced fractures and pegmatites. Two outcrops of grey granite were reported to occur east of the Town of Lac du Bonnet by Tammemagi (1980) and McCrank (1985), but these outcrops were found to be too small to support dimension stone quarries (Schmidtke, in prep).

An exposure of grey granite occurs adjacent to the Brightstone Road in the NW 1/4, Sec. 34, Tp. 15, Rge. 10EPM, approximately 15 km northwest of the Town of Lac du Bonnet (Fig. GS-37-3). Brightstone road is accessed via PR. 317. The outcrop is approximately 30 000 m²; 25% of which is grey granite. A further 30 to 50% of the outcrop is light pink granite that contains white K-feldspar-bearing pegmatites. The light pink granite appears to be a transitional phase between the typical pink LDBB granite, which contains pink pegmatites, and the grey LDBB granite, which contains white pegmatites. The light pink granite may be overlying near surface grey LDBB granite.

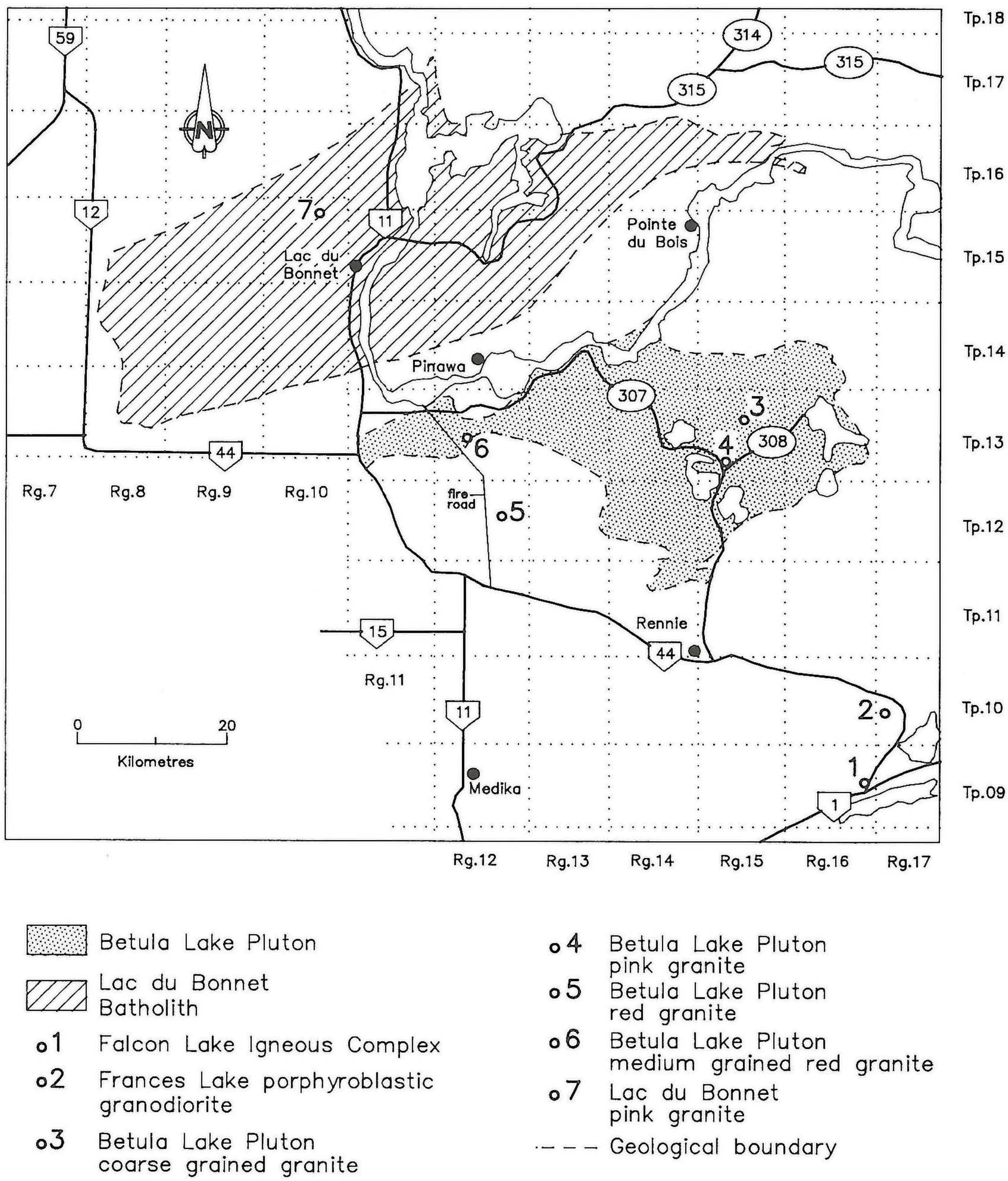

Figure GS-37-2: Location of granitic intrusions investigated as potential sources of dimension stone.

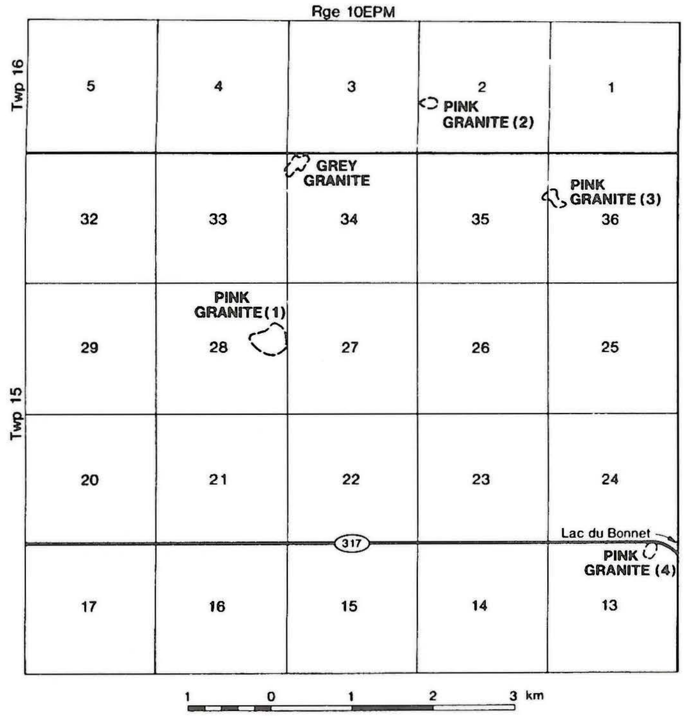

Figure GS-37-3: Locations of the outcrop of grey Lac du Bonnet Batholith granite mapped and sampled as a potential source of dimension stone and the outcrops sampled as potential sources of granitic aggregate.

Figure GS-37-4 illustrates both the distance between fractures and the fracture orientations in the grey, light pink and pink LDBB granites. The fracture sets strike southeast, northeast and north in the grey, light pink and pink granites. The fractures are spaced 10 to 15 m apart in the grey and light pink granites and less than 1 to 10 m apart in the pink granite.

This outcrop is a potential source of dimension stone. However, the 7 000 m² of grey granite exposed at surface may not be large enough to support a dimension stone quarry. Diamond drill cores from the exposures of light pink granite are required in order to determine the depth to the underlying grey granite.

Betula Lake Pluton

The Betula Lake Pluton is an equigranular to porphyritic granite that extends from the fireguard road eastwards past Meditation Lake in the Whiteshell Provincial Park. Three dimension stone quarries are located in the Betula Lake Pluton.

Investigations were concentrated on outcrops in the vicinity of the two Canital Granite exploration permits at the junction of PR 307 and 309, and south of Meditation Lake (Fig. GS-37-5) to determine if the area surrounding, and including, the quarries is a high potential mineral resource zone within the Whiteshell Provincial Park.

The Betula Lake Pluton within the White Lake - Meditation Lake zone is composed of pink to brown porphyritic granodiorite. Outcrops within the zone were assessed using a combination of aerial photograph interpretation and field examination. Outcrops that appear to have widely spaced fractures on 1:15 840 scale aerial photographs and are located a minimum distance of 1.5 km from cottages were examined. Most of these outcrops were field checked to assess the accuracy of the aerial photograph interpretation. In all cases, the field-checked outcrops proved to have widely spaced fractures. Several outcrops near Meditation Lake exhibit local textural variations and contain thin veins; however, they are also considered to be potential sources of dimension stone because they have widely spaced fractures.

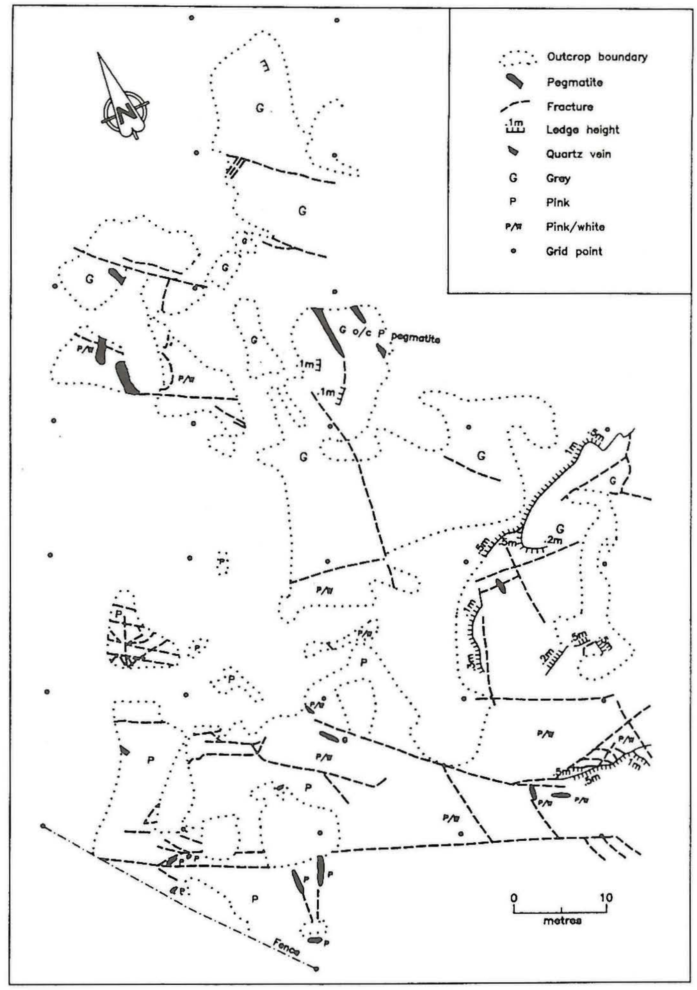

Figure GS-37-4: Fracture map of the outcrop of grey Lac du Bonnet Batholith granite.

Granite in the vicinity of the "Prairie Gold" quarry has a homogeneous pink colour and porphyritic texture and contains minor inclusions and veins. The granite outcrops on the west side of PR 307 appear to be darker than the outcrops on the east side of PR 307, but it is difficult to assess colour from surface samples. The granite in the vicinity of the "Meditation" quarry is brown, sparsely porphyritic and has textural and colour variations and thin red granitic veins.

GRANITIC AGGREGATE

A number of granitic intrusions in southeast Manitoba (Figs. GS-37-2 and 5) were investigated as potential sources of dimension stone (Leathers, 1985). Those intrusions that have homogeneous colours and textures and an areal extent of at least 1 km² were sampled as potential sources of decorative granitic aggregate for landscaping and construction. Samples from the selected intrusions were crushed and screened to approximately 2 cm (3/4 inch) size for display (see Fig. GS-37-2 and Table GS-37-1).

BENTONITE

Extensive resources of nonswelling calcium bentonite are situated along the Manitoba Escarpment in the Miami-Morden area (Fig. GS-37-1) of southwestern Manitoba (Bannatyne, 1963). Quarries, formerly operated by Pembina Mountain Clays Limited from 1939 to December 1990, have been rehabilitated leaving only very small exposures in the vicinity of the former workings. During field trips in June and September, these exposures and several others in road and stream cuts were sampled to permit future evaluation

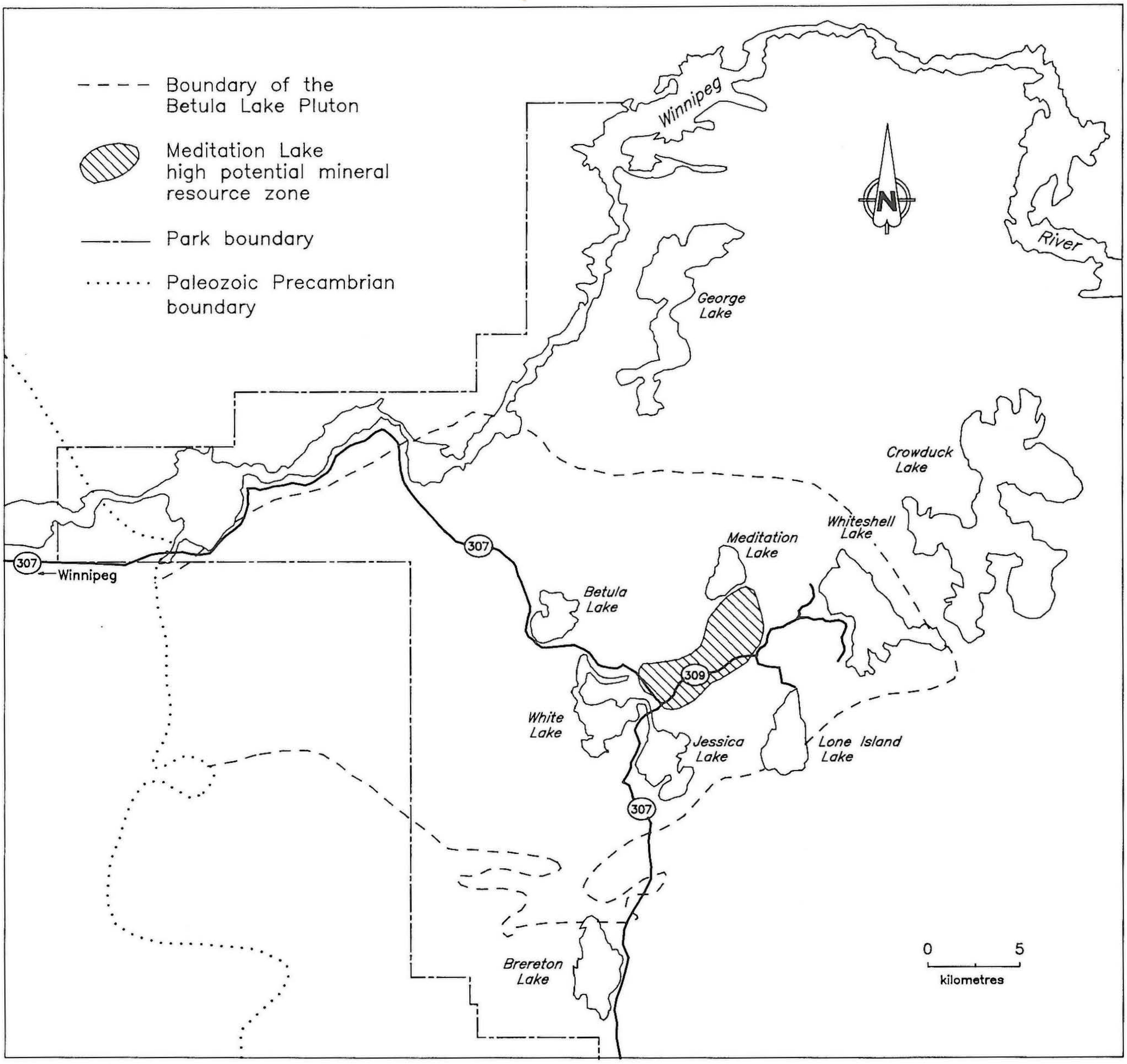

Figure GS-37-5: A high potential mineral resource zone delineated in the Whiteshell Provincial Park.

Table GS-37-1
Potential Granitic Aggregate Sites

Site #	Colour	Access	Comments	Surface use
1	black	PR 301	abandoned quarry	provincial park
2	pink-red	PTH 44		provincial park
3	brown	PR 309	near Canital test quarry	provincial park
4	pink	PR 309	near Canital test quarry	provincial park
5	red	fireguard road	near inactive quarry	provincial forest
6	brown	fireguard road	near abandoned test quarry	provincial forest
7	pink	PR 317	four outcrops sampled	private surface, Crown minerals

of the resources. Information on bentonite contained in the Department's nonconfidential industrial minerals files have been indexed (see Schmidtke and Lenton, GS-44, this volume) and is available for examination.

SILICA SAND

Considerable quantities of silica sand are present in the Hecla-Black Island-Manigotagan area and within the Swan River valley (Watson, 1985).

Silica sand, averaging 95.5 to 97.5% SiO_2, was quarried from the Ordovician Winnipeg Formation on the south side of Black Island (Fig. GS-37-1) from 1962 to 1990 by Selkirk Silica. Rehabilitation of the quarry was completed on September 1, 1993; however, good sections are still exposed. Channel samples were collected, over one metre intervals from the north end of the quarry, to determine if higher purity material could be selectively quarried.

Cretaceous Swan River Formation silica sand, which averages 97.5% SiO_2, (Fig. GS-37-1) has been investigated over the years (Watson, 1985; Gunter, 1989); but detailed sampling of stream exposures was not done. Twelve channel samples, over one metre intervals of the Swan River Formation, were collected in the SW 1/4, Sec. 10, Tp. 37, Rge. 26 WPM. Purity tests of this material will be conducted in tandem with those for the Winnipeg Formation.

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GS-38 HIGH PURITY SILICA STUDIES-GEOCHEMICAL AND MINERALOGICAL STUDIES OF WINNIPEG FORMATION SILICA SANDS

by G.H. Gale, N.M. Halden[1] and S. Mejia[1]

Gale, G.H., Halden, N.M., and Mejia, S., 1993: High purity silica studies-geochemical and mineralogical studies of Winnipeg Formation silica sands; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 146-148.

SUMMARY

Silica sand from Black Island was subjected to heavy mineral separation, hot acid leach and image analysis. Impurities occur as inclusions within the quartz grains. The Black Island silica sands are probably not amenable to beneficiation using chlorination and flotation methodologies.

INTRODUCTION

Silica sands were quarried on Black Island between 1929-32 and 1956-90. The main uses of this quartz-rich sand have been for container glass. Recent evaluations of the Winnipeg Formation have indicated the presence of large tonnages of high grade silica-rich material (Watson, 1985). The deposits are currently owned by Selkirk Silica, a Division of Marine Transport Ltd. The desire to expand both local and regional industrial mineral markets prompted several initiatives aimed at beneficiating the Winnipeg sandstones in general, and the Selkirk Silica products specifically, under the current Mineral Development Agreement. One of the proposed beneficiation methodologies involved the use of chlorination and flotation techniques to upgrade the silica sands to 99.9999% SiO_2.

Earlier studies initiated by the Geological Services Branch had revealed that acid leaches of the sands were unable to provide the ultra high purity material required for some manufacturing processes. This project was undertaken to establish whether the impurities identified during the earlier study, especially Fe, Al, Ti and Zr, were present as discrete acid resistant grains, which would be amenable to further beneficiation by chemical methods, or whether the impurities were present as microscopic sized inclusions that would not be amenable to chlorination and flotation processes.

The material used in this study was supplied by Selkirk Silica as representative of their quarry product. This starting material was subjected to heavy mineral separation on a Wifley shaker table, leaching of the silica fraction with concentrated acids, magnetic separation and image analyses to determine the distribution of the impurities. The various procedures are described in the relevant sections below.

SHAKER TABLE ANALYSIS

The composition of the starting material was not determined, but is considered to have approximated the average end product analysis (Table GS-38-1) provided by Tooley (1988).

A 50 kg sample of product run material was processed on a Wifley shaker table at various speeds and table settings. The resultant quartz sand light fraction concentrates were analysed using neutron activation techniques by Neutron Activation Laboratories, Ontario. The analyses of the different quartz fractions obtained are presented in Table GS-38-1.

Available literature indicates that these products contain higher Al, Fe, P, etc. than can be tolerated in high purity silica products.

ACID LEACHES

Samples 8 and 9 (Table GS-38-1) were selected for acid leach. Sample 8 was leached for 3 hours in concentrated hot aqua regia and sample 9 was leached for 3 hours in concentrated hot perchloric acid.

The leached samples were passed through a Franz Isodynamic Magnetic separator at the settings shown in Table GS-38-2. Negative tilt was used for sample 8A in order to obtain a sample of nonmagnetic material that was repulsed up the gradient by the magnetic field. Less than 10% of the sample was collected as a nonmagnetic fraction using this technique.

1 University of Manitoba

Table GS-38-1_Analyses of Black Island silica sand

Sample	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	99.558%	-	-	-	-	-	-	-	-	-	-	-
Al_2O_3	.219%	-	-	-	-	-	-	-	-	-	-	-
Fe_2O_3	.020%	-	-	-	-	-	-	-	-	-	-	-
TiO_2	.005%	-	-	-	-	-	-	-	-	-	-	-
CaO	.018%	-	-	-	-	-	-	-	-	-	-	-
MgO	.037%	-	-	-	-	-	-	-	-	-	-	-
LOI	.106%	-	-	-	-	-	-	-	-	-	-	-
Al		440	430	440	475	358	390	425	420	480	465	460
P		55	135	55	120	50	105	135	55	50	200	70
K		30	25	30	20	20	25	25	30	25	20	20
Ca		150	110	100	75	70	130	120	125	180	85	130
Ti		85	93	77	84	69	65	60	60	81	83	98
Fe		135	115	85	180	60	85	55	75	95	160	220
Li		2.0	3.2	3.2	3.0	2.9	2.9	2.3	2.9	2.7	3.1	3.5
Na		30	24	24	22	24	24	24	24	24	25	20
Mg		16	14	18	17	13	30	13	14	16	17	16
Mn		1.4	1.4	1.2	1.4	1.0	1.0	1.2	1.0	1.3	1.1	1.3
Ni		<<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cu		2.0	1.9	2.0	1.9	1.1	2.5	1.2	1.8	2.2	2.8	1.5
Zr		9	12	14	15	13	15	12	12	16	13	11
Cd		0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

1. Bulk analyses from Tooley (1988).
2-12. Analyses (PPM) of light fractions from shaker table. Analyses by Activation Laboratories Ltd.

IMAGE ANALYSES

Six portions of samples 8 and 9 (Table GS-38-2) were subjected to image analysis at the Microbeam Laboratory, University of Manitoba, in order to determine the mode of occurrence of the elements other than Silicon.

A scanning electron microscope (SEM) and a energy dispersive X-ray spectrometer (EDX) were used to study polished sand grains mounted in petro-epoxy. The EDX spectrometry allows for qualitative identification of minerals on the basis of their elemental compositions; elements are identified by comparison of peaks displayed in the spectrum with a standard table of X-ray emissions.

Table GS-38-2
Description of samples analysed by SEM-EDX. Samples analysed at University of Manitoba

Sample	Description
8	Light fraction from shaker table, aqua regia leach
8A	8+ Franz separator @1.7A, (tilt -5 degrees)
8B	8+ Franz separator @1.7A, (tilt +2 degrees) magnetic fraction
8C	8+ Franz separator @1.7A, (tilt +2 degrees) nonmagnetic fraction
9	Light fraction from shaker table, perchloric leach
9A	Franz separator @1.7A, (tilt +2 degrees) nonmagnetic fraction

The SEM is interfaced with a Image Analyzing System (IAS). The SEM-IAS combination permits the collection of high resolution backscattered electron (BSE) images of a polished sample surface. The BSE signal of a polished mineral sample is dependent on the average atomic number (Z) of the mineral. Quartz typically has a low average atomic number and hence a relatively "dark" grey level, but zircon, which has a high average atomic number, tends to have a "bright" grey level. Grains of various minerals may be unambiguously discriminated in BSE images based on their grey-level signature. Minerals identified in this manner may then be "measured". For example, the proportion of the field of view occupied by minerals of a particular grey-level may be quantified, grain shapes and sizes may also be measured.

This study has determined the proportion of quartz grains containing inclusions, the elemental composition of these inclusions and individual grains of minerals. Photographs were taken of typical or unique grains of contaminants or inclusions. Once the impurities were located, the SEM and EDX were used to generate the spectrum required for mineral identification.

RESULTS

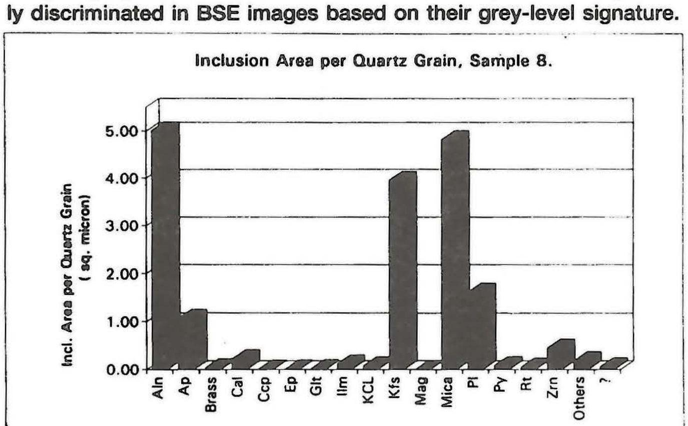
The presence of trace quantities of Al, P, Fe, Ti, K, Ca, Na, Mg, and Zr were detected in the samples analysed. A complete list of inclusions in each sample, inclusion size, size of quartz grain containing the inclusion, percentage of grains with inclusions per sample, the relative proportions of the inclusion phases per sample and whether the inclusion is completely or partially enclosed in the quartz grain have been documented (Mejia and Halden, 1993).

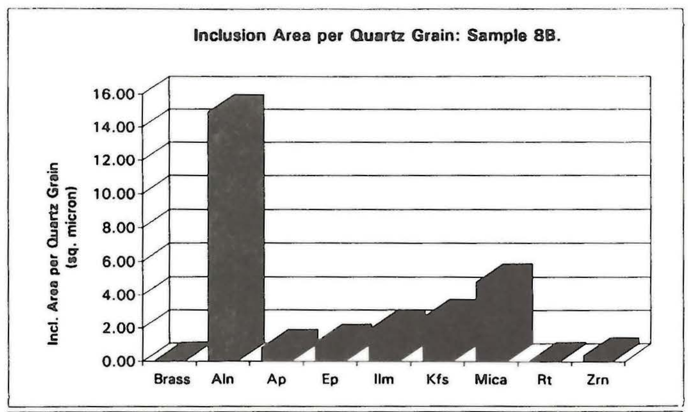
Minerals identified in this study include mica, apatite, pyrite, ilmenite, magnetite, rutile, plagioclase, K-feldspar, zircon, epidote and a Fe, REE bearing silico-phosphate, qualitatively identified as allanite (Fig. GS-38-1, -2). Samples 8A, 8B and 9 have significant proportions of allanite, K-feldspar and mica. Samples 8C and 9 have a significant number of zircon inclusions. Apatite is common in sample 9A, but this does not appear as high P contents in the chemical analyses.

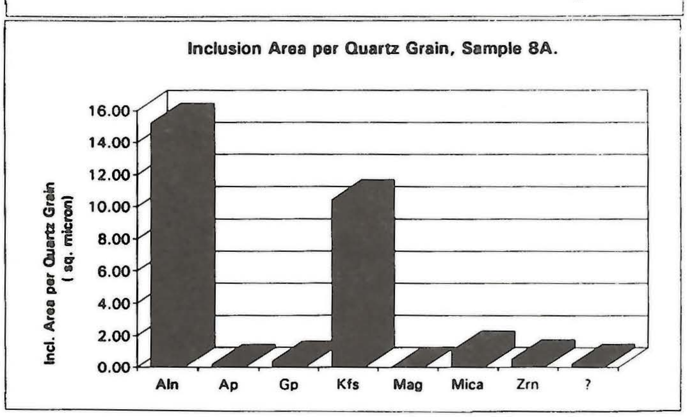
CONCLUSIONS

In samples 8 and 9, which were not subjected to magnetic separation, 12% and 10% respectively, of the grains contained inclusions.

Sample 8A with 8.63% inclusions contained the lowest proportions of inclusions in quartz grains.







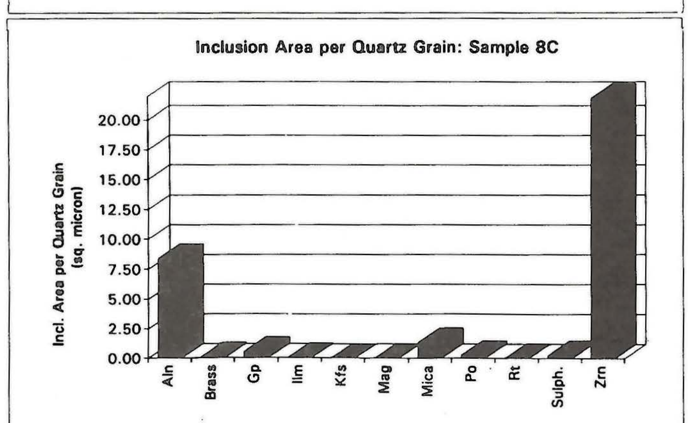
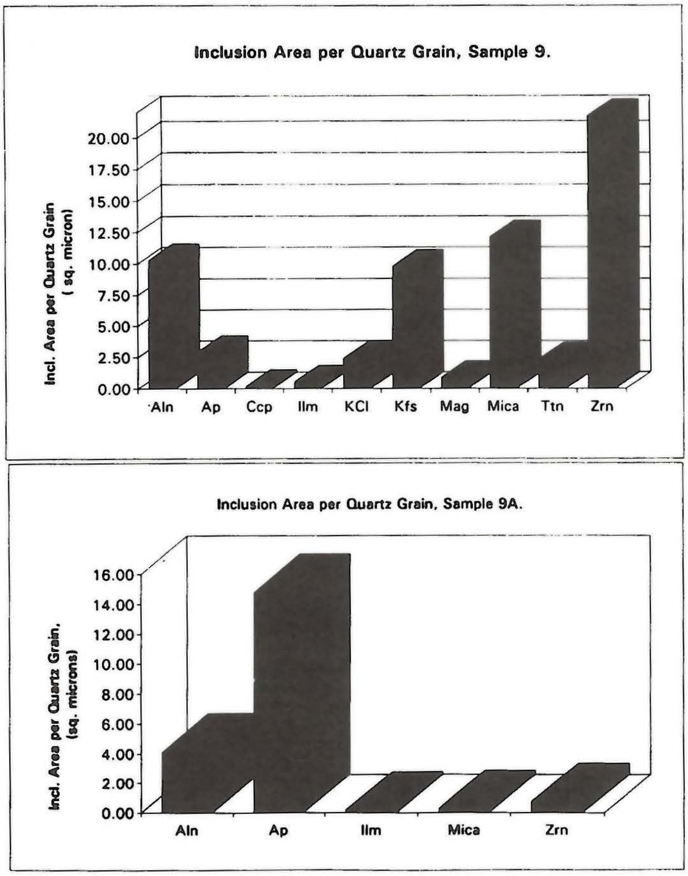


Figure GS-38-1: Average area (in square microns) of inclusions per quartz grain for each sample. Abbr.: Aln-allanite, Ap-apatite, Ccp-chalcopyrite, Ilm-ilmenite, Kcl-potassium chloride, Kfs-potassic feldspar, Mag-magnetite, Mica-muscovite(?), Ttn-titanite, Zrn-zircon, Ep-epidote, Rt-rutile, Gp-gypsum, Po-pyrrhotite, Sulph.-sulphides, Cal-calcite, Glt-glauconite, Pl-plagioclase, Py-pyrite.



The proportion of quartz grains with inclusions ranged from 8.6% (nonmagnetic, negative tilt), to 19% in sample 8B (magnetic, positive tilt). Sample 9A (nonmagnetic fraction, perchloric acid leach) appears to have the least diversity in inclusions. These data indicate that the grains with inclusions can be concentrated to some extent by magnetic separation techniques.

Inclusion size is widely variable, but can be broadly broken down into two groups, greater and less than 160 microns. In order to further beneficiate this material by acid or gas leaching, flotation methods or combinations of the two it would be necessary to reduce the quartz grain size of the sample to about 160 microns in order to liberate the inclusions or to bring the inclusions to the surface of the quartz grains. Even this approach will probably not produce an *ultra pure* product because the quartz will still contain some inclusions less than 160 microns in size.

Based on these observations and our current knowledge of chlorine gas and flotation techniques it is our view that such techniques would be ineffective in the beneficiation of Black Island sands. Further beneficiation of the sands using acid leaches and magnetic separation techniques is possible and should be investigated in more detail.

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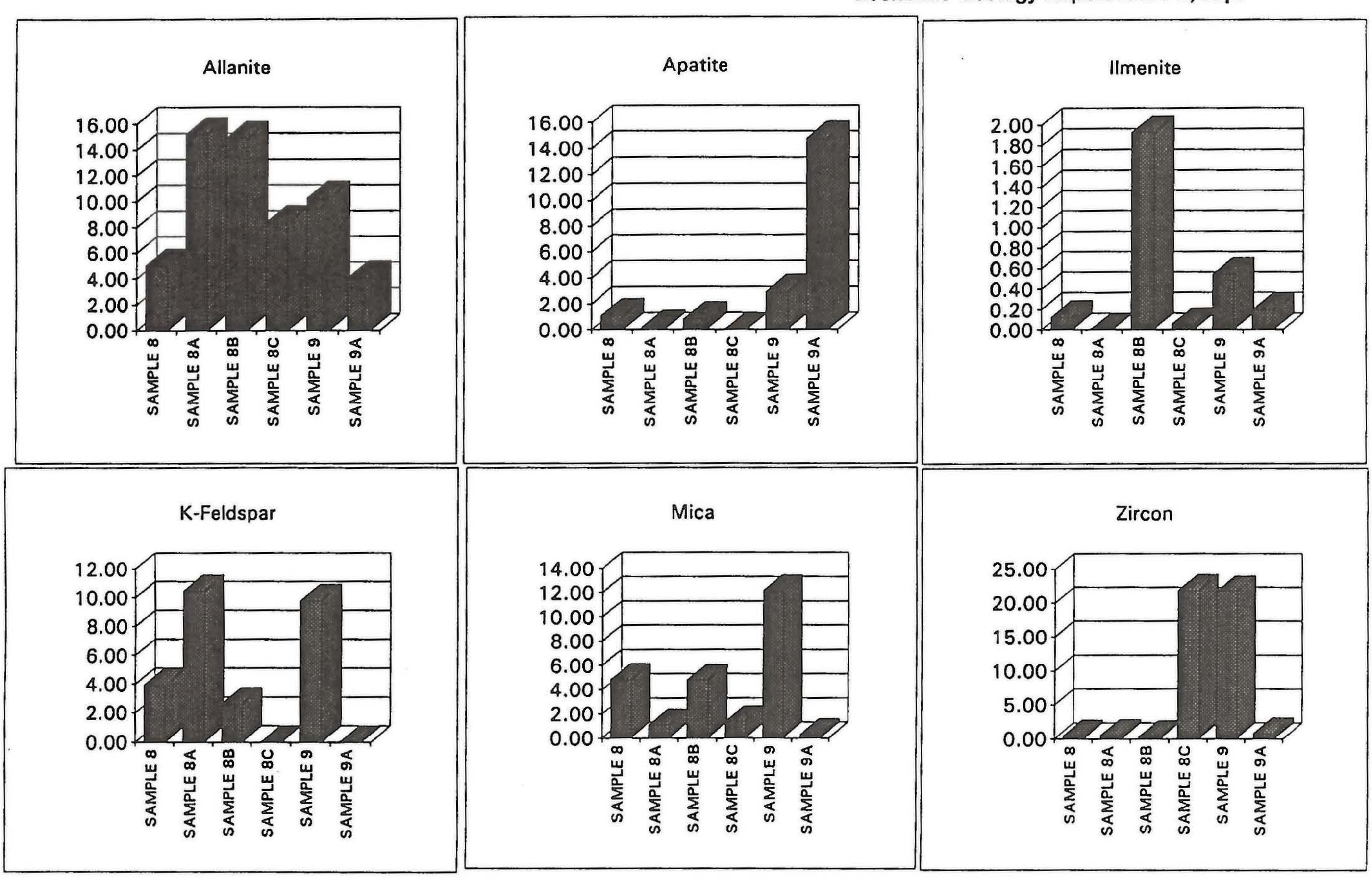

Figure GS-38-2: Distribution in square microns per quartz grain for selected minerals in each sample.

GS-39 HIGH PURITY LUMP QUARTZ IN SOUTHEASTERN MANITOBA

by P. Theyer and W.D. McRitchie

Theyer, P. and McRitchie, W.D., 1993: High purity lump quartz in southeastern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 149-151.

SUMMARY

Occurrences of high purity quartz in southeastern Manitoba were identified and investigated to determine their suitability as feedstock in a direct reduction process for the production of silicon. One of the ten investigated quartz occurrences was found to be of suitable tonnage and grade.

INTRODUCTION

High purity lump quartz as a potential feedstock for silicon metal production, should contain in excess of 98.5% SiO_2 (Dosaj *et al.*, 1993). In addition, common contaminants of quartz can only be tolerated to the following maximum concentrations: (in brackets): irontotal (<0.2%), calcium (<0.4%), alumina (<0.4%), and titania (<0.04%).

High purity quartz meeting or exceeding these stringent specifications occurs in southeastern Manitoba as; a) sandstone from the Ordovician Winnipeg Formation on Black Island, b) low-iron pegmatites (Tanco mine), and c) quartz veins (this report).

Potential sources of high purity quartz were investigated, paying special attention to estimated purity and tonnage.
Quartz occurrences meeting minimum tonnage (1 000 000 tonnes) and visually estimated purity requirements were sampled and analyzed for SiO_2, CaO, Al_2O_3, TiO_2, and Fe^{tot}.

This study was restricted to southeastern Manitoba, since transportation cost of the raw material is a critical factor to the profitability of this product.

Data on potential sources of high purity quartz were gathered by W.R. Gunter of Manitoba Energy and Mines in 1992 (unpubl. notes). The scope of his preliminary study was augmented by scrutinizing geological reports and maps (Moore, 1914; DeLury, 1920; Davies, 1953; McRitchie and Weber, 1971a, 1971b), and by interviewing prospectors and geologists with an active interest in the region. The input of two prospectors, Messrs. J. Sopotiuk and R. Sellers, led to the identification of a previously unrecorded quartz vein in the region south of Long Lake. Preliminary estimates indicate a potential tonnage well in excess of 1 000 000 tonnes, with contamination free zones that appear to approach the required chemical specifications.

Figure GS-39-1 shows the locations of the quartz veins investigated in 1993. Table GS-39-1 summarizes the salient data of the investigated occurrences.

Location 1

"Quartz Mountain" (Fig. GS-39-2), located approximately 5 km northwest of Buffalo Lake, was brought to the attention of staff of Manitoba Energy and Mines by a local prospector. Field inspection and chemical analyses indicate that this 0° trending quartz vein com-

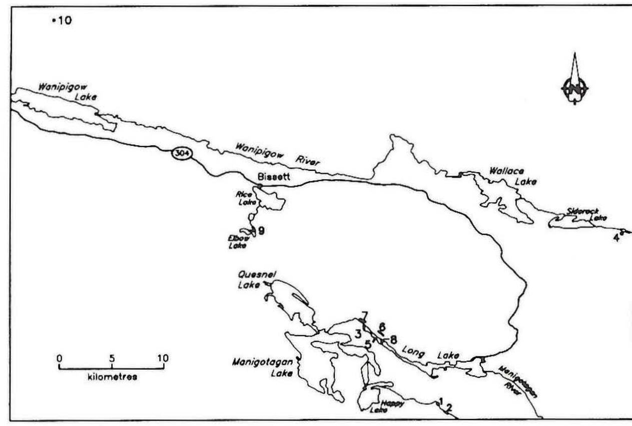

Figure GS-39-1 (Theyer) cartography by M. Timcoe

Figure GS-39-1: Location and number of quartz veins investigated in 1993.

plex probably exceeds the minimum tonnage (1 000 000 tonnes) and purity requirements. Quartz is exposed over approximately 310 m length by 50 to 60 m width tapering to 38 m near the southern end. A 20 m wide section in the northern portion was assessed as virtually 100% pure quartz whereas a 20 m wide section in the south was assessed at 95% purity.

A composite high purity quartz sample from the southern part of this occurrence contained 98.9% SiO_2.

Location 2

This quartz vein, located northwest of Buffalo Lake and recorded by McRitchie and Weber (1971b, Map 69-3), is exposed over approximately 110 m strike length. Two samples were collected, one representative of "pure" quartz and one representing a less pure quartz fraction. The low silica tenor renders this quartz unsuitable. (98.1%, 97.3% SiO_2).

Location 3

This quartz vein, located at the south shore near the western end of Long Lake, was originally recorded by McRitchie and Weber (1971a, Map 69-2). A large portion of the quartz in this lense contains ghosts of silicified felsic tuff and minor oxidized pyrite on fracture planes.

Samples collected from the east and the west ends of this occurrence (93.3%, 96.2% SiO_2) showed silica contents that are too low to meet the minimum specifications.

Table GS-39-1
Inspected Quartz Occurrences

Location	Name	Length	Width	Purity of Quartz	Sulphides/Oxides	Samples	SiO_2%
1	Quartz Mountain	310 m	50-60 m	95-100%	none	yes	98.9
2	Buffalo Lake	110 m	10-30 m	impure	minor	yes	98.1,97.3
3		1.2 km		impure	minor	yes	93.3, 96.2
4	Crystal Cave	25 m	15 m	very impure	very minor	no	
5				very impure	minor	no	
6	Champagne vein	400 m	up to 15 m	impure in parts	up to 2%	no	
7		?	narrow			no	
8	Camp vein			very impure	traces	no	
9	Elbow Lake	?	5-8 m	pure in places	trace sulphides	yes	99.1
10	Gnoms vein	120 m	up to 6 m	pure in places	up to 1% py	yes	99.5

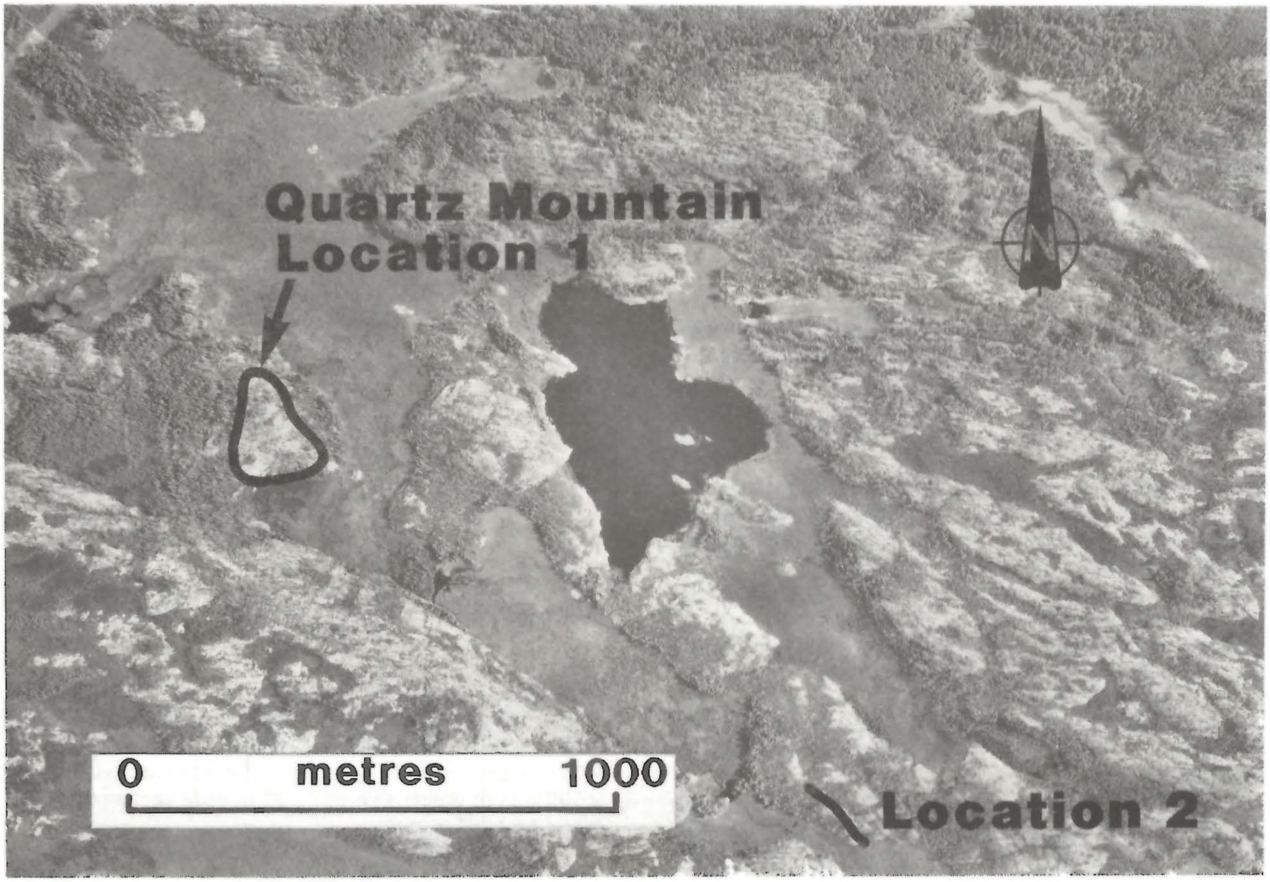

Figure GS-39-2: Location of quartz vein number 1 (Quartz mountain).

Location 4

The "Crystal Cave" quartz occurrence on the south shore of Crystal Lake is too small to contain the minimum tonnage and it is contaminated with abundant silicified granodioritic breccia. No samples were taken.

Location 5

This north-striking quartz vein near the south shore of Long Lake (McRitchie and Weber, 1971a, Map 69-2) is small (180m by 5 m) and contains abundant feldspathic ghosts. No samples were collected.

Location 6

The "Champagne vein", located north of Long Lake and recorded by McRitchie and Weber (1971a, 1971b) is approximately 400 m long and up to 15 m wide. Pyrite and up to 2% chalcopyrite, are especially abundant within and in isolated zones in the vicinity of an exploration pit.

Location 7

This small quartz vein is located north of the northwestern end of Long Lake (Moore, 1914). Insufficient tonnage. No samples were taken.

Location 8

The "Camp vein" located at the north shore of Long Lake is an east-striking approximately 200 m long, 10 to 15 m wide quartz vein. Ubiquitous feldspathic remnants (up to 25% of the vein) are randomly dispersed and trace to minor iron oxide stains render this vein unsuitable as a source of high purity quartz. No samples were taken.

Location 9

The Elbow Lake quartz veins recorded in Davies (1953, Map 52-1) consist of several subparallel, metre-wide quartz veins that form an approximately 5-8 m wide zone exposed over 1.5 km on strike. The purity of the quartz is highly variable; zones several metres long and wide containing minor feldspar impurities and/or sulphides abut equally large zones of seemingly pure white quartz.

Location 10

The "Gnoms vein" is accessible from Abitibi's logging trail system and by traversing through bush using a winter road (Fig. GS-39-3). This vein is exposed over an approximately 120 m strike length.

At the northeast edge of a swamp several 5 to 10 cm thick quartz veins with interstitial feldspar bands add up to approximately 1 m total width.

Twenty five metres west of the previous section, the vein measures approximately 1.5 m thickness and consists of milky grey to glassy quartz with abundant rusty patches. No visible sulphides.

Three metres west of the previous section, the vein measures up to 4 m width, but pinches to 1.5 m width within 10 m strike to the southwest.

At the top of the hill the vein swells to approximately 6 m width along approximately 10 m strike length; at this point it contains approximately 1% disseminated pyrite.

The remainder of the vein, in a southwesterly direction, is approximately 0.5 to 1 m thick.

The small volume and relative abundance of sulphides render this occurrence unsuitable as a source of high purity quartz.

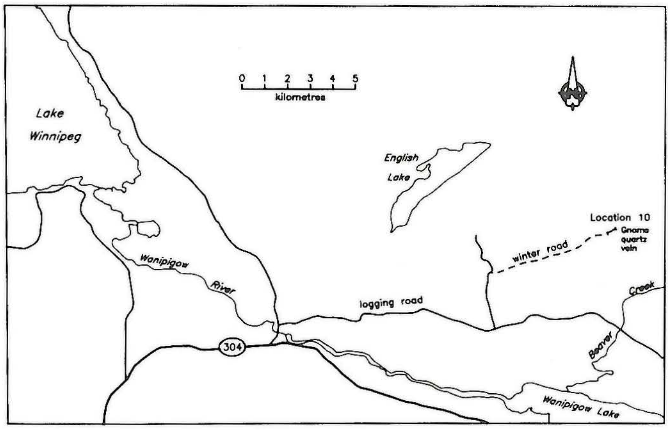

Figure GS-39-3: Location and access to quartz vein number 10 (Gnoms vein).

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GS-40 GEOLOGICAL AND GEOCHRONOLOGICAL STUDIES IN THE RICE LAKE BELT

by K.H. Poulsen[1], D.M . Davis[2], W. Weber[3] and R.F.J. Scoates[1]

Poulsen, K. H., Davis, D. M., Weber, W. and Scoates, R.F.J., 1993: Geological and geochronological studies in the Rice Lake belt; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 152.

SUMMARY

Preliminary geochronological results indicate the presence of *ca.* 2871 Ma zircons in the Garner Lake komatiitic intrusion in the Rice LAke greenstone belt. A newly discovered tonalitic basement underneath sediments hosting the Garner Lake intrusion suggests that these sediments may be part of an older pre-2.8 Ga assemblage.

INTRODUCTION

During a short field season, geological studies and a sampling program for a geochronological project were undertaken in the Beresford, Garner and Gem lakes area, in the eastern part of the Rice Lake greenstone belt. The purpose of this project is to confirm/reject the existence of a pre-2.8 Ga volcanosedimentary sequence in this portion of the belt (inferred from lithological association and recent geochronological data; *cf.* Weber, 1988; Brommecker *et al.*, 1993; Turek and Weber, 1991). Pending confirmation, the project will document the extent of this sequence and compile all regional structural features onto four 1:50 000 scale maps.

GENERAL GEOLOGY

The Rice Lake greenstone belt is Manitoba's most important past-producing gold district. Most known gold deposits occur in the central part of the belt, dominated by 2730 Ma volcanic and intrusive rocks of intermediate (generally dacitic) composition (Turek *et al.*, 1989). This is in apparent contrast to the nearby Red Lake district (Ontario) where such rocks are subordinate to, and in sharp contact with, a pre-2.8 Ga sequence composed mainly of basalts and komatiites, clastic and chemical sedimentary and minor felsic volcanic rocks (Stott and Corfu, 1991). New stratigraphic, structural and geochronological evidence (Weber, 1988, Brommecker *et al.*, 1989, 1993; Turek and Weber, 1991) suggests that this difference may be not real, and that the Rice Lake belt also contains two fundamentally dissimilar sequences. The pre-2.8 Ga sequences at Red Lake are especially important since they are known to host not only important gold deposits but also magmatic nickel and volcanogenic massive sulphide mineralization.

Komatiites have now been recognized in several locations in the Rice Lake belt, *e.g.* north of Garner Lake (Brommecker *et al.*, 1993), at Wallace Lake (Theyer, 1983), near the Vanson shaft and at Saxton Lake (Scoates, 1971). They were thought to be late tectonic intrusions owing to their common preservation as slices within major faults and shear zones. Characteristic textures (spinifex, polysuturing) and distinctive chemical compositions indicate, however, that both komatiitic flows and subvolcanic intrusions are present (Brommecker *et al.*, 1993). They are associated with magnesian and tholeiitic basalts, oxide facies iron formation, quartzites and carbonates (Wallace Lake, McRitchie, 1971) and felsic pyroclastic rocks (Garner Lake). This association of lithologies is identical to that in the pre-2.8 Ga Balmer, Ball and Bruce channel assemblages at Red Lake (Stott and Corfu, 1991).

The suite of komatiites and associated rocks occur mainly to the north of the E-W Wanigipow fault in the western part of the belt, but at the eastern end are located south of this fault and northeast of the NW-trending Moore Lake-Beresford Lake shear zone. This shear zone defines the contact with the central intermediate volcanic and intrusive rocks. The Moore Lake-Beresford Lake shear zone is the older and more cryptic of the two structures, but is of greater fundamental importance to the distribution of rock units and gold deposits in the Rice Lake belt (than is the Wanipigow fault) (Brommecker *et al.*, 1989).

Preliminary geochronological results indicate the presence of *ca.* 2871 Ma zircons in the Garner Lake komatiitic intrusion. A newly discovered tonalitic basement underneath sediments hosting the Garner Lake intrusion suggests that these sediments may be part of the older pre-2.8 Ga assemblage.

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2 Royal Ontario Museum, 101 Queen's Park, Toronto, Ontario M5S 2C6

3 Manitoba Energy and Mines, 535-330 Graham Avenue, Winnipeg, Manitoba R3C 4E3

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GS-41 QUATERNARY STUDIES RELATED TO DRIFT PROSPECTING, RICE LAKE GREENSTONE BELT AND BERNIC LAKE AREA, SOUTHEASTERN MANITOBA

by P.J. Henderson[1], C.E. Dunn[1], and W.B. Coker[1]

Henderson, P.J., Dunn, C.E., and Coker, W.B., 1993: Quaternary studies related to drift prospecting, Rice Lake greenstone belt and Bernic Lake area, southeastern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 153-154.

SUMMARY

During ice retreat, the Rice Lake greenstone belt and Bernic Lake area were inundated by glacial Lake Agassiz resulting in deposition of fine grained glaciolacustrine sediments within the major valleys. At higher elevations, drift deposits are generally thin and discontinuous. Lithologically distinct tills overlie Paleozoic rocks on Black Island and the adjacent mainland.

Partial data sets from neutron activation analysis of vegetation samples show differential uptake of elements by common trees. Of note are the enrichments of Au, Ni, and Cr in samples from the vicinity of the Bird River Sill. Conifer twigs yield more Au and Ni than the bark or trunkwood from several tree species, whereas the bark accumulates more Cr than other plant organs.

Quaternary geological studies oriented toward fine tuning prospecting methods in the Rice Lake greenstone belt and Bernic Lake area were conducted in 1992/93, in cooperation with Manitoba Energy and Mines, as part of the joint Canada-Manitoba Partnership Agreement on Mineral Development. The project is two-fold:

1. Regional surficial geology mapping and drift sampling in the Rice Lake greenstone belt (Henderson). The main purpose is to establish a regional geochemical database and provide a geological basis for interpreting the glacial dispersal of components of till derived from mineralized bedrock. The greenstone belt has a high potential for gold mineralization and potential for base metal mineralization. Many reported gold occurrences date back to the first gold discovery in 1911 (Theyer, in press); and
2. Detailed coordinated studies of drift geochemistry and biogeochemistry in areas of known bedrock mineralization in order to determine the relationship between plant and drift chemistry and mineralization (Coker and Dunn). This program focuses on methodologies for prospecting for rare elements (Li, Cs, Rb, Ta, Be, REE) and platinum group elements.

1 Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

REGIONAL STUDIES

During 1993, surficial geology mapping and drift sampling continued in the westernmost part of the Rice Lake belt (NTS 62P/1 and 52M/4) (Fig. GS-41-1). Field work involved follow-up studies of till geochemical anomalies recognized from the work of the previous summer (Henderson, 1993), field checking of air photo interpretations, examination of Quaternary stratigraphic sections, and regional till and humus sampling.

Geochemical Database

Sampling was focused within and south of the greenstone belt where road and waterways permitted access. A total of 230 sediment samples were collected from the area at approximately 1 to 5 km spacing, primarily from hand-dug pits 0.5 to 1.0 m deep. Till is the preferred sediment sample medium, although the material appears to be extensively reworked in places, and approaches a poorly-sort-

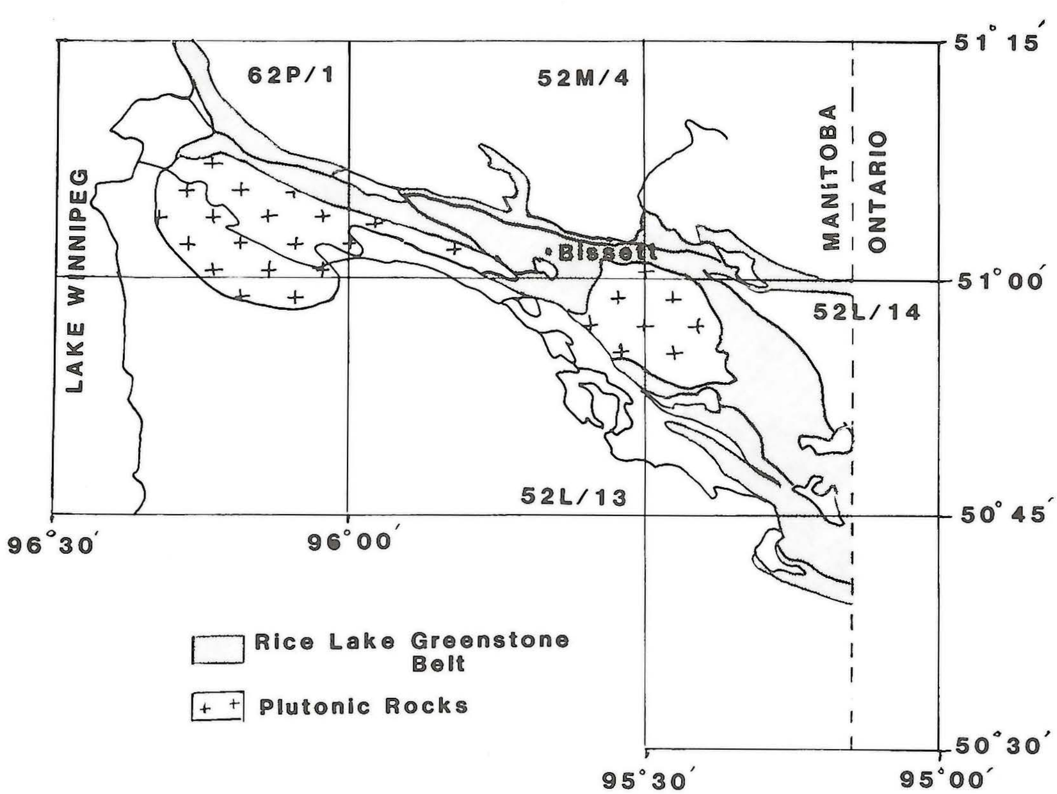

Figure GS-41-1: Location of study area 62P/1 (English Brook) and 52M/4 (Bissett) within the Rice Lake greenstone belt.

ed sandy gravel, that lacks the fine grain sizes characteristic of till.

All humus samples and the 0.002 mm and 0.063 mm fraction of tills are being analyzed for trace metal content, including gold. In addition, the carbonate content, texture and clast lithologies of tills will be determined.

Surficial Geology

Surficial geology maps (scale 1:50,000) for NTS sheets 62P/1 (English Brook) and 52M/4 (Bissett) are in preparation.

The area was glaciated predominantly by ice flowing toward the southwest. Exposed bedrock surfaces are striated, polished and glacially moulded with the dominant striation trend ranging from 240° to 250°. There is a continuum, however, in striation directions ranging from 227° to 260°. Closer to Lake Winnipeg striation patterns are more complex. Older striae, indicating ice flow towards the south (180°), southwest (210°), west (280°) and southeast (140°) have been measured. At present, the significance of these relative ages is not fully understood, although it appears that the confluence between southwesterly ice flow and southeasterly flowing ice, recognized in the Interlake area (the Red River Lobe), may have extended into the western margin of the study area.

During ice retreat, the entire area was inundated by glacial Lake Agassiz resulting in extensive deposition of fine grained glaciolacustrine sediments within the major valleys (Nielsen, 1980). At higher elevations, drift deposits are generally thin and discontinuous. Thick deposits (up to 10 m) are confined to the Wanipigow and Manigotagan River valleys and coastal areas of Lake Winnipeg. These consist of glaciolacustrine rhythmically bedded sand, silt and clay and glaciofluvial ice-contact deposits modified by lacustrine processes. Lithologically distinct tills (possible multiple till units) have been observed overlying Paleozoic rocks on Black Island and the adjacent mainland.

DETAILED STUDIES

In early June, 1993, biogeochemical and surficial geochemical studies were conducted in three areas:

1. the Bird River Sill (PGEs);
2. the Bernic Lake area (Rare element pegmatites); and
3. the "Donner Option" (PGEs) east of English Lake.

Samples were collected of several tissue types from common tree species, and of humus, B-horizon soil and till. The analytical program in progress involves the determination of a wide range of elements (including PGEs) in order to compare and contrast their distribution, and establish the optimum sample media to assist in exploration for concealed mineralization in these environments.

Partial data sets from neutron activation analysis of the vegetation samples show differential uptake of elements by common trees. Of note are the enrichments of Au, Ni, and Cr in samples from the vicinity of the Bird River Sill. Conifer twigs yield more Au and Ni than the bark or trunkwood from several tree species, whereas the bark accumulates more Cr than other plant organs.

In the same area, there is moderate enrichment of Cs. This is unusual for an ultramafic environment, and suggests that the Cs is probably related to the alkali metal-rich pegmatites at Bernic Lake. Two possible explanations for this enrichment are: 1) airborne contamination from the Tanco mine at Bernic Lake, approximately 10 km to the southeast; and 2) widespread diffusion of alkali metals during emplacement of the pegmatites. An argument in favour of the latter is the marked differentiation of Cs between species and plant tissues; it exhibits enrichment in jack pine bark relative to spruce bark, yet higher concentrations in spruce twigs than jack pine twigs. If the Cs is derived from airborne particulates, similar concentrations might be expected in all species and external tissue types. A second line of evidence in favour of regional diffusion of Cs is that the conifer trunkwood yields higher than normal Cs concentrations, indicating that Cs has been introduced to trees in solution through plant roots. It is possible, however, that Cs-rich airborne particulates have settled over a wide area, leached into the groundwater, and subsequently been taken up by plant roots.

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GS-42 QUATERNARY GEOLOGICAL STUDIES IN SOUTHERN MANITOBA

by G.L.D. Matile

Matile, G.L.D., 1993: Quaternary geological studies in southern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 155-156.

INTRODUCTION

Surface mapping continued in the southern NATMAP areas (Matile *et al.*, 1992) as part of the cooperative federal/provincial Southern Prairies NATMAP initiative, aimed at providing a comprehensive inventory of surficial materials in southern Manitoba.

Drift sampling of these two areas was completed in 1992. The samples, collected from surface sites, river sections, and rotasonic drill core, are being processed by the GSC with release of the resultant data in a GSC Open File planned for the winter of 1993-94.

The results of the 1991 and 1992 low density prairie till/soil sampling programs, coordinated by R. Garrett and H. Thorleifson of the GSC, will be released in late 1993.

SOUTHEASTERN MANITOBA

Field mapping of the eastern half of the southeast NATMAP area was completed this summer. This work comprised 1 m deep dutch auger holes, shovel holes and existing exposures at regular intervals along major roadways. Veneer and surface sediments were described and coded into the database format. Four east-west transects were completed at 200 m spacing, and one north-south transect at 400 m spacing, comprising a total of 460 line km.

In conjunction with field mapping, road accessible bedrock outcrops were searched for glacial striae. A total of 35 outcrops were found to have measurable striae, including four sites that have crossing striae (Fig. GS-42-1). The age relationship between the two sets of crossing striae was not discernible at these four sites.

SOUTHWESTERN MANITOBA

The Geological Survey of Canada continued field mapping of the Virden area (62F) as part of the southern NATMAP program. This summer a total of 5, two-person party months were devoted to field work. The field work consisted of checking airphoto interpretation, collection of samples for materials characterization, and examination of stratigraphic sections. At present 5 of the sixteen 1:50 000 map sheets have been covered.

This work is beginning to address a number of regional and local glacial problems. During the final stages of deglaciation, an ice-dammed lake, glacial Lake Hind, was formed in the Oak Lake basin. Little is known about the retreat of the ice to the northwest of this basin or of the nature and source of sediment carried into the basin by meltwater. Equally spaced, radiating meltwater channels are a significant feature of this ice lobe. The question to be answered, before ice retreat history can be further developed, is whether the channels are ice marginal features or subglacial. If they are ice marginal they could be used to trace the final retreat of that ice lobe. Preliminary interpretations suggests that they are subglacial.

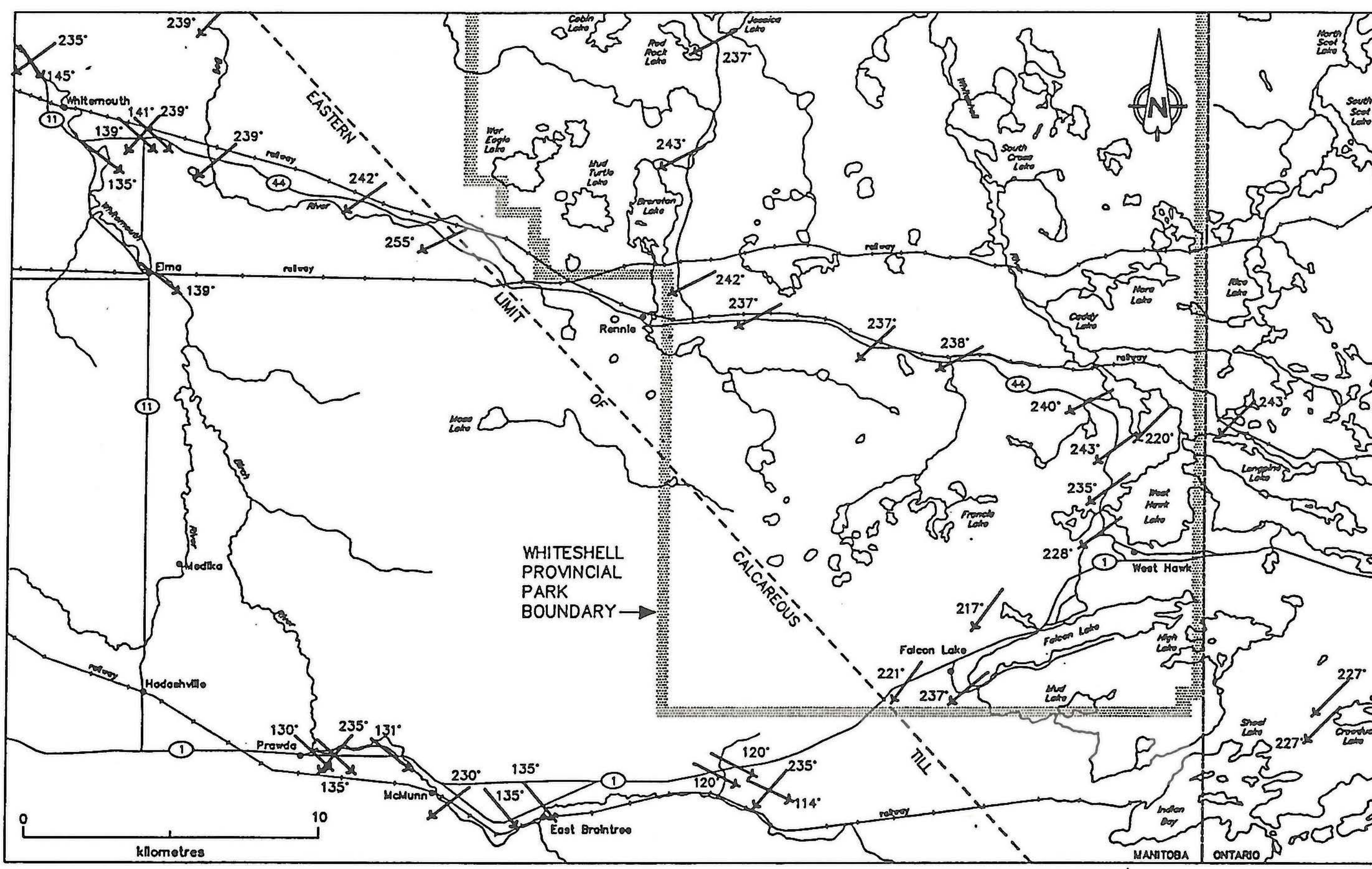

Figure GS-42-1: *Glacial striae.*

LOW DENSITY PRAIRIE TILL/SOIL SAMPLING PROGRAM

In August, 1993 the GSC released kimberlite indicator mineral and soil geochemical data for orientation traverses across the prairie region (Garrett and Thorleifson, 1993). The results indicated that low density regional sampling can produce meaningful geochemical and indicator mineral patterns.

The sampling was done in 1991, in preparation for a region-wide indicator mineral and geochemical survey carried out in 1992. Fifty till samples and over 100 soil samples were collected along transects from southeast of Winnipeg to Calgary, north to Edmonton and back to Winnipeg.

An average of 2 indicator minerals were recovered per sample, including 13 peridotitic garnets (high Mg and Cr), 17 eclogitic garnets (high Cr, Mg and Ti), 62 chrome diopsides (high Cr and Ca, low Na and Fe) and 4 picroilmenites (high Mg). Sites south of Brandon and Winnipeg yielded 5 peridotitic garnets, including a G10 subcalcic chrome pyrope near the town of Reston. The highest chrome diopside concentration was found in the Yorkton-Roblin area.

In 1992, till and soil samples were collected at over 1000 sites across 735 000 square km^2 of the prairie region. The GSC expects to start releasing data from these samples in late 1993.

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GS-43 AEROMAGNETIC SURVEY OF SOUTHERN MANITOBA

by I. Hosain[1] and D. Teskey[2]

Hosain, I. and Teskey, D., 1993: Aeromagnetic survey of southern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 157.

The Geological Survey of Canada and Manitoba Energy and Mines carried out the third phase of the annual aeromagnetic coverage of southern Manitoba. The area covered and the area for future coverage are illustrated in Figure GS-43-1. Survey specifications are 0.01 nt sensitivity and better than 25 m positioning accuracy using GPS. Flight Altitude is 150 m at 800 m line spacing. The data will be valuable for mineral and hydrocarbon exploration. Industry participation is welcomed in this program. Participants in any given survey year will obtain exclusive use of the geophysical results obtained in that year, prior to release to the public. For further information, please contact:

Dennis Teskey	(613) 992-9763
Ifti Hosain	(204) 945-6540

Phase 3 1993/94 - Dauphin Area, Manitoba

Altitude	= 150 metres MTC
line spacing	= 800 metres
control line spacing	= 5 kilometres
line direction	= east-west
control line direction	= north-south

One industry participant requires one winter exclusivity rights. Release of the data is anticipated for April, 1994.

1 Manitoba Energy and Mines, 535-330 Graham Avenue, Winnipeg, Manitoba R3C 4E3

2 Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

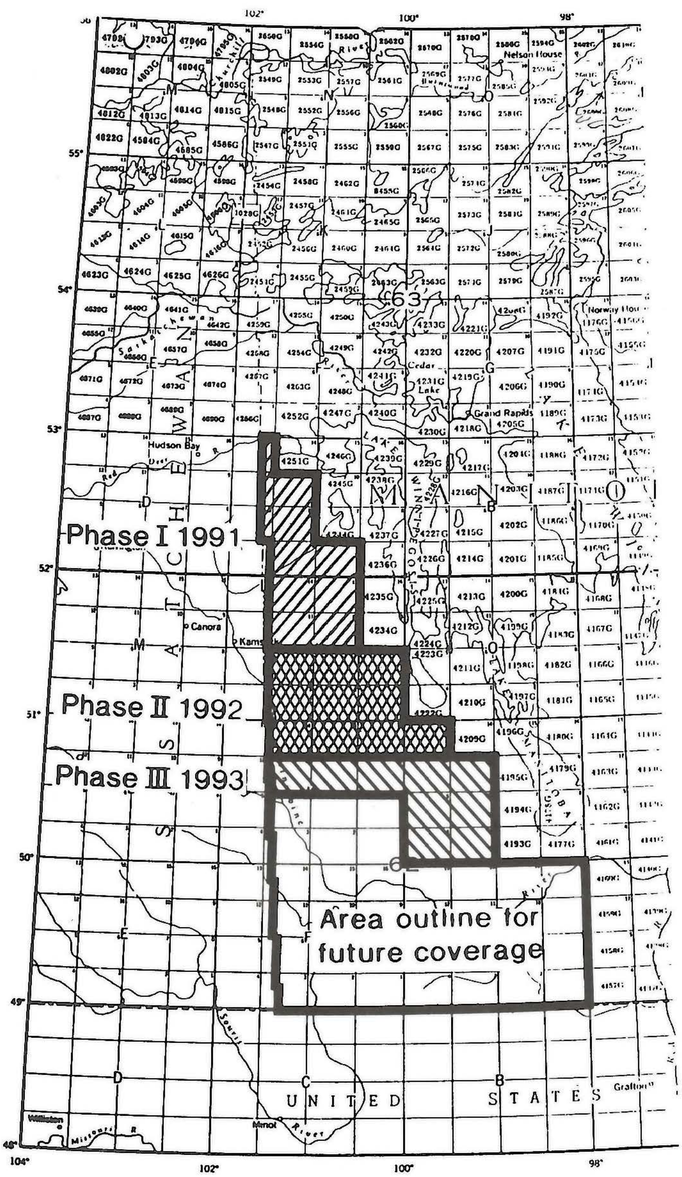

Figure GS-43-1: Aeromagnetic surveys, southern Manitoba.

GS-44 INDUSTRIAL MINERALS INFORMATION SYSTEMS (NTS 62G, 62P)

by B.E. Schmidtke and P.G. Lenton

Schmidtke, B.E. and Lenton, P.G., 1993: Industrial minerals information systems (NTS 62G, 62P); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 158.

In 1993, the Geological Services Branch of the Manitoba Department of Energy and Mines initiated a project to create a digital database of available information on Industrial Minerals in Manitoba. The objective of the project is to produce a comprehensive Industrial Minerals database from all available information in the nonconfidential industrial minerals files, published reports, geologists' field notes and files, nonconfidential assessment work, and mineral inventory cards. The database is intended to be a tool for exploration and land use planning and to provide the public with comprehensive information on industrial minerals in Manitoba.

Several existing mineral database programs were considered. However, in-house development of a dBase IV program was decided to be the only option because of financial constraints.

The initial step involved the development of a framework of fields for the system. These include commodity, exact geographic location, history, lease information, land use classification, reserves, quality and possible markets as well as references to all available reports. Data sheets with fields for the organization and summary of data were developed. The first area chosen for study comprised Hecla and Grindstone provincial parks in NTS 62P (Fig. GS-44-1). This area has been proposed as an Endangered Space by the Manitoba Naturalists' Society and as a potential location for Manitoba's second National Park. The Hecla-Grindstone area has high potential for production of several Industrial Minerals, including silica sand, horticultural quality sphagnum peat, and dolomite aggregate. Kaolin also occurs in the area, but reserve estimates cannot be made with the available information.

A start was also made on the compilation of data sheets on the bentonite deposits in NTS 62G, which are currently under investigation by the department.

All of the summarized data that could be georeferenced was plotted on 1:50 000 topo sheets. Individual occurrences were assigned unique numbers that will link the data bases. The dBase IV program will be developed during the winter of 93/94 and the extracted data will be recorded.

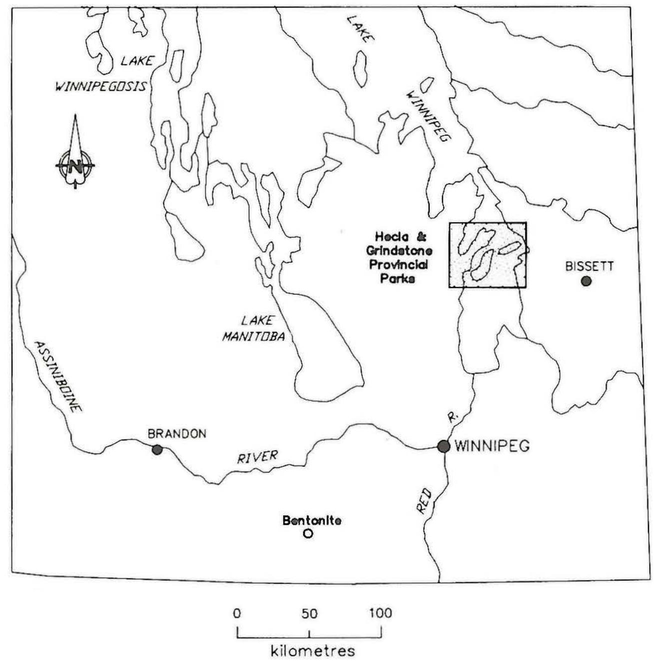

Figure GS-44-1: Study area comprising Hecla and Grindstone provincial parks.

GS-45 GEOLOGICAL INFORMATION SYSTEMS AND GIS PROJECTS

by P.G. Lenton

Lenton, P.G., 1993: Geological information systems and GIS projects; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1993, p. 159.

SUMMARY

Manitoba Energy and Mines is actively developing geological information management systems and, under the NATMAP program, producing digital compilation maps. Previous production of digital maps concentrated in the Flin Flon region. During the current year, more emphasis will be placed on the Snow Lake region and the Kisseynew belt with release of the a 1:10 000 map of Anderson-Stall Lakes area. Compilation maps of the south Kisseynew (1:100 000) and Snow Lake region (1:50 000) are targeted for spring 1994 release. Work in geological information management will concentrate on design of mineral deposit and industrial minerals databases.

CURRENT STATUS

Computerized collection and storage of geological information and the production of maps using GIS technology has advanced rapidly in recent years. Most work in the Geological Services Branch is centred in two areas; information management systems specific to provincial programming and NATional MAPping Program (NATMAP) projects for geological compilation and analysis. The objectives of these programs are complementary. Geological Services Branch information management systems are one of the principal sources of data for the NATMAP compilation program.

NATMAP sponsored map production using GIS technology has followed two paths; production of colour preliminary maps immediately following the field season and production of compilation maps for larger regions. The 1:50 000 south Kisseynew maps and 1:20 000 Elbow Lake maps released in 1991-92 and the 1:10 000 Anderson-Stall compilation (A. Bailes and A. Galley (GSC)) released this fall represent preliminary map products of current projects. The first compilation products were the 1:250 000 Cormorant Lake compilation released in the fall of 1992 and the 1:50 000 compilation of the Flin Flon region of Manitoba and Saskatchewan released at Flin Flon in June of 1993. Compilation maps currently under development and scheduled for spring 1994 release include a 1:100 000 compilation of the Kisseynew south margin of Manitoba and Saskatchewan and 1:50 000 compilation in the Snow Lake area.

The NATMAP compilation projects generate large volumes of digital data. Making this data accessible to the public involves a new approach to information distribution. The GSC has undertaken compilation of much of the currently available information onto a CD-ROM. This large volume data source will include topographic and geological map data for the 1:50 000 Flin Flon compilation and Elbow Lake project as well as geophysical, geochemical and LandSat data for the NATMAP project area. Geological outcrop descriptions for Elbow Lake and Athapapuskow Lake (south east segment of the 1:50 000 Flin Flon compilation) are included as text files. This information release is a preliminary test of the technique intended as the principle method of data dissemination for the NATMAP program.

Geological field data for Manitoba projects included on the NATMAP CD-ROM are derived from GEODATA files generated during field mapping programs. The GEODATA system was developed by the Geological Services Branch to manage geological field data during mapping programs and facilitate production of final maps and reports on completion of the field programs. GEODATA comprises a series of relational databases containing all observations made in the field and the results of chemical and petrographic analysis. This system has been used for all Geological Survey projects for the last four years. Data sets currently in use and their status are:

- Athapapuskow Lake, E. Syme, complete
- Elbow Lake, E. Syme and J. Whalen (GSC), complete
- Snow Lake region, A. Bailes and A. Galley (GSC), ongoing
- Tartan Lake, P. Gilbert, partial
- Wekusko Lake, P. Gilbert, ongoing
- Kisseynew projects, H. Zwanzig and D. Schledewitz, ongoing
- Cranberry Lakes, E. Syme, ongoing
- Cross Lake, T. Corkery and P. Lenton, partial

The NATMAP database is a subset containing the core of the observational data in the GEODATA files, but lacks the depth of detail available in the original files. To complement the NATMAP release, the original data files are available for the Athapapuskow Lake and Elbow Lake projects. These files provide detailed outcrop level descriptions for 6300 locations in the Athapapuskow and Elbow Lakes areas mapped by E. Syme from 1986 to 1992. A data viewing program is under development for use with GEODATA files. This PC-based program will be provided with the databases allowing users to query, view and print the data. Each project report will include geographic coordinates, station location maps and preliminary geological maps. In the future, databases for all Geological Services projects will be available as open file releases on completion of the field programs.

Information management projects currently under development include revision of the GEODATA system to allow greater versatility for mineral deposit and alteration zone documentation and the creation of a Mineral Deposits Information System. The system is to include all available information for mineral occurrences in Manitoba. This will include; location, commodity, description, history (exploration and production), holders, status and geological information derived from field examination (were applicable). The prototype for the database system is the Mineral Deposit Series reports that contain complete documentation of occurrences by NTS area. The intent of the project is to incorporate this information in an easily distributed and easily searched format. The first stage in the design is the creation of an Industrial Minerals Information System. Currently under development, this system will form the nucleus of the more comprehensive Mineral Deposits system.

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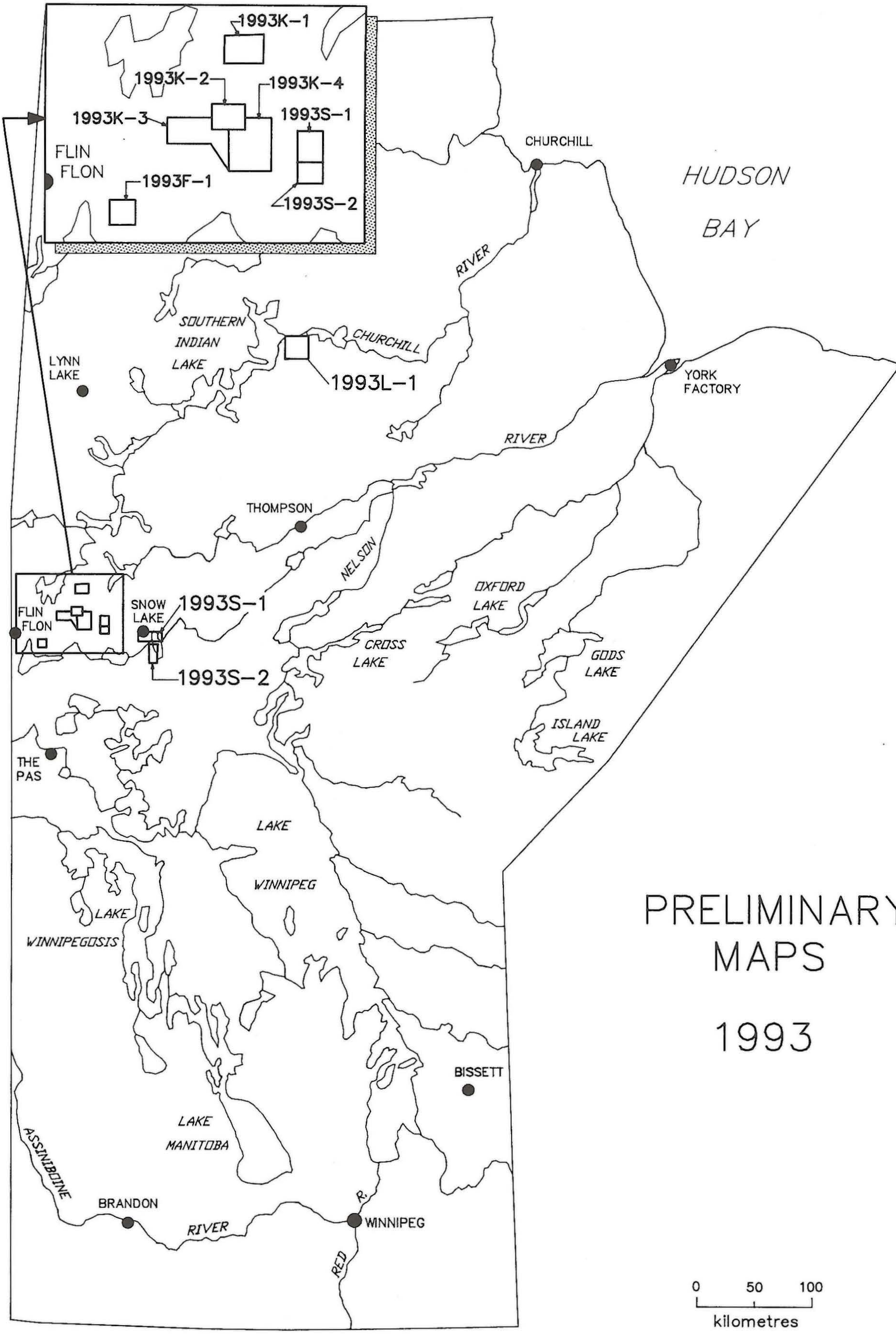
PRELIMINARY MAPS 1993

GEOLOGICAL SERVICES BRANCH		Scale
1993F-1	Baker Patton Felsic Complex (Parts of NTS 63K/12, 63K/13) by G.H. Gale	1:10 000
1993K-1	Jungle Lake (part of 63N/2) by H.V. Zwanzig and M. Parent	1:20 000
1993K-2	Puffy Lake (part of 63N/2, 3 and 63K/14, 15 by H.V. Zwanzig, D.C.P. Schledewitz and M. Parent	1:10 000
1993K-3	Webb Lake-Fay Lake, west half (NTS 63K/14NE) by D.C.P. Schledewitz	1:20 000
1993K-4	Webb Lake-Fay Lake, east half (NTS 63K/15NW) by D.C.P. Schledewitz	1:20 000
1993L-1	Partridge Breast Lake area (Parts of NTS 64H/4, 5 and 64G/1, 8) by M.T. Corkery	1:50 000
1993S-1	Geology of Anderson-Stall-Kormans area (Parts of NTS 63K/16SE and 63J/13SW) by A.H. Bailes and A.G. Galley	1:10 000
1993S-2	Wekusko Lake, southwest (NTS 63J/12NW) by H.P. Gilbert	1:20 000
1993S-3	North Star Lake (NTS 63K/15SE1) by D.E. Prouse and G.H. Gale	1:10 000
1993S-4	North Star Lake (NTS 63K/15SE4) by L.I. Norquay, D.E. Prouse and G.H. Gale	1:10 000

PRELIMINARY MAPS

1993



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	Pipestone Lake
	M.T. Corkery	Cross Lake-Northern Superior Province, Nelson and Churchill Rivers, Partridge Breast Lake
	H.P. Gilbert	Tartan Lake, Wekusko Lake-South
	Dr. J.J. Macek	Thompson belt and SW extension
	D.C.P. Schledewitz	Kississing Lake, Webb/Fay Lakes
	E.C. Syme	Flin Flon, Athapapuskow Lake, Elbow Lake
	Dr. H.V. Zwanzig	Churchill Province, Kisseynew belt
Compilation Geologist/Mineralogist	C.R. McGregor	Sub-Phanerozoic Precambrian compilations; mineralogy
Geological Compiler (Atlas)	D. Lindal	1:250 000 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	Northern Superior Province: PGE investigations
	G. Ostry	File Lake-Sherridon area
	K. Ferreira	Mineral Deposit Geological Assistant
Resident Geologist (The Pas)	D.E. Prouse	North Star Lake; exploration activity, drill core program
Resident Geologist (Flin Flon)	T. Heine	Flin Flon - Snow Lake region; North Star, Elbow Lake
	L. Norquay	North Star Lake
Industrial Minerals Geologists	B.E. Schmidtke	Silica; industrial mineral inventory
	J.D. Bamburak	High-magnesium dolomite; building stone; high-calcium limestone
Computerization:	P.G. Lenton	Geological Data Management and Analysis
	G.G. Conley	Stratigraphic data files
	L.E. Chackowsky	Geographic Information Systems
Geophysics, Geochemistry and Terrain Sciences:		
Section Head	I.T. Hosain	SW Manitoba/Interlake
	Dr. M.A.F. Fedikow	Snow Lake/Southeast Manitoba
	Dr. E. Nielsen	Elbow Lake, Naosap Lake
	G. Matile	Southern Manitoba