Manitoba
Energy and Mines
Geological Services

Report of Activities 1994

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Manitoba
Energy and Mines
Geological Services

REPORT OF ACTIVITIES 1994

1994

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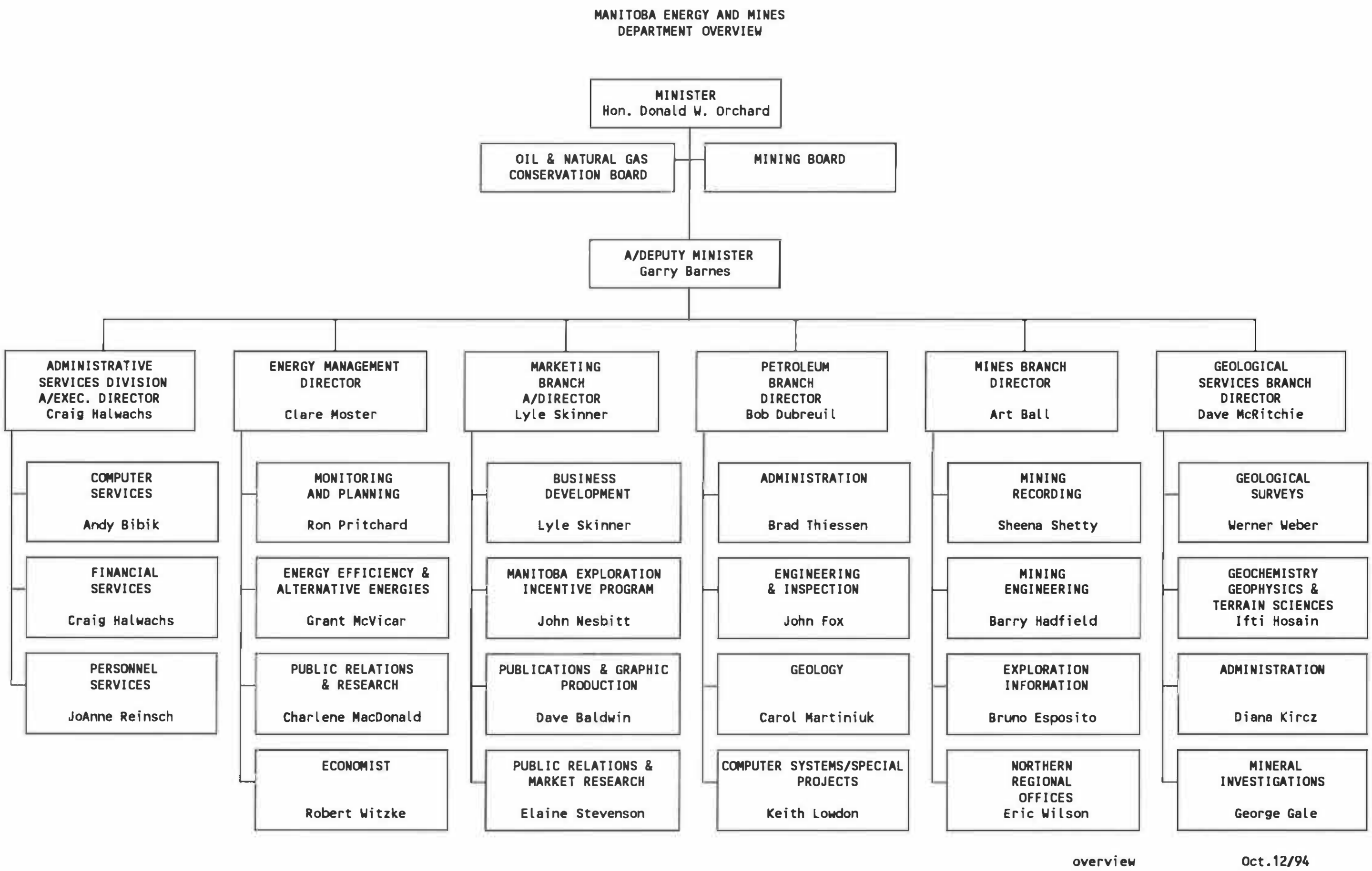
MANITOBA ENERGY AND MINES
DEPARTMENT OVERVIEW



Minister of
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Minister responsible for Manitoba Hydro

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This year has been particularly active for both the mining and petroleum industries in Manitoba. The demand for information on, not only Manitoba's geological endowment, but also our incentive programs, has kept pace with that accelerated activity.

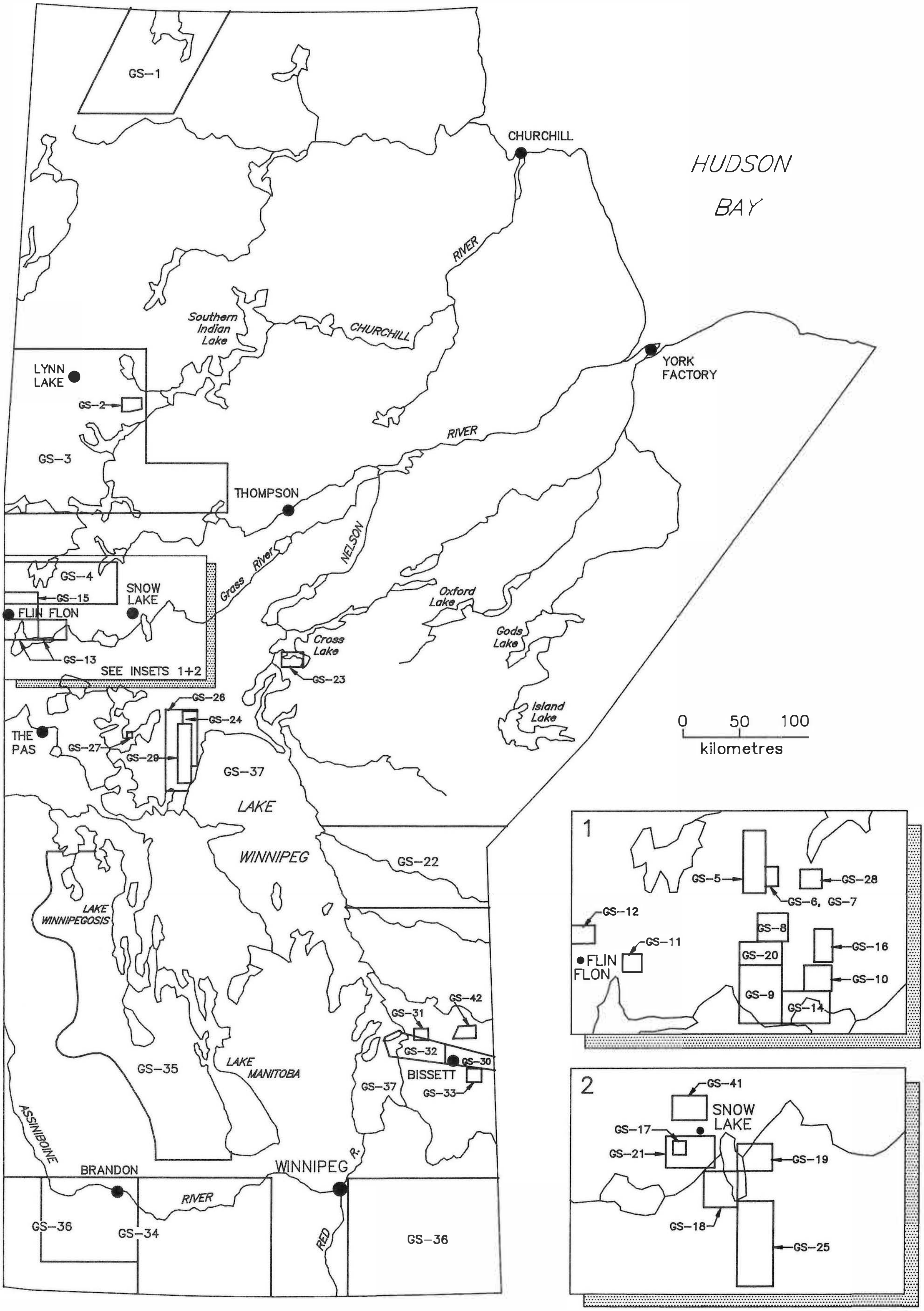
We have been encouraged by the response to our invitation to "Break new ground in Manitoba" and we believe our incentives can assist as "Your Keys to Success". I am confident our larger convention site will facilitate the growing interest in Mining, Minerals and Petroleum in this province.

Mining continues to be the second largest primary resource industry in Manitoba and the annual convention provides both the industry and the department with the opportunity to showcase achievements during the past year. As these reports indicate, significant work has been accomplished on several fronts.

There has been a resurgence in exploration and mining for gold, copper, nickel and other minerals facilitated by rapid changes in sophisticated technology. In particular it is exciting to see the developments underway at Flin Flon, Thompson, Cross Lake, Bissett, Lynn Lake and Snow Lake.

Again, Canada's mining and petroleum industries are to be commended for taking the initiative to utilize technological developments to ensure continued growth and prosperity in this valuable industrial sector. I am confident the information gathered in *Report of Activities 1994* will direct you to new ventures that are both productive and profitable.

Donald W. Orchard
Minister of Energy and Mines



Location of 1994 Projects

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by W.D. McRitchie and S.B. Lucas[1]

McRitchie, W.D. and Lucas, S.B., 1994: Introductory summary; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 1-4.

GENERAL

In 1994 the operations of the Geological Services Branch (GSB) were augmented once again with support from the Geological Survey of Canada (GSC) through the NATMAP Shield Margin and Southern Prairies programs. The four main objectives of the Survey programming continue to be: (1) generating baseline data supporting exploration for copper and zinc in the region feeding the Flin Flon smelter, (2) cooperative investigations with industry along the Thompson Nickel Belt and its southwest extension, (3) evaluation of new domestic commodities in conjunction with the Marketing Branch, and (4) generating information and guidelines supporting diamond and precious metal exploration in Manitoba. In addition, a federal/provincial cooperative study of Lake Winnipeg sediments was implemented, and Phase III of the LITHOPROBE Trans-Hudson Transect involved VIBROSEIS reflection seismic profiles in the Lynn Lake region and across the Thompson Nickel Belt extension in the Easterville region.

Provincial A-base activities were augmented by funding provided under the Canada/Manitoba Partnership Agreement on Mineral Development (PAMD). Of the twelve provincial (PAMD) Sector A projects active during 1994/95, eight had field components focussed on the Flin Flon/ Snow Lake region, three entail completion of reports and maps stemming from earlier work, and one is developing computer databases, compilations and minerals-oriented GIS for the NATMAP Shield Margin program.

GSC contributions encompassed sixteen projects (nine funded by PAMD), eight with active field work focussed primarily in the Flin Flon/Snow Lake area, as well as projects in the Thompson Belt, southeast Manitoba and on Lake Winnipeg.

Along with the rest of the Department, the GSB developed a new strategic plan early in the year; discussions are progressing to secure continued cooperation between the GSC and GSB over the next five years. Industry feedback to the Interim Evaluation of the Canada/ Manitoba Partnership Agreement on Mineral Development will be a key factor in determining the level and focus of future GSB investigations.

Several new publications were released during the year (see listing at end of this volume). New insights into the geochemical makeup, origin and exploration potential of volcanic sequences in the Flin Flon/ Snow Lake region were published in technical journals. New crustal models for this region blend the stratigraphic and structural relationships determined through mapping with new isotope data and seismic profiles from LITHOPROBE. Other publications included five Mineral Deposit Reports for the Leaf Rapids, Lynn Lake, Flin Flon and Bissett regions. Commodity studies included reports on dimension stone (ER93-1) and magnesium dolomites (OF92-4). New publications planned for release in November include nine new preliminary maps and two coloured NATMAP compilation maps that cover the Kisseynew domain south flank in Manitoba and Saskatchewan and the Snow Lake and File Lake area. A second, revised edition of the Geological Highway Map is also scheduled for release in November. Important new panels illustrate examples of sustainable development in the mineral sector. A report on the Netley Marsh area, released in June, provides new insights into modern geological processes, geomorphology and sedimentology along the south shore of Lake Winnipeg. The report is styled to appeal to land-use planners, scientists and the public.

The GSB is also committed to developing a minerals-related GIS system for the province, a capability which will benefit all client groups. A schema for a mineral deposit database is under development, with demonstration of a pilot industrial minerals database planned for the November convention. Further progress was also made on the Stratigraphic Database, a separate geologically focussed database that complements the Manitoba Oil and Gas database (MOGWIS), which is maintained by the Petroleum Branch. In cooperation with the GSC and the Saskatchewan Geological Survey (SGS), additional colour compilation maps were developed for the cross-border region of the Flin Flon area and for Snow Lake under the Federal/Provincial NATMAP Shield Margin project.

Land-use issues continue to require geological input in matters relating to the selection of Endangered Spaces candidate areas, aboriginal land claims, and proposals for creation of new potentially restrictive land-use designations such as ecological reserves, rezoning of provincial parks, and a national park in the Manitoba Lowlands.

Throughout the year GSB staff responded to numerous enquiries from industry clients, many of whom were responding to the new exploration incentives offered by the province. GSB staff gave several technical presentations highlighting various aspects of Manitoba's mineral potential, including a wide variety of displays that summarize ongoing work and new products. Other educational initiatives included geological presentations in Whiteshell Provincial Park and in Winnipeg, as well as support for the EDGEO program for science teachers in cooperation with the Department of Geological Sciences, University of Manitoba.

The Atlas of the Western Canada Sedimentary Basin by the Canadian Society of Petroleum Geologists, GSC, Alberta Dept. of Energy and the Alberta Geological Survey was published this year. This benchmark tome includes several contributions from GSB staff dealing with relevant aspects of the Precambrian basement and overlying Paleozoic sequences in Manitoba.

The need for continued economies in Winnipeg led to relocation of the Department's offices to Suite 360, 1395 Ellice Avenue. All rock preparation functions, field equipment, publication storage, stratigraphic core and petroleum exploration core have been consolidated at 10 Midland Street. This building has been thoroughly renovated and now provides year-round facilities for examining petroleum core in a heated building, with on-site technical support. The Branch's X-ray laboratory was moved to the Analytical Laboratory on Logan Avenue. A dramatic increase in demand for services from the GSB Analytical Laboratory created temporary backlogs in sample processing. Total private sector assay submissions in the first eight months of 1994 (1375 samples) equalled the annual workload of earlier years.

The regional office at Thompson is now fully staffed with a regional manager (reporting to the Mines Branch), three geologists and cartographic support. The Thompson and Flin Flon offices are now fully operational and maintain a high level of interaction with explorationists in these areas.

FIELD OPERATIONS

Flin Flon/Snow Lake

A wide range of geological mapping and mineral deposit investigations continues to focus on this region. Much of the work is coordinated through the Federal/Provincial NATMAP Shield Margin project.

Several cooperative investigations with industry were implemented on the Callinan copper-zinc deposit, the newly discovered Photo Lake copper-zinc deposit, sub-Paleozoic VMS deposits and the Thompson Nickel Belt. These agreements increase the level of information exchange between the private sector and the geological survey organizations, give a sharper and more immediate focus to GSB mapping, and allow companies more intensive access to the in-depth experience and insights of Survey geologists.

Field tours were given by GSB geologists in late May/early June for geologists from IETS, HBMS and the GSC, to apprise them of some of the new findings and concepts emerging from the work of the GSC and GSB. A series of field trips involving NATMAP participants from GSB, GSC, Saskatchewan Geological Survey (SGS) and the University of New Brunswick focussed on resolving problems of regional tectonostratigraphic and structural correlation that were identified in the development of the cross-border compilation maps.

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

One hundred forty-four (144) till and humus samples were collected in the Flin Flon area (63K/13). A total of 956 samples have now been collected to provide information on glacial dispersion in the Flin Flon-Snow Lake region to base and precious metal explorationists. A three-day field demonstration in the Swan River area was given by GSB to GSC geoscientists working in the Flin Flon region, to provide insights into the ice-flow history, glacial stratigraphy, glacial deposition styles and post Glacial Lake Agassiz history of west-central Manitoba and Saskatchewan.

A new project aimed at unravelling the structural geology of the Flin Flon area between Cliff Lake (Manitoba) and Hamel Lake (Saskatchewan) was initiated as an M.Sc. thesis at Queen's University. Preliminary results indicate the presence of a regional low-angle S_1 cleavage related to F_1 recumbent folding and early movement on the Club Lake and Railway thrust fault systems. These structures are folded by the F_2 Hidden Lake synform and Beaver Road antiform and are cut by later high-angle shear zones and faults.

Joint GSC/GSB stratigraphic and structural mapping was undertaken along the West Arm, Inlet Arm and Northeast Arm of Schist Lake in order to document the complex tectonic relations between tectonostratigraphic assemblages in the Flin Flon area. Augmented by a geochronology and geochemistry program at GSC, the results of this project should highlight the long-lived history of shear zone deformation, metamorphism, sedimentation, volcanism and plutonism that characterizes each of these major tectonic corridors. Importantly, these concurrent tectonic processes occurred after early island arc and oceanic volcanism and associated Cu-Zn VMS mineralization (*i.e.*, after 1880 Ma).

The Callinan Mine project is a cooperative project between the GSB, SGS and Hudson Bay Mining and Smelting Co. Ltd. Its objectives are to provide a definitive surface geology map of the Callinan-Flin Flon area and a three-dimensional interpretation of the geology and geochemistry of the Callinan Mine to assist exploration.

Mapping of the Baker Patton felsic volcanic complex at a scale of 1:5 000 has been completed in digital form. Detailed structural studies on a portion of the area confirm major disruptions of the stratigraphy during brittle deformation. The geochemistry of the complex and alteration zones associated with VMS deposits can now be investigated using the established stratigraphy.

A reconnaissance study of deformed Ordovician limestones on Limestone Point Lake was initiated as part of an overall examination of Phanerozoic deformation and reactivation of Precambrian basement structures in the Flin Flon belt - Hanson Lake Block area (Concordia University).

1:10 000 and 1:5 000 scale geological mapping continued in the Nokomis, Webb and Fay Lake regions on the northern flanks of the Flin Flon belt. The geological setting of the Nokomis gold deposit is now defined, and the interleaved thrust complexes in the Kisseynew Belt Transition Zone are better understood. The regional aspects of this work have been captured in the new NATMAP 1:100 000 Saskatchewan/Manitoba geological compilation that covers the south flank of the Kisseynew Domain between longitudes 100°15' and 102°45'.

A brief mapping project near Fay and Syme lakes included collection of geochemical samples to better delineate the extent and character of the mafic and ultramafic pillowed volcanic flows southeast and east of Ponton Lake.

Mapping at 1:10 000 scale has also been completed in the northern part of the North Star Lake area in digital format. Stratigraphic units previously identified in the southern part of the map area have been traced northwards to the Lon Zone copper-zinc occurrence.

GSC contributions defined tracer isotope characteristics of the supracrustal and plutonic rocks in the region; U/Pb-dated selected geological units to establish a geochronological history; mapped the granites in the Elbow Lake region; and compiled geological maps for the sub-Paleozoic basement in the region to the south, based on potential field data and relogging of exploration drill core. Several other projects provided new information on the structural evolution of the area, yielding new insights into the timing of deformational events that have complicated the key mineralized strata.

Field structural studies related to Ph.D. theses (University of New Brunswick), continued this summer in the Elbow Lake and Snow Lake areas. Structural mapping in the Elbow Lake area showed that the mafic volcanic rocks were the locus of protracted deformation throughout the entire interval of calc-alkaline plutonism (1.88-1.84 Ga) to post-peak metamorphic ductile-brittle deformation (1.80 Ga). Although the older plutons are penetratively deformed (*e.g.*, 1876 Ma granodiorite of the Gants Lake batholith), deformation was consistently localized in the volcanic rocks. Strands of the Elbow Lake Shear Zone (ELSZ) are contiguous with shear zones in the Athapapuskow-Cranberry lakes area and Iskwasum Lake area.

This year a brief reconnaissance confirmed the existence of widespread ocean floor basalts and ultramafic lithologies in the Iskwasum Lake region, as well as encountering the southwest extension of the ELSZ, represented on Iskwasum Lake as a 900 m wide zone of mafic mylonites and tectonites. The ELSZ appears to be a long-lived structure that may have initiated during early assembly of the Flin Flon tectonic collage, and was reactivated during subsequent plutonic events. The Iskwasum Lake mafic-ultramafic intrusive complex resembles other ocean-floor basalt-associated complexes at Elbow, Claw, and Athapapuskow lakes.

Mapping (1:50 000) of plutonic rocks in the Iskwasum Lake area highlighted the intimate relationships between calc-alkaline plutonism and shear zone deformation throughout the area, and will form the basis for an M.Sc. thesis on the plutonic rocks at the University of Ottawa.

In the Snow Lake area, structural relations between File Lake Formation turbidites, Missi Group sandstones and Amisk Group volcanic rocks were resolved through detailed mapping of the McLeod Road fault and its immediate hanging wall and footwall. The fault cuts an F_2 synform of File Lake and Missi rocks but is itself syn-metamorphic, thus constraining it to part of the overall D_2 event. Integrated structural-metamorphic studies are planned for File Lake rocks between Snow and Squall lakes to assess the structural relief and possibly the geometry of metamorphic isograds.

Field work was also completed for an integrated structural geology-geochronology project in the File Lake, Woosey Lake and east Wekusko Lake areas. A protracted history of south-directed thrusting, folding and cleavage development at File and Woosey lakes, and recognition of *ca*. 1835 Ma felsic-mafic volcanic rocks and associated fluviatile sandstones and conglomerate in the east Wekusko Lake area (Herb Lake) are documented. This subaerial volcano-sedimentary package is clearly younger than the classic Missi Group sedimentary rocks in the Flin Flon area (*ca*. 1845 Ma), and necessitates a revision in the stratigraphic nomenclature for the Flin Flon-Snow Lake Belt.

A cooperative mapping program between the GSB and Hudson Bay Exploration and Development Co. Ltd. was undertaken to accelerate development of a newly discovered copper-zinc deposit at Photo Lake. The investigation is designed to identify the geological setting of the deposit and map (1:5 000 scale) the favourable host rock stratigraphy. Map production is in digital format.

Outcrop stripping and 1:5 000 scale mapping were used to trace extensions to the Osborne Cu-Zn deposit stratigraphy an additional 1.5 km northeast of the deposit. The felsic volcanic host sequence has now been defined over an aggregate length of approximately 5.0 km. Additional alteration zones characterized by veinlet and disseminated chalcopyrite, pyrite-pyrrhotite, silicification and sillimanite-garnet were documented. Three field trips in the region of the Osborne Cu-Zn deposit were given to industry explorationists.

1:20 000 mapping of volcanic rocks and turbidite sequences southwest of Wekusko Lake has led to a twofold subdivision into the Wekusko Lake and Hayward Creek structural domains. The structural history is consistent with that closer to Snow Lake. The volcanic rocks exhibit a flat REE profile with moderately enriched LREE typical of arc tholeiites elsewhere in the Snow Lake area. Extensive iron oxide stains along the southeast margin of the Wekusko Lake pluton appear to be due to contamination by adjacent mineralized (pyritic) greywacke/siltstone.

The sub-Phanerozoic mapping program completed drill core examination, concentrating on the western half of NTS 63J and the easternmost portion of NTS 63K. The extension of tectonostratigraphic assemblages from the Snow Lake and Wekusko Lake areas was successfully mapped to at least 54°N, and a regional southwest increase in metamorphic grade was documented. A new 1:250 000 scale interpretive map for the buried Precambrian basement in NTS 63J and a revised version for NTS 63K are planned for release in 1995.

Lynn Lake and Northern Manitoba

A reconnaissance of recent burns in the Lynn Lake area targeted several areas in which detailed mapping is now warranted in tracts associated with known gold and base metal mineralization.

Preliminary results from a vegetation geochemical survey in the Eden Lake area indicate alder twigs are the preferred sampling medium for tracing light rare earth element-enriched allanite and britholite zones hosted by aegirine-augite syenite.

Geophysical data from assessment files, geological reports and computer modelling of aeromagnetic data were used to assess residual exploration potential of seven Endangered Spaces candidate areas in northern Manitoba. Short duration field examinations at Nueltin and Topp lakes confirmed a low mineral potential for the Topp Lake area, but discovered a narrow east-trending zone of mineralization in the southern sector of the Nueltin Lake Endangered Spaces candidate area that may warrant further investigation.

Thompson Nickel Belt and its Southwest Extension

GSB staff led several field tours and demonstrations in the Thompson Nickel Belt for industry and university personnel, to demonstrate new insights into the Ospwagan Group stratigraphy associated with the nickel mineralization. Industry representation on the field tours included geologists from companies active in Manitoba, as well as delegates actively engaged in exploration for nickel in Finland, Australia and South Africa.

Drill core from the region was relogged as part of a major new geological compilation project aimed at updating the subdivision of Precambrian units in this important boundary zone, and correlating the basement geology from the exposed Shield to the William Lake area to the southwest. A GSC/GSB lithogeochemical and U-Pb geochronological sampling program was initiated to compare the ultramafic rocks of the Thompson nickel belt with those in the southwest extension towards Grand Rapids, and those of the circum-Superior belt in northern Quebec and Labrador.

Stratigraphic mapping and documentation in the Grand Rapids region improved delineation of Silurian dolostone formations east and west of Provincial Highway 6, and discovered several new exposures containing *Virgiana decussata*, a key marker fossil near the base of the Silurian. Four additional holes were drilled to improve knowledge of the Paleozoic stratigraphy and better definite the boundary between the Superior Province and Thompson Nickel Belt extension. Several of the holes drilled this year and in earlier years were geophysically logged by the GSC, and static water level measurements were conducted on all drill holes in the area to expand the otherwise sparse documentation on groundwater conditions. The Precambrian intersects, along with data from relogged exploration core south of Snow Lake, will provide valuable incremental evidence on the nature of the basement, required for compilation maps for NTS areas 63J, 63K and 63G.

Stratigraphic studies and future production of isopach and depth-to-basement maps for the Thompson Nickel Belt extension will be facilitated, now that accurate locations and elevations have been determined for drill hole collars with GPS assistance from the Manitoba Land Information Centre (Surveys and Mapping Branch). An open file report based on logging of Paleozoic drill core from the Falconbridge William Lake property and adjacent areas will be released this fall.

Follow-up investigations of carbonate megabreccia on Shoulderblade Island, South Moose Lake, revealed a doughnut-shaped configuration with inwardly dipping beds, isolated outcrops with sporadic anomalous Precambrian lithic fragments and unusually high amounts of biotite in the matrix carbonates of otherwise normal Silurian country rock (dolostone clasts). The origin of this anomalous association remains to be determined.

At Pipestone Lake detailed mapping, sampling and petrologic investigations of titanium- and vanadium-bearing oxide rich zones in anorthositic gabbros were facilitated by improved access and exposures generated by concurrent exploration mounted by Gossan Resources and Cross Lake Mineral Exploration Ltd.

Central and Southern Manitoba

East of Lake Winnipeg a resource assessment of the Poplar River Endangered Spaces candidate area confirmed the dominantly granitoid nature of the bedrock, and concluded that the area has low base and precious metal mineral development potential. Industry has expressed concern that the region may have potential for diamond occurrences; accordingly, consideration is being given to mounting kimberlite indicator mineral investigations in future years.

The search for indications of Mississippi-Valley-type (MVT) lead-zinc mineralization in the Interlake region focussed on geochemical sampling of spring waters in the Grand Rapids Uplands. Preliminary results suggest that the pH of the waters draining from the emergent points may be too high to carry metal solutes at detectable levels. Accordingly, the investigation was extended to include sampling of marly precipitates from fen pools associated with the springs. Again as part of ongoing interest in exploring new approaches to evaluate the MVT potential of the Paleozoic carbonates, the GSB supported a program by the departments of Agriculture, Environment and the provincial Water Resources Branch, to analyze groundwaters in the southern Interlake region.

The exploration for diamond pipes in the province was bolstered in 1993 with the discovery of numerous indicator minerals in basal till samples collected by the joint federal/provincial low density till sampling program. This year the sampling density in the Westlake Plain area between the Manitoba escarpment, Lakes Manitoba and Winnipegosis, and from the Pelican Rapids road south to Neepawa was increased by 182 till samples based on a randomly plotted 10 km grid. 70 kg samples and a 3 kg split, collected at each sample site, will be processed for kimberlite indicator minerals and geochemistry, when funds are available.

In response to queries from industry, carbonate veins in the Precambrian granite inlier at Highrock Lake were sampled to determine their mode of origin. REE profiles for the carbonates are quite different from, yet overlap, those of calcite from kimberlite. Major and trace-element analyses of the veins closely resemble those of limestones in the neighbouring Red River Formation, suggesting a most likely origin through remobilization associated with the inferred meteor impact event.

Scientists from the GSC and GSB have completed the geophysical survey phase of a cooperative multidisciplinary geoscientific study of Lake Winnipeg. This study is the first of its kind in Manitoba and will provide a new understanding of Lake Winnipeg's geological architecture and the geological processes affecting its waters. Subsequent sampling and coring focussed on investigating the key features and sediment sequences on the lake bottom. This information will be critical for land-use planning and environmental management. The survey was conducted in cooperation with the Canadian Coast Guard from its ship CCGS Namao. Funding partners include the Province of Manitoba, Manitoba Hydro, Fisheries and Oceans Canada and the GSC.

GSB staff responded to several Marketing Branch requests for dolomite, bentonite, kaolinitic clay, and silica sand samples required for beneficiation and chemical tests. Samples of black shales and associated encrustations at Black Island were collected to examine their potentially unique geochemistry.

Southeast and Southwest Manitoba

Geological mapping in the Bissett area was undertaken by GSC and GSB to complete gaps in previous coverage and resolve uncertainties of correlation for the PAMD-funded digital database for southeast Manitoba. Known occurrences of (older sequence) ultramafic flows in the Garner Lake area have been extended and previously unmapped hydrothermally altered intermediate-felsic volcanic rocks were identified. A new serpentinite belt was discovered northeast of Saxton Lake, with the aid of recent gradiometer data.

A 3.0 Ga age was determined for a tonalite along the northern margin of the Rice Lake Belt. This is one of the oldest units in the region, although similar ages from detrital zircons in the Conley and Edmunds Lake formations imply that the tonalites may have been basement to the supracrustal greenstone assemblages.

A brief appraisal of the Broadleaf River area confirmed the need for additional geological mapping in the region immediately north of Wallace Lake, where mafic metavolcanic rocks appear to be more abundant than shown on previous maps. Large batholithic complexes dominate the less prospective region from Kosteck Lake north to Aikens Lake.

PAMD-funded Quaternary investigations by the GSC in the Rice Lake greenstone belt consisted of fill-in sampling in the eastern region and additional sampling and surveys in the west. Three sites with significantly high gold grain counts were identified.

Client requests were followed up by field examination of road-accessible serpentinites in the Manigotagan area for use in carving or as dimension stone. Several tours of industrial mineral sites were given for representatives of industry, the Museum of Man and Nature and Natural Resources Canada. A visit to the west shores of Cedar Lake confirmed the existence of amber on beaches that have been regenerated since the lake levels were raised.

In southeast Manitoba the search for sources of high-purity lump-silica focussed on detailed mapping and sampling of quartz veins near Buffalo Lakes. Several veins appear to be sufficiently large and pure to warrant follow-up trenching and drilling.

Surficial deposits at approximately 2000 sites, in the east half of NTS 62H were mapped and described by the GSB as part of the Southern Prairies NATMAP initiative. Compilation of four 1:100 000 scale map sheets will be conducted this winter, along with development of a digital database containing descriptive data from previous surveys and this summer's work. Results will have direct application to the search for kimberlite pipes in this region.

In the Virden area, exploration for diamonds and petroleum was boosted as the GSC completed Phase IV of their airborne magnetic surveys. This year the program was funded in part through contributions from two mining companies. Exclusivity rights will permit release of the data into the public domain in the fall of 1995.

September 28, 1994.

GS-1 MINERAL RESOURCE STUDIES IN PROPOSED ENDANGERED SPACES, ES-A AND ES-C, NORTHWEST MANITOBA*

by D.C. Peck, H.D.M. Cameron and I.T. Hosain

Peck, D.C., Cameron, H.D.M. and Hosain, I.T., 1994: Mineral resource studies in proposed Endangered Spaces, ES-A and ES-C, northwest Manitoba; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 5-10.

SUMMARY

As part of the Province's commitment to meet the guidelines for the World Wildlife Fund's (Canada) Endangered Spaces campaign, the mineral potential of two proposed endangered spaces (ES) was investigated. However, owing to a paucity of outcrop and both time and resource restrictions, a thorough assessment of these candidate areas could not be completed. The results from the current study suggest: (1) each of the three aeromagnetic anomalies investigated appear to relate to lithologic types having very little mineral potential (magnetite-bearing metasedimentary and granitic rocks); (2) all of the outcrops examined within ES-C are part of a large Proterozoic granitic batholith (*Topp Lake batholith*) and are largely devoid of potentially valuable mineral occurrences; (3) it is not possible to satisfactorily assess the mineral potential of ES-A by means of bedrock mapping and lithogeochemistry alone.

Whereas ES-C appears to have very low mineral potential, the mineral potential of ES-A remains unclear. The existing geological database for ES-A suggests that the area is underlain by a relatively complex metasedimentary sequence that is probably (in part) correlative with the Early Proterozoic Hurwitz Group. Part of the Hurwitz Group, occurring immediately to the north of ES-A within the Northwest Territories, is prospective for base- and precious metal mineralization. It is strongly recommended that any decision concerning the mineral potential of ES-A be deferred until such time that a systematic, regional geochemical study of surficial materials (till, esker sands, lake sediments, lake waters, *etc.*) and a more comprehensive investigation of the bedrock geology and known geophysical anomalies are completed.

INTRODUCTION

A four week field program, designed to address the mineral potential of two candidate sites for the Province's Endangered Spaces (ES) campaign, was completed during July and August of 1994. The Endangered Spaces campaign is an international program, involving the World Wildlife Fund and a number of supporting nations (including Canada), whose principal objective is to identify and protect 12% of each distinct ecosystem within each participating country. A copy of the Province of Manitoba's action plan for the Endangered Spaces campaign can be obtained from the Provincial Government's Executive Council (Sustainable Development Co-ordination Unit).

The locations of the two candidate areas (ES-A and ES-C) are shown in Figure GS-1-1. Both areas occur within the western part of the Seal River lithotectonic domain of the Churchill Province (Schledewitz, 1980). Endangered Space A is an area of approximately 2400 km^3 that completely encompasses the Manitoba portion of Nueltin Lake (NTS 64N and 64O, Fig. GS-1-2). Endangered Space C is an area of approximately 2000 km^3, bounded by the Seal River in the south and Shannon Lake in the north (NTS 64N and 64O, Fig. GS-1-3). The locations of specific outcrops and/or aeromagnetic anomalies that were investigated during the current study are shown on Figures GS-1-2 and GS-1-3. Both areas are characterized by limited bedrock exposure (<0.1%) and extensive drift cover (sandy and bouldery till; see Dredge *et al.*, 1986). Large south-southwest-trending eskers, esker complexes and moraines, formed by the Keewatin ice mass during the last glacial period, bifurcate both areas. Glaciolacustrine and till-derived sand deposits and muskeg (forested bog peat and fen peat) occupy areas of low relief within both ES-A and ES-C. Access to both areas was by fixed-wing charter plane from Treeline Lodge, located at the southwestern end of Nueltin Lake.

The objective of the current study was to investigate the mineral potential of both candidate areas. Given both time and financial restrictions, an emphasis was placed upon prospecting representative bedrock outcrops at regular intervals or wherever significant airborne geophysical anomalies were present. Both areas were systematically flown in order to identify new (unmapped) bedrock outcrops or large felsenmeer (boulder trains). This exercise proved extremely worthwhile for ES-C, where numerous new exposures were identified in areas that were shown as drift covered on existing geological maps (Davison, 1963; Weber *et al.*, 1975; Schledewitz, 1980). However, very few new exposures were identified within ES-A, where outcrop is estimated to represent much less than 0.1% of the total land area.

Specific study sites were selected with the aid of a geophysical review of airborne magnetic (see Schledewitz, 1980) and scintillometer survey data (Soonawala, 1980). Colour contoured vertical magnetic gradient maps (1:100 000 scale) were prepared by the G.S.C. in Ottawa. Numerical modelling of several weak to moderate intensity circular aeromagnetic anomalies suggested the presence of kimberlite in two areas (ES-A-4, Lowry Lake, Fig. GS-1-2; stations 98-94-110 to 117, Minuhik Lake, Fig. GS-1-3). In addition, a strong, positive linear magnetic anomaly that extends across the entire east-west dimension of ES-A was investigated at several locations in order to determine the source of the elevated magnetic signature. Geochemical data for surficial materials (Coker and Ellwood, 1981) were also considered during the site selections.

During the current study, only a limited amount of overburden sampling (*i.e.*, sampling of eskers in the vicinity of the potential kimberlite occurrences) was conducted. It was not possible to carry out a systematic surficial geochemical sampling program in either of the candidate areas in the allotted time period and with the designated financial resources.

CANDIDATE AREA ES-A

The geology of ES-A is described in Davison (1963), Weber *et al.* (1975a, b) and Schledewitz (1980). The area is principally underlain by Archean (?) to Early Proterozoic (Aphebian and Hudsonian) paragneiss and migmatite derived from semi-pelitic and psammitic clastic sedimentary rocks. Some of these metasedimentary rocks may be correlative with the Hurwitz Group in the Northwest Territories, which is known to be prospective for epigenetic Au mineralization (Aspler *et al.*, 1989). Garnet-bearing, semi-pelitic migmatite (metatexite; see Fig. GS-1-4) is the most common lithologic type that was observed in area ES-A. Subordinate lithologic types observed within ES-A include calc-silicate gneiss, pre- and syn-Hudsonian, massive to foliated, aphyric and porphyritic to megacrystic granitoid rocks (monzonite, quartz monzonite, tonalite, granodiorite and granite), and rare gabbroic to ultramafic dykes and/or sills. ES-A contains very sparse outcrop (<0.1%), so that detailed geological mapping (*i.e.*, 1:5000 scale) is not possible in this area. Brief inspections of selected outcrops within or adjacent to Nueltin and Nahili Lakes (Fig. GS-1-2) confirm the findings of Schledewitz (1980). No major shear zones, faults, alteration zones or sulphide occurrences were observed in any of the outcrops examined, with the notable exception of a sulphide-bearing gabbro-pyroxenite intrusion that crops out in the western part of Nueltin Lake (location ES-A-3, Fig. GS-1-3, see below).

An east-trending and very strong aeromagnetic anomaly extends across the southern end of Nueltin Lake and the entire width of ES-A (location ES-A-1, Fig. GS-1-2). The anomaly typically measures >3000 γ, and elliptical peaks >4000 γ occur at several points along the 50 km of strike length covered by the magnetic anomaly. The strongest component of the anomaly measures >7500 γ, and occurs several kilometres inland from the eastern shoreline of Nueltin Lake at the eastern terminus

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

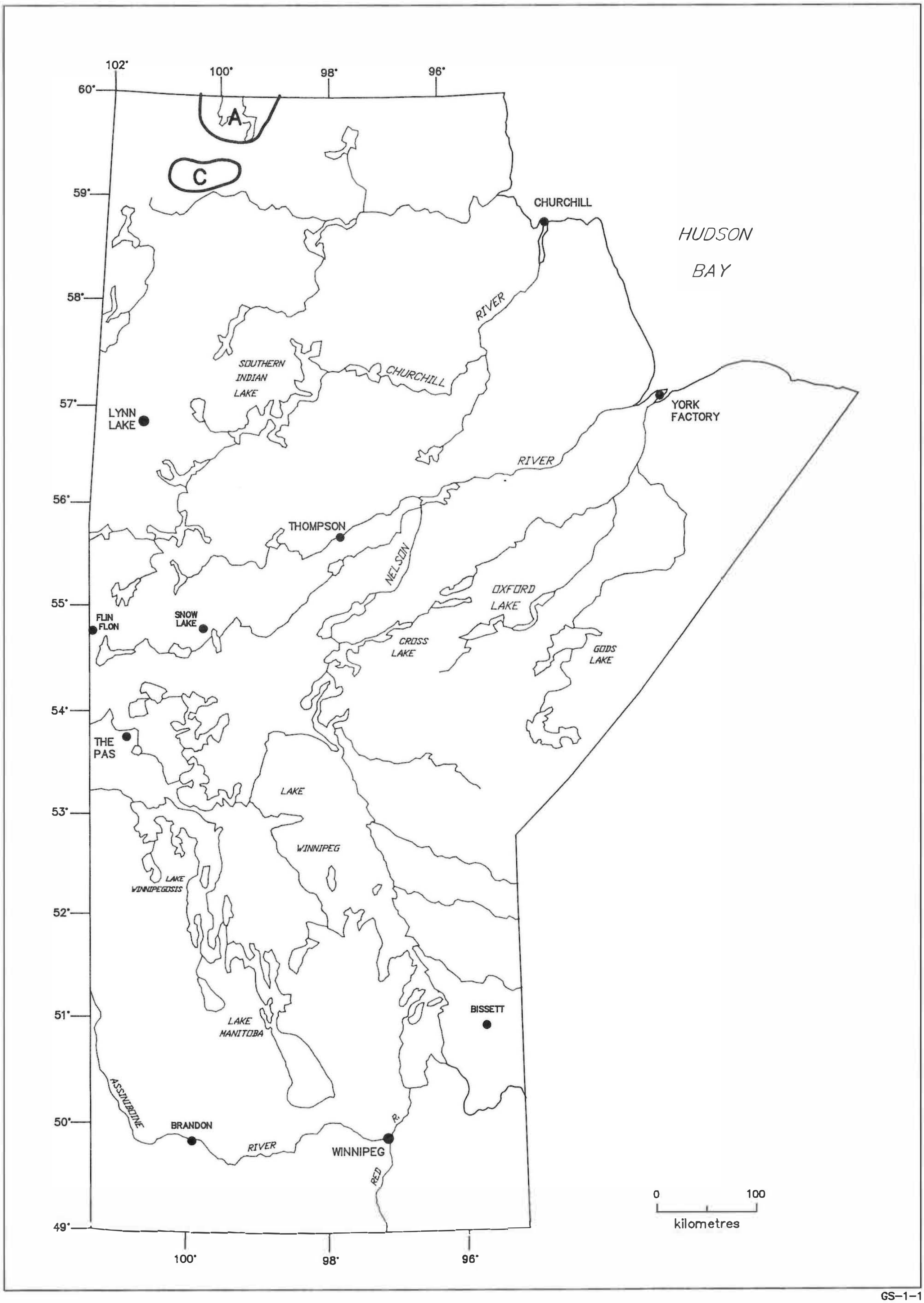

Figure GS-1-1: *Location of candidate areas ES-A and ES-C (Endangered Spaces campaign), northwestern Manitoba.*

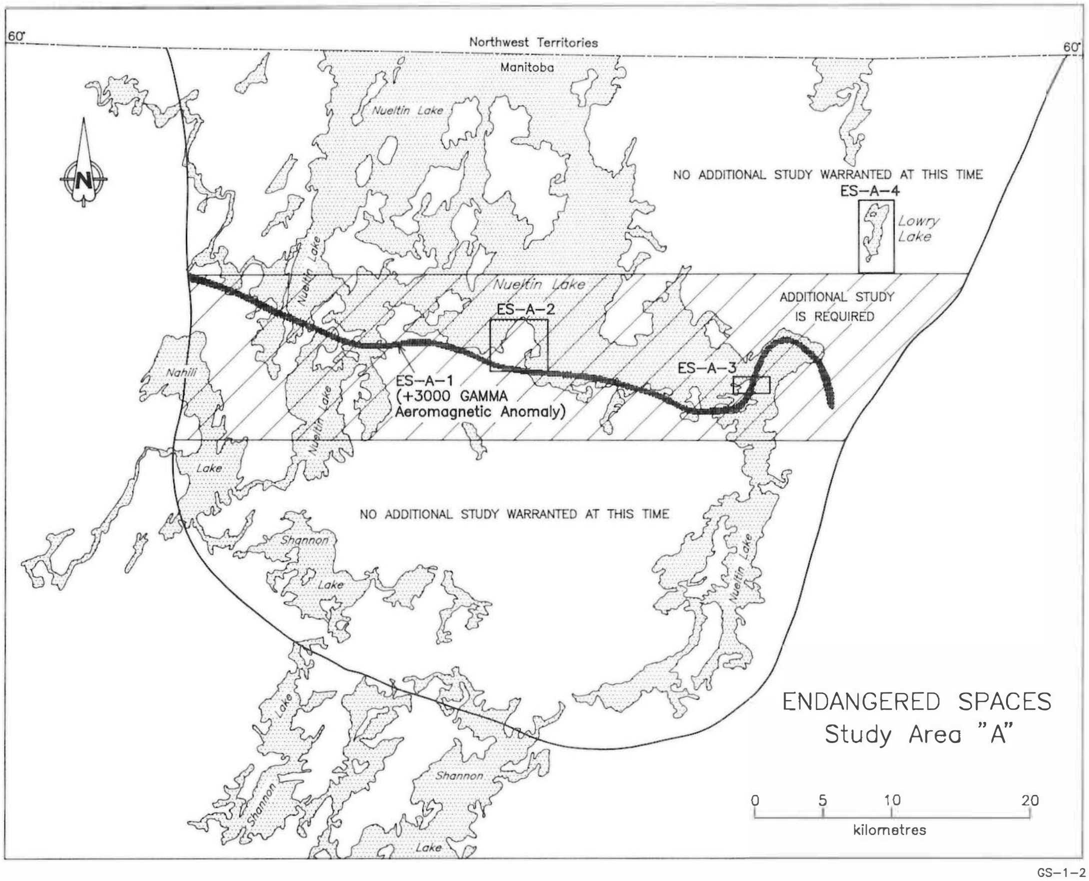

Figure GS-1-2: *Location of selected study areas within candidate area ES-A, Nueltin Lake region, northwestern Manitoba. ES-A-1 represents the general trend of a positive aeromagnetic anomaly that would appear to relate to the presence of magnetite-bearing paragneiss that was observed in outcrops within location ES-A-2. Location ES-A-3 hosts an outcrop of pyrrhotite-bearing gabbro. Location ES-A-4 (Lowry Lake) was investigated owing to the existence of several weak to moderate intensity positive aeromagnetic anomalies (possible kimberlite intrusions). See text for additional discussion.*

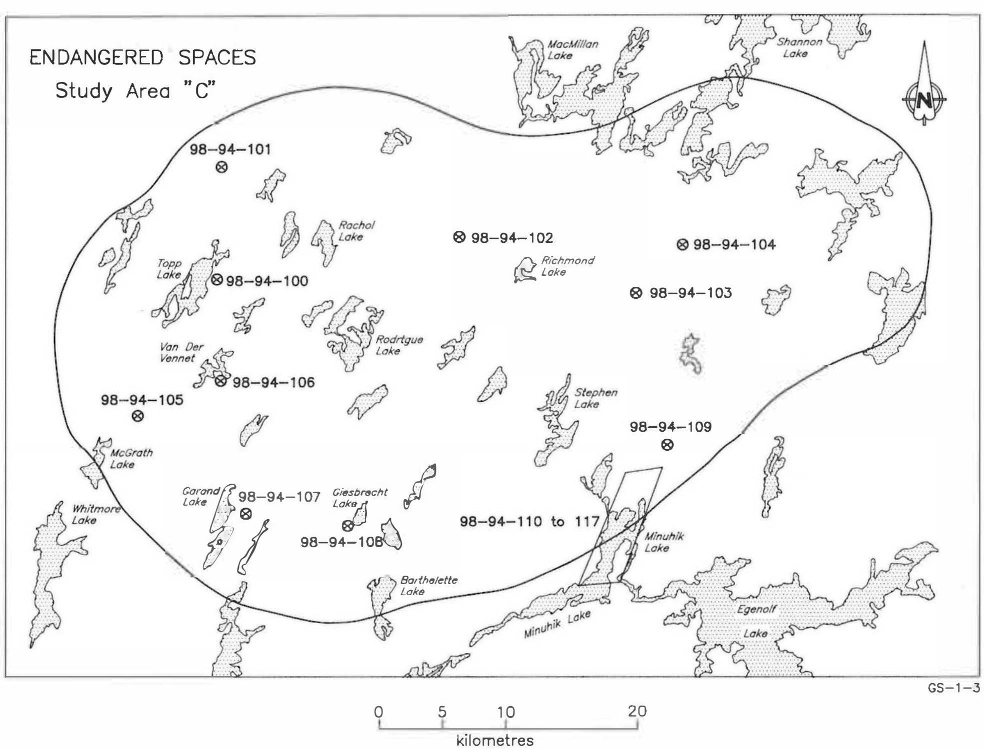

Figure GS-1-3: *Location of stations investigated within candidate area ES-C, northwestern Manitoba. Each station hosts areas of outcrop comprising granitic rocks belonging to the Topp Lake batholith. Stations 98-94-110 to 117 represent a series of outcrops and esker sample locations to the south of circular aeromagnetic anomalies that occur immediately to the north of Minuhik Lake. See text for discussion.*

of the anomaly (see Fig. GS-1-2). The linearity and intensity of this magnetic feature is consistent with the presence of an iron formation. One outcrop of iron formation was identified by Davison (1963), but this outcrop was not found during the current study. The entire length of the anomaly was surveyed from the air in order to locate outcrops. However, no new bedrock exposures were observed, and the source of the anomaly remains in question. Results from the current investigation suggest that one of two observed lithologies may represent the source of the anomaly, *viz.*: (1) a magnetite-bearing meta-arkose that crops out along the southern shoreline of Nueltin Lake (location ES-A-2, Fig. GS-1-2); and, (2) a pyrrhotite ± magnetite-bearing gabbroic intrusion that crops out near the western end of Nueltin Lake (location ES-A-3, Fig. GS-1-2). These units are described in detail below.

Magnetite-Bearing Metasedimentary Rocks

Magnetite-bearing paragneiss is exposed at several locations on the shoreline of a small bay (600 m long) along the south shore of Nueltin Lake (location ES-A-2, Fig. GS-1-2). The unit underlies the major east-trending aeromagnetic high that extends across the south end of Nueltin Lake. The rock is a fine grained pink and grey weathering *lit-par-lit* gneiss with approximately 5% white to pink feldspathic *lits* up to 2 cm thick. It is interpreted to have formed from a sandstone, and is petrologically similar to some Sickle Group arkosic metatexites (Gilbert *et al.*, 1980). Magnetite generally occurs as disseminated pinhead- to 3 mm-size grains and also locally as discrete 1 to 3 mm layers.

The magnetite-bearing paragneiss also incorporates 3 to 50 cm thick arkosic layers, containing 0.8 to 5 cm thick internal bands. The arkosic layers are interbedded with finer grained, 20 cm-thick layers containing abundant magnetite and quartz. No sulphides were observed in the outcrops examined.

Layers of calc-silicate rock up to 20 cm thick also occur at location ES-A-2 (Fig. GS-1-2). Clots of magnetite up to 3 cm long occur near the calc-silicate layers. Sills of pink pegmatitic granite up to 1 m thick intrude the units parallel to the layering. The calc-silicate rocks strike approximately 285° and dip 36° to 40° north.

The magnetite-bearing paragneiss has an overall width of approximately 60 m and is flanked to the north and south by locally garnetiferous psammitic metagreywacke, associated calc-silicate rocks and tonalitic paragneiss containing little or no magnetite.

It is probable that the aeromagnetic anomaly, at least within location ES-A-2 (Fig. GS-1-2), is related to the above-mentioned magnetite-rich metasedimentary sequences. Samples have been submitted for geochemical analysis in order to determine whether any Au enrichment is associated with the magnetite-rich gneiss.

Sulphide-Bearing Gabbro-Pyroxenite Intrusion

A shallowly dipping gabbroic intrusion is exposed in a 10 m long by <1 to 3 m wide outcrop on the shoreline of a narrow bay in the southeastern part of Nueltin Lake. The gabbroic intrusion is 5 m long and has a minimum exposed width between 20 and 50 cm. The north contact of the gabbro is not exposed and its upper surface conforms to the dip slope of the outcrop. The gabbroic body consists of medium- to coarse-grained, sulphide-bearing gabbro that grades to melagabbro (north side of outcrop). The gabbroic body intrudes older tonalitic (arkosic?) gneiss, and is cut by white granite pegmatite and apparently coeval quartz-biotite veins. The contact between the gabbro and the gneiss trends easterly, parallel to the regional, linear magnetic anomaly (described above) and dips approximately 35°N. The gabbro contains 2 to 10%, recrystallized, interstitial to blebby pyrrhotite and lesser amounts of associated chalcopyrite. The gabbro body has a strong response to a hand-held magnet and appears to contain a minor amount of magnetite in addition to moderately magnetic pyrrhotite. The mineralization is interpreted as marginal-type magmatic sulphides that commonly develop at the base or along the side walls of mafic to ultramafic intrusions. The coarse crystal size of the exposed gabbro, despite its proximity to the gneiss, suggests that it may be part of a thermally buffered magma that, either owing to high flow rates, large magma volumes or a high ambient temperature in the host rock, failed to develop a fine grained chilled margin. The gabbroic body is not obviously foliated; it postdates the major deformation that produced the gneissic fabric in the tonalitic host rocks.

No other outcrops (of any rock type) were observed in this area. However, small boulders of pyrrhotite-bearing melagabbro and pyroxenite were found on a small boulder till ridge approximately 200 m north of the gabbro outcrop. Three samples of mineralized gabbro were submitted for geochemical analysis. At the time of writing, only precious metal (ACTLABS, Ancaster, Ontario) and base metal analyses (Manitoba Energy and Mines, Analytical Laboratory) were reported. All of the samples contain <5 ppb Pt, <3 ppb Pd and between 24 and 31 ppb Au. These low precious metal contents indicate that the pyrrhotite did not reach equilibrium with the parent magma, and represents relatively late crystallizing, intercumulus sulphide. This suggestion is corroborated by the low Ni and Cu contents of the samples (<50 ppm Ni and <400 ppm Cu).

The occurrence of magnetic, mineralized gabbro along the trend of the above-mentioned linear magnetic anomaly may be a coincidence. However, Davison (1963) reports another occurrence of this gabbro several kilometres to the east and its position coincides with the strongest peak associated with the magnetic anomaly (*ca.* 7500 γ). An attempt to locate this outcrop was unsuccessful. The easterly strike of the gabbro-

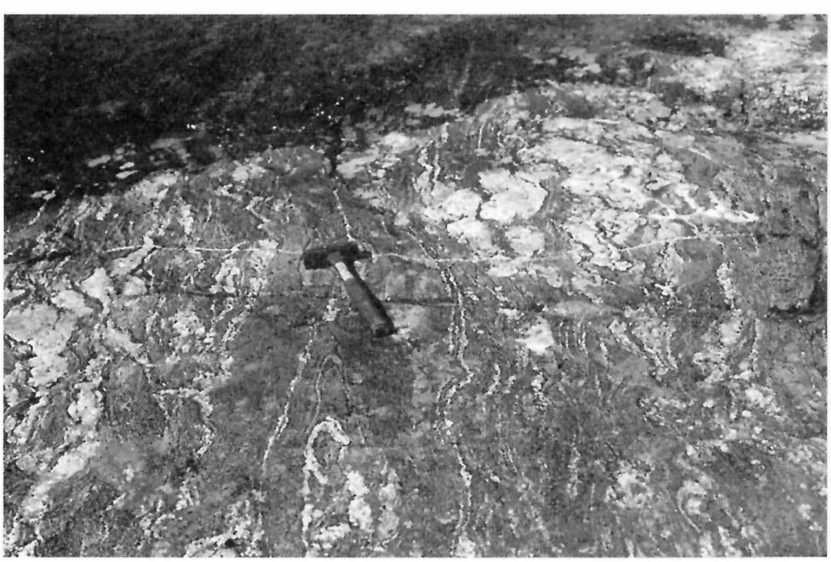

Figure GS-1-4: Minor folds in semi-pelitic migmatite (metatexite) from the northwestern part of the Manitoba portion of Nueltin Lake, ES-A. The irregular, white pegmatite bodies are interpreted to represent mobilizate.

tonalite contact is parallel to both the trend of the aeromagnetic anomaly and two prominent east-trending lineaments that were identified on 1:1 000 000 scale black-and-white satellite images. The trend of the lineaments is unusual in that most structures (and measured rock foliations; see Schledewitz, 1980) visible on air photographs or satellite images for ES-A strike northeasterly. Given these observations, a more detailed investigation of this gabbroic intrusion may be warranted. An attempt was made to conduct a ground EM survey over the magnetic anomaly in the vicinity of the outcrop hosting the gabbroic body, but inclement weather and time restrictions forced this exercise to be postponed.

Lowry Lake Aeromagnetic Anomalies

Five circular to elliptical, weak to moderate magnetic anomalies (highs) that potentially relate to subsurface kimberlite intrusions were identified beneath and to the east of Lowry Lake in the easternmost part of ES-A (location ES-A-4, Fig. GS-1-2). The anomalies were recognized from airborne aeromagnetic data (Geological Survey of Canada, 1961). Large samples (*ca.* 10 kg) of sandy overburden were collected from an esker complex that passes over and to the south of the magnetic anomalies underlying Lowry Lake. A series of small outcrops of magnetite-bearing megacrystic granitic rock occur immediately to the south and west of one of the circular magnetic highs, along the western shoreline of the lake and within the lake. The granite contains up to 50% pink K-feldspar phenocrysts (Fig. GS-1-5), up to 3 cm long, and a medium grained quartz- and biotite-rich matrix in which up to 5% magnetite is disseminated. Subangular to subrounded xenoliths, up to 50 cm long, of mafic to intermediate gneiss occur locally within the granite (Fig. GS-1-5). This magnetite-bearing granite would appear to be a likely source for the magnetic highs in the Lowry Lake area; no further geological work is recommended.

CANDIDATE AREA ES-C

Geological investigations within ES-C included field studies at ten selected areas of bedrock outcrop (stations 98-94-100 to 109, Fig. GS-1-3), many of which were previously unrecognized, and at Minuhik Lake (Fig. GS-1-3) where circular aeromagnetic anomalies were identified. The outcrops were selected in order to obtain a representative perspective on the regional geology of ES-C. Wherever possible, outcrops that were associated with geophysical anomalies were selected; however, rocks in ES-C, in general, have very little expression on the vertical magnetic gradient maps that were produced for this study. As indicated on previous geological maps for the area (*e.g.,* Schledewitz, 1980), ES-C is underlain by the relatively homogeneous Topp Lake granitic batholith. Outcrops examined during the present study (Fig. GS-1-3) consisted of coarse grained to megacrystic, porphyritic syenogranite and/or granite (Fig. GS-1-6). Local aplitic granites, white-weathering graphic granite pegmatite and xenoliths of older tonalitic gneiss collectively account for less than 5% of the total area of exposed bedrock. Petrographic and whole-rock geochemical studies of samples collected from each location (stations 98-94-100 to 98-94-117, Fig. GS-1-3) are ongoing. No significant sulphide mineralization, iron oxide stains, shear zone or vein network development was observed. None of the pegmatite veins examined contained rare-metal minerals such as spodumene or beryl; however, it cannot be definitively stated that such minerals do not occur in some of the pegmatites within ES-C.

Seven overburden samples were collected from esker ridges extending immediately to the south of a series of aeromagnetic anomalies that occur to the north of Minuhik Lake in the southeastern part of ES-C (Fig. GS-1-3). Several weakly positive circular aeromagnetic anomalies form the north-trending anomaly that parallels the commonly observed strike of bedrock ridges in this part of ES-C. Examination of the limited amount of outcrop in this area revealed that the circular aeromagnetic anomalies are likely related to bedrock or subcrop topology of magnetite-bearing phases of the granitic batholith that underlies most of ES-C. Several outcrops and numerous large boulders of strongly magnetic granite containing up to 5%, disseminated, medium grained magnetite were observed in close proximity to individual circular aeromagnetic anomalies in the Minuhik Lake area.

Based on the very limited amount of field work that was carried out during the current study, and upon reviewing the existing geophysical database, it is concluded that area ES-C has very limited mineral potential. An economically interesting mineral association that might occur within this area is lithophile-element mineralization associated with granitic pegmatite (*e.g.,* Sn-W-Ta-Nb, rare-earth elements). There was no indication of the presence of structurally favorable sites for epigenetic gold and base-metal mineralization within ES-C. Furthermore, the granitic batholith occurring within this candidate site appears to be a potassic (S-type) granite and, therefore, is unlikely to host porphyry-style Cu-Au mineralization that occurs in association with I-type (mantle-derived) granitoids (*e.g.,* western cordillera of North and South America).

RECOMMENDATIONS

Based on observations made during the current investigation, the following recommendations are advanced:

1. It is not currently possible to make definitive statements regarding the economic potential of either ES-A or ES-C, largely because there is inadequate bedrock exposure in both areas and given the fact

Figure GS-1-5: Intermediate orthogneiss xenolith in a magnetite-bearing megacrystic granite from an outcrop along the western shoreline of Lowry Lake, ES-A.

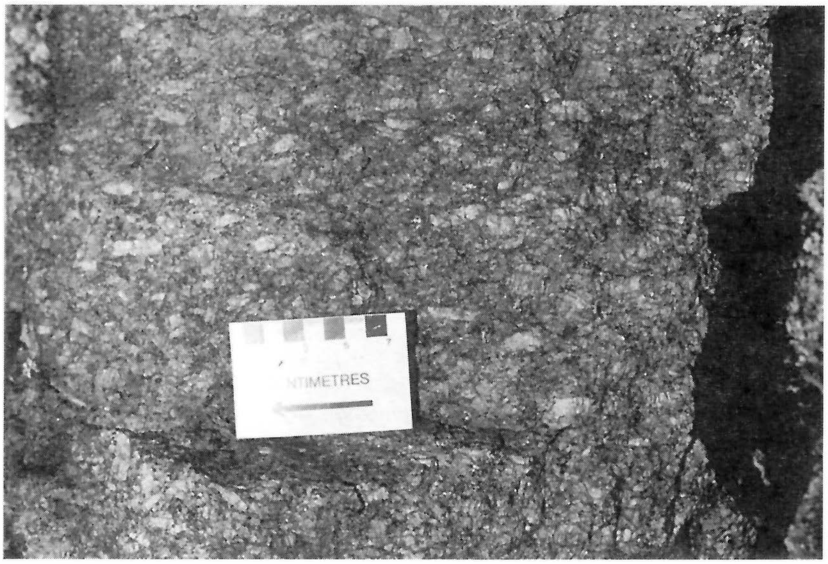

Figure GS-1-6: Foliated, porphyritic syenogranite from an outcrop at station 98-94-109 (see Fig. GS-1-3 for location), ES-C. This rock type is prevalent in most of the outcrops examined in ES-C, and appears to be the principal lithologic type within the Topp Lake batholith.

that a systematic, detailed overburden geochemical survey has not been undertaken. This type of geochemical survey should focus on pathfinders for Au, diamonds and base metals. With this in mind, the results of the current study indicate that ES-C is an area of low mineral potential. No additional geological investigations are recommended for this candidate area, unless the exploration community expresses a strong interest in evaluating its rare-metal potential;

2. Given its more complex geology, part of which may be analogous to the Hurwitz Group (Aspler *et al.*, 1989), much additional work is required within ES-C before an appraisal of its mineral potential can be completed. This work should include a helicopter-supported, systematic overburden geochemistry and/or biogeochemistry survey of selected target areas within ES-A. Such targets should be identified in view of known overburden geochemical anomalies (Coker and Ellwood, 1981) and the results described herein. Additional ground EM surveys should be conducted at regular intervals over the linear aeromagnetic anomaly that extends across the south end of Nueltin Lake (despite the fact that limited field evidence suggests that the anomaly relates to a magnetite-bearing paragneiss).

ACKNOWLEDGMENTS

Mr. and Mrs. G. Gurke are thanked for the warm hospitality that they extended during the course of the field studies. Cartographic assistance rendered by Mr. J.M. Pacey is gratefully acknowledged. Mr. D. Schledewitz and Mr. K. Lehnert-Thiel provided critical information pertaining to the regional geology.

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GS-2 PRELIMINARY OBSERVATIONS FROM A VEGETATION GEOCHEMICAL SURVEY OVER PART OF THE EDEN LAKE AEGIRINE-AUGITE SYENITE, LYNN LAKE AREA (NTS 64C/9)*

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

Fedikow, M.A.F., Dunn, C.E. and Kowalyk, E., 1994: Preliminary observations from a vegetation geochemical survey over part of the Eden Lake aegirine-augite syenite, Lynn Lake area (NTS 64C/9); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 11-15.

SUMMARY AND CONCLUSIONS

Vegetation geochemical orientation survey results have identified alder (*Alnus crispa*) twigs as the most efficient tissue type for acquisition and storage of light rare earth elements (LREE) in the Eden Lake syenite. An ashed sample of this tissue type from the area of LREE-enriched allanite-britholite mineralization contains 757.5 ppm ΣREE. Lichen (*Cladonia spp.*; 415.3 ppm) and the outer bark of jack pine (*Pinus banksiana*; 165 ppm) represent possible alternative tissue types for sampling. Collection of lichen samples, however, is labour intensive and time consuming and may prohibit collection of this tissue type in an exploration-oriented survey. The possibility of downslope leakage-type vegetation geochemical anomalies in overburden covered terrain is currently under investigation. A total of 57 alder twig samples were collected for a distance of 200 m from the outcrop-overburden interface, prepared and forwarded for analysis. Analyses are unavailable at the time of writing.

INTRODUCTION

The vegetation and radiometric study undertaken in 1993 (Fig. GS-2-1; Fedikow *et al.*, 1993) was continued in 1994 guided by preliminary geochemical results obtained from the 1993 orientation program. Vegetation sampling in 1994 was undertaken approximately 200 m

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

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

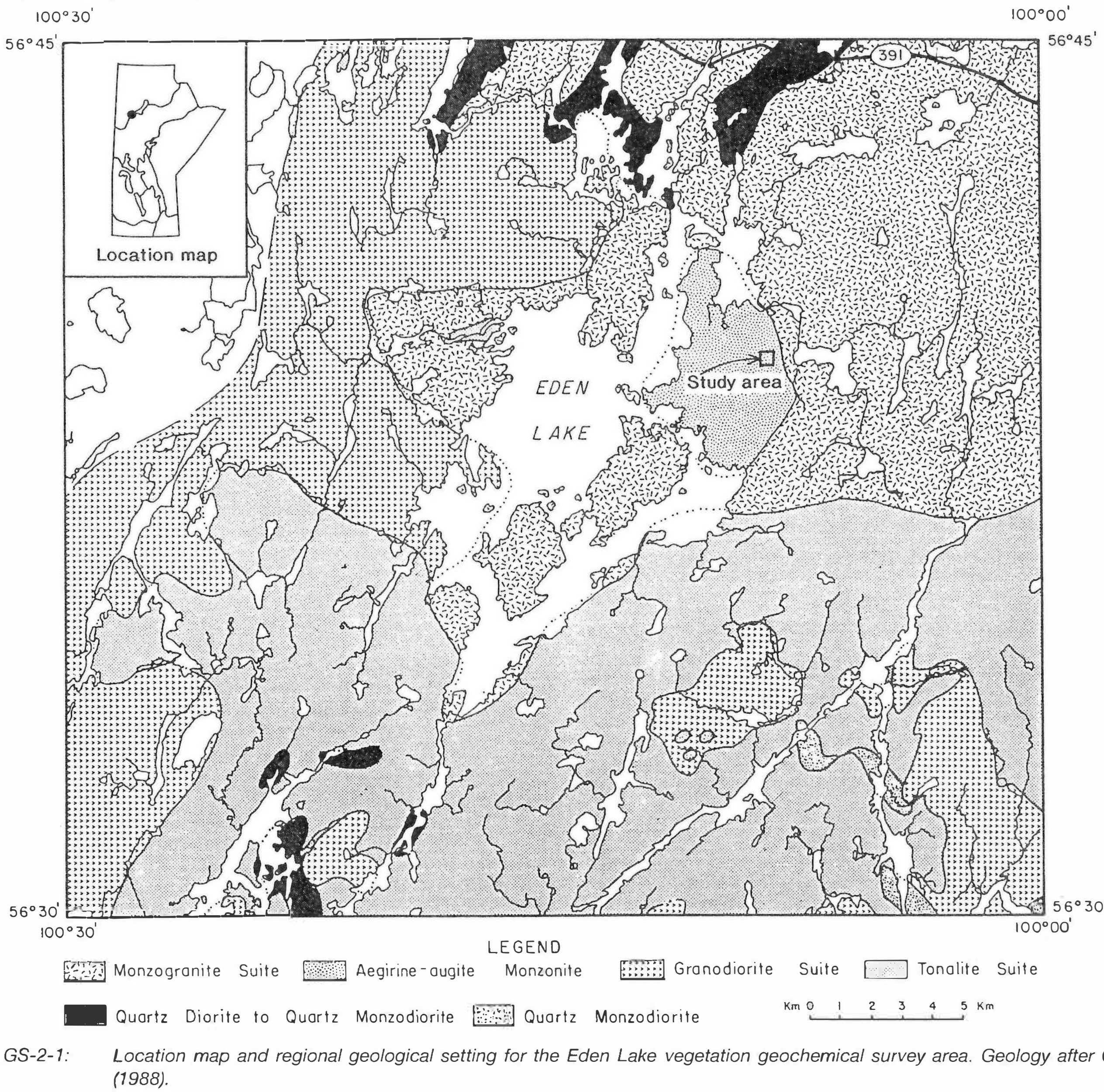

Figure GS-2-1: Location map and regional geological setting for the Eden Lake vegetation geochemical survey area. Geology after Cameron (1988).

downslope from the allanite-britholite mineralized zone in relatively well drained areas of no outcrop (Fig. GS-2-2). A total of 57 samples representing alder (*Alnus crispa*) twigs were collected. Ashed (470°C) samples will be analysed by instrumental neutron activation. A description of the project, including the geological setting, the geochemical characteristics of the rare earth element enriched mineralized zone and the methods and rationale for sample collection, is available in Fedikow *et al*. (1993).

RESULTS

Rare Earth Elements

Table GS-2-1 summarizes available geochemical data for the vegetation species and tissues sampled in 1993. These data represent analyses of vegetation tissues collected from within a 5 m^2 sampling box centered on the vein type allanite and britholite mineralization. The enrichment of the light rare earth elements La, Ce and Nd (LREE) indicated in the analyses of the allanite and britholite (Fedikow *et al*., 1993) are reflected in the analyses of some of the tissues sampled for the orientation survey. The highest concentration of La, Ce, Nd and, to a lesser degree, Sm are present in alder twigs. Total rare earth element (ΣREE) content of the alder twigs is 757.5 ppm which exceeds that of lichen at 415.3 ppm, the next most efficient tissue for concentrating these elements at this site. Alder leaves also contain highly elevated LREE concentrations with 93 ppm, 120 ppm and 66 ppm, respectively, for La, Ce and Nd. The heavier REE are present in low concentrations in almost all tissues sampled (Table GS-2-1).

Geochemical partitioning for REE within two species at the orientation site was undertaken with the collection of samples of all available tissues from a single black spruce tree and a jack pine tree. For the black spruce, samples were collected at both chest height and from the crown or upper 40 cm of the tree. Six tissue types for the jack pine were collected (Table GS-2-1). LREE contents in black spruce needles are comparable for both chest height and crown samples whereas chest height twigs contain higher LREE and ΣREE (57.2 ppm) than their crown counterparts (ΣREE = 14.6 ppm). Crown cones have comparable LREE and ΣREE to both crown needles and twigs. In chest height tissue samples, black spruce twigs contain approximately twice the ΣREE contents (57.2 ppm) and higher LREE than other black spruce tissues from this tree.

Significant concentrations of REE have been recorded from all tissues of a twisted and gnarled jack pine sampled for geochemical partitioning (Table GS-2-1). Six tissue types were collected from this tree and the analytical data confirms that the highest REE contents occur in outer bark (ΣREE = 165.0 ppm). Jack pine twigs, needles, cones, trunk wood and inner bark have a lower range of ΣREE of 9.8 - 25.6 ppm. Since the sampling area is considered to be free of anthropogenic contamination the observation of higher REE in the outer bark is considered both real and significant in terms of future sample collection.

Other Elements

Base and precious metal contents of all vegetation tissues are low with the exception of a single analysis of 2.0% Zn in birch (*Betula papyrifera*) twigs. Exceptional contents of Ba and Sr are documented from tissues of the black spruce, alder and birch. Chest height black spruce tissues have the range 2050 - 4300 ppm for Ba and 5100 - 6400 ppm for Sr. Alder twigs contain both the highest Ba (6900 ppm) and Sr (1.2%) measured in the orientation survey. The source for Ba and Sr, as well as the LREE, is twofold. McRitchie (1989) determined the range 1300 - 3300 ppm Ba and 1400 - 2200 ppm Sr in rock samples from the Eden Lake syenite. These analyses are confirmed by those of Halden and Fryer (in prep.), who quote some Eden Lake syenite analyses in the range 1089 - 4736 ppm Ba and 1057 - 3820 ppm Sr. Accordingly, the aegirine-augite syenite and the thin soil veneer developed upon this bedrock represents one source of the Ba and Sr in the vegetation. A second source for Ba and Sr may be the allanite-britholite mineralization, although analyses of constituent minerals in the allanite-britholite zone are not yet available.

U and Th contents for the Eden Lake syenite are in the range 690 - 1400 ppm and 775 - 3500 ppm, respectively (McRitchie, 1989). Young and McRitchie (1989) document 3.28% ThO_2 in britholite from Eden Lake. Despite this high background level for U and Th, all tissues sampled at the orientation site, with the exception of lichen and jack pine outer bark, are below 1 ppm for both Th and U (Table GS-2-1). Lichen contains 8.1 and 4.5 ppm Th and U, respectively, whereas jack pine outer bark contains 4.5 ppm Th and 2.4 ppm U. Alder twigs, although conspicuous by their LREE contents, do not contain measurable Th or U (<0.1 ppm Th and <0.2 ppm U).

Black spruce and jack pine cones, collected as part of the geochemical partitioning study, contain the highest Cs (black spruce = 22 ppm, jack pine = 19 ppm) of all tissues. Alder leaves (17 ppm Cs) and lichen (14 ppm) have comparable concentrations of this element.

CONCLUSIONS

The most significant of the tissues sampled for the orientation program can be ranked in terms of highest LREE contents as follows:

Alder Twigs (740 ppm)
Lichen (396 ppm)
Alder Leaves (279 ppm)
Jack Pine Outer Bark (156 ppm)
Birch Twigs (136 ppm)
Birch Leaves (61 ppm)
Black Spruce Twigs (40 ppm)

This tissue ranking based upon LREE acquisition and storage provides guidelines for future sampling programs utilizing vegetation tissue in the search for vein type LREE mineralization at Eden Lake. Geochemical sampling on a regional or local scale should utilize alder twigs or jack pine outer bark. Although lichen contains the second highest LREE contents of all tissues sampled, the actual collection of a single lichen sample was time consuming at 37 minutes. Additionally, inorganic mineral particulate from the growth substrate acquired during sample collection could easily contaminate this tissue type.

ONGOING STUDIES

The occurrence of the allanite-britholite mineralization on an easterly sloping outcrop ridge suggests the possibility that drainage of meteoric water through the mineralized zone may give rise to a leakage type anomaly in down-slope vegetation tissues. To test this hypothesis vegetation samples were collected up to 200 m from the outcrop-overburden interface. Guided by the results of the orientation survey, alder twigs were collected from 57 sites (Fig. GS-2-2), dried, the leaves were removed, and the sample was forwarded for analysis to Activation Laboratories Ltd. (Ancaster). Results are unavailable at the time of writing.

These data will form the basis of a final report describing the vegetation geochemical signature of the allanite-britholite mineralized zone.

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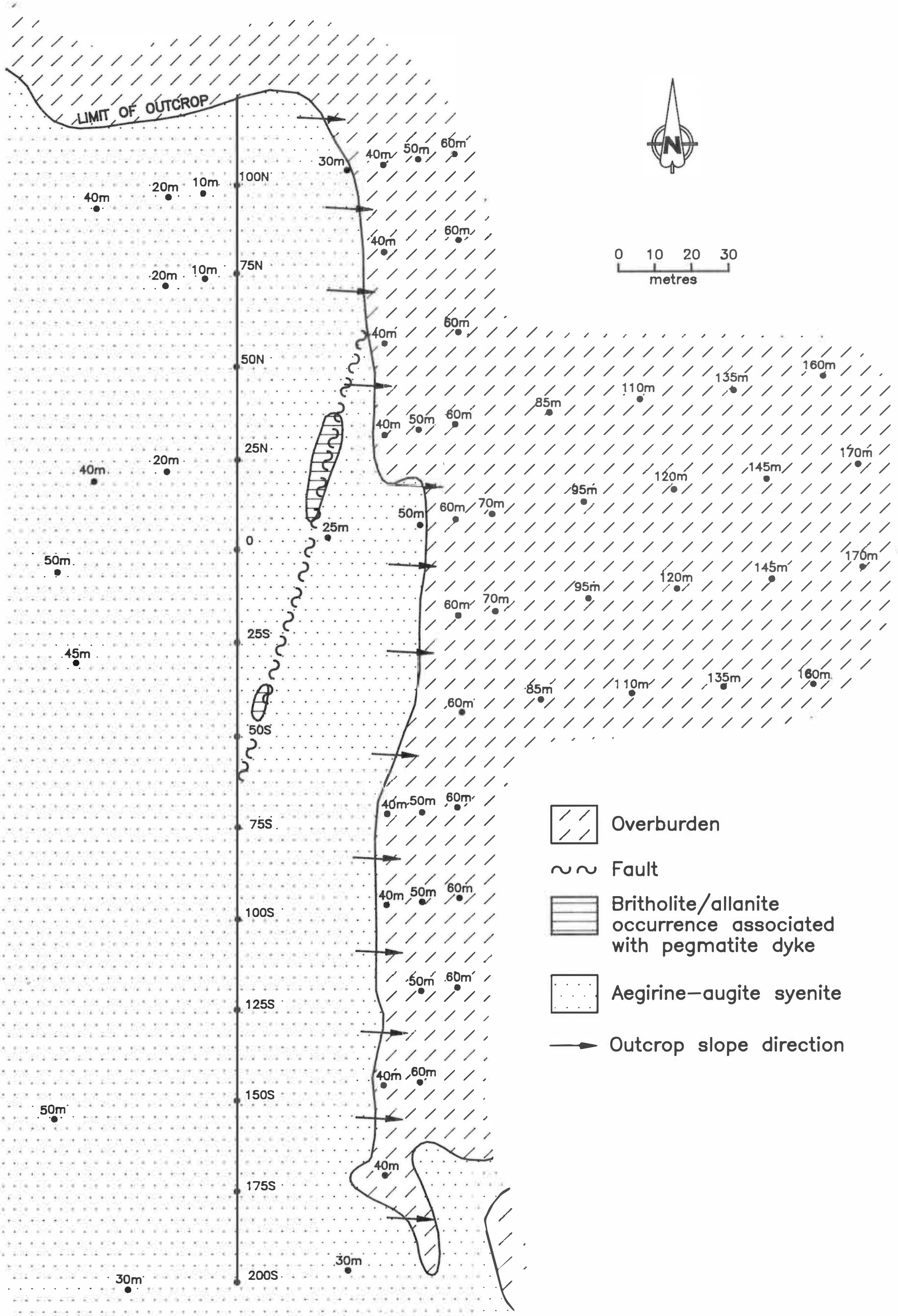

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Figure GS-2-2: Location of alder twig samples collected at the allanite-britholite occurrence, Eden Lake area, 1994.

Table GS-2-1

Summary of neutron activation analyses for ashed (470° C) tissues collected adjacent to the allanite and britholite mineralized survey site, Eden Lake area. Analyses in ppm unless otherwise indicated. For the purposes of this study the values for rare earth elements recorded as below the limits of determination (<) have been utilized for the calculation of total REE.

Species/Tissues	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	∑REE	Ba	Sr	Sc	Th	U	Zn	Ash (%)
Black Spruce																
(Picea mariana)																
Outer Bark	7	13	6	0.9	0.2	<0.5	0.4	0.06	28.5	3950	5100	1.4	0.9	0.4	1800	2.59
Inner Bark	3	5	<5	0.2	<0.02	<0.5	<0.05	<0.05	13.9	4300	5800	<0.1	<0.1	<0.1	2500	3.18
Twigs	12	22	6	1.5	0.4	<0.5	0.7	0.12	57.2	3800	5800	2.3	1.4	1.2	3100	2.08
Trunk wood	6	8	<5	0.2	<0.02	<0.5	<0.05	<0.05	19.3	3800	6400	0.1	<0.1	<0.1	3100	0.36
Needles	2	3	<5	0.2	<0.01	<0.5	<0.05	<0.05	10.8	2050	6050	0.2	<0.1	<0.1	2250	5.27
Black Spruce																
(Picea mariana)																
Crown																
Cones	1	<3	<5	0.2	<0.03	<0.5	<0.05	<0.05	9.9	330	780	0.4	<0.1	<0.1	1800	0.62
Twigs	3	6	<5	0.3	<0.03	<0.5	<0.05	<0.05	14.6	5700	7100	0.5	0.2	<0.1	2200	1.95
Needles	1	<3	<5	0.2	<0.02	<0.5	0.1	<0.05	10.2	920	3300	0.3	<0.1	<0.1	1200	2.44
Jack Pine																
(Pinus banksiana)																
Outer Bark	33	74	49	5.6	1.3	0.6	1.2	0.19	165.0	950	1600	3.5	4.5	2.4	4200	1.61
Inner Bark	3	7	<5	0.5	<0.02	<0.5	<0.05	<0.05	16.2	640	1600	0.1	<0.1	<0.1	3900	2.36
Twigs	2	5	<5	0.3	<0.02	<0.5	0.2	<0.05	13.0	120	1000	0.3	0.2	0.5	3500	1.66
Trunk wood	9	11	<5	0.2	<0.01	<0.5	<0.05	<0.05	25.6	640	2100	0.1	<0.1	<0.1	6200	0.30
Cones	1	<3	<5	0.2	<0.03	<0.5	<0.05	<0.05	9.8	<50	<300	0.2	0.1	<0.1	2200	0.42
Needles	2	5	<5	0.3	<0.02	<0.5	0.2	<0.05	13.0	120	1000	0.3	0.2	0.5	3500	2.17
Alder																
(Alnus crispa)																
Twigs	270	320	150	13	3.3	1.1	<0.05	<0.05	757.5	6900	12000	0.3	<0.1	<0.2	5100	1.51
Leaves	93	120	66	5.4	1.2	<0.5	<0.05	<0.05	286.2	1300	4700	<0.1	1.0	1.0	1500	3.84
Birch																
(Betula papyrifera)																
Twigs	45	61	30	3.2	0.8	<0.5	<0.05	<0.05	140.6	5700	7100	0.5	<0.1	<0.1	20000	1.09
Leaves	16	26	19	1.6	0.4	<0.5	<0.05	<0.05	63.6	1400	2400	0.1	0.4	<0.1	6000	3.23
Lichen																
(Cladonia spp.)	86	190	120	13	3	0.9	2.1	0.31	415.3	1000	1500	6.0	8.1	4.5	2700	1.08

Species/Tissues	Au (ppb)	As	Br	Ca (%)	Co	Cr	Cs	Fe (%)	Hf	K (%)	Mo	Na	Ni	Rb	Sb
Black Spruce															
(Picea mariana)															
Outer Bark	6	3	14	34.5	5	9	1.6	0.48	1.5	1.9	2	1750	<50	56	0.8
Inner Bark	<5	<0.5	24	30.0	4	<1	2.6	0.06	<0.5	11.2	<2	401	<50	200	0.1
Twigs	18	5.7	27	23.8	7	16	4.4	0.84	1.7	10.9	<2	2550	<50	170	0.7
Trunk wood	<5	4.2	190	33.9	8	50	2.7	0.07	<0.5	7.4	<2	296	<50	220	0.5
Needles	<5	<0.5	38	29.9	2	3	1.2	0.06	<0.5	5.6	<2	145	<50	70	0.1
Black Spruce															
(Picea mariana)															
Crown															
Cones	<5	2.7	36	4.0	10	5	22	0.23	<0.5	24.7	<2	758	160	940	0.6
Twigs	16	2.6	23	21.5	17	8	1.9	0.23	<0.5	22.3	<2	746	<50	320	0.5
Needles	<5	2.8	48	20.9	2	6	8.2	0.12	<0.5	14.4	<2	347	64	320	0.3
Jack Pine															
(Pinus banksiana)															
Outer Bark	17	6.1	11	24.2	8	23	4.0	1.16	2.1	4.0	<2	4530	190	66	1.5
Inner Bark	13	<0.5	46	24.6	3	<1	4.2	0.07	<0.5	18.5	<2	2600	<50	230	0.4
Twigs	5	2.2	55	15.2	5	3	2.1	0.16	<0.5	18.9	<2	377	<50	180	0.3
Trunk wood	6	<0.5	32	27.1	4	3	3.9	0.05	<0.5	13.3	<2	304	<50	220	0.3
Cones	<5	1.9	51	2.0	6	<1	19.0	0.24	<0.5	21.4	<2	261	120	780	0.6
Needles	5	2.2	55	15.2	5	3	2.1	0.16	<0.5	18.9	<2	377	<50	180	0.3
Alder															
(Alnus crispa)															
Twigs	9	1.5	12	26.1	10	3	7.0	0.15	<0.5	14.3	6	492	<50	310	0.4
Leaves	<5	<0.5	30	17.2	9	4	17	0.20	<0.5	25.1	<2	253	<50	1000	0.4
Birch															
(Betula papyrifera)															
Twigs	16	2.6	23	21.5	17	8	1.9	0.23	<0.5	22.3	<2	746	<50	320	0.5
Leaves	<5	<0.5	21	15.4	8	<1	3.2	0.13	<0.5	28.9	<2	184	80	530	<0.1
Lichen															
(Cladonia spp.)	22	12	130	7.0	13	51	14	1.67	4.2	20.6	5	7310	<50	500	1.6

GS-3 GEOLOGICAL INVESTIGATIONS IN THE LYNN LAKE GREENSTONE BELT AND THE KISSEYNEW GNEISS BELT (PARTS OF NTS 63O/14, 64C/11, 64C/14 AND 64C/16)*

by D.C. Peck, P. Theyer and E.W. Kowalyk

Peck, D.C., Theyer, P. and Kowalyk, E.W., 1994: Geological investigations in the Lynn Lake greenstone belt and the Kisseynew gneiss belt (parts of NTS 63O/14, 64C/11, 64C/14 and 64C/16); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 16-24.

SUMMARY

Several known mineral occurrences in the Lynn Lake greenstone belt and the Kisseynew metasedimentary gneiss belt were re-examined in areas affected by recent forest fires. Field investigations, discussions with explorationists, and new geochemical data obtained during the current study suggest that additional detailed mapping and exploration is warranted: (1) at several areas of new exposure along the Johnson Shear Zone - a major zone of brittle and ductile deformation along the southern margin of the Lynn Lake greenstone belt that hosts several low-grade gold deposits; (2) at new and improved bedrock exposures within areas containing known base-metal sulphide occurrences (TOR Group) and gold mineralization (Farley deposit) hosted by the northern belt of the Wasekwan Group metavolcanic sequence, in the vicinity of Barrington Lake; (3) at the Kadeniuk Lake copper occurrence, hosted by Sickle Group arkosic gneiss and migmatite from the northern part of the Kisseynew metasedimentary gneiss belt; and (4) at a graphitic and locally Zn-enriched solid sulphide occurrence hosted by Burntwood River Suite metasedimentary gneisses from the Notigi Dam area, approximately 100 km southeast of the town of Leaf Rapids. Of the four areas identified for future detailed mapping and mineral exploration activities, the Johnson Shear Zone appears to hold the greatest potential for the discovery of new economic mineral deposits.

INTRODUCTION

Approximately two weeks were spent examining mineral occurrences and recently burned areas in the Lynn Lake and Notigi Dam areas of northwestern Manitoba. The purpose of these investigations was to identify areas that may require additional geological investigation, either because they harbor new exposures of bedrock caused by recent forest fires, or because additional mapping of mineral occurrences in these locations could aid in identifying mineral exploration targets.

Most of the occurrences examined are proximal to the town of Lynn Lake (Fig. GS-3-1). One day was spent examining a known occurrence of graphitic solid pyrrhotite that is located in a quarry immediately southwest of Notigi Dam, approximately 100 km to the south and east of Leaf Rapids (Fig. GS-3-1). In addition, two days were utilized to conduct bedrock sampling of selected rock units within the Lynn Lake greenstone belt for U/Pb (zircon) age dating (analyses to be carried out by Dr. N. Machado, Université du Québec à Montréal).

INVESTIGATION OF RECENTLY BURNED AREAS IN THE LYNN LAKE REGION

Forest fires ignited during June of 1993 caused extensive burns in the vicinity of Barrington Lake (NTS 64C/16), in the northwestern part of the Lynn Lake belt, and within the Franklin Lake - Finch Lake region (NTS 64C/11, 14) in the south-central part of the belt. Both areas have been mapped at a scale of 1:50 000 (Gilbert *et al.*, 1980; Gilbert, 1993). Time restrictions permitted only a brief examination of the burned areas. Consequently, an emphasis was placed on surveying areas known to contain precious or base metals.

Barrington Lake Area

In the Barrington Lake region, fires burned extensive areas underlain by Wasekwan Group metavolcanic rocks belonging to the northern Lynn Lake greenstone belt (Gilbert *et al.*, 1980). The surveyed parts of the burn areas (areas B1 and B2, Fig. GS-3-2) occur to the east (B1) and west (B2) of Barrington Lake and extend several kilometres inland. Fires on the eastern side of Barrington Lake produced very little new exposure, although immediately adjacent to the southeastern shoreline, most of the foliage and lichen cover has been burned off a well exposed section of the Wasekwan Group that has been previously explored for copper (TOR2 and Caribou claims, Location 21 in Ferreira, 1994). This segment of the Lynn Lake greenstone belt lies several hundred metres north of the main cluster of INPUT anomalies associated with the Agassiz Metallotect (Fedikow *et al.*, 1989) in the Barrington Lake area. The geology of the area is described in detail by Gilbert (1993). However, remapping of this specific area at a scale of 1:1000 is recommended. Further inland from the eastern shoreline of Barrington Lake, only two new outcrops were found, and both consisted of medium- to coarse-grained, massive to foliated biotite granodiorite and tonalite that are probably part of the pre- and post-Sickle granitoid suites that are recognized in the area (Gilbert, 1993).

Fires on the west side of Barrington Lake caused extensive destruction of foliage along the trend of the Agassiz Metallotect, extending westward from Barrington Lake to the Farley Lake gold deposit (Granduc Mining Corporation) (Fig. GS-3-2). The area was surveyed from the air and several better exposed and new outcrops are visible.

Johnson Shear Zone

A fire ignited during 1993 caused extensive deforestation along a south-trending zone extending from the western shoreline of Franklin Lake to Finch Lake (NTS 64C/11). Part of one day was spent conducting both aerial and ground surveys of part of the burned area in the vicinity of Franklin Lake (area JS-2, Fig. GS-3-2), where it was believed that new exposures of the regionally extensive Johnson Shear Zone (Fedikow *et al.*, 1991) would be present.

The burned area immediately to the west and south of Franklin Lake represents a highly promising gold and base metal target that is under explored (Paul Pawliw, pers. comm., Granduc Mining Corporation, August, 1994). It is strongly recommended that a major, detailed study of the geology, petrology, structure and geophysics of this area be undertaken, based on discussions held with Granduc Mining Corporation personnel and government geologists, a review of some of the existing geological, geophysical and geochemical data (see Gilbert *et al.*, 1980; Syme, 1985; Fedikow *et al.*, 1991), and given the extent of the burn.

A series of traverses through part of the burn revealed many new structural features, sulphide occurrences and lithologic types within an approximately 2 x 2 km area adjoining the western shoreline of Franklin Lake. The Johnson Shear Zone appears to be tightly folded in this area on a kilometre scale, and the north-south extent of rocks affected by this structure is at least four times wider than shown by Gilbert *et al.* (1980). Immediately north of the west end of Franklin Lake, the authors recognized several new or significantly improved bedrock exposures of the Wasekwan Group. The varied Wasekwan Group lithologic types observed from this area include olivine-bearing basaltic flows, turbidite, banded iron formation, pillow basalt, felsic flows, mafic to felsic lapilli tuff and pyroclastic breccia, many of which were not previously identified in this area. Abundant fine grained pyrite mineralization and locally extensive silicification were observed in both Wasekwan Group units and younger(?) mafic and felsic plutonic rocks throughout the area affected by the Johnson Shear Zone. Numerous minor folds were observed in mylonitized Wasekwan Group rocks in this area (Fig. GS-3-3).

A previously unrecognized layered gabbroic (leucogabbro, gabbro and melanogabbro) intrusion that has a minimum thickness of 250 m and a presently undetermined strike length occurs 750 m southwest of Franklin Lake. If this intrusion extends to the west, it may represent part of a 200 m wide x 2200 m long gabbro-pyroxenite intrusion that crops out immediately to the north of Mail Lake (Gilbert *et al.*, 1980, Map GP80-1-4). Sherritt Gordon Mines Ltd. conducted limited diamond drilling immediately east of the gabbro-pyroxenite intrusion located at Mail

* Funded by Provincial A-Base

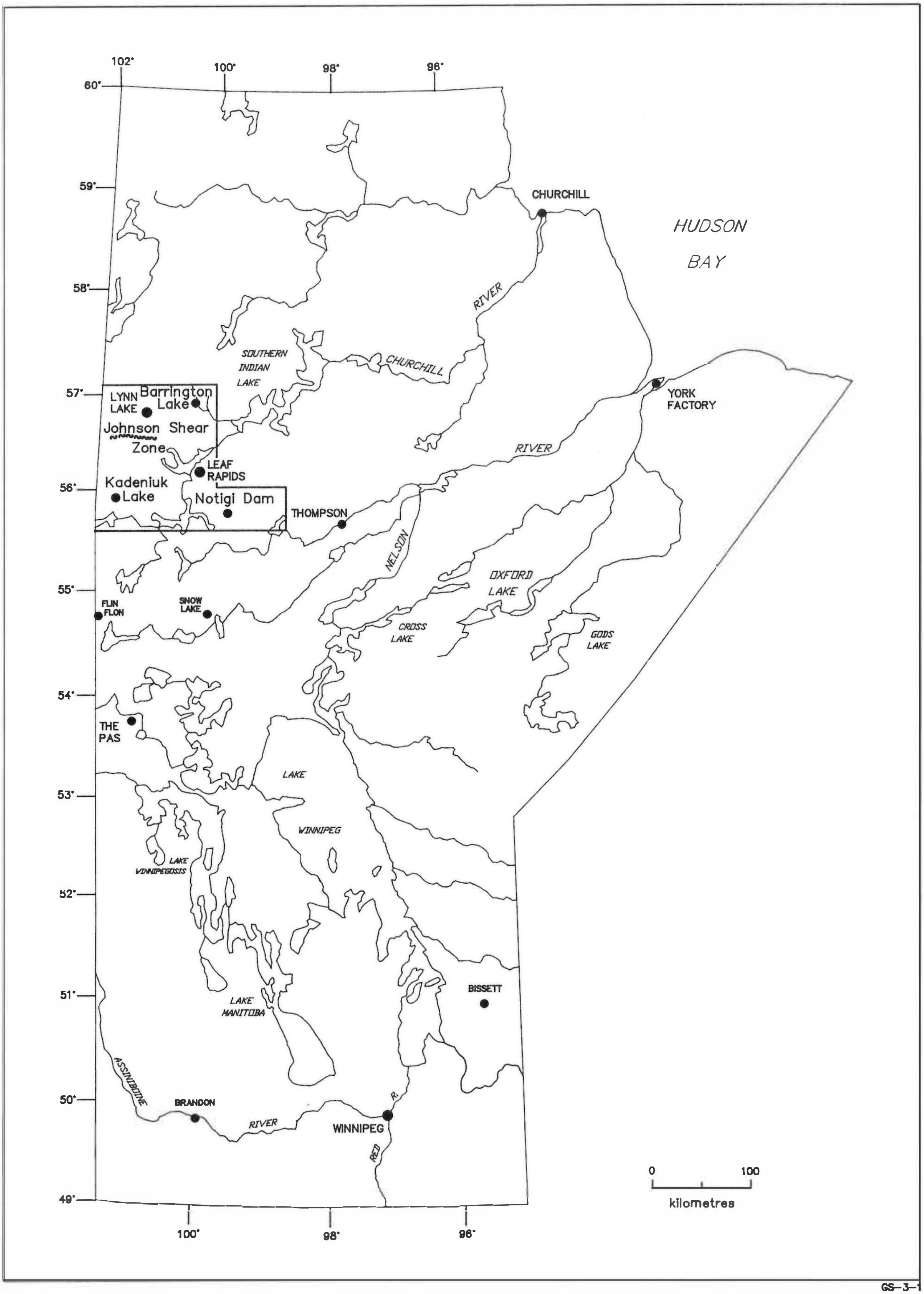

Figure GS-3-1: *Location of areas investigated during the current project.*

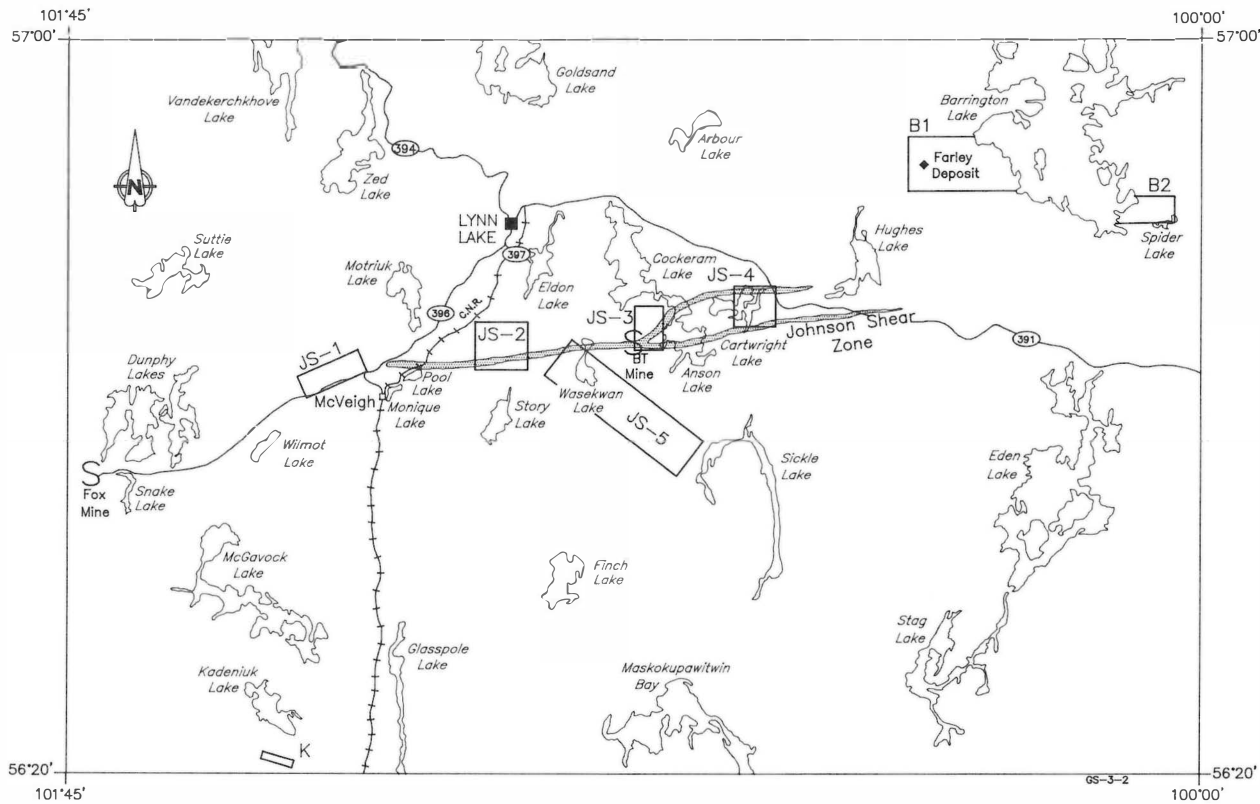

Figure GS-3-2: Location of proposed sites for detailed geological investigations within the Lynn Lake region. Sites JS-1 to JS-5 occupy areas affected by the Johnson Shear Zone. Sites B1 and B2 occur within the northern belt of the Wasekwan Group, within or adjacent to the Agassiz Metallotect (Fedikow et al., 1989).

Lake, and intersected minor sulphide mineralization and a minor amount of massive magnetite in altered diorite (Location 10, Ferreira, 1993). Minor amounts of erratically distributed blebby and variably remobilized disseminated pyrrhotite + chalcopyrite + pyrite mineralization occurs within the previously unrecognized layered gabbroic intrusion. One mineralized sample with several percent pyrrhotite, collected for whole-rock geochemical analysis (sample 98-94-410-1; analyses conducted by ACTLABS, Ancaster, Ontario), contains less than 5 ppb of Au, Pt and Pd, and <120 ppm of Cu.

Immediately west of Anson Lake, the Johnson Shear Zone bifurcates into two subparallel shear zones that extend eastward to Cartwright Lake (Gilbert *et al.*, 1980). The southern splay is known to be spatially associated with gold mineralization at Cartwright Lake (Peck, 1986). Immediately west of the hinge area of this splay in the Johnson Shear Zone lies the Burnt Timber gold deposit (Granduc Mining Corporation). Area JS-3 (Fig. GS-3-2) was investigated for part of one day with Paul Pawliw (Keystone Gold Project, Granduc Mining Corp.). Recent (post-1986) forest fires have resulted in improved exposures of bedrock in this generally low-lying, bog- and drift-covered area. Two relatively small northeast-trending outcrop ridges of Wasekwan Group mafic metavolcanic and associated mafic to intermediate clastic and volcaniclastic metasedimentary rocks represent new exposures of bedrock in the area affected by fires. Both ridges are readily accessible by road and a short traverse (*ca.* 1 km) from the Burnt Timber open pit. Well developed volcanic features were observed in basaltic flows in these areas, including pillowed flows, amygdaloidal flows (Fig. GS-3-4), flow-top breccia, and interflow mudstone. Sedimentary rocks locally contain up to 5% disseminated magnetite. The sedimentary units are generally thinly bedded; locally display crossbedding, scour structures and lateral thinning/thickening; and range in composition from mudstone to greywacke to arkosic wacke. Both pillowed flow tops and cross-beds indicate a northwest facing direction for the metavolcanic-metasedimentary package. A penetrative foliation (approximately 030°) parallels flow contacts. A spaced cleavage and asymmetric minor folds are also locally developed. Some of the less well layered rock types are mafic to intermediate tuff or reworked equivalents of pyroclastic deposits.

Despite their apparent proximity to the north splay of the Johnson Shear Zone, no recognizable shear zone is exposed in these outcrops. However, weak to moderate development of quartz veins, silicification, boudinage and shear fabrics are locally observed. Traces of disseminated pyrrhotite + chalcopyrite mineralization are present in a gabbro sill within a sequence of pillowed basalt flows and local iron oxide stains are rare within late quartz veins and some of the sedimentary units. The geology of the two outcrop areas is probably correlative with the base of the Wasekwan Group, as developed in the Cartwright Lake (Peck and Smith, 1989) and Cockeram Lake areas (Gilbert *et al.*, 1980).

Area JS-3 is an ideal location for detailed (1:500) mapping and related lithogeochemical, structural and sedimentological studies of potentially Au-bearing Wasekwan Group rocks. Such a project could be completed in one to three weeks, depending on the amount of detailed information sought. The area occupies a structurally enigmatic section of the Johnson Shear Zone between two significant gold deposits (Burnt Timber and Bonanza deposits, see Fedikow *et al.*, 1991), and will provide significant additional information about the tectonic setting and geochemical characteristics of the southern part of the Lynn Lake greenstone belt.

A third area underlain by the Johnson Shear Zone that was affected by a recent forest fire is located west of Gemmell Lake (area JS-1, Fig. GS-3-2). A very complex mafic-intermediate-felsic Wasekwan Group stratigraphy that is locally intruded by a sill-like gabbro-pyroxenite pluton (Gilbert *et al.*, 1980, Map GP80-1-4) is newly exposed.

Two additional areas were identified where detailed geological investigations of sheared and potentially gold-bearing Wasekwan Group rocks are warranted, based on brief site visits and/or discussions with Granduc Mining Corporation staff. These include a north-trending belt of Wasekwan Group strata that occurs immediately south of Wasekwan Lake (area JS-5, Fig. GS-3-2) (the Miskwa Lake belt; Gilbert *et al.*, 1980) and a segment of weakly sheared Wasekwan Group strata at Cartwright

Figure GS-3-3: *Asymmetric minor folding in mylonitized Wasekwan Group rocks occurring within the Johnson Shear Zone, immediately to the west of Franklin Lake, Lynn Lake greenstone belt.*

Figure GS-3-4: *Amygdaloidal basalt from new exposures of Wasekwan Group rocks located approximately 2 km west of Anson Lake, Lynn Lake greenstone belt.*

Lake (area JS-4, Fig. GS-3-2). In the latter area, a locally auriferous and Zn-rich iron formation occurs (Peck, 1986). In addition, the variably fractured and locally pyritic rhyolite flow that crops out at several locations along the east side of Cartwright Lake (Peck and Smith, 1989) and immediately north of the Bonanza Au Deposit (Fedikow *et al.*, 1991) should be re-examined in order to better characterize its potential for VMS and epigenetic Au deposits. This rhyolite unit was the focus of a limited amount of exploration work by Sherritt Gordon Mines Ltd. in 1984. However, the rhyolite probably deserves additional attention, given that: (1) a petrologically and structurally similar and possibly coeval granitic sill hosts the proximal Bonanza Deposit (Peck, 1986); (2) the rhyolite is probably part of the relatively large rhyolite body that occurs in the Pole Lake area east of Cartwright Lake (Gilbert *et al.*, 1980); and (3) VMS-type mineralization is currently being explored for in petrologically similar and potentially coeval felsic volcanic units in the western part of the Lynn Lake greenstone belt (Snake Lake dacite, Gilbert *et al.*, 1980).

The Johnson Shear Zone hosts or is spatially associated with several gold deposits (Fedikow *et al.*, 1991), including one currently operating gold mine (Burnt Timber deposit). Areas JS-1 to JS-5 (Fig. GS-3-2) represent suitable (but not the only) locations where detailed geological mapping (1:5000 scale or greater) and related structural and geochemical studies could aid in better characterizing the metallogenic evolution of this structure and in identifying new exploration targets. A coordinated, multi-disciplinary re-examination of the Johnson Shear Zone is now a justifiable proposition, owing to the wealth of new exposures and to several economic factors, including improving gold prices and renewed interest in gold mining in the Lynn Lake area. It remains to be proven whether any world-class gold deposits are developed within or adjacent to the Johnson Shear Zone, and whether or not this structure evolved in a similar manner to large, belt-bounding structures like those associated with the major gold camps in the Abitibi Subprovince of Ontario and Quebec (*e.g.*, Colvine *et al.*, 1988).

INVESTIGATION OF SELECTED MINERAL OCCURRENCES IN THE KISSEYNEW METASEDIMENTARY GNEISS BELT

Kadeniuk Lake Copper Occurrence

Sediment-hosted, stratabound copper mineralization developed within arkosic gneiss belonging to the Sickle Metamorphic Suite (Gilbert *et al.*, 1980) has been explored periodically over the past 20 years. The copper mineralization is located along a southeast-trending outcrop ridge approximately 1.5 km southwest of the southern end of Kadeniuk Lake (see area K, Fig. GS-3-2 and NTS Map 64C/6). Access is by float plane to a small lake immediately southwest of the occurrence, and from there by traverse along a well blazed trail that terminates at a series of trenches. Baldwin (1976) describes the mineralization as being disseminated, conformable, stratabound and syn-sedimentary, and composed of a variety of copper and iron sulphides and minor native copper. The mineralization is hosted by arkose-derived migmatite and gneiss belonging to the base of the Sickle Group. The mineralization is well exposed in a series of trenches that were excavated in 1976. Three diamond drill holes partially intersected the mineralized arkosic migmatite, but none reached the base of the mineralized zone (Baldwin, 1976).

The Kadeniuk Lake copper occurrence was re-examined during the 1994 field season in order to determine whether additional detailed mapping and mineralogical/geochemical studies of the property are warranted. Results from a one day investigation of the mineralized arkosic migmatite concur with the descriptions of the copper mineralization given by Baldwin (1976). Four Cu-rich grab samples from sulphide-bearing arkosic gneiss, one grab sample of pyrite-rich arkosic gneiss, and one grab sample of unmineralized arkosic gneiss were analysed for a range of elements (Table GS-3-1; analyses conducted by ACTLABS, Ancaster, Ontario). The Cu-rich samples contain up to 10% chalcopyrite and up to 2.65% Cu, 315 ppb Au and 13.1 ppm Ag. The mineralized samples display no significant enrichment in either base or precious metals relative to the unmineralized sample (sample 98-94-406-1C, Table GS-3-1). The mineralized samples are depleted in Al and Na and enriched in Ba, Cd, Fe, K and Th relative to the unmineralized sample (Table GS-3-1). The average abundance of selected metals in the Cu-rich samples are plotted against their abundances in both the pyritic and unmineralized sample (Figs. GS-3-5, -6). The plots illustrate the strong enrichment in Cu and K in the mineralized samples (Fig. GS-3-5), and a preferential enrichment in Au, Ag and Cd in the Cu-rich samples relative to the pyrite-rich sample (Fig. GS-3-6).

The Kadeniuk Lake occurrence is a rare example of stratabound, sediment-hosted copper mineralization within the Sickle Group. Given that the geological environment for the mineralization is by no means unique within this part of the Kisseynew metasedimentary gneiss belt, a three week detailed mapping (1:1000 scale or greater) and lithogeochemical sampling program is suggested.

Massive Sulphide Mineralization - Notigi Dam Area

A graphitic solid pyrrhotite body is exposed in a road ballast quarry located on the south side of Provincial Road 391, approximately 5 km southwest of the Notigi Dam control structure. This occurrence has been the target of very limited exploration (D. Baldwin, pers. comm., August, 1994). The sulphide body appears to be the source of a linear INPUT anomaly (assessment file 91676, NTS 64O/14). The occurrence is hosted by Burntwood River Suite arkosic gneiss and derived migmatite that are well exposed along road cuts between the dam and the solid sulphide body. The arkose is rich in garnet and locally contains pinitized cordierite and <1% graphite. Where migmatized, the gneiss contain up to 30%, massive, coarse grained plagioclase-rich pegmatites. The sulphide body is up to 3 m thick and has been folded. The solid sulphide mineralization is predominantly composed of medium grained pyrrhotite (70 to 90%), medium grained, disseminated graphite (10 to 15%) and biotite-bearing quartzofeldspathic gangue (5 to 15%). The sulphide body locally contains minor disseminated sphalerite, chalcopyrite and pyrite. Stringer quartz veins, which commonly carry several percent pyrite and/or pyrrhotite in addition to coarse grained biotite, are locally present in close proximity to the solid sulphide band. Disseminated pyrrhotite and/or pyrite occurs in many outcrops along the road between the quarry and Notigi Dam. In addition, sulphide facies iron formation crops out immediately east of the dam.

Several samples were collected from the quarry in order to determine the mineralogy and geochemistry of the solid sulphide mineralization and its host rocks. Along the south face of the quarry, grab samples of the solid sulphide body (samples 98-94-200-1A and 200-1B, Table GS-3-2) were obtained from the main exposure. One sample of unmineralized arkosic migmatite (sample 98-94-200-2, Table GS-3-2) was also collected from this location. In addition, continuous chip samples were collected at 20 cm wide (vertical) sample intervals across a relatively narrow (<1.5 m wide) exposure of solid to disseminated sulphide mineralization along the northwestern face of the quarry (samples 98-94-200-3A to 3I). The top of the sampled section (sample 98-94-200-3A) represents the uppermost part of the solid sulphide mineralization. The base of the sampled section (98-94-200-3I) represents a disseminated sulphide-bearing arkosic migmatite unit that immediately underlies the solid sulphide band. The contact between the solid and disseminated mineralization is abrupt.

The samples were analysed for a range of elements in order to characterize the geochemistry of the solid sulphide body in relation to the unmineralized hosts rocks (see Table GS-3-2). The solid sulphide mineralization is enriched in Ni, Cu, Cd, U and Ag relative to both the

Table GS-3-1
Geochemical data for surface grab samples from the Kadeniuk Lake Cu occurrence

Analyte	Sample Number TYPE Units	D.L.	98-94-406-1A CPY	98-94-406-1B CPY	98-94-406-1C UM	98-94-406-1D CPY	98-94-406-1E PY	98-94-406-1F CPY
Al	%	0.01	4.72	4.6	6.22	4.52	4.49	4.38
Ag	ppm	0.4	9.8	10.4	<0.4	13.1	2.3	7.5
Au	ppb	2	264	275	3	315	50	196
Ba	ppm	50	1400	1600	710	1600	1800	1800
Cd	ppm	0.5	3.8	3.5	<0.5	4.8	1.7	3.9
Cr	ppm	5	74	62	58	58	55	57
Cu	%	<0.01	2.42	2.27	<0.01	2.65	0.49	1.85
Fe	%	0.01	3.36	2.92	2.59	2.84	2.58	2.89
K	%	0.01	2.73	2.82	2.10	2.50	0.77	2.72
Mn	ppm	1	310	313	400	311	660	314
Na	%	0.01	1.48	1.35	2.73	1.37	1.33	1.26
Ni	ppm	1	22	21	25	18	27	20
Pb	ppm	2	21	24	7	19	27	16
Rb	ppm	5	54	55	42	77	33	78
Sr	ppm	1	270	276	246	263	740	298
Ti	%	0.01	0.26	0.23	0.29	0.19	0.17	0.2
Th	ppm	0.2	11.0	9.1	4.7	7.9	8.8	9.1
U	ppm	0.5	2.5	1.3	2.5	2.1	5.1	1.9
V	ppm	2	39	40	49	31	29	36
Zn	ppm	1	66	60	80	82	72	61

(Abbreviations: CPY - chalcopyrite-rich sample; PY - pyrite-rich sample; UM - unmineralized sample; D.L. - detection limit)

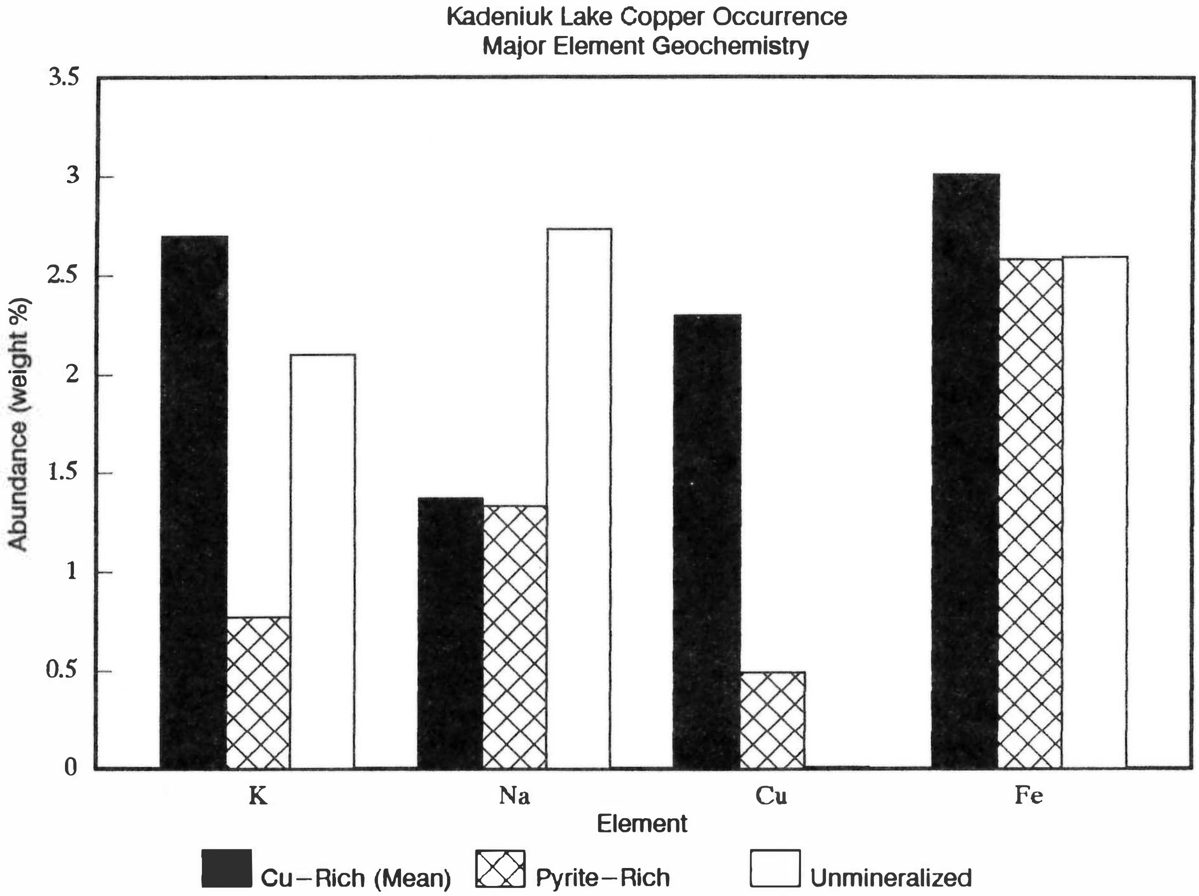

Figure GS-3-5: *Plot of selected whole-rock major element abundances in four grab samples of copper-rich disseminated sulphide mineralization, one pyrite-rich sample and an unmineralized arkosic gneiss. Samples are from the Kadeniuk Lake copper occurrence. See Table GS-3-1 for additional details.*

disseminated sulphide mineralization and the barren host rock (Table GS-3-2). None of the mineralized samples display significant Au enrichment. A geochemical profile, based on these chip samples, illustrates a systematic variation in metal abundances across the sampled interval (Fig. GS-3-7). The most Fe- and S-enriched part of the profile occurs near the top of the sampled interval (sample 98-94-200-3B, Table GS-3-2), but the most Zn-enriched sample (0.74% Zn) occurs at the base of the solid sulphide interval (sample 98-94-200-3E, Table GS-3-2, Fig. GS-3-7). The Zn enrichment is accompanied by a sympathetic enrichment in V, Cu and Cd (Fig. GS-3-7, Table GS-3-2). Maximum U and V abundances occur immediately above the Zn peak, and the maximum Mn abundance occurs in the upper part of the disseminated sulphide zone (Fig. GS-3-7, Table GS-3-2).

The geochemical data suggest that the Notigi Dam solid sulphide body and similar solid pyrrhotite bodies within this part of the Kisseynew belt should be (re)investigated as potential hosts to economic Zn-Cu mineralization. The limited field studies undertaken during the current study indicate a probable sedimentary exhalative environment, in which vertically zoned disseminated to solid sulphides developed within graphitic arkosic sediments. There appear to be numerous similar linear INPUT anomalies in this region (Assessment File 91676, *op. cit.*), and although several of these may relate to pyritic and graphitic sulphide mineralization (Elphick, 1972), some may also represent solid sulphide occurrences. The fact that both Zn and Cu are locally enriched within the Notigi Dam occurrence suggests that metal-rich fluids locally infiltrated the arkosic sediments. The low K and Na in the disseminated sulphide mineralization relative to the barren arkose (Table GS-3-2) suggests that alkali depletion was involved in the development of the sulphides. The role of carbon in controlling precipitation of base metal sulphides and other metals (*e.g.*, U, Cd, Ag) should be examined.

ACKNOWLEDGMENTS

Mr. P. Pawliw and Mr. P.J. Chornoby provided invaluable suggestions concerning specific aspects of the geology of the Lynn Lake region. INCO E.T.S. contributed digitized topographic base maps and technical information for the Lynn Lake area. Mr. G. Rogers brought the Notigi Dam occurrence to our attention. Mr. J.M. Pacey is thanked for preparation of the figures. Mr. H.D.M. Cameron provided expert advice on the Burntwood River suite gneisses. Dr. D.A. Baldwin, Mrs. K. Ferreira, Dr. M.A.F. Fedikow, Mr. H.P. Gilbert and Mr. E. Syme supplied essential technical information and advice pertaining to the geology and mineral deposits of the Lynn Lake greenstone belt.

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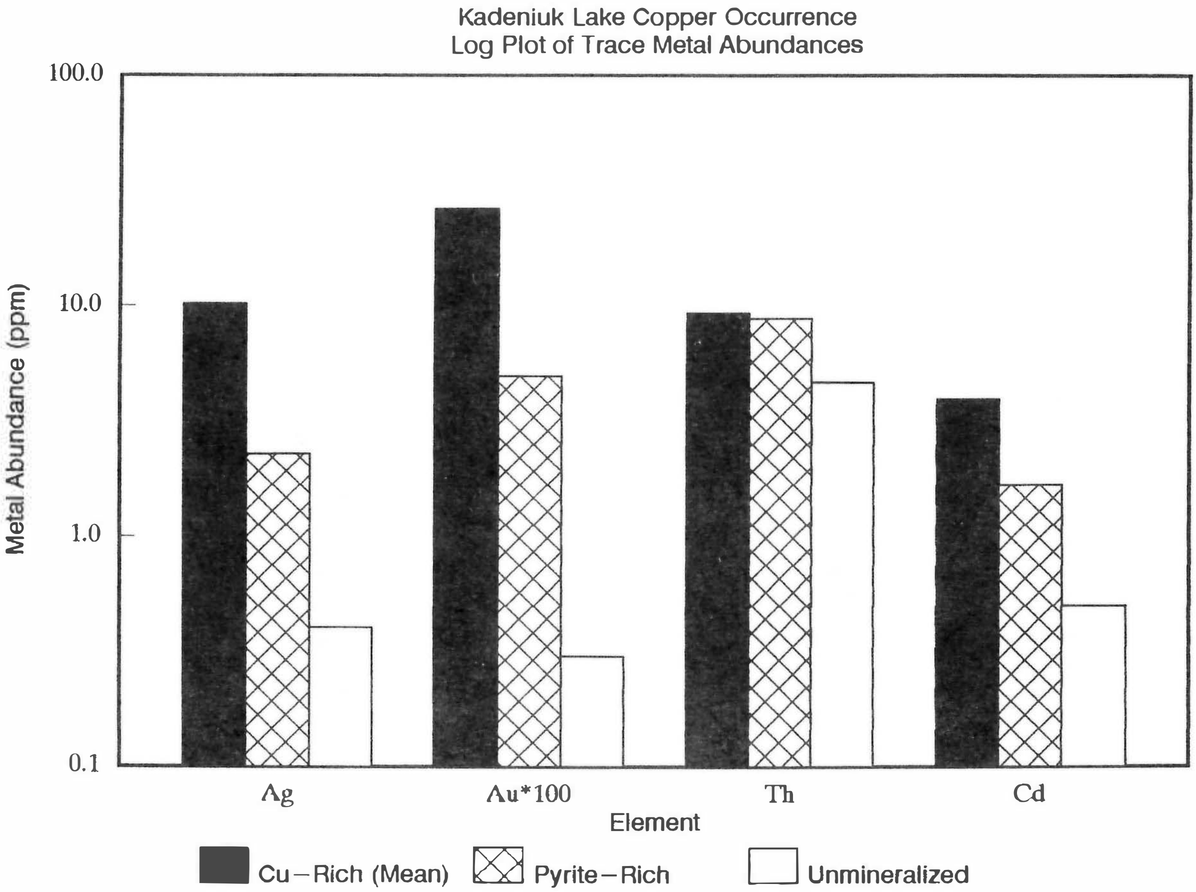

Figure GS-3-6: *Plot of selected whole-rock trace metal abundances in four grab samples of copper-rich disseminated sulphide mineralization, one pyrite-rich sample and an unmineralized arkosic gneiss. Samples are from the Kadeniuk Lake copper occurrence. See Table GS-3-1 for additional details. Note that the gold values have been multiplied by a factor of 100 for scaling purposes.*

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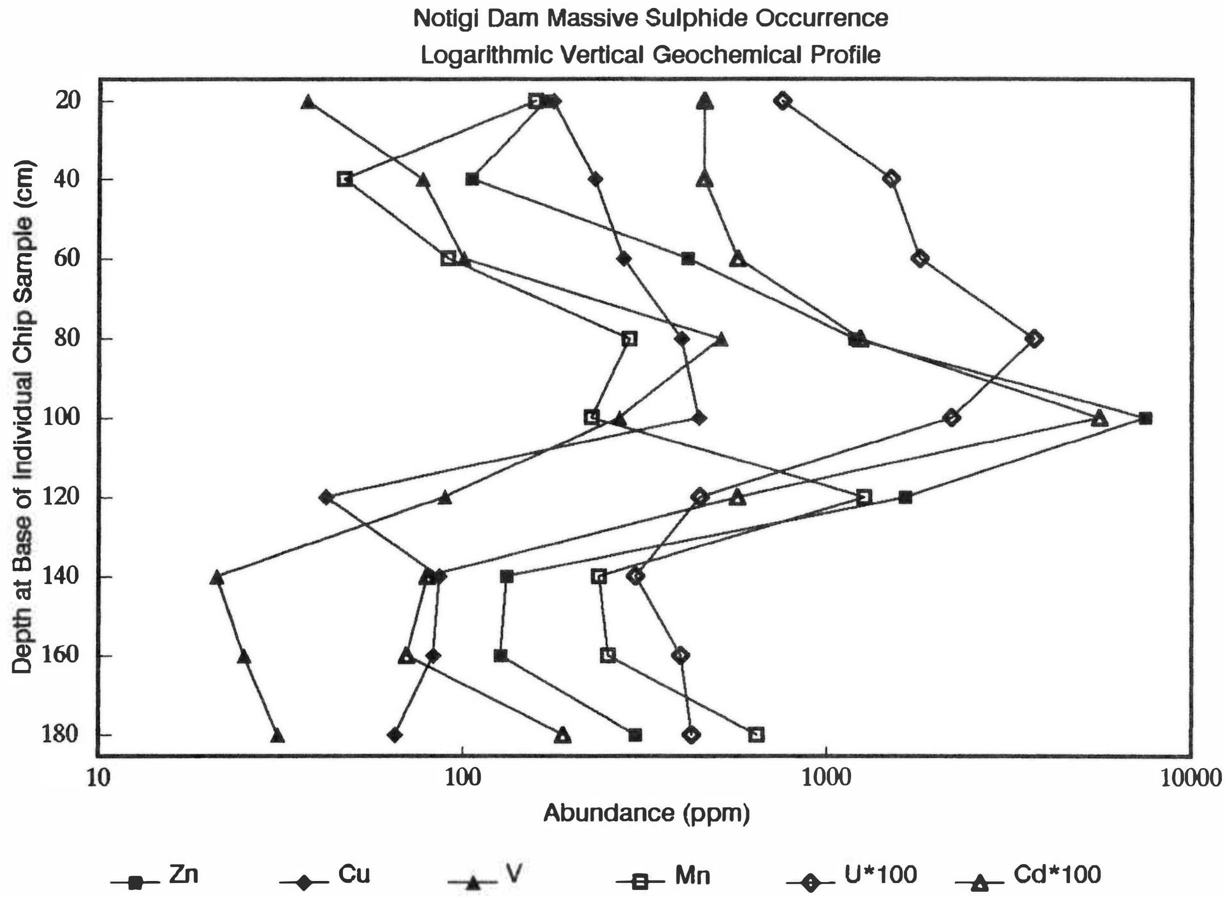

Figure GS-3-7: *Plot of whole-rock abundances for continuous chip samples collected across a solid to near-solid sulphide band hosted by Burntwood River Suite paragneiss in the vicinity of Notigi Dam. Note the vertical zonation in the abundances of the selected elements. The total thickness of the serial sample is 1.8 m, so that each sample represents an approximately 20 cm thick section of the band.*

Table GS-3-2
Geochemical data for serial and grab samples from the Notigi Dam massive sulphide occurrence (serial samples taken across the massive sulphide lens are 98-94-200-3A to 3I; see text for details)

	Units	Det. Limit	98-94-200-1A	98-94-200-1B	98-94-200-2	98-94 200-3A	98-94-200-3B	98-94-200-3C	98-94-200-3D	98-94-200-3E	98-94-200-3F	98-94-200-3G	98-94-200-3H	98-94-200-3I
Au	ppb	1	4	7	4	15	7	4	4	4	7	11	4	7
Ag	ppm	0.4	2.0	2.4	<0.4	2.4	1.9	1.6	1.5	2.4	0.6	0.7	0.6	0.9
As	ppm	0.5	3.6	7.2	<0.5	4.5	8.2	3.5	7.5	5.1	0.7	1.5	1.7	<0.5
Ba	ppm	50	<50	160	850	<50	<50	<50	410	280	98	140	<50	<50
Cd	ppm	0.5	<0.5	<0.5	<0.5	4.6	4.6	5.7	12.3	55.9	5.7	0.8	0.7	1.9
Co	ppm	1	54	48	16	36	50	42	38	38	7	10	10	10
Cr	ppm	5	23	41	160	18	19	23	48	35	10	23	27	19
Cu	ppm	1	427	302	5	177	230	277	400	445	42	86	83	65
Fe	%	0.01	44.90	40.00	5.08	29.70	40.5	35.9	32.6	31.4	9.25	7.31	6.58	8.03
K	%	0.01	0.29	0.25	2.40	0.04	0.17	0.25	0.64	0.21	0.03	0.01	0.01	0.01
Mn	ppm	1	8	125	335	158	47	91	288	227	1270	238	253	645
Mo	ppm	5	29	26	<2	34	58	33	35	31	5	8	6	15
Na	%	0.01	0.04	0.07	1.20	0.03	0.04	0.04	0.11	0.06	0.04	0.02	0.02	0.04
Ni	ppm	1	524	433	74	331	435	384	331	334	42	43	39	42
Pb	ppm	2	9	8	14	4	4	4	4	5	4	12	6	4
Pt	ppb	5	10	6	7	<5	<5	<5	<5	<5	<5	<5	<5	<5
Se	ppm	5	9	8	<3	11	13	12	7	6	<3	5	<3	<3
Sr	ppm	1	6	3	156	25	12	12	40	21	54	16	11	24
Th	ppm	0.2	1.7	1.1	16	0.8	2.2	2.7	5.3	2.9	0.3	0.6	<0.2	<0.2
Ti	%	0.01	0.03	0.06	0.42	0.03	0.06	0.08	0.11	0.07	0.01	0.01	0.01	0.03
U	ppm	0.5	7.8	8.2	3.2	7.5	15.0	18.0	37.0	22.0	4.5	3.0	4.0	4.3
V	ppm	2	87	163	115	37	77	100	510	269	89	21	25	31
Zn	ppm	50	65	65	154	168	105	415	1190	7440	1640	132	127	300
S	%	0.01	34.2	30.6	0.03	22.90	28.78	25.00	22.62	22.82	2.73	3.69	3.25	3.89
C/T	%	0.01	4.85	nd	0.34	nd	nd	nd	4.27	nd	nd	nd	nd	nd
C/O	%	0.01	1.26	nd	0.08	nd	nd	nd	1.14	nd	nd	nd	nd	nd
C/G	%	0.01	3.17	nd	0.22	nd	nd	nd	2.47	nd	nd	nd	nd	nd
CO2	%	0.01	1.53	nd	0.15	nd	nd	nd	2.44	nd	nd	nd	nd	nd

GS-4 GEOLOGICAL COMPILATION MAP OF THE FLIN FLON BELT - KISSEYNEW BELT TRANSITION ZONE, MANITOBA-SASKATCHEWAN (NTS 63L/16, 63N/2-4; PARTS OF 63K/13-16, 63L/15, 63M/1, 63M/2, 63N/1)*

by H.V. Zwanzig and D.C.P. Schledewitz

Zwanzig, H.V. and Schledewitz, D.C.P., 1994: Geological compilation map of the Flin Flon belt - Kisseynew belt transition zone, Manitoba-Saskatchewan (NTS 63L/16, 63N/2-4; Parts of 63K/13-16, 63L/15, 63M/1, 63M/2, 63N/1); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 25-26.

INTRODUCTION

A compilation map of the north margin of the Flin Flon volcanic belt and south flank of the Kisseynew gneiss belt provides a lithologic and tectonostratigraphic overview of an important part of the Paleoproterozoic Trans-Hudson Orogen (Fig. GS-4-1). The two map sheets cover *ca.* 8500 km^2 from the Sturgeon-Weir River, Saskatchewan (*ca.* 102°15') to File Lake, Manitoba (100° 15'). The map is a preliminary product of the Shield Margin Project of the National Mapping Program (NATMAP). It was prepared jointly by K. Ashton at the Saskatchewan Geological Survey, the authors at Manitoba Geological Services, and D. Viljoen and others at the Geological Survey of Canada. It is released as OF94-5 by Manitoba Energy and Mines, and under separate numbers in Saskatchewan and Ottawa.

This report is an explanation of the concepts and subdivisions used in the compilation. These concepts are still under revision but can serve as a guide for understanding the preliminary map and for producing a final Shield Margin compilation by the NATMAP working group.

COMPILATION ORDER

The compilation aims to be primarily a lithologic map designed to match the Flin Flon area compilation (Syme *et al.*, 1993). The first order subdivisions are between classes of Paleoproterozoic rocks: intrusive rocks, tectonites, metasedimentary rocks and predominantly volcanic rocks (Table GS-4-1). Subvolcanic intrusions and units of gneiss with a significant volcanic component are included with volcanic rocks. An attempt was made to show continuity across metamorphic and strain gradients. Although all rocks are middle or upper amphibolite facies, primary structures are locally well preserved on the margin of the Flin Flon belt. Highly strained gneisses and migmatites are common in the Kisseynew belt.

The second level subdivisions are based on stratigraphic order or tectonic affinity within each class. They are designated by a leading capital letter (*e.g.,* **F** for Flin Flon assemblage). The stratigraphic position is generally known only for the major groups. Existing names are retained to provide continuity with other maps where possible, but the

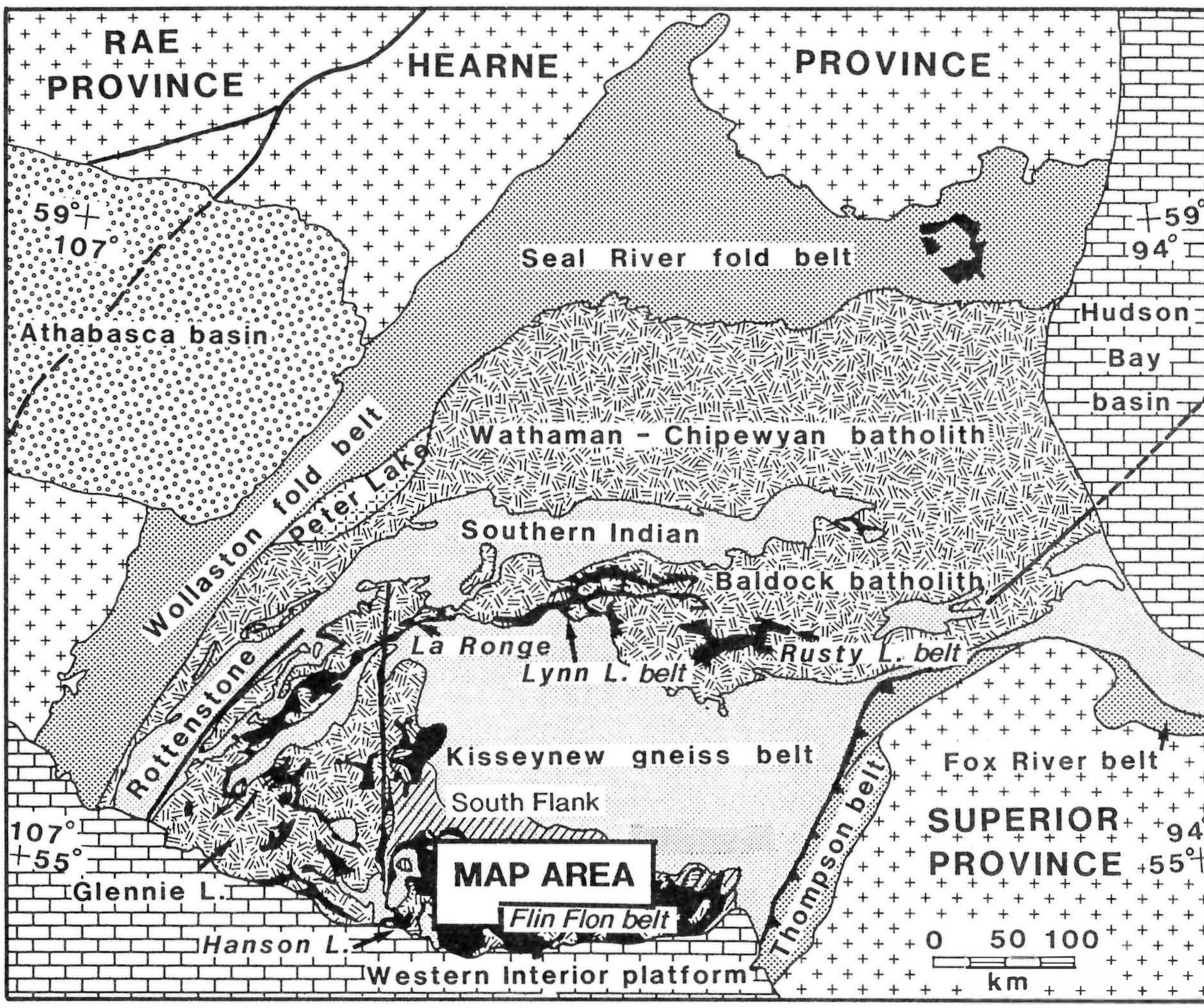

Figure GS-4-1: Geological setting of the map area in western Trans-Hudson Orogen showing Paleoproterozoic tectonic domains between the Archean Hearn and Superior Structural Provinces.

* Funded by Provincial A-Base

application of names may have to be further modified in a final map. Where packages of rocks are structural entities, it was necessary to use preliminary subdivisions comprising assemblages formed in similar tectonic environments, but not necessarily in the same terrane. These are given in arbitrary order because relative ages are not known. Further subdivision into assemblages, each from a contiguous terrane, may have to be made in the final map. The term *Amisk* is applied to predominantly volcanic rocks older than the Missi Group. Rocks for which the tectonic affinity is uncertain are listed separately.

The third order of subdivision are units defined by rock type, and these are designated by number (*e.g.,* **F1** for Flin Flon assemblage basalt and basaltic andesite). Some units fall into fourth order subunits of closely related lithologies, and these are designated by lower case trailing letters (*e.g.,* **F1b** Flin Flon assemblage mafic porphyritic and aphyric flows). The protoliths provide a heading for gneisses; the mineral assemblages that characterize a gneissic lithology provide subheadings and subunits. Mafic to felsic order is given where relative age is unknown, which is the case for most units and subunits. Well preserved rocks and less recognizable schists, gneisses or migmatites are differentiated at the subunit level.

Colours on the map are chosen to represent the rock types (third order subdivisions). Similar lithologies in different groups having slight contrasts. Slightly different subunits can have the same colour. More saturated colours are used in the better preserved rocks of the Flin Flon belt, and pastel colours are used in the gneiss belt. Bright purple to orange designate the youngest intrusions.

Table GS-4-1
Summary of Compilation Legend

INTRUSIVE ROCKS

Syn- to post-Missi Intrusions (<1845 Ma)

J Uniform intrusions include late continental arc gabbro to potassic granite, and syntectonic - collisional leucogranitoids

Pre-Missi (>1845 Ma) and Intrusions of Unknown Age

I Mafic to ultramafic, and major calc-alkaline arc plutons

L Layered tholeiitic ultramafic to felsic sills

TECTONITES

T Rocks with exceptionally high-strain textures

METASEDIMENTARY ROCKS, LOCAL VOLCANIC AND INTRUSIVE ROCKS

Missi Group (1.85-1.83 Ga continental arc to syncollisional overlap basin assemblage)

M meta-arenite, conglomerate, volcanic rocks and minor intrusions

Burntwood Group (1.85 Ga turbidite basin assemblage)

B Metagreywacke-mudstone and derived migmatite, minor volcanic and intrusive rocks

Pre-Missi (>1845 Ma) Metasedimentary and minor Volcanic Rocks

W Wackes, volcaniclastic rocks, protoquartzite and minor pelite of uncertain age, structurally and/or stratigraphically interleaved with unassigned volcanic rocks (V)

PREDOMINANTLY VOLCANIC ROCKS, MINOR INTRUSIONS and MIXED GNEISSES

Rocks of the 1.9 - 1.85 Ga Amisk Group Composite Terrane

G Gneisses of Mixed or Uncertain Origin

V Unassigned Volcanic Rocks and Minor Intrusions

C Long Bay conglomerate (oceanic island)

F Flin Flon composite assemblage (volcanic arc terranes)

A Athapapuskow composite assemblage (back arcs/ocean floor)

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1993: Geology of the Flin Flon area, Manitoba-Saskatchewan; Geological Survey of Saskatchewan, Manitoba Geological Services and Geological Survey of Canada, G.S.C. Open File 2658, 1:50 000 scale.

GS-5 STRATIGRAPHIC AND STRUCTURE SECTIONS, PUFFY LAKE TO JUNGLE LAKE: THE FLIN FLON BELT - KISSEYNEW BELT TRANSITION ZONE (PARTS OF NTS 63N/2, 63N/3, 63K/14 AND 63K/15)*

by H.V. Zwanzig

Zwanzig, H.V., 1994: Stratigraphic and structure sections, Puffy Lake to Jungle Lake: the Flin Flon belt - Kisseynew belt transition zone (Parts of NTS 63N/2, 63N/3, 63K/14 and 63K/15); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 27-34.

INTRODUCTION AND SUMMARY

The reconstruction of tectonostratigraphic sequences proposed for the Kisseynew belt south flank (Zwanzig, 1993) is supported here with a schematic north-south structure section between Walton and Puffy lakes (Fig. GS-5-1; GS-5-2). A set of generalized stratigraphic columns were derived from the section and restored to their original relative positions by unfolding the section.

The distribution of units in the restoration supports the model that the older parts of three tectonostratigraphic sequences represent different environments: (1) a composite volcanoplutonic massif, (2) a basin margin, and (3) a turbidite basin. The younger parts of these sequences are all terrestrial rocks (Missi Group), but systematic lateral fining from conglomerate to arenite at the base of the Missi Group takes place between sequences 1 and 3. Moreover, the lower contact of the Missi Group is a profound unconformity in sequence 1, a disconformity in sequence 2 and is apparently conformable in sequence 3.

The three sequences occur in a stack of fold nappes. Each synclinal nappe contains a core of Missi Group rocks (units 11-14), generally with units symmetrically disposed about the axial surface. The anticlinal nappes are developed in sequence 1 at the base of the structural pile. They contain high-grade volcanoplutonic rocks (units 1-7, 18-19). Structurally higher anticlinal nappes contain metaturbidite gneiss and local amphibolite of sequences 2 and 3 (Burntwood Group, units 9-10). Units 1 and 2 are repeated across an upright fold *(Ponton Lake synform)*, which is superimposed on the nappes in the south. Units 3 to 7 are repeated in a younger higher structure *(Walton Lake nappe)* in the northeast.

SEQUENCE OF FOLDING

The cross-fold relationships and the relative ages of folds, veins and metamorphic minerals suggest that many of the sedimentary nappes (in sequences 2-3) are F_1 and predate the metamorphic thermal peak;

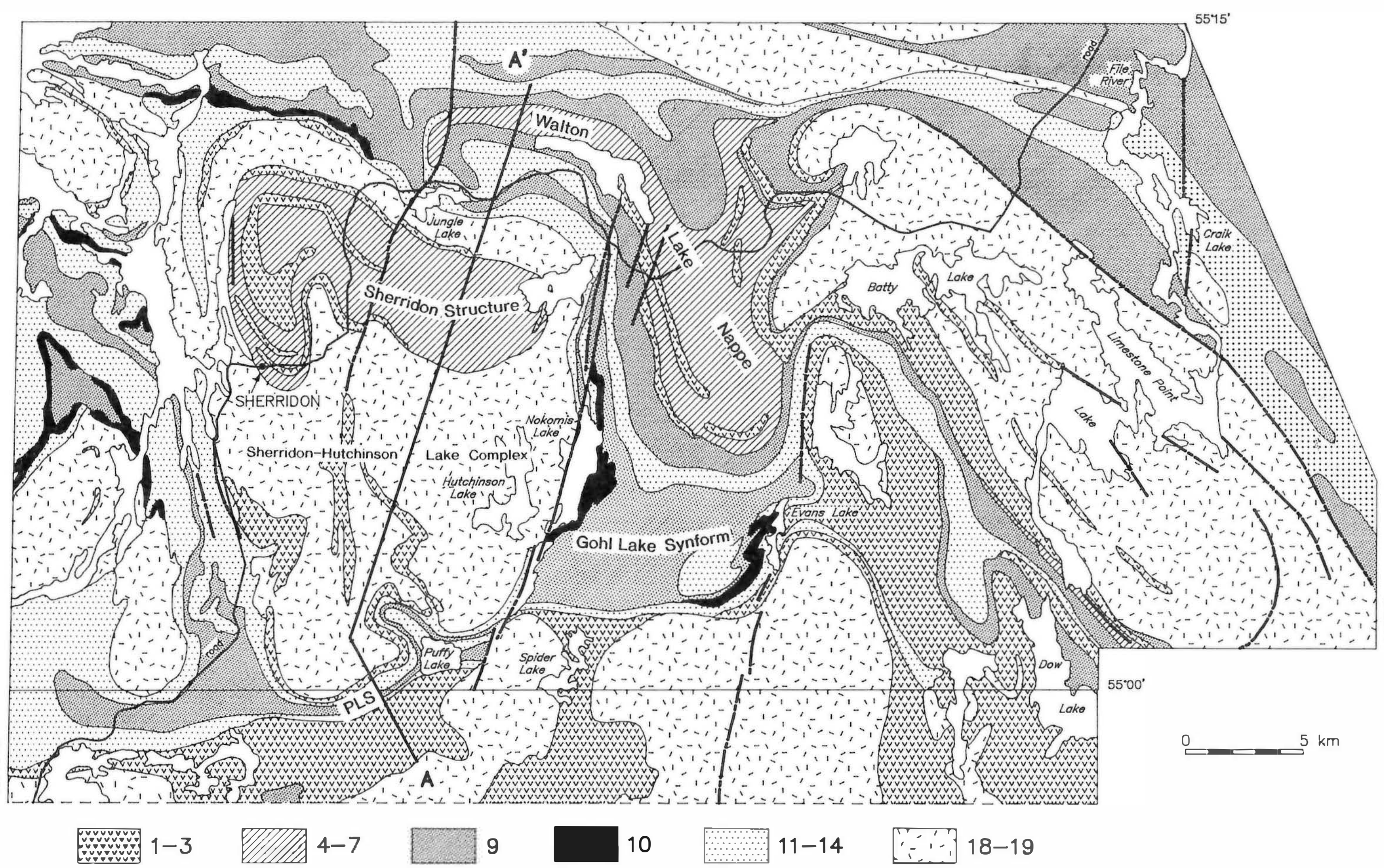
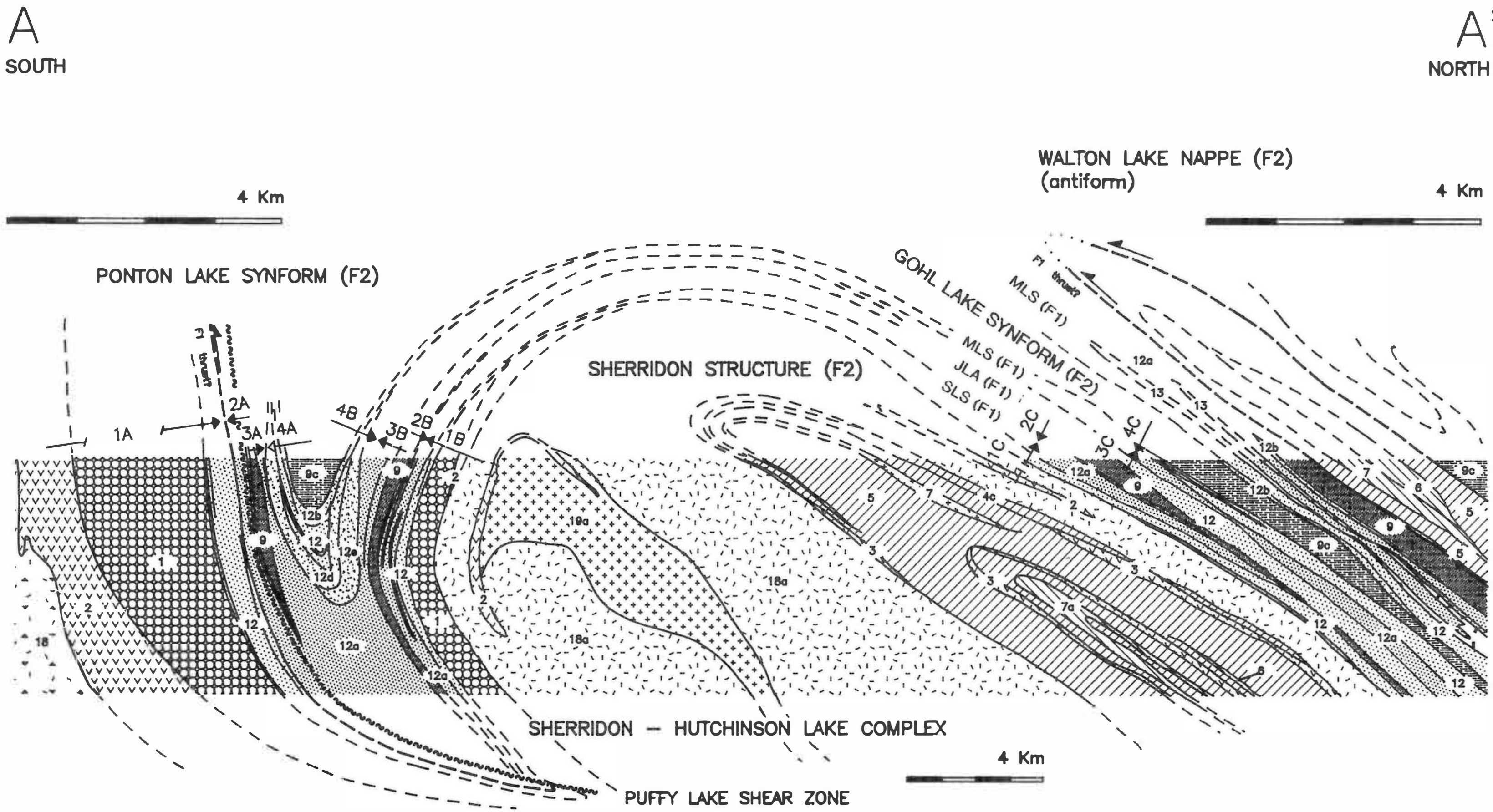


Figure GS-5-1: *Simplified geology of the Sherridon - Batty Lake region showing the line of structure section A-A'. Legend: 1-3 mafic to intermediate volcanic rocks; 4-7 felsic to intermediate volcanic-derived gneiss; 9 Burntwood Group metagreywacke gneiss; 10 Burntwood Group amphibolite; 11-14 Missi Group; 18-19 granodiorite to granite (all ages).*

* Funded by Provincial A-Base



INTRUSIVE ROCKS

- **19a** Gneissic granite
- **18** Tonalite to granodiorite
- **18a** Gneissic tonalite to granodiorite

MISSI GROUP

- **14** Felsic gneiss (mainly rhyolite)
- **14a** Dacitic fragmental rock and basalt
- **13** Amphibolite (volcanic, clastic and intrusive rocks)
- **13a** Amygdaloidal basalt
- **13b** Porphyritic basalt, trachyandesite and volcaniclastic rocks
- **12** Quartzofeldspathic gneiss (arenite)
- **12a** Unit 12 with local amphibolite
- **12b** Protoquartzite, minor pelite
- **12d** Quartz-rich gneiss (arkose)
- **12e** Meta-arenite with epidote
- **11** Metaconglomerate, ribbon gneiss
- **11b** Conglomerate and arenite

BURNTWOOD GROUP

- **10** Amphibolite (gabbro, basalt)
- **9** Garnet-biotite gneiss (metagreywacke)
- **9a** Unit 9 ±amphibole
- **9c** Migmatitic biotite gneiss ±gar-sil-cord

AMISK TERRANE VOLCANIC and RELATED ROCKS

- **7** Coarse grained quartz-biotite-garnet gneiss (probably Fe-Mg alteration)
- **7a** Quartz-garnet-biotite gneiss ±amphibole (mainly sedimentary rocks)
- **6** Garnet gneiss ±cordierite ±sillimanite ±anthophyllite (alteration)
- **5** Garnetiferous felsic gneiss (vocanogenic)
- **4c** Layered intermediate gneiss
- **3** Amphibolite and interlayered felsic gneiss
- **2** Amphibolite ±diopside ±garnet (volcanic)
- **1** Basalt ±pillows, mafic-ultramafic sills

*Figure GS-5-2: Schematic structure section showing F1 fold nappes: **SLS** Star Lake syncline, **JLA** Jungle Lake anticline and **MLS** Mud Lake syncline, possible F1 thrusts, refolded by major F2 structures. Supracrustal rocks have 2x exaggeration (upper scale bars) compared to the Sherridon - Hutchinson Lake complex (lower scale bar). Locations of stratigraphic columns are shown by arrows. Columns with the same number (e.g., 2A to 2C) represent the limb of an F1 fold nappe (e.g., inverted limb of JLA). Columns with the same letter are in the same F2 fold limb.*

The anticlinal nappes (*Sherridon structure* and *Walton Lake nappe*) in the volcanoplutonic massif (sequence 1) are F_2 and developed during the thermal peak. These folds and the adjacent F_2 synforms (*Ponton Lake synform* and *Gohl Lake synform*) refold the sedimentary nappes. Apparently F_1 folds developed above a crystalline volcanoplutonic basement and were detached along unrecognized faults in the Missi Group. The crystalline basement became involved in post-Missi folding only during the metamorphic peak. Two sets of younger folds, one recumbent (F_3) and one upright (F_4), developed during continued flow, compression and uplift. Post-metamorphic fault zones (F_5) cut these structures.

This sequence of events is illustrated in the fold pattern at Jungle Lake, one of the few places where major folds of all ages form interference structures. Fig. GS-5-3 is a structural interpretation of the area. It shows the top of the Sherridon - Hutchinson Lake domal complex and the overlying polydeformed metasedimentary section. Three highly attenuated F_1 fold nappes form the mantle of the dome. In this report these are called from bottom to top the Star Lake syncline (SLS), Jungle Lake anticline (JLA) and Mud Lake syncline (MLS). Above these nappes, the structural interpretation is less well defined. The upper F_1 syncline (MLS) appears to be refolded by the Gohl Lake F_2 synform, which has the Burntwood Group in the core. MLS is also refolded about the Walton Lake nappe, which has felsic gneiss (unit 4-7) in the core that closes north of Jungle Lake. The F_2 structures are refolded, in turn, by an S-shaped pair of F_3 folds and by a NNE-trending pair of upright F_4 folds associated with the Molly Lake fault. The open flexure at Walton Lake is probably an $F_{4\text{-}5}$ fold at the tip of the Nokomis Lake fault.

METHOD OF RESTORATION

Structure section A-A' (Figs. GS-5-1, GS-5-2) was drawn from Preliminary Maps 1993K-1 and 1993K-2 and from Open File maps OF92-2-1 and OF92-2-2 (Zwanzig and Schledewitz, 1992). Contacts were projected down dip and up the plunge from the east. Intrusive and volcanic orthogneisses in the Sherridon - Hutchinson Lake complex were drawn at half the scale of the supracrustal rocks to the north and south by shortening the crest of the dome. This allowed thin supracrustal units to be shown with little distortion in critical parts of the section. The listric shallowing of dip at a lower structural level is consistent with seismic data (Lucas *et al.*, 1994). The choice of the line of section avoided F_3 and F_4 crossfolds. It allowed unfolding the F_1 and F_2 structures in the plane of the section by restoring inverted structural panels to an upright position using a hinge in the north.

Stratigraphic columns are drawn directly from the field maps and detailed field data (Fig. GS-5-4). The restoration was accomplished by arranging them in the order indicated by unfolding the major structures. First, the F_2 Ponton Lake synform and the F_2 Sherridon structure were unfolded about their true hinges and then the F_1 nappes were unfolded about arbitrary hinges. The columns are about 25 km apart as measured along the unfolded section. (If N-S stretching of the section is removed as pure shear, these distances are decreased to a minimum of 5 km.) The top of each column is fixed in the hinge zone of an F_1 synclinal nappe, but the base of the Missi Group is taken as the stratigraphic datum. The Missi unconformity provides the direction of stratigraphic facing, which is consistent with pillow tops in unit 1 of column 1A (Fig. GS-5-4). Probable facing reversals in the other columns were not removed because facing criteria have generally been obliterated.

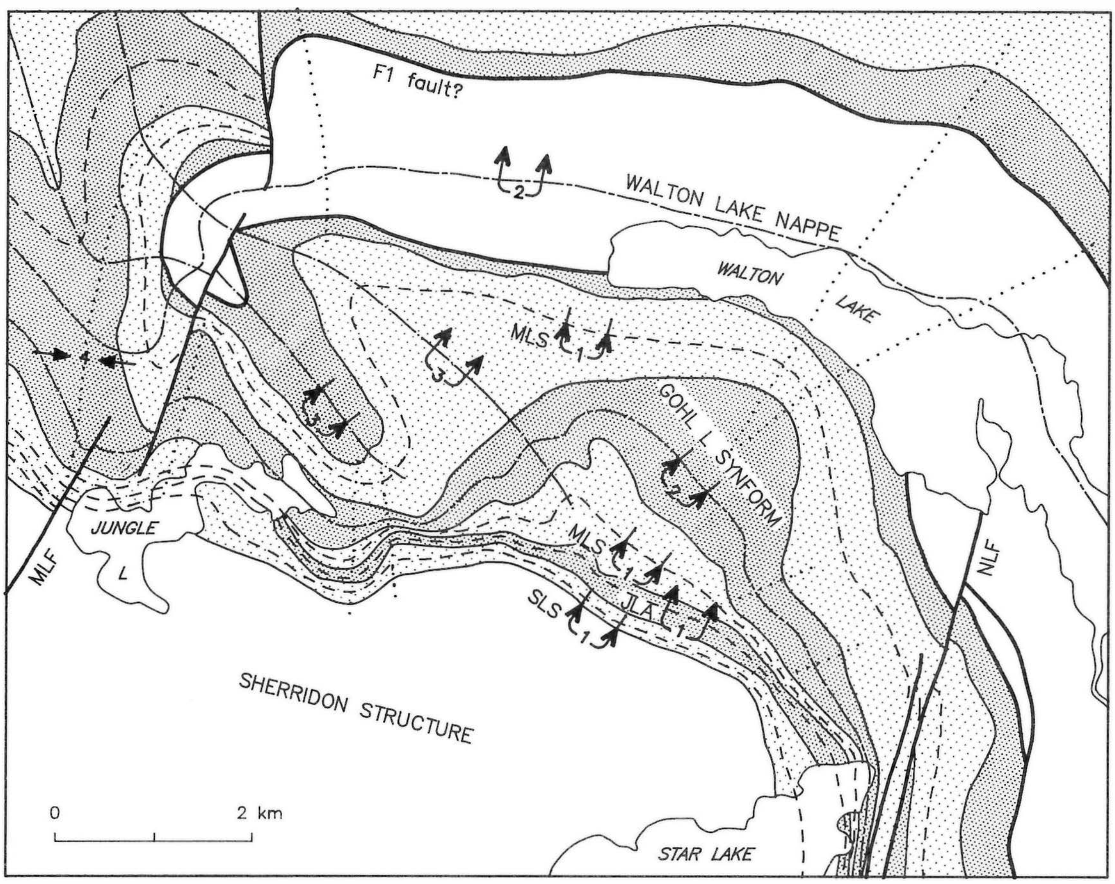


*Figure GS-5-3: Structural interpretation of the Jungle Lake area with five ages of structure shown on the symbols for synclines and anticlines. Highly attenuated F1 nappes (dashed axial traces) occur in the outer mantle of the F2 Sherridon structure; an F1 thrust fault and the **MLS** are folded around the F2 Walton Lake nappe. A typical S-shaped F3 fold pair (dash-dot axial traces) affects the older structures northeast of Jungle Lake but dies out to the southeast. Segments of the Molly Lake fault (**MLF**) appear to be linked with open F4 folds (dotted axial traces) north of Jungle Lake. The north tip of the F4-5 Nokomis Lake fault zone (**NLF**) emerges northeast of Star Lake. Burntwood and Missi groups are patterned as close and open dots; the volcanoplutonic infrastructure is blank.*

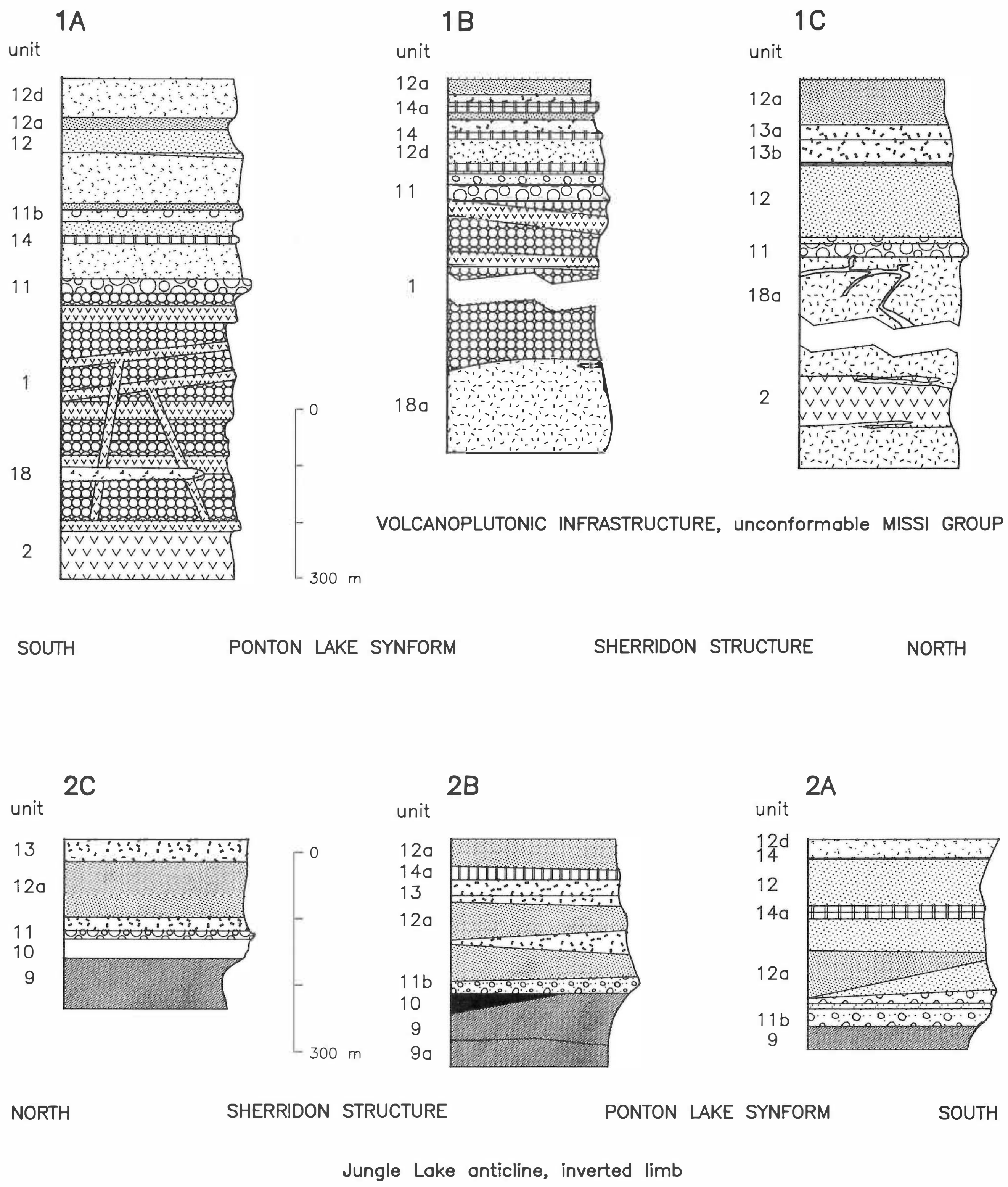


Figure GS-5-4: *Stratigraphic columns of volcanoplutonic sequence 1 (1A-1C) and basin margin sequence 2 (2C-2A). The relative position (north-south) and facing of 2C-2A have been reversed in the restoration. The change in pre-Missi Group rocks between 1C and 2C across the lower anticlinal nappe is abrupt, whereas changes in the Missi Group along 1A-1C-2C-2A suggest gradual fining and increased mafic volcanism at the basin margin. A legend is given on Fig. GS-5-2.*

SEQUENCE 1: VOLCANOPLUTONIC MASSIF - UNCONFORMABLE MISSI GROUP

The oldest rocks are the metavolcanic rocks of the 1.9 to 1.88 Ga Amisk composite terrane (units 1-2). They occur on the margin of the Flin Flon belt (Fig. GS-5-1; south end of section A-A' in Fig. GS-5-2). They are repeated across the Ponton Lake synform, in the highly deformed mantle of the Sherridon - Hutchinson Lake domal complex.

Heterogeneous gneiss (unit 3), felsic gneiss (units 4-5) and their alteration products (units 6-7) are also considered to be highly metamorphosed and tectonized components of the volcanoplutonic massif because they are intruded by the same early plutons (units 18-19) as the Amisk terrane. Units 3 to 7 occur in the Sherridon structure, which is the core of the Sherridon - Hutchinson Lake complex. These units are repeated at a higher structural level in the Walton Lake nappe.

The restored stratigraphic position of these rocks is illustrated in Fig. GS-5-4, which was prepared by unfolding the Ponton Lake synform and the Sherridon structure. The sections show that the Missi Group was deposited on a heterogeneous volcanic and intrusive terrane. Unpublished minor element and trace element data suggest that units 1 and 2 and the package of units 3 to 7 represent diverse lithotectonic assemblages. The same unit of basal Missi conglomerate extends uniformly along the entire north-south section and for 35 km east to west. The unconformity is not repeated in the F_1 structures. This relationship indicates that any detachment for the overlying F_1 folds is above the basal conglomerate. Higher units in the Missi Group cannot be traced from one column to another; there may be thrust faults in this part of the section.

SEQUENCE 2: BASIN MARGIN SUBSTRATE - DISCONFORMABLE MISSI GROUP

Columns 2A to 2C (Figs. GS-5-2, GS-5-4) are on the inverted limb of the lowest F_1 anticlinal nappe (JLA) that contains 1.85 Ga (Machado, unpublished data) Burntwood Group metaturbidite (units 9-9c). Stratigraphically below the Missi Group, but above the turbidite, is a relatively thin mafic unit (10) derived from gabbro, basalt, epiclastic rocks and iron formation. The unit extends 45 km from east to west and a maximum of 20 km from north to south. The Missi Group contact is sharp but does not cut the amphibolite at a measurable angle; the contact is considered to be disconformable. The basal formation in the Missi Group grades laterally from a thin conglomerate (unit 11) to interbedded conglomerate and arenite (unit 11b).

In Fig. GS-5-4 the large inverted structural panel was restored to upright position by hinging it in the north (at point 2C) and removing the SLS. This restoration (1) moves all Burntwood Group rocks that overlie sequence 1 and places them north of the Sherridon - Hutchinson Lake complex, (2) places unit 10 at the first occurrence of metaturbidite, probably at the basin margin, (3) places the thin unit of basal Missi conglomerate at the basin margin and the finer grained interbedded facies into the basin to the north, and (4) places a prominent unit of intermediate to mafic porphyritic volcanic rocks in the Missi Group adjacent to the same unit in sequence 1. All these relationships are consistent with structural stacking of the Burntwood and Missi groups during F_1 and tectonic transport from the Kisseynew belt over the Flin Flon belt.

SEQUENCE 3: BASIN SUBSTRATE - CONFORMABLE MISSI GROUP

Columns 3A to 3C (Figs. GS-5-2, GS-5-5) are on the upright limb of the lowest F_1 anticlinal nappe (JLA) that contains the Burntwood Group metaturbidite (units 9, 9a). The contact with the Missi Group is not exposed in section A-A'. However, the contact is exposed at Evans Lake, where it is apparently conformable with unit 13 amphibolite, and northeast of Nokomis Lake, where it is apparently conformable with unit 12 meta-arenite (GS-6, this volume).

Columns 4A to 4C (Figs. GS-5-2, GS-5-5) are on the overturned limb of the MLS south of the Gohl Lake synform. In this section the Burntwood Group grades conformably upward into the Missi Group through a unit of protoquartzite with thin interbeds of pelite (unit 12b) (Zwanzig, 1993; GS-6, this volume).

In the restoration, columns 3A to 3C had to be pulled north for two lengths of the section plus what had been eroded from the nappes in the south and what is buried under the Walton Lake nappe in the northeast. Columns 4A to 4C had to be restored to an upright position about an arbitrary hinge in the north. The amount of translation involved in the restoration cannot be determined from the sections because the nature and amount of internal strain is unknown.

WALTON LAKE NAPPE: VOLCANOPLUTONIC MASSIF - DISTAL BURNTWOOD AND MISSI GROUP

The gneisses in the core of the Walton Lake nappe (units 3-7) have the same rhyolitic composition with mafic calc-silicate and Fe-Mg alteration interlayers as the gneisses in the Sherridon structure. They are considered to belong to the same tectonic assemblage and were once contiguous. However, unlike the Sherridon gneisses, units 3 to 7 in the Walton Lake nappe are structurally overlain and underlain by Burntwood Group turbidites that grade up into the distal facies Missi Group. Unit 12b is the gradational unit at the base of the Missi Group. The whole distal sedimentary package was probably thrust over units 3 to 7 in the Walton Lake nappe and over the Batty Lake tonalite during D_1. The Walton Lake nappe and its Burntwood and Missi groups mantle may have been emplaced over the lower nappes during D_2 (Zwanzig, 1993).

FULL RESTORATION

Unfolding the main part of the section does not depend on a detailed knowledge of the sequence of folding or assumptions about uncertain structures. However, restoration of the northern part of the section is sensitive to the order of unfolding, and involves a probable thrust. A preliminary schematic restoration using the fold sequence in Fig. GS-5-3 was attempted across the full section. The F_2 structures were removed in Figure GS-5-6, and then the F_1 nappes were removed in Figure GS-5-7. The contact between the Burntwood Group and the core gneisses in the Walton Lake nappe is taken to be an F_1 thrust fault (TF), which is shown connected by a ramp to a possible flat in the Missi Group, and linked by an imbricate fault with the JLA. The faults shown in Figure GS-5-6, or similar faults, were required as a basal detachment for the F_1 folds.

Unfolding the F_2 structure (Gohl Lake synform) has placed the core gneisses in Walton Lake nappe against the matching Sherridon gneisses in SS. Two more columns (3D and 4D) were added to complete the section above TF. Before D_2 flattening the pile of F_1 nappes shown in Fig. GS-5-6 was about 12 km thick. Removing the F_1 structures has pulled back the conformable basin sequence (columns 3D-4A) from the volcanoplutonic gneisses at least 50 km along fault TF (Fig. GS-5-7). Most of the shortening above TF had apparently been taken up by the SLS and JLA.

DISCUSSION

The schematic restoration shows a simplified section across the boundary zone between the Flin Flon and Kisseynew belts with much of the post-Missi deformation removed. Whereas F_1 and F_2 structures were unfolded, the section line was drawn to avoid F_3 and F_4 folds. The minimum length of the section may be in the order of 100 km, three fourth of this representing the basin facies. The Amisk terrane comprises several volcanic assemblages intruded by pre-Burntwood granitoid rocks. The Burntwood Group appears to be in thrust contact with the older rocks. Its top consists of basalt and differentiated mafic sills at the basin margin (Josland Lake intrusions, GS-6, this volume). A sliver of high-Mg, high-Ni amphibolite is attached to the metaturbidites in the basin (base of column 4D).

Missi Group basal conglomerate covered the Amisk terrane, interfingered with arenite at the basin margin and extended into protoquartzite and minor pelite in the basin. Intermediate to mafic high-K volcanic rocks are locally prominent at the basin margin, and basalt is locally prominent in the basin. Thin units of high-K rhyolite are widely scattered (chemical data, unpublished).

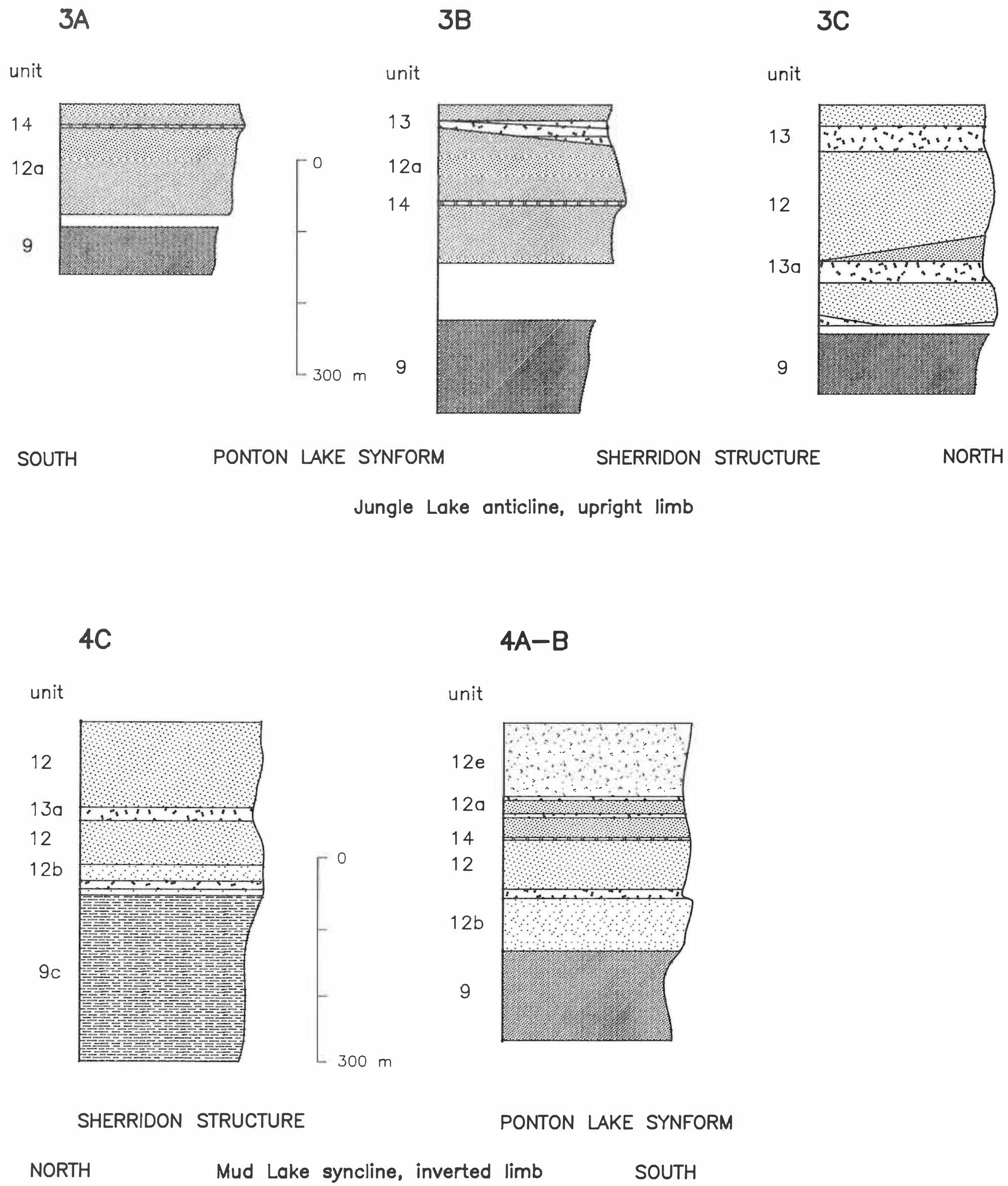


Figure GS-5-5: *Stratigraphic columns of the basin sequence 3 (3A-3C-2A-4C-4A-B). The relative position (north-south) and facing of 4C-4A-B have been reversed in the restoration. Missi Group basal protoquartzite appears in the columns of the most distal facies. A legend is given on Fig. GS-5-2.*

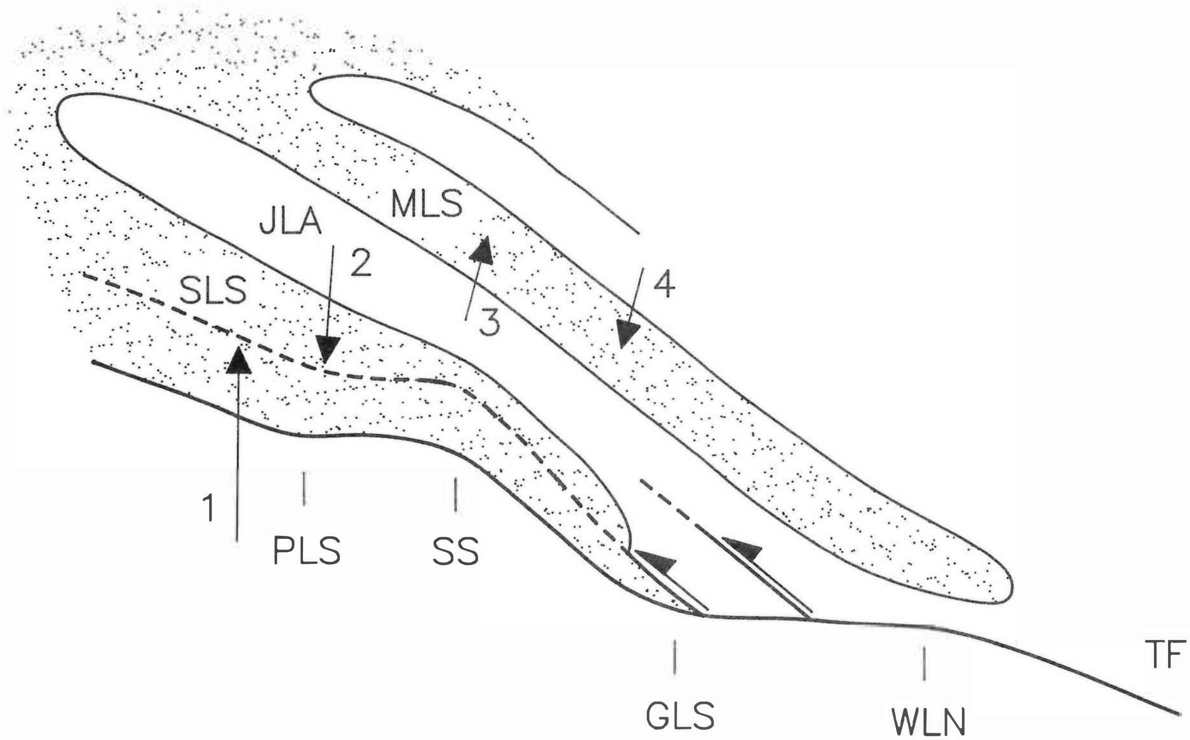


Figure GS-5-6: F1 structures, as they probably existed before D2: **SLS** Star Lake syncline, **JLA** Jungle Lake anticline, **MLS** Mud Lake syncline, **TF** thrust fault. The location of the future F2 folds is also shown: **PLS** Ponton Lake synform, **SS** Sherridon structure, **GLS** Gohl Lake synform and **WLN** Walton Lake nappe. Stratigraphic sections are labeled 1 to 4 corresponding to the columns in the figures and text; the dotted pattern is the Missi Group.

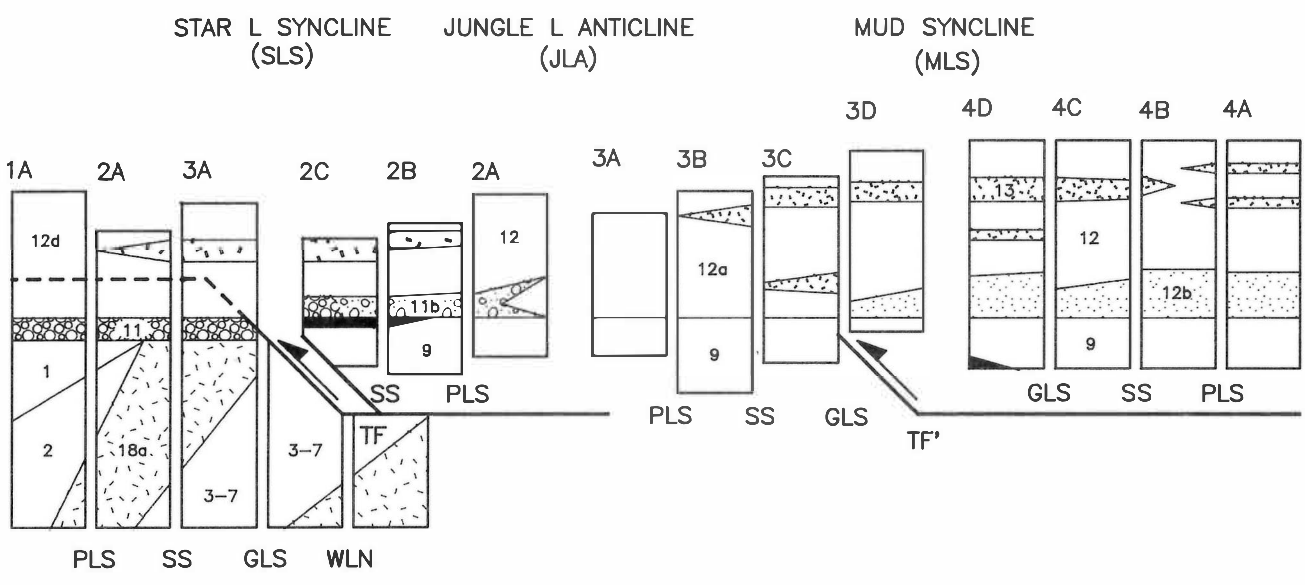


Figure GS-5-7: Schematic restoration of section A-A' using the base of the Missi Group as datum, but showing the future location of F1 and F2 folds and faults. Pre-Missi structures are contacts between volcanic assemblages and with their stitching plutons. These may have a different vergence than the younger structures. A speculative early thrust fault has been restored by separating **TF'** from its present location at **TF**. The possible effect of **TF** on columns 1A to 1C has not been removed. Three major F1 fold nappes, which occur above TF-TF', are shown as wide spaces between columns. Four major F2 folds shown as narrow spaces between columns have acronyms (below columns) defined in Figure GS-5-6. Units are defined in Figure GS-5-2.

Unfolding the section across F_1 and F_2 structures demonstrates that the major structures resolved in this analysis verge from the Kisseynew belt towards the Flin Flon belt. The sedimentary rocks were telescoped and transported over the Amisk terrane. Folding predominated over faulting. If a basal thrust zone was present, it stepped upwards out of the Burntwood Group in the basin and into the Missi Group, above the basal conglomerate at the margin of the Flin Flon belt. The total separation between columns 1A and 4A is in the order of 100 km with considerable flattening strain removed before unfolding.

F_3 and F_4 folds are generally S-shaped, have curved axial surfaces and die out towards the south. Their geometry implies significant sinistral rotation of section A-A'. Tectonic transport in the F_1 structures may have been east over west, rather than north over south.

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GS-6 GEOLOGIC SETTING OF THE NOKOMIS LAKE GOLD DEPOSIT (NTS 63N/3)*

by H.V. Zwanzig

Zwanzig, H.V., 1994: Geologic setting of the Nokomis Lake gold deposit (NTS 63N/3); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 35-38.

SUMMARY

The main protolith for amphibolite at the top of the Burntwood Group is a number of overturned, differentiated gabbro sills; a 10 m thick layer of felsic gneiss within the gabbro complex is interpreted to be a ferrotonalite sill. The tonalite hosts the Nokomis Lake gold deposit and has a distinctive mottled texture, which is interpreted to result from hydrothermal alteration. Black garnetiferous amphibolite in the stratigraphic footwall of the deposit is interpreted to be the iron-rich top of an underlying sill. Fine grained amphibolite, felsite and layered gneiss at the top of the section are interpreted as basalt, dacite tuff and metasedimentary rocks. The widespread alteration and the presence of gold showings and iron formation up to 40 km away in the same stratigraphic marker suggest that hydrothermal fluids may have been discharged onto the sea floor near the top of the Burntwood Group. A comparison with existing major element chemistry suggests that the sills are Josland Lake intrusions as mapped by Bailes (1980).

The mapping at Nokomis Lake supports the conclusions of Zwanzig and Schledewitz (1992) and Zwanzig (1993) that a stack of regional fold nappes contains three different sequences from (1) the volcanoplutonic Flin Flon belt, (2) a basin margin, and (3) the sedimentary basin in the core of the Kisseynew belt (GS-5, this volume). The stratigraphic facies changes at the base of the Missi Group that define the transition from conglomerate in the lower nappe to finer grained metasedimentary rocks in the upper nappes are well displayed from southwest to northeast across the Nokomis Lake area. Burntwood Group basaltic rocks, differentiated sills and the Nokomis Lake gold deposit occur in the overturned limb of the nappe that contains the basin-margin sequence.

INTRODUCTION

The Nokomis Lake gold deposit, which occurs on the southern flank of the Kisseynew gneiss belt, is *ca.* 100 m long, 1.5 m thick (on average) and Rio Tinto has outlined 90 700 tonnes grading 10.3 g/t Au (Ostry and Trembath, 1992). It has been classified as 'a chemical sediment type deposit due to its stratabound nature and lack of obvious associated alteration' (Ostry and Trembath, 1992). Excellent exposure was produced by a forest fire in 1989. New evidence from these outcrops and existing geochemical data indicate that the host rocks are differentiated sills with local alteration, and not metasedimentary rocks.

Geological mapping at 1:10 000 scale (Zwanzig and Shwetz, Preliminary Map 1994K-2) and geochemical sampling were carried out over 40 km^2 in the vicinity of the deposit (Fig. GS-6-1). This work upgrades of the existing 1:20 000 and 1:50 000 scale maps (Zwanzig 1984; Zwanzig and Schledewitz, 1992). The main goal was to determine the origin of the felsic gneiss that hosts the Nokomis Lake deposit and the origin of the enclosing amphibolite at the top of the Burntwood Group. The field observations are supported by a preliminary review of existing geochemical data. A secondary goal was to help determine the regional structural setting of these rocks.

STRATIGRAPHY

Early Intrusive Rocks

Strongly foliated intrusive rocks on the west side of Nokomis Lake are the oldest rocks in the area. They comprise hornblende-biotite tonalite to biotite granodiorite (unit 18a) with a comagmatic margin phase of melagranodiorite to quartz diorite (unit 18d). The intrusion, herein called the Hutchinson Lake pluton, extends north and west beyond Star Lake, where it intrudes felsic gneisses in the Sherridon structure (Zwanzig, 1993). West of South Nokomis Lake the Hutchinson Lake pluton is intruded by foliated granite (unit 19a) of the 1874 Ma (Hunt and Zwanzig, 1990) Ragged Lake pluton. Both plutons intrude Amisk volcanic rocks and are overlain by the basal conglomerate of the Missi Group.

Burntwood Group

The oldest rocks east of Nokomis Lake are Burntwood Group garnet-biotite gneiss (unit 9) derived from turbiditic metagreywacke-mudstone, and greywacke-derived migmatite (unit 9c). Their base is not exposed but they are stratigraphically overlain by 0-200 m of Burntwood Group amphibolite (units 10-10d). Some of these units are described below; the other units are described in Zwanzig (1993).

Fine grained amphibolite and minor felsic gneiss: metabasalt, diabase and metagreywacke (unit 10)

Uniform to weakly layered dark grey-green amphibolite forms up to 3 m thick units of uncertain origin, possibly basalt. The rock contains scattered garnets in some areas. It occurs locally throughout the amphibolite sequence, most commonly near the top.

Locally interlayered quartz-feldspar-bearing gneiss with garnet, hornblende and biotite (25-35% combined) is interpreted as metagreywacke. Fine grained mafic interlayers may be dykes. Fine grained, pale buff weathering felsic layers, 1 to 2 m thick, are interpreted as metadacite (tuff or dykes) where uniform, and metasedimentary rocks or tectonites where layered. These heterogeneous rocks form the stratigraphic top of the Burntwood Group on the east shore of Nokomis Lake. They are overlain by Missi Group metaconglomerate with interbeds of meta-arenite.

Amphibolite ± diopside: basic metagabbro (unit 10a)

Grey weathering amphibolite forms thick sheets that make up much of the amphibolite section in the Burntwood Group east of Nokomis Lake. The rock contains medium grained fibrous amphibole, widespread diopside and traces of calcite. It is uniform or weakly layered and interpreted as basic gabbro. Some areas feature light grey-green lenses, folded crosscutting veins, or layers rich in diopside; these are interpreted as carbonatized gabbro. One or two 20 m thick sheets of unit 10a occur at the stratigraphic base (east) of the amphibolite. A >100 m thick sheet east of unit 10 grades from nearly ultramafic (unit 10b) in the east to light grey, plagioclase-rich in the west. This sheet is interpreted as differentiated sills. A unit to the west is compositionally layered.

Mafic-ultramafic rock: melagabbro (unit 10b)

The most mafic rock forms a uniform dark green weathering unit near the centre of the amphibolite package. It contains medium grained fibrous amphibole, minor diopside and ≈15% fine grained plagioclase. The unit has a sharp eastern contact and grades west into the thickest sheet of unit 10a, indicating that it is the base of a differentiated sill.

Amphibolite ± garnet (unit 10c)

Uniform and patchy fine- to medium-grained hornblende-plagioclase amphibolite, 15-60 m thick, probably comprises one or more gabbro/diabase sills. The unit stratigraphically overlies a sill of unit 10a near the stratigraphic base of the amphibolite sequence. The western margin of unit 10c comprises black weathering, medium grained, highly mafic amphibolite with accessory garnet, probably ferrogabbro at the top of the sill. The upper 1 to 5 m of the unit contain up to 35% garnet with magnetite and a trace of fine disseminated iron sulphide that are probably due to Fe-enrichment during alteration.

Felsic mottled gneiss (unit 10d)

A sheet of grey felsic gneiss, up to 10 m thick, lies west of the garnet-rich amphibolite, and is in sharp contact with melagabbro to the west. The gneiss contains plagioclase, 5 mm aggregates of quartz, hornblende, biotite, magnetite and accessory titanite and apatite. Pink weathering albite, calcite, <5% garnet (1-2 mm) and fine grained disseminated Fe sulphide occur variably in parts of unit 10d. The rock is interpreted to be a tonalite as based on relict igneous texture found on

* Funded by Provincial A-Base

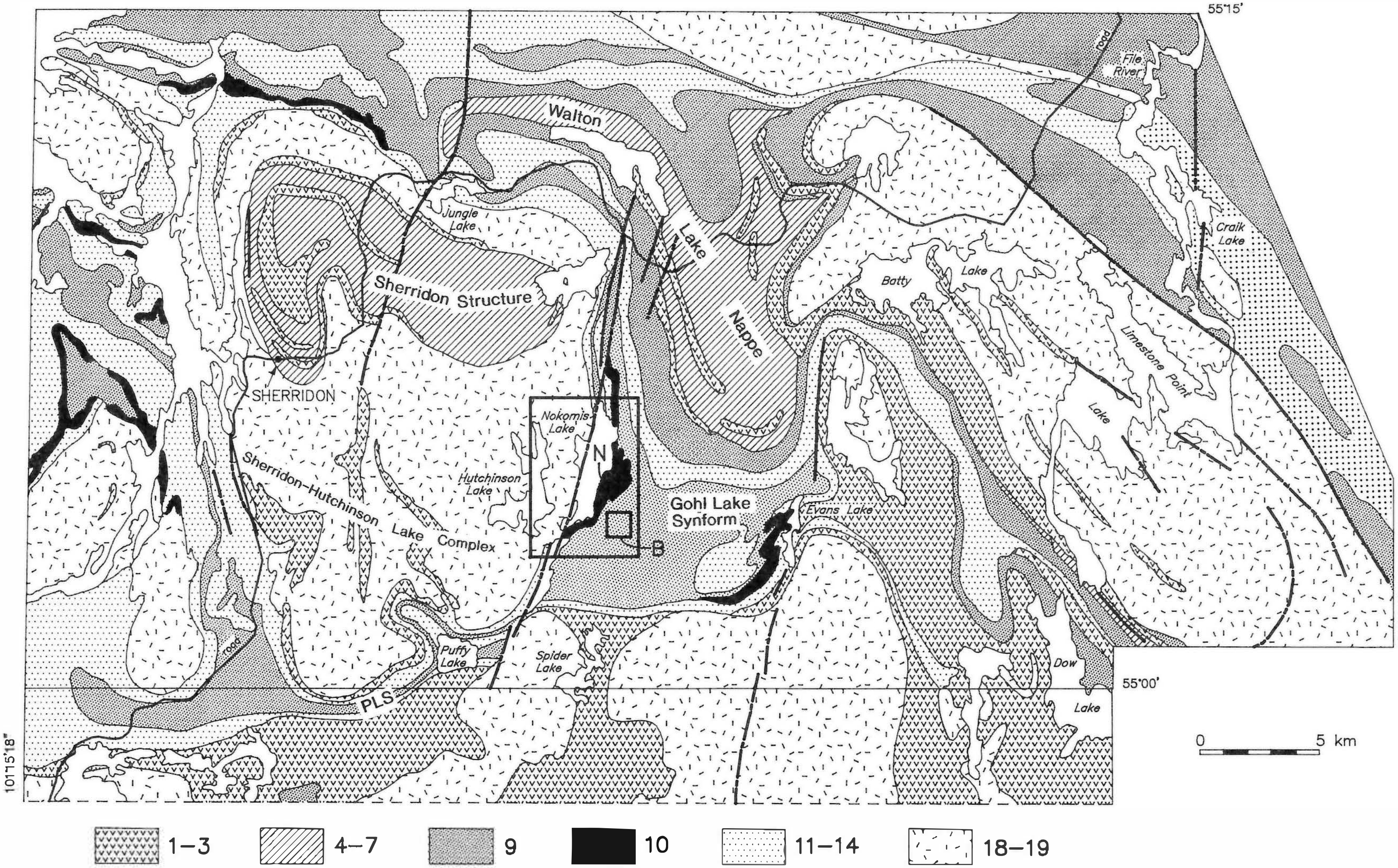

Figure GS-6-1: *Simplified geology of the Sherridon - Batty Lake region showing the outline of the Nokomis Lake map area.* ***N****-Nokomis Lake gold deposit,* ***B****-area of detailed mapping (GS-7, this volume).*
Legend: 1-3 mafic to intermediate volcanic rocks; 4-7 felsic to intermediate volcanic-derived gneiss; 9 Burntwood Group metagreywacke/gneiss; 10 Burntwood Group amphibolite/gabbro; 11-14 Missi Group metasedimentary and volcanic rocks; 18-19 tonalite to granite (ages undivided).

a few outcrops (e.g., on the drill road east of Viking Lodge fishing trailer). Albite is more prominent at the stratigraphic top and amphibole is more abundant at the base. The felsic sheet is therefore interpreted to be a sill that differentiated at the top of the ferrogabbro (unit 10c).

Rare, fine grained, uniform felsic layers a few centimetres thick are interpreted as microtonalite or dacite dykes. The earlier interpretation that they are cherty beds (Gale and Ostry, 1984) is not apparent on the clean exposures.

In most areas the gneiss is cut by a stockwork of straight and folded hornblende-magnetite-rich veins, 1 to 5 mm thick. In many localities the black veins have diffuse margins, leaving lighter domains several centimetres in diameter and imparting a distinctive mottled texture to the rock. The veinlets and the matrix locally contain <10% disseminated sulphide minerals. Gold mineralization (<24 ppm in assay) is associated with the sulphides (Ostry and Trembath, 1992). The east contact zone is garnet rich; veins continue into the amphibolite to the east. The mottling and veins are interpreted as the result of premetamorphic hydrothermal alteration that included iron, carbonate and sodium migration.

Missi Group

The basal conglomerate (unit 11), >8 m thick, and the Missi unconformity are exposed 500 m east of South Nokomis Lake. The overlying rocks are quartz-rich gneiss derived from meta-arkose (unit 12d). This gneiss is overlain by intermediate to mafic volcanic and sedimentary rocks (unit 13) in the core of a synclinal nappe (Star Lake syncline in GS-5, this volume). Ribbon gneiss derived from conglomerate with interbeds of meta-arenite lies on the overturned limb of this nappe. These rocks have an aggregate thickness of 10 m where they occur on the east shore of Nokomis Lake and on nearby islands. They stratigraphically overlie metasedimentary rocks and amphibolite of the Burntwood Group in the basin-margin sequence.

East of Nokomis Lake, Missi Group arenite (unit 12) is in the limbs, and layered amphibolite (sedimentary or tuffaceous) and porphyritic to aphyric amygdaloidal metabasalt are in the core of another synclinal nappe (Mud Lake syncline in GS-5, this volume). The base of this section is exposed northeast of Nokomis Lake along the power line, where the Missi Group, without conglomerate, is in sharp sedimentary contact with the Burntwood Group.

The third and highest synclinal nappe, northeast of Gohl Lake, has a transitional basal unit (12b) featuring 30 m of protoquartzite with sillimanite knots and scattered garnet and thin interbeds of biotite-garnet schist (pelite). The core of this fold contains meta-arenite with local amphibolite (unit 12a).

Leucogranite and pegmatite

Fine grained leucogranite to pegmatite containing <3% biotite, <1% garnet (1 mm), <3% sillimanite (in 5 mm long *faserkiesel*) and <1% retrograde muscovite form veins and sills up to 50 m thick. These granitic sheets converted the Burntwood Group metagreywacke north and south of Gohl Lake into a migmatite. Multiple episodes of veining and coeval folding have been recorded by Zwanzig and Shwetz (GS-7, this volume).

REGIONAL CHEMICAL CORRELATION

The geochemistry of units 10 to 10d near the Nokomis Lake gold deposit (Ostry and Trembath, 1992) and at Evans Lake (Zwanzig, 1992) is compared to differentiated mafic to felsic sills (Josland Lake intrusions) near File Lake (Bailes, 1980) and to amphibolites elsewhere in the Burntwood Group (Table GS-6-1). An igneous origin is indicated for the rocks at Nokomis Lake by similar average values of major elements for the Josland Lake intrusions. All suites fall into similar groups based on increasing fractionation as indicated by Fe, Mg and Ni. Random variations in Na_2O, K_2O and CaO indicate that these elements were mobile and that all conclusions are therefore preliminary until trace element data is obtained.

The igneous suites range in composition from melagabbro to intermediate and felsic intrusive rocks. The suites are characterized by tholeiitic trends of Fe, Ti and Na enrichment, and increasing Mg/Ni with increased fractionation. There are abundant Fe-rich members, which include Fe-rich amphibolite (Table GS-6-1, No. 9: average of 4 samples from Evans Lake) and chemically equivalent ferrogabbro (No. 10: average of 5 samples from File Lake). Extreme iron enrichment (No. 12-14) may involve alteration at Nokomis Lake but also occurs in unaltered ferrogabbro at File Lake and pillowed ferrobasalt at Granville Lake. Quartz diorite and ferrotonalite at File Lake, and chemically equivalent felsic mottled gneiss at Nokomis Lake, display even greater Fe/Mg ratios.

The chemical similarity of these rocks is significant only because they are all closely associated with the basin-margin facies of the Burntwood Group and with small gold deposits, both on the north and south sides of the Kisseynew belt. However, their age may have a considerable span from volcanic rocks with comagmatic sills at the top of the Burntwood Group (Zwanzig, 1990) to axial planar members of the Josland Lake intrusions into F_1 recumbent folds (Bailes, 1980). The magmatism occurred in a persistent tectonic environment of faulting and folding at the Kisseynew basin margin.

Similar rocks also occur in the lower part of the Burntwood Group south of Walton Lake (unit 1 in Zwanzig, 1993). On the north flank of the Kisseynew belt they occur within and at the top of the Burntwood Group (Zwanzig, 1981 and 1990). On the Kisseynew north flank at Granville Lake, the amphibolite sections contain up to 300 m of metabasalt with well preserved pillow structures. Pillow breccia occurs at Evans Lake and some fine grained amphibolite layers at Nokomis Lake also may be metabasalt.

STRUCTURE AND METAMORPHISM

The Nokomis Lake area straddles the eastern boundary between the Sherridon - Hutchinson orthogneiss complex and a refolded stack of regional fold nappes in the overlying supracrustal rocks (Zwanzig and Schledewitz, 1992). The structure across Nokomis Lake and to the northeast is very similar to the structure in the northern part of section A-A' (GS-5, this volume).

The relationships between various sets of crosscutting veins and minor folds and metamorphic structures were used to test the relative ages of regional folds that cross the area east of Nokomis Lake. The lowest pair of fold nappes in the sedimentary rocks is assigned to F_1, based on superimposed folding (GS-5, this volume). East of Nokomis Lake these folds appear to predate the main foliation (S_2), the early veins and the thermal-peak mineral assemblages (GS-7, this volume). Veins are generally not abundant in the structurally lowest rocks and most pegmatite dykes are restricted to late fault zones. Garnet porphyroblasts within the structurally lowest metagreywacke beds apparently grew during late stages of D_2 or during D_3, after emplacement of overlying nappes.

The higher part of the nappe pile contains younger granitic veins and sheets in addition to the older veins (GS-7, this volume). Abundant younger granite intruded the core of an F_2 synform northeast of Nokomis Lake during reactivation of the fold by F_3 structures: southwest-verging F_3 minor folds with synkinematic granite veins are developed in both limbs of the synform. F_3 shear zones and very strong regional zones of D_3 flattening are evident above and below the Burntwood Group amphibolite.

Open F_4 upright folds and F_5 brittle faults form the Nokomis Lake fault zone, which straddles the west shore and centre of the lake. Late upright pegmatite dykes with a NNE trend are associated with these folds and faults. The faults have steep easterly dips and steep, oblique, slickenside striae. Separation and late kinematic indicators are sinistral. Gently east-dipping units are repeated by sinistral and east-side-up (oblique reverse) slip. Spectacular fault breccias with a structureless cataclasite matrix postdate the youngest pegmatites and the high-grade metamorphism.

Table GS-6-1
Average Major Element Geochemistry, Units 10-10d, and Regional Comparison

NO	Area	Unit	SiO_2	Al_2O_3	Fe_2O_3T	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Ni	LOI	Mg/Ni	Fe/Fe+Mg	*n
1	N	10b	47.0	13.97	9.74	11.72	13.08	1.38	0.33	0.49	0.02	0.17	(284)	0.74	(281)	0.46	2
2	F	18(1)	46.4	12.50	6.99	12.30	15.00	0.79	0.30	0.19	0.12	0.12		6.10		0.35	1
3	G	9c	47.6	13.94	7.01	14.02	13.95	1.31	0.25	0.09	0.02	0.14	190	2.81	474	0.36	2
4	N	10a	48.3	15.10	8.10	13.70	11.60	1.10	0.20	0.50	0.11	0.60		0.60		0.45	1
5	F	18(1)	48.3	16.43	9.07	12.07	9.88	1.81	0.46	0.47	0.07	0.15	177	2.07	342	0.51	3
6	G	8a	51.2	12.80	10.80	10.10	10.90	3.00	0.10	0.80	0.08	0.17	200		328	0.53	1
7	W	1	46.7	15.43	10.99	11.28	9.59	3.36	0.25	0.43	0.06	0.16	132	2.10	438	0.57	1
8	F	18(1)	48.3	17.02	8.59	12.73	8.18	1.96	0.43	0.24	0.07	0.15	99	3.11	558	0.55	3
9	N	10	49.2	14.30	15.37	9.55	6.87	2.66	0.24	1.20	0.09	0.22	42	1.14	1045	0.72	4
10	F	18(2)	47.1	13.92	16.97	10.56	7.38	1.81	0.33	1.23	0.05	0.24	79	1.84	664	0.73	5
11	G	8a	47.2	13.63	15.22	10.59	7.57	2.11	0.26	2.11	0.25	0.23	<120	2.20	>440	0.70	4
12	N	10c	46.6	11.47	26.27	7.10	3.63	2.15	0.26	2.73	0.10	0.32	3	0.49	7096	0.89	4
13	F	18(2)	46.8	11.65	21.01	9.31	4.26	2.41	0.31	3.04	0.11	0.28		2.30		0.85	1
14	G	8a	49.3	15.95	16.05	8.95	3.95	2.95	0.25	2.27	0.33	0.22	<28	0.10	>2024	0.83	2
15	N	10d	56.9	10.23	14.93	7.78	0.78	3.55	0.28	1.43	0.40	0.15		3.43		0.96	4
16	F	18(3b)	57.6	11.08	19.26	6.45	1.05	2.14	0.33	1.54	0.37	0.35		1.44		0.95	2
17	N	10d	66.7	10.25	9.73	5.94	0.60	3.78	0.37	0.86	0.16	0.10	<6	1.43	>894	0.94	14
18	F	18(3c)	67.3	11.45	10.97	3.80	0.97	3.79	0.31	0.72	0.16	0.18		1.16		0.93	4

1 Mafic parts of sills, Nokomis and Evans lakes.
2 Melagabbro with 70% cumulus augite pseudomorphs, Yakymiw Lake, SW of File Lake.
3 Mafic-ultramafic intrusive, originally with coarse grained clinopyroxene, Granville L.
4 Mafic amphibolite/gabbro, base of sill, Nokomis Lake.
5 Gabbro near base of sill, cumulus plag. and pyrox. pseudomorphs, Josland L.
6 Pillow basalt, Granville Lake.
7 Mafic amphibolite with diopside, south of Walton Lake.
8 Gabbro to leucogabbro, subequal pyroxene pseudomorphs and plagioclase, Josland L.
9 Weakly layered amphibolite ± garnet, sills/flows, Evans Lake.
10 Ferrogabbro, high mafic content, 5% opaque minerals, Josland Lake; chilled base of intrusion, Morton Lake.
11 Highly mafic flow(?), Granville Lake; amphibolite, Kamuchawie Lake; pillow basalt and amphibolite south of Granville Lake.
12 Garnet amphibolites, probable top of a sill, Nokomis Lake and Evans Lake.
13 Gabbro near base of sill, Morton Lake.
14 Pillowed ferrobasalt near base of the section, Granville Lake.
15 Intermediate mottled gneiss, Nokomis Lake.
16 Granophyric quartz diorite, albitic, 5% mafic minerals, Josland and Yakymiw L.
17 Felsic mottled gneiss, Nokomis Lake.
18 Granophyric tonalite with a high content of albite and 3% opaque minerals.

* AREA: N-Nokomis and Evans lakes; F-File Lake to Morton Lake; G-Granville Lake; W-Walton Lake
UNIT: Area N-this report; area F-Bailes (1980); area G-Zwanzig (1981); area W-Zwanzig (1993)
Fe_2O_3T: Total iron as Fe_2O_3 n: Number of analyses in the average ( ): Single analysis

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GS-7 SYNKINEMATIC MIGMATITES IN THE VICINITY OF NOKOMIS LAKE (NTS 63N/3)*

by H.V. Zwanzig and J.V. Shwetz

Zwanzig, H.V. and Shwetz, J.V., 1994: Synkinematic migmatites in the vicinity of Nokomis Lake (NTS 63N/3); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 39-41.

SUMMARY

This report provides an overview of the structural setting of the granitoid veins and sheets, and a preliminary description of the migmatites and their field relationships. The main results of the field observations are given below.

1. The granitoid veins and sheets are part of a migmatite complex, possibly derived from the metagreywacke-mudstone of the Burntwood Group, but largely injected in their present site.
2. At least four generations of injection occurred during prograde and retrograde metamorphism. The leucosomes are synkinematic; the older quartzofeldspathic ones have been affected by three phases of deformation and the younger granitoids by two.
3. The most voluminous leucosome comprises fine grained leucogranite and pegmatite belonging to one of the younger generations that typically contains small amounts of biotite, garnet, sillimanite knots and retrograde muscovite.
4. All but the oldest veins have biotite-rich selvages (melanosome) at contacts with their metagreywacke host.
5. Much of the garnet in the metagreywacke was lost by retrogression to biotite. This reaction suggests that the migmatitic leucosomes developed in an open chemical system with free access by granitic magmas and metamorphic fluid.

INTRODUCTION

Detailed geological mapping and geochemical sampling of synkinematic migmatites were carried out by J.V. Shwetz on the southern flank of the Kisseynew gneiss belt east of Nokomis Lake (Fig. GS-6-1, this volume). Outcrops exposed by a forest fire in 1989 allowed 1:5 000 scale mapping of a small part of the area covered by the new 1:10 000 scale map (Preliminary Map 1994K-2). The detailed mapping and sampling were part of an undergraduate thesis, a partial requirement for a B.Sc. at the University of Manitoba. The thesis is under the supervision of Dr. Petr Cerný and will examine the petrological, metamorphic, and structural history of the granitoid injections as related to their emplacement within the Burntwood Group. The objectives will be accomplished by petrographic study, whole-rock geochemical analysis, partial chemical analysis of mineral separates, and microprobe analysis.

LEUCOSOMES AND MELANOSOMES

The light coloured or granitoid component of the migmatites (leucosomes) are subdivided according to age and relationship with regional foliation and folds. They are early quartzofeldspathic veins (S_{1-2}) and slightly older granitoid veins (S_{2-3}), which appear to be mobilizates in Burntwood Group metagreywacke. In contrast, S_{3a} granitic sheets and dykes and S_{3b} granodioritic dykes are younger and slightly more discordant. All leucosomes except the oldest have biotite-rich selvages (melanosomes).

Early Leucosome

The oldest leucosome (S_{1-2}) consists of quartz-rich boudins and veins that make up <15% of the outcrop. Veins are generally <1 cm thick, but boudins have a maximum thickness of 10 cm. The veins contain pale-grey to white quartz and white weathering feldspar, interpreted as plagioclase. Boudins generally have a quartz core rimmed with quartz and feldspar (Fig. GS-7-1a). Rare biotite selvages are thin. Elongate mafic pods on some vein contacts or near boudin necks may represent early melanosome. The pods contain deformed crystals, up to 10 mm long, of corroded garnet, cordierite and sillimanite surrounded by biotite. Most garnets have pressure shadows of quartz and plagioclase. The cordierite has been pinitized and contains quartz intergrowths.

The veins and boudins are part of the regional foliation (S_2). Greater than 50 cm boudin spacing along strike indicates an early development of the veins and considerable flattening in S_2. Minor folds in veins and foliation show that F_3 and F_4 affected S_2.

Granitoid Leucosome

White- to cream-weathering granitoid veins (S_{2-3}) ranging from 5 to 35 cm in thickness occur, along with the first generation of leucosome, as layers in the Burntwood Group. These veins are texturally unzoned and have up to 10 mm quartz and feldspar grains with accessory biotite ± garnet. Their composition is probably tonalitic (Fig. GS-7-1a). The largest garnets are 10 mm in diameter and are strongly poikiloblastic. The veins have prominent 1 to 10 mm thick biotite-rich selvages or rare garnet-biotite selvages. The veins cut the older set and are less boudinaged. Most show effects of two phases of deformation. Locally, branches of veins enter the axial surface of F_3 minor folds indicating synkinematic development during early stages of D_3.

Granite Sheets

A prominent set of white- to pale pink-weathering leucogranite sheets (S_{3a}) ranges in thickness from 0.5 to >50 m. It consists of quartz, plagioclase, potassium feldspar and less than 5% of other phases (biotite, garnet, sillimanite, tourmaline). The grain size is generally 4 to 7 mm. More than 60% of the granitic sheets contain prismatic or flattened aggregates of sillimanite that were partially retrogressed to muscovite. Sillimanite also lines shear zones that cut the granite. Garnets are generally widely scattered in the granite but are more abundant near shear zones. The granitoid dykes and sills were emplaced as planar sheets and pods, but their form has been altered by folding, faulting and boudinage. Dykes trend northwest to northeast; they cut earlier veins and locally cut layering in the metagreywacke, but most are parallel to S_2.

Biotite-rich selvages are common at the granite-metagreywacke contacts. These selvages range from millimetres to centimetres in width and are medium to coarse grained. Biotite-rich schlieren, possible metagreywacke rafts, throughout the granite range from several centimetres to metres in length.

Pegmatite occurs as diffuse patches and a sharp-walled dykes throughout the granite and in the metagreywacke. Pods make up less than 15% of the granite, and are up to 3 m wide. Pegmatite contains microcline and quartz crystals, with a maximum length of 10 cm. Few of the pegmatitic patches contain navy blue tourmaline-quartz intergrowths with tourmaline crystals up to 10 cm long.

Sharp-walled pegmatite dykes cutting the main granite have been subdivided on the basis of mineralogy and field relationship. The most abundant set contains feldspar, quartz and biotite. These dykes are up to 1 m wide, typically unzoned, and nearly vertical. Another set contains feldspar, quartz, biotite, tourmaline ± muscovite and garnet. It occurs in one locality as zoned dykes, 1 to 2 m wide. The third type of pegmatite is composed of potassium feldspar, quartz, and biotite, and is slightly myrmekitic. These dykes are <50 cm wide and cut the Burntwood Group metagreywacke. A fourth distinctive variety contains feldspar, quartz, biotite, tourmaline and sillimanite-muscovite. It comprises 2 to 4 m thick composite dykes of internally zoned veins with myrmekitic intergrowths in the feldspar along the margins. These dykes have been subjected to minor silicification and slight brittle deformation.

The S_{3a} granite veins and sheets display open to tight F_3 and F_4 folds (Fig. GS-7-1b). Locally, S_{3a} sheets occupy the axial plane of these structures. Some bodies are massive, but most have at least one measurable foliation. An S_3 foliation, coplanar with S_2, occurs in the margin of some sheets, but a weak, steeply dipping, NNE-trending S_4 foliation is more common (Fig. GS-7-1c). Retrograde muscovite appears to have randomly overgrow all foliations.

a)

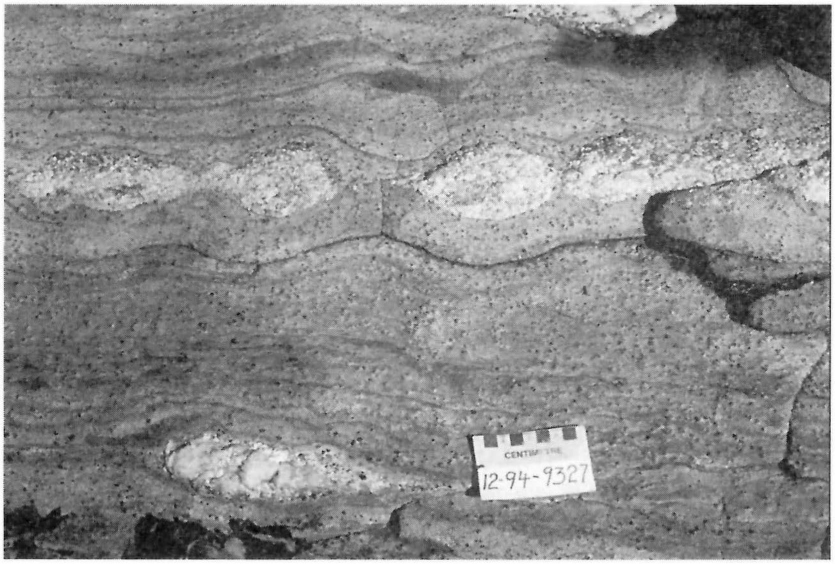
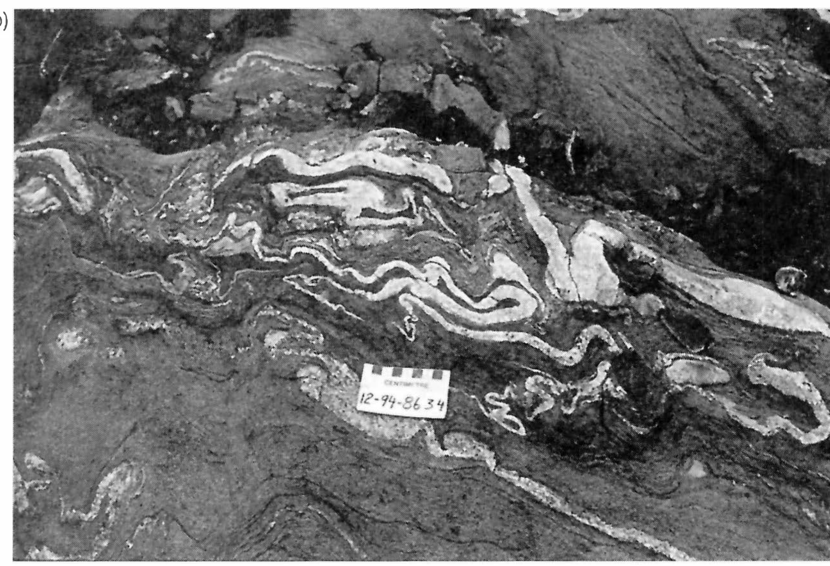


Figure GS-7-1: *Field relationships among leucosomal veins and to fold sets. (a) S1-2 boudin (left of the 10 cm scale card) with quartz core and quartz-feldspar margin, and boudined granitoid S2-3 vein (above the card). (b) S3a granite veins (above scale card) with F3 tight folds (axial plane parallel to long edge of card) and more open F4 cross folds (axial plane parallel to short edge of card). (c) S3b granodiorite vein (to left of card) with folded S3 foliation parallel to the contacts, and S3a granite veins (upper left of photograph) with F4 folds and axial planar S4 foliation.*

b)



c)

Granodiorite Sheets

Light-grey to buff-weathering dykes and veins of a fine- to medium-grained porphyritic granodioritic rock (S_{3b}) make up <1% of the outcrop area. The rock contains up to 10% biotite. Subhedral plagioclase phenocrysts, up to 4 mm, are prominent in the dykes that occur in the Burntwood Group, but the dykes lose their porphyritic texture where they enter the main granite (S_{3a}). These dykes are up to 30 cm wide, cut the metagreywacke and the granite, but are also locally cut by the granite. The dykes feature 3 mm biotite-rich selvages where in contact with the granite.

MESOSOME

The regional host of the granitoid rocks is medium-grey-weathering layered biotite gneiss and garnet-biotite gneiss of the Burntwood Group. The mesosome can be recognized locally as interbedded metagreywacke and metamudstone. Where veins and dykes of S_{2-3} and S_{3a} are abundant, the mesosome contains little or no garnet. It is slightly more schistose, with coarser black biotite that replaced the original garnet. Sillimanite, and locally cordierite, are preserved. On a few outcrops, secondary muscovite occurs in the mesosome.

DISCUSSION

The field relationship between veins and folds indicates that the leucosomes were synkinematic and continued to develop during several phases of deformation. Quartz veins (S_1) may have formed prior to the thermal peak of metamorphism. The veins were boudinaged and feldspar intergrew with quartz at their margin to convert them into S_{1-2}. These veins generally comprise less than 10-15% of the migmatite. Less than 30% of the veins acquired granitic margins rimmed with garnet, cordierite, and sillimanite during continued prograde metamorphism. The high-grade vein assemblage may have formed during the emplacement of a coarsely crystalline F_2 fold nappe to the northeast (Walton Lake nappe, GS-5, this volume). The bulk of the granitoid leucosomes in the migmatite complex described in this report were emplaced in the F_2 Gohl Lake synform (GS-5, this volume) underneath the nappe during continued deformation (D_3) and flux of magma and metamorphic fluid.

The granitoid leucosome (S_{2-3}) was likely emplaced before and during a late phase of folding (F_3). The main granite sheets (S_{3a}) comprise over 75% of some areas with granodiorite (S_{3b}) as a minor phase. The granite and a variety of related pegmatitic phases do not represent a simple *in situ* melt. They may reflect changing conditions in a granitic plumbing system during progressive folding. The granite was concentrated in the F_2 synformal hinge zone, which was reactivated during D_3. The F_3 minor folds do not change symmetry across the early axial surface and thus overprint the F_2 fold. Continued high temperatures during D_3 are indicated by sillimanite, which formed from the breakdown of muscovite in the granite. In the metagreywacke, garnet retrogression to biotite during this time may have required a flow of potassic metamorphic fluid and the introduction of melt from deeper levels within the Kisseynew belt. Upright NNE-trending F_4 folds and S_4 foliation in the granite indicate WNW compression during the last stages of granite and pegmatite emplacement. The end stage of crystallization of these granitic melts may have provided potassic fluid for retrograde muscovite.

GS-8 GEOLOGY OF THE WEBB LAKE-FAY LAKE AREA (NTS 63K/14NE AND 63K/15NW)*

by D.C.P. Schledewitz

Schledewitz, D.C.P., 1994: Geology of the Webb Lake-Fay Lake area (NTS 63K/14NE and 63K/15NW); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 42-46.

SUMMARY

The oldest secondary fabric observed in the Fay Lake-Syme Lake to Ponton Lake segment of the Fay Lake-Webb Lake area is a penetrative ductile foliation (S_1) with a variable dip. The zone along the trend of the contact between Missi Group rocks and rocks of the Flin Flon greenstone belt is characterized by penetrative foliation and mylonitic fabrics. These S_1 fabrics have been overprinted by conjugate shears and folding in a regime of brittle-ductile deformation. Steeply dipping dextral extensional shear bands with easterly to southeasterly trends intersect the S_1 metamorphic layering at a low oblique angle and the related sinistral conjugate shears have a northeasterly to northwesterly trend. The youngest structures are conjugate faults of a clearly brittle character that overprint all other fabrics. These structures vary from small scale centimetre-size structures to large scale north-trending faults.

INTRODUCTION

Mapping was confined to a three-week period in late May to mid-June in the area of Fay Lake to Syme Lake and the area of Ponton Lake to Koscielny Lake (Fig. GS-8-1). Mapping in the Fay Lake to Syme Lake area was undertaken to exploit the excellent bedrock exposure in areas logged by Repap Inc. in 1992 and 1993. Further east in the Ponton Lake - Koscielny Lake area, pillowed volcanic flows southeast and east of Ponton Lake were sampled to better delineate the character and distribution of the mafic and ultramafic flows indicated by limited sampling from this region by Zwanzig (1993). Preliminary results of mapping in the Webb Lake-Fay Lake project area indicated a varied mineralogical and geochemical character to the volcanic rocks of the Flin Flon belt north of Koscielny Lake (Schledewitz, 1993). These results necessitated additional sampling and mapping in 1994.

Both the Fay Lake-Syme Lake and Ponton Lake - Koscielny Lake areas examined in 1994 straddle the boundary of the Kisseynew gneiss terrane and the Flin Flon volcanic belt.

FAY LAKE - SYME LAKE REGION

The area examined lies along the north side of Fay Lake and Syme Lake (Fig. GS-8-2). Bedrock exposures in newly logged areas are clean, readily accessible and easily located using post-logging air photographs.

A 400 to 600 m wide zone, referred to as Zone A, lies along the north shore of Fay Lake and Syme Lake. It comprises Missi Group

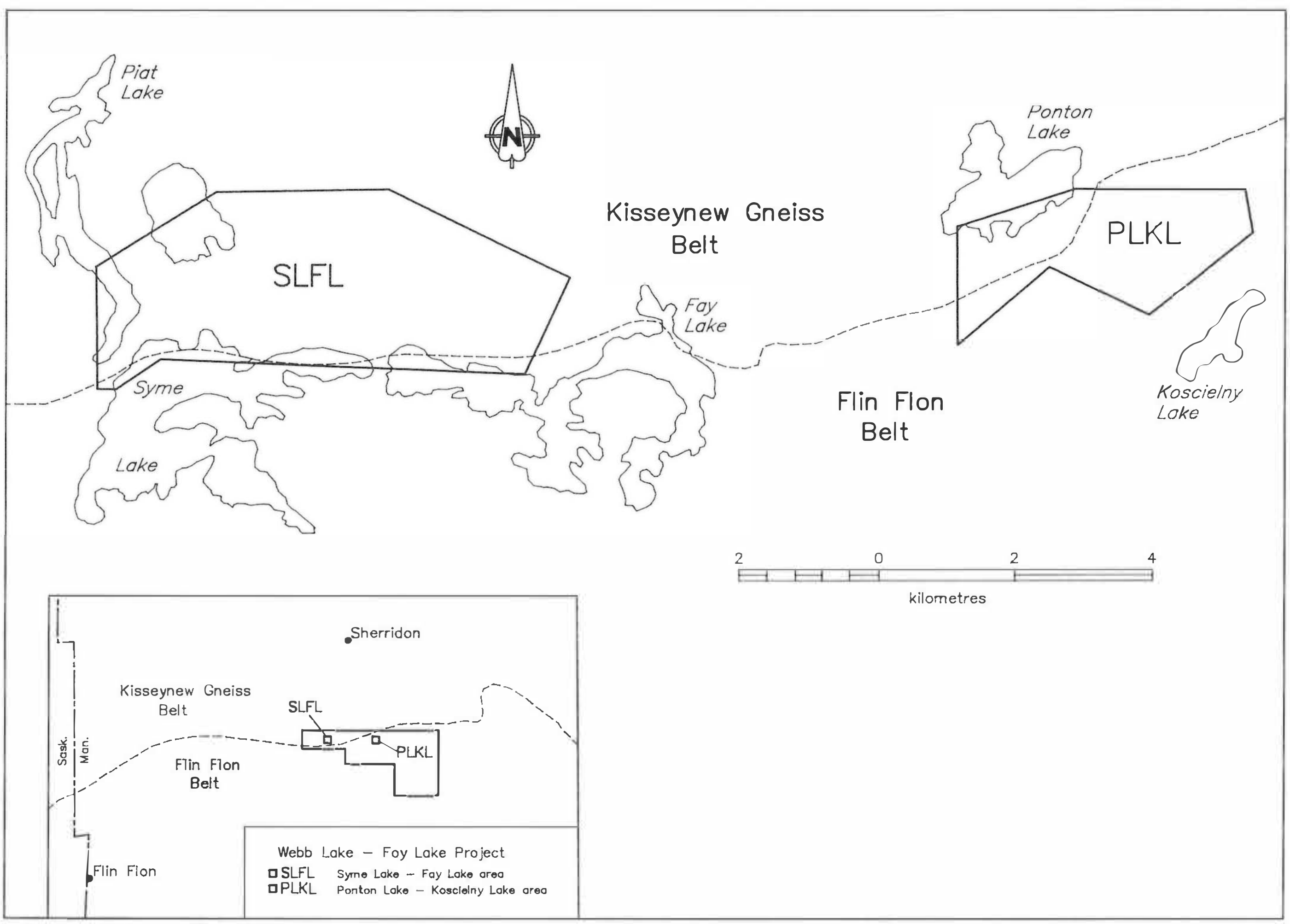


Figure GS-8-1: Location of the Syme Lake-Fay Lake (SLFL) and Ponton Lake - Koscielny Lake (PLKL) areas mapped in 1994.

* Funded by Provincial A-Base

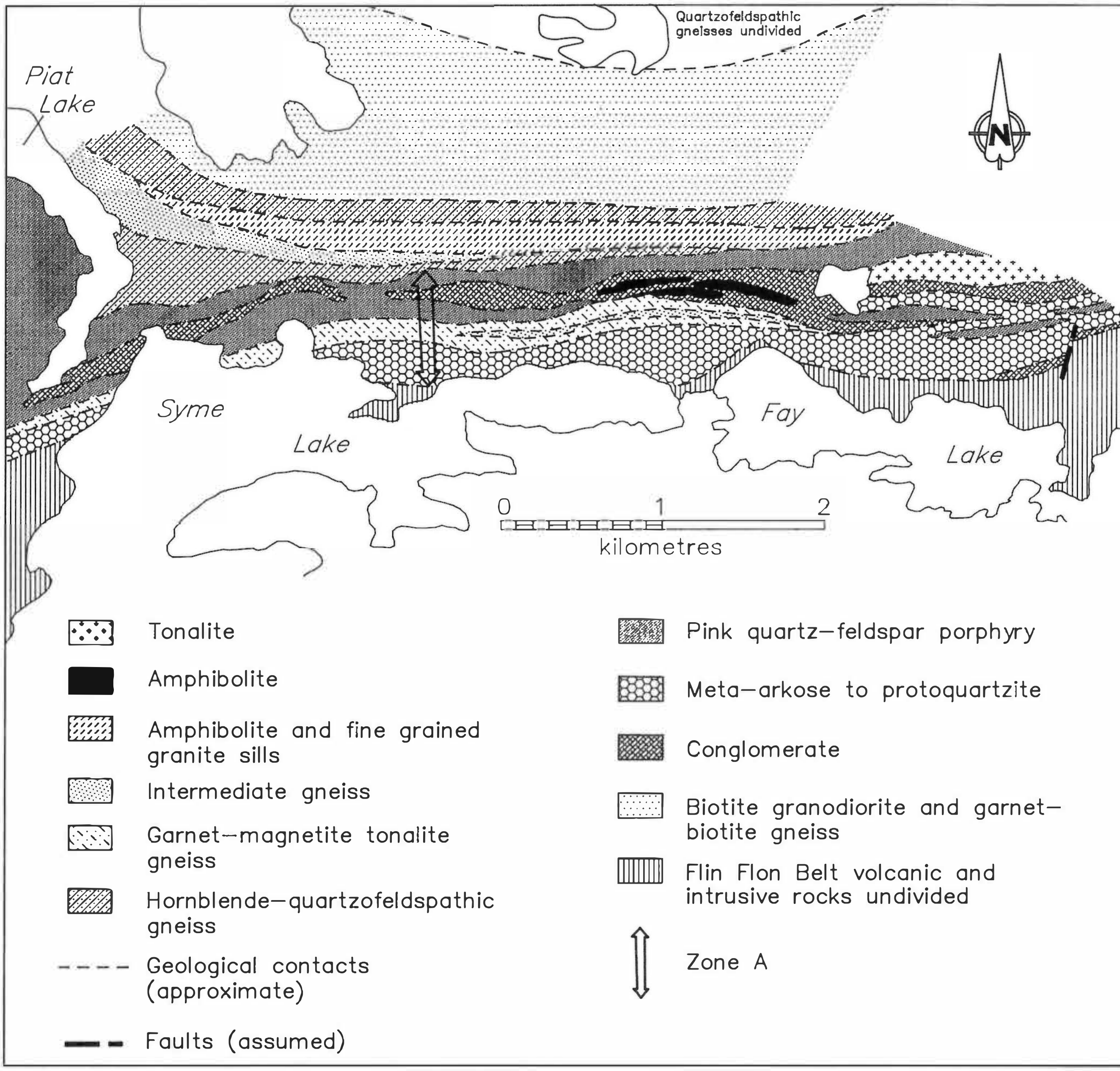


Figure GS-8-2: Simplified geology of the Syme Lake-Fay Lake area.

paragneiss intruded by felsic quartz porphyry, fine grained variably garnetiferous and magnetiferous tonalite, quartz diorite, gabbro and diabase. These intrusive rocks, with the exception of the diabase, predate the earliest penetrative fabric observed in the Missi Group rocks. The contacts of these pre-S_1 intrusive rocks generally parallel the earliest foliation indicating a high degree of strain. The Missi Group rocks are well foliated conglomerate and fine grained quartzofeldspathic rocks with sporadic isolated quartz pebbles and quartz pebble-bearing lenses. A single outcrop of Missi Group metaconglomerate within Zone A along Piat Creek between Piat Lake and Syme Lake exhibits three distinct fabrics. Primary layering S_0 is defined by interlayered conglomerate, light grey orthoquartzite layers and dark grey fine grained more micaceous layers. S_0 is tightly folded with a well developed penetrative axial planar foliation and major transposition of primary layering. The metamorphic layering and axial planar fabric, which is at a high oblique angle to primary layering S_0 at this locality, appear to be the earliest secondary fabric (S_1). The metamorphic layering S_1 was overprinted by a second penetrative fabric S_2, which is at an angle of 15° to 20° to S_1 and axial planar to S-folded S_1 metamorphic layering.

The southern contact of these Missi Group rocks with rocks of the Flin Flon volcanic belt is exposed only at the west end of Fay Lake. At this locality, Missi Group foliated fine grained quartzofeldspathic granoblastic rocks lie to the north of a medium- to coarse-grained amphibolite. The amphibolite is similar to gabbroic rocks that intrude rocks of the Flin Flon volcanic belt as mapped along and east of Fay Lake (Schledewitz, 1992, 1993). A 9 m wide, foliated, layered, variably garnetiferous, hornblende-bearing, quartzofeldspathic granoblastic rock lies between these two rock types. The contacts and layering dip steeply and variably to the north and south and exhibit rare isoclinal intrafolial folds. The 9 m thick hybrid gneiss at the contact indicates shearing and intrusion during ductile deformation. This layering was folded about steeply dipping north- and northwest-trending axial planes with only a weak axial planar fabric.

S_1 in Zone A is folded on a large scale into a open arcuate structure with a northwest-trending axial plane. S_1 was reworked during this deformation, and S_1 and S_2 were largely coplanar with local overprinting by S_2.

The rocks immediately north of Zone A are more highly strained and comprise a suite of felsic and intermediate gneisses and amphibolites (Fig. GS-8-2). The affinities of these rocks are more problematic and the distinction between orthogneiss and paragneiss is not always clear. Lying immediately to the north is a complex of foliated biotite granodiorite and variably garnetiferous biotite-feldspar-quartz gneiss of the Burntwood Group (Schledewitz, 1992, 1993). These rocks are tightly folded with northwest-trending axial planes and intermediate to shallow dips to the northeast (Fig. GS-8-4). The formation of these folds, characterized by the absence of an axial planar fabric, postdates the generation of a very well developed penetrative foliation and metamorphic layering S_1. The earlier S_1 fabric has been reworked, having undergone layer-parallel slip during this phase of folding. The S_1 layering and foliation is also overprinted by an easterly trending upright penetrative fabric (S_2), which is highly variable in intensity ranging from a schist to a mylonite.

This style of tight folds with intermediate to shallowly dipping axial planes contrasts with the single large open structure that occurs to the south in Zone A. The presence of the easterly S_2 fabric relates to a detachment zone(s) that accommodated the differential movement required to produce differing structures in adjacent areas.

A third foliation (S_3), a variably muscovite-bearing schistosity, sporadically overprints S_1 and S_2. Muscovite also occurs along foliation planes in areas of boudinage. The youngest structures are a set of brittle conjugate faults (S_4) with sinistral apparent displacement on north- to northwest-trending structures and dextral displacement on northeasterly structures.

PONTON LAKE - KOSCIELNY LAKE

Missi Group

A 650 m wide section of Missi Group paragneiss and sills of quartz porphyry, quartz diorite and amphibolite lies south of Ponton Lake. This section comprises quartzofeldspathic paragneiss with sporadic crossbeds, isolated pebble beds, cobbles and thin lenses of conglomerate (Fig. GS-8-3). As in the section of Missi Group rocks in Zone A along the north side of Syme Lake and Fay Lake, the emplacement of the intrusive rocks predated the earliest recognizable secondary penetrative fabric (S_1). The contacts of these pre-S_1 intrusive rocks are generally parallel the earliest foliation indicating a high degree of strain. Intrafolial folds with a down dip plunge are common in some layers.

On a large scale the contact between the Missi Group rocks and the rocks of the Flin Flon belt are folded into a large S-shaped structure (Fig. GS-8-4). S_1 in the Missi Group rocks in general parallels this contact. Locally, S_1 fabric is folded and overprinted at a low oblique angle by a well developed S_2 schistosity. This overprinting relationship is most evident on the northwest-trending short limb of the large scale S-fold (Fig. GS-8-4). Post-S_1 conjugate ductile-brittle shears (S_2) were observed at several localities. Steeply dipping dextral extensional shear bands with easterly to southeasterly trends intersect the S_1 metamorphic layering at a low oblique angle while the related sinistral conjugate shears have a northerly trend.

Amisk Group

Several types of pillowed flows were distinguished and sampled during the course of mapping in the area southeast and east of Ponton Lake. However, the large volumes of massive to amygdaloidal basalt, diorite, gabbro, and diabase sills and dykes disrupt the mappable continuity of the different types of flows (Fig. GS-8-3). The massive to amygdaloidal basalt, which locally exhibits columnar jointing, predates the intrusion of the gabbro and diabase. The preserved areas of pillowed flows vary from 20 m^2 to 1 km^2. The presence of at least one penetrative fabric and the effects of recrystallization obscure the distinction between massive mafic flows and fine grained mafic intrusions.

The most common types of pillowed flows are green, plagioclase phyric and aphyric mafic flows with small pillows, commonly with epidotized cores. Identification of flow top breccia locally indicates that the highly penetrative fabric is oblique to the primary layering in many cases. However, the zones of supracrustal rocks are generally elongated parallel to the penetrative fabric suggesting a high degree of strain. Less common types of flows are:

a) dark green, pyroxene and plagioclase phyric, pillowed and massive;
b) dark grey-green, basaltic, pillowed with epidosite cores;
c) rusty, grey, plagioclase phyric, large pillows up to 1.5 m with dark green pillow selvages that contain garnet;
d) a single occurrence of well preserved pale green pillows with well developed pipe vesicles that contain very dark green to black fine grained biotite.

The post-Missi S_1 fabrics in the Ponton Lake - Koscielny Lake area and to the west in the Fay Lake-Syme Lake area have been deformed into large scale asymmetric S- and Z-shaped structures (Fig. GS-8-4). S_2 is coplanar to S_1 on the long limbs, but clearly overprints S_1 at low oblique angles on the short limbs of these structures. The contact between the Missi Group rocks and rocks of the Flin Flon belt appears to parallel the trend of the post-Missi S_1 fabric. The trend of a schistosity defined by the orientation of flattened pillows in Flin Flon belts rocks appears to parallel the trend of the S_1 fabric in the Missi Group rocks. This schistosity (S_1) is intersected by a younger penetrative foliation (S_2), which locally transposes the earlier fabric. At one locality a dextral shear sense is indicated along the S_2 orientation. The effects of the overprinting by post-Missi S_1 and S_2 deformational fabrics are so pervasive that they are generally the earliest recognizable fabrics. However, at a single locality approximately 1.8 km east of Ponton Lake, north-trending primary igneous layering is intersected at a high angle by only one penetrative fabric that transposed much of the layering into a easterly orientation preserving only short segments of the primary fabric. The primary layering is in a differentiated rhythmically layered gabbro sill and a similarly oriented well preserved segment of a pillowed mafic flow. Both top and dip to the west at 40° to 90°. Although this is a single location, it does indicate that pre-S_1 fabrics may have been oriented at a high angle to S_1.

DISCUSSION

Mapping of the regions that straddle the boundary of the Kisseynew gneiss terrane and the Flin Flon volcanic belt was undertaken to integrate the structural geology of the two apparently differing terranes. To the north the region is characterized by post-Missi Group southwest-vergent ductile flow. This has deformed metamorphosed and foliated Missi Group and Burntwood Group supracrustal-derived gneisses and igneous rocks. This ductile event has also deformed the Amisk Group infrastructure gneisses that comprise both supracrustal volcanic rocks of the Amisk Group and plutonic rocks of both pre- and post-Missi Group. 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.

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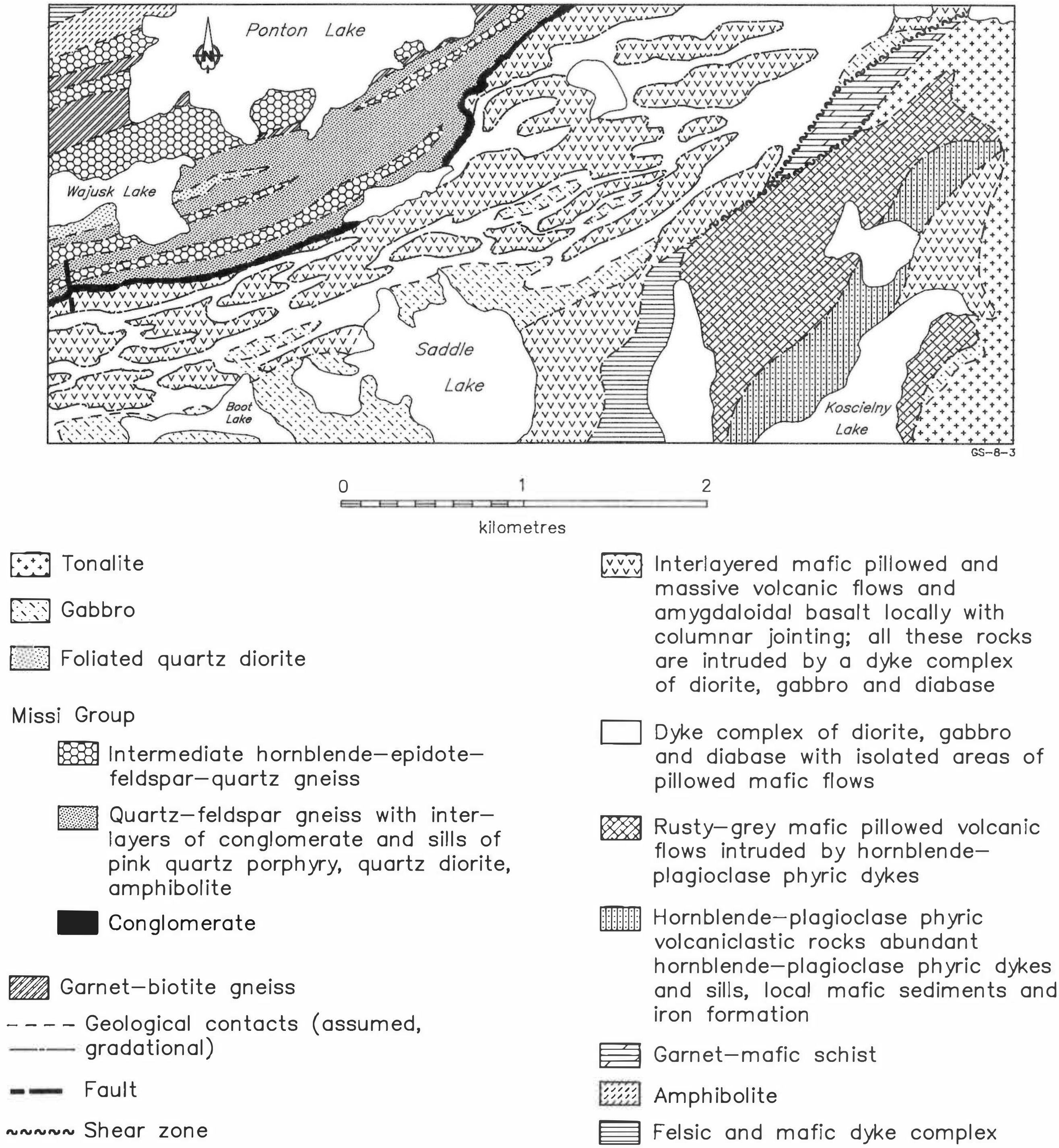

Figure GS-8-3: Simplified geology of the Ponton Lake - Koscielny Lake area.

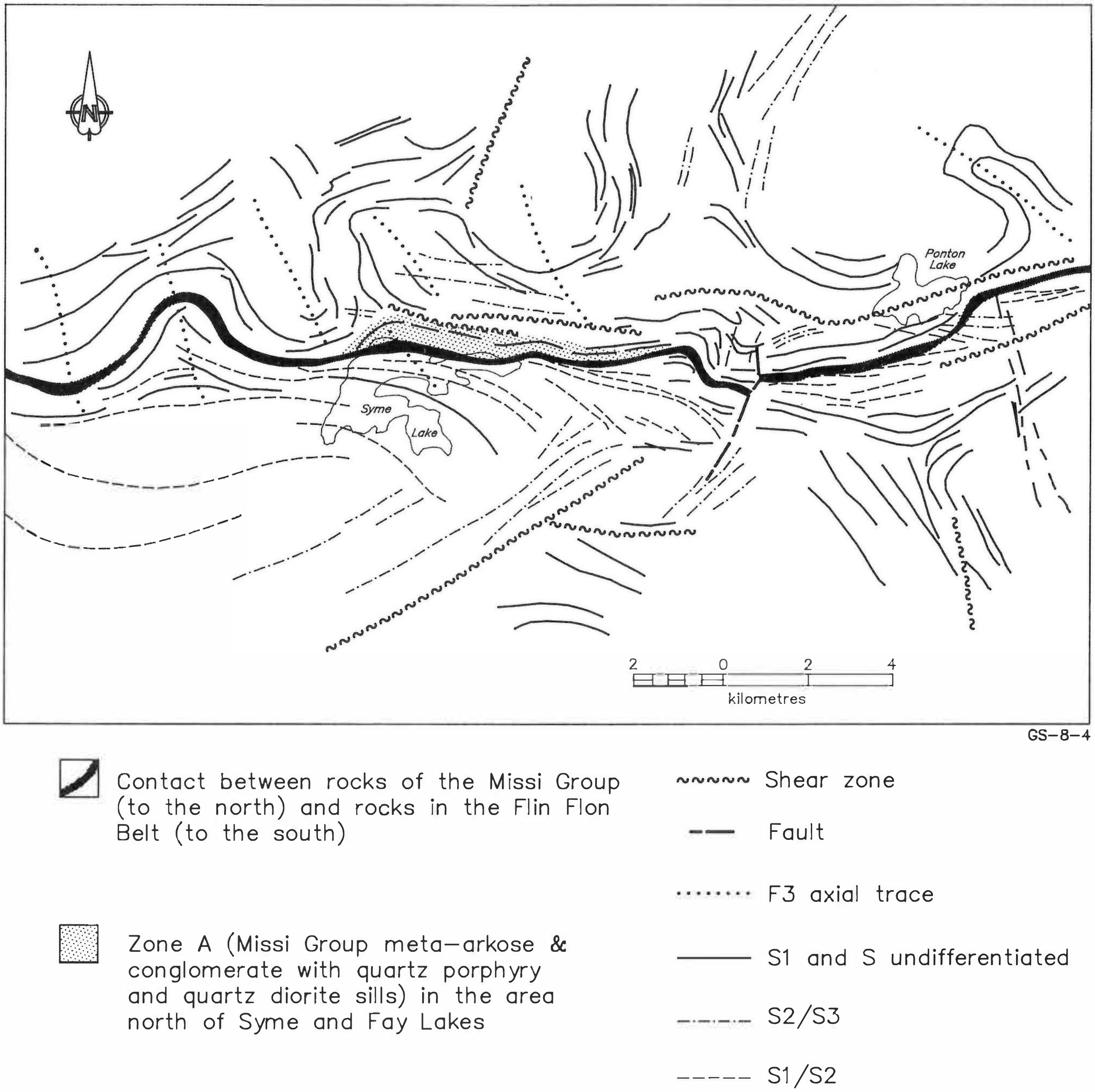

Figure GS-8-4: Structural trends in the Syme Lake to Ponton Lake region.

GS-9 SUPRACRUSTAL ROCKS OF THE ISKWASUM LAKE AREA (63K/10W)*

by E.C. Syme

Syme, E.C., 1994: Supracrustal rocks of the Iskwasum Lake area (63K/10W); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 47-56.

SUMMARY

Geochemically and lithologically distinct ocean-floor formations previously mapped at Elbow Lake are tectonically juxtaposed at Iskwasum Lake by the southern continuation of the Elbow Lake Shear Zone. This structure extends through Iskwasum Lake as a previously unrecognised zone of mafic mylonites and tectonites up to 900 m wide. The main mylonitic fabric in the ELSZ predates most other structures and fabrics mapped at Iskwasum Lake. The fact that the shear zone is folded is consistent with its apparent antiquity, suggesting that the structure is an early manifestation of the terrain accretion that led to the formation of the "Flin Flon collage".

The Iskwasum Lake mafic-ultramafic intrusive complex is lithologically similar to gabbroic complexes at Elbow Lake, Claw Lake and Athapapuskow Lake, and all are associated with ocean-floor basalts. Preliminary data from Claw Lake suggest that the layered intrusions and the ocean-floor basalts are coeval and possibly consanguineous. Geochronologic and geochemical studies are underway to aid in the interpretation of the tectonic setting of the layered complexes.

INTRODUCTION

Supracrustal rocks in the Iskwasum Lake area (NTS 63K/10W) were examined during a three week reconnaissance. The area is part of the Paleoproterozoic Flin Flon metavolcanic belt, and lies south of the recently mapped Elbow Lake area (Syme, 1990, 1991, 1992; Fig. GS-9-1). The goals of the reconnaissance were to: 1) evaluate existing geological maps (Hunt, 1970); 2) trace structures from Elbow Lake through the Iskwasum Lake area; 3) identify the volcanic and intrusive lithologies for possible correlation with rock types in adjoining map areas; and 4) evaluate the massive sulphide potential of the area. Concurrent studies in the Iskwasum Lake area include those of D. Morrison (granitoid rocks in 63K/10) and Heine (1993; GS-10, this volume: mineral occurrences in 63K/10).

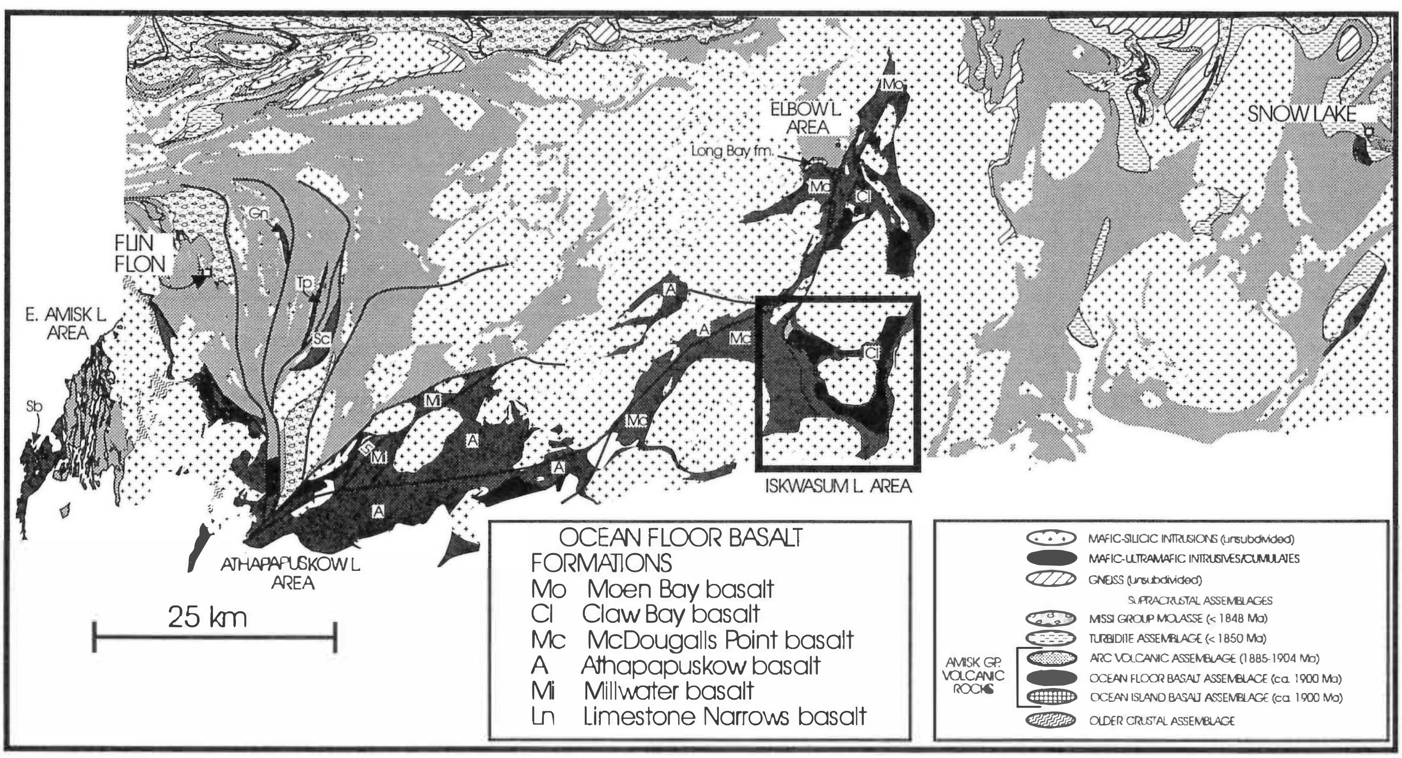

Figure GS-9-1: Geological map of the central portion of the Flin Flon belt (from Stern et al., in prep.), showing the distribution of ocean-floor basalts, ocean-island basalts, and arc volcanic rocks.

* Funded by Provincial A-Base

Bedrock exposure quality in the Iskwasum Lake area is poor. Shoreline outcrops are generally small and lichen covered, and inland outcrops, though locally abundant, are almost totally covered with a thick carpet of moss and lichen. Similar conditions prevailed in the adjacent Elbow Lake area, precluding detailed mapping until a forest fire in 1989 created sufficient clean exposure to allow 1:20 000 geological mapping (Syme, 1990, 1991, 1992). Consequently during this study work was concentrated on the better-exposed shore of Iskwasum Lake.

Preliminary Map 1994F-1 is a compilation of existing maps and information obtained this season. The geology of the supracrustal rocks is based on Hunt (1970), extensively modified by the current project and unpublished work by J. Young (pers. comm., 1994) on the mafic/ultramafic rocks in the area. D. Morrison (unpublished data) re-mapped all of the granitoid rocks in 63K/10; his work is abstracted in Preliminary Map 1994F-1.

GEOLOGICAL SETTING

Based on existing mapping and new geochronological and geochemical data from the Flin Flon belt, Lucas *et al.* (in prep.) and Stern and Lucas (1994) describe a 1.88-1.87 Ga episode of intraoceanic accretion that led to the formation of an accretionary collage consisting of diverse tectonostratigraphic assemblages. The "Flin Flon collage" consists of 1.9 Ga juvenile arc volcanic rocks, isotopically evolved arc plutonic rocks, 1.9 Ga ocean-floor and rare ocean-island basalts, and 1.85 Ga greywacke-turbidite. The collage was subsequently stitched by 1.87-1.84 Ga calc-alkaline plutons related to a younger magmatic arc that developed upon the older accretionary complex (Lucas and Stern, in press; Lucas *et al.*, in prep.; Stern and Lucas, in press; Stern *et al.*, in press, in prep.).

Supracrustal rocks in the Iskwasum Lake area form part of a large tract of approximately 1.9 Ga ocean-floor basalts that occurs between Elbow Lake and Athapapuskow Lake (Fig. GS-9-1; Syme and Bailes, 1993; Syme, 1993; Stern *et al.*, in prep.). Ocean-floor basalts have MORB and back-arc basin (BABB) affinities, and can be geochemically subdivided into 1) N-types, resembling N-MORBs and Marianas-type BABB, and 2) E-types, resembling transitional and plume MORBs (Stern *et al.*, in prep.). The ocean-floor basalts form laterally continuous units distinguished by flow organization, alteration assemblage, weathering colour and aeromagnetic signature (Table GS-9-1), as well as geochemical characteristics (Stern *et al.*, in prep.). Two of these informal formations are present in the Iskwasum Lake area: Claw Bay basalt/ Centre Lake mafic tectonite and McDougalls Point basalt. Both formations were defined and mapped in the Elbow Lake area (Syme, 1991, 1992). McDougalls Point basalt is also an important unit in the Cranberry lakes area (Syme, 1993).

At Elbow Lake Claw Bay basalt and McDougalls Point basalt are tectonically juxtaposed by the southern continuation of the Elbow Lake Shear Zone (ELSZ; Syme, 1991, 1992; Ryan and Williams, 1993, GS-20, this volume). The ELSZ extends through Iskwasum Lake as a previously unrecognised zone of mafic mylonites and tectonites up to 900 m wide. The shear zone is folded and, as at Elbow Lake, separates McDougalls Point basalt on the west from Claw Bay basalt/Centre Lake mafic tectonite on the east. A large mafic-ultramafic intrusive complex correlative with mafic complexes at Elbow and Claw lakes (Syme, 1991, 1992) is associated with Centre Lake mafic tectonite and is similarly restricted to the east side of the structure.

MAJOR SUPRACRUSTAL ROCK TYPES

Claw Bay basalt/Centre Lake mafic tectonite

Mafic metavolcanic rocks in the central and eastern Iskwasum Lake area were termed "Barb Lake amphibolite" by Hunt (1970). These rocks are continuous with the better known Claw Bay basalt (and its high-strain equivalent Centre Lake mafic tectonite) in the Elbow Lake area (Syme, 1992; Syme and Whalen, 1992; Table GS-9-1). They are not extensively exposed at Iskwasum Lake, and no new understanding of their petrogenesis was made. However, recent geochemical studies (Stern *et al.*, in prep.) have confirmed the preliminary interpretation (Syme, 1992) that Claw Bay basalt is the product of ocean-floor volcanism.

At Elbow Lake scattered facing determinations suggest that Claw Bay basalt is isoclinally folded (Syme, 1991). Moderately preserved Claw Bay basalt at Elbow Lake grades eastwards (towards the Gants Lake batholith) into strongly deformed, laminated Centre Lake mafic tectonite. Primary pillow structures such as selvages have been obliterated in the mafic tectonite. Epidosite domains that formed in the cores of pillows are flattened into oval or lens shapes, and the rocks commonly display a crude banding or lamination due to the attenuation of heterogeneities (such as selvages) that were present in the original pillows. Adjacent to the Gants Lake batholith the tectonite is a thinly laminated, fine grained mafic gneiss that contains ribbon-like epidosites.

Claw Bay basalts have major element and incompatible trace element trace element characteristics within the range exhibited by modern N-MORBs, and have LILE/HFSE ratios suggesting a small crustal (arc?) component (Stern *et al.*, in prep.). They were likely emplaced in an ensimatic back-arc basin, remote from arc magmatism or terrestrial sedimentation (Stern *et al.*, in prep.).

McDougalls Point basalt

McDougalls Point basalt ("Grass River pillow lavas" of Hunt, 1970) underlies a broad area between Iskwasum Lake and the Cranberry lakes (Fig. GS-9-2), but is little exposed on the shore of Iskwasum Lake.

At Elbow Lake (Syme, 1991, 1992) McDougalls Point basalt is a well preserved basaltic sequence at least 1100 m thick, folded in north-northeast trending isoclinal folds. Flows in McDougalls Point basalt weather light buff to brownish buff, are light grey on fresh surface, and are dominantly pillowed. They are mainly aphyric, but also include plagioclase phyric and plagioclase-pyroxene phyric members. Apart from minor interflow hyalotuff layers and extensive synvolcanic diabase/gabbro intrusions, there are no significant non-basaltic members in the sequence.

Basalt and diabase outcrops on the western shore of Iskwasum Lake display moderate to strong penetrative fabrics and obliteration of most primary textures. Pillows, amygdales and amoeboid pillow breccia are preserved in low-strain domains. Good preservation of pillows and flow contacts is found only beyond about 300 m from the edge of the ELSZ mylonite belt. These better preserved flows are lithologically similar to McDougalls Point basalt on Elbow Lake (Table GS-9-1), and include map-scale units of aphyric and porphyritic basalt.

Like Claw Bay basalt, McDougalls Point basalt is an N-MORB with a small crustal (arc?) component, likely erupted in an ensimatic back arc basin (Stern *et al.*, in prep.). The two units are lithologically and geochemically distinct. For example, REE patterns for McDougalls Point basalt are typically flat, at 10 times chondrite, while Claw Bay basalts have LREE-depleted, flat, and weakly LREE-enriched patterns (Syme, 1992; Stern *et al.*, in prep.).

Iskwasum mafic-ultramafic intrusive complex

The Iskwasum mafic-ultramafic complex is a large, apparently stratiform intrusion ("Serpentinites and associated rocks" of Hunt, 1970), emplaced in Centre Lake mafic tectonite on the east side of the ELSZ. No outcrops of this distinctive unit occur on the west side of the shear zone. The intrusion is truncated in the northeast by the 1864 Ma (Whalen and Hunt, in press) Elbow Lake pluton, and extends south from Barb Lake, through the islands of Iskwasum Lake, and along the east side of the Grass River. A narrow, discontinuous band extends northeast, along the Grass River strand of the ELSZ.

Shoreline exposures of the complex include variably tectonized gabbro and serpentinite. Preservation of primary structures and textures is poor relative to the excellent state of preservation and exposure of similar rocks at Claw Lake (Syme, 1992). Portions of the complex were mapped by J. Young (unpublished data).

The gabbroic component of the complex is typically medium grained, mesocratic, with 1-2 mm lath-shaped plagioclase and interstitial green amphibole after pyroxene. Anastomosing pale yellow-green epidote/zoisite fractures and veins, anastomosing cm-scale shear zones, variably developed alteration, and local gabbroic pegmatite veins and patches combine to produce a highly heterogeneous rock.

Table GS-9-1
Summary of ocean-floor and ocean island basalt formation characteristics, Flin Flon - Iskwasum Lake (geochemical classification from Stern *et al.*, in prep.)

Generation	Trend	Structures, fabrics, age relationships
S_0	N - NNE	• primary bedding and flow contacts in McDougalls Point basalt
S_1	N - NNE	• weak bedding-parallel foliation in McDougalls Point basalt • N-trending foliation in Iskwasum mafic complex, Centre Lake mafic tectonite
S_2	Folded: NE, WNW, NW, NNE	• Elbow Lake shear zone on Iskwasum Lake - juxtaposes McDougalls Point basalt against Centre Lake mafic tectonite and Iskwasum mafic-ultramafic complex - dominant mylonite/tectonite fabric on Iskwasum Lake - cuts across S_0 and S_1 • associated penetrative foliation extends >1 km into wall rocks
S_3	NNW, N	• N-trending East Iskwasum shear zone - crenulation cleavage to mylonitic foliation, mainly in Iskwasum mafic complex - S_3 cleavage overprints S_2 foliation
S_4	N	• S-trending faults, Grass River area - dextral and sinistral offset of folded Elbow Lake shear zone - shear fabric within and adjacent to some faults, locally overprinted by S_6 spaced cleavage.
S_5	W	• Berry Creek fault - dextral fault/shear zone - dextral deflection of Elbow Lake shear zone, Loucks Lake shear zone, and Gants Lake batholith into an westerly trend • associated ENE-trending F_5 folds in Loucks Lake mylonite, S_5 axial planar spaced fractures, S_5 ultramylonite zones adjacent to the Berry Creek fault on southern Iskwasum Lake • W-trending spaced fabric in Gants Lake batholith within 2 km of Berry Creek fault, overprinting S_2 structures
S_6	NE	• NE-trending regional cleavage - spaced chlorite crenulation cleavage, spaced fracture cleavage, spaced quartz-filled cleavage; minor penetrative foliation; includes cm-m scale ductile shear zones on southern Iskwasum Lake - overprints S_2, S_3 and S_4 fabrics on central and northern Iskwasum Lake, Grass River - same generation as S_7?
S_7	NE	• NE-trending shear zone, southern Iskwasum Lake - truncates S_3 East Iskwasum shear zone. S_7 tectonite/mylonite fabric overprints and re-orients S_3 cleavage, and is axial planar to F_7 folds in S_3 cleavage - anastomosing dextral shears developed in and coplanar with S_2 shear zone, southern Iskwasum Lake
S_8	N	• East Iskwasum fault - truncates NE-trending S_7 shear zone, southern Iskwasum Lake - cuts across the S portion of the Gants Lake batholith reoriented into the S_5 Berry Creek direction - well developed shear fabric within and adjacent to the fault, including in the S_7 zone • spaced cleavage and minor shear zones in Gants Lake batholith, locally overprinting W-trending S_5(?) structures, within 1 km of the fault

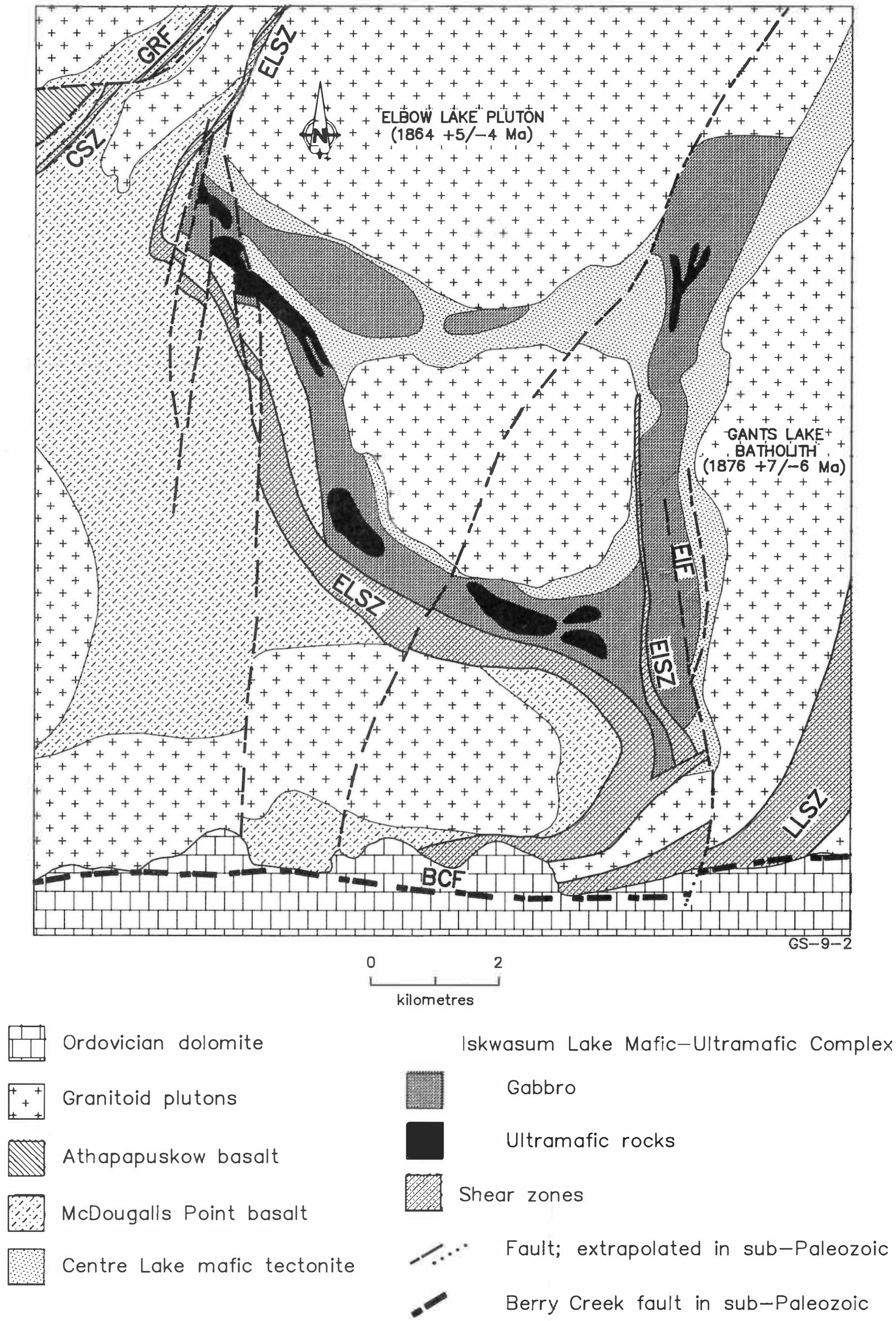

Figure GS-9-2: *General geology of the Iskwasum Lake area (topography omitted). **BCF**-Berry Creek fault (position shown in the sub-Paleozoic); CSZ-Cranberry shear zone; **EISZ**-East Iskwasum shear zone; **EIF**-East Iskwasum fault; **ELSZ**-Elbow Lake shear zone; **GRF**-Grass River fault; **LLSZ**-Loucks Lake shear zone. Pluton U-Pb zircon age determinations from Whalen and Hunt (in press).*

Ultramafic rocks on Iskwasum Lake typically weather buff-brown and are composed of varying proportions of serpentine, talc, carbonate and hematite. Massive varieties are rich in serpentine, whereas sheared ultramafic rocks are typically represented by talc-carbonate-hematite schists. Veins of fibrous, brittle asbestos up to 10 cm wide, and talc veins up to a few cm wide, occur locally in the altered ultramafic rocks. Asbestos and talc localities on Iskwasum Lake have been located and investigated by Hunt (1970), Gunter and Yamada (1986), Gunter (1988), and Heine (1993).

Layered gabbro-pyroxenite-peridotite intrusive complexes occur in Claw Bay basalt/Centre Lake mafic tectonite on the west, east and south sides of the 1864 Ma (Whalen and Hunt, in press) Elbow Lake tonalite pluton. The lithologic similarity and near continuity of these complexes peripheral to the Elbow Lake pluton suggest they may be related, perhaps originally in a single large stratiform intrusion (Syme, 1992). Preliminary U-Pb zircon data from a gabbroic pegmatite at Claw Lake suggest that the gabbroic complexes are the same age as ocean-floor basalts in the Athapapuskow - Elbow segment of the belt (Stern *et al.*, in prep).

STRUCTURE

The principal structural elements distinguished during this study are listed in Table GS-9-2. The listing is preliminary and not intended to be comprehensive; it summarizes observed fabric age relationships within the mapped shoreline corridor.

Bedding (S_0) and early foliation (S_1)

The earliest structures observed are bedding or flow contacts (S_0) within McDougalls Point basalt. These are commonly north- to north-northeast-trending, but are rotated sinistrally into the S_2 Elbow Lake shear zone. No primary flow attitudes were determined in the small portion of Claw Bay basalt/Centre Lake mafic tectonite exposed on Iskwasum Lake.

A weak bedding-parallel foliation (S_1) occurs in McDougalls Point basalt west of Iskwasum Lake, and appears to be the earliest fabric on the west side of the ELSZ. The earliest fabric east of the ELSZ, developed in Centre Lake mafic tectonite and the Iskwasum mafic-ultramafic intrusive complex, is a strong, north-trending penetrative foliation and tectonic lamination. Present data do not allow confident correlation of the northerly "S_1" fabrics on the west and east sides of the ELSZ; they are grouped together on Table GS-9-1 because they are both the earliest recognised fabrics on their respective sides of the ELSZ.

Elbow Lake Shear Zone (S_2)

The strongest cleavage regionally developed on Iskwasum Lake (S_2) is related to the Elbow Lake Shear Zone (ELSZ). Within the shear zone the fabric is commonly mylonitic, comprising tectonically laminated mafic rocks derived from basalt, tectonites derived from gabbro, serpentinite and pyroxenite, and cm-m scale synkinematic felsic intrusive sheets. A penetrative fabric related to the shear zone is developed for at least 1 km into adjacent wall rocks. On western Iskwasum Lake the ELSZ (and the S_2 fabric) cuts S_0 and S_1 at a high angle. In the Grass River area S_2 and S_0 are subparallel, possibly indicating early folding of S_0.

The ELSZ on Iskwasum Lake is 60 to 900 m wide. It is narrowest in the north, where it follows the southwesterly course of the Grass River from Elbow Lake. The shear zone is folded through 90° where the Grass River widens and changes to a southeasterly course. The ELSZ then trends broadly southeast through northern Iskwasum Lake. At the southern part of the lake the shear zone is again folded, and apparently dragged dextrally into a westerly orientation by the Berry Creek Fault (BCF).

For most of its length on Iskwasum Lake the ELSZ is a tectonic boundary that separates lithologically and geochemically distinct rock units: McDougalls Point basalt on the west, and Centre Lake mafic tectonite plus Iskwasum mafic-ultramafic complex on the east. At Elbow Lake the ELSZ similarly juxtaposes unrelated tectonostratigraphic assemblages (Syme, 1990, 1991, 1992). Significantly, the wide belt of tectonite and mylonite that comprises the ELSZ is not everywhere the boundary between McDougalls Point basalt and Centre Lake mafic tectonite/Iskwasum Lake mafic-ultramafic complex. On northern Iskwasum Lake, where the Grass River enters from the north, an apparent splay from the ELSZ takes a more northerly trend and forms the tectonic contact between McDougalls Point basalt on the west and the mafic-ultramafic complex on the east. The splay is a more discrete structure than the ELSZ, and is marked along its length by early cataclasis and subsequent ductile deformation. The precise age of this structure relative to the main mylonitic zone is not known; however, this fault is folded with the ELSZ and is offset by S_4 south-trending faults.

At Elbow Lake the ELSZ has a long and complex movement history, but a sinistral component of displacement can be documented (Syme, 1991, 1992; Ryan and Williams, 1993). Similarly, at Iskwasum Lake S_0 and S_1 appear to have been deflected into S_2 in a manner consistent with sinistral shear. However, local dextral kinematic indicators (winged porphyroclasts and C-S fabrics) indicate that the shear zone is as complex as at Elbow Lake. Lineations in the ELSZ are steep. On southern Iskwasum Lake the lineation plunges steeply (80°) southeast, while on the western part of the lake it plunges steeply (55°-76°) southwest.

Loucks Lake Shear Zone (ca. S_2?)

The Loucks Lake Shear Zone (LLSZ) is a major, north-trending structure within the Gants Lake batholith. Hunt (1970) mapped the portion of the LLSZ on southern Loucks Lake as mafic supracrustal rocks; however, the shear zone in this area includes a wide variety of mylonitic rocks mainly derived from felsic granitoid rocks. Rock types are broadly zoned about the central mylonite corridor which runs down the centre of Loucks Lake. Rocks on the southwest shore of Loucks Lake consist of plagioclase porphyroclastic quartz diorite, on central Loucks Lake comprise grey quartz dioritic to tonalitic mylonite with abundant cm-m scale porphyroclastic granite pegmatite sheets, and on the southeast shore are porphyroclastic quartz diorite, mafic mylonite with felsic sheets, and foliated granodiorite.

The maximum age of the main mylonitic fabric in the LLSZ is constrained by the fact that it affects an 1876 Ma phase (Whalen and Hunt, in press) of the Gants Lake batholith. The shear zone is deflected dextrally into (and is thus older than) the S_5 BCF, and is locally overprinted by an S_6 northeast-trending cleavage and an S_8 north-trending spaced cleavage. The age of the main mylonitic fabric in the LLSZ relative to S_1 to S_4 is not known.

The Loucks Lake Shear Zone has been the locus of multiple episodes of intrusion and deformation. Granitoid mylonites and ultramylonites at one location on the Grass River between Iskwasum Lake and Loucks Lake are intruded by foliation-parallel diabase, gabbro and basalt dykes 5 cm to 2 m wide. Garnet porphyroblasts overgrow the main mylonitic fabric in the felsic rocks, demonstrating that the shearing predates regional metamorphism. These multicomponent rocks locally become layered mylonites comprising sheets of pink granitoid mylonite, grey porphyroclastic quartz diorite, and recessive mafic tectonite (mafic dykes?). Near the BCF the layered mylonites are folded in east-northeast trending isoclinal F_5 folds and are transected by non-penetrative fabrics related to the BCF.

East Iskwasum Shear Zone (S_3)

The East Iskwasum Shear Zone (EISZ) is a curvilinear, north-trending structure exposed in eastern Iskwasum Lake. The shear zone is apparently continuous with a fault mapped by Hunt (1970) trending north to Barb Lake, and transects portions of the Iskwasum mafic-ultramafic complex and Centre Lake mafic tectonite.

The EISZ is 50 m wide in the north and widens southward to 450 m. The age of the shear zone relative to other major structures on Iskwasum Lake is relatively well constrained. An early foliation parallel to S_2 and oblique to the trend of the EISZ is overprinted by a strong dextral S_3 crenulation cleavage parallel to the zone. This S_3 cleavage locally intensifies to form a mylonitic fabric. S_3 is in turn overprinted by a northeast-trending crenulation cleavage interpreted as S_6. The south end of the EISZ is abruptly truncated by an S_7 northeast-trending shear zone.

Table GS-9-2
Summary of main fabric generations, Iskwasum Lake

Formation (reference)	Location; thickness (T); strike extent (E)	Components major; (minor)	Morphologic features, alteration
N-type basalts			
Claw Bay basalt/ Centre Lake mafic tectonite (Syme, 1991, 1992)	Elbow Lake - Iskwasum Lake T > 1000 m? E = 40 km	• pillowed flows and derived layered mafic tectonite • (massive flows)	• dark green weathering pillowed flows • epidosite domains and veins common • aphyric and plagioclase phyric • common amygdales 1-10 mm • rare radial pipe vesicles
Moen Bay basalt (Syme, 1991, 1992)	Elbow Lake T > 400 m E = 10 km	• pillowed flows • (heterolithologic breccia)	• greenish buff to dark green weathering pillowed flows • aphyric and porphyritic • non-amygdaloidal to weakly amygdaloidal
McDougalls Point basalt (Syme, 1991, 1992)	Elbow Lake - Cranberry lakes - Iskwasum Lake T > 1100 m E = 35 km	• pillowed flows • synvolcanic diabase dykes, sills • (massive flows) • (interflow hyaloclastite, hyalotuff)	• light buff weathering pillowed flows • aphyric, plagioclase phyric and plagioclase-pyroxene phyric • interpillow chert • epidosite domains and veins not prominent • weakly amygdaloidal to non-amygdaloidal • pillow drain-outs
Millwater basalt (Syme, 1987, 1988)	Athapapuskow Lake T > 1000 m E > 12 km	• pillowed flows • reworked hyalotuff	• light buff weathering pillowed flows • epidosite domains and veins generally absent • few, carbonate-filled amygdales (1-10 mm) • common radial pipe vesicles
Grassy Narrows basalt (Bailes and Syme, 1989)	Manistikwan Lake T > 500 m E > 4 km	• pillowed flows	• buff weathering pillowed flows • aphyric and plagioclase phyric • few amygdales
Two Portage ferrobasalt (Bailes and Syme, 1989)	Bear Lake - Northeast Arm (Schist Lake) T = 120-200 m E > 12 km	• massive flows • (pillowed flows) • (interflow rhyolite crystal tuff)	• dark grey to greenish brown weathering massive and pillowed flows • aphyric; microgabbroic textures • few amygdales (1-3 mm)
E-type basalts			
Athapapuskow basalt (Syme, 1987, 1988)	Athapapuskow Lake - Cranberry lakes T > 1000 m E > 60 km	• thin massive flows (1.5-5 m) • thick massive flows (to >30 m) • (pillowed flows) • (hyalotuff, breccia)	• dark green weathering massive and rare pillowed flows • aphyric • highly amygdaloidal flow tops with epidote- and quartz-filled amygdales to 2 cm • epidosite domains and veins common • abundant fine grained metamorphic magnetite • high aeromagnetic signature
Limestone Narrows basalt (Syme, 1988)	Athapapuskow Lake T = 300-500 m E > 6 km	• pillowed flows	• buff brown weathering pillowed flows • spherulitic, cream-coloured outer margin (2-3 cm) on pillows • common carbonate-filled amygdales (2-10 mm) • some radial pipe vesicles
Scotty Lake basalt (Bailes and Syme, 1989)	Northeast Arm (Schist Lake) T > 1400 m E = 8 km	• massive flows • pillowed flows • (compound flows) • synvolcanic basalt dykes, sills • interflow hyaloclastite	• rusty brown weathering massive and pillowed flows • aphyric • some flows have skeletal crystal textures preserved • few amygdales (1-5 mm) • rare pipe vesicles
Ocean Island basalts			
Long Bay conglomerate (Syme, 1991, 1992)	Elbow Lake T = 600 m E = 4 km	• basaltic debris flow conglomerate • (basaltic sandstone)	• green weathering conglomerate • thick, normally graded beds with rounded basalt, diabase, gabbro, and pyroxenite clasts • maximum clast size 1.4 m • basalt clasts are scoriaceous to strongly amygdaloidal with large amygdales (to 10 mm) and vesicle banding, suggesting that source flows were subaerial.

South-trending faults, Grass River area (S_4)

South of Elbow Lake a narrow strand of the ELSZ extends southwest along the Grass River outlet (Syme and Whalen, 1992) into the Iskwasum Lake area. Mapped net offsets along the ELSZ at Elbow Lake are sinistral, but both dextral and sinistral kinematic indicators occur on the Grass River strand (Syme, 1992). The suggestion that multiple ages of structures are contained within the ELSZ is compatible with the detailed observations of Ryan and Williams (1993, GS-20, this volume).

Direct evidence for multiple deformation within the ELSZ was obtained on the Grass River north of Iskwasum Lake. Discrete south-trending faults peel out of the southwest-trending ELSZ corridor, and cut the ELSZ mylonite belt at a high angle where the ELSZ is folded into an easterly orientation (Fig. GS-9-3). Of five mapped south-trending S_4 faults, four display dextral offsets and one is sinistral. Segments of the ELSZ vary considerably in width and orientation between the S_4 faults, suggesting that there is a vertical component of displacement. S_4 faults range from discrete, presumably brittle, breaks to ductile shear zones containing well developed S_4 shear fabrics. An associated foliation commonly extends 60 m into the wall rocks of S_4 ductile shear zones.

Ryan and Williams (GS-20, this volume) document ductile-brittle and brittle structures that overprint the ductile fabrics within the ELSZ and indicate late (probably <1800 Ma) deformation along the shear zone. The south-trending S_4 faults may be a manifestation of this phase of deformation, where its locus is decoupled from the main ELSZ corridor.

The age of the south-trending faults, relative to other mapped structures at Iskwasum Lake, is fairly well constrained. The faults must postdate the fold in the ELSZ on the Grass River. South-trending S_4 faults are presumed to predate the S_5 Berry Creek fault based on relationships extrapolated using 1:50 000 vertical gradient aeromagnetic maps. The easternmost S_4 fault produces a 1200 m sinistral offset on a pluton contact, but 2500 m further south produces no offset on the magnetic anomaly associated with the BCF (Fig. GS-9-2). Minor shear zones parallel to S_4 are locally overprinted by an S_6 spaced cleavage, demonstrating that the ubiquitous northeast-trending S_6 structures are younger (Fig. GS-9-3).

Berry Creek Fault (S_5)

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-Precambrian boundary. South of Iskwasum Lake the BCF is virtually coincident with the topographic scarp that marks the edge of the Paleozoic carbonates. Despite this lack of exposure the BCF is readily identified on 1:50 000 vertical gradient aeromagnetic maps as a distinct linear magnetic low trending east-west, truncating magnetic anomalies to the north and south.

Within 2 to 3 km of the BCF a number of major rock units and contained structures (including the ELSZ, LLSZ and Gants Lake batholith) have been deflected into a westerly orientation by dextral movement on the BCF. Although there are no Precambrian outcrops corresponding to the exact trace of the BCF, exposures 100 to 300 m north clearly show structures attributable to the fault. On the south shore of the Grass River south of Iskwasum Lake, Loucks Lake mylonites are folded about west-trending F_5 isoclines that plunge 75° towards 071° (Fig. GS-9-4). S_5 axial planar foliations, fractures, quartz veins, and felsic ultramylonite bands cross the folded mylonitic fabric.

The Berry Creek Fault at Iskwasum Lake presents a significantly different appearance than on Simonhouse Lake, only 25 km to the west. On Simonhouse Lake the BCF is a sharply defined, sinistral oblique-slip, brittle structure with associated carbonatization, brecciation and shearing in a mafic tectonite possibly representing earlier ductile deformation in the BCF (Syme, 1993). At Iskwasum Lake the BCF is clearly a ductile dextral feature. These relationships suggest that the Berry Creek structure contains ductile and brittle components that differ in age and kinematics.

Northeast-trending cleavage (S_6)

A northeast-trending cleavage that typically overprints older fabrics is widely developed in the Grass River - northern Iskwasum Lake area. The cleavage is less well developed, but does occur, on central and southern Iskwasum Lake. S_6 cleavages include a spaced chlorite crenulation cleavage, spaced fracture cleavage, rare spaced quartz-filled fracture cleavage, and rare penetrative foliation. On southern Iskwasum Lake cm-m scale ductile S_6 shear zones overprint the S_2 fabric in the ELSZ.

The relationship of this cleavage to the mapped folds in the ELSZ is noteworthy. The northeast-trending cleavage has approximately the expected orientation to be axial planar to the fold in the ELSZ on the Grass River; however, the cleavage must postdate the fold because it overprints S_4 faults that cut folded ELSZ tectonites.

The S_6 cleavage on Iskwasum Lake may be related to similar fabrics mapped east of Elbow Lake in the Centre Lake domain (Syme, 1991), where the strong foliation and tectonic lamination in Centre Lake mafic tectonite (S_2 in Syme, 1991) is refolded in northeast-trending, generally rather open minor folds, which in some cases contain axial planar foliations, fracture cleavage, or mineral-filled fractures (P_4 structures in Syme, 1991).

Northeast-trending shear zone (S_7)

A northeast-trending S_7 shear zone is coplanar with the S_2 ELSZ at southernmost Iskwasum Lake. This 240 m wide zone borders Gants Lake batholith where the batholith has been folded into a southwest-northeast attitude by the BCF. On that basis it is interpreted to postdate the Berry Creek structure, and is broadly similar in age to the S_6 northeast-trending cleavage described above.

The shear zone clearly and unambiguously truncates the south end of the S_3 ElSZ, where the S_3 foliation is folded into open to isoclinal F_7 folds with an axial planar S_7 foliation/spaced cleavage, and is transposed into the S_7 northeast orientation. An S_7 mylonitic fabric is locally developed.

East Iskwasum Fault (S_8)

The East Iskwasum Fault is a north-trending linear structure along the east shore of Iskwasum Lake. The fault is interpreted to be late on the basis of its crosscutting relationships with other major structures: it clearly truncates the northeast-trending S_7 shear zone at southern Iskwasum Lake, and cuts across that portion of the Gants Lake batholith that was deflected into a southwesterly orientation by the S_5 dextral BCF. There is insufficient exposure to document offset of the Berry Creek structure itself, but on vertical gradient aeromagnetic maps a 500 m sinistral offset on the Berry Creek structure coincides with the extrapolated position of the East Iskwasum fault.

Tectonic lamination and local mylonitic fabric developed in gabbro within the East Iskwasum fault zone attest to intense ductile deformation, confined to a corridor about 60 to 100 m wide. Minor structures associated with the fault, including anastomosing shear zones, open fractures and spaced cleavage, occur in the Gants Lake batholith up to at least 1200 m west of the fault trace. These S_8 structures are younger than cleavages and mylonitic zones coplanar with the S_5 Berry Creek structure, and provide independent evidence that the East Iskwasum fault postdates the BCF. Stretch lineations in the S_8 shear plane are subvertical.

CONCLUSIONS AND REGIONAL IMPLICATIONS

The existing geological map of the Iskwasum Lake area (Hunt, 1970) must be re-interpreted in light of the new data collected during this reconnaissance. Hunt's (1970) first-order subdivision of mafic volcanic rocks into "Barb Lake amphibolite" (here, Centre Lake mafic tectonite) and "Grass River pillow lavas" (McDougalls Point basalt) may be valid, but his "Iskwasum Lake pyroclastics" do not exist as an identifiable unit. Most of the rocks mapped by Hunt (1970) as pyroclastic or sedimentary are ELSZ mylonites and tectonites, and deformed McDougalls Point basalts adjacent to the ELSZ. Similarly, the mafic supracrustal rocks shown by Hunt (1970) at Loucks Lake are in fact felsic mylonites derived from granitoid rocks.

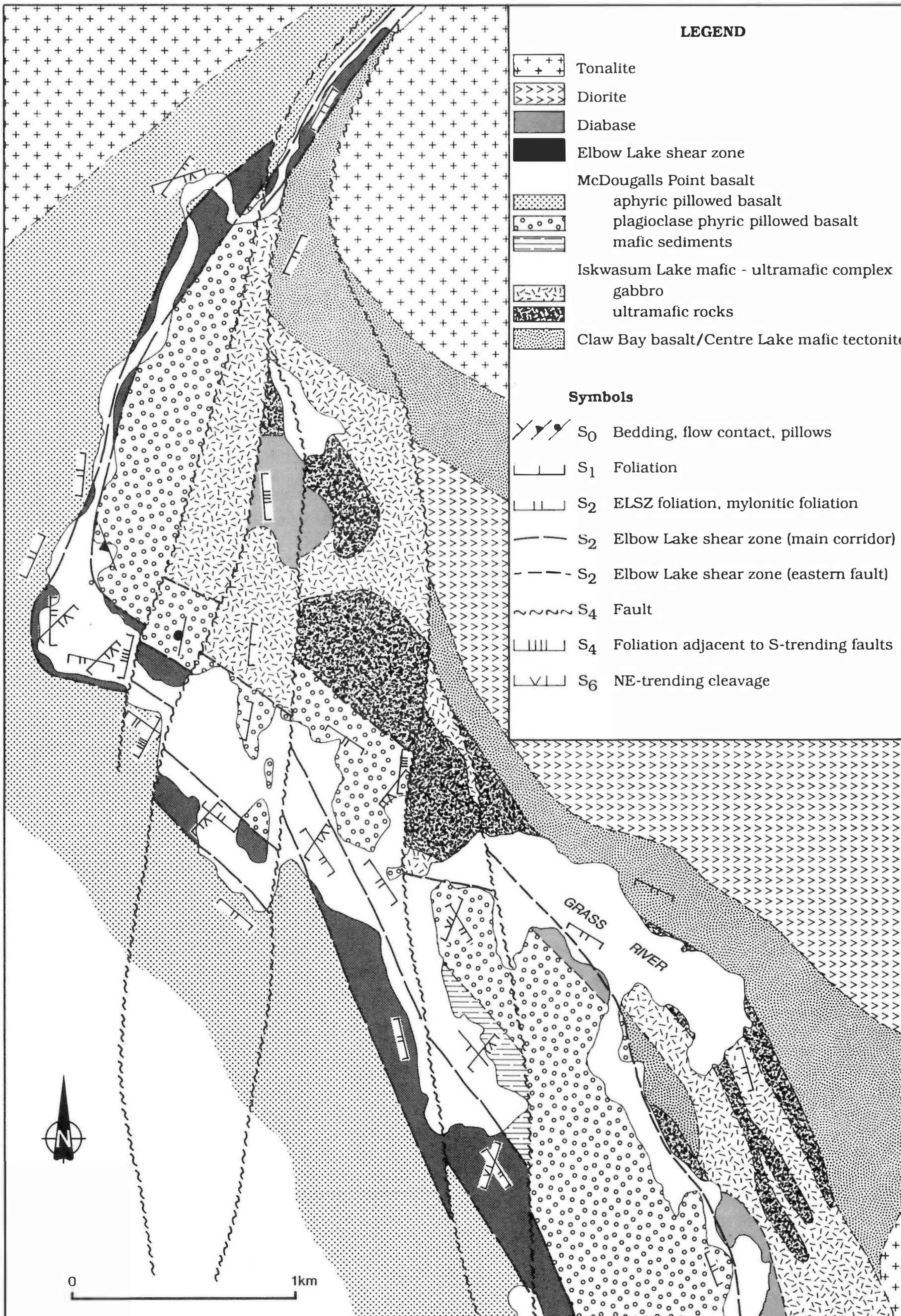

Figure GS-9-3: *Detail of the geology in the Grass River area. The S_2 Elbow Lake shear zone is folded through 90° and is offset by S_4 south-trending faults. The faults and ELSZ are coplanar in the northern Grass River area.*

Figure GS-9-4: *Mylonites in the Loucks Lake shear zone folded in F_5 folds associated with the Berry Creek fault, Natural Resources dock, south end of Iskwasum Lake. Light: felsic mylonite and porphyroclastic quartz diorite sheets. Dark: chlorite-carbonate schist derived from mafic dykes. The mafic schist has an S_5 foliation axial planar to F_5 folds.*

Major structures mapped at Elbow Lake (*e.g.*, east and west strands of the Elbow Lake shear zone, Grass River fault) were traced into the Iskwasum Lake area, demonstrating the lateral continuity of these features. The ELSZ on Iskwasum Lake is a complex, long-lived structure (Ryan and Williams (GS-20, this volume) document 70 Ma of deformation along the ELSZ at Elbow Lake), and the main mylonitic fabric is interpreted to predate most other structures mapped on Iskwasum lake. The fact that the shear zone is folded is consistent with its apparent antiquity. The ELSZ separates geochemically and lithologically distinct ocean-floor formations, suggesting that the structure is an early manifestation of the accretion of distinct tectonostratigraphic assemblages (Lucas *et al.*, in prep.) that led to the formation of the "Flin Flon collage".

Recognition at Iskwasum Lake of basaltic units previously mapped at Elbow Lake extends and completes the definition of these units in the western Flin Flon belt (*e.g.*, Syme, 1988, 1992, 1993; Table GS-9-1). It is now clear that ocean-floor basalts form a continuous belt from Athapapuskow Lake, through the Cranberry lakes, to Elbow and Iskwasum lakes (Fig. GS-9-1). Lithologically and geochemically distinct basalt formations within the Athapapuskow - Elbow segment were probably erupted in a back-arc environment remote from coeval arc volcanism and sedimentation (Stern *et al.*, in prep.). These ocean-floor basalt formations have historically provided very little Cu-Zn sulphide production in the Flin Flon belt, whereas the arc volcanic rocks at Flin Flon and Snow Lake have been the principal hosts for VMS deposits (Syme and Bailes, 1993). Geochemical criteria used to distinguish ocean-floor from arc volcanic rocks in the Flin Flon belt are documented in Stern *et al.*(in press) and Stern *et al.* (in prep.).

The Iskwasum Lake mafic-ultramafic intrusive complex is lithologically similar to gabbroic complexes at Elbow and Claw lakes (Syme, 1991, 1992), and to the Limestone Narrows gabbro-ultramafic body at Athapapuskow Lake (Syme, 1988). All are associated with ocean-floor basalts. The preliminary age determined for the Claw Lake body (Stern *et al.*, in prep.) suggests that the layered intrusions and the ocean-floor basalts are coeval and possibly related. Geochronologic and geochemical studies are underway to determine the relationship between the gabbroic bodies and the MORB basalts with more certainty, and to interpret the tectonic setting in which the gabbros were emplaced.

Supracrustal rocks at Iskwasum Lake are intruded on the east side by the composite Gants Lake batholith, one of the largest and oldest (1876 Ma) calc-alkaline granitoid plutons in the Flin Flon belt (Whalen, 1993; Whalen and Hunt, in press). The Gants Lake batholith is emplaced at an important boundary in the Flin Flon belt (Syme *et al.*, 1993), stitching the contact between the Athapapuskow-Elbow ocean-floor basalt terrane to the west and arc volcanic rocks (Norquay *et al.*, 1993) to the east. This juxtaposition *ca.* 1870-1880 Ma of different tectonostratigraphic assemblages is thought to have occurred in an intraoceanic accretionary complex along thrust and/or strike-slip faults (Lucas *et al.*, in prep.). Was the locus of emplacement of the Gants Lake batholith controlled by such a structure? The stitching relationship suggests it may have been, but the relative ages of the batholith and the fabric in host rocks are more equivocal. Tectonites derived from mafic volcanic rocks border the batholith on the west side (Syme, 1991, 1992, this study; Ryan and Williams, GS-20, this volume) and east side (D. Morrison, unpublished data). On Iskwasum Lake a mylonite zone at the margin of the batholith forms the contact with the supracrustal rocks, similar to relations east of Elbow Lake (Syme, 1991, 1992; Ryan and Williams, GS-20, this volume). Ryan and Williams (GS-20, this volume) tentatively conclude that the Claw Bay tectonite fabric postdates intrusion of the Gants Lake batholith. Thus, if the Gants Lake batholith was emplaced in an early shear zone, the fabric associated with that structure has not been identified. However, mylonitization along the margin of the batholith and the Loucks Lake Shear Zone within the Gants Lake batholith, may be manifestations of long-lived tectonism at this "terrane" boundary.

The Berry Creek Fault is a regional dextral structure that offsets and reorients earlier structures such as the ELSZ, LLSZ and Gants Lake batholith. To the west, the fault appears to contain a component of north-side-down normal slip, resulting in downfaulting of the low grade Flin Flon belt against mid-crustal gneisses of the Namew Gneiss complex (White *et al.*, 1994). Relations at Iskwasum and Simonhouse lakes (Syme, 1993) suggest that the Berry Creek Fault contains ductile and brittle components.

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GS-10 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., 1994: Mineral occurrences in the Iskwasum Lake (NTS 63K/10), Elbow Lake and North Star Lake (NTS 63K/15) areas; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 57-60.

SUMMARY

The Iskwasum Lake map area (NTS 63K/10) contains approximately 100 mineral occurrences, most of which have been indicated by diamond drill programs. Fifteen were examined during 1993 (Heine, 1993). Five additional occurrences were located and examined during 1994. In addition, the Jupiter No. 2 and 3 occurrence in the North Star Lake area (NTS 63K/15) was located and mapped. Attempts to locate several sulphide occurrences in the Loonhead Lake area in the northeastern part of NTS 63K/15 were unsuccessful: only a single trench with an adjacent stripped area was found.

Field activities consisted of locating mineral occurrences and associated workings (trenches, stripped areas, shafts, *etc.*) on 1:5 000 scale air 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 Reports 30 (63K/15) and 31 (63K/10).

NTS 63K/10 (ISKWASUM LAKE)

The Iskwasum Lake map area contains occurrences of gold, platinum group elements, sulphides, asbestos, and talc, some of which have been evaluated in exploration programs. Trenches are generally overgrown and caved, and bedrock is extensively covered by moss and black lichen.

Sulphides

Several trenches were excavated approximately 160 m east of a large meander on the Grass River (Occurrence 1, Fig. GS-10-1). Hunt (1970) indicates that the rocks in the occurrence area are part of the Barb Lake amphibolites and associated rocks. This sequence has been

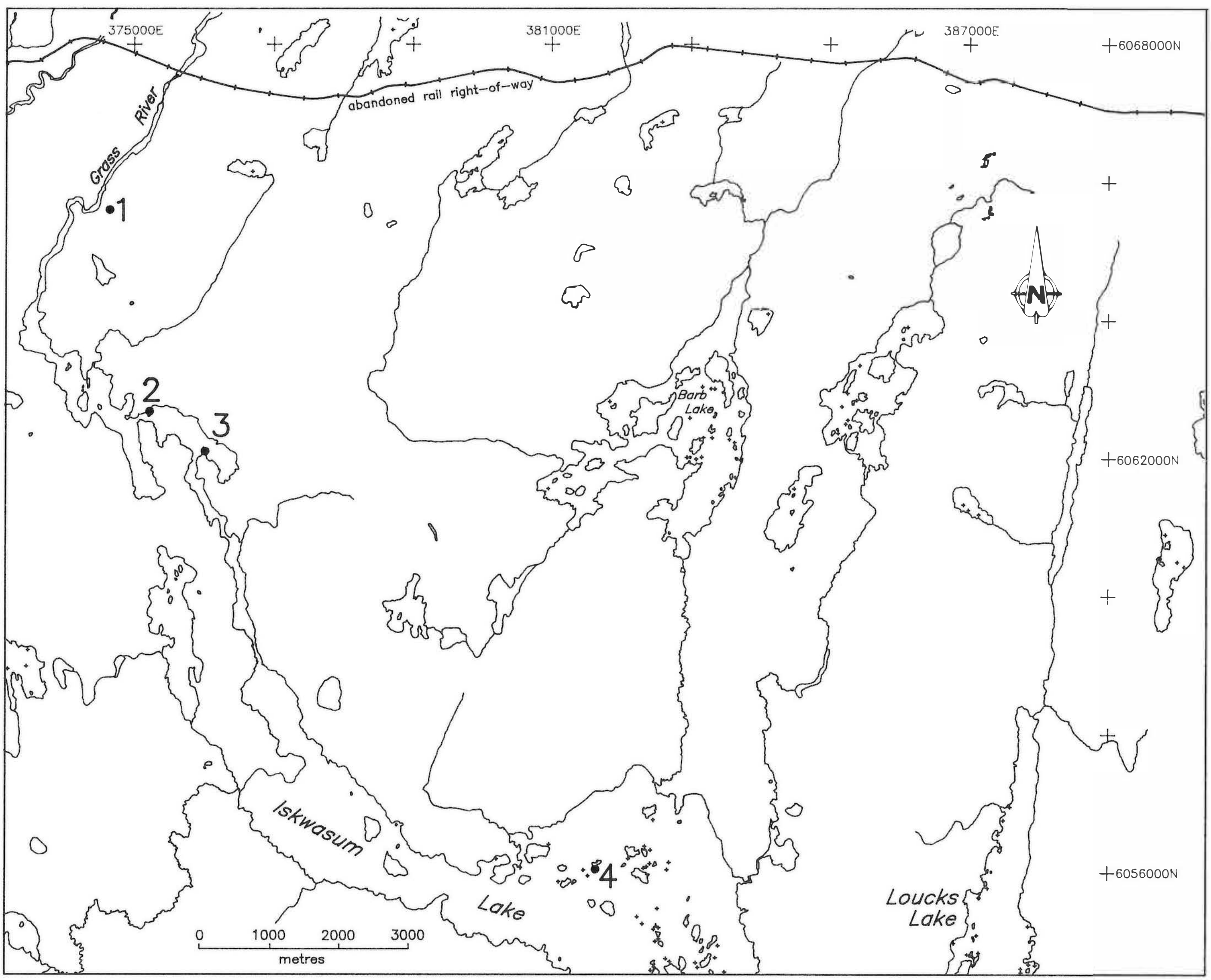

Figure GS-10-1: Mineral occurrences in the Iskwasum Lake area (NTS 63K/10). The occurrence members are referred to in the text.

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

recently investigated by Syme (1994, GS-9 this volume). A variety of undifferentiated massive mafic to ultramafic rocks underlie the area, and a granitic intrusion occurs approximately 350 m to the east. Recent investigations of the mafic-ultramafic sequence indicates that it is co-eval with the host basalts (R. Stern, unpub. data).

The trenches expose north-trending steeply east-dipping magnetite- and sulphide-bearing cherty iron formation. The chert ranges from white to dark grey, and occurs as bands up to 25 cm thick interlayered with magnetite-rich and pyritic seams; thinly layered and fissile areas are present. The rock in the trenches and on the waste piles is mostly stained with brown and light yellow-green iron oxides. Pyrite occurs as disseminations and lensoid masses to 10 cm long conformable with the foliation of the chert. In places sulphide comprises up to 50% of the rock.

Fine grained biotitic feldspar phyric rhyolite containing rare quartz phenocrysts is present at the south end of the occurrence. The thickness and extent of this unit are unknown.

Talc

Talc occurs within the mafic to ultramafic sequence that extends along and to the east of the Grass River into Iskwasum Lake. Hunt (1970) tabulated eleven occurrences; additional investigations were undertaken by Gunter and Yamada (1986) and Gunter (1988). Several of the occurrences (Fig. GS-10-1) were examined in detail as part of the current investigations.

Several talc occurrences are exposed along the north shore and on a small island in the Grass River approximately 4 km NNW of Iskwasum Lake (Occurrence 2, Fig. GS-10-1). Along the shoreline, talc-carbonate rock occurs in 3 m high outcrops. The rock is very soft with local ill-defined harder and less talcose intervals. Carbonate is an ubiquitous constituent as brown-weathering euhedral to subhedral grains up to 3 mm. Most of the rock in the exposure contains 5 to 10% fine-grained magnetite with some grains up to 1 mm. Analyses of samples collected from an occurrence a short distance to the north of the shoreline outcrops indicate the presence of dolomite, magnesite, serpentine and chlorite, in addition to talc and unspecified carbonate (Gunter, 1988). The talc content of these rocks ranges from 4.83 to 62.63% (R. Gunter, pers. comm., 1994). Similar rocks are exposed on two small islands approximately 1000 m SE of the shoreline exposures (Occurrence 3, Fig. GS-10-1).

The best talc occurrence examined occurs on an islet approximately 3 km NNE of the south end of Iskwasum Lake (Occurrence 4, Fig. GS-10-1). The exposure weathers white and contains areas of massive talc. Fractures are filled with coarse grained pale green talc. Brown-weathering carbonate constitutes up to 30% of the rock as discrete grains up to 3 mm. Boudinaged carbonate layers are present. Very fine-grained magnetite is present throughout the unit. Blocks of less altered mafic rock are locally present within the talc; *e.g.*, a well defined, fine grained, subangular fragment approximately 50 cm long is present along the eastern shore. The quantity and distribution of this potentially deleterious material remains to be determined.

Gold

Several trenches were excavated on Bartlett Point south of Fourmile Island (Occurrence 5, Fig. GS-10-2) prior to 1970 (A.F. 92740, 92741), most of which are flooded or completely overgrown. The easternmost trench appears to have been excavated subsequent to the work reported in the assessment files, and bedrock is well exposed both in the trench and in several adjacent stripped areas.

Rousell (1970) indicates that the area is underlain by mafic volcanic flows and chlorite schist. Ordovician dolomitic limestone covers the Precambrian sequence a short distance to the west. The trenches and stripped areas expose variably sheared quartz phyric tonalite similar to that which hosts the auriferous quartz veins on Fourmile Island. The tonalite is medium grained, with quartz grains averaging 3 mm and comprising 20 to 80% of the lithology. The tonalite commonly contains fine grained, schistose mafic xenoliths up to 2 m thick that display a dominant east orientation. Northwest of the more recent trench, the rock exposed in the northern part of a stripped area consists of fine grained mafic schist. The surface of this unit tends to be pitted where calcareous areas have weathered out. Minor lighter coloured, more felsic masses (fragments?) are present in the mafic schist close to the contact with the tonalite, exposed in the southern part of the stripped area.

A single quartz vein up to 20 cm thick and several irregular masses with restricted distribution are exposed in the trench. The quartz vein, masses and surrounding country rock are ankeritic, with the veins and masses containing up to 20% rusty weathering Fe-carbonate. Disseminated pyrite comprises <1% of the chloritic rock inclusions; no sulphides were noted in the quartz veins and masses. No assay values for this occurrence have been reported.

NTS 63K/15 (ELBOW LAKE)

North Star Lake Area

The gold occurrence on the Jupiter No. 2 and 3 claims (Occurrence 6, Fig. GS-10-3), located approximately 2300 m south-southeast of North Star Lake, was first staked in 1930 (Stockwell, 1935). In the 1930's a number of trenches and two shafts were excavated. Gold values were obtained from several of the veins but no commercial production has been recorded. Although the area was burned during the 1989 fire, new growth obscures much of the rock exposed in the trenches.

Stockwell (1935) described the geology of the occurrence and showed the distribution of the quartz veins on several maps. The occurrence is located within the Eastern Zone of Norquay *et al.* (1993), and is underlain by metamorphosed pillowed and massive basalt, flow breccia, volcaniclastic sediments, and a variety of mafic to felsic intrusions. The dominant host rocks to the occurrence consist of foliated pillowed basalt, flow breccia and gabbroic units that may represent massive volcanic flows. Although the pillows have been only moderately flattened and selvages are well preserved, top directions are ambiguous. The sequence has been intruded by feldspar porphyry and granodioritic dykes that cut the main foliation at a slight angle. The feldspar porphyry postdates the quartz vein.

The quartz vein system exposed in the trenches is up to 2.2 m thick and has been traced along strike for approximately 640 m (Stockwell 1935). It discontinuously occupies a thin (<3 m) schistose and chloritic zone within the dominantly volcanic sequence. This schistose area is parallel to the dominant regional schistosity (S_1 of Norquay *et al.*, 1993), trends approximately 020°, dips subvertically, and has been traced along strike beyond the limits of the quartz vein. The vein shows considerable variation in thickness along strike. It is not clear if the marked thickening of the vein in some areas, particularly where the shafts have been excavated, is the result of shear folding, as suggested in one of Stockwell's claim sketches (see Fig. 11 in Stockwell, 1935) and as has been demonstrated for a similar gold occurrence at the North Star No. 1 and 2 occurrence (Heine, 1993), or due to boudinage of a single relatively uniform vein. Parts of the vein contain abundant chloritic wall rock inclusions, and in some areas the proportion of included lithic material dominates the vein material. Minor carbonate is present in the veins.

Sparse disseminated pyrite occurs in the quartz veins. Chalcopyrite is present as rare grains in quartz. No visible gold was found despite an extensive search. Recent work in one of the shafts has shown that the quartz veins are auriferous: the best assay obtained was approximately 29 gm Au/t (0.854 oz. Au/ton) across 2.2 m (86 in.) (A.F. 92096). D. Ziehlke (pers. comm., 1994) indicated that it was possible to find visible gold in the sides of the shaft.

Loonhead Lake area

A compilation by BP Minerals Limited indicates a number of outcrops and trenches that expose sulphide mineralization in the Loonhead Lake area (A.F. 92828). Noko Resources Inc. undertook a soil geochemical survey and excavated several trenches east of Loonhead Lake (A.F. 92902). A single trench and stripped area was located approximately 1200 m northwest of the southwesternmost bay on Loonhead Lake. A light grey, fine grained, schistose and limonitic interval approximately 3 m thick and trends 254° along the side of the trench and along the top of a cliff. Fine-grained pyrite(?) is disseminated throughout the schist.

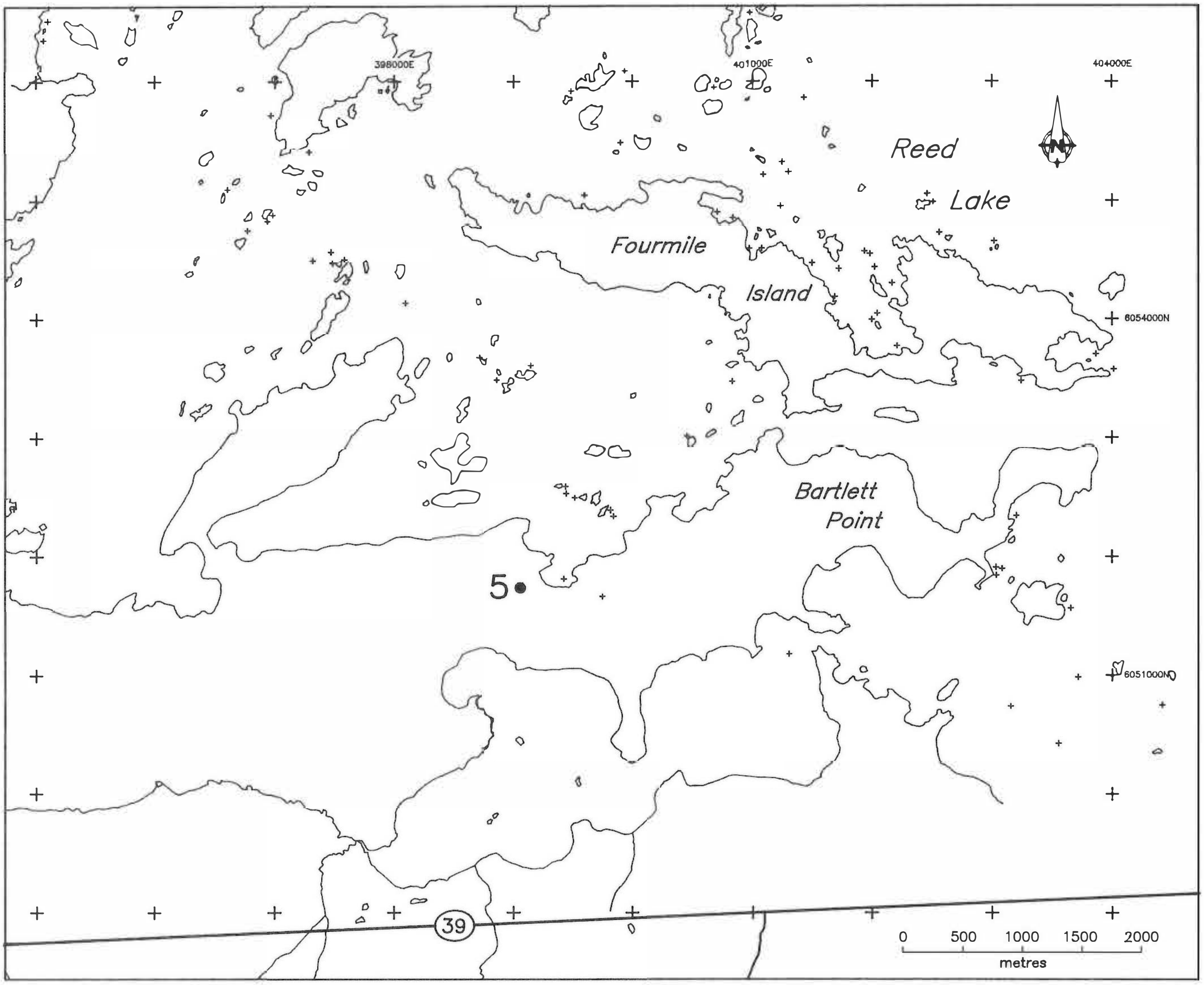

Figure GS-10-2: Mineral occurrence location in the Reed Lake area (NTS 63K/10). The occurrence number is referred to in the text.

ACKNOWLEDGMENTS

Ms Rebecca Jacksteit provided capable and enthusiastic assistance throughout the field programme.

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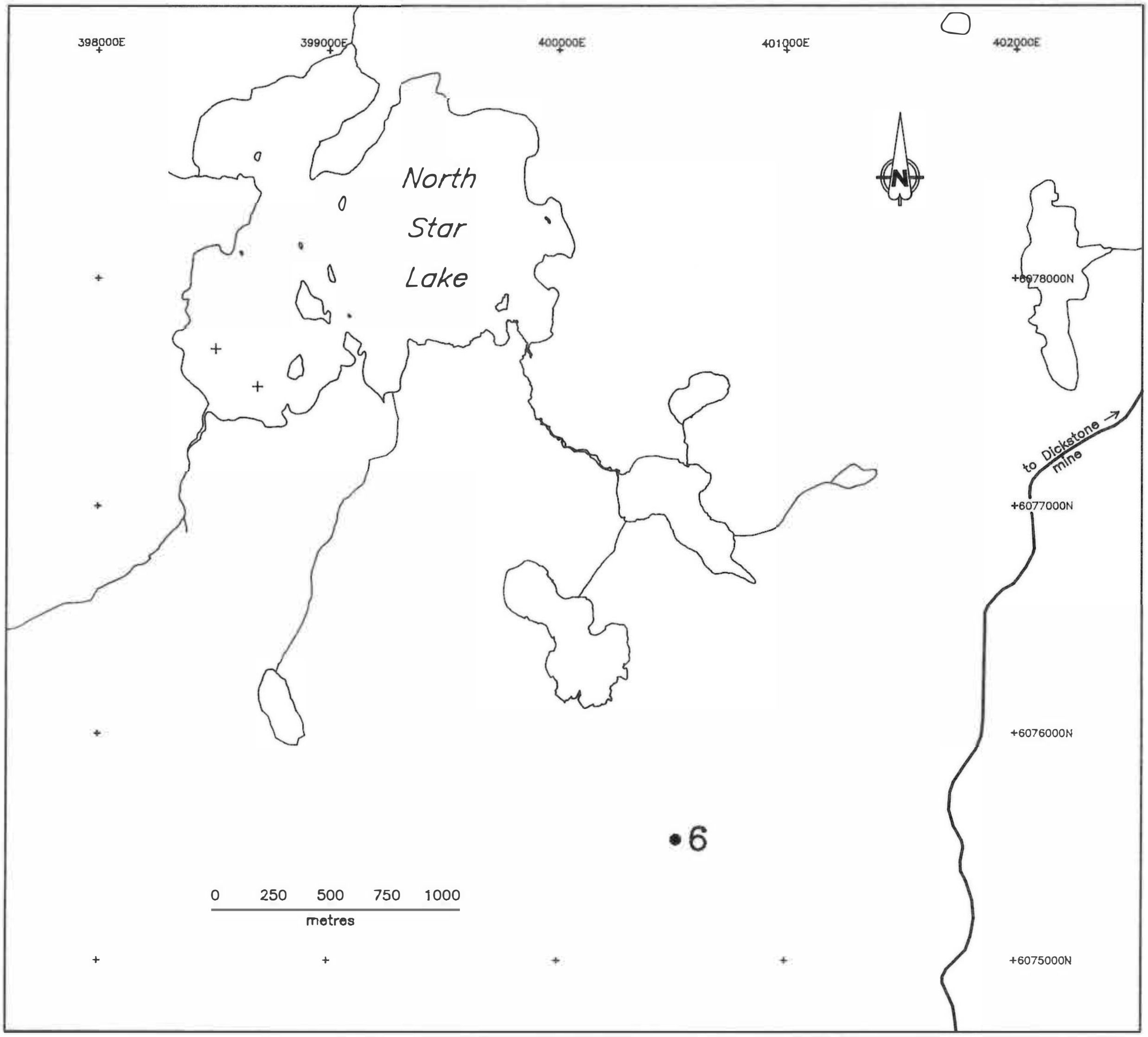

Figure GS-10-3: Location of mineral occurrence 6 (Jupiter No. 2 and 3 claims), North Star Lake area (NTS 63K/15).

GS-11 BAKER PATTON FELSIC COMPLEX (PARTS OF 63K/13 AND 63K/12)*

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

Gale, G.H., Dabek, L.B., Prouse, D.E. and Norquay, L.I., 1994: Baker Patton felsic complex (parts of 63K/13 and 63K/12); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 61-63.

SUMMARY

Detailed mapping of the Baker Patton Felsic Complex (BPC) has been completed at 1:5 000 scale. The preliminary geological map is published at 1:10 000 scale (Gale *et al.*, 1994). The area south of Bryan Lake is distinctly different from other parts of the BPC in that it is underlain predominantly by quartz-feldspar phyric massive rhyolite that has been intruded by diorite and gabbro. The rocks between Amulet and Flintoba lakes are predominantly rhyolite and gabbro. The rocks west of the Pine Bay Mine are predominantly a thick sequence of reworked mafic rocks, but also include rhyolite that probably correlates with rhyolite within the BPC. At least three phases of regional ductile deformation are present. Several sets of brittle faults disrupt the lithologic units along approximately E-W and N-S loci and make correlation of aphyric rhyolite units tenuous.

INTRODUCTION

Geological mapping of the BPC (NTS 63K/12 and 63K/13) was continued south of Bryan Lake, in the Amulet Lake area, in the immediate vicinity of the North Star Mine and east of the Hotstone copper occurrence (Fig. GS-11-1; Gale *et al.*, 1994). This program was designed

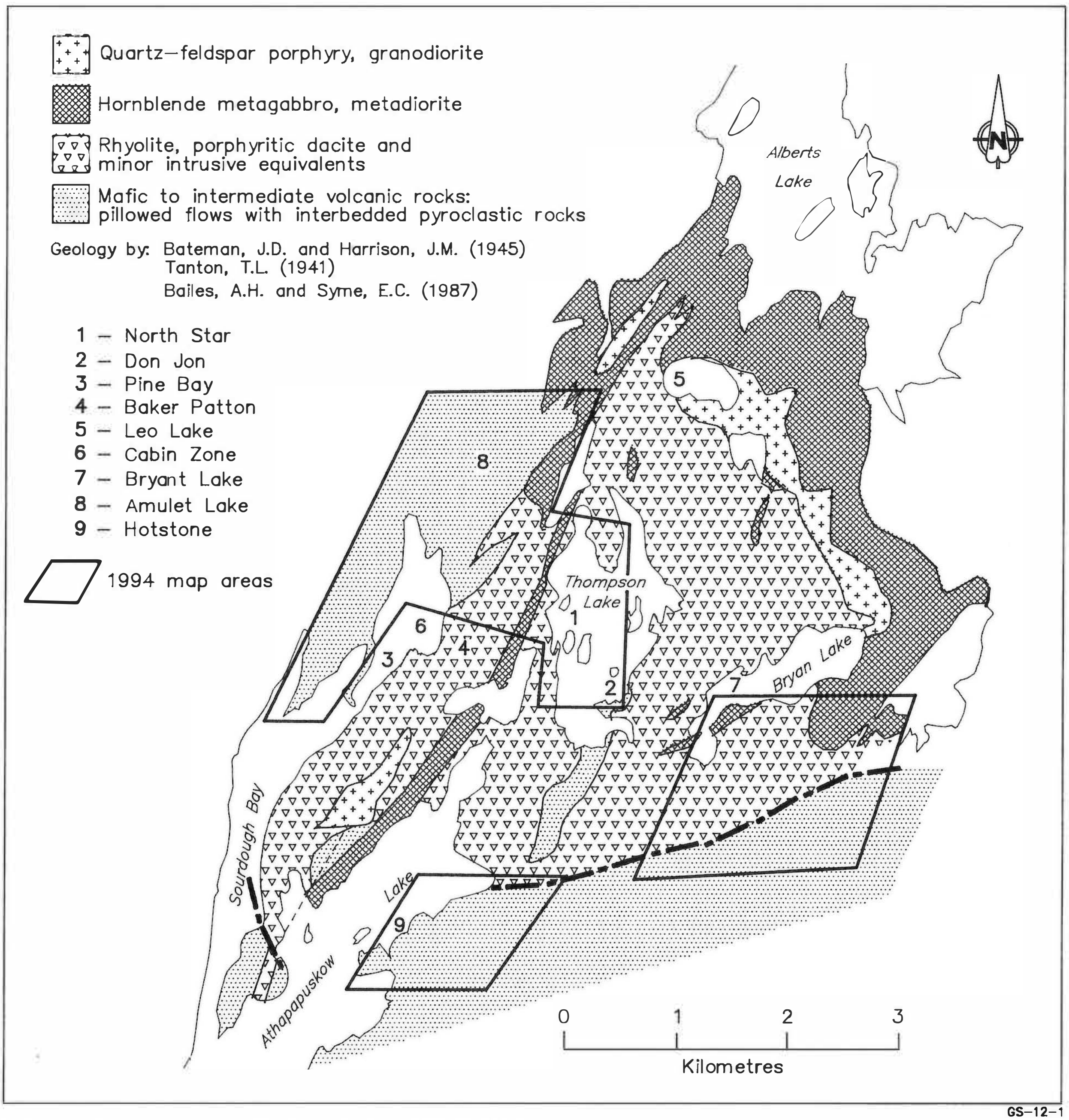

Figure GS-11-1: General geology of the Baker Patton Felsic Complex.

* Funded by Provincial A-Base

to delineate lithologic units and structures at 1:5 000 scale within the predominantly rhyolitic extrusive rocks of the BPC. Portions of the BPC were mapped at 1:5 000 and larger scales by Gale and Foote (1988), Norquay and Gale (1990), Ferreira (1991) Gale *et al.* (1992), Gale *et al.* (1993) and Gale (1993).

A portion of the area was mapped using cut grid lines and outcrop outline maps provided by Placer Dome Inc. and Minnova Inc. 1:5 000 scale airphotos were used for control in areas without outcrop maps. The main geological subdivisions are included on Preliminary Map 1994F-2. Rock names are based on field characteristics and are pending geochemical and petrographic confirmation. The geological data are available in digital, mylar or paper copy from Manitoba Energy and Mines upon request.

BRYAN LAKE AREA

The area south and east of Bryan Lake is underlain predominantly by quartz-feldspar phyric rhyolite, minor quartz phyric and aphyric rhyolite and felsic to intermediate layered rocks. These rocks have been intruded by fine- to medium-grained diorite and medium grained gabbro, which have in turn been intruded by a granodiorite pluton (Buckham, 1944).

Quartz-feldspar phyric rhyolite is generally massive. Typically it contains 2 to 5%, 2 to 3 mm, subhedral, grey-beige feldspar crystals and 1 to 3%, 1 to 3 mm, angular to subrounded, smokey grey to pale blue quartz crystals that locally are up to 10 mm in diameter. Some of the quartz grains may be amygdules. This rock represents either a thick sequence of massive rhyolite flows or a subvolcanic intrusion(s).

Massive aphyric rhyolite occurs commonly as one to several metre thick units that crosscut the quartz-feldspar phyric rhyolite. These rocks are probably rhyolite dykes.

Locally, there are small exposures of fine grained, pale green-grey, massive rock with 5% plagioclase. This rock is either andesite or altered rhyodacite. Trace to 2% pyrite and/or magnetite are common in both the aphyric rhyolite and the andesite.

A 400 m thick unit of layered felsic rocks is exposed immediately south of Jenny Lake. The layers vary from beige to dark grey and from well layered to massive. The layers vary in composition and include quartz-rich felsic rocks, massive felsic (rhyolite?) rocks, semi-pelite and pelite, and greywacke. This unit commonly contains 1 to 2% subhedral garnet, 0.5 to 2.0 mm, and 1 to 2% disseminated magnetite <1 mm. Garnet is most common in the pelite. Rounded quartz grains and possible crossbeds were observed in one exposure. These rocks are considered to be felsic volcaniclastic sedimentary rocks. The layered rocks host a 1 m thick sulphide layer with 2 to 3% chalcopyrite within a silicified zone that contains 20% biotite and 3 to 4% garnet.

A 50 m thick unit of quartz porphyritic granite strikes northeast from the east side of Pothook Lake into the map area, but pinches out south of Jenny Lake. This unit is probably related to a larger mass that occurs south of Kenokamow Lake. This rock has up to 10% 1 cm quartz grains in a medium grained, grey-pink matrix that contains 60% quartz, 25% K-feldspar, 5% plagioclase and 10% biotite. The quartz grains are lineated and a moderate to strong foliation is defined by biotite. The northwest contact of this unit is gradational with the diorite and it occurs as partially altered rafts within the diorite.

Diorite and gabbro comprise approximately 50% of the exposures mapped in this area; there are large exposures immediately south of the area mapped. Diorite is fine- to medium-grained and composed of approximately 15% subhedral white-beige feldspar and minor quartz and 85% hornblende, pyroxene, chlorite and greenish (epidotized) feldspar. The gabbro is fine- to medium-grained and occurs primarily as narrow dykes in the east part of the area. At the southwest end of Bryan Lake a 400 m thick body of gabbro contains blocks and lenses of altered rhyolite near its contact with the rhyolite. Locally, small zones contain 1 to 30 cm angular to subangular quartz-feldspar phyric and/or aphyric rhyolite fragments in a fine grained chloritized diorite and/or gabbro matrix that constitutes 20 to 30% of the rock. These zones, which occur adjacent to diorite and/or gabbro, are considered to be intrusion breccia related to the mafic intrusions. The gabbro and diorite, which intrude most of the other rock units in this area, may be related to the same magmatic event.

A large granodiorite body occurs east of Jenny Lake (Buckham, 1944). This is a medium- to coarse-grained, pink-grey rock that has a massive to weakly foliated texture. Buckham (1944) indicates that the granodiorite intrusion is the youngest unit in the area, but within the map area it is in fault contact with the diorite intrusion.

AMULET LAKE-FLINTOBA LAKE AREA

The area between Amulet and Flintoba lakes is underlain predominantly by aphyric rhyolite and minor basalt that have been intruded by quartz phyric rhyolite and fine- to medium-grained gabbro.

The rhyolite consists of massive, locally flow banded, vesicular beige to green-beige lobes in a matrix of tuff, lapilli tuff and breccia; white weathered rhyolite is present, but is not common. In general, the interlobe and interfragment matrix is fine grained, pale green to green-brown, and schistose; lapilli and breccia have the same colour and textural characteristics as the adjacent massive lobes. These units of lobes and tuff-breccia are considered to represent individual flows. Lapilli tuff, consisting of recessively weathered angular and subangular fragments in a dense massive rhyolite matrix, commonly occurs between individual flows. In several places the lapilli tuff are 1 to 2 m thick and appear to be redeposited hyaloclastite; however, the flow contacts are commonly not exposed and the relationship of lapilli tuff to the individual flows is unknown.

Anhedral to euhedral, pink to white feldspar occurs throughout the rhyolite flows. The feldspar content varies from 0% to 10% and is generally more abundant in the interlobe and interfragment matrix than in the massive rhyolite. This phenomenon is common elsewhere in the BPC and probably represents zones of extensive potassium alteration.

It is commonly difficult to separate the individual aphyric rhyolite flows on the basis of their physical features, which are similar. Locally, individual flows, 10 to 50 m thick, can be distinguished on the basis of the colour of the massive rock and the presence of layers of redeposited lapilli tuff hyaloclastite.

A unit of basalt pillows, breccia and tuff occurs northwest of Flintoba Lake. The rock is fine grained, pale green to green; blocks and pillows have 10 to 20% amygdules. The fragments are 3 to 15 cm and may constitute 5 to 20% of the exposed surface. Pillows are 20 to 50 cm in maximum dimension and occur as lenses throughout the unit.

Quartz-feldspar phyric felsic clastic dykes cut the rhyolite. These have up to 25% 1 to 6 mm quartz phenocrysts, up to 15% 1 to 3 mm anhedral to euhedral feldspar phenocrysts and up to 2% mafic rock fragments that vary from <1 to 15 cm in length. Contacts with the enclosing rock are sharp and grade from relatively phenocryst free and schistose to phenocryst-rich within 10 to 20 cm from the contact.

A 3 to 5 m thick felsic rock with up to 5% 1 to 2 mm quartz phenocrysts with indistinct contacts occurs southeast of Amulet Lake. Locally, this rock is associated with layered lapilli tuff. It is uncertain whether this unit is a crystal tuff or a felsic dyke.

PINE BAY MINE AREA

The rocks that underlie the Pine Bay Mine peninsula and extend northwards towards Amulet Lake include basalt and rhyolite flows, breccia and volcaniclastic sedimentary rocks in a 750 m thick section.

A 50 to 100 m thick unit of dark green feldspar-bearing basalt is exposed along the east shore of the peninsula. Locally, from east to west it consists of pillowed flows, massive and pillowed flows, tuff-breccia and tuff. The contacts of this unit are not exposed; the massive parts of the flow have reasonably sharp contacts with pillowed flows and tuff-breccia. Pillows are commonly 30 x 50 cm and contain 1 to 3 mm quartz amygdules. The pillowed portions of the unit are generally a few tens of metres thick and can be traced for only a few hundred metres along strike. The tuff breccia consists of a fine grained schistose mafic matrix that supports 10 to 25 cm irregular subrounded amygdaloidal basalt clasts that are similar to the pillows. The westernmost part of this unit consists of tuff and minor lapilli tuff that is intercalated with, and structurally overlies, tuff-breccia. This material is typically not layered and represents either hyaloclastite tuff developed at the top of a flow or reworked pyroclastic material. This basalt unit is tentatively considered to represent a single basalt flow.

The basalt unit is overlain to the west, in part, by a monolithic breccia with subrounded to subangular, matrix supported pale green, quartz amygdaloidal andesite fragments. Locally, amoeboid blocks up to 40 cm in diameter resemble pillows. Fragments, which constitute up to 60% of the unit, are commonly 10 to 20 cm in size, but range from 1 to 20 cm, and contain 2 to 15% 1 to 2 mm quartz amygdules. Locally, the groundmass is amygdaloidal and contains up to 30% 1 to 2 mm feldspar. This unit is probably a flow breccia.

Aphyric rhyolite overlies both the andesite breccia and basalt. The rhyolite unit contains massive 1 to 3 m thick lobes, breccia, tuff breccia and lapilli tuff.

A unit of quartz-feldspar phyric felsic rock contains up to 30% 1 to 15 mm grey euhedral to angular quartz and up to 25% euhedral to subhedral, 1 to 5 mm, white feldspar in a fine grained pink to beige matrix. Locally, the feldspar content is highest towards the east margin of the unit.

A distinctive quartz phyric rhyolite flow structurally overlies the quartz-feldspar phyric rock. Grey to pale white quartz grains, 1 to 15 mm, compose 5 to 35% of the rock. Although many of the larger grains appear to be amygdules, some of the subangular grains may represent phenocrysts. The subangular feldspars are pale white, 2 to 3 mm and compose up to 5% of the rock. Quartz filled amygdules are most abundant towards the west margin and in the southernmost exposures. In the northernmost exposures the western margin of this unit is a 2 to 3 m thick zone of layered lapilli tuff with 0 to 20% quartz crystals, whereas exposures at the southern tip of the peninsula contain lapilli and blocks in a light brown tuff matrix.

The westernmost portion of the Pine Bay area consists of mafic heterolithic and monolithic breccia that vary in thickness from a few metres to several tens of metres. Several of these units can be followed along strike for several kilometres. These rocks vary internally from matrix-supported to clast-supported. Locally, distinctly layered volcaniclastic sedimentary rocks with cm- to dm- thick graded beds are interpreted to be debris flows.

The breccia is overlain to the west by a unit of pale green andesite flow breccia and amoeboid pillows. Several 1 to 2 m thick fine grained andesite dykes cut the breccia at a low angle to the beds.

NORTH STAR MINE AREA

Dacite and rhyolite flows in the vicinity of the North Star Mine are aphyric and cannot be traced with any certainty northwest of the mine area. In contrast, interlayered aphyric and quartz phyric pyroclastic rocks that can be traced southwards from the Leo Lake area terminate abruptly at a fault immediately north of the North Star Mine (Preliminary Map 1994F-2). Although right handed displacement is inferred from outcrop patterns and tension veins, the amount and direction of vertical displacement is not known.

HOTSTONE AREA

Mapping of the area east of the Hotstone occurrence was initiated, but only a small portion of the area has been mapped in detail. The area is underlain by intercalated basalt to andesite and rhyolite flows, breccia, tuff and mafic intrusions.

The basaltic flows are generally pale to dark green, aphyric and moderately to highly vesicular. Individual flows include tuff, flow breccia, pillows and massive basalt. Pillowed portions of the flows are less voluminous than the flow breccia and tuff. An andesite flow with highly amygdaloidal anastomosing small lobes and blocks in tuff matrix appears to have limited areal extent. Breccia that consists of up to 30 cm angular to subangular blocks of basalt is exposed at several places south and northeast of the Hotstone occurrence; it may represent a single debris flow/avalanche deposit.

Felsic rocks include highly vesicular beige to light grey aphyric rhyolite, massive white aphyric rhyolite, quartz phyric rhyolite and quartz-feldspar phyric rhyolite.

The aphyric rhyolite flows comprise lobes, lapilli tuff and tuff. The quartz phyric rhyolite contains up to 30% 1 to 9 mm smoky grey quartz phenocrysts in a fine grained light green to grey matrix; this rock is probably an intrusion. The quartz-feldspar phyric rhyolite occurs as lenses and 10 to 15 m thick dykes(?) in fine grained massive mafic rocks. These felsic rocks are similar to those exposed south of Bryan Lake.

STRUCTURAL OBSERVATIONS

Original depositional features are rarely observed in the BPC, but beds, flow bands, debris flows, tuff layers and compositionally different units give a rough outline of local depositional surfaces. Depositional top indicators include graded beds, flame structures, scour channels and pillows.

The earliest deformational fabric (S_1) is expressed as a steeply dipping, penetrative, commonly anastomosing, pressure solution cleavage in massive competent felsic rocks, but a schistosity in mafic and particulate felsic rocks. The pressure solution cleavage is characterized by biotite domains that are up to 1 cm thick and separated by 5 to 10 cm thick microlithons. A large open to tight fold (F_1?) identified from the distribution of lithologies is probably related to the development of this fabric.

In massive, competent felsic rocks the S_1 fabric is commonly crosscut by a younger fracture cleavage (S_2). S_2 is expressed by fractures that separate ≤1 cm thick quartzofeldspathic microlithons. S_2 deflects and crenulates the solution cleavage if present.

S_1 and S_2 fabrics were subsequently folded during a later phase of deformation (D_3) that produced steeply plunging, upright, open to tight folds and crenulations (F_3). In the Thompson Lake and Murray Lake areas these folds are oriented at 270° to 300°.

The latest deformation events in the BPC produced several sets of brittle faults. The most common brittle faults belong to a conjugate set that have orientations of 300° to 330° for the dextral conjugate, and 005° to 030° for the sinistral conjugate in both the Thompson Lake and Murray Lake areas.

GEOCHEMISTRY

A large geochemical database has been assembled during the course of this mapping project. This data will be used to refine the volcanic stratigraphy and document both the geochemical changes within the magma during the development of the BPC and the effects of the various alterations associated with the mineralization.

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GS-12 CALLINAN MINE PROJECT (NTS 63K/13)*

by G.H. Gale, by T.H. Heine and L.I. Norquay

Gale, G.H., Heine, T.H. and Norquay, L.I., 1994: Callinan mine project (NTS 63K/13); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 64.

The Callinan project was initiated as a cooperative project by Manitoba Energy and Mines (MEM) and Hudson Bay Mining and Smelting (HBM&S) to map and investigate the surface and subsurface geology of the Callinan Mine. The ultimate goal of the project is to provide a 3-D integrated geological and geochemical model of the mine. HBM&S participants include mine geologists S.M. Trevor, D. Colli and J.J. O'Donnell and exploration geologists Dr. D. Price, J. Pickell and K. Gilmore. Saskatchewan Energy and Mines geologist D. Thomas has conducted detailed mapping in the study area and his database will be utilized in the preparation and interpretation of the surface geology.

Activities to date include digitization by HBM&S of existing company base and geological maps to establish rectified common base maps, three weeks of underground mapping by MEM staff, a pilot geochemical study and surface orientation field trips.

Planned activities include preparation of a preliminary geological map of the surface exposures, additional surface and underground mapping, drill core examination and geochemical studies.

GS-13 SURFICIAL GEOLOGY INVESTIGATIONS IN THE ATHAPAPUSKOW LAKE AREA (PARTS OF NTS 63K/11 AND 63K/12)*

by I. McMartin[1]

McMartin, I., 1994: Surficial geology investigations in the Athapapuskow Lake area (Parts of NTS 63K/11 and 63K/12); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 65-67.

INTRODUCTION

During the summer of 1994, surficial geology investigations were carried out in the Cormorant Lake area (NTS 63K) as part of the NATMAP Shield Margin activities (McMartin, 1993, 1994a). Field work was concentrated in the Athapapuskow Lake area and consisted of surficial geology mapping, till sampling, and detailed mapping of ice flow indicators along roads and shorelines. Regional till sampling was completed with air support north of the Shield Margin (NTS 63K/9, 63K/10 and 63K/11) and on the Paleozoic cover in Saskatchewan (63L). Detailed stratigraphic work was carried out on sand and gravel pit sections along roads and in backhoe excavations in the Wanless area. This report outlines the Quaternary geology investigations carried out in the Athapapuskow Lake area.

ICE FLOW RECORD

Lake Athapapuskow straddles the Paleozoic/Precambrian contact near the Manitoba-Saskatchewan border (Fig. GS-13-1). The study area is dominantly influenced by ice that flowed from the Keewatin Sector of the Laurentide Ice Sheet. At least three, and possibly four, ice flow directions across the study area indicate a north-northeastern provenance. Only at one site east of North Arm Bay of Athapapuskow Lake (Fig. GS-13-1), striations trending 160° were measured on a protected outcrop face. This southeasterly movement appears related to an earlier flow found sporadically across the Cormorant Lake area (McMartin, 1994a).

An early southwesterly flow (210° to 225°) was observed at several sites on the Shield in the northern part of Athapapuskow Lake, and this early flow was found in the Amisk Lake - Creighton area to the west of Athapapuskow Lake (Henderson and Campbell, 1992). The exposed Shield rocks are commonly striated, polished, grooved or carved into *roches moutonnées*, with a predominant direction toward 198° (186° to 202°). This main ice flow was also recognized in other Shield areas part of the NATMAP project (Gobert and Nielsen, 1991; Henderson and Campbell, 1992; McMartin, 1994a; Nielsen, 1992, 1993). Towards the southern half of the study area, which is underlain by Paleozoic dolomitic rocks, the ice flow appears to deviate more westerly as it spans the main lithological boundary, trending progressively 198°, 205°, and 211° (Fig. GS-13-1). This digression in ice flow directions was also observed in other Shield margin areas within the NATMAP project area (McMartin, 1994a, 1994b). Throughout the Shield portion of the Athapapuskow Lake area, a later less pervasive and slightly more westerly flow at 201° to 216° was recognized by fine striations in truncation with the dominant flow (Fig. GS-13-1). This later flow possibly found its counterpart over Paleozoic rocks, with a major southwestward readvance (218° to 235°) recorded in the southern part of the study area and documented west of The Pas Moraine and all along the Shield margin east of Simonhouse Lake (McMartin, 1994a).

SURFICIAL GEOLOGY

Glacial sediments

Three till units, which are associated with the last glacial expansion of the Laurentide Ice Sheet (Late Wisconsinan), have been recognized in the Athapapuskow Lake area.

The lower and most pervasive unit consists of a locally derived till overlying bedrock striated towards the SSW. On the Shield, this unit is sandy and noncalcareous, and forms a discontinuous cover, preferably on the down-ice side of bedrock hills. South of the Shield margin, this unit grades into a sandy-silty calcareous till, forming a thin but rather continuous blanket overlying dolomitic bedrock (Till 2, McMartin, 1993).

A calcareous Shield-derived till was found at a dozen sites on the Shield, as far as 15 km north of the Paleozoic. At one site this calcareous till was found overlying the lower till (Millwater Section, Fig. GS-13-1). This unit consists of a sandy-silty, weakly to moderately calcareous till that is very discontinuous in cover and has a variable clast composition. Visual field examination and pebble counts on the 4 to 8 mm fraction reveal that most of the calcareous tills contain very few dolomitic clasts. This could be related to the leaching of the carbonate pebbles in the upper C horizon where the samples were taken, or to the significant maturity of the sediment. Analysis of carbonate content and calcite/dolomite ratios will help to determine whether these calcareous tills are derived from unmapped Paleozoic outliers, secondary Precambrian carbonates, or previously deposited calcareous tills. At the Millwater Section, a strong fabric measured in this unit indicates an eastern provenance (280°), although no striae trending in this direction were measured in the study area.

A younger till was recognized at a few locations on the Shield, overlying massive clay at 3 sites and a calcareous till at the Millwater Section. This upper till consists of a sandy-clayey, non-calcareous, Shield-derived diamicton with a variable clast content. On the Paleozoic cover, a sandy-clayey weakly calcareous, clast-poor diamicton was found at several sites associated with a major readvance towards the southwest in Glacial Lake Agassiz (Till 3, McMartin, 1993). This summer's work in Saskatchewan southwest of the study area, has provided additional documentation on the nature and extension of this unit.

Glaciofluvial sediments

Several glaciofluvial ice contact elongated deposits running approximately north-south have been observed on the Shield, most of them ending in Lake Athapapuskow. Similar deposits have been described for the Naosap Lake area (Groom, 1989; Nielsen, 1993) and the Amisk Lake - Annabel Lake area (Henderson and Campbell, 1992). These deposits occur as discontinuous elongated terraces and ridges that are composed of moderately well sorted cross-bedded sands, pebbles and cobbles, commonly deformed and faulted, and interlayered with diamictic units of variable thicknesses. When these sediments are more confined to the lee of bedrock knobs, they commonly contain thicker diamicton layers, up to 15 m thick in the Schist Lake area (Fig. GS-13-2). The diamictons are relatively clast poor, commonly calcareous and commonly associated with sandy units below or above. The whole sequence is either capped with fine glaciolacustrine sediments, nearshore sediments or with a coarse grained loose diamicton. Laterally in the down current direction and within short distances, the coarse facies grade into laminated fine glaciolacustrine sediments. These deposits are interpreted as a series of longitudinally overlapping subaqueous outwash fans formed at or near the retreating ice front as meltwater flowed from subglacial conduits into Lake Agassiz (*cf.* Rust and Romanelli, 1975).

Glaciolacustrine sediments

Fine grained glaciolacustrine laminated or massive sediments deposited in Glacial Lake Agassiz occur at all elevations in the study area, and are mostly concentrated in the low areas between bedrock highs unless they are part of subaqueous outwash sequences.

Coarse nearshore sediments and wave-washed tills are common in the area and form thin, discontinuous deposits of relatively well sorted and bedded sand and pebble gravel. These sediments unconformably overlie glaciofluvial or glacial sediments, and formed as lake levels dropped and Glacial Lake Agassiz drained from the area.

* Funded by NATMAP Shield Margin Project

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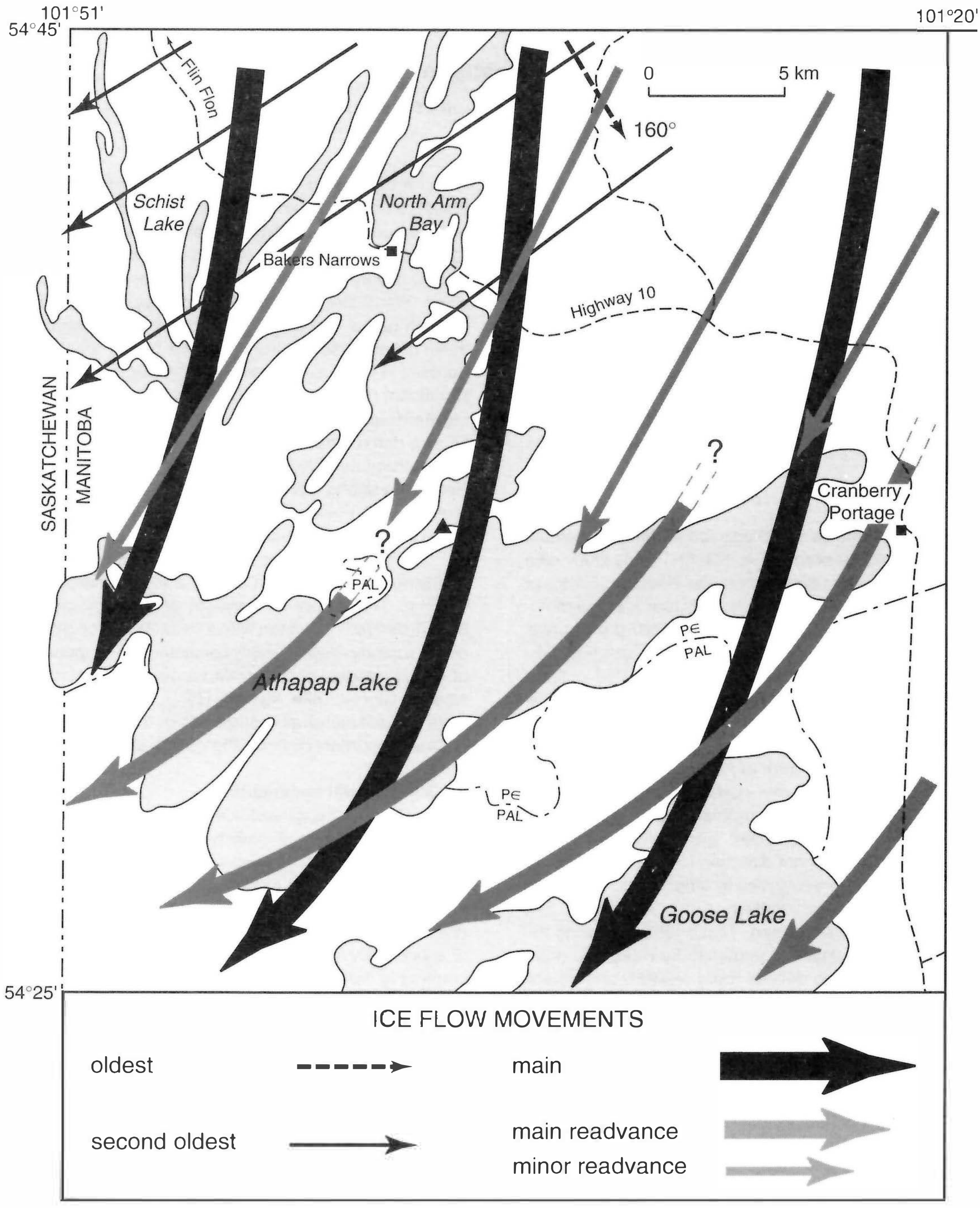


Figure GS-13-1: *General ice flow movements compiled from 152 sites measured in the study area. The Millwater Section is located in the central part of Athapapuskow Lake (filled triangle). The Precambrian/Paleozoic boundary appears in the southern half of the study area (broken line).*

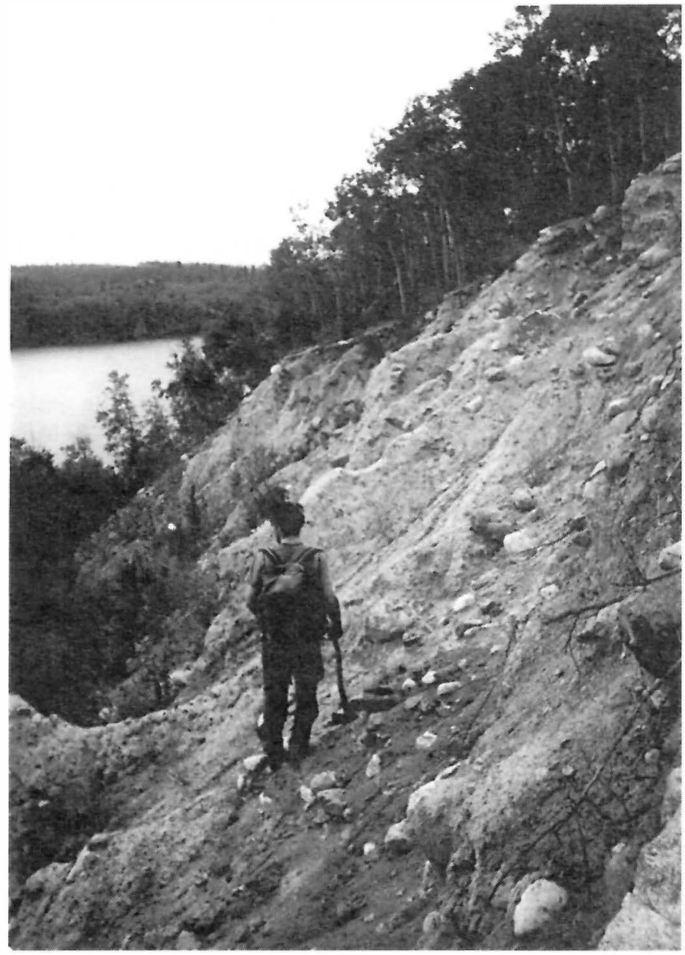
DRIFT PROSPECTING

The systematic drift prospecting program initiated as part of the NATMAP Shield Margin Project was pursued in the study area (McMartin and Pringle, 1994). A total of 292 till samples and 271 humus samples were collected this summer mostly from hand dug pits, including 146 till and 109 humus samples in the Athapapuskow Lake area. In this area, both diamictons from glaciofluvial sequences and wave washed tills were avoided for drift prospecting purposes. The analysis of the samples consists of textural, petrological and geochemical determinations, consistent with those used in the drift prospecting program.

ACKNOWLEDGMENTS

I am grateful to Robert Boucher and Manfred Hebel for their invaluable field assistance, to Erik Nielsen and Penny Henderson for discussions and comments, and to Tracy Barry for preparing the diagram.

Figure GS-13-2: Thick sandy-silty and non-calcareous diamicton exposed along Schist Lake near Flin Flon. The whole section is confined laterally by bouldery-sandy outwash sediments and is part of an ice- contact glaciofluvial deposit that runs along the lakeshore.



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GS-14 AMISK GROUP VOLCANIC ROCKS HOSTING THE REED LAKE GABBRO*

by B.L. Williamson[1]

Williamson, B.L., 1994: Amisk Group volcanic rocks hosting the Reed Lake gabbro; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 68-80.

SUMMARY

Amisk Group volcanic rocks at the west end of Reed Lake, previously described as chlorite schist or hornblende schist, were briefly investigated as part of a study focusing on the Reed Lake gabbro intrusion. They were recognized to be metamorphosed volcanic rocks, mostly volcaniclastic. Chemical analyses indicate that they are comparable to arc tholeiites recognized in the Flin Flon and Snow Lake areas.

INTRODUCTION

As an adjunct to a study focused on the Reed Lake gabbro intrusion which lies at the west end of Reed Lake, the host rocks to the intrusion were studied and sampled in reconnaissance fashion to establish a general basis for comparison of the magmatic suites. Observations indicated that the previous description of the rocks by Rousell (1970) as "chlorite schist", "hornblende schist" and "banded gneiss" do not recognize their essentially volcanic and volcaniclastic nature. Fedikow and Lebedynski (1991) mention the felsic volcanic and fragmental rocks that host the Spruce Point Cu-Zn deposit at the east end of Reed Lake, but focus on the structure and alteration of the deposit. The chemical composition of these rocks and their chemical affinities to other suites recognized by Syme (1988, 1992) in the Flin Flon and Elbow Lake areas and by Bailes (1988) in the Snow Lake area have not been documented. This contribution is intended to provide a preliminary characterization of the volcanic rocks and their chemical composition.

PETROGRAPHY

Twenty-three samples from 17 sites (Fig. GS-14-1) were subdivided into two rock types: basalt and volcaniclastic (volcanic breccia, tuff). Volcanic breccia are readily identified in the field by coarse felsic clasts in a chloritic matrix, but finer tuff and basalt can be difficult to distinguish. In the absence of clear fragments or phenocrysts, layered and foliated tuff may be difficult to distinguish from sheared basalt. Diagnostic flow tops and pillows were not observed. Foliations were recognized in some locales, but whether they originate from original bedding or from later imposed deformation was not determined. Modal composition was determined by visual estimate, and mineral identification was confirmed by whole rock XRD analysis on about half the samples.

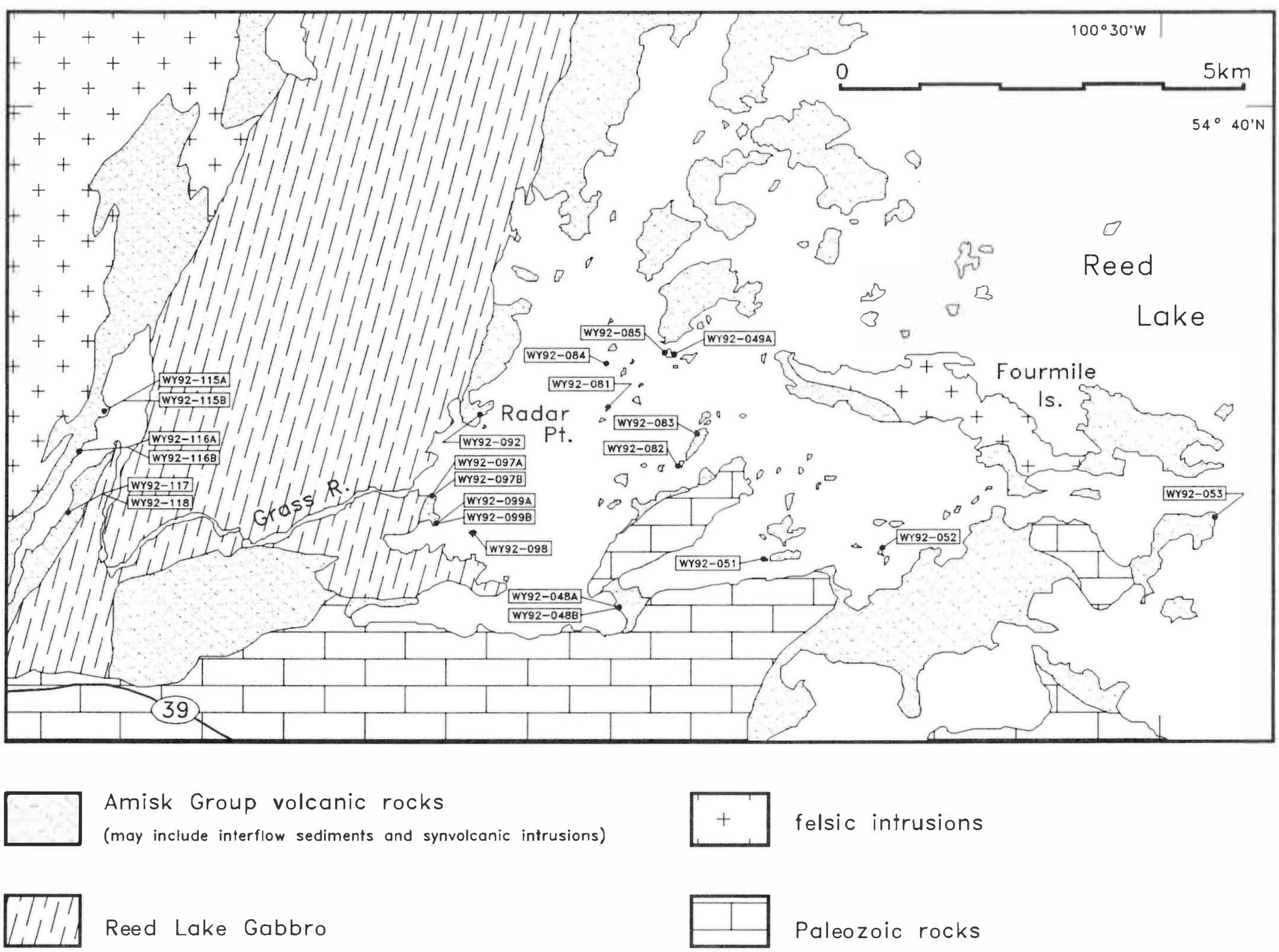

Figure GS-14-1: Generalized geology of the west end of Reed Lake (after Rousell, 1970), showing sample locations.

* Funded by NATMAP Shield Margin Project
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BASALT

Basalt is generally fine grained, massive, homogeneous, light grey to dark grey or black on fresh surface, and weathering to greenish grey or brown on weathered surfaces. Rarely, lath-shaped phenocrysts occur in a fine grained (<0.6 mm) felted groundmass of quartz, albitic feldspar, chlorite and hornblende. Phenocrysts of pyroxene (or secondary hornblende after original pyroxene) in some cases exhibit relicts of the original pyroxene twin planes. Rare plagioclase phenocryts (≈1 mm long) exhibit preserved albite twinning. One sample consisted of a relatively coarse grained (0.5-2 mm) mass of interlocking hornblende (after pyroxene) and twinned plagioclase. Alteration to epidote (clinozoisite?) is variable, and some samples contain secondary carbonate (dolomite?).

Modal mineralogy consists of approximately 50% mafic alteration minerals in variable proportions (chlorite, 10-40%; hornblende/tremolite, 20-50%); 50% quartz + albitic feldspar in variable proportions from essentially all feldspar to predominantly quartz and trace to 1% opaques. Epidote generally constitutes 15 to 30% and carbonate, trace to 20%.

VOLCANICLASTIC ROCKS

Volcaniclastic rocks occur as volcanic breccia and coarse- to fine-grained tuff. Volcanic breccia were identified at two locations: a small island in the channel south of Fourmile Island, and at the isthmus of Radar Point. Volcanic breccia have a chloritic, massive to foliated matrix hosting felsic blocks (and possibly bombs) up to 50 cm (Fig. GS-14-2a). Volcanic breccia is matrix supported (about 30-50% fragments). Tuff was identified by the presence of <1 cm fragments (Fig. GS-14-2b) and was not separated into different subtypes in the field. A single outcrop displayed interlayered mafic and felsic tuffs (Fig. GS-14-2c). Based upon thin section and chemical data they can be classed as felsic (*i.e.*, quartz-rich) or mafic (*i.e.*, hornblende-chlorite-biotite-rich). Felsic tuff is light to dark grey on fresh surface, weathers dirty white to dark grey, and occasionally exhibits orange hematite stains. Mafic tuff is usually strongly foliated and dark green reflecting its largely chloritic matrix, and may be sparsely to densely speckled with dirty white felsic fragments.

In thin section, tuff is distinguished by a foliated fabric, well defined compositional layering (mafic/felsic mineral proportions on a millimetre scale) and grain size variation. The matrix locally exhibits flow texture around fragments (Fig. GS-14-3). The tuff consists of an extremely fine grained matrix (<0.1 mm) containing thin quartz lenses (0-25%, 0.5-2 mm thick), which are usually coarser grained (0.1-0.3 mm) than the matrix, and occasional crystal fragments (hornblende after original pyroxene, or quartz + clinozoisite, after original feldspar, 1-3 mm). Tuff is composed of quartz, albitic feldspar, hornblende, biotite, chlorite, epidote, minor carbonate and trace opaques (<1%). Felsic or mafic subtypes are defined on mineral proportions:

	Mafic tuff		Felsic tuff
30-60%	mafic:	<20%	mafic
	5-40% chlorite		
	up to 50% hornblende		
	up to 10% biotite		
10-60%	quartz + feldspar	70-80%	quartz + feldspar
<5%	opaques	<1%	opaques
0-40%	epidote	0-15%	epidote
0-10%	carbonate	0-5%	carbonate

GEOCHEMISTRY

Whole rock major and trace elements, REE and PGE are presented in Appendix GS-14-A. Most elements were analyzed by the Mineralogy and Chemistry Subdivision at the Geological Survey of Canada by their standard techniques; PGE were analyzed by Acme Analytical Laboratories. The whole rock chemistry clearly reflects the petrographic distinctions between the main rock units (Table GS-14-1).

AFM and Jensen plots (Fig. GS-14-4) indicate the suite to be tholeiitic, particularly, high-Fe basalt with mafic and felsic tuff grading into tholeiitic andesite and dacite compositions. In contrast, the AFM plot indicates a distinct gap between felsic and mafic rocks, suggesting the possibility of a bimodal magma suite.

The Pearce-Cann Ti-Zr-Y plot (Fig. GS-14-5a) shows widespread scatter in which the mafic tuff and basalt broadly fall about the fields defined for low potassium tholeiites. Figure 14-5b shows a similar broad scatter, falling near the field of island-arc basalts (IAB).

Comparison of Reed Lake data with other Amisk Group volcanic rocks reported by Bailes (1988) and Syme (1992) from the Flin Flon, Chisel Lake, and Elbow Lake areas indicates some chemical similarities. The plot of Ti *vs.* Zr shows the mafic rocks have comparable compositions to Flin Flon and Chisel Lake basalts (Bailes, 1988), including low Zr levels, and best plot near the field of arc lavas (Fig. GS-14-6). The plot of Mg/Ni *vs.* Fe/(Fe+Mg) for the Reed Lake mafic rocks clearly demonstrates an arc tholeiite affinity, comparable to Flin Flon arc tholeiites (reported by Syme, 1992; Fig. GS-14-7). The Reed Lake rocks are obviously distinct from the defined fields of Flin Flon back-arc and ocean-floor basalts and Elbow Lake basalts.

Stern *et al.* (in prep.) plot TiO_2 *vs.* MgO to distinguish the tectonic settings of Amisk Group volcanic rocks. The Reed Lake data lie within the island arc field, coincident with the range of Flin Flon arc rocks, and distinct from the range of Amisk ocean-floor basalts that lie within the field of MORB + BABB (Fig. GS-14-8).

On the standard "spider" diagram, Reed Lake basalt samples display patterns and concentrations that closely resemble the average island arc tholeiite of Pearce (1982) (Fig. GS-14-9). Arc tholeiites from the Flin Flon area described by Syme (1992) and Stern *et al.* (in prep.) show a similar pattern, but tend to be more depleted in certain high field strength elements (*i.e.*, Zr, Ti, Y, Yb) than the Reed Lake samples. Comparison of Reed Lake samples with arc basalts from the Chisel-Morgan lakes area (reported by Bailes, 1988) shows closer similarities in patterns and concentrations, with the exception of extreme Ni depletion in the Chisel-Morgan samples.

Plots of chondrite-normalized REE for Reed Lake basalt samples indicate an average flat pattern at about 5 to 10 times chondrite levels, with the exception of one sample that shows a slightly more enriched overall level and a substantial positive Eu anomaly (Fig. GS-14-10a). Mafic tuff samples show a similar overall flat trend, but over a wider range (about 2-10 times chondrite levels) and with greater variability (slightly positive to slightly negative slopes)(Fig. GS-14-10b). Felsic tuff samples are slightly enriched compared to mafic rocks and show a moderate LREE depletion (Fig. GS-14-10c). Other Amisk Group arc tholeiites previously reported from the Snow Lake area (Bailes, 1988; Stern et *al.*, in prep.) show similar flat patterns at about 10 times chondrite levels.

GABBROIC ROCKS

Two locations described as gabbro by Rousell (1970) were examined and sampled. The rocks are dark green, fine grained (1-2 mm) and consist of about 70% hornblende (after original pyroxene?) and 30% feldspar with subophitic to automorphic texture. Field relationships suggest that these are small gabbro bodies, but the relationship of

Table GS-14-1
General identifying chemical characteristics of Reed Lake volcanic rocks

Rock Type	SiO_2	MgO	Fe_2O_3(t)	H_2O	Zr(ppm)	Sc(ppm)	V(ppm)	Ni(ppm)	Co(ppm)
Felsic tuff	>70%	<2%	<7%	<2%	>60	<20	<5	<10	<10
Mafic tuff	<60%	>2%	>9%	>2%	<60	>30	>100	>10	>25
Basalt	<55%	>4%	>11%	>3%	<40	>35	>200	>25	>40

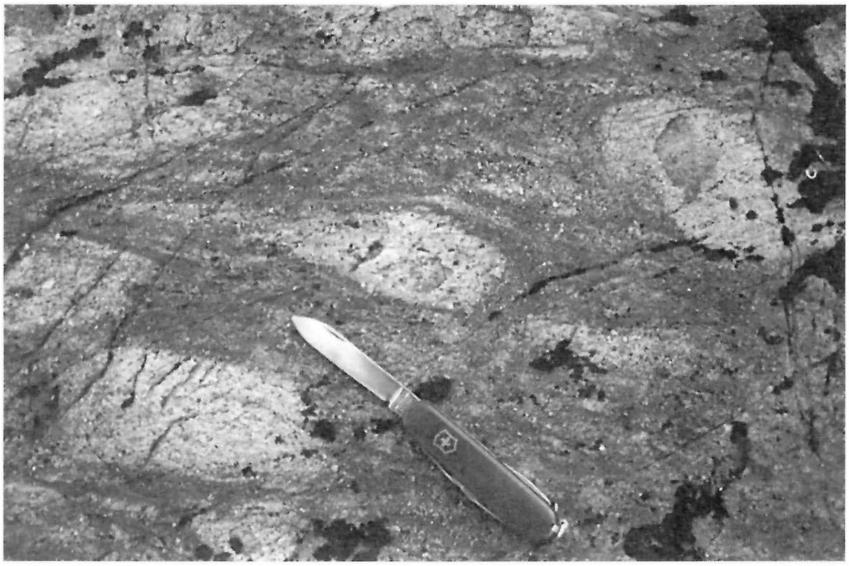
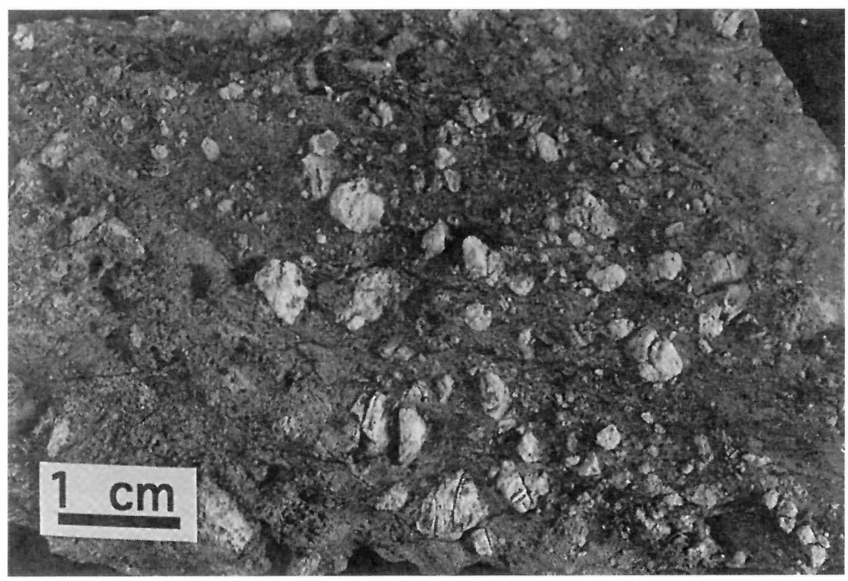


Figure GS-14-2: *a) Volcanic breccia, composed of felsic blocks in a chloritic matrix. Knife is 16 cm long. b) Mafic tuff with coarse felsic lapilli (white) in dark chloritic matrix (WY92-052). c) Interlayered mafic and felsic tuff (WY92-116A and -116B, respectively) on the Grass River south of Flag Lake. Notebook is 21 cm high.*



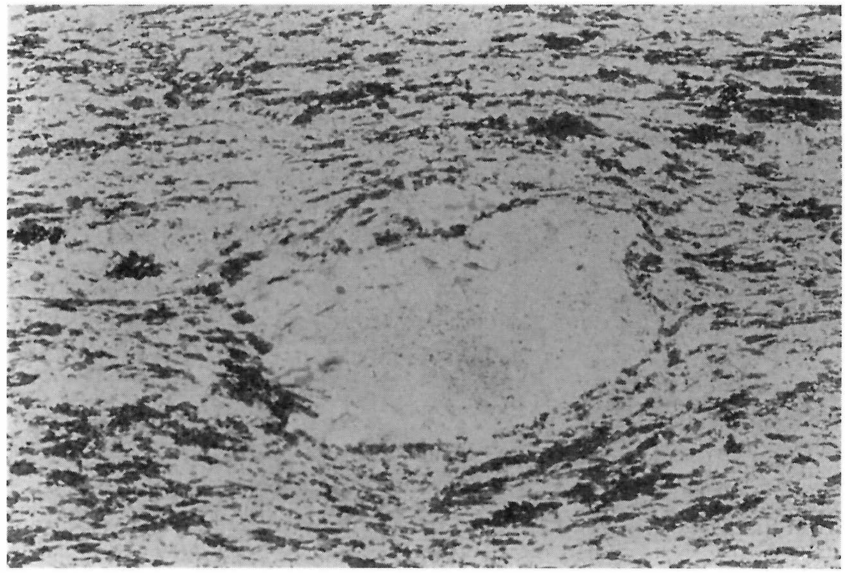


Figure GS-14-3: *Photomicrograph (plane polarized) of felsic tuff (WY92-099A): fine layered matrix flows around coarser quartz fragment. Field of view is about 2 mm wide.*

these gabbros to the Reed Lake Gabbro on the west shore of Reed Lake is unclear.

The chemical composition of the gabbro samples (WY92-082 and WY92-083) is listed in Appendix GS-14-A. The chemical similarity between these gabbros and the basalt suggests that the gabbro bodies may be more closely related to the volcanic assemblage than to the Reed Lake Gabbro, but conclusive evidence will require a more precise definition of the chemical nature of the Reed Lake Gabbro.

ACKNOWLEDGMENTS

Thanks are due to O.R. Eckstrand for helpful discussion and direction in preparing this report, and to Richard Lancaster (GSC) for redrafting of several figures. The manuscript benefited from review by O.R. Eckstrand, R.A. Stern and E.C. Syme.

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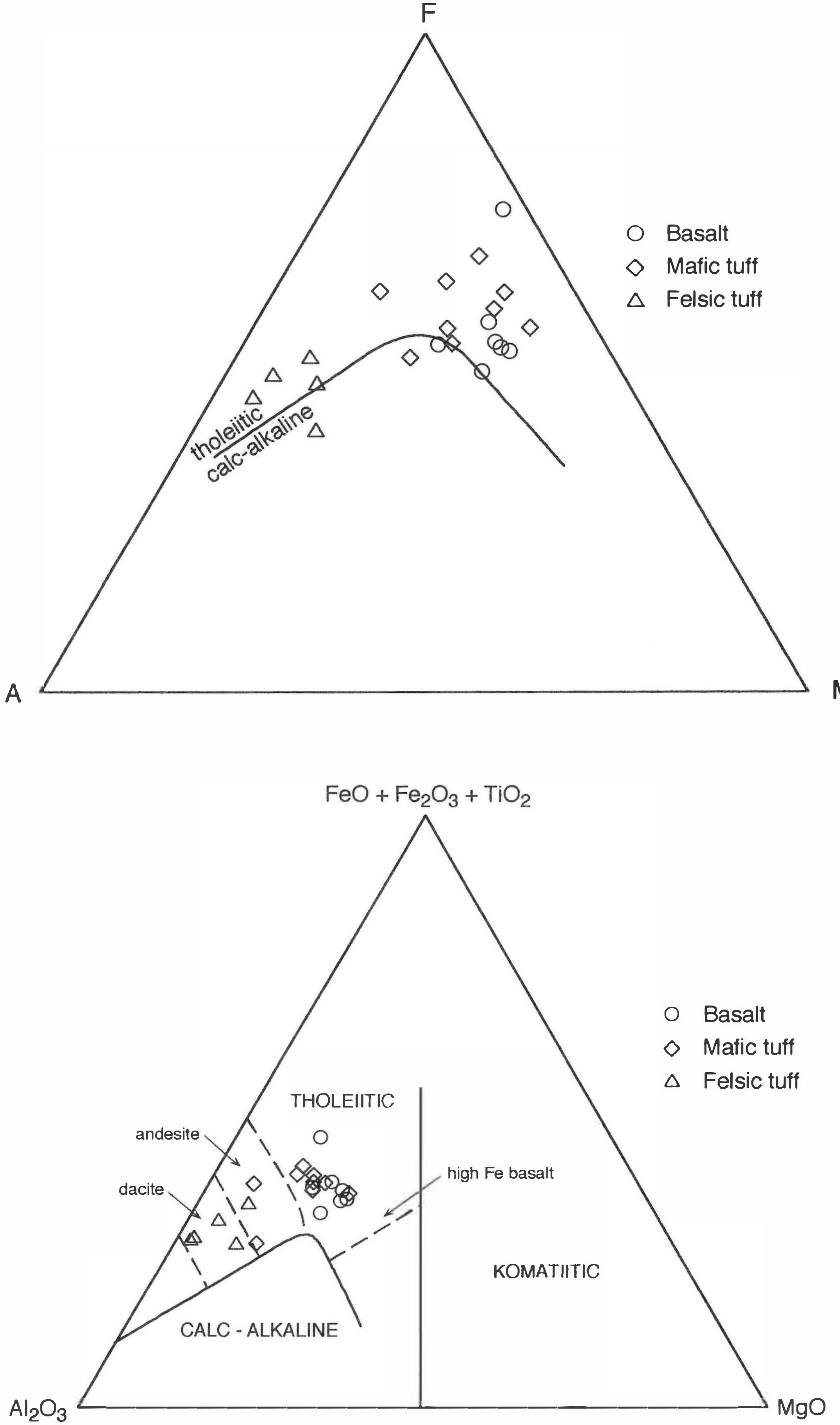


Figure GS-14-4: *a) AFM plot of Reed Lake basalt, mafic tuff and felsic tuff. The tholeiite/calc-alkaline discriminant line is as given by Irvine and Baragar (1971). b) Jensen plot of Reed Lake basalts, mafic tuffs and felsic tuffs (after Jensen, 1976).*

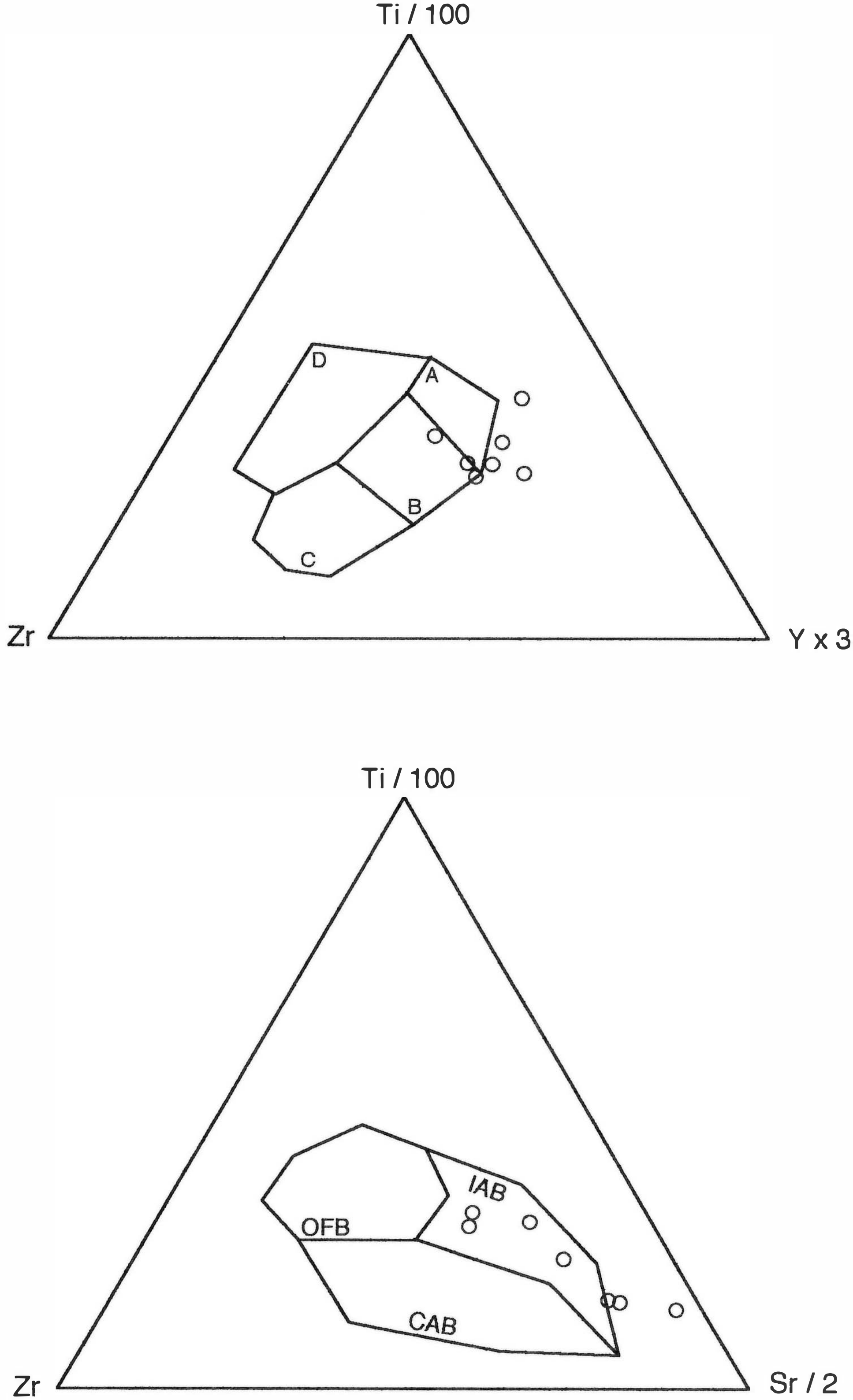


Figure GS-14-5: *a) Pearce-Cann plot (Ti-Zr-Y) for distinguishing tectonomagmatic environment of origin of basalts (after Pearce and Cann, 1973). Low-potassium tholeiites plot in fields A+B, calc-alkaline basalts in fields B+C, ocean-floor basalts in field B, and within-plate basalts in field D. b) Alternative Pearce-Cann plot (Ti-Zr-Sr) for distinguishing tectonomagmatic environment of origin. IAB=island arc-basalt, CAB=calc-alkaline basalt, OFB=ocean-floor basalt.*

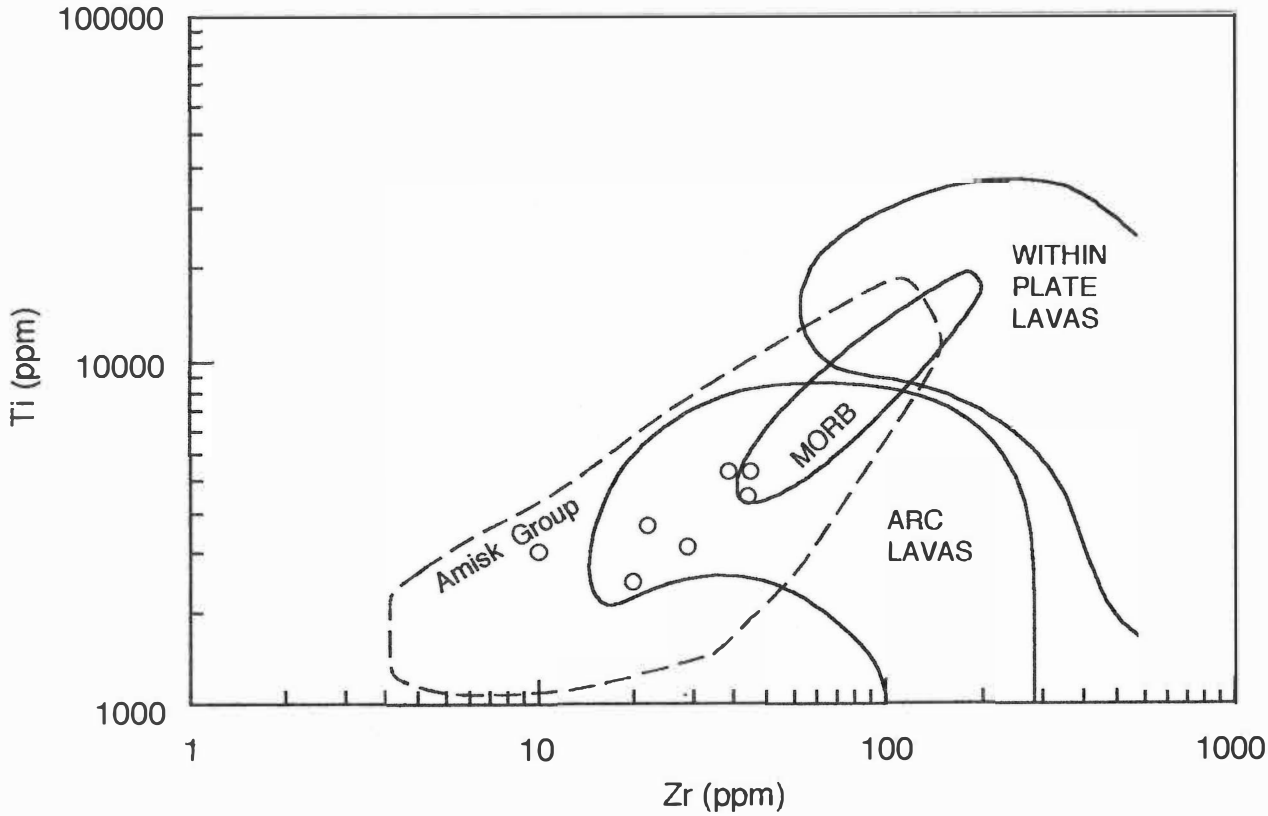


Figure GS-14-6: *Plot of Ti vs. Zr for Reed Lake basalts. The field circumscribed for Amisk Group samples (dashed line) is from Bailes (1988). The solid lines defining fields for MORBs, arc lavas and within plate-lavas are from Pearce et al. (1981).*

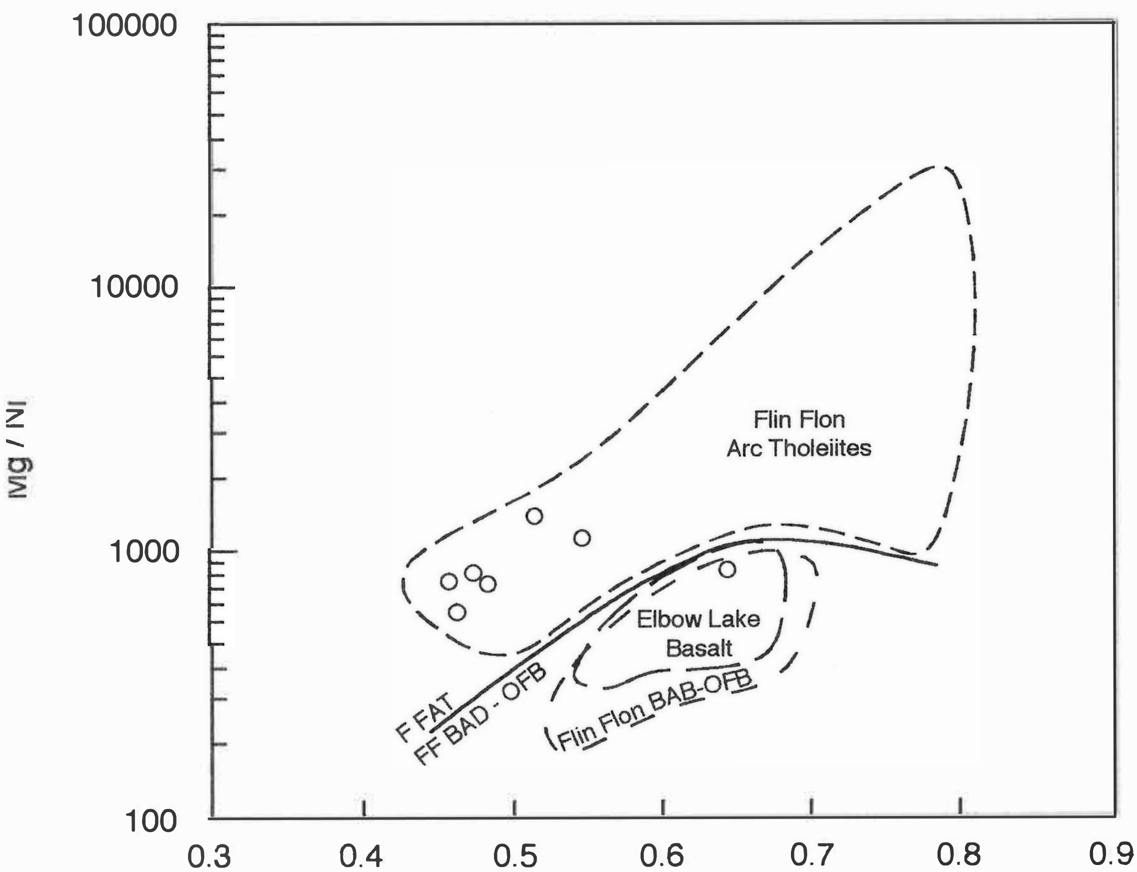


Figure GS-14-7: *Plot of Mg/Ni vs. Fe/(Fe+Ma) for Reed Lake basalt. The fields circumscribed for Flin Flon and Elbow Lake basaltic rocks (dashed lines) and the discriminant line (solid) separating Flin Flon arc tholeiites (FFAT) and Flin Flon back-arc/ocean floor basalts (FFBAB-OFB) are from Syme (1992).*

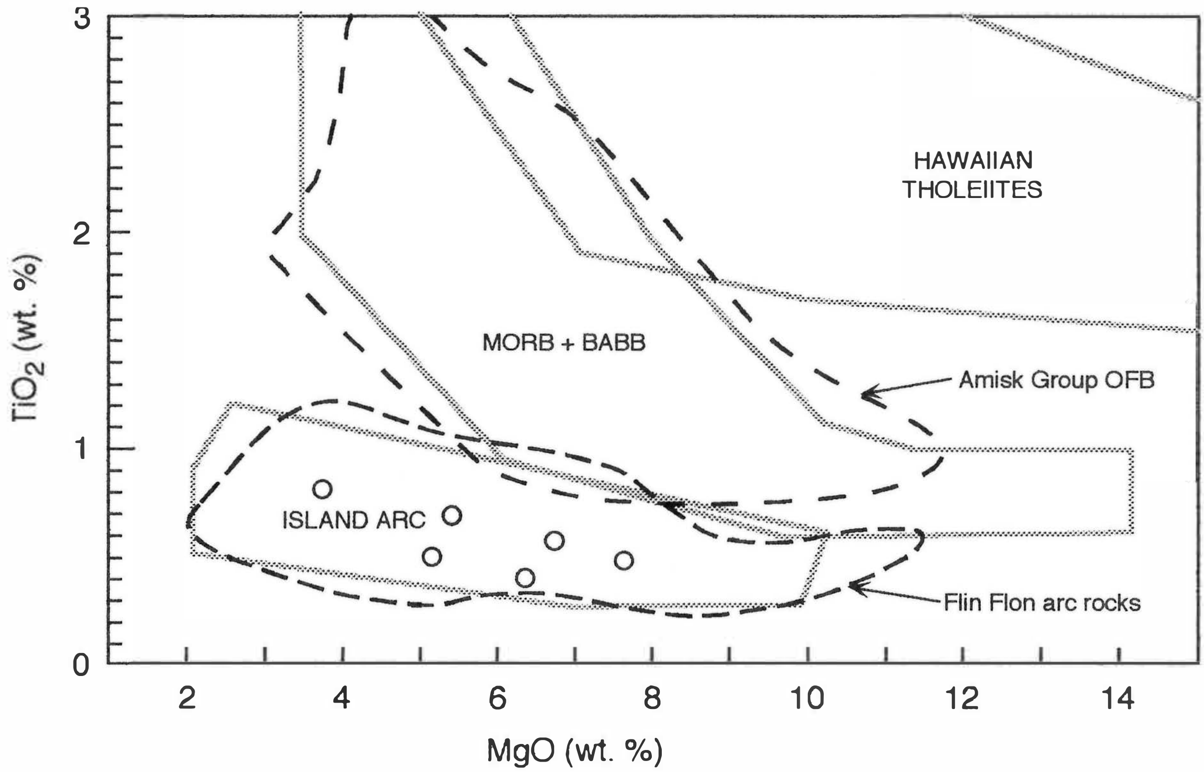


Figure GS-14-8: *Plot of TiO_2 vs. MgO for Reed Lake basalts. The ranges circumscribed for Amisk Group rocks (dashed lines) and the discriminant fields (solid lines) are from Stern et al. (in prep.).*

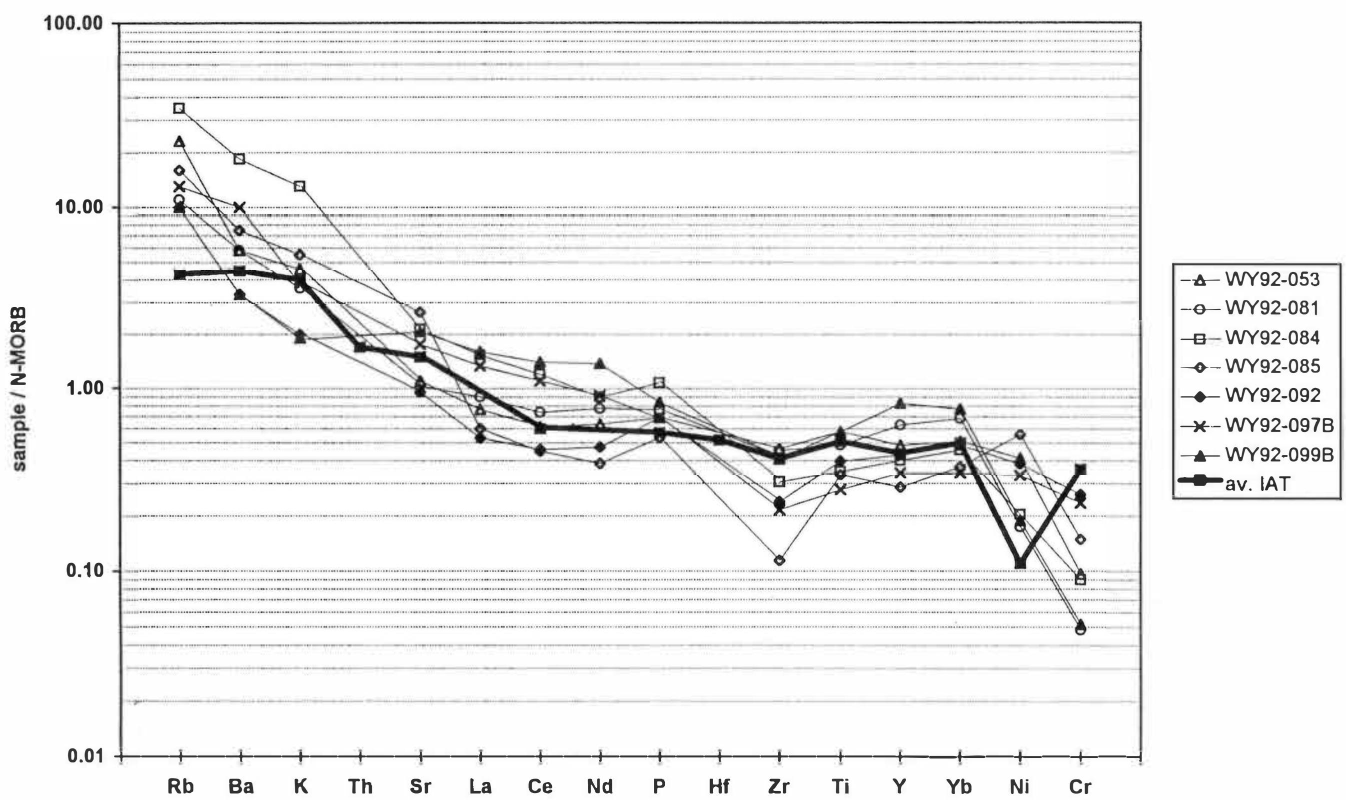
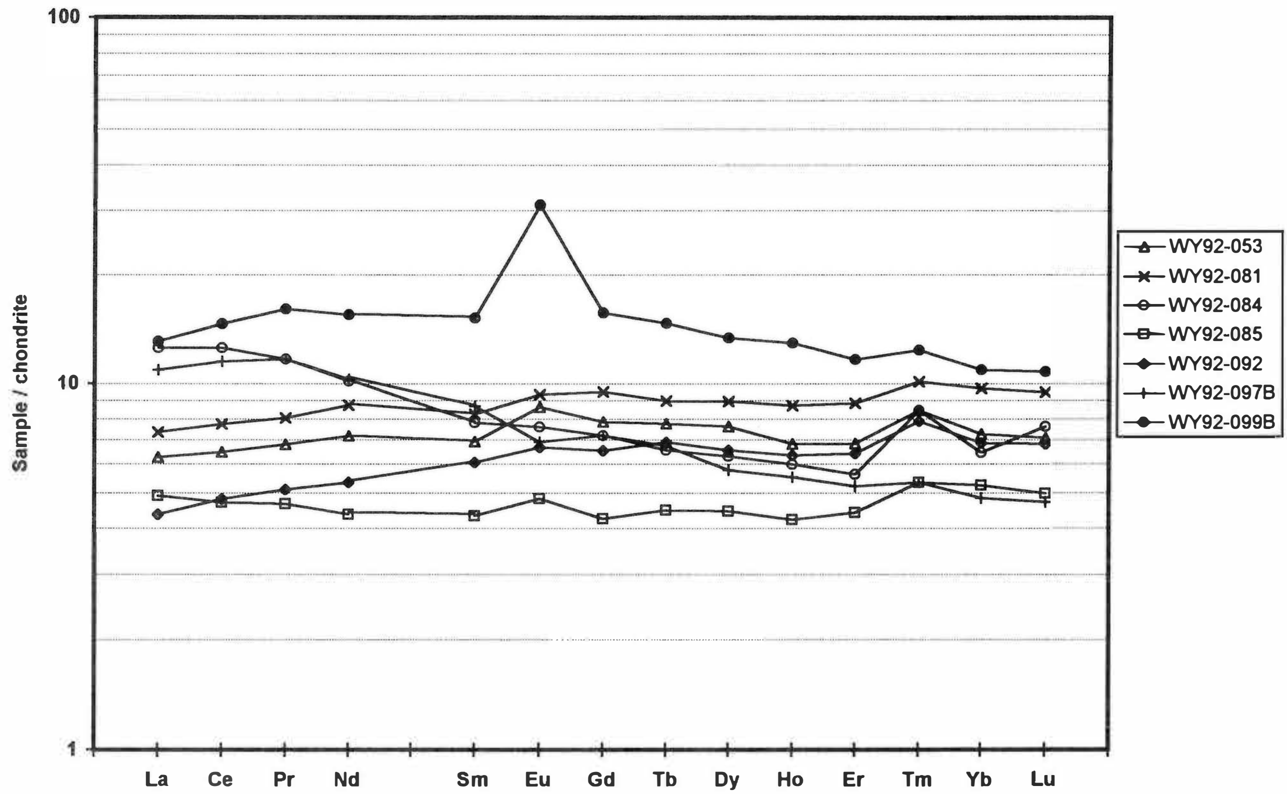
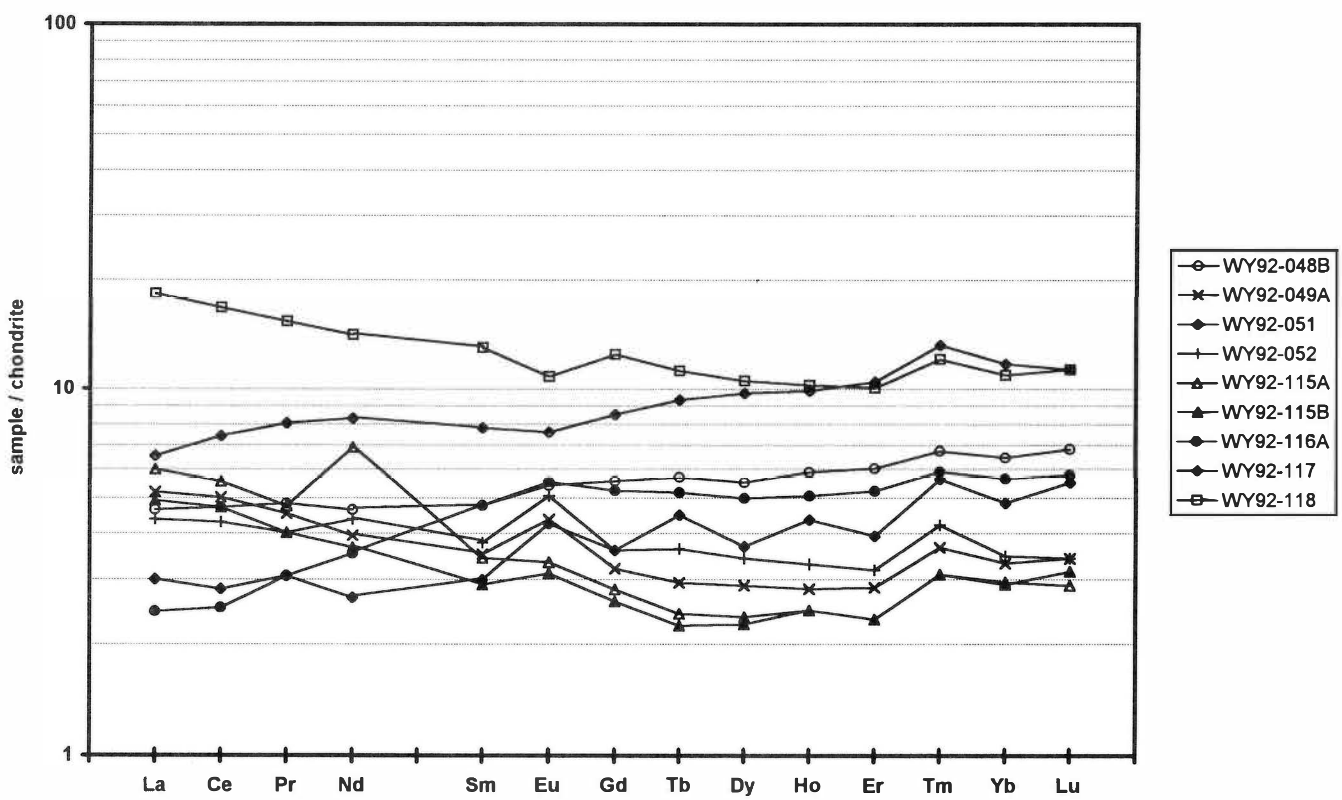


Figure GS-14-9: *Spider diagram of Reed Lake basalts, with a comparison average island arc tholeiite from Pearce (1982). Samples are normalized to N-MORB values of Saunders and Tarney (1984).*



Reed Lake mafic tuffs



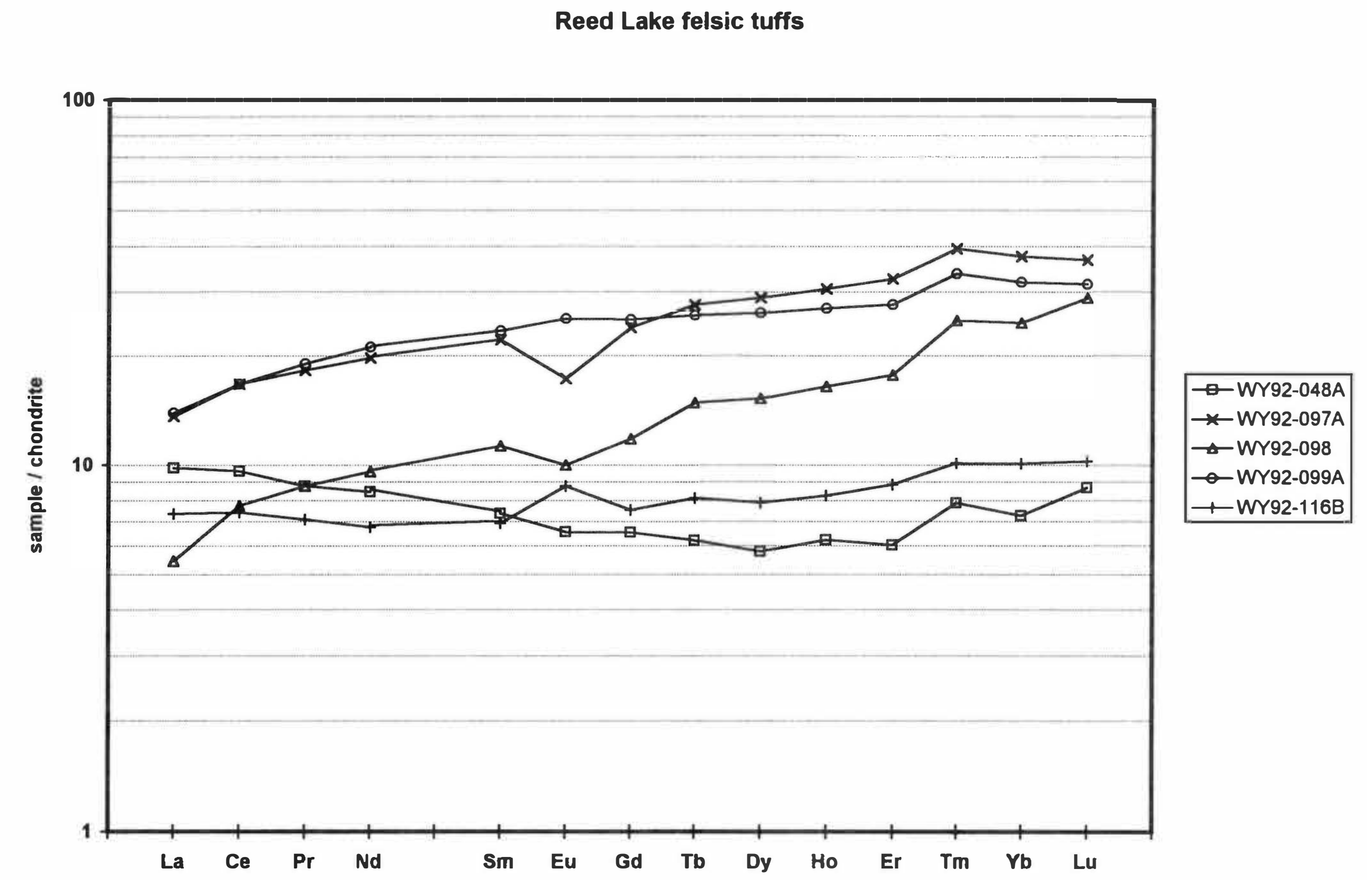


Figure GS-14-10: *REE plots of a) basalt, b) mafic tuff and c) felsic tuff from Reed Lake. Samples are normalized to chondrite values from Taylor and McLennan (1985, p. 298).*

Appendix GS-14-A1: Major element chemistry (wt. %) of Amisk Group Volcanics, Reed Lake area

Sample	Lithology	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O	CO_2	S	Total
WY92-053	basalt	49.60	0.81	15.70	3.00	8.50	0.17	7.39	6.78	3.70	0.46	0.09	3.90	0.00	<0.02	100.20
WY92-081	basalt	55.00	0.68	13.20	3.40	7.30	0.14	5.44	6.30	2.20	0.36	0.10	3.80	1.60	<0.02	99.60
WY92-084	basalt	53.20	0.49	5.10	2.80	8.60	0.15	5.17	5.08	3.30	1.30	0.14	3.30	0.30	<0.02	99.10
WY92-085	basalt	48.00	0.47	15.40	3.40	8.70	0.17	7.67	7.24	2.50	0.55	0.07	4.30	1.00	0.02	99.70
WY92-092	basalt	49.20	0.56	14.60	3.30	8.40	0.22	6.78	9.70	2.90	0.20	0.09	3.10	0.30	0.02	99.50
WY92-097B	basalt	50.80	0.39	16.20	3.40	7.20	0.18	6.39	8.83	2.40	0.38	0.09	3.60	0.10	<0.02	100.10
WY92-099B	basalt	54.40	0.81	12.30	4.50	8.10	0.20	3.75	10.50	0.40	0.19	0.11	2.90	1.00	0.13	99.40
WY92-082	gabbro	49.50	0.81	13.50	3.30	10.60	0.22	7.21	9.26	2.70	0.37	0.06	3.20	0.10	<0.02	101.00
WY92-083	gabbro	48.40	0.80	13.80	3.20	10.70	0.23	6.89	10.10	2.70	0.13	0.06	3.10	0.10	0.06	100.40
WY92-048B	mafic tuff	51.40	0.87	16.70	2.60	10.30	0.10	5.62	1.49	2.30	2.21	0.18	5.00	1.60	<0.02	100.50
WY92-049A	mafic tuff	49.00	0.23	19.40	4.30	4.40	0.13	4.16	12.30	1.30	0.43	0.05	3.40	0.30	<0.02	99.50
WY92-051	mafic tuff	56.80	0.81	13.90	2.80	8.10	0.23	4.58	1.75	3.60	1.94	0.13	3.30	1.60	<0.02	99.70
WY92-052	mafic tuff	47.70	0.64	16.10	2.90	8.80	0.20	5.49	7.88	1.00	0.79	0.08	4.70	3.40	0.05	99.90
WY92-115A	mafic tuff	51.60	0.26	15.70	4.80	7.70	0.17	4.17	9.19	1.50	0.33	0.09	3.40	0.20	0.33	99.60
WY92-115B	mafic tuff	50.80	0.24	13.90	4.40	7.20	0.14	7.06	10.20	1.60	0.20	0.06	3.20	0.10	0.31	99.50
WY92-116A	mafic tuff	55.30	0.57	14.80	3.10	9.20	0.19	4.01	7.99	2.90	0.20	0.06	1.80	0.00	0.02	100.20
WY92-117	mafic tuff	59.00	0.43	13.30	2.30	8.50	0.14	5.16	2.95	3.40	0.61	0.06	3.00	0.40	0.04	99.30
WY92-118	mafic tuff	59.80	0.57	14.90	3.10	6.50	0.15	2.01	6.31	2.90	1.00	0.17	1.80	0.00	0.07	99.40
WY92-048A	felsic tuff	73.90	0.22	10.80	1.40	3.10	0.04	1.73	0.91	3.30	1.61	0.07	1.70	1.00	<0.02	99.80
WY92-097A	felsic tuff	75.60	0.26	10.70	1.60	2.50	0.04	0.48	2.97	3.40	0.32	0.05	1.00	0.10	0.03	99.10
WY92-098	felsic tuff	69.70	0.28	11.40	1.20	5.30	0.08	1.64	0.60	1.90	3.65	0.06	2.30	0.80	<0.02	99.00
WY92-099A	felsic tuff	73.70	0.26	11.40	0.30	4.20	0.04	0.56	2.00	4.40	0.59	0.06	1.00	0.20	0.02	98.80
WY92-116B	felsic tuff	73.80	0.29	11.00	1.10	4.10	0.06	0.91	2.74	3.70	0.28	0.09	0.80	0.10	0.05	99.10

Appendix GS-14-A2: Trace element chemistry of Amisk Group volcanics, Reed Lake area

Sample	Rb	Sr	Zr	Be	Sc	Nb	Ba	Cr	V	Ni	Cu	Co	Zn	Pt	Pd	Rh	Au
WY92-053	23	150	41	<0.5	42.0	10	70	28	260	57	140	48	67	18	7	<5	6
WY92-081	11	140	40	<0.5	41.0	<10	70	14	280	24	12	40	83	5	4	<5	2
WY92-084	35	290	27	0.7	39.0	<10	220	26	260	28	13	40	69	27	11	<5	3
WY92-085	16	360	<10	<0.5	48.0	<10	90	43	290	77	110	58	89	60	42	<5	10
WY92-092	<10	130	21	<0.5	44.0	<10	40	76	270	53	230	49	87	12	11	<5	9
WY92-097B	13	240	19	0.6	41.0	<10	120	68	240	46	<10	41	99	21	22	<5	2
WY92-099B	<10	280	36	0.5	36.0	<10	40	15	410	26	190	44	64	19	6	<5	9
WY92-048A	17	85	58	<0.5	15.0	11	110	14	<5	17	44	6	65	<3	5	<5	5
WY92-097A	16	160	190	0.6	8.0	<10	100	<10	<5	<10	73	9	31	11	4	<5	4
WY92-098	38	<20	180	0.5	11.0	13	100	10	<5	<10	19	6	110	40	7	<5	2
WY92-099A	17	110	180	0.8	11.0	13	140	<10	<5	<10	<10	6	29	9	5	<5	2
WY92-116B	16	100	63	<0.5	16.0	13	140	<10	<5	<10	33	<10	16	<3	<3	<5	12
WY92-082	11	88	39	<0.5	48.0	11	50	27	270	46	42	63	85	<3	<3	<5	<1
WY92-083	<10	91	36	<0.5	52.0	<10	50	23	280	48	180	68	88	<3	<3	<5	4
WY92-048B	27	76	38	0.6	36.0	13	310	33	280	41	170	40	170	5	19	<5	12
WY92-049A	18	110	14	<0.5	33.0	<10	50	26	220	32	34	41	57	9	26	<5	3
WY92-051	29	31	65	<0.5	33.0	10	390	12	190	14	41	35	120	8	6	<5	6
WY92-052	21	160	10	<0.5	44.0	<10	70	20	340	19	150	37	81	15	25	<5	5
WY92-115A	15	200	13	<0.5	48.0	10	140	16	290	17	98	40	62	9	41	<5	2
WY92-115B	16	190	13	<0.5	46.0	<10	90	230	260	38	65	43	43	12	27	<5	2
WY92-116A	11	120	28	<0.5	36.0	<10	90	16	280	22	32	38	52	12	10	<5	2
WY92-117	21	63	20	<0.5	36.0	11	120	12	270	19	180	38	83	8	13	<5	35
WY92-118	30	240	58	1.1	29.0	<10	310	12	100	12	47	25	62	4	4	<5	2

NOTE: Values reported are in ppm, except for Pt, Pd, Rh and Au in ppb.

Appendix GS-14-A3: Rare Earth Element chemistry (ppm) of Amisk group volcanics, Reed Lake area.

Sample	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
WY92-053	17.0	2.3	6.2	0.93	5.1	1.60	0.75	2.40	0.45	2.9	0.58	1.70	0.30	1.80	0.27
WY92-081	22.0	2.7	7.4	1.10	6.2	1.90	0.81	2.90	0.52	3.4	0.74	2.20	0.36	2.40	0.36
WY92-084	14.0	4.6	12.0	1.60	7.2	1.80	0.66	2.20	0.38	2.4	0.51	1.40	0.30	1.60	0.29
WY92-085	10.0	1.8	4.5	0.64	3.1	1.00	0.42	1.30	0.26	1.7	0.36	1.10	0.19	1.30	0.19
WY92-092	15.0	1.6	4.6	0.70	3.8	1.40	0.58	2.00	0.40	2.5	0.54	1.60	0.28	1.70	0.26
WY92-097B	12.0	4.0	11.0	1.60	7.3	2.00	0.60	2.20	0.39	2.2	0.47	1.30	0.19	1.20	0.18
WY92-099B	29.0	4.8	14.0	2.20	11.0	3.50	2.70	4.80	0.85	5.1	1.10	2.90	0.44	2.70	0.41
WY92-048A	14.0	3.6	9.2	1.20	6.0	1.70	0.57	2.00	0.36	2.2	0.53	1.50	0.28	1.80	0.33
WY92-097A	76.0	5.0	16.0	2.50	14.0	5.10	1.50	7.30	1.60	11.0	2.60	8.10	1.40	9.30	1.40
WY92-098	32.0	2.0	7.4	1.20	6.8	2.60	0.87	3.60	0.86	5.8	1.40	4.40	0.89	6.10	1.10
WY92-099A	65.0	5.1	16.0	2.60	15.0	5.40	2.20	7.70	1.50	10.0	2.30	6.90	1.20	7.90	1.20
WY92-116B	20.0	2.7	7.1	0.97	4.8	1.60	0.76	2.30	0.47	3.0	0.70	2.20	0.36	2.50	0.39
WY92-082								REE not determined							
WY92-083								REE not determined							
WY92-048B	15.0	1.7	4.5	0.66	3.3	1.10	0.47	1.70	0.33	2.1	0.50	1.50	0.24	1.60	0.26
WY92-049A	7.0	1.9	4.8	0.62	2.8	0.81	0.38	0.98	0.17	1.1	0.24	0.71	0.13	0.82	0.13
WY92-051	23.0	2.4	7.1	1.10	5.9	1.80	0.66	2.60	0.54	3.7	0.84	2.60	0.47	2.90	0.43
WY92-052	7.1	1.6	4.1	0.55	3.1	0.87	0.44	1.10	0.21	1.3	0.28	0.79	0.15	0.86	0.13
WY92-115A	5.5	2.2	5.3	0.65	4.9	0.79	0.29	0.86	0.14	0.9	0.21	0.58	0.11	0.73	0.11
WY92-115B	5.5	1.8	4.5	0.55	2.6	0.67	0.27	0.80	0.13	0.9	0.21	0.58	0.11	0.72	0.12
WY92-116A	12.0	0.90	2.4	0.42	2.5	1.10	0.48	1.60	0.30	1.9	0.43	1.30	0.21	1.40	0.22
WY92-117	9.0	1.1	2.7	0.42	1.9	0.69	0.37	1.10	0.26	1.4	0.37	0.98	0.20	1.20	0.21
WY92-118	25.0	6.7	16.0	2.10	10.0	3.00	0.94	3.80	0.65	4.0	0.87	2.50	0.43	2.70	0.43

GS-15 HIGHLIGHTS OF SURFICIAL GEOLOGY AND TILL GEOCHEMICAL SAMPLING IN THE FLIN FLON AREA (NTS 63K/13)*

by E. Nielsen

Nielsen, E., 1994: Highlights of surficial geology and till geochemical sampling in the Flin Flon area (NTS 63K/13); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 81-82.

SUMMARY

This report briefly describes the till and humus sampling program conducted in the Flin Flon area to aid in the search for base and precious metals. Relatively homogeneous basal till is widespread although lee deposits commonly occur in areas of high relief. Calcareous till deposited by an early westerly ice flow from Hudson Bay is found in several exposures between Flin Flon and Kisseynew Lake. The generally noncalcareous surface till found throughout most of the area was deposited by ice flow moving toward the south-southwest and southwest. A total of 195 till samples from 144 hand-dug pits and 144 humus samples have been submitted for geochemical analyses.

INTRODUCTION

The regional till sampling program initiated in the Flin Flon-Snow Lake area in 1989 was completed this past summer with the sampling of an additional 144 sites in the Flin Flon area (Fig. GS-15-1). This brings the total number of sites sampled under this program in the last five summers to approximately 950.

ICE FLOW HISTORY

Striation measurements in the Flin Flon area indicate evidence for three distinct ice advances. The oldest ice flow event, for which evidence was found at four sites, was toward the southeast (140°-160°). Evidence for this event was found only in the Flin Flon-Tartan Lake area. The second and most prominent ice-flow event, which affected the entire region during the last main glaciation, was towards 195° to 210°. This was the same main glacial event that was documented previously in the Naosap Lake and Elbow Lake areas to the east (Nielsen, 1992, 1993). The last ice-flow event to have affected the area was ice movement towards 220° to 240°. Striations with these orientations occur predominantly in the northern half of the map area, suggesting a major glacial readvance or possibly a change in the ice-flow trajectory during deglaciation. As neither a moraine nor stratigraphic evidence for a readvance was found, a change in ice-flow trajectory during deglaciation is favoured. Henderson (pers. comm., 1994), however, mapped a large moraine extending to the west from the western end of Kisseynew Lake in Saskatchewan. The moraine suggests a temporary halt in the general northward ice retreat coincident with the change in ice-flow direction.

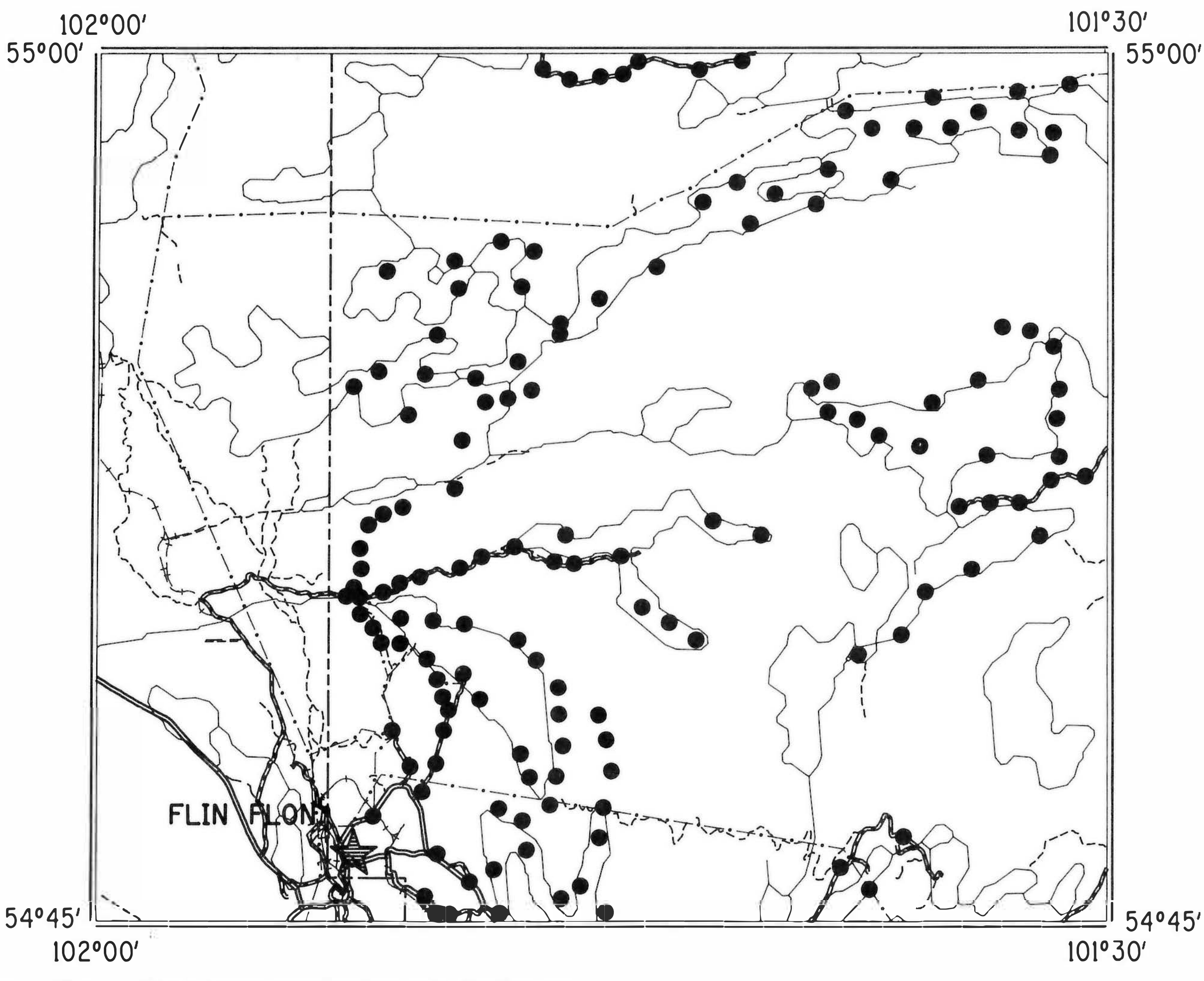


Figure GS-15-1: Till and humus sampling sites in the Flin Flon area.

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

a)

Figure GS-15-2: *Examples of water-eroded pillowed basalt in the Flin Flon area. a) Flow was towards the lower left. b) Flow was towards the left. The lense cap measures 7 cm in diameter.*

b)

Bedrock outcrops around the town of Flin Flon expose numerous examples of p-forms (Fig. GS-15-2). These water-eroded bedforms occur mainly on the stoss, top and flanks of bedrock hills and testify to the presence of subglacial flow separation around bedrock knobs. Subglacial meltwater flowing over the bedrock surface differentially eroded the less resistant pillow selvages leaving the more resistant pillows to stand in sharp relief. P-forms are particularly noticeable in the Flin Flon area because of the almost continuous bedrock outcrops and the variable hardness of the rocks. The generally higher relief around Flin Flon may also have channeled water into this area and made these features more numerous than in adjacent areas with lower relief.

SURFICIAL GEOLOGY

The surficial geology of the Flin Flon area is unlike most of the areas to the east (Nielsen, 1992, 1993). The higher elevation of this area (much of the area is >335 m a.s.l.) means that glaciolacustrine deposits, so widespread to the east, are relatively scarce and, consequently, till outcrops throughout most of the region.

The till sheet is generally thin with the notable exception of sites such as along Annabel Creek, west of Embury Lake, where a relatively deep preglacial valley is oriented approximately perpendicular to the general ice flow. Till along Annabel Creek reaches thicknesses in excess of 30 m where multiple tills and flow tills have accumulated in subglacial and proglacial environments. Buried valleys such as this have subsequently been re-excavated by fluvial processes during the Holocene, leaving high till sections banked against the bedrock walls. Multiple till sections were found at sites both along Annabel Creek and along the road north to Kisseynew Lake. These multiple till sections consist of a lower, unoxidized, fine textured, calcareous till overlain by an oxidized, sandy and noncalcareous till. Till fabrics were measured and samples collected to determine if the apparent differences in the two units are due to different till provenances or are simply a function of pedogenic processes and near-surface carbonate leaching. The calcareous till is tentatively assigned to an early ice flow from Hudson Bay that dispersed Paleozoic carbonate erratics across the area.

GEOCHEMISTRY

The <2μ fraction of the till samples and the -10 mesh fraction of the humus samples will be analysed by ICP-atomic emission spectrometry for 28 elements. The <63μ fraction of the till samples will be analysed for "Gold + 33" elements by neutron activation. The resulting data can then be directly compared to data obtained from similar studies in previous years.

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GS-16 THE NORTH STAR LAKE PROJECT (NTS 63K/15)*

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

Norquay, L.I., Prouse, D.E. and Gale, G.H.., 1994: The North Star Lake project (NTS 63K/15); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 83-84.

SUMMARY

Mafic and felsic supracrustal rocks in the vicinity of, and south of, the Lon Zone were mapped using 1:5 000 scale airphotos. Structural investigations indicate the presence of at least four phases of ductile deformation. A late brittle deformation produced a regional fault zone that cuts across the entire map area.

INTRODUCTION

Five weeks were spent in the North Star Lake area in order to complete mapping of supracrustal rocks in the northern part of the project area (Norquay *et al.*, 1991, 1992, 1993). Field work during 1994 was devoted to completion of mapping in previously unmapped portions of the project area, definition of subunits within previously defined map units, and structural studies.

GENERAL GEOLOGY

The North Star Lake project area (Fig. GS-16-1) is predominantly underlain by a supracrustal assemblage of felsic and mafic volcanic rocks, their hypabyssal equivalents and volcaniclastic and clastic sedimentary rocks. Chemical sedimentary rocks (iron formation) are also present.

The supracrustal sequence is bounded on the west by the Gants Lake batholith (Whalen, 1993). Several smaller granitoid bodies, which have also intruded the supracrustal sequence, include the Norris Lake pluton (Bailes, 1980) and several small stocks of quartz megacrystic granodiorite ('quartz-eye granite' of McGlynn, 1959). A mafic-ultramafic intrusion and a number of late breccia pipes occur in the southern portion of the map area (Norquay *et al.*, 1992; Ayed and Halden, 1993).

Physiographically and geologically the area has been subdivided into three major zones: Eastern, Central and Western zones (Norquay *et al.*, 1993). The Eastern zone consists predominantly of basaltic flows and fine- to medium-grained mafic intrusive rocks. The Central zone consists predominantly of layered volcaniclastic and sedimentary rocks with subordinate felsic and mafic volcanic rocks. The Western zone is composed predominantly of felsic volcanic and volcaniclastic rocks, minor mafic volcanic rocks, and fine- to coarse-grained felsic and mafic intrusive rocks.

The Eastern zone rocks in the area mapped during the 1994 field season are predominantly basaltic pillowed flows and pyroclastic rocks that have been intruded by fine- to medium-grained dioritic and medium- to coarse-grained gabbroic dykes and stocks (Norquay *et al.*, 1994a). These rocks are similar to those of the Eastern zone that are exposed immediately east of North Star Lake (Norquay *et al.*, 1993; 1994b). The west boundary of this zone is in fault contact with the Central zone; the east contact is an intrusive contact of the Norris Lake pluton.

The Central zone rocks are exposed only in a few places within the area mapped during the 1994 field season and only several units can be demonstrated to be continuous across the north and south map sheets (Norquay *et al.*, 1994a, 1994b). In addition, in the north portion of the map area most of the Central zone lithologies have been removed along a series of late faults related to Zacks fault (Norquay *et al.*, 1993).

A unit of predominantly mafic rocks, which were mapped as mafic volcanic rocks (Norquay, *et al.* 1991), has been subdivided into mafic breccia, mafic volcanic rocks, layered mafic sedimentary(?) rocks, layered garnetiferous biotite-hornblende-quartz rocks, quartz-rich hornblendite, garnetiferous quartz-rich hornblendite, fine- to medium-grained mafic intrusions, medium grained pyroxene-bearing ultramafic intrusion and a medium- to coarse-grained 'pseudogabbro' with porphyroblastic feldspar and quartz aggregates. Thin units of felsic volcaniclastic rocks occur throughout part of this unit as either interfolded or faulted wedges of the underlying(?) felsic volcaniclastic rocks.

DEFORMATION AND METAMORPHISM

Four phases of ductile deformation have been identified. Several late phases of deformation produced semi-brittle to brittle faults (Norquay and Halden, 1993; Norquay, in prep.).

Two phases of regional metamorphism have been identified in the North Star Lake area. A regional metamorphism (M_1), associated with the first phase of deformation (D_1), produced abundant phyllosilicates in psammopelitic and aluminous felsic rocks and hornblende in mafic rocks. The phyllosilicates define a well developed schistosity (S_1). Peak regional metamorphism (M_2), which produced garnet, hornblende, staurolite and kyanite or sillimanite is associated with the second phase of deformation (D_2). Mineral assemblages associated with retrograde metamorphism occur locally in brittle faults.

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

The second phase of deformation (D_2) produced open to tight folds (F_2) that fold S_1. These folds generally have northerly-trending axial traces, axial planes that dip steeply to the east, and fold axes that plunge shallowly to moderately to the north. Minor folds associated with this phase of deformation usually have Z-asymmetry.

A large F_2 structure has been defined in the vicinity of Lake 4 (Fig. GS-16-1). Minor fold structures associated with this F_2 structure have northerly trending, upright axial planes and fold axes that plunge moderately to the north. The minor F_2 structures in the vicinity of Lake 4 are similar in style and orientation to the minor F_2 structures in the vicinity of Lake 1 (Norquay *et al.*, 1993; 1994b). The Lon Zone, a copper-zinc sulphide occurrence, occurs on the eastern long limb of this F_2 structure (Norquay *et al.*, 1994a).

An early episode of ductile-brittle shear (D_3) occurred in the Central zone immediately west of a regional brittle fault (Zacks fault). In this area the lithologic units generally strike north (Fig. GS-16-1). The ductile shear has produced tight minor shear folds (F_3) with Z-asymmetry that fold S_1 and commonly fold intrafolial quartz veins. These minor shear folds have locally undergone semi-brittle failure along their axial planes or short limbs. F_2 structures occur only to the west of the zone containing the F_3 shear folds.

The fourth phase of deformation (D_4) produced flexural folds (F_4) that exhibit a variety of styles. The variation in fold styles resulted from deformation of different lithologies and the diverse orientations of earlier fabrics. The F_4 structures have upright, easterly to northeasterly trending axial planes and fold axes with moderate to steep plunges.

Late phases of deformation produced semi-brittle to brittle faults.

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* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

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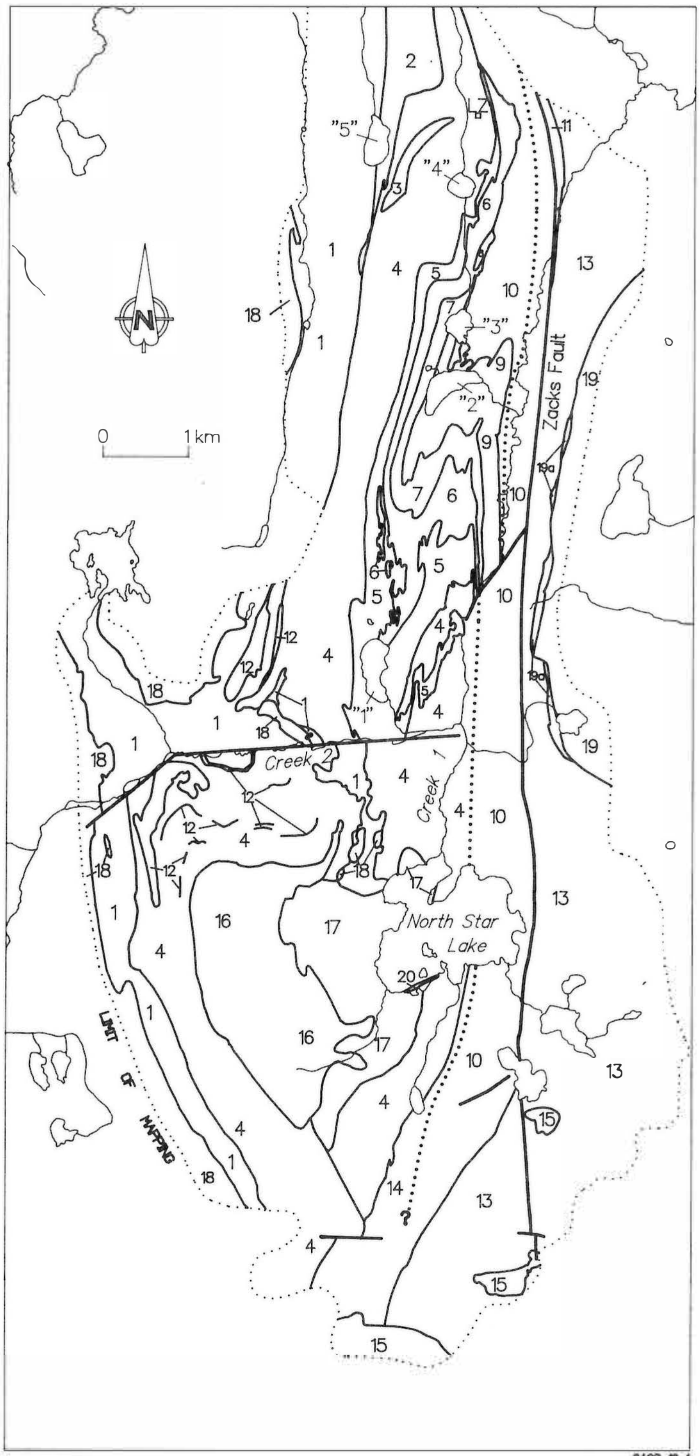

Figure GS-16-1: Geology of the North Star Lake area.

GS-17 IMPLICATIONS OF AN UNCONFORMITY AT THE BASE OF THE THREEHOUSE FORMATION, SNOW LAKE (NTS 63K/16)*

by A.H. Bailes and D. Simms[1]

Bailes, A.H. and Simms, D., 1994: Implications of an unconformity at the base of the Threehouse Formation, Snow Lake (NTS 63K/16); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 85-88.

INTRODUCTION

A 10 km^2 area surrounding Hudson Bay Exploration and Development Co. Ltd.'s newly discovered Photo Lake Cu-Zn-Au massive sulphide deposit was mapped at 1:5000 scale during a six week field season (Fig. GS-17-1). The mapping is a cooperative endeavour of Manitoba Energy and Mines and HBED. Information and maps acquired during this program will be released in November 1995.

The main objective of the project is to produce a digital geological map and database that will expedite exploration and development on the Photo Lake property. An unexpected outcome of the project was the discovery of an unconformity at the base of the Threehouse formation. The nature and significance of this unconformity are the topic of this report.

GENERAL GEOLOGY

Supracrustal rocks at Snow Lake are part of the Flin Flon belt, a polydeformed tectonic collage composed of structurally imbricated intraoceanic volcanic rocks extruded mainly between 1904 and 1885 Ma (Stern *et al.*, in press; Lucas *et al.*, 1994). Flin Flon belt metavolcanic rocks host numerous economically significant VMS deposits (Syme and Bailes, 1993; Fig. GS-17-1).

At Snow Lake, VMS deposits occur in a bimodal mafic-felsic volcanic sequence. The geochemistry of mafic flows in the sequence indicates that they were extruded in three separate tectonic settings: primitive arc (Welch), evolved arc (Snell, Moore, Threehouse) and back arc/ocean floor (Snow Creek) (Stern *et al.*, 1994; Fig. GS-17-2). The Photo Lake VMS deposit occurs in rocks belonging to the evolved arc sequence.

A fundamental lithological change in the evolved arc sequence occurred with onset of deposition of the Threehouse formation. At the Chisel Lake mine site, the base of the Threehouse formation is characterized by an abrupt, apparently conformable change from stratigraphically underlying hydrothermally altered volcanic rocks to unaltered hanging wall mafic volcaniclastic rocks of the Threehouse formation (Fig. GS-17-2). One of the problematic aspects of Snow Lake geology is that the simple stratigraphic succession at Chisel Lake is elsewhere replaced by more complex relationships. In the past these complexities have been attributed either to facies changes within the Threehouse formation or to original topographic relief on primary volcanic constructs in underlying rocks (Bailes and Galley, 1991). Recognition of an angular unconformity at the base of the Threehouse formation at Photo Lake suggests that at least some, if not most, of the apparent complexities in Snow Lake stratigraphy may be due to erosion of parts of the volcanic section prior to deposition of the Threehouse formation.

PHOTO LAKE GEOLOGY

At Photo Lake the unconformity at the base of the Threehouse formation is indicated by cobbles of an earlier intrusion, the Photo Lake quartz-feldspar porphyry, in the basal Threehouse mafic volcaniclastics and by angular truncation of underlying formations, including those that host the Photo Lake VMS deposit. Lithologies underlying the unconformity include at least 700 m of felsic flows and the Photo Lake quartz-feldspar porphyry sill. The felsic flows, the quartz-feldspar porphyry and basal Threehouse mafic wackes are all intruded by a subvolcanic porphyritic gabbroic complex that feeds overlying Threehouse basalt flows.

Angular truncation of the north-northwest-trending Photo Lake quartz-feldspar porphyry sill and host felsic flows at their contact with the north-trending Threehouse formation is not only consistent with the base of the Threehouse sequence being unconformable, but also suggests that there was pre-Threehouse tilting and erosion of strata. A corollary of the latter is that the "normal" pre-Threehouse stratigraphic sequence, as defined in the Chisel mine area, may no longer be valid elsewhere because of different levels of pre-Threehouse erosion. The regional implications of an angular unconformity at the base of the Threehouse formation are evident from an examination of two areas: 1) the domain north of Chisel Lake, and 2) at Anderson Lake.

STRATIGRAPHY NORTH OF CHISEL LAKE

One of the unexplained features of the area north of Chisel Lake is that the units here have no counterparts to those exposed south of Chisel Lake (Fig. GS-17-1) despite apparent repetition of the sequence by a major fold structure. In the past, two explanations for this have been entertained: 1) presence of unrecognized structures (*e.g.*, thrust faults) that complicate normal stratigraphy (Bailes, 1993); and 2) fundamental volcanological facies changes (*e.g.*, the transition to a caldera fill sequence) in the unexposed area underlying the Threehouse formation. Although either of these explanations may still be valid, the recognition of an unconformity at the base of the Threehouse formation at Photo Lake permits an alternative interpretation. This explanation involves preservation of previously unrecognized post-Chisel but pre-Threehouse stratigraphy in the section structurally repeated north of Chisel Lake.

Recent drilling on the Chisel North Zn-rich massive sulphide deposit shows it occurs 1.5 km down-plunge and along stratigraphy from the surface expression of the Chisel Lake deposit (Fig. GS-17-3; Galley *et al.*, 1993). The hanging wall of the northern two thirds of the North Chisel deposit consists of mafic breccia, mafic flows, rhyolite breccia and rhyolite flows, and not the expected Threehouse mafic volcaniclastic rocks. This is possibly a consequence of differential erosion of pre-Threehouse rocks above the Chisel and Chisel North deposits, with the hanging wall above the northern two thirds of the Chisel North deposit now suggested to be part of a post-Chisel/pre-Threehouse succession.

If this reasoning is applied to the exposed strata north of Chisel Lake at Photo Lake, the possibility exists that much of these rocks could belong to a portion of the stratigraphy that elsewhere was removed by pre-Threehouse erosion. This could explain the completely different stratigraphic succession in the area north of Chisel Lake without having to use a model that invokes either thrust faults or a caldera. Because we have no context in which to evaluate the metallogeny and economic potential of post-Chisel/Threehouse rocks, this package of rocks will be evaluated further in 1995.

STRATIGRAPHY AT ANDERSON LAKE

At Anderson Lake the Threehouse formation occurs 30 m in the stratigraphic hanging wall to the Anderson Lake Cu-rich massive sulphide deposit (Fig. GS-17-2). This is difficult to explain because at Chisel Lake the Threehouse formation and the package that hosts the Anderson Lake Cu-rich deposit are separated by at least 2 km of intervening strata (Bailes, 1990). In the past this has been interpreted as nondeposition of post-Anderson and pre-Threehouse rocks in the Anderson Lake area relative to the Chisel Lake area. However, this explanation has never been entirely satisfactory because it requires considerable slope on the pre-Threehouse volcanic constructs and it fails to explain truncation of a number of pre-Threehouse units at the base of the Threehouse formation. In contrast, a pre-Threehouse unconformity is consistent with both the absence of a thick post-Anderson sequence (due to removal by erosion) and the apparent truncation of units at the base of the Threehouse unit. An implication of this is that some base metal deposits in the Snow Lake area may locally have been truncated by erosion at the base of the Threehouse formation.

* Funded by Provincial A-Base
1 Hudson Bay Exploration and Development Co. Ltd.

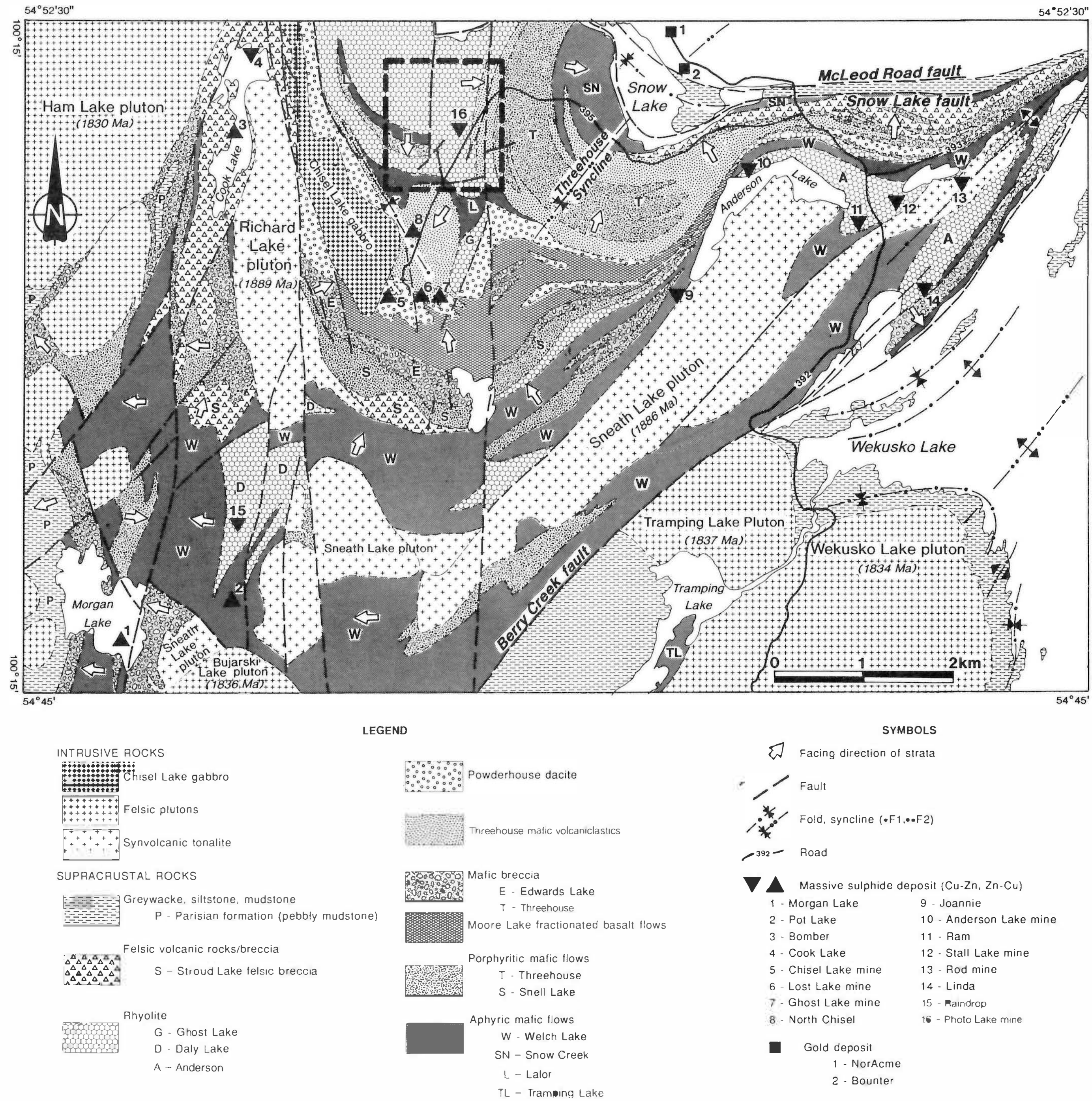

Figure GS-17-1: General geology of the Snow Lake area. The area of 1:5000 mapping at Photo Lake is outlined by bold dashed line.

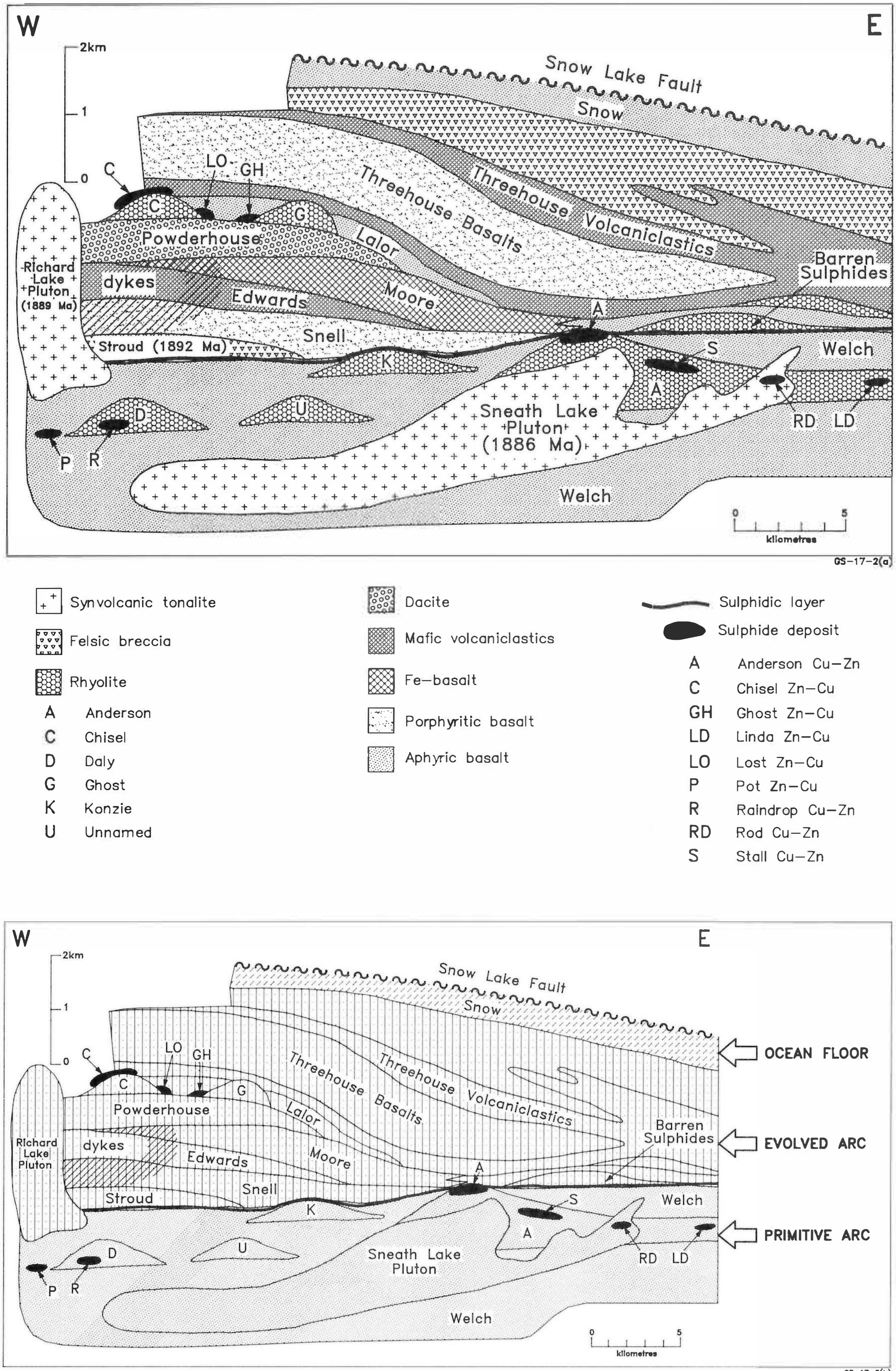

Figure GS-17-2: a) Schematic composite stratigraphic cross section, Snow Lake area.
b) Volcanic rocks subdivided according to tectonic setting.

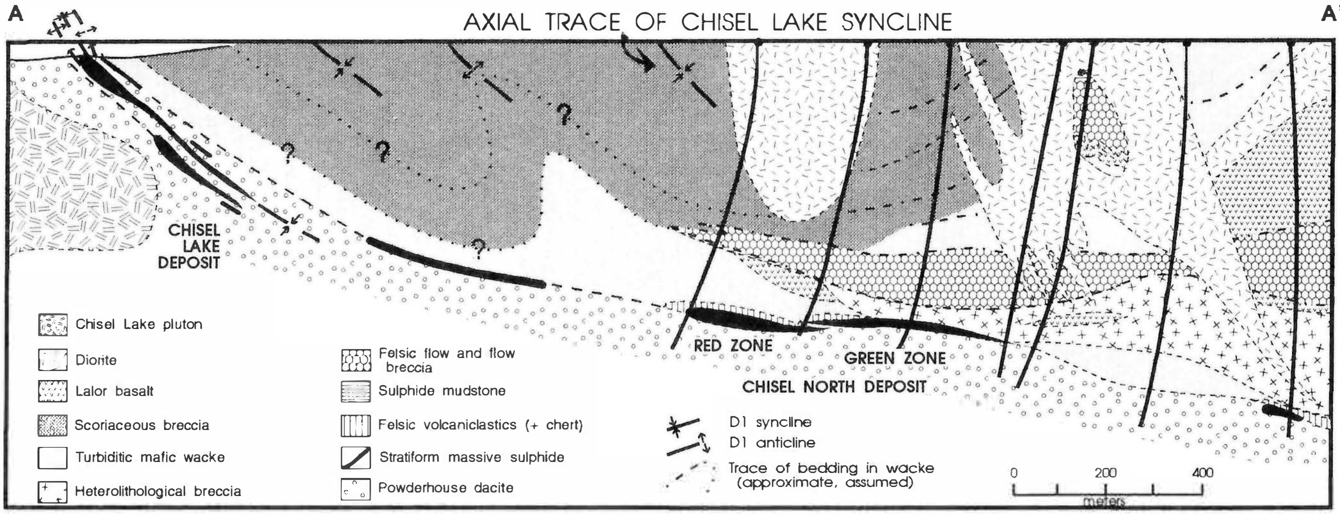

Figure GS-17-3: *Cross section illustrating along strike variation in hangingwall stratigraphy between Chisel and Chisel North Zn-rich massive sulphide deposits (from Galley et al., 1993).*

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GS-18 SOUTHWEST WEKUSKO LAKE PROJECT (NTS 63J/12)*

by H.P. Gilbert

Gilbert, H.P., 1994: Southwest Wekusko Lake project (NTS 63J/12); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 89-103.

SUMMARY

The volcanic Hayward Creek domain southeast of Goose Bay consists largely of mafic to felsic volcaniclastic rocks with subordinate intercalated massive flows (Fig. GS-18-1). A 200 m thick rhyolite unit extends along the north margin of the volcaniclastic sequence. Massive basalt is extensive in the south and southwest parts of the Hayward Creek domain. The volcaniclastic rocks are interpreted as subaqueous debris flow deposits derived from massive and fragmental volcanic rocks. The Hayward Creek domain is in fault contact with a greywacke/siltstone turbidite sequence (Wekusko Lake domain, Bailes, 1992) that crops out along the west side of Wekusko Lake and is inferred to extend east under a large part of the lake. The volcanic rocks of the Hayward Creek domain are geochemically similar (and possibly time equivalent) to the Snow Lake volcanic arc assemblage, whereas the turbidite sequence is significantly younger.**

Major tight to isoclinal F_1 folds were deformed in an open northeast-plunging F_2 antiform in the north part of the Hayward Creek domain. F_3 folds and related L_3 lineation plunge steeply east to south-southeast. The Hayward Creek Fault marks the west and north boundaries of the Hayward Creek domain. This domain extends northeast between the granodioritic Wekusko Lake pluton to the northwest and an older quartz dioritic pluton to the southeast. Quartz diorite to diorite intrusive phases that predate both granitoid plutons occur along the pluton margins and in a hybrid zone west of Hayward Creek that contains metasedimentary enclaves (turbidite-derived) that are partly assimilated and altered to migmatite. Pegmatite, aplite, intrusion breccia, diabase and felsic porphyry are the youngest intrusive units in the project area.

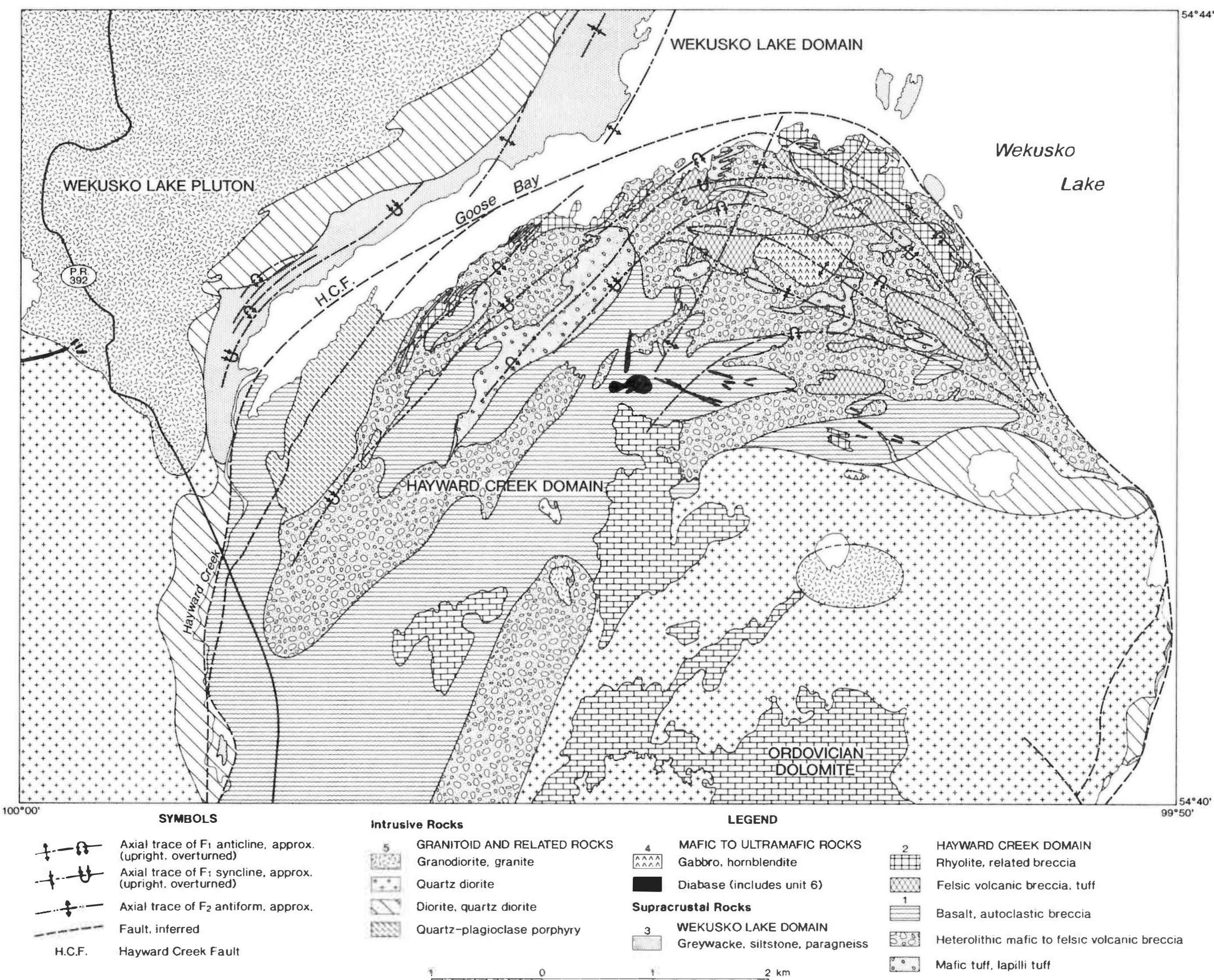

Figure GS-18-1: Geological map of the central part of the southwest Wekusko Lake project area.

* Funded by Provincial A-Base

** The arc assemblage at Snow Lake has been dated at 1892 Ma (Machado and David, 1991); detrital zircons in Wekusko greywacke turbidites indicate a maximum age for this unit of 1855 Ma (David *et al., 1993).*

The turbidite sequence north of Goose Bay is characterized by minor but extensive disseminated pyrite along the margins of the Wekusko Lake pluton to the north. Diamond drilling at Goose Bay has also indicated base metal mineralization in this section (pyrite-pyrrhotite, and traces of Cu, Zn, Au, and Ag in argillite).

INTRODUCTION

The southwest Wekusko Lake project was initiated in 1992 as part of a regional geological mapping program in the eastern part of the Flin Flon-Snow Lake greenstone belt (Bailes, 1986). The project area extends from the southern extremity of Wekusko Lake north to latitude 54°45'N, and west to longitude 100°00' (Preliminary Map 1994S-1). Mapping was completed this season, after a total of 17 weeks' field work over three years. The following objectives were accomplished in 1994:

1. Completion of coverage of the supracrustal rocks;
2. Mapping of the margins of granitoid terranes to define the main intrusive phases; reconnaissance mapping of granitoid plutons;
3. Geochemical sampling of volcanic rock units;
4. Review of the stratigraphic relationship between the Hayward Creek and Wekusko Lake domains.

Forest fires that swept through the project area in 1989 considerably enhanced the quality of bedrock outcrops. However, the collapse of the old forest and subsequent secondary forest growth severely hampered access to some inland areas during the latter part of the field mapping. The project will be concluded by analysis of field, petrographic and geochemical data, which will provide the basis for a geological report and 1: 20 000 scale geological map.

STRUCTURE

New structural data are consistent with the structural history previously described in both the southwest Wekusko Lake area (Gilbert, 1993) and the Wekusko Lake (north) area (Bailes, 1992). Early tight or isoclinal F_1 folds and related regional S_1 foliation were deformed in a major, steeply northeast-plunging, open F_2 antiform southeast of Goose Bay (Fig. GS-18-1). Repeated F_1 folds (northeast- to north-trending) occur in the turbidites that extend north from Goose Bay to the northeast part of Wekusko Lake (Preliminary Map 1992S-2). The regional S_1 foliation is locally accompanied by a northeast-trending foliation interpreted as S_2. In the southeast part of the project area, open to tight F_2 minor folds in greywacke (3a) plunge steeply southwest or northeast and locally display weak axial planar foliation (Fig. GS-18-2). The variable plunge of F_2 folds is attributed to F_3, which is characterized by steep east- to south-southeast-plunging folds with wavelengths up to 25 m and associated L_3 mineral lineation and fragment elongation which is widely developed east of Goose Bay.

The east part of the Hayward Creek Fault extends along the shore of Wekusko Lake, south of Goose Bay (Fig. GS-18-1). This fault is not exposed, but related branches in volcanic rocks at the shore are characterized by steeply dipping chloritic or sericitic schists. Strongly sheared volcanic rocks at the northeast margin of the Hayward Creek domain that are probably coplanar with the main fault strike north or northwest with moderate to steep dips (>45°). Regional foliation (S_1) is locally deflected (at 10-100 m scale) by apparent sinistral movement along this part of the fault. The fault marks the contact between volcanic rocks (1, 2) of the Hayward Creek domain to the southwest, which are interpreted as coeval with the arc assemblage in the Snow Lake area, and younger greywacke turbidites (3) of the Wekusko Lake domain to the northeast (Machado and David, 1991; David *et al.*, 1993). The north part of the fault is interpreted to curve west to southwest through Goose Bay, folded by the northeast-trending F_2 antiform east of Goose Bay. The southward extension of the fault west of P.R. 392 is inferred to be largely coincident with Hayward Creek.

A wide (>230 m) shear zone in basalt at the south extremity of Wekusko Lake is part of the Crowduck Bay Fault that extends north and northeast through the central part of Wekusko Lake (Ansdell and Connors, 1993).

STRATIGRAPHY

Mafic and felsic volcanic rocks (1, 2)

(1a) Basalt, autoclastic breccia; minor associated intrusive rocks
(1b) Heterolithic, mafic to felsic volcanic breccia
(1c) Mafic tuff, crystal tuff, lapilli tuff
(2a) Rhyolite, autoclastic breccia; minor associated intrusive rocks
(2b) Felsic volcanic breccia, minor felsic tuff
(2c) Intermediate to felsic tuff, lapilli tuff

Provincial Road 392 (P.R. 392) section

Volcanic rocks in the Hayward Creek domain were mapped last year, except for the section along P.R. 392 south of Goose Bay (see units 1a, 1b, 1c, 2a and 2b in Gilbert, 1993). The south part of the P.R. 392 section is the homoclinal northwest-facing limb of an overturned F_1 syncline and consists mainly of mafic tuffaceous volcaniclastic mass flows (1c) that are transitional into coarser volcaniclastic breccia (1b) with subordinate basalt (1a) and rare intercalated rhyolite (2a) to the northwest (Table GS-18-1; Preliminary Map 1994S-1).

Mafic tuffaceous volcaniclastic rocks (1c) in the south part of the section are cyclic and consist of thick (1-3 m) crystal lapilli tuff beds that alternate with thinner mafic tuff units (15-45 cm). The thicker beds, which are massive to weakly graded, contain mafic and minor felsic lapilli, conspicuous plagioclase phenoclasts (2-10 mm, up to 35% of the rock) and wispy, lenticular hornblendic aggregates (2-10 mm, up to 10%). Rare mafic volcanic blocks up to 35 cm across occur sporadically in the tuff. Crystal lapilli tuff beds are gradational with overlying massive to laminated mafic tuff units.

Diffuse laminae (2-6 cm) are pale to dark grey, and are locally accentuated by plagioclase phenoclasts (1-2 mm, up to 10% of the rock). The basal zone of mafic tuffaceous mass flows is locally characterized by epidotic alteration (Fig. GS-18-3).

The tuffaceous mass flows in the south part of the section grade into overlying heterolithic volcanic breccia (1b), which is the predominant lithology to the north. Fragments in the breccia are unsorted, subangular to subrounded, and consist mainly of plagioclase phyric and/or amygdaloidal basalt and altered basalt, with minor felsic volcanic fragments. The fragments (20-40% of the breccia) are mainly lapilli, but include blocks up to 35 cm across. The breccia is intercalated with basalt and related flow breccia, from which it is partly derived (Fig. GS-18-4).

Aphyric to sparsely plagioclase ± hornblende phyric basalt and minor flow-breccia (1a) in the north part of the section are locally amygdaloidal and inferred to be subaqueous, although pillows are not developed. Epidote stringers and ovoid pods are ubiquitous. Silicification is common in the underlying volcanic rocks to the south: quartz-plagioclase-garnet gneiss forms a conspicuous, east-northeast-trending, 10 to 20 m wide alteration zone 2.2 km north of the P.R. 391/392 junction (Preliminary Map 1994S-1; Fig. GS-18-5).

Several felsic volcanic units (2a, b) occur in the north part of the P.R. 392 section, south of Goose Bay. A representative unit (>40 m thick), 1 km south of the Hayward Creek bridge, consists of felsic breccia with mainly angular, 2 to 20 cm rhyolite fragments and minor (1 m) lensoid massive zones. Pervasive fracturing is inferred to be due to thermal stress at emplacement because no tectonic fabric is evident in the quartz and plagioclase phenocrysts.

Hayward Creek domain north margin

Mafic to felsic fragmental rocks at the north margin of the Hayward Creek domain east of Goose Bay (Fig. GS-18-1) were re-examined in order to establish their stratigraphic position. These rocks locally display turbidite structures and were mapped as unit 3 on Preliminary Map 1993S-2, but have been re-mapped as mafic and felsic tuff (1c, 2c) because they are conformable with underlying heterolithic volcanic breccia (1b) to the south, and are lithologically distinct from turbidites (3) of the Wekusko Lake domain (Table GS-18-2). Thus the contact between the Wekusko Lake and Hayward Creek domains extends through Goose Bay and does not intersect the south shore of Goose Bay, as shown on Preliminary Map 1993S-2.

Table GS-18-1
List of formations for the southwest Wekusko Lake area. Only those subunits described in this report are shown. The legend on Preliminary Map 1994S-1 provides a complete list of geological subunits.

PALEOZOIC (ORDOVICIAN)			
	7	Dolomite (Red River Formation)	
——unconformity——			
PRECAMBRIAN (PROTEROZOIC)			
Intrusive rocks			
	6	LATE MAFIC INTRUSIVE ROCKS	
		(a)	Diabase, aphyric to porphyritic
		(b)	Quartz diorite, diorite
	5	GRANITOID AND RELATED ROCKS	
		(a)	Granodiorite, granite; minor related porphyry, tonalite, pegmatite and aplite
		(b)	Quartz diorite, tonalite; minor leucotonalite
		(c)	Diorite; minor leucodiorite and quartz diorite
		(d)	Intrusion breccia
		(e)	Quartz-plagioclase porphyry
	4	MAFIC TO ULTRAMAFIC ROCKS	
		(b)	anorthositic gabbro, leucogabbro
		(c)	quartz gabbro
		(f)	diabase, megaphyric, trachytic
Supracrustal rocks			
	3	SEDIMENTARY ROCKS	
		(a)	Feldspathic greywacke, pebbly wacke, siltstone
		(b)	Siltstone, mudstone, argillite
		(d)	Paragneiss, migmatite
	2	FELSIC VOLCANIC AND RELATED FRAGMENTAL ROCKS	
		(a)	Rhyolite, autoclastic breccia; minor associated intrusive rocks;
		(b)	Felsic volcanic breccia, minor felsic tuff
		(c)	Intermediate to felsic tuff, lapilli tuff
	1	MAFIC VOLCANIC AND RELATED FRAGMENTAL ROCKS	
		(a)	Basalt, autoclastic breccia; minor associated intrusive rocks;
		(b)	Heterolithic, mafic to felsic volcanic breccia
		(c)	Mafic tuff, crystal tuff, lapilli tuff

Wekusko Lake south end

Medium to dark blue-green weathering, aphyric pillowed basalt (1a) forms a 650 m thick east-southeast-facing monoclinal section at the south end of Wekusko Lake (Preliminary Map 1994S-1). The mafic volcanic rocks extend at least 200 m further east in a highly sheared zone interpreted as part of the Crowduck Bay Fault (Ansdell and Connors, 1993). Pillows up to 2 m long are generally undeformed and provide reliable top directions throughout the section. Minor hyaloclastic breccia and/or carbonate or chert occur locally between pillows. Epidotic alteration occurs in the peripheral parts of some pillows, in interpillow domains or pervasively through mafic flows. Medium- to coarse-grained massive synvolcanic gabbro sills comprise ≈20% of the section. The stratigraphic significance of the pillowed basalt section is unknown; it is lithologically distinct from pillowed basalt in the Hayward Creek domain to the northwest, which is commonly porphyritic and/or amygdaloidal and characterized by poorly developed pillows that do not provide top directions. In contrast with basalt at south Wekusko Lake, most basalt in the Hayward Creek domain is associated with autoclastic breccia but is not pillowed and lacks intercalated gabbro sills. The south Wekusko Lake basalt section may comprise a fault slice within the (inferred) south extension of the Crowduck Bay Fault. The stratigraphic significance of this unit will be further investigated by geochemical analysis.

Pale grey to white, very fine grained rhyolite or felsic tuff (2a or 2c) occurs at the margin of the sedimentary rocks (3) 2 km north-northwest of the southern extremity of Wekusko Lake. The 8 m wide shoreline outcrop displays fine dark grey laminae (0.5-5 mm) and patchy pyrite + malachite mineralization. Diamond drilling through the unit intersected 51 m of "rhyolite with pyrite and arsenopyrite" (Assessment File 90603, Manitoba Energy and Mines). A similar lithology has been logged in a diamond drill hole 1 km along strike to the southwest at the Copper-Man property (M. Muzylowski, pers. comm., 1994).

Geochemistry of mafic volcanic rocks

Preliminary results indicate basalt and basaltic andesite in the Hayward Creek domain are geochemically similar to mafic volcanic rocks in the Snow Lake area (excluding the N-MORB Snow Creek basalt; see Bailes, 1993). The Jensen (1976) cation plot shows Hayward Creek domain rocks correspond closely with Snow Lake area mafic volcanic rocks (Fig. GS-18-6). The Ti *vs.* Zr plot (Fig. GS-18-7) also shows these two rock suites overlap, and correspond to the field of modern HFS-element depleted arc tholeiites (Pearce *et al.*, 1981). Limited data (four samples) suggest Hayward Creek mafic volcanic rocks are slightly more depleted in Ti and significantly more depleted in Y than both Snow Lake mafic volcanics and modern arc tholeiites, possibly

Table GS-18-2
Comparison of turbidites in the Hayward Creek (1, 2) and Wekusko Lake (3) domains

TURBIDITE (1,2) **(HAYWARD CREEK DOMAIN)**	TURBIDITE (3) **(WEKUSKO LAKE DOMAIN)**
Features common to turbidites in both domains: Bouma zonation (divisions A,D,E); localized chert; scour; reverse to normal graded bedding; flame structure; soft sediment deformation; rip-ups; calcareous concretions; sandstone dykes.	
Features characteristic for turbidites in respective domains:	
Gradational with underlying unsorted volcaniclastic mass flows (tuff, lapilli tuff, volcanic breccia).	No outcrops available to examine underlying rock units.
Volcanic breccia and tuff are locally intercalated with the turbidites. Sporadic (airfall ?) volcanic blocks.	No intercalated volcanic breccia and tuff; no sporadic volcanic blocks.
Pebble-bearing units common. Graded bedding generally at 0.1-1 m scale; no basal gritty sandstone.	Pebble-bearing units rare Graded bedding in narrow (1-6 cm) basal gritty sandstone units and at 0.1-1 m scale.
Very fine grained tops are gradational with underlying tuffaceous wacke.	Argillitic tops (E) occur both in gradational contact with or sharply defined from underlying turbidite deposits.
Pale to medium green to green -grey minor beige-grey weathering; green tones probably reflect significant amphibole content.	No green tones; rocks weather very pale grey or beige to dark grey; biotite and chlorite dominant.

due to a relatively higher degree of partial melting during the formation of the source magma (Fig. GS-18-8; Pearce, 1982).

Sedimentary rocks (3)

Turbidite greywacke and siltstone (3a, b) of the Wekusko Lake domain, which are inferred to underlie a large part of Wekusko Lake, extend from the north shore of Goose Bay to the northwest part of Wekusko Lake (Preliminary Map 1992S-2). South of Goose Bay, the turbidites outcrop sporadically along the shoreline toward the south end of Wekusko Lake. The maximum width of the exposed section is 1.5 km at the north margin of the project area and 2.1 km at northwest Wekusko Lake. The estimated maximum true thickness, allowing for repeated folding, is 650 m. The turbidites are lithologically comparable to the File Lake Formation 35 km to the northwest (Bailes, 1980).

Feldspathic greywacke, pebbly wacke, siltstone (3a)
Siltstone, mudstone, argillite (3b)

Greywacke, siltstone and mudstone (3a, b) in the north part of the project area are characterized by very well preserved turbidite features (Table GS-18-3). Turbidite cycles 0.2 m to 2 m thick generally consist of AE or AB(E) Bouma divisions; divisions C and D occur in a minority of cycles. Bouma divisions are generally intergradational within cycles, although localized basal lag deposits (A) are scoured by overlying greywacke (B), and siltstone (D) is locally in sharp contact with argillite (E) that represents the background sediment of the depositional basin.

Feldspathic greywacke (A) is typically grey weathering; coarse grained to gritty sandstone in some turbidites north of Goose Bay is pale beige due to a lower content of silty matrix. Conformable zones (5 to 20 cm wide) of chlorite porphyroblasts occur locally in siltstone and argillite (D, E). Andalusite (± garnet) porphyroblasts occur in greywacke and siltstone along the southeast margin of the quartz diorite pluton southeast of the Hayward Creek domain. The blasts (up to 3 cm long) are randomly oriented or subparallel to L_3 (Fig. GS-18-14); the porphyroblasts locally constitute ovoid knots up to 8 x 3 cm.

Abundant volcanic quartz and plagioclase grains and rare pumice pebbles indicate a felsic to intermediate volcanic provenance for Wekusko Lake turbidites. Rare angular to subrounded pebbles of quartz porphyry and quartz may have been derived from minor synvolcanic intrusions in the source area. The depositional environment is inferred to be a deep water basin (below the influence of wave action) at the margin of an emergent volcanic terrane. The source rocks may have been part of a formerly extensive volcanic terrane, of which the present Hayward Creek domain is a small remnant.

Paragneiss, migmatite (3d)

Semipelitic gneiss and related migmatite (3d) extend south from the head of Goose Bay along the west side of Hayward Creek. The metasedimentary rocks are pervasively intruded by quartz dioritic to dioritic rocks along the margin of an extensive granitoid terrane (west of the project area) that is bounded to the east by the Hayward Creek Fault (Fig. GS-18-1). The gneissic metasedimentary rocks occur as xenoliths (0.1-1 m) and larger skialithic enclaves within the intrusive rocks. Early leucotonalite *lit-par-lit* veins in the paragneiss were variably attenuated and disrupted prior to incorporation of the xenoliths. Deformation has resulted from pluton emplacement and earlier tectonism. Biotite and muscovite porphyroblasts (1-3 mm) in the paragneiss are attributed to

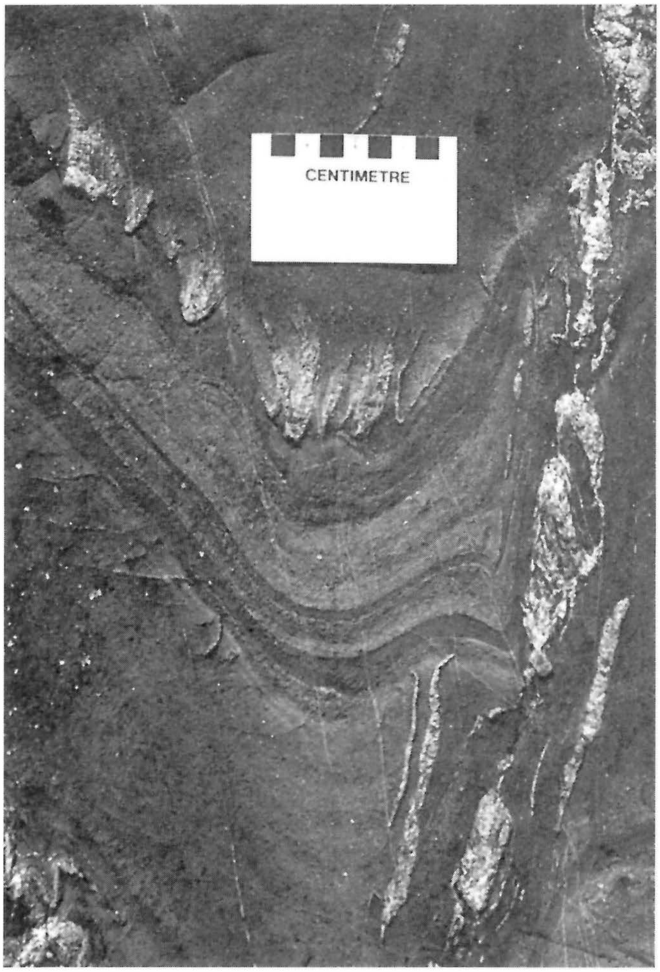

Figure GS-18-2: *Folded greywacke and siltstone (3a) in the southeast part of the project area; steeply southwest-plunging* F_2 *minor folds display flattening and faulting parallel to the axial plane.*

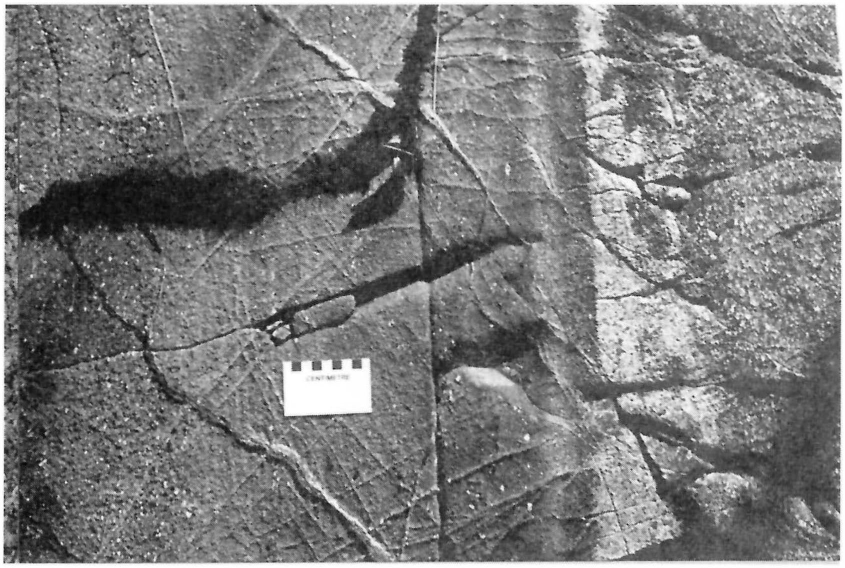

Figure GS-18-3: *Contact zone between two mafic tuffaceous mass flows. The lower crystal tuff unit (at left) grades into fine grained, diffusely laminated mafic tuff; the contact with the overlying mass flow is sharp, with epidotic alteration at the base.*

Figure GS-18-4: *Autoclastic breccia with an isolated pillow and pillow selvage fragments within a sequence of heterolithic mafic volcanic breccia emplaced by mass flow.*

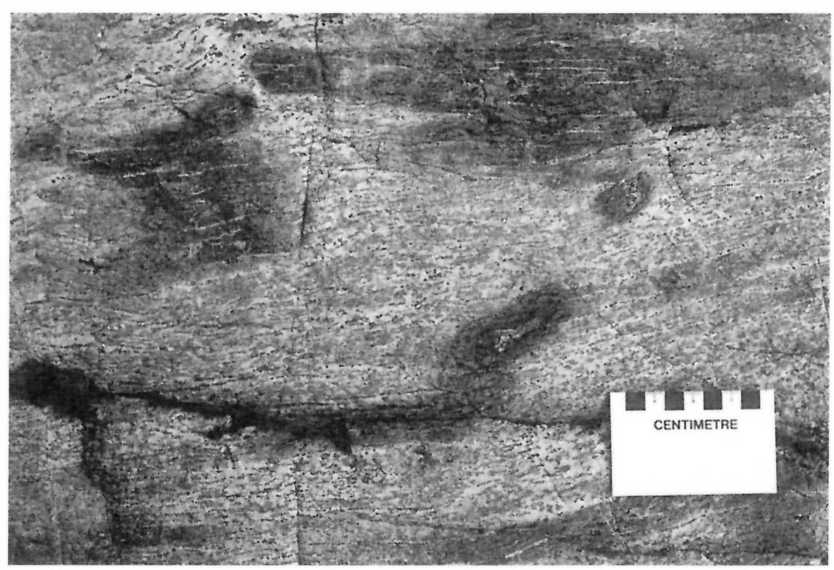

Figure GS-18-5: *Quartz-plagioclase-garnet gneiss derived from silicified mafic volcanic rock. Note minor dark gray remnants of unaltered rock.*

thermal metamorphism; hornblende blasts occur locally in gneiss adjacent to minor dioritic phases within the pluton. Sporadic garnets (up to 1.5 cm) in quartz diorite adjacent to paragneiss are attributed to contamination by the metasedimentary rocks.

Intrusive rocks (4, 5, 6)

Intrusive rock units range in age from synvolcanic (*ca.* 1892 Ma; Machado and David, 1991) to late, post-1834 Ma Wekusko Lake pluton (Gordon *et al.*, 1990). Classification of these rocks by relative age is not possible because the order of emplacement of all intrusive phases is not clearly established; units 4 and 5 and their subunits are thus grouped lithologically. Mafic intrusive rocks that postdate the Wekusko Lake pluton are designated unit 6. Units 4 and 5 were described by Gilbert (1993, 1992). The following lithologic descriptions include newly identified subunits and previous subunits that were more fully documented during the 1994 field season.

Mafic to ultramafic rocks (4)
Anorthositic gabbro, leucogabbro (4b)
Quartz gabbro (4c)
Diabase, megaphyric, trachytic (4f)

A northeast- to east-northeast-trending anorthositic gabbro dyke (4b) at least 55 m wide and over 1 km long occurs within mafic volcanic and granitoid rocks just north of Manitoba Basin Creek (Preliminary Map 1994S-1). Related anorthositic and quartz gabbro dykes intrude the southeast margin of the quartz diorite pluton (5b) to the north, and a small (60 m) magnetite-bearing quartz gabbro stock (4c) intrudes the north margin of the same pluton. Anorthositic gabbro is massive, locally ophitic and consists of subhedral plagioclase (70-85%; 0.5-2 cm, up to 5 cm), hornblende after pyroxene (<15%), intersertal quartz aggregates (up to 8%), and minor biotite (<4%). The rock is locally gradational with coarse- to very coarse-grained gabbro or hornblendite.

Megaphyric, trachytic diabase dykes (4f) comprise an east-southeast- to southeast-trending dyke swarm within volcanic rocks (1, 2) in the central part of the Hayward Creek domain (Fig. GS-18-1; Gilbert, 1993). The diabase is characterized by abundant tabular plagioclase phenocrysts (15-45%; 0.3-3 cm long), commonly accompanied by pyroxene phenocrysts altered to hornblende (8-20%; 1-4 mm). Unit 4f predates the Wekusko Lake pluton (5a) and leucocratic phases of the marginal quartz dioritic suite because xenoliths of the diabase occur within the latter northwest of Goose Bay (Fig. GS-18-1). West of Hayward Creek, prominent trachytic diabase dykes (1-20 m wide) are emplaced in metasedimentary enclaves (3) and in an early diorite phase (5c) of a quartz diorite/diorite intrusive complex. Xenoliths and skialithic remnants of trachytic diabase (4f) occur within younger, more leucocratic phases of the intrusive complex. Trachytic diabase also intrudes early diorite (5c) at the margin of the quartz diorite pluton southeast of the

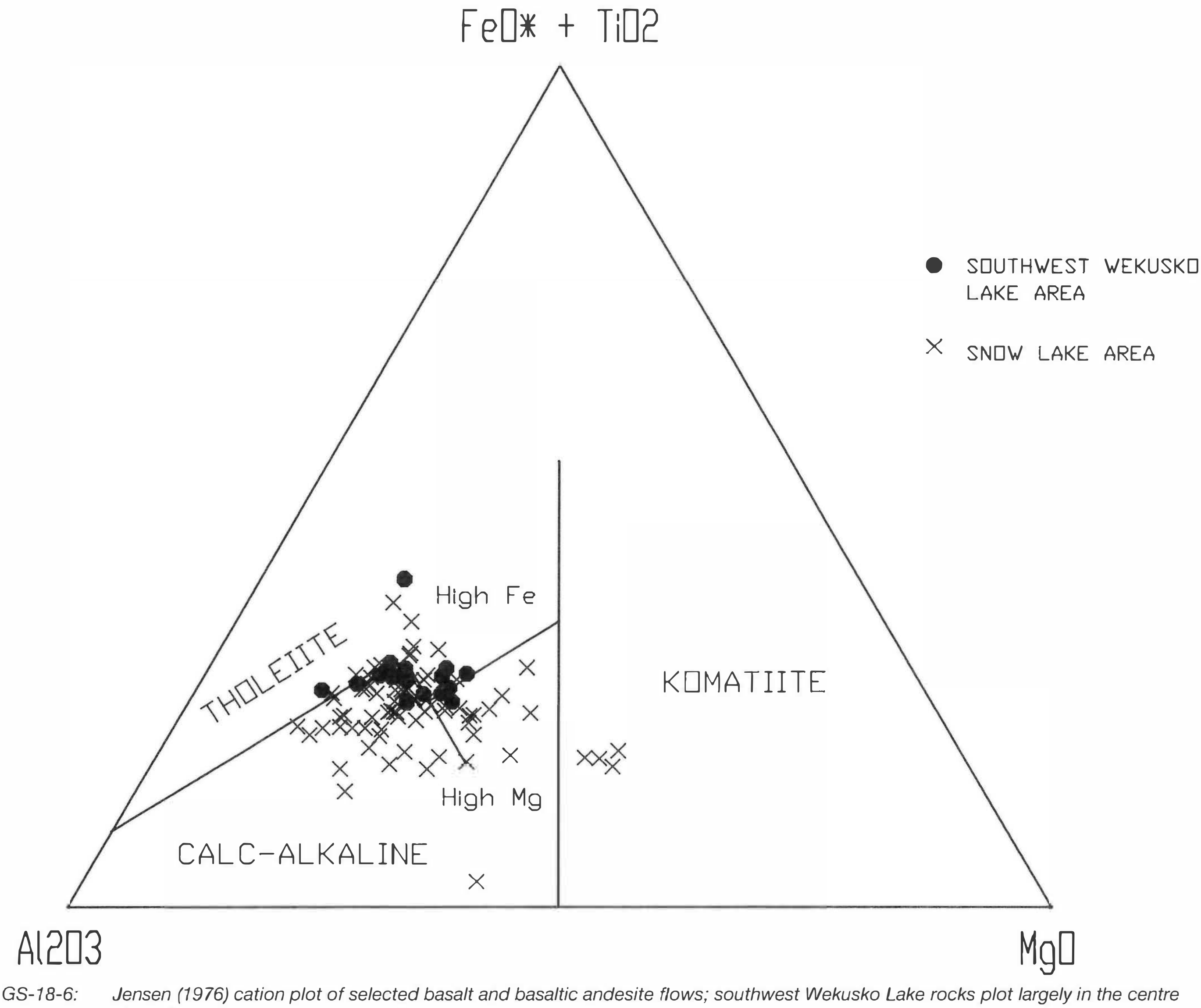

Figure GS-18-6: Jensen (1976) cation plot of selected basalt and basaltic andesite flows; southwest Wekusko Lake rocks plot largely in the centre of the field of Snow Lake arc tholeiites. Snow Lake geochemical data from A.H. Bailes (unpublished).

Table GS-18-3
Sedimentary structures in turbidites (3a, b, c) at southwest Wekusko Lake

EROSIONAL/DEPOSITIONAL STRUCTURES	
Bouma Division A	
SCOUR MARKS	1-2 cm traction marks and channel scours up to 12 cm deep.
GRADED BEDDING	normal; rare reverse to normal. Rapid grading of sand particles over 1 to 5 cm and/or more gradual grading of sand to mud particles over 10 cm to 1 m.
LAG DEPOSITS	Localized discontinuous basal sandstone (1-3 cm thick) truncated by overlying greywacke (Fig. GS-18-9).
Division B	
LAMINATION	4-15 mm parallel micaceous laminae due to traction currents.
Division C	
CONVOLUTE LAMINATION	Irregular laminae due to turbulent current action.
Divisions D and E	
LAMINATION	2-10 mm bedding lamination in siltstone/mudstone deposited by waning turbidity current. Chert (E) occurs as 1-5 mm laminae within mudstone or (more rare) as laminated beds up to 15 cm thick at the top of the cycle (Fig. GS-18-10).
Divisions A to D	
RIP-UPS	Siltstone/mudstone angular to tabular fragments (1-10 cm long) occur at all levels of the turbidite cycle; large blocks (up to 0.4 m long) occur in the lower parts of the cycle.
PENECONTEMPORANEOUS STRUCTURES	
LOAD STRUCTURES	(a) Flame structures (1-3 cm, up to 12 cm long; (Fig. GS-18-10). (b) Ball structure; basal sandstone is incorporated into the mobilized underlying mudstone due to loading.
GRAVITY-INDUCED FAULTS AND DISRUPTED BEDDING	Small to large folds (2 cm to 0.5 m amplitude) are conspicuous at two islands northeast of Goose Bay (Fig. GS-18-1). Sedimentary faults and disrupted bedding locally accompany slump folds (Fig. GS-18-11).
SANDSTONE INTRUSIONS	Injection of sandstone into overlying siltstone is attributed to dewatering and upward transfer of water during compaction of sediments.
CALCAREOUS CONCRETIONS	Diagenetic ovoid concretions up to 0.4 m long are typical of the coarser grained lower part of the cycle, but occur at all levels, commonly in horizons (Figs. GS-18-12, GS-18-13). Zoned concretions have epidotic cores and ankeritic margins. Actinolite porphyroblasts and silicic alteration are locally characteristic.

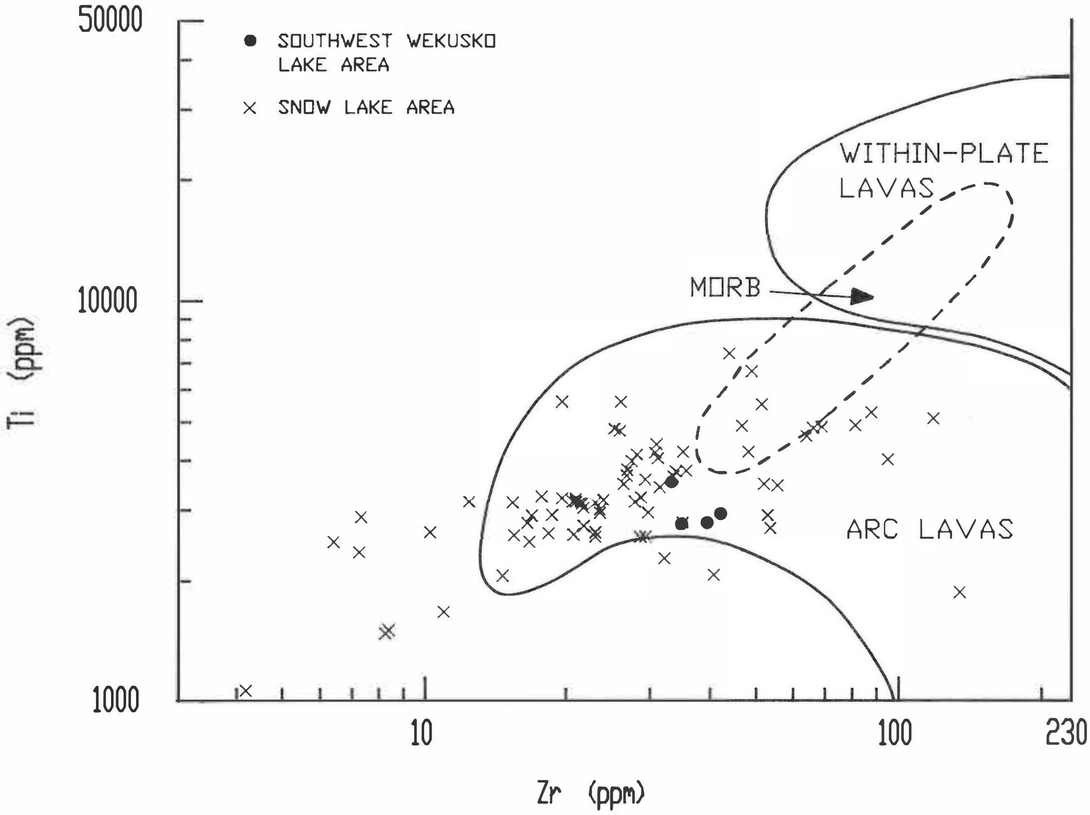

Figure GS-18-7: Ti vs. Zr plot of selected basalt and basaltic andesite flows. Four mafic flows at southwest Wekusko Lake plot within the field of Snow Lake mafic flows, which correspond to modern arc tholeiites (Pearce et al., 1981). Snow Lake geochemical data from Bailes (1988).

Hayward Creek domain, but occurs as xenoliths within the pluton (Gilbert, 1993).

Granitoid and related rocks (5)

Granodiorite, granite, tonalite; minor related quartz-feldspar porphyry, pegmatite and aplite (5a)
Quartz diorite, tonalite; minor leucotonalite (5b)
Diorite; minor leucodiorite and quartz diorite (5c)
Intrusion breccia (5d)
Quartz-plagioclase porphyry, felsite (5e)

Wekusko Lake pluton

The southeast part of the Wekusko Lake pluton underlies the northwest part of the project area. It consists of massive quartz-eye granodiorite to granite (5a) that is gradational to tonalite toward the southeast margin. Pale grey to pink weathering granodiorite to granite contains ovoid quartz and subhedral K-feldspar phenocrysts (0.4-1.0 cm, up to 1.5 cm) in a coarse grained, quartzofeldspathic matrix with subordinate biotite (± hornblende). Minor quartz-feldspar porphyry dykes occur near the pluton margin. The 1834 Ma Wekusko Lake pluton (Gordon *et al.*, 1990) postdates the regional S_1 foliation of unit 3a. The southeast margin of the pluton is characterized by a 10 to 150 m wide contact zone in which greywacke and siltstone are intruded by granitoid dykes.

A mixed, predominantly quartz dioritic intrusive suite that is pervasively intruded by the main granodiorite/tonalite plutonic phase extends for over 4.5 km along the southeast margin of the Wekusko Lake pluton, in a 0.75 km wide zone parallel to the north shore of Goose Bay (Fig. GS-18-1). The quartz dioritic suite consists of:

(a) equigranular to porphyritic hornblende quartz diorite and tonalite with quartz, plagioclase ± hornblende phenocrysts (5b); subordinate quartz-plagioclase porphyry (5e);
(b) medium- to fine-grained diorite (5c) and subordinate diabase (4e) that generally predate granitoid rocks (5).

Intrusion breccia (5d) occurs within granodiorite in the southeast part of the Wekusko Lake pluton, 1 km northwest of Goose Bay. The breccia is characterized by diverse angular xenoliths derived from both the main plutonic granodiorite phase and the marginal quartz dioritic suite of the Wekusko Lake pluton in a quartz-plagioclase porphyry matrix.

Granitoid terrane west of the Hayward Creek domain

A mixed quartz diorite/diorite intrusive complex west of the Hayward Creek Fault is separated from the lithologically similar quartz diorite suite at the southeast margin of the Wekusko Lake pluton by a southward protuberance of the pluton, immediately west of the mouth of Hayward Creek (Fig. GS-18-1). The quartz diorite/diorite complex west of the creek extends northwest along the margin of the younger Wekusko Lake pluton, and south along the west side of the Hayward Creek domain. The intrusive complex contains early phases of fine- to medium-grained diorite, quartz diorite and tonalite (5c, b) which are commonly porphyritic (quartz, plagioclase or hornblende phenocrysts, or pseudomorphic biotite aggregates). Reaction between these rocks and metasedimentary enclaves (3) locally resulted in *lit-par-lit* gneiss and migmatite. The hybrid gneisses and the early intrusive phases are intruded by "quartz-eye" tonalite, quartz diorite and leucodiorite of the intrusive complex.

Granitoid terrane southeast of the Hayward Creek domain

The Hayward Creek domain is flanked to the southeast by a 7.5 x 4.5 km ovoid hornblende quartz diorite pluton (5b). Coarse- to very coarse-grained diorite (5c) at the pluton margin is mostly older than the quartz diorite. Marginal intrusions that postdate the quartz diorite include tonalite, leucotonalite, diorite, gabbro, quartz gabbro and anorthositic gabbro. Coarse grained granodiorite zones within the pluton near the north and south margins do not display contact relationships with the quartz diorite but are interpreted as relatively younger intrusions, possibly coeval with the Wekusko Lake pluton.

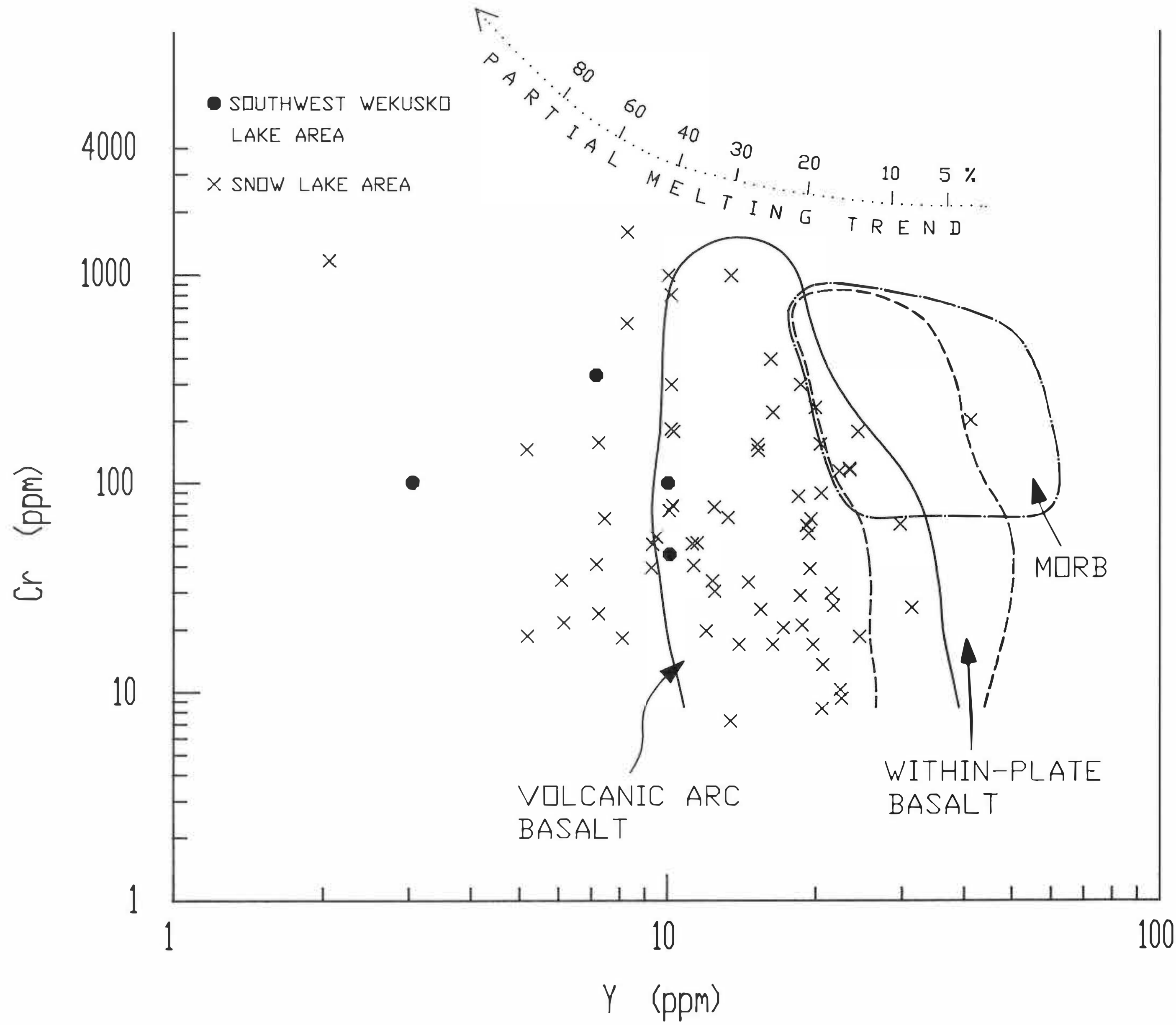

Figure GS-18-8: *Cr vs. Y plot of selected basalt and basaltic andesite flows. Four southwest Wekusko Lake flows show Y-depletion relative to Snow Lake area rocks and modern arc tholeiites, reflecting higher levels of partial melting in the genesis of the source magma (Pearce, 1982). Snow Lake geochemical data from A.H. Bailes (unpublished).*

Massive early diorite (5c) at the quartz diorite pluton margin consists mainly of hornblende and plagioclase, with up to 10% quartz. The rock is homogeneous except for rare igneous layering defined by alternating hornblendic/feldspathic laminae 1 to 5 cm thick, and sporadic pegmatitic diorite patches that contain 1 to 3 cm hornblende crystals and up to 7% magnetite. Diorite in contact with anorthositic gabbro (4b) near the south extremity of Wekusko Lake contains disseminated pyrite and chalcopyrite over a 1 m wide zone. Porphyritic diorite south of P.R. 391 contains up to 10% plagioclase (1-5 cm) and hornblende (3-6 mm) phenocrysts. The main quartz diorite plutonic phase (5b) is medium grained, massive to slightly gneissoid and contains up to 15% hornblende ± subordinate biotite, commonly in lenticular aggregates. The rock locally contains plagioclase and/or hornblende phenocrysts (2-15 mm, up to 15% each) and minor mafic xenoliths or derived schlieren.

Late mafic intrusive rocks (6)

Diabase, aphyric to porphyritic (6a)

Late east- to southeast-trending diabase dykes (6a) within the Wekusko Lake pluton are aphyric to porphyritic, with up to 15% elongate plagioclase phenocrysts (0.5-1.5 cm long). Related diabase dykes up to 70 m wide west of Hayward Creek intrude both the quartz diorite/diorite complex and younger Wekusko Lake pluton (Fig. GS-18-1). The mafic dykes were penecontemporaneous with minor intrusions of quartz-plagioclase porphyry (5e), which are pervasive along the dyke margins and within the dykes, where the diabase is dissected into ovoid to amoeboid masses separated by septae of felsic porphyry that were apparently intruded into the plastic cooling diabase (Fig. GS-18-15).

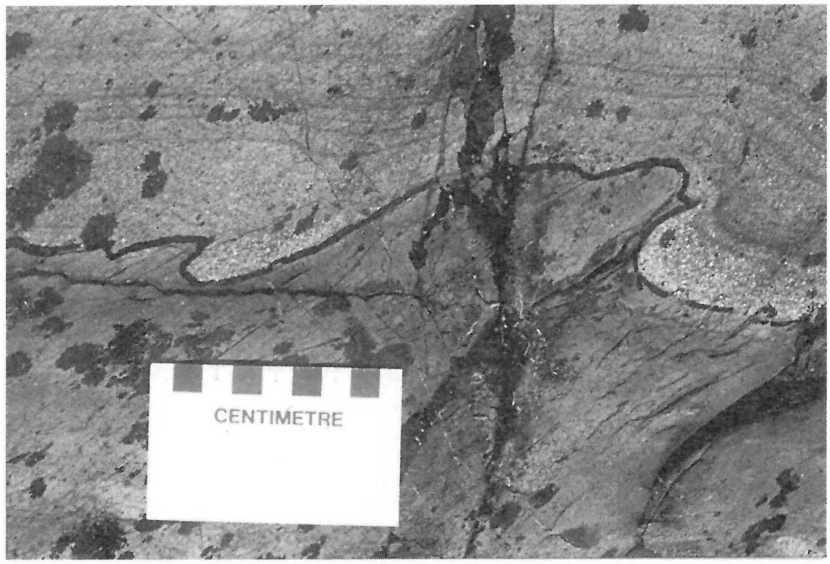

Figure GS-18-9: *Contact between two turbidite units showing scour marks, flames, and a thin (3 cm) basal gritty sandstone lag deposit (division A) that is overlain by laminated greywacke (division B).*

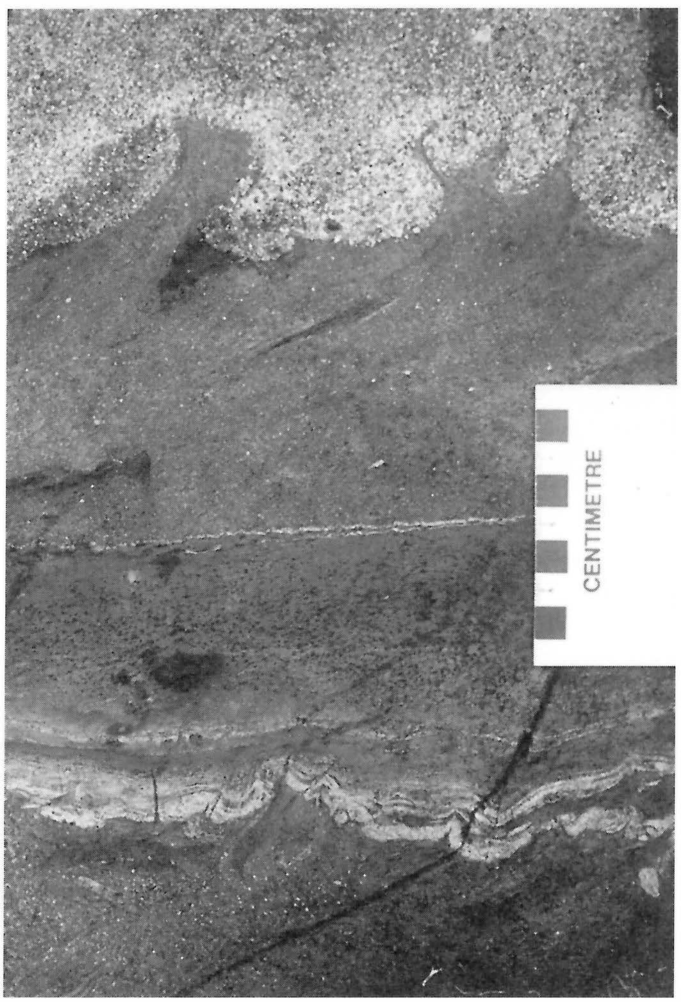

Figure GS-18-10: *Thin (20 cm) turbidite unit overlying laminated chert (division E); scour and flame structures occur at the contact with graded gritty sandstone above.*

Figure GS-18-11: Disrupted argillitic siltstone bed due to gravity-induced folding of unconsolidated turbidite deposits.

Quartz diorite, diorite (6b)

A 0.9 km long stock of quartz diorite to diorite (6b) is emplaced in granodiorite (5a) in the northwest corner of the map area (Preliminary Map 1994S-1). Numerous plagioclase phyric dykes (6a) in the vicinity of the stock suggest that units 6b and 6a may be genetically related (A.H. Bailes, pers. comm., 1994).

ECONOMIC GEOLOGY

Conspicuous, rusty weathered zones occur sporadically for over 3 km at the southeast margin of the Wekusko Lake pluton, along the contact with greywacke and siltstone (3). The granitoid rocks at these localities contain disseminated pyrite (largely oxidized) that is attributed to contamination of the granitoid rocks by adjacent metasediments. The mineralization along the pluton margin and drill core intersections of mineralized argillite at Goose Bay (solid pyrite-pyrrhotite, with traces of chalcopyrite, sphalerite, Au and Ag; Assessment Files 92656 and 92662, Manitoba Energy and Mines) indicate the Wekusko Lake turbidites have potential for base-metal mineralization. Massive sulphide deposits are hosted by stratigraphically equivalent paragneisses northeast of Wekusko Lake in the Kisseynew sedimentary gneiss domain (Zn-Cu BUR Zone and Zn-Pb-Ag Kobar-Ruby deposit; Fedikow, 1991).

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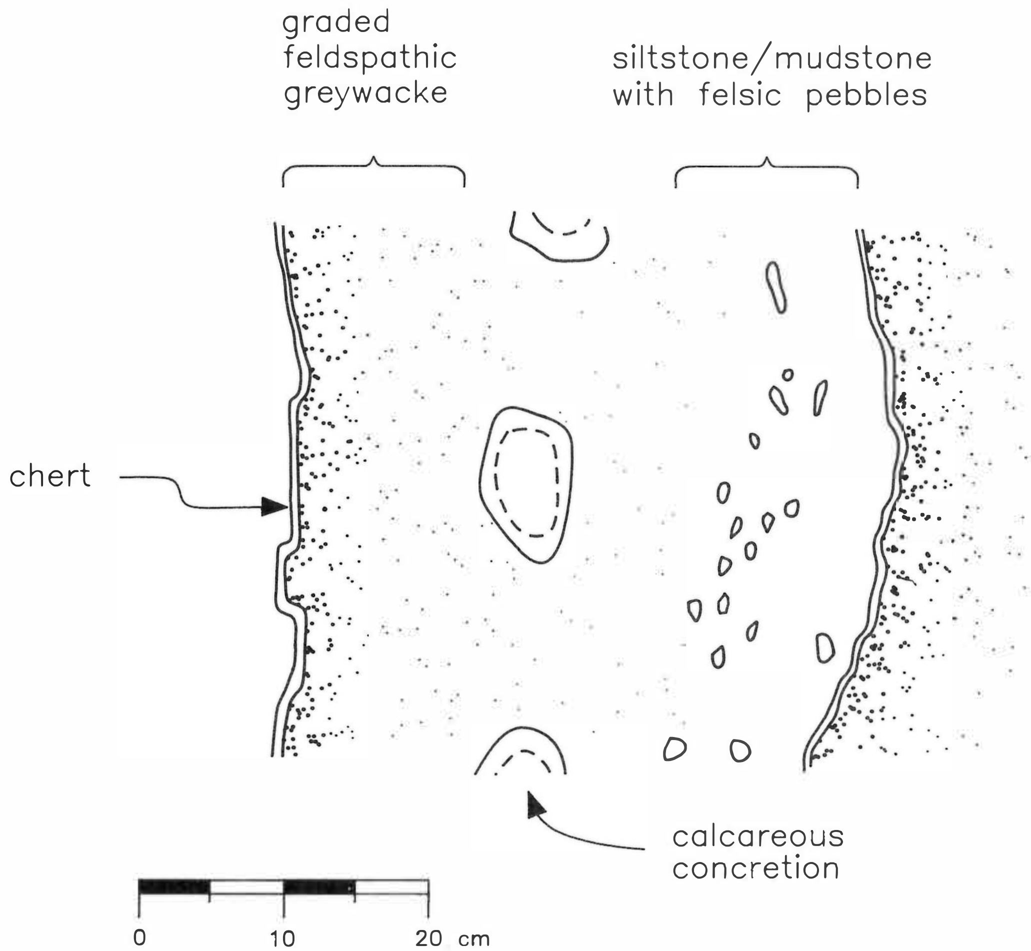

Figure GS-18-12: 40 cm turbidite unit showing the graded base, a zoned calcareous concretion in the central part, and pebbly siltstone in the upper part of the unit.

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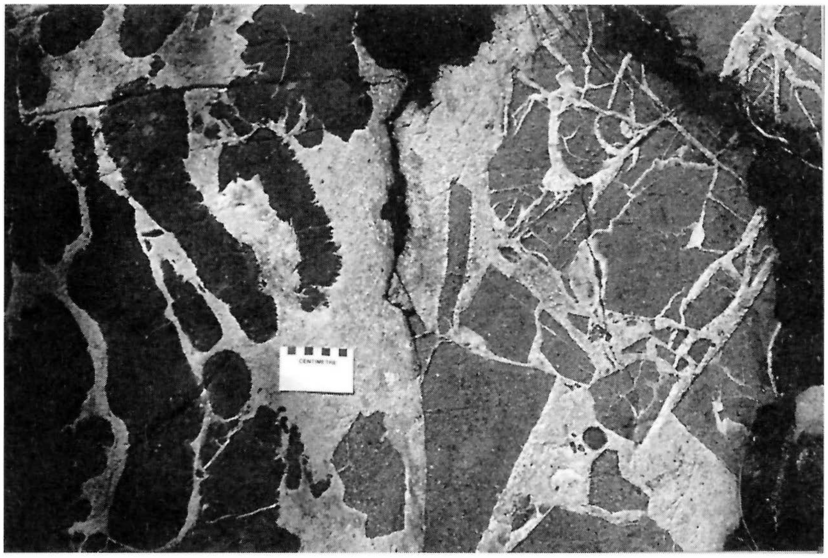
Figure GS-18-13: *Concentrically zoned calcareous concretions in the contact zone between two turbidite beds.*

Figure GS-18-14: *Andalusite porphyroblasts up to 3 cm long in greywacke (3a), in the south part of Wekusko Lake.*

Figure GS-18-15: *Quartz-plagioclase porphyry (5e) in the quartz diorite/diorite complex west of P.R. 392. Enclaves of diorite (5c) are veined agmatically by the porphyry (at right), whereas aphyric diabase xenoliths (6a) in the porphyry (at left) display highly irregular lobate shapes, suggesting the mafic rock was still warm and plastic during emplacement of the porphyry.*



GS-19 REVISION OF STRATIGRAPHY AND STRUCTURAL HISTORY IN THE WEKUSKO LAKE AREA, EASTERN TRANS-HUDSON OROGEN*

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Connors, K.A. and Ansdell, K.M., 1994: Revision of stratigraphy and structural history in the Wekusko Lake area, eastern Trans-Hudson Orogen; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 104-107.

SUMMARY

The stratigraphic and structural relationships in the east Wekusko Lake area have been refined by mapping during summer 1994 and preliminary geochronological results. The Herb Lake package, which was previously interpreted as the youngest volcanic unit, is stratigraphically overlain by the Felsic volcanic package. The Herb Lake fold is thus an anticline. U-Pb ages of between 1832 and 1836 Ma have been obtained for felsic volcanic rocks from these packages. The McCafferty Liftover package is now considered to be in fault contact with the Herb Lake and Felsic packages to the north. The age of this package is unknown, although an 1856 Ma rhyolite on the east shore of Wekusko Lake may form part of this package. Two packages of fluvial/alluvial sedimentary rocks have been previously interpreted as part of the Missi Group. The Western package locally includes felsic volcanic rocks, similar in appearance to the rocks of the Felsic package, but is younger than 1834 Ma based on preliminary detrital zircon ages. Felsic volcanism was thus continuing during the deposition of these sedimentary rocks. The Eastern package is cut by granitoid intrusions considered to be about 1833 Ma in age, and therefore, appears to be older than the Western package. The complexities exhibited in the east Wekusko Lake area among rocks interpreted as Missi Group brings into question the usefulness of this stratigraphic term. Early folds cut by the 1834 Ma Wekusko pluton indicates that there was a close temporal relationship between early deformation, sedimentation and magmatism. The F_1/S_1 and F_2/S_2 structures formed in a developing fold and thrust belt that predated peak metamorphic conditions. The newly identified Kiski Fault appears to be folded by the Herb Lake Fold, although its age is still unclear.

INTRODUCTION

The east Wekusko Lake area (Fig. GS-19-1) occurs at the eastern end of the Flin Flon domain that forms part of the Paleoproterozoic Trans-Hudson Orogen. Ansdell and Connors (1993, in press) subdivided the east Wekusko Lake area into a number of lithological packages and determined the relative timing of folding and faulting. Additional mapping in summer 1994 and preliminary geochronology results have been used to refine the stratigraphic relations between these packages, the location and nature of the boundaries between them, and some key age relationships.

Some of the salient features that have been identified include:

1. The Felsic volcanic package stratigraphically overlies volcanic rocks of the Herb Lake package, which indicates that the Herb Lake fold must be an anticline.
2. Three new U-Pb ages show that these volcanic rocks representative a period of volcanic activity bracketed between about 1832 and 1836 Ma (*i.e.*, about 1835 Ma).
3. The McCafferty Liftover package is separated from the 1835 Ma volcanic rocks by faults, including the newly identified Kiski Fault. The age of this package is unknown, but it is possible that a rhyolite on the east shore of Wekusko Lake, dated at 1856 Ma, may be part of this package.
4. The western package of sedimentary rocks, previously mapped as part of the Missi Group, includes some felsic volcanic rocks that are lithologically similar to rocks in the Felsic volcanic package, but must postdate 1834 Ma based on preliminary detrital zircon analysis of sandstone.
5. The eastern package of sedimentary rocks predates about 1833 Ma, the inferred age of two plutons that crosscut these rocks.
6. The variation in age and rock type between the lithological packages at east Wekusko Lake, and by comparison, other rocks in the Flin Flon and Kisseynew domains defined as Missi Group, brings into question the usefulness of the stratigraphic term 'Missi Group' for all continental sedimentary and associated volcanic and intrusive rocks.

STRATIGRAPHIC RELATIONSHIPS

Herb Lake and Felsic volcanic packages

The contact relationships between the Herb Lake and Felsic packages have been examined in detail, and outcrops have been identified that suggest that the Felsic volcanic package stratigraphically overlies the Herb Lake volcanic rocks. Typically, along the contact, felsic debris flows with dominantly felsic clasts overlie mafic volcanic rocks with vesicular flow tops of the Herb Lake package, which are themselves intruded by feldspar phyric gabbro. At two locations, clasts of the underlying mafic rocks occur in the lowermost part of the felsic debris flow. These mafic clasts are distinct as they contain long thin needles of feldspar (up to 5 cm long and 3-4 mm wide), which are similar to those in the small gabbro intrusions in the underlying mafic rocks. Near the nose of the Herb Lake fold, the Herb Lake mafic rocks are intruded by an aphyric siliceous body, very similar to the rhyolite flows and porphyries of the Felsic package, which has incorporated numerous mafic xenoliths along the margin. Together, these relationships indicate that felsic volcanic rocks of the Felsic package overlie Herb Lake volcanic rocks. In one location, the contact is exposed for about 20 m, is sharp and shows only minor relief (5-20 cm), suggesting that there is no significant erosion between the two packages. The Herb Lake and Felsic packages thus represent a progression from dominantly mafic (basaltic to andesitic) to dominantly felsic volcanism at about 1835 Ma.

The present constraints on the age of the Herb Lake and Felsic packages are shown in Table GS-19-1. The Chickadee Rhyolite (Fig. GS-19-1) was initially dated at 1832 ±2 Ma (Gordon *et al.*, 1990), and the same sample has since been redated using more concordant zircon fractions at 1836 ±2 Ma (Ansdell and Connors, 1994b). The U-Pb zircon age of a feldspar phyric rhyolite from the Herb Lake package, which is now known to stratigraphically overlie the Chickadee Rhyolite, is 1833 +6/-2 Ma. These ages are indistinguishable from an U-Pb age of 1836 +6/-5 Ma obtained from a quartz-feldspar porphyry from the Felsic package. The similarity of the ages supports the interpretation that the contact between the two packages is stratigraphic and does not represent a major time break. Volcanic rocks of the Herb Lake and Felsic packages are the effusive products of magmatism at about 1835 Ma, which thus postdates Amisk Group volcanism in the Flin Flon domain by at least 50 million years. Detailed geochemical and isotopic studies undertaken to provide constraints on the petrogenesis of the Herb Lake mafic rocks are ongoing. A reconnaissance study showed that the mafic rocks are enriched in Zr, Y and TiO_2 relative to typical oceanic island arc volcanic rocks of the older Amisk Group (Gordon and Lemkow, 1987; Stern *et al.*, in press).

The Felsic package is thickest along the west side of the Herb Lake package, and although it is significantly thinned to the south and east, it is continuous around the nose of the Herb Lake fold and part of the way along the eastern limb. It is likely that the felsic volcanic rocks have been truncated by the faults, namely the Herb Lake and Stuart Bay faults, that form the contacts with the eastern and western packages of sedimentary rocks (Fig. GS-19-1). The facing directions described above indicate that the Herb Lake fold is an anticline.

* Funded by NATMAP A-Base funding

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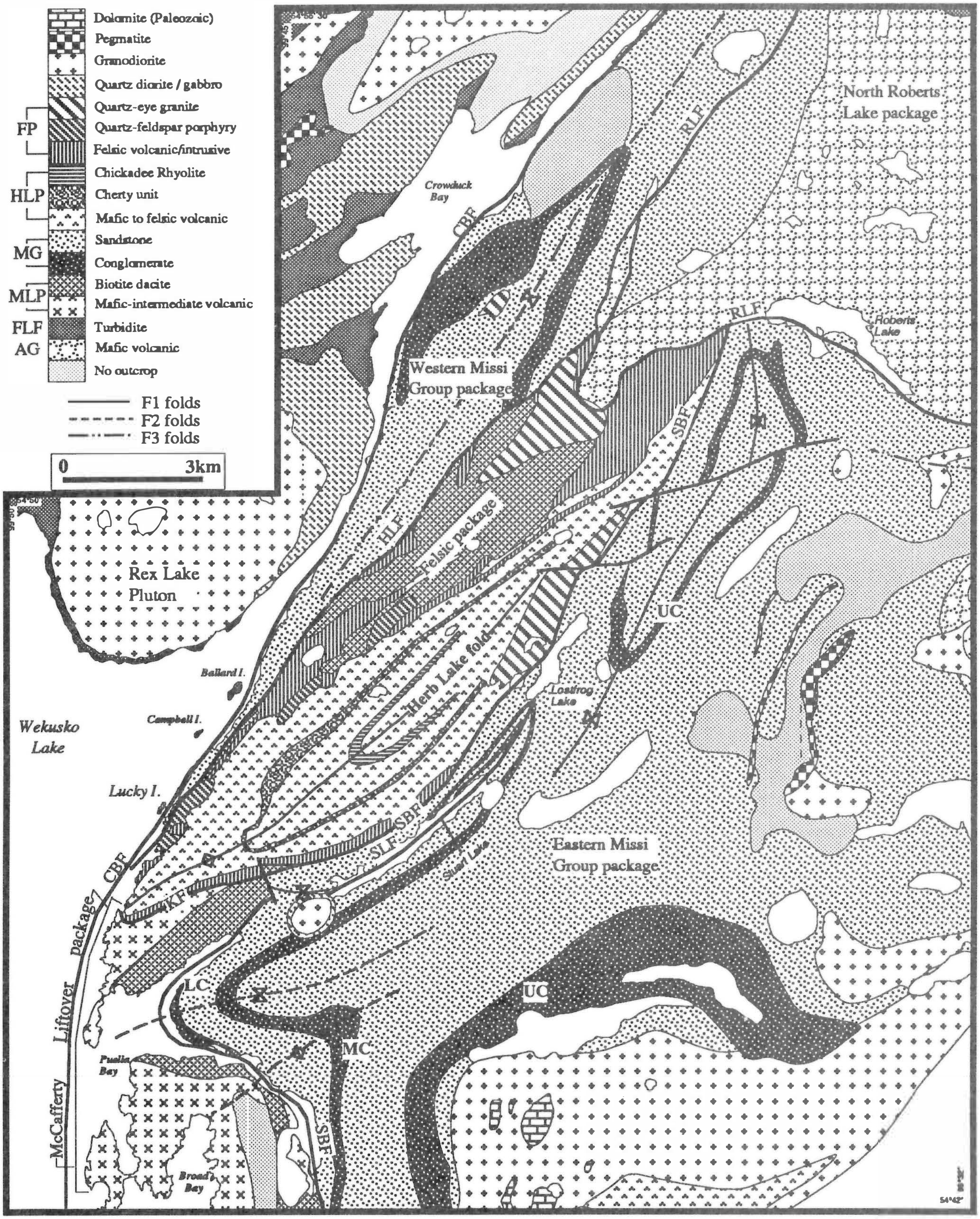

Figure GS-19-1: *Simplified geological map of the east Wekusko Lake area (based on Armstrong, 1941; Frarey, 1950; Gordon and Gall, 1982, and this study). Abbreviations in Legend: AG - Amisk Group, FLF - File Lake Formation, FP - Felsic package, HLP - Herb Lake package, MG - Missi Group, MLP - McCafferty Liftover package. Abbreviations on map: CBF - Crowduck Bay Fault, HLF - Herb Lake Fault, KF - Kiski Fault, RLF - Roberts Lake Fault, SBF - Stuart Bay Fault, SLF - Stuart Lake Fault, LC - Lower conglomerate, MC - Middle conglomerate, UC - Upper conglomerate.*

Table GS-19-1
U-Pb and Pb-Pb zircon ages from east Wekusko Lake

	Age ±2σ (Ma)	
Herb Lake volcanic package		
Chickadee Rhyolite (from Gordon *et al.,* 1990)	1836 ± 2	U-Pb
Feldspar phyric rhyolite (AY-KA93-120)	1833+6/-2	U-Pb
Felsic volcanic package		
Qz-fsp porphyry, Rex-Laguna Mine (AY-KA93-110)	1836+6/-5	U-Pb
Rhyolite, west of Herb Lake Fault (AY-KA93-108)	1856 ± 1	U-Pb
Western sedimentary package		
Pebbly sandstone above 1856 Ma rhyolite	1834 ±15	Pb-Pb
(AY-KA93-109; detrital zircons)	1841 ± 6	Pb-Pb
	1844 ± 7	Pb-Pb
	1862 ± 7	Pb-Pb
Eastern sedimentary package		
Cross-bedded sandstone overlying lower conglomerate	1859 ± 8	Pb-Pb
(AY-KA93-18; detrital zircons)	1862 ± 5	Pb-Pb

U-Pb ages using techniques outlined by Parrish *et al.* (1987); ^{207}Pb-^{206}Pb ages using techniques outlined by Kober (1987).

To the west of the Herb Lake Fault, a spherulitic rhyolite and associated volcaniclastic rocks that were considered to be part of the Felsic package strikes oblique to the general bedding trend (Ansdell and Connors, 1994a). One zircon fraction from a geochronology sample of the rhyolite yielded a concordant U-Pb zircon age of 1856 ±1 Ma. Four other fractions were variably discordant and yielded ^{207}Pb/^{206}Pb ages ranging from 1820 to 1856 Ma. Further analyses are required to clarify the U-Pb systematics of this sample, but we suggest that the age of the rhyolite is approximately 1856 Ma. This is 20 million years older than the felsic rocks described above, and may form part of a volcanic suite distinct from the Herb Lake and Felsic packages.

McCafferty Liftover package

The McCafferty Liftover package consists of an east-younging sequence of subaqueous mafic to intermediate volcanic and volcaniclastic rocks, distinctly different in appearance from the mafic rocks of the Herb Lake package. An arcuate outcrop of heterogeneous extrusive and intrusive rocks of intermediate composition found on Puella Bay (Fig. GS-19-1), classified as "biotite dacite", is interpreted to form part of the McCafferty Liftover package. Younging directions indicate that these "dacitic" rocks stratigraphically overlie the pillowed mafic flows and turbiditic crystal tuffs, and are deformed by the same deformation events. However, the origin of these rocks remains equivocal and warrants further study.

The contact between this package and the Herb Lake-Felsic package is now interpreted as a fault (*Kiski Fault;* Fig. GS-19-1). At one location the contact is exposed and both hangingwall and footwall units are altered and intensely deformed. The McCafferty Liftover package is also separated from sedimentary rocks to the east by the Stuart Bay Fault.

The age of the McCafferty Liftover package can therefore not be constrained by the ages reported above; however, the 1856 Ma rhyolite to the west of the Herb Lake Fault may possibly be part of this package. It is also plausible that the McCafferty Liftover rocks could be older and similar in age to other Amisk Group mafic rocks in the Flin Flon domain.

Sedimentary rocks

Polymictic conglomerate and cross-bedded to parallel-laminated sandstone are the dominant rock types in the Eastern and Western packages of continental sedimentary rocks, previously mapped as Missi Group (Shanks and Bailes, 1977; Ansdell and Connors, 1993, 1994a). The Western package is fault-bounded except at the southern termination where the sedimentary rocks overlie the 1856 Ma rhyolite. East of Ballard Island (Fig. GS-19-1), the Western package of sedimentary rocks includes a 20 to 30 m thick band of felsic volcanic rocks (largely debris flows and rhyolite). The eastern (upper) contact between the felsic volcanic rocks and the overlying sedimentary rocks is gradational with volcanic debris flow grading into a sedimentary conglomerate. Although the lower contact is not exposed, it appears to be approximately parallel to layering in both units. The sandstone and rhyolite (or debris flows) crop out within as little as 30 cm of each other, and there is no evidence either for faulting along, or a gradational change across, the lower contact. This contact may represent an abrupt change from deposition of fluvial sandstones to extrusion of rhyolite flows, suggesting that continental sedimentation and felsic volcanism were synchronous. Detrital zircon ages obtained from a pebbly sandstone of the Western package overlying the 1856 Ma rhyolite are listed in Table GS-19-1. The youngest detrital zircon has an age of 1834 ±15 Ma, roughly equivalent to the age of the felsic volcanic rocks in the Herb Lake-Felsic packages. The field and geochronological evidence suggests that the Western sedimentary rocks largely but not completely postdate felsic volcanism.

The Eastern package of sedimentary rocks appears lithologically similar to the Western package, although no intercalated felsic volcanic rocks have been identified. However, these sedimentary rocks are cut by a felsic dyke (Fig. GS-19-1), similar in appearance to the Wekusko Lake pluton (1834 +8/-6 Ma, Gordon *et al.*, 1990), and by a circular, gabbroic to granodioritic intrusion (Fig. GS-19-1), which is mineralogically and texturally similar to the Rex Lake Pluton (1832 +4/-3 Ma, Gordon *et al.*, 1990). These intrusive relationships suggest that the eastern Missi package is older than about 1833 Ma, but younger than the age of the youngest detrital zircon analyzed thus far (1859 ±8 Ma; Table GS-19-1).

The geochronological information obtained thus far suggests that the Western package of sedimentary rocks may be younger than the Eastern package of sedimentary rocks. Both of these sedimentary packages, along with the Herb Lake and Felsic volcanic packages, have been classified as Missi Group. However, the apparent variation in age between the packages indicates that Missi Group nomenclature in the east Wekusko Lake area does not adequately convey the lithological and temporal complexities of the rocks.

STRUCTURAL HISTORY

The structures in the east Wekusko Lake area have been described by Ansdell and Connors (1993, 1994a) and Connors and Ansdell (1994, in press), although recent thin section studies and field work have led to a revised structural history. Faults and folds are identified on Figure GS-19-1.

The Stuart Bay Fault is interpreted as an early fault, which is syn- or post-F_1 folding as it is not folded by the Herb Lake Fold or by F_1 folds in its hanging wall to the east. The Stuart Bay Fault and S_1 are overprinted by the F_2 syncline-anticline pair at Puella Bay. The F_3/S_3 generation of structures are pervasively developed close to the Crowduck Bay (CBF) and Roberts Lake Faults and within the western Missi Group package. The L_3 extension lineation is also best developed in proximity to these faults. The Herb Lake Fault is interpreted as the same age as the F_3/S_3 structures. The timing of the newly identified Kiski Fault, which separates the Herb Lake and Felsic packages from the McCafferty Liftover package, is uncertain; it may be folded by the F_1 Herb Lake fold, but the hinge is not well exposed and the adjacent rocks of the McCafferty Liftover package do not appear to be folded.

The Stuart Bay Fault and F_1/S_1 structures are interpreted to have formed in a fold-thrust belt (Connors and Ansdell, in press). The F_2/S_2 structures may represent the final stage of this deformation event. The F_3/S_3 structures and associated faults developed synchronously with regional metamorphism (Connors and Ansdell, in press). The fact that the CBF and S_3 remain steep while the F_3 fold axes and L_3 extension lineation systematically shallow to the north suggest that the CBF formed as a strike-slip Fault within a transpressional setting. The Roberts Lake fault appears to be a thrust fault, suggesting that both strike-slip and thrust faults were active at approximately the same time.

Some early F_1 folds in the File Lake formation are truncated by the Wekusko pluton (1834 Ma; Bailes, 1992). This indicates that sedimentation, volcanism and plutonism may have been coeval with or postdated ongoing early F_1 or pre-F_1(?) deformation. Further work is required to determine the temporal relationship between deformation events, magmatism and sedimentation.

ACKNOWLEDGMENTS

The enthusiastic and competent assistance of Sue Schaan, Ian Russell, Pauline Orr, and Craig Therens is greatly appreciated. Technical support was provided by Neill Brandson. Geological discussions with Al Bailes, Terry Gordon, Steve Lucas, and Richard Stern, and criticism of this paper by Steve Lucas are appreciated. Terry Gordon is especially thanked for providing us with his unpublished maps.

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GS-20 STRUCTURAL GEOLOGY OF THE ELBOW LAKE AREA, FLIN FLON - SNOW LAKE GREENSTONE BELT, MANITOBA*

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Ryan, J.J. and Williams, P.F., 1994: Structural geology of the Elbow Lake area, Flin Flon-snow Lake greenstone belt, Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 108-114.

SUMMARY

A relatively fine grained unit of the Long Bay conglomerate, exposed on the north side of Long Bay, records a complex deformational history within the wall rocks of the Elbow Lake Shear Zone. The structures developed include an early flattening fabric, a shear zone fabric, and three generations of folds. The regional foliation (S_2) appears to be a consequence of tectonic deformation, after the emplacement of the 1872-1864 Ma granitoid plutons. The recognition of two generations of hornblende porphyroblasts in the rocks in the eastern portion of the map area indicates a localized metamorphic episode (M_1) that predates regional metamorphism (M_2). The development of F_5 folds and a locally pervasive S_5 foliation across a 9 km wide zone appears to be associated with post-M_2 sinistral transpression along the Elbow Lake Shear Zone.

INTRODUCTION

Detailed structural mapping (1:15 840 and 1:5 000) was completed in the Elbow Lake area during the summer of 1994 as the second year of a Ph.D. project by the first author at the University of New Brunswick. The aim of this project is to establish the kinematic history of the Elbow Lake Shear Zone (ELSZ; Galley *et al.*, 1987; Syme, 1991) and the relative timing of regional deformation and metamorphism.

Previous work in the Elbow Lake area includes Stockwell (1935), McGlynn (1959), Galley *et al.* (1987), Syme (1990, 1991, 1992), Whalen (1992), and Ryan and Williams (1993), as well as a host of mineral exploration programs dating back to the early 1900's. Last year's mapping concentrated within the ELSZ in the northeast and central parts of Elbow Lake. This year's mapping concentrated on the shear zone rocks in south-central Elbow Lake and on the wall rocks on the east and west sides of the lake. One week of mapping was completed around a small, N-S trending lake, informally referred to herein as Iron Lake, located 3 km east of Elbow Lake. The ELSZ is well exposed due to a fire in the Elbow Lake area in 1989. Short excursions to Sexton Lake (to the north), the Cranberry Lakes (to the southwest), and Iskwasum Lake (to the southeast) were made to investigate possible extensions of ELSZ type structures.

Specific topics addressed this summer include:

1. establishing the chronology of structure development in the wall rocks as well as within the shear zone;
2. the exact boundaries of the Claw Bay shear zone (CBSZ);
3. the nature of the intense foliation around and within the large plutons; and
4. the possibility that an amphibolite grade, "regional type" metamorphism having occurred around 1870-1860 Ma, which was overprinted by a more pervasive regional metamorphism generally believed to have occurred between 1815 and 1805 Ma (*e.g.*, Gordon *et al.*, 1990; Hunt and Zwanzig, 1993).

GENERAL GEOLOGY

The Elbow Lake area hosts a variety of Amisk Group metavolcanic and related intrusive rocks (1910-1880 Ma), and large granitoid plutons (1871-1845 Ma; Hunt and Whalen, in press). The map area is transected by the north-northeast-trending ELSZ and the north-northwest-trending CBSZ, which coalesce in the east-central portion of the lake. The ELSZ is several tens of metres wide in the northern and southern parts of the map area, and reaches a maximum width of about 2000 m where it is intersected by the CBSZ. Regional metamorphism increases from sub- to middle-greenschist facies (very fine grained chlorite and muscovite) on the west side of the ELSZ to upper greenschist-lower amphibolite facies (coarser grained chloritic matrix with actinolite, biotite and hornblende porphyroblasts) on the east side. Rock types are described in Syme (1990, 1991, 1992) and Whalen (1992). For an overview of the distribution of rock types, see Syme and Whalen (1992) and Whalen (1993b).

Foliations within both the ELSZ and CBSZ are generally vertical and locally anastomose around low-strain domains which vary in scale from centimetres to hundreds of metres. Shear zone rocks have flattened and stretched primary features. The degree of flattening is highly variable throughout the shear zones but appears to increase inward. Within the shear zones, an intense stretching lineation is generally vertical, but locally plunges moderately north or south. Mappable structures within the ELSZ (*e.g.*, shear zone intersections, shear drag folds, S/C fabrics) indicate transcurrent shear deformation. Both sinistral and dextral shear indicators occur, but the sinistral variety is more abundant. Ryan and Williams (in press) provide two possible models to explain the significance of vertical stretching lineations in a transcurrent shear zone: 1) an early thrust shear zone that was tilted vertically and reactivated in transcurrent shear, and 2) transpressional deformation; the second is favoured.

Shear zones at Elbow Lake have endured a complex history through prograde and retrograde regional metamorphism recording at least 70 Ma of deformation (Ryan and Williams, 1993). Ryan and Williams (in press) group the multiple generations of structures within three broad deformational episodes. F_1 and F_2 fold structures and regional S_2 foliation developed during D_1. F_3, F_4 and F_5, associated with the main ductile shear zones, developed during D_2. Post-F_5, ductile-brittle and brittle structures are grouped within D_3. Peak regional metamorphism appears to have occurred during or after F_4 deformation, but prior to F_5 (Ryan and Williams, in press).

STRUCTURAL OBSERVATIONS

Particular outcrops within the ELSZ exhibit a very complex deformational history. An outcrop in southern Elbow Lake contains sinistrally sheared tonalite dykes and dextrally shear folded veins and dextrally sheared layers. The relative timing between these different senses of shear cannot be established. The foliation associated with these structures is locally cut by narrow (10's cm) shear zones with well developed sinistral S/C fabrics. These fabrics are overprinted by a late, pervasive set of ductile to brittle dextral shears. The dextrally folded veins are mylonitized and exhibit very well preserved, fine grained S/C fabrics in thin section, with a vertical, east-side-up sense of shear. The same sense of shear was found in other samples from the central and southern parts of the study area, and is interpreted to have developed late in the metamorphic history because the fabrics are typically poorly recovered. The east-side-up sense of displacement late in the metamorphic history is consistent with higher grade rocks exposed on the east side of the shear zone. The vertical displacement is probably a component of the sinistral deformation (see "Tectonometamorphic Synthesis" section below).

The opposing shear sense indicators that occur locally throughout the ELSZ can be explained by shear sense reversals during the deformational history. Macroscopic evidence for shear sense reversals includes the overprinting of the ELSZ by dextral movement along the CBSZ, which is in turn overprinted by a reactivation of the ELSZ in sinistral shear (Ryan and Williams, in press). Opposing shear sense indicators do not necessitate shear sense reversals, because they can be produced synchronously during a single shear episode, depending on how the bulk deformation is accommodated on a local scale (Jiang and White, in prep.; Williams and Schoneveld, 1981). Overprinting

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TABLE GS-20-1
Tectonometamorphic synthesis of the Elbow Lake area.

Deformation Episode	Generation	Structures Developed in Different Domains				Metamorphism	Inferred age and setting
		West, north-central and south-central Elbow Lake	Long Bay	Eastern Elbow Lake	Iron Lake		
D_1	S_1	Possible early fabric preserved in low-strain domain on Leaping Moose Island	Early flattening of clasts in Long Bay conglomerate		S1 foliation defined by hornblende	Localized hornblende grade metamorphic episode (M1) related to emplacement of the older plutons. These minerals locally define the S1 fabric, and are deformed by S2	Proto-ELSZ prior to emplacement of **1864 Ma** Elbow Lake tonalite. **1872 - 1845 Ma** granitoid plutonism, inducing M1
	F_2	S2 fabric at low angle to bedding west of ELSZ, minor F2 folds. S2 fabric east of ELSZ	Isoclinal F2 folds with axial planar S2 cleavage. S2 is	S2 regional fabric variably developed	S2 well-developed in the Centre Lake Mafic tectonite		
D_2	F_3	Early S3 ELSZ foliation preserved on Leaping Moose Island, folded by CBSZ	F3 folds with axial-plane cleavage, may not be related to the ELSZ				
	F_4		S4 shear fabric in Long Bay conglomerate, likely not related to the CBSZ fabric	Vertical Z-folds of S3 with axial-plane S4 cleavage. The CBSZ contains both sinistral and dextral kinematic indicators. S4 is locally a differentiated crenulation		Peak regional metamorphic minerals (M2) overgrow S2 and S3, and may be synchronous with or slightly post-date S4.	Peak regional metamorphism (M2) between **1815 and 1805 Ma**, associated with Hudsonian Orogeny
	F_5	Large-scale S-folds developed in S0 and S2, related sinistral shear along ELSZ. S5 cannibalizes S3 fabrics. Sinistral, dextral and vertical shear sense indicators. S5 locally forms a differentiated layering	F5 folds with S5 axial-plane cleavage	Small and large-scale F5 S-folds overprint S2 and S4, with a well-developed S5 crenulation cleavage. S5 is developed deep into the wall rocks to the ELSZ		M2 porphyroblasts (locally hornblende) are crenulated by S5. Metamorphic isograds are offset along ELSZ. Enough water around to produce differentiated layering locally. Grade remained high enough for fine actinolite and biotite to grow parallel to S5 locally	Greenschist facies, retrograde deformation during exhumation of the belt
D_3	F_6	Moderately plunging, open F6 S-folds with axial-plane crenulation cleavage, deforming the S5 in southern map area. Likely unrelated to folds at Iron Lake			Large-scale, open F6 S-folds deform S2. No axial-plane cleavage, but has associated fractures. Likely younger than folds in southern Elbow Lake		
		Kink bands, N, NNE, and NNW trending ductile to brittle shears, including the late dextral set in the south		Locally developed ductile to brittle shears	Late ductile to brittle shears, kink folds	Chlorite alteration Further offset in metamorphic isograds	Deformation in the ductile to brittle regime
		Small and large scale N, NNW and NNE brittle faults		Small and large scale N, NNW and NNE brittle faults	Small and large scale brittle faults		Deformation in the brittle regime, probably after **1800 Ma**

relationships on a variety of scales may be more conclusive. In view of this, shear sense indicators should be applied with extreme caution, as they may provide an ambiguous or incorrect picture of movement.

Eastern Elbow Lake

Mapping on eastern Elbow Lake was concentrated from Claw Bay, as far east as Centre Lake, northward to Island Bay, a small bay northeast of Leaping Moose Island. Ryan and Williams (1993, in press) indicate that an early fabric of the ELSZ (S_3) is overprinted by dextral shear along the CBSZ (S_4). The overprinting relationship is superbly exposed on Leaping Moose Island (Syme, 1991). The CBSZ fabric is overprinted by large and small F_5 S-folds, with a well developed axial-planar crenulation cleavage interpreted to be related to reactivation of the ELSZ in sinistral shear (Ryan and Williams, 1993). Locally, both the S_4 and S_5 crenulation cleavages have an associated differentiated layering. Differentiated layering is generally associated with prograde deformation and metamorphism (*e.g.*, Williams, 1972, 1990), because it requires an abundance of fluid during its formation. The F_5 structures at Elbow Lake have demonstrably developed during retrograde metamorphic conditions (Ryan and Williams, in press). An abundance of fluid during retrograde deformation is peculiar, and probably indicates that the ELSZ acted as a conduit for fluids (*cf.* Sibson, 1981), even late in the metamorphic history.

East of Claw Bay, rocks contain a pervasive north-northwest-trending regional foliation interpreted as S_2 (Syme, 1991; Ryan and Williams, in press; see the sections on Iron Lake and Long Bay for discussion). A package of high strain, heterolithologic amphibolite facies mafic schist (Centre Lake mafic tectonite, Syme, 1991) occurs between Claw Bay and the Gants Lake batholith (GLB) to the east. S_2 varies from north-northwest in Claw Bay to north along the margin of the GLB. Because S_2 and S_4 are generally sub-parallel in the Claw Bay area, they are difficult to separate in outcrop. Two locations, one in Claw Bay and one in Island Bay, exhibit good examples where S_4 is a differentiated crenulation cleavage overprinting S_2. In both locations, S_4 cleavage is overprinted by F_5 S-folds with an S_5 axial-plane crenulation cleavage.

The boundary between the mafic tectonite and the Claw Bay basalt, from which the tectonite is derived, is poorly understood. It is unclear whether the boundary is a sharp, ductile strain gradient or a brittle fault. No significant change was observed in the intensity of strain within the tectonite between Claw Bay and the GLB. This is in contrast to the results of Syme (1991, 1992), who mapped a much larger proportion of these rocks, and reported a significant increase in the intensity of strain towards the margin of the GLB. During the present study, however, tectonite rocks mapped in Claw Bay are as highly strained as any observed along the GLB. There are local low-strain domains along the GLB that preserve primary features, just as in Claw Bay (see "Iron Lake" section below).

The S_5 crenulation cleavage varies in intensity away from the ELSZ, but can be recognized over 3 km eastward into the wall rocks. A large megacrystic tonalite sill (Unit 30b; Syme 1992) is well exposed north of Centre Lake and has a very intense, locally mylonitic, north-northwest-trending S_2 foliation. This foliation is so intensely crenulated by S_5, that the protolith cannot be recognized locally.

Western and South-Central Elbow Lake

Rocks in west-central Elbow Lake are dominated by pillowed MacDougalls Point basalt flows. Well exposed, superbly preserved flows outcrop best on the northern tip of MacDougalls Point. Here, these flows trend north-northwest and young to the west-southwest, based on criteria such as flow top breccias, pillow shapes, fine cross-beds in volcaniclastic turbidites, and sedimentary chert locally draped over pillows. These flows locally contain a foliation, at a low angle to bedding, and it is interpreted as the S_2 regional fabric of Syme (1992) recognized in the northwest Elbow lake area. S_2 tends to be parallel to flattened clasts and pillows, and F_2 folds locally affect bedding.

Flows (S_0) and S_2 are folded on a macroscopic scale (100's m), as outlined by Syme (1992) who recognized changes in the younging direction of flows. Minor folds (1-10 m) in bedding have a well developed vertical axial-planar cleavage that trends towards 025° and locally mimics larger scale structures. The long limbs of the major folds consistently trend northwest to north-northwest and are ≈1 km long. The short limbs typically trend south-southwest and are only a couple hundred metres long, making these structures very asymmetric S-folds, with interlimb angles between 30° and 60°. Minor folds in thin layers are locally tighter.

The style and orientation of these large folds are similar to large scale F_5 S-folds recognized in higher grade rocks east of the ELSZ, which overprint peak regional metamorphic mineral assemblages (Ryan and Williams, in press). The large folds west of the ELSZ are herein also grouped with F_5 structures (pending confirmation in thin section) and interpreted as related to sinistral transpression (post-peak metamorphism) along the ELSZ.

On an island west of MacDougalls Point, S_5 is overprinted by a 3 m wide sinistral shear zone, which is only a couple degrees off the orientation of S_5, and is highly altered with rusty carbonate. Brittle faults overprint most ductile fabrics in western Elbow Lake, a common observation throughout central Elbow Lake (Ryan and Williams, 1993).

The boundaries of the ELSZ mapped through south-central Elbow Lake are similar to those of Syme and Whalen (1992). A long narrow island east of MacDougalls Point is composed dominantly of diabase intrusions within the supracrustal rocks, which are, in turn, intruded by a large lenticular tonalite/quartz diorite body. The tonalite and basalt have an intense ductile shear fabric. Sinistral and dextral kinematic indicators are found within the tonalite, but the eastern margin of the shear zone in this region is dominated by dextral indicators. Stretching lineations and mineral lineations are ubiquitously steep to vertical. One high strain zone within the tonalite has very well developed C-C' shear bands, indicating a vertical, west-side-up sense of shear. This shear displacement is in stark contrast to other vertical shear sense indicators recognized throughout Elbow Lake, and is inconsistent with high grade rocks on the east side of the ELSZ. The medium- to coarse-grained diabase appears to have been fairly strong under ductile shear and is locally undeformed. Syme and Whalen (1992) have interpreted the presence of a narrow shear zone between this island and the eastern shore of the mainland. A couple of tiny (10 m), low-lying island exposures exhibit a strong shear fabric consistent with this interpretation. The western shoreline in this location comprises a large layered diabase intrusion that has very well preserved igneous layering.

North of the layered diabase, especially on the large peninsula south of Chinaman Island, outcrop exposures are dominated by highly strained mafic schist, heavily intruded by dykes of various orientation and composition. These rocks contain a pervasive S_2 regional foliation, with well developed axial-planar differentiated crenulation cleavage, which is affected by a large scale F_5 fold. Abundant, variably deformed dykes parallel to foliation within the ELSZ indicate that the shear zone has been the locus for dyke emplacement during its deformational history. However, within low strain domains within the shear zones and wall rocks, dykes occur in various orientations. This indicates that at least some of the dykes are transposed parallel to, and not necessarily intruded parallel to the shear fabric.

In conclusion, large scale F_5 S-folds can be mapped on both sides of the ELSZ. On the west side, the folded anisotropy is a combination of S_0 and S_2. On the east side, the folded anisotropy is a combination of S_2 and S_4, which are locally difficult to differentiate. The effects of F_5 persist deep into the wall rocks. Even the east and west margins of the East Elbow Lake tonalite stock (EELTS) appear to be affected by F_5 (a rather open S-warping of the western margin and a well developed S-geometry in the eastern margin).

Long Bay

Long Bay trends northeast, on the western side of Elbow Lake. A brief study was conducted in this area to investigate F_1 isoclinal folds overprinted by the regional foliation (S_2) mapped by Syme (1991) within the Long Bay conglomerate. The Long Bay conglomerate is interpreted as cyclic proximal subaqueous debris flow deposits (Syme, 1991). It contains only mafic clasts, dominated by high-magnesian basalt. Fragments range in size from sand grains to 1.4 m long boulders.

Spectacular outcrops of conglomerate occur southwest of the mouth of Webb Creek. Individual beds are 7 to 10 m thick, trend vertically east, and young north according to normal graded bedding. These coarse grained rocks typically contain a strong vertical, north-trending cleavage. Locally this fabric sweeps into an east-northeast-trending shear foliation. It is unclear as to which generation of regional structures these fabrics belong.

An outcrop within a finer grained unit of the conglomerate, exposed just north of the mouth of Webb Creek, records a complex deformational history including development of an early flattening fabric, a shear zone fabric, and three generations of folds. S_1, defined by extreme flattening of clasts, is isoclinally folded about an F_2 fold with an associated S_2 axial-planar cleavage. The F_2 isocline is folded about a steeply east-northeast-plunging F_3 fold, with a weakly developed S_3 axial-planar cleavage. The F_2 fold, in the northern limb of the F_3 fold, plunges moderately 100°. A vertical shear foliation (S_4) trends 100° and is unaffected by the F_2 and F_3 folds. The F_2, F_3 and S_4 fabrics are folded about steeply south-plunging F_5 folds with a fairly well developed axial planar cleavage (S_5). F_5 folds and S_5 in this outcrop are in the proper orientation and have a suitable style to be equivalent to the major F_5 structures that dominate the central part of Elbow Lake. If this fabric is related to regional S_5, it is interesting that this fabric penetrates so far west into the wall rocks.

Supracrustal rocks west of the ELSZ have been previously mapped as lower greenschist facies (Syme, 1992; Ryan and Williams, 1993), but the Long Bay conglomerate is overgrown by porphyroblasts of actinolite. It is unclear whether the actinolite is associated with regional or contact metamorphism related to the Echo Lake pluton, which occurs 1.2 km to the west. Regardless, these minerals may provide an important relative time marker for the development of the various fabrics in these rocks when studied in thin section. Where F_2, F_3 and F_5 are not present in the same outcrop, these structures are difficult to differentiate. It not clear which of these fold generations is the isoclinal F_1 folds of Syme (1991).

Iron Lake

Iron Lake is situated about 3 km northeast of Claw Bay and provides easy access to the eastern margin of the EELTS and the GLB. Iron Lake sits within a 700 m panel of highly strained, amphibolite facies Centre Lake mafic tectonite (Unit 2a; Syme, 1991). The primary purpose of the study at Iron Lake was to investigate the relationship between the intense foliation that occurs within the plutons and the host volcanic rocks, and attempt to answer four questions:

1. Is there an increase in the intensity of strain in the mafic tectonite between Claw Bay and the GLB to the east as suggested by Syme (1991, 1992)?
2. Is the intense regional fabric recognized between Claw Bay and the GLB related to syn-emplacement (space-making) deformation?
3. Is the fabric associated with post-emplacement tectonic deformation, which preferentially deformed the margins and wall rocks surrounding the rigid batholiths?
4. Regardless of the origin of the fabric, what is the relationship between the fabric and both contact and regional metamorphic minerals?

Most of the plutons in the Elbow Lake area tend to have a well developed foliation parallel to their margins (Whalen, 1992), commonly defined by flattened quartz phenocrysts. This is particularly important in southern Elbow Lake where the ELSZ coincides with the western margin of the Elbow Lake Tonalite (1864 +5/-4 Ma; Whalen and Hunt, in press). Dykes of similar composition to the tonalite pluton overprint a foliation interpreted as being related to early deformation along the ELSZ (Ryan and Williams, 1993). A complication in this interpretation is that the early foliation could be associated with flattening strain during emplacement of the pluton, a commonly accepted emplacement mechanism (*e.g.*, Bateman, 1985; Jelsma *et al.*, 1993). Paterson and Fowler (1993), in a recent review of pluton emplacement processes, concluded that most diapiric emplacement models are far too simplistic and that "near field" flow in the wall rocks can only account for a maximum of 30% of the space required. They cite examples of plutons from around the world that are internally zoned, have concentric foliations, margin-parallel structures, and have been traditionally viewed as "classic" ballooned, or forcibly emplaced plutons. Paterson and Fowler (1993) show that in every case, ballooning cannot account for all the structures and foliations present at the margins, and that these are more likely a consequence of post-emplacement tectonic deformation. Iron Lake provided access to two plutons where this problem could be studied, away from the effects of the ELSZ.

The mafic tectonite in the Iron Lake area is heterolithologic, well layered and variably strained. Some layering in the tectonite can be attributed to pre-foliation fracture fill and alteration bands (common in lesser strained diabase on Gold Dust Island in Elbow Lake). Where the altered fractures are transposed into the regional fabric, they locally resemble a mafic gneissosity and can exaggerate the apparent strain. The tectonite is generally black on fresh surfaces and weathers charcoal grey. The rocks contain abundant epidosite pods, commonly flattened parallel to the regional fabric. The protolith of the tectonite is a multi-phase dyke complex within a basaltic flow host. Highly flattened pillows with thin (0.5 - 1.0 cm) selvages can be recognized locally, even within 100 m of the GLB. Syme (1991) reported locations of relatively undeformed pillowed basalts in low-strain domains within the tectonite between Iron Lake and Claw Lake to the south-southeast (see Syme, 1991, Figure GS-4-5, p. 18). Dykes in this intrusive complex have a variety of compositions, including basalt, diabase, gabbro, andesite, various intermediate porphyries, and locally rhyolite. The more mafic dykes are almost exclusively transposed into the regional fabric. Some of the more intermediate dykes are slightly discordant but contain a fabric indicating that they are broadly syn-deformational.

The intense, vertical north-trending foliation and layering within the mafic tectonite at Iron Lake is part of the regional foliation pervasively developed throughout the eastern Elbow Lake area, and less well developed to the northwest. This fabric is overgrown by randomly oriented hornblende porphyroblasts, presumably associated with peak regional metamorphism. The grain size of amphibole appears to be as strongly dependant on bulk rock composition as it is on metamorphic grade because grain size can vary locally from 2 to 14 mm between layers. The tectonite foliation is locally folded by large scale (50 m) S-folds in which the long limbs maintain the northerly trend and the short limbs are typically rotated into an easterly orientation. These folds are similar in orientation to the large F_5 S-folds that occur throughout the Elbow Lake area but are more open and lack the typical, well developed axial-plane crenulation cleavage. The hinge area of a couple of the folds at Iron Lake have associated fractures, suggesting that these rocks were deformed at a fairly low metamorphic grade, and therefore would be F_6 folds on a regional scale. A 1 m wide quartz-feldspar porphyritic, biotite-bearing quartz diorite dyke overprints S_2 and is folded and fractured by the F_6 fold. This dyke is a possible target for geochronology to establish an upper limit for S_2 development and a lower limit for F_6 folding.

An outcrop on the western shore of Iron Lake, occurring within the east-trending short limb of an F_6 fold, exhibits small (10's cm) low-strain domains that appear to contain an earlier hornblende foliation (S_1) almost at a right angle to the later fabric, indicating that the tectonite fabric is at least an S_2 transposition foliation. If this fold was "unfolded" so that S_2 trends north, S_1 would trend east, almost at a right angle to the margin of the GLB. Syme (1991) similarly concluded that the regional foliation throughout the Elbow Lake area is S_2 because of large F_1 isoclinal folds in the Long Bay conglomerate, that are overprinted by S_2. The axial planes of the F_1 folds in Long Bay trend vertically east, coincidentally parallel to the S_1 fabric at Iron Lake, but it is impossible to directly correlate these structures. In fact, the easterly orientation of S_1 at Iron Lake is problematic because the hornblende that defines the foliation is presumably related to contact metamorphism associated with the GLB. If the foliation developed during or after emplacement of the GLB, its orientation should be controlled by the margin of the batholith, and subsequently trend north. It is possible that the hornblende grew randomly within the S_1 foliation plane, and thus helped define it. Thin section work may solve this problem.

Pre-regional metamorphism hornblende porphyroblasts have been recognized elsewhere. Thin sections of a sample of mafic schist from Claw Bay exhibit two distinct populations of hornblende. The populations are optically similar, but members of one set are long, thin and have been flattened and pulled apart parallel to the S_2 fabric. Members of the other set are short, stubby and appear to have randomly overgrown S_2. The two sets have been interpreted as being related to early contact metamorphism and peak regional metamorphism respectively (Ryan and Williams, in press), although there is a distance of over 2 km between the sample and the nearest exposed sizeable pluton. An S_2-parallel andesite dyke on the western shore of Iron Lake contains elongate garnet porphyroblasts (8 mm) that appear to be flattened parallel to S_2. This observation, coupled with randomly oriented hornblende in the mafic host rock, provides more evidence for a metamorphic episode that predated regional metamorphism.

A poorly exposed breccia occurs about 200 m into the GLB, at the northeast corner of Iron Lake. The extent of the unit cannot be mapped, but it is at least 40 m across and may represent a diatreme. The breccia is clast supported; clasts are dominantly granodiorite, but abundant mafic clasts also occur. The latter must have been transported from elsewhere because there are no xenoliths of mafic host rock within the granodiorite at this location. The breccia contains randomly oriented clasts of foliated (S_2) granodiorite and mafic schist. The grey matrix is not foliated and is randomly overgrown by fine hornblende (1 mm) and biotite (4 mm). The fine foliation in the mafic schist is defined by fine grained hornblende. The brecciation must postdate S_2 development, defined by early hornblende, and must predate biotite-hornblende metamorphism that overprints the matrix. This random porphyroblast growth is likely the same generation as the randomly oriented hornblende that overprints S_2 throughout the area.

Highly strained, pink to grey weathering, quartz-potassic feldspar porphyritic granite (Unit 31e; Syme, 1992) intruded the western margin of the GLB. The unit is about 150 m wide with a northwest strike length of at least 4 km (Syme and Whalen, 1992). On the northwest shore of Iron Lake, the western contact of the granite is demonstrably intrusive. The eastern contact appears to be a fault contact (related to the Centre Lake fault of Syme, 1992) with a sliver of mafic tectonite to the east. The fault is not exposed but can be constrained to a 5 m wide valley. The intense foliation in the highly strained granite is defined by ribbon quartz and flattened potassic feldspar crystals with aspect ratios on the horizontal surface of 10-20:1 and 3:1, respectively. The rock appears to have been highly recrystallized after deformation. There are two poorly developed lineations in this rock: a sub-horizontal lineation defined by elongate quartz, and a steeply to moderately south-plunging lineation defined by an alignment of micas. It is unclear if the lineation is a true stretching lineation. This rock type lacks unambiguous kinematic indicators. The high degree of recrystallization may account for the lack of well developed lineations and kinematic indicators. Alternatively, the fabric is a flattening strain.

This unit could be interpreted as the most highly strained rock in the tectonite package whose strain intensity increases from Claw Bay eastward to the margin of the GLB. Caution is advised in such an interpretation: without consistent strain markers, it is difficult to establish the relative state of strain between different rock types. For example, aspect ratios in quartz ribbons in the granite are of the same magnitude as in pillow selvages in the mafic rocks. Aspect ratios in the potassic feldspars are lower than the epidosite pods within the mafic tectonite. Even if the granite is at a higher state of strain than the mafic rocks to the west, it is more a function of relative competence than proximity to the GLB. If the mafic rocks were altered to hornblende prior to S_2 development, which appears to be the case, they will be stronger than the granitoid during ductile strain. There are good examples of this competence inversion with metamorphic grade throughout the entire Elbow Lake area. At several localities on Elbow Lake, where quartz-feldspar porphyritic intermediate dykes that contain basaltic dykes or layers are ductilely sheared at greenschist facies, the basalt accommodates most of the strain and the intermediate dykes remained undeformed. To the east, where rocks in a similar setting are deformed under amphibolite facies, the amphibolitized mafic dykes are boudinaged and the quartz-feldspar rich rocks develop a strong fabric.

Regarding the question of whether the tectonite foliation is associated with batholith emplacement or post-emplacement tectonic deformation, the following observations are noted. Where the western margin of the GLB is well exposed on the north shore of Iron Lake, the most intense fabric within the granodiorite occurs directly at the contact. Quartz-pink feldspar pegmatite dykes, which are commonly associated with later stages of magmatism, are variably oriented with respect to the margin, but contain the foliation; this suggests that deformation is late. Similar evidence was recognized along the eastern margin of the EELTS, west of Iron Lake. The foliation, defined by flattened quartz and feldspar and an alignment of biotite, is most intense at the margin of this batholith and decreases slightly in intensity inward. About 150 m into the tonalite, a 13 m wide plagioclase phyric (5-10 mm), straight-walled, vertical, hornblende-altered diabase dyke trends 170°, slightly oblique to foliation, and contains the foliation. The diabase is cut by a quartz-potassic feldspar phyric rhyolite dyke that also contains the foliation. Hence, it would appear that the foliation developed after the emplacement of three unrelated igneous phases, and has be related to post-emplacement tectonic deformation. C-C' relationships, well developed in the tonalite at the margin of the diabase dyke, indicate a sinistral sense of shear. A narrow shear zone 100 m east contains good C-C' relationships indicating dextral shear, but the relative timing of the two shear zones cannot be established.

Long, thin mafic layers (*e.g.*, 5 cm x 3 m) are commonly observed within the GLB. Where these features were recognized, no undeformed mafic xenoliths were observed. These mafic layers may represent highly flattened and/or stretched xenoliths of mafic host rock. This fabric is locally crosscut by thin (10's cm) shear zones, with both sinistral and dextral examples. Quartz- and epidote-filled tension gashes are commonly associated with these shear zones. Examples of quartz-two feldspar pegmatites that overprint S_2 foliation were observed in the GLB. U/Pb zircon analyses of Whalen and Hunt (in press) yielded ages of 1844 +17/-10 Ma and ≈1834 Ma for young phases of the GLB and 1872 ± 3 Ma for one of the older phases.

Sexton Lake

Syme (1992) concluded that the zone of ductile deformation associated with ELSZ narrows dramatically north of Moen Bay on Elbow Lake, and that deformation appears to be accommodated along a number of narrow fault zones. Sexton Lake lies about 4 km north-northeast of Moen Bay on Elbow Lake, and provides access to the northern extension of the ELSZ. D. Schledewitz (pers. comm., 1993) indicated that possible extensions of the ELSZ may occupy a couple of valleys that lie southwest of Sexton Lake. These structures trend north-northeast towards the Gauthier Lake pluton (GLP), but lack of exposure precludes establishment of whether the ELSZ cuts, is deflected around, or is stitched by the pluton. Whalen (1993a) concluded that the GLP is probably the same age as the 1845 ±3 Ma Big Rat Lake Pluton (Whalen and Hunt, in press). F_5 deformation along the ELSZ postdates regional metamorphism (1815-1805 Ma) and therefore should not be stitched by the pluton. A day trip to Sexton Lake yielded little information about the kinematic history of the ELSZ and the nature of this apparent fault termination.

Two parallel valleys trending about 020° are spaced a couple hundred metres apart, and are only 10 to 20 m wide. No outcrops extend into the centre of the valleys, but a marked vertical foliation is locally developed parallel to the valley edges. Lineations are steep to vertical, as at Elbow Lake, but no useful kinematic indicators were found. The structures in these valleys are likely extensions of the ELSZ, but the apparent abrupt termination of this structure, which had such a pervasive effect at Elbow Lake, is enigmatic.

On the west side of the westernmost valley, a felsic volcanic breccia has an extreme flattening fabric generally north-northwest-trending, which is folded with an axial-planar cleavage trending ≈025°, parallel to the valley. The relationship is similar to F_5 overprint of the S_2 regional fabric on the west side of Elbow Lake.

The south and east sides of Sexton Lake exhibit an intrusive relationship between the Gants Lake batholith and amphibolite facies mafic host rocks to the west. The amphibolite has an intense, vertical north-trending foliation (S_2) and is likely part of the Centre Lake mafic tectonite.

TECTONOMETAMORPHIC SYNTHESIS

Table GS-20-1 provides a synthesis of the tectonometamorphic history of Elbow Lake. Various mapped structures are grouped into three broad deformational episodes. The nature and timing of plutonism and metamorphism is listed relative to the development of structures, to bracket the absolute timing of continued deformation along the ELSZ. Structures developed in different domains are grouped in generations for convenience, but direct correlation is generally impossible.

DISCUSSION AND CONCLUSIONS

No constraints can be placed yet on the amount of displacement across the ELSZ, because marker units cannot be traced across the shear zone. Basaltic flows on both sides of the shear zone have ocean-floor assemblage characteristics, but a different geochemical signature. Post-peak regional metamorphic (*i.e.*, after ≈1815-1805 Ma) movement along the ELSZ associated with the development of F_5 structures appears to have been sinistral. This is consistent with most of the useful kinematic indicators in the shear zone. Locally, however, both sinistral and dextral indicators appear to have developed prior to the late sinistral movement. If the dyke that overprints a shear zone foliation in southern Elbow Lake yields an age of 1864 Ma as predicted, this will prove that these rocks suffered shear zone deformation prior to 1864 Ma. The occurrence of a domain rich in mafic xenoliths, many of which contain shear zone fabrics, within the Elbow Lake tonalite is consistent with this conclusion. Ductile-brittle and brittle structures that overprint ductile fabrics within the ELSZ indicate late (probably <1800 Ma) continued deformation along the shear zone, possibly even during uplift and unroofing. At least 70 Ma of deformation can be documented along the ELSZ. Evidence of shear sense reversals are provided by F_3, F_4 and F_5 structures. Even if marker units were present across the ELSZ, it would only provide a net displacement and the absolute kinematic history could not be established.

Two puzzling questions remain about rocks at Elbow Lake, and much of the Flin Flon belt for that matter: (1) when did stratigraphy get vertically tilted and (2) by what mechanism? Based on the symmetry associated with the intersection between F_5 structures and S_0, S_2 and S_4, bedding was upright prior to F_5 deformation. The symmetry plane associated with the intersection of the CBSZ (S_4) and S_2 regional fabric at eastern Elbow Lake indicates that bedding was likely upright prior to F_4, and hence, prior to peak regional metamorphism. A simple model to explain steepening could be compressional folding early in the deformational history. Such folding, however, should produce shallow fold axes, which are noteworthy by their absence at Elbow Lake. The shallowest early folds recognized in the map area are the F_2 folds in the Long Bay area that appear to isoclinally fold a flattening fabric. Some combination of S_1, F_2 and F_3 deformation could easily accommodate the necessary strain to tilt bedding upright prior to F_4, but it would be unrealistic to exclude the possibility that thrust stacking could have played a role in steepening stratigraphy early in the accretion and amalgamation of the different volcanic terranes. Shallow folds occur in the southern Elbow Lake area, but they affect the ELSZ fabric and are at least F_6 structures on the regional scale.

The F_5 folds appear to be associated with sinistral shear along the ELSZ, and yet a pervasive S_5 fabric developed across a wide zone from Long Bay in the west to Centre Lake in the east (at least 9 km wide). The ELSZ reaches a maximum width of only 2 km. The shear zone was not capable of accommodating all of the flattening strain. This is more evidence in support of the sinistral transpression model that Ryan and Williams (in press) invoked to explain many of the features observed at Elbow Lake, including vertical stretching lineations in a shear zone that has obviously deformed in transcurrent shear. The Cranberry Shear Zone (CSZ) at the Cranberry Lakes was mapped as part of the Grass River fault (GRF), which is associated with the ELSZ, by Syme (1993). The CSZ trends southwest then west-southwest through the three Cranberry Lakes, and its relationships between lineations and foliations are similar to the ELSZ. How could a transpressional shear zone maintain structures and fabrics along a curviplanar zone? For the orientation of the ELSZ, GRF and CSZ (sweeping from ≈020° at Elbow Lake to ≈080° at First Cranberry Lake), sinistral transpression can be easily maintained along its strike length. The CSZ does not appear to be folded into this orientation.

There is evidence in several locations that an early episode of hornblende porphyroblastesis affected the rocks in the eastern part of the map area, prior to the development of S_2. This can be explained by contact metamorphism associated with the large batholiths in the area. Some of the examples, however, are located over 2 km from the nearest exposed sizeable pluton, and over 4 km from the largest, the GLB. Based on current aeromagnetic and gravity imagery (Broome *et al.*, 1993), there are no obvious large plutons immediately below the sample location sites. Contact aureoles around other large plutons throughout the granite-greenstone belt, especially the younger ones, are only hundreds of metres (*e.g.*, ≈100 m aureole around the Wekusko Lake pluton, J. Kraus, pers. comm., 1994). It is possible that because of the large volume of granitoid material that was emplaced in these volcanic rocks between 1872 and 1864 Ma, a localized hornblende "regional type" metamorphism (M_1) may have occurred, especially if the plutons were emplaced at a great depth. These rocks were subsequently recrystallized during regional metamorphism (M_2) between 1815 and 1805 Ma.

The regional foliation (S_2) appears to be a consequence of tectonic deformation that was post 1872 - 864 Ma granitoid emplacement. This highly strained package trends at least from east of Sexton Lake, south-southeast into the northeast Iskwasum Lake area, and is locally over 3 km wide. This high strain corridor may represent a pre-M_2 major (crustal ?) shear zone, whose orientation is controlled by the margin of the GLB.

ACKNOWLEDGEMENTS

Natasha Connell is gratefully acknowledged for providing very capable and enjoyable assistance in the field and for help with digital mapping. Dave Schledewitz is thanked for providing a day trip to Sexton Lake and for discussion about the possible northern extension of the ELSZ. Ric Syme is thanked for providing a very informative field trip in the Cranberry Lakes area, emphasizing the southwest extension of ELSZ related structures. Duane Morrison is thanked for running a field trip in the Iskwasum Lake area, highlighting structures mapped by himself and Ric Syme (this volume) during 1994, which are possibly related to the southeastward extension of ELSZ structures. Kevin Ansdell and Karen Connors are thanked for visiting Elbow Lake and for discussions about possible geochronology targets. Steve Lucas is thanked for visiting Elbow Lake and insightful discussions. NATMAP is gratefully acknowledged for logistical support. Neill Brandson (Manitoba Energy and Mines) is thanked for logistical support.

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GS-21 Metamorphic P-T History of Snow Lake, Manitoba, Progress Report

by T. Menard[1] and T.M. Gordon[1]

Menard, T. and Gordon, T.M., 1994: Metamorphic P-T history of Snow Lake, Manitoba, progress report; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 115.

As part of the LITHOPROBE Trans-Hudson Orogen project, we are studying the metamorphic petrology of the Snow Lake area in northern Manitoba in order to establish its thermal and tectonic history. Summer field work involved collecting drill core samples of alteration zones in and near the Anderson Lake, Chisel Lake, and the recently discovered Photo Lake Zn-Cu sulphide deposits, in cooperation with Hudson Bay Exploration & Development Co., Ltd. Outcrop samples from the Snow Lake area were collected, following work by Bailes and Galley (1992a, b, c), Galley *et al.* (1993), and Kraus and Williams (1993).

Preliminary results suggest that metamorphism of hydrothermally altered volcanic rocks at Snow Lake produced natural examples of the model systems FMASH and KFMASH (K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O). These systems are commonly used as simplified approximations of metapelites, but natural samples with these chemical systems are rare because most rocks have additional system components and correspondingly have complex mineral assemblages. New techniques in theoretical phase petrology (Menard and Spear, 1993) will be applied to these rocks to determine the sequence of prograde reactions, the resulting mineral compositional zoning patterns, and the variation in multidimensional compositional space. A rigorous analysis of multidimensional composition space should be a more useful approach to alteration trends than any method that involves simplification and projection.

Once the phase petrology is understood, traditional (Essene, 1982) and modern (Gordon, 1992) thermobarometric techniques will be used to retrieve P-T estimates for various portions of the thermotectonic history. Finally, Gibbs method metamorphic P-T paths (Selverstone and Spear, 1985; Menard and Spear, in press) will be computed from the mineral compositional zoning. The alteration zones under study were metamorphosed at staurolite grade and consequently have broadly similar metamorphic histories. The occurrence of apparently out-of-sequence kyanite + biotite + chlorite assemblages was documented and explained by Zaleski *et al.* (1991) as a result of mineral compositions and not differences in metamorphic grade. As noted by Kraus and Williams (1993), garnet, staurolite, and kyanite porphyroblasts overgrew an F_1 fabric but were deformed and wrapped by F_2 and F_3 fabrics, indicating that the thermal peak of metamorphism occurred after F_1 and prior to F_2. In some samples, however, garnet has curved inclusion trails, indicating that it grew during F_2 (or mimetic after F_2 folds). This variation in apparent timing of mineral growth is expected to also have resulted from differences in rock composition. Consequently, we should be able to document different stages of the metamorphism. These data will provide constraints for the interpretation of the thermal and tectonic history of the area.

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GS-22 POPLAR RIVER MINERAL ASSESSMENT PROJECT (PARTS OF NTS 53D, 53E, 63A AND 63H)*

by P. Theyer

Theyer, P., 1994: Poplar River mineral assessment project (Parts of NTS 53D, 53E, 63A and 63H); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 116-117.

SUMMARY

Shoreline reconnaissance complemented by pace-and-compass traverses of five major lakes in the Poplar River area (Fig. GS-22-1) showed that this area is underlain by massive to weakly deformed granodiorite to quartz monzonite and by minor granite, granitic pegmatite and hornblendite.

The investigated area yielded no evidence of supracrustal rocks nor of any economic mineralization. The viability of a building stone quarry in the Harrop Lake area might be considered in the event of the construction of an all-weather road that would link this area to the provincial highway system.

INTRODUCTION

Approximately 12% of the area of Manitoba is to be placed under protection to preserve a range of natural habitats. A six-week field program was initiated in the Poplar River area in southeast Manitoba in 1994 to investigate the mineral potential as a basis for land-use planning. In a related project, the mineral potential of two candidate areas in northwestern Manitoba was investigated by Peck *et al.* (see GS-1, this volume).

The Poplar River area extends from the Manitoba-Ontario boundary to Lake Winnipeg. This area encompasses the following NTS quadrangle sheets: 53D/5, 6, 11, 12, 13 and 14; 53E/3 and 4; 63A/7, 8, 9, 10, 14, 15 and 16; and 63H/1, 2, 3, 5, 6, 7 and 8.

Shoreline reconnaissance of major lakes that are accessible by fixed-wing aircraft was complemented by traverses to investigate major gradiometer anomalies that were identified on vertical gradient total field magnetic maps at 1:100 000 scale. Rock type identifications were made under field conditions using mineral ratio estimates, and as such, are preliminary.

I. Hosain (pers. comm., 1994) analyzed the available geophysical data: a uranium reconnaissance survey at 1:250 000 (Soonawala, 1978) and four INPUT geophysical surveys performed over targets located just outside of the Poplar River area. He detected no radioactive anomalies that warranted follow-up by this field program.

PREVIOUS WORK

Tyrrell (1898) first described rocks in the area. Johnston (1936a, 1936b, 1936c, 1936d, 1936e, 1936f) mapped granodiorite, quartz diorite and granite between Lake Winnipeg and the Ontario border from 51°N to 54°N. The Poplar River area was mapped by Ermanovics (1970) at 1:250 000 scale by pace-and-compass traverses supplemented by extensive helicopter-borne operations. Percival and Stern (1984) described the granitoid rocks of the Berens belt in Ontario and presented a geological compilation map. The results of recent investigations of the geology of the Berens River domain are published in Geology of Ontario (1991).

GENERAL GEOLOGY

The area is underlain by granitoid rocks of the Berens River subprovince (Card and Ciesielski, 1986) of the northwestern Superior Structural Province. The area is bounded to the south by the Family Lake greenstone belt and to the north by the Cobham - Gorman greenstone belt.

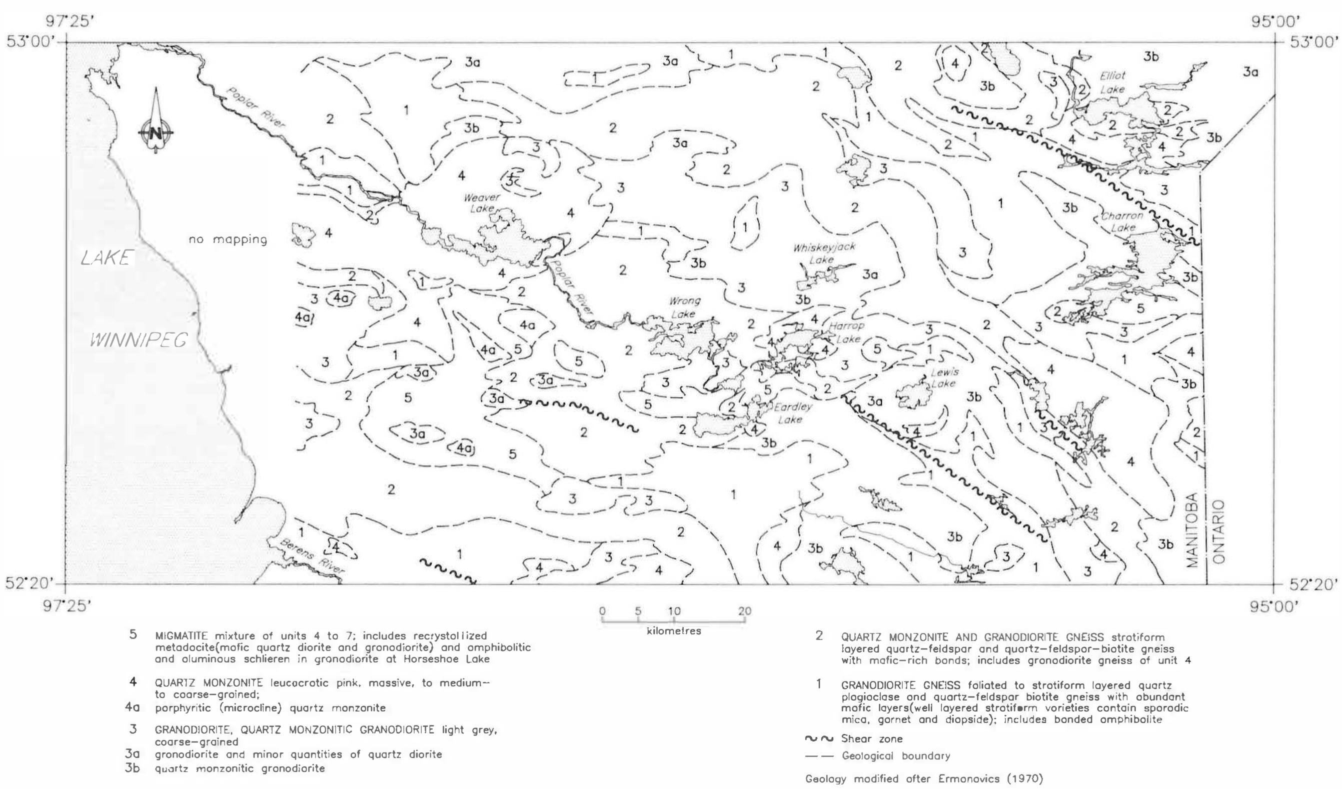

Figure GS-22-1: Geology of the Poplar River area.

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

The Cherrington Lake greenstone belt (Stone, 1991) is approximately 18 km long and up to 5 km wide. It consists of a southeast-striking sequence of mafic volcanic flows, thin ultramafic layers, and ferruginous chert. The northwestern end of this belt straddles the Manitoba-Ontario boundary in the vicinity of Charron Lake (Stone and Crawford, 1993).

CHARRON LAKE

The Charron Lake area is underlain by granodioritic to quartz monzonitic rocks (Fig. GS-22-1) that contain amphibolite lenses up to several hundred metres long by tens of metres wide. Pegmatitic granite dykes, in places >100 m long and 2 to 5 m wide, are the youngest intrusive rocks. Supracrustal rocks of the Cherrington Lake greenstone belt (Stone, 1991) were not observed in the Charron Lake area.

A 310°-striking shear zone at northeastern Charron Lake exceeds 20 km in length and ranges from 200 to 400 m in width. Ermanovics (1970) described ultramylonite and pseudotachylite in this shear zone. Intense brittle shearing and mylonitization resulted in rocks that are characterized by cm-thick laminae, resembling well layered sedimentary rocks. A gradiometer anomaly that covers the Cherrington Lake greenstone belt extends over Charron Lake northwest to southern Elliot Lake (proprietary data); it is attributed to magnetite concentrations in the shear zone.

Mineralization

Mylonitized rocks in the shear zone at northeastern Charron Lake contain traces of disseminated pyrite and up to cm-thick magnetite-enriched layers.

ELLIOT LAKE

The Elliot Lake area is underlain by massive to weakly sheared granodiorite and quartz monzonite (Fig. GS-22-1). Granodiorite was intruded by quartz monzonite and then cut by granitic pegmatite. Diorite dykes and rafts and hornblendite lenses are present in places. The hornblendite is characterized by large hornblende crystals (up to 3 cm) and is intruded by abundant quartzofeldspathic dykes and sheets. A northwest-striking magnetic low extends from the Cherrington Lake greenstone belt in Ontario to northeastern Charron Lake and southeastern Elliot Lake. It coincides with the strike of a shear zone in granodiorite in the southwestern Elliot Lake area; the shear zone contains a diorite dyke up to 4 m thick.

Mineralization

Traces of pyrite occur in rocks of the Elliot Lake area.

HARROP LAKE

The Harrop Lake area is underlain by massive quartz monzonite, granodiorite and large expanses of pink granite. Some outcrops on western Harrop Lake are characterized by joint spacings exceeding 2 m.

Mineralization

No sulphide mineralization was observed in rocks at Harrop Lake. Certain areas underlying western Harrop Lake may have potential for dimension stone if Harrop Lake were to become accessible via an all-weather road.

WRONG LAKE

The Wrong Lake area is underlain by massive homogeneous quartz monzonite that is intruded by granodiorite and crosscut by abundant pegmatitic granite dykes in places. The pegmatitic granite dykes contain K-feldspar and quartz crystals up to 15 cm long.

Mineralization

No sulphide mineralization was observed in the Wrong Lake area.

EARDLEY LAKE

The Eardley Lake area is underlain by fine grained granite, quartz monzonite and granodiorite, crosscut by granitic pegmatite dykes.

Mineralization

No sulphide mineralization was observed in the Eardley Lake area.

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GS-23 GEOLOGICAL ENVIRONMENTS AND CHARACTERISTICS OF TI-V-FE OXIDE MINERALIZATION IN THE WESTERN PART OF THE PIPESTONE LAKE ANORTHOSITE COMPLEX*

by D.C. Peck, H.D.M. Cameron and M.T. Corkery

Peck, D.C., Cameron, H.D.M. and Corkery, M.T., 1994: Geological environments and characteristics of Ti-V-Fe oxide mineralization in the western part of the Pipestone Lake Anorthosite Complex; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 118-129.

SUMMARY

The Late Archean Pipestone Lake Anorthosite Complex (PLAC) is an 800 m wide x 17 km long layered anorthositic intrusion that hosts at least four zones of disseminated and/or massive Ti-V-Fe oxide mineralization. Geological mapping (1:2500 scale) of the western part of the complex has been completed. A tentative lithostratigraphy for the PLAC is proposed. All of the known oxide-rich zones occur within the upper 300 m of the PLAC. Two of these zones (South and Main Central) contain massive to semi-massive oxide layers, up to 3 m in thickness, that typically contain >60% Fe_2O_3, 15% TiO_2 and 1% V_2O_5. Results from an ongoing exploration program (Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc.) have delineated a drill-inferred Ti-V-Fe deposit of approximately 6 million tonnes representing approximately 20% of the known strike length of the Main Central zone. Three separate ilmenite-rich gabbroic units have been identified in the PLAC. The largest of these, the Disseminated zone, is commonly >60 m thick and contains an average of 5% and a maximum of 7% TiO_2. Preliminary results indicate that the uppermost ilmenite-bearing gabbroic unit (North Contact zone) contains even higher TiO_2 abundances (locally >9%).

The results from this study corroborate those from the ongoing exploration program, and highlight the exceptional characteristics of the Ti-V-Fe mineralization in the PLAC: (1) the oxide mineralization forms several steeply dipping layers and layered units having significant lateral and down-dip extent; (2) the mineralization is impoverished in deleterious metals such as Mn, Cr and S; and (3) the large tonnage but low grade ilmenite mineralization remains an attractive exploration target owing to the relatively large grain size of the ilmenite.

Preliminary findings suggest a magmatic origin for the Fe-Ti-V mineralization, in which oxide minerals were deposited from transition metal- and oxygen-enriched magmas that evolved during the later stages of crystallization of the PLAC. One or more graduate research projects dealing with the geology, mineralogy and petrogenesis of the PLAC and its oxide deposits are anticipated to commence next year.

INTRODUCTION

Detailed field investigations (*ca.* 5 weeks duration) were conducted on the Late Archean (2758 ± 3 Ma; U-Pb zircon age determination, Corkery *et al.*, 1992) Pipestone Lake Anorthosite Complex (Fig. GS-23-1). The field studies were initiated in order to complement previous mapping of the PLAC (Cameron, 1992). The impetus for the current investigation arose from the initiation of an ongoing exploration program (1993) that is focussed on massive and disseminated Ti-V-Fe oxide mineralization that occurs within the PLAC.

Anorthosite on Pipestone Lake was first described by Tyrrell in 1903. The regional geology of the Pipestone Lake area (Fig. GS-23-2) is described by Rousell (1965), Bell (1962, 1978), Corkery (1983, 1985) and Corkery *et al.* (1992). Alcock (1919), Horwood (1934), Rousell (1965) and Rose (1967) described the layered nature of anorthositic and gabbroic phases in the PLAC and reported on titanium- and vanadium-rich layers of massive magnetite, and on gabbros containing disseminated magnetite and/or ilmenite. Noranda Exploration Company Ltd. held claims covering much of the area for approximately 20 years but eventually dropped the ground in 1976, following completion of line cutting, trenching, a ground magnetometer survey and limited diamond drilling (15 drill holes). McRitchie (1986) investigated the geology of petrologically similar anorthositic rocks belonging to the West Channel anorthosite body, located approximately 15 km to the west of the PLAC.

In 1984, an initiative by the Geological Services Branch to evaluate potential local sources of strategic minerals resulted in the studies carried out by Cameron (1984-86, 1992). This work led to renewed interest from the exploration industry in the Ti-V-Fe oxide mineralization hosted by the PLAC. An active block of contiguous claims covers most of the area underlain by the PLAC and is jointly held by Cross Lake Mineral Exploration Inc. and Gossan Resources Ltd. (VSE). The joint venture partners have to date: (1) established an approximately 10 x 1 km cut grid (75 m line spacing) that covers over 80% of the PLAC; (2) completed a detailed ground magnetometer survey over the grid, which confirms the locations of two previously known (*e.g.*, Cameron, 1992), laterally extensive magnetic anomalies associated with massive (>80% oxide minerals) and semi-massive (>40% and <80% oxide minerals) oxide mineralization (Main Central and South zones); and (3) at the time of writing, completed in excess of 90 diamond drill holes (>10,000 m of core) designed to test the lateral and vertical extent of the massive and disseminated Ti-V-Fe mineralization. The drilling program has involved two phases: (1) an early phase (winter, 1994) comprising approximately 26 drill holes and focussing on massive oxide mineralization (Main Central zone); and, (2) a second phase (summer, 1994) comprising approximately 80 drill holes that are principally designed to test the lateral and vertical extent of the Main Central zone and of spatially associated disseminated ilmenite mineralization (Disseminated zone). A few drill holes were directed toward the South Zone and a newly discovered Ti-rich unit that crops out in the northern part of the complex (North Contact Zone; L. Chastko, Gossan Resources Ltd., personal communication, September, 1994). Some of the drilling results have been made public through news releases (March, April, August and September, 1994).

Field work conducted by the authors during the summer of 1994 included 1:2500 scale geological mapping and lithogeochemical sampling over a 3.5 km section of the western part of Gossan's exploration grid (Fig. GS-23-2). The area mapped extends from southwestern Pipestone Lake to the east shore of Cross Lake (Fig. GS-23-2). The mapping was undertaken in order to: (1) improve the existing geological database for the PLAC (summarized in Cameron, 1992); (2) establish a detailed stratigraphy for the PLAC that could be used to investigate the geological controls on the location and grade of Ti-V-Fe oxide mineralization within the PLAC; and (3) to investigate previously undescribed outcrops of Ti-V-Fe oxide mineralization within the western part of the PLAC. The grid mapping was supplemented by detailed mapping of five selected areas containing bedrock exposures of Ti-V-Fe mineralization from different stratigraphic levels within the PLAC. This report describes the results of the 1:2500 scale grid mapping and of concurrent lithogeochemical studies. Detailed mapping of the cleared outcrops was not completed and will resume in 1995.

Ti-V-Fe and major element geochemical analyses for selected samples collected from the PLAC during the 1994 field season are given in Table GS-23-1. In addition, 31 drill core and surface samples of sulphide-bearing and oxide-bearing rocks were collected in order to assess the degree to which platinum-group elements were concentrated by magmatic sulphides and oxides formed during the emplacement of the complex. The samples were submitted for the determination of their Pt, Pd and Au contents (ACTLABS, Ancaster, Ontario) and the results are presented in Table GS-23-2.

GEOLOGY

Figure GS-23-3 represents a simplified version of the detailed geological map (1:2500 scale) for the western part of the PLAC (Peck *et al.*, 1994). The area mapped is approximately 3.5 x 1 km and extends from the western end of the exploration grid (line 4800 m west) to the western shoreline of Pipestone Lake (line 1350 m west) (Figs. GS-23-2, -3). The

* Funded by Provincial A-Base

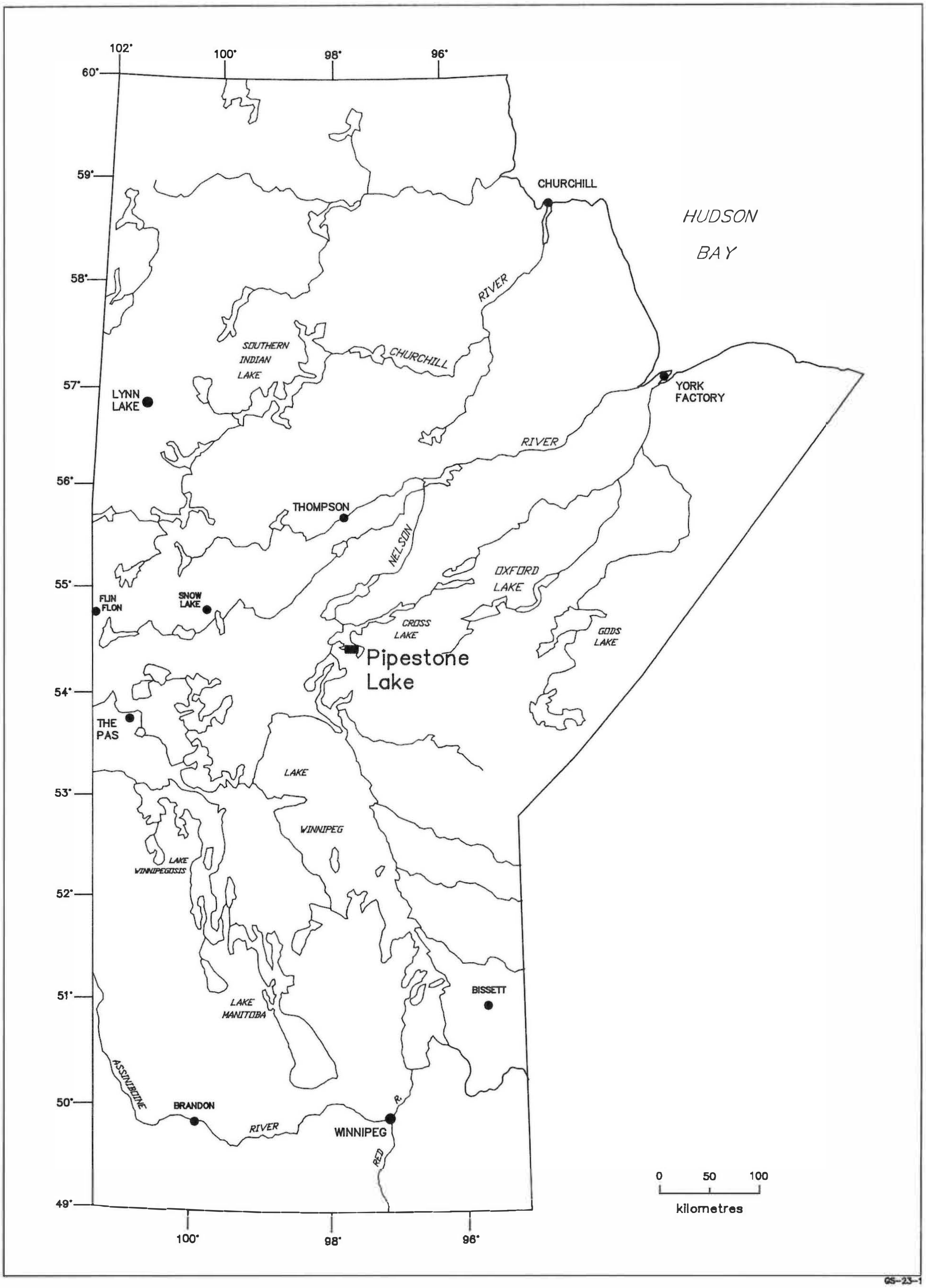

Figure GS-23-1: *Location of the Pipestone Lake area, central Manitoba.*

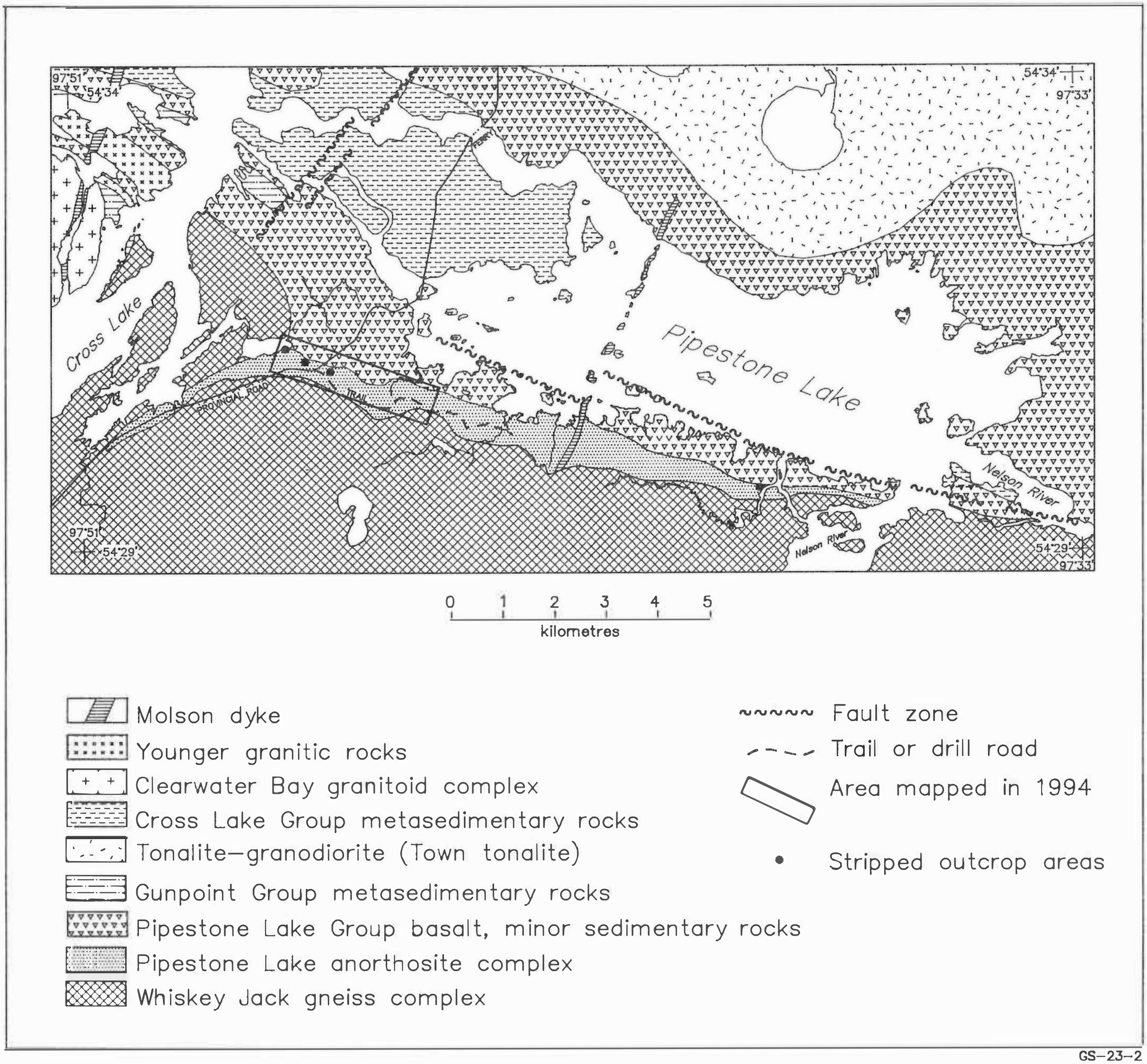

Figure GS-23-2: Regional geology of the Pipestone Lake area (modified after Cameron, 1992).

position of the contacts shown on Figure GS-23-3 was, wherever possible, extrapolated from observed contacts in the outcrops. However, the position and orientation of many of the contacts shown on the map were inferred from adjacent contacts, and will hopefully be more precisely defined following completion of the ongoing drilling of the western part of the PLAC (Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc.). As is the case with many layered intrusions, the PLAC shows both lateral and vertical variations in the textures and compositions of individual stratigraphic units. The scale of mapping employed during the current study allowed for recognition of major lithologic units and permitted correlation of thick layers (*i.e.*, >10 m) or layered units between outcrops. It was not possible to trace thin layers (*i.e.*, <10 m) between outcrops. This type of correlation should be possible if more detailed mapping of outcrops (*i.e.*, 1:100 scale) and logging of drill core is conducted.

The nomenclature adopted for assigning names to specific igneous rock types and for the description of igneous fabrics is derived from I.U.G.S. conventions (LeMaitre, 1989; Irvine, 1982). In order to simplify the nomenclature, the prefix "meta-" has not been used in conjunction with primary (*i.e.*, igneous) terminology. However, it is important to recognize that the PLAC has been subjected to regional dynamothermal metamorphism (amphibolite facies) that caused pervasive replacement of igneous mineral assemblages by their metamorphic equivalents, *i.e.*, throughout the PLAC, primary pyroxenes are ubiquitously pseudomorphed and replaced by a variety of calcic amphiboles; see Cameron (1992). Owing to pervasive metamorphic replacement of pyroxenes by amphibole, the distinction between orthopyroxene and clinopyroxene could not be make in the field. Therefore, the term "gabbro", as applied in this report, is a general field term for gabbroic rocks and does not refer only to rocks containing clinopyroxene + plagioclase mineral assemblages. Whole-rock geochemistry and detailed petrographic investigations of the PLAC should provide an indication of the proportions and crystallization of the primary mafic phases within the PLAC.

The western part of the PLAC comprises, for the most part, cumulate rocks, *i.e.*, intrusive rocks in which an early (high temperature) mineral phase has been physically concentrated into proportions that

Table GS-23-1
Analyses of grab samples from the Pipestone Lake anorthosite complex.

FeO* = total Fe as ferrous oxide; NR = not reported; FeO and Fe_2O_3 calculated assuming all TiO_2 is present in stoichiometric ilmenite and that the excess FeO* is bound in magnetite (massive magnetite layers) or silicate minerals (assuming FeO:Fe_2O_3 ratio of 3.3:1).
Totals not reported because major element oxide data are incomplete.
Major Element Oxide Abundances (wt. %)

Sample No.	Zone	Rock Type	SiO_2	TiO_2	Al_2O_3	FeO*	FeO	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O
ILMENITE-RICH SAMPLES (>10% ilmenite)													
68-94-13-1	M2	Msv Ilmenite	5.60	44.5	NR	42.1	40.7	1.55	1.05	1.66	1.08	0.27	0.06
68-94-5-1	M2	Ilm-Melagabbro	42.5	5.02	13.5	19.8	16.2	3.89	0.3	9.45	5.34	2.05	0.34
68-94-13-2	M2	Ilm-Melagabbro	41.1	4.25	13.0	21.3	17.3	4.45	0.29	9.77	5.71	1.78	0.36
68-94-29-1	M2	Ilm-Melagabbro	37.7	5.18	13.1	22.7	18.6	4.61	0.27	7.53	4.89	1.91	0.32
68-94-33-1	M2	Ilm-Melagabbro	36.3	5.83	13.6	25.3	20.7	5.11	0.26	8.3	5.15	1.84	0.22
68-94-36-1A	M2	Ilm-Melagabbro	38.6	4.78	13.4	22.4	18.2	4.62	0.33	9.57	6.54	1.87	0.37
68-94-40-1	M2	Ilm-Melagabbro	42.8	4.84	13.2	20.2	16.6	4.05	0.26	9.23	5.24	2.28	0.29
68-94-50-1A	M2	Ilm-Melagabbro	41.8	4.53	12.5	21.7	17.6	4.50	0.32	8.59	5.29	2.07	0.36
68-94-50-1B	M2	Ilm-Melagabbro	42.0	4.57	12.8	20.2	16.5	4.10	0.3	9.21	5.61	2.16	0.4
68-94-37-1	M3	Ilm-Melagabbro	39.6	3.86	8.64	16.2	13.3	3.25	0.18	14.4	13.2	0.82	0.17
MAGNETITE-RICH SAMPLES (>10% magnetite)													
68-94-61-1A	M2	Msv Magnetite	5.4	15.6	NR	NR	NR	NR	0.33	0.42	2.95	0.11	0.02
68-94-61-1B	M2	Msv Magnetite	3.7	16.1	NR	NR	NR	NR	0.34	0.04	2.31	0.09	0.01
68-94-61-1C	M2	Msv Magnetite	2.9	17.6	NR	NR	NR	NR	0.34	0.01	1.88	0.08	0.01
68-94-61-1D	M2	Msv Magnetite	13.7	20.7	NR	47.2	27.4	21.9	0.42	3.44	1.96	0.51	0.12
68-94-61-1E	M2	Msv Magnetite	4.4	17.1	NR	NR	NR	NR	0.37	0.08	2.62	0.09	0.01
68-94-61-1F	M2	Msv Magnetite	12.1	13.7	NR	NR	NR	NR	0.36	2.51	3.33	0.35	0.1
68-94-61-1G	M2	Msv Magnetite	5.7	16.4	NR	NR	NR	NR	0.36	0.54	2.28	0.09	0.03
68-94-24-1	M1	SemiMsv Mgte	25.3	6.87	17.6	36.8	15.7	23.4	0.18	6.52	3.64	1.08	0.18
68-94-23-1	M1	Mgt-Melagabbro	43.3	2.45	13.4	17.4	13.9	3.88	0.2	11.9	7.05	1.57	0.16
CUMULATES WITH <5% DISSEMINATED OXIDES													
68-94-60-1A	A1	Meg Anorthosite	47.7	0.22	NR	1.91	1.51	0.44	0.04	14.0	1.23	2.31	0.94
68-94-60-1B	A1	Meg Anorthosite	49.2	0.12	NR	1.90	1.49	0.46	0.03	13.5	1.33	2.36	0.8
68-94-60-1C	A1	Meg Anorthosite	47.2	0.04	NR	0.85	0.66	0.21	0.02	14.7	0.69	2.35	1.03
68-94-62-1	A1	Meg Anorthosite	49.3	0.3	NR	2.44	1.94	0.55	0.03	12.8	1.28	3.5	0.42
68-94-51-1	A1	Leucogabbro	49.2	0.56	NR	5.76	4.55	1.34	0.09	13.2	3.3	2.31	0.25
68-94-44-1	A1	Diabase	49.6	1.59	14.5	14.8	11.7	3.41	0.23	9.47	5.58	2.17	0.36
68-94-46-2	A1	Diabase	51.6	1.04	14.0	12.3	9.71	2.91	0.21	10.0	6.12	2.19	0.39
68-94-28-1	L1	Msv Anorthosite	48.0	0.08	NR	1.60	1.25	0.39	0.01	14.6	0.46	2.48	0.45
68-94-45-1	L1	Msv Anorthosite	49.3	0.26	NR	2.26	1.79	0.52	0.03	13.2	0.86	3.04	0.27
68-94-38-1	L1	Oik Anorthosite	48.6	0.39	NR	2.40	1.93	0.52	0.04	13.7	1.03	2.67	0.38
68-94-26-1	L1	Leucogabbro	43.3	1.53	NR	10.6	8.49	2.36	0.07	12.5	2.13	2.3	0.19
68-94-3-1	L1	Leucogabbro	50.0	0.2	NR	2.53	1.99	0.60	0.03	13.8	0.92	2.97	0.33
68-94-32-1A	L1	Leucogabbro	47.7	1.21	NR	9.59	7.64	2.17	0.1	11.2	3.66	2.47	0.47
68-94-32-1B	L1	Leucogabbro	47.8	1.16	NR	7.13	5.73	1.55	0.09	10.9	2.02	3.42	0.45
68-94-52-1	L1	Gabbro	46.5	0.65	18.2	11.2	8.73	2.70	0.19	11.0	7.57	2.05	0.25
68-94-52-2	L1	Diabase	49.4	1.64	13.7	14.9	11.8	3.42	0.2	9.77	4.88	1.95	0.29
68-94-41-1	L2	Leucogabbro	44.8	1.14	NR	10.3	8.15	2.36	0.11	11.6	4.15	2.4	0.22
68-94-29-2	L3	Leucogabbro	48.9	1.35	NR	9.06	7.26	2.00	0.11	10.8	3.33	3.36	0.57
68-94-36-1B	M2	Quartz Gabbro	58.8	1.91	12.3	13.2	10.5	2.93	0.29	5.89	3.51	2.24	0.14

are different from those (higher or lower) which would have resulted from static, equilibrium crystallization of a magma. Only rarely are layers observed that could represent static, equilibrium crystallization of a parental magma; these include homogeneous (leuco)gabbro and diabase layers in which there is no evidence of crystal-liquid sorting. Throughout most of the area mapped, plagioclase is the principal cumulus phase, forming euhedral, tabular crystals. Pyroxenes (amphibolitized) generally occur as later-formed postcumulus crystals, and commonly form oikocrysts that enclose earlier plagioclase crystals. Textural evidence suggests that two pyroxenes were present in most of the rock units examined. One of the pyroxenes (higher temperature phase) commonly forms subequant, prismatic crystals and may locally represent a cumulus phase that coprecipitated with plagioclase. A second lower temperature pyroxene occurs ubiquitously as skeletal oikocrysts and formed during the late stages of crystallization of the parent magma from intercumulus liquids. The later pyroxene is commonly intergrown with oxide minerals that are present as postcumulus crystals in most of the rock units examined. Development of the oxide-rich and massive oxide layers appears to reflect a change in the cotectic proportions for the parent magma for the PLAC. A process or processes led to non-cotectic crystallization such that oxide minerals were the dominant (semi-massive oxide layers) or sole (massive oxide layers)

Table GS-23-1 (continued)
Analyses of grab samples from the Pipestone Lake anorthosite complex.

	Trace Element Abundances (ppm)							Ti-V-Fe Abundances and Ratios					
Sample No.	V	Cr	Ni	Cu	Zn	Ba	Sr	TiO_2	V_2O_5	FeO*	Fe/V*100	Ti/V*10	Fe/Ti
ILMENITE-RICH SAMPLES (>10% ilmenite)													
68-94-13-1	408	<6	<7	16	100	<25	7	44.5	0.06	42.1	8.02	65.3	1.23
68-94-5-1	326	<6	<7	37	113	80	113	5.02	0.05	19.8	4.71	9.23	5.10
68-94-13-2	721	<6	<7	58	127	77	81	4.25	0.11	21.3	2.29	3.53	6.49
68-94-29-1	724	<6	<7	86	115	63	92	5.18	0.11	22.7	2.44	4.29	5.68
68-94-33-1	28	<6	<7	26	267	29	140	5.83	<0.01	25.3	70.1	124	5.62
68-94-36-1A	1400	<6	9	37	127	51	74	4.78	0.21	22.4	1.24	2.05	6.08
68-94-40-1	360	<6	<7	63	76	62	117	4.84	0.05	20.2	4.36	8.06	5.41
68-94-50-1A	123	<6	<7	40	136	68	67	4.53	0.02	21.7	13.7	22.1	6.21
68-94-50-1B	140	<6	<7	59	151	63	96	4.57	0.02	20.2	11.2	19.6	5.72
68-94-37-1	118	<6	<7	10	114	29	81	3.86	0.02	16.2	10.7	19.6	5.44
MAGNETITE-RICH SAMPLES (>10% magnetite)													
68-94-61-1A	6502	257	258	45	201	<25	<3	15.6	0.96	NR	-	1.44	-
68-94-61-1B	6391	266	173	38	155	<25	<3	16.1	0.94	NR	-	1.51	-
68-94-61-1C	6636	69	71	17	370	<25	<3	17.6	0.98	NR	-	1.59	-
68-94-61-1D	4941	454	54	29	179	<25	4	20.7	0.73	47.2	0.74	2.51	3.0
68-94-61-1E	6192	31	61	28	229	<25	<3	17.1	0.91	NR	-	1.65	-
68-94-61-1F	4996	283	195	31	169	<25	3	13.7	0.73	NR	-	1.64	-
68-94-61-1G	5758	34	52	29	229	<25	9	16.4	0.85	NR	-	1.71	-
68-94-24-1	3836	301	219	89	165	43	90	6.87	0.56	36.8	0.74	1.07	6.94
68-94-23-1	1291	75	112	257	113	43	99	2.45	0.19	17.4	1.057	1.14	9.20
CUMULATES WITH <5% DISSEMINATED OXIDES													
68-94-60-1A	61	52	15	46	12	57	259	0.22	0.01	1.90	2.43	2.16	11.2
68-94-60-1B	56	58	21	26	18	45	218	0.12	0.01	1.90	2.64	1.28	20.5
68-94-60-1C	35	<6	12	6	8	59	225	0.04	0.01	0.85	1.88	0.69	27.4
68-94-62-1	135	20	14	105	21	83	225	0.3	0.02	2.44	1.40	1.33	10.5
68-94-51-1	231	125	46	88	46	26	184	0.56	0.03	5.76	1.94	1.45	13.3
68-94-44-1	381	91	60	138	87	55	114	1.59	0.06	14.8	3.02	2.50	12.1
68-94-46-2	283	208	55	105	104	55	88	1.04	0.04	12.3	3.39	2.20	15.4
68-94-28-1	32	<6	226	415	24	37	263	0.08	<0.01	1.60	3.89	1.50	26.0
68-94-45-1	97	14	10	20	21	55	232	0.26	0.01	2.26	1.81	1.61	11.3
68-94-38-1	110	9	15	30	25	38	252	0.39	0.02	2.40	1.70	2.13	7.99
68-94-26-1	904	1250	103	106	39	25	204	1.53	0.13	10.6	0.91	1.01	9.00
68-94-3-1	80	22	10	42	26	45	225	0.2	0.01	2.53	2.46	1.50	16.4
68-94-32-1A	401	96	57	52	61	66	184	1.21	0.06	9.59	1.86	1.81	10.3
68-94-32-1B	321	35	50	92	39	82	262	1.16	0.05	7.13	1.73	2.17	7.97
68-94-52-1	319	127	85	107	71	35	123	0.65	0.05	11.2	2.72	1.22	22.3
68-94-52-2	425	28	44	149	90	39	90	1.64	0.06	14.9	2.72	2.31	11.8
68-94-41-1	619	1160	126	34	70	39	163	1.14	0.09	10.3	1.29	1.10	11.7
68-94-29-2	313	32	12	8	56	62	193	1.35	0.05	9.06	2.25	2.59	8.70
68-94-36-1B	189	<6	<7	16	77	68	36	1.91	0.03	13.2	5.42	6.06	8.95

crystallizing phase. Detailed petrologic and lithogeochemical studies are required to address the factors involved in the development of the oxide-rich units.

The PLAC is an anorthositic intrusion, in the sense that it contains abundant anorthosite, and that crystallization and sorting of cumulus plagioclase was the principal mechanism controlling the textures and compositions of the various layer types observed in the complex. If it is assumed that plagioclase was the first silicate mineral to crystallize, then any residual liquids that evolved during the crystallization of the PLAC would have been depleted in elements that were more abundant in plagioclase than in the original, parental liquid(s). Assuming that the PLAC was derived from an Al-rich basalt parent magma, then elements such as Fe, Mg, Ti, Mn, Ni, Cr and V should have increased in abundance in the residual liquids resulting from plagioclase fractional crystallization. This type of fractionation trend is observed in many layered intrusions, and is known as the Fenner Trend, perhaps best documented in studies of the Skaergaard Intrusion of Greenland (*e.g.*, Wager and Brown, 1968). Fenner-trend magmas evolve to Fe-rich compositions through the fractional crystallization of plagioclase. All of the textures and layering features observed from the western PLAC are consistent with its derivation from a Fenner-trend magma originating with an Al-rich basaltic composition and evolving to an high-Fe basalt composition through the fractional crystallization of plagioclase. For example, the southern part of the PLAC comprises massive and megacrystic anorthosite in which variable proportions of a mafic to ultramafic residual liquid appear to have been trapped between physically concentrated, early cumulus plagioclase grains. This part of the complex is interpreted to represent the base of the PLAC magma chamber. The stratigraphy for the western part of the PLAC reflects a general, though not systematic, increase in the proportion of mafic phases to the north, which indicates that north is stratigraphically up. The increase in the abundance of mafic phases is associated with a general increase in oxide mineral abundances and a proportional decrease in plagioclase abundance and average grain size.

Within the area mapped, the northernmost part of the PLAC appears to represent a stratigraphic repetition, in which anorthositic rock types (A2 zone) reappear to the north of a melagabbro unit (Fig. GS-23-3). The re-emergence of anorthositic rocks near the interpreted

Table GS-23-2
Au, Pt and Pd tenors of surface and drill core samples of sulphide-bearing and selected additional cumulate rock types from the Pipestone Lake anorthosite complex. Assays were conducted by ACTLABS, Ancaster, Ontario, via instrumental neutron activation analysis.

SampleNo.	RockType	Zone	Au ppb	Pt ppb	Pd ppb	% Sulphide (visual)
(surface grab samples)						
68-94-3-1	anorthosite	A1	2	6	<3	<1
68-94-28-1	anorthosite	A1	8	8	12	≈3
68-94-29-1	melagabbro	M2	1	<5	5	≈2
68-94-29-2	melagabbro	M2	5	7	5	nil
68-94-32-1A	leucogabbro	L1	3	<5	<3	≈2
68-94-32-1B	leucogabbro	L1	3	<5	4	≈2
68-94-38-1	anorthosite	L1	3	5	<3	trace
68-94-45-1	anorthosite	L1	1	<5	<3	<1
68-94-46-2	diabase	A1	4	17	17	nil
68-94-51-1	anorthosite	A1	7	8	6	≈4
68-94-52-1	gabbro	L1	4	<5	3	nil
68-94-52-2	diabase	L1	6	<5	<3	nil
68-94-60-1A	anorthosite	A1	2	<5	6	≈1
68-94-60-1B	anorthosite	A1	77	<5	5	<1
68-94-60-1C	anorthosite	A1	3	6	8	trace
68-94-61-1A	msv. magnetite	M2	2	5	12	trace
(drill core samples; core provided by Gossan Resources Ltd.)						
68-94-100-1	gabbro	L1	337	<5	<3	<1
68-94-101-1	melagabbro	M2	6	<5	<3	trace
68-94-102-1	melagabbro	M2	6	<5	7	<1
68-94-103-1	layered suite	L1	4	<5	<3	<1
68-94-104-1	layered suite	L1	504	<5	5	<1
68-94-105-1	layered suite	L1	16	<5	8	<1
68-94-106-1	gabbro	L1	9	<5	3	nil
68-94-107-1	layered suite	L1	5	<5	8	trace
68-94-108-1	melagabbro	M2	5	<5	<3	≈1
68-94-109-1	layered suite	L1	6	<5	3	trace
68-94-110-1	layered suite	L1	4	<5	<3	trace
68-94-111-1	melagabbro	M2	1	<5	<3	<1
68-94-112-1	gabbro	M2	1	<5	<3	trace
68-94-113-1	leucogb + pxte	L1	57	<5	6	<1
68-94-114-1	melagabbro	M2	3	<5	<3	trace
68-94-115-1	gabbro	M2	2	<5	3	trace
68-94-116-1	melagabbro	M2	2	<5	<3	trace
68-94-117-1	mafic schist	M2	5	<5	<3	trace
68-94-118-1	layered suite	L1	1	<5	<3	trace
68-94-119-1	gabbro	M2	5	<5	3	trace

top of the PLAC is tentatively attributed to a new injection of Al-rich magma into the PLAC magma chamber, rather than to folding or faulting. This conclusion is based on the fact that the A2 zone is both laterally extensive and spatially associated with a geologically distinct suite of cumulate rocks, in comparison to the much thicker southern (basal) anorthosite unit (A1 zone).

LITHOSTRATIGRAPHY

The general stratigraphy of the PLAC has been described in previous reports (*e.g.*, Cameron, 1992). The results of the current investigation confirm many previous stratigraphic observations (Cameron, 1992) and provide additional insights into the crystallization history of the complex. Faulting and the development of shear zones have disrupted the stratigraphy in some parts of the area mapped (Fig. GS-23-3). However, the stratigraphy is nonetheless interpretable, and a type section for this part of the complex has been identified (Fig. GS-23-4).

The major stratigraphic units recognized within the western part of the PLAC, from base (south) to top (north), are described below (refer to Figs. GS-23-3, -4). Outcrop locations, structural measurements and a more detailed geology are provided on the preliminary map for the western part of the PLAC (Peck *et al.*, 1994). The stratigraphy has been subdivided into mappable and internally consistent zones that are made up of one or more lithologic types (units). Zone names are abbreviations in which the alphabetic reference is derived from the first letter of the predominant lithologic type within the zone and the numeric references are given in order of the stratigraphically lowermost zone (lowest number) to the uppermost zone (*e.g.*, A1 zone refers to the lowermost anorthosite-rich cumulate sequence).

Intrusive Breccia (unit 8, B zone) is developed along the contact between the base of the PLAC cumulate succession (units 3 to 7) and the Whiskey Jack Gneiss Complex (unit 9). The breccia is subdivided into fragment-poor (<50% fragments; 8a) and fragment-rich (>50% fragments; 8b) subunits (Fig. GS-23-4 and Peck *et al.*, 1994). The breccia forms a <1 to 150 m wide zone that is made up of variable proportions of anorthosite cumulate fragments and tonalite, granodiorite and lesser granite pegmatite veins. The fragments range in size from a few centimetres to several metres in maximum dimension and appear to have been derived from overlying anorthosite cumulates. Most of the

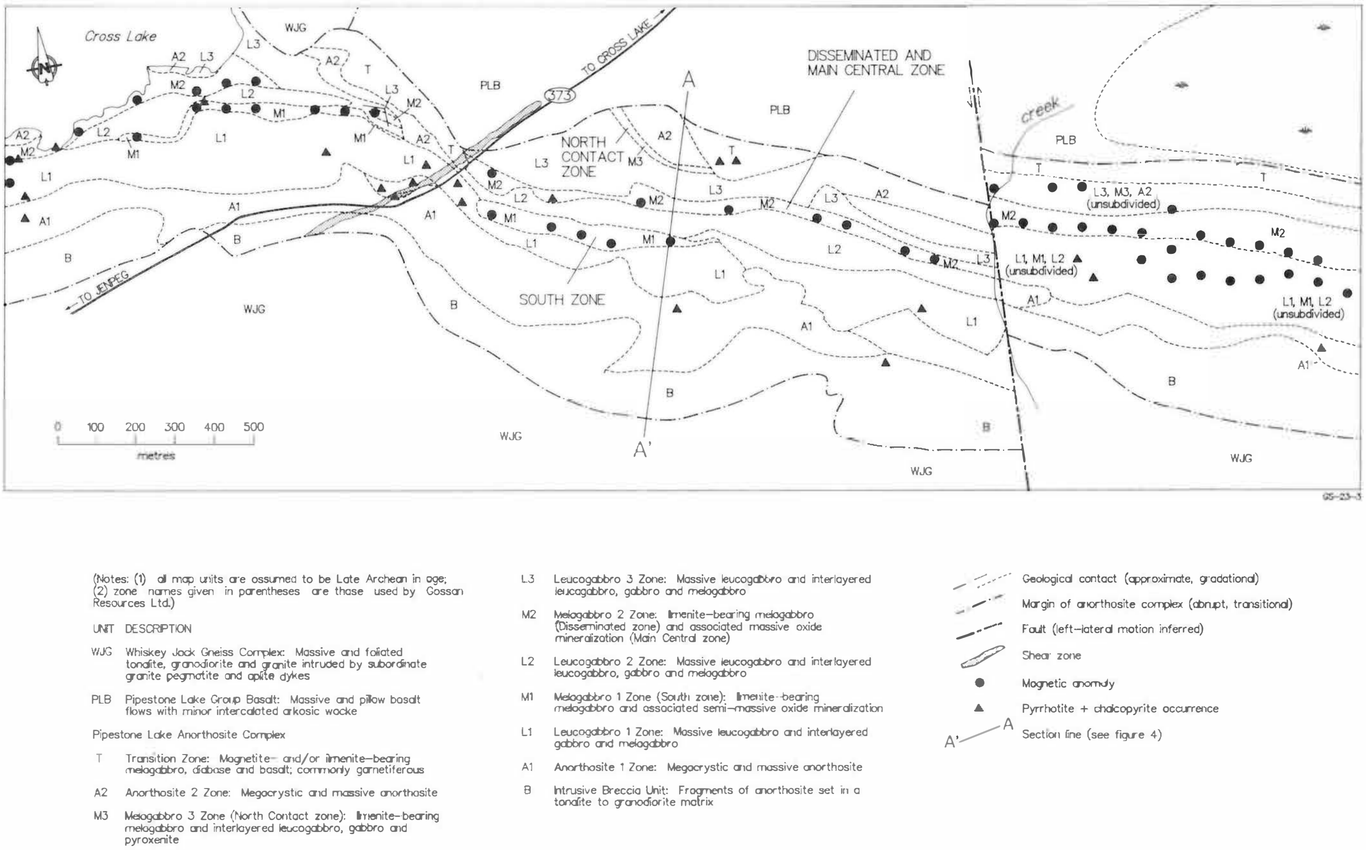

Figure GS-23-3: Generalized geology of the western part of the Pipestone Lake Anorthosite Complex (simplified from the 1:2500 scale preliminary map for the western part of the Pipestone Lake Anorthosite Complex, Peck et al., 1994). Section line A-A' was used to construct the type stratigraphic section shown in Figure GS-23-4.

fragments are subangular in form and show evidence of early brittle deformation (initial fragmentation of originally homogeneous anorthosite cumulates) and later ductile deformation (boudinage). The most common fragment type is megacrystic anorthosite, which is the most abundant cumulate rock type immediately overlying the breccia unit in this part of the PLAC. The vein network is made up of medium- to coarse-grained, massive or foliated granitoid rocks that range in composition from tonalite to granodiorite. Massive, late granite pegmatite dykes locally intrude the breccia unit. The granitoid veins within the breccia locally form anastomosing networks that are generally oriented parallel to the basal contact of the PLAC, although individual veins may be oriented in any direction. Vein widths vary from a few centimetres to several metres and the veins typically display sharp but irregular contacts with the anorthosite fragments. No chilled margins have been observed in the veins, suggesting that they were formed at relatively high temperatures. The relative proportions of vein material and anorthosite fragments is quite variable, ranging from >10:1 to <1:10. Within the breccia unit, there is a general increase in fragment abundance toward the north. The amount of vein material decreases to nil immediately adjacent to the base of the PLAC cumulate succession. This apparent gradation may be indicative of back-injection of felsic melts that were formed during the emplacement of the PLAC into older Whiskey Jack gneisses. Alternatively, post-PLAC granitoid magmas were preferentially injected along the base of the intrusion and were unable to penetrate into the main part of the complex. Of these two scenarios, the first hypothesis appears most consistent with the observed geology in this part of the PLAC.

Anorthosite (unit 3, A1 and A2 zones) is the principal rock type within four mappable subunits: massive anorthosite (3a); megacrystic anorthosite (3b); oikocrystic anorthosite (3c); and layered anorthosite (3d). Anorthosite is also the major lithologic type in the A1 and A2 zones that are the basal and upper members, respectively, of the PLAC cumulate succession (Figs. GS-23-3, -4). A zone of weak to intense potassic and silicic alteration (unit 3e) locally occurs along the base of the A1 zone, predominantly within megacrystic anorthosite and immediately adjacent to the intrusive breccia unit (Fig. GS-23-3). The anorthosite layers are commonly tens of metres thick and consist of coarse grained (>5 mm) to pegmatitic cumulus plagioclase, minor (<10%), medium- to coarse-grained intercumulus pyroxene ± olivine, and <1% intercumulus magnetite and ilmenite. Spectacular megacrystic textures characterize many outcrops of anorthosite in the complex (Fig. GS-23-5). Individual plagioclase crystals up to 25 cm long have been observed in outcrops of the megacrystic anorthosite. The megacrystic textures are likely related to more rapid and efficient heat transfer between the PLAC parent magmas and the country rock along the upper and lower contacts of the intrusion, resulting in undercooling and rapid crystal growth of plagioclase (see Chubb *et al.*, in press).

Megacrystic anorthosite from the PLAC could be considered for use as flooring tiles, but the degree of fracturing observed in outcrops of this rock type appears to be too intense for utilization as facing stone. Further studies of the fracture patterns and general appearance of megacrystic anorthosite in the PLAC are warranted.

In a few outcrops, megacrystic anorthosite is cut and partly brecciated by irregular diabase veins that are locally interconnected with intercumulus gabbroic to pyroxenitic material that forms the matrix of the anorthosite (Fig. GS-23-6). This observation suggests that mafic to ultramafic residual liquids were formed and, locally, coalesced and migrated through the crystal pile during crystallization of the anorthositic parts of the PLAC.

Leucogabbro (unit 4, L1 to L3 zones) is the principal rock type in three mappable cumulate zones that occur in the lower (L1), middle (L2) and upper (L3) parts of the PLAC (Fig. GS-23-4). In many outcrops, leucogabbro layers display gradational contacts with adjacent anorthosite and/or gabbro layers. In the western PLAC, leucogabbro forms thinner

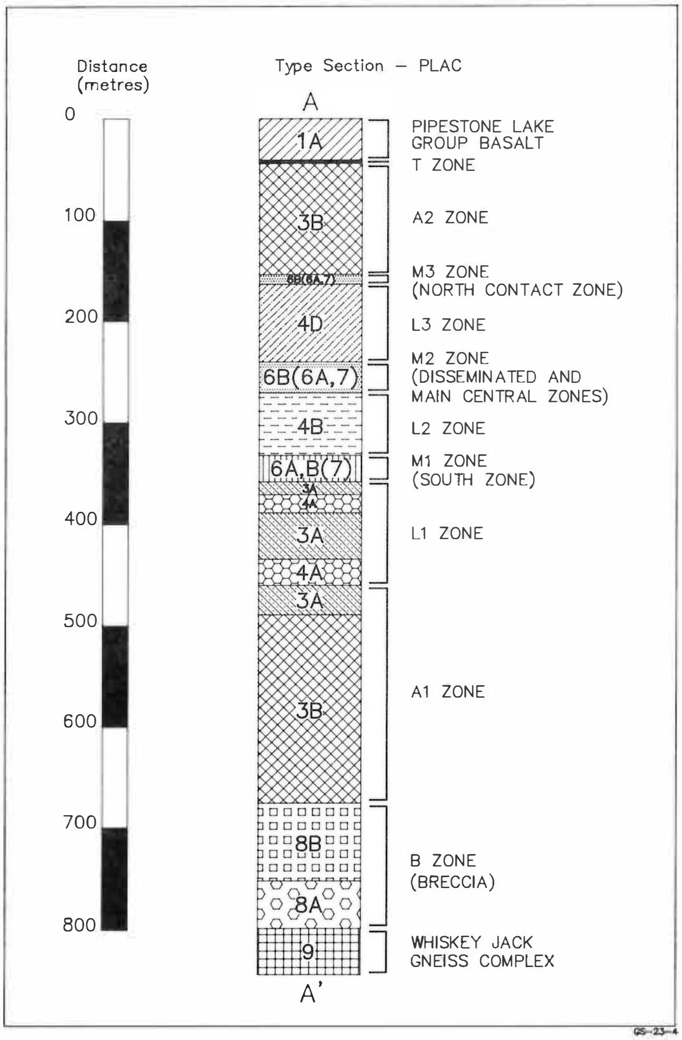

Figure GS-23-4: Type lithostratigraphic section for the western part of the Pipestone Lake Anorthosite Complex (refer to Figure GS-23-3 for location of the section line, A-A'). Unit and zone nomenclature and descriptions are given in the text.

(typically <5 m) and texturally less homogeneous layers than anorthosite. The leucogabbro units commonly display an oikocrystic texture, in which case the unit is referred to as 'leopard rock'. The grain size of the leucogabbro layers is typically medium to coarse (maximum plagioclase grain size ≈1 cm). Oxide mineral abundances are typically <1%, except in the vicinity of semi-massive to massive magnetite (South and Main Central zones), where oxide mineral abundances locally reach 30%. Magnetite-rich leucogabbro locally crops out in the central part of the western PLAC (unit 4c), and is spatially associated with Main Central zone oxide mineralization. Ilmenite and magnetite typically occur as fine to medium grained, subequant to lensoidal crystals that appear to have crystallized during the late cumulus or early postcumulus stage. The leucogabbro zones (L1 to L3; Figs. GS-23-3, -4) are much better layered (cm- and m-scale modal and textural layering; locally graded), are more enriched in oxide minerals and are generally thinner than the two anorthosite zones (A1 and A2).

Gabbro and diabase (unit 5) are common within the central and upper parts of the western PLAC. Gabbro cumulates are best developed within layered leucogabbro (4d), where they form <5 m thick medium- to coarse-grained layers that interdigitate with leucogabbro and/or anorthosite layers. Some gabbro layers contain cumulus pyroxene in addition to cumulus plagioclase.

Diabase forms fine-grained veins and dykes that show a wide range in thickness and orientation. The diabase typically has a gabbroic composition. Plagioclase phyric diabase (Fig. GS-23-7) is quite abundant within the PLAC and the overlying basalt sequences. Some of these plagioclase phyric dykes may represent feeders to both the PLAC cumulate sequences and plagioclase phyric basalt flows belonging to the Pipestone Lake Group. Locally, magnetite-bearing diabase layers form the top of the PLAC and have a gradational contact with basalt flows from the overlying Pipestone Lake Group.

Diabase in the lower parts of the PLAC typically develops as irregular, <1 m thick veins and dykes that are commonly oriented at right angles to the igneous layering. Higher in the stratigraphy, diabase commonly forms layer-parallel veins and sill-like bodies of variable thickness (<1 to 5 m). Diabase layers and/or sills are commonly associated with massive oxide layers within the Main Central zone (Cameron, 1992). Some of the diabase dykes observed within the PLAC may be part of the Molson Dyke swarm (Fig. GS-23-2), but most are believed to be coeval and possibly cogenetic with the PLAC and the overlying Pipestone Lake Group basalt. The diabase veins and dykes are more likely to represent true liquid compositions than any of the coarse-grained cumulates from the PLAC. For this reason, detailed geochemical studies of the various diabase types within the PLAC should be undertaken in order to establish constraints on the origin of the PLAC, the associated Pipestone Lake Group basalt and the Ti-V-Fe oxide mineralization.

Melagabbro and pyroxenite (unit 6, M1 to M3 zones) occur in the middle and upper parts of the PLAC. Pyroxenite is only rarely present in outcrops from this part of the complex. Melagabbro is the principal host rock for most of the disseminated ilmenite mineralization in the PLAC. Melagabbro typically crops out as homogeneous layers, up to 60 m thick, or thinner (<5 m) units interlayered with plagioclase-rich cumulates (leucogabbro, gabbro and rare anorthosite) and subordinate pyroxenite. Melagabbro is typically medium grained and displays a penetrative foliation defined by the parallel alignment of amphibole, cumulus plagioclase and local disseminated ilmenite and/or magnetite. Strongly sheared melagabbro develops a mylonitic fabric involving alternating, thin (<5 mm) plagioclase-rich and amphibole + oxide-rich bands.

Melagabbro is the principal rock type in at least three mappable cumulate units within the PLAC (M1 to M3 zones, Figs. GS-23-3, -4). Each of these zones hosts disseminated ilmenite and/or magnetite and locally contains or is closely associated with massive and/or semi-massive oxide layers. The M1 zone contains a lower, massive to semi-massive oxide unit (South zone). The M2 zone comprises a homogeneous melagabbro layer and an underlying 3 to 10 m thick sequence of interlayered massive oxide and oxide-bearing leucogabbro, gabbro, melagabbro and pyroxenite (Main Central zone). The M2 zone melagabbro layer consists of a thin, magnetite + ilmenite section that grades upward into a thicker ilmenite-bearing section (Disseminated zone; Figs. GS-23-4). In the western part of the complex, outcrops of the M3 zone are rare. The zone is developed in the upper 100 m of the stratigraphy, and comprises interlayered melagabbro, leucogabbro and minor gabbro and pyroxenite. Significant ilmenite concentrations (up to 30% disseminated ilmenite and rare massive ilmenite bands) are reported from drill core samples obtained from the M3 zone in the central part of the PLAC (Gossan Resources, news release, October, 1994). Gossan Resources Ltd. has referred to the mineralized part of the M3 zone as the North Contact zone (Fig. GS-23-4)

The Transition (T) zone, identified during this study, crops out in the western part of the PLAC. The zone comprises fine grained, commonly garnetiferous sheared diabase(?) and melagabbro and forms the boundary between overlying basalt flows (Pipestone Lake Group) and underlying coarser-grained melagabbro and anorthosite belonging to the PLAC. The Transition zone gabbroic rocks contain up to 10% disseminated magnetite ± ilmenite. Metre-size fragments (inclusions?) of metasedimentary rocks (wackes) are locally observed within the zone. The fine-grained gabbroic rocks commonly grade into pod-shaped bodies of coarser-grained gabbro and melagabbro. The Transition zone may represent a sheeted dyke complex that fed the basalt flows. Alternatively, it may represent a chilled margin of the PLAC that developed along the roof of the intrusion and against the base of a pre-existing

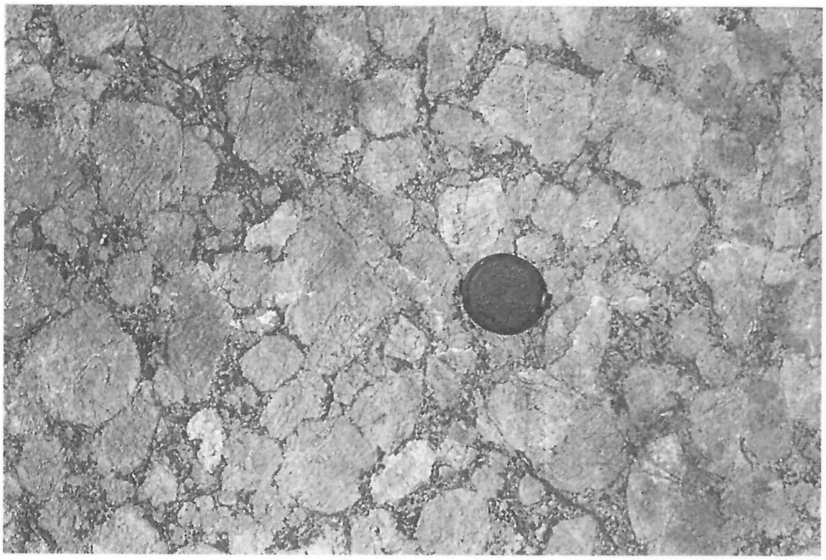

Figure GS-23-5: *Megacrystic anorthosite from the western part of the Pipestone Lake Anorthosite Complex.*

Figure GS-23-6: *Irregular contact between a diabase vein (dark) and an anorthosite cumulate (light) from the A1 zone. The outcrop is located in the western part of the Pipestone Lake Anorthosite Complex. Note that the diabase vein is texturally and compositionally similar to irregular accumulations of intercumulus gabbroic material (dark) within the anorthosite and contains fragments of the anorthosite (see text for additional discussion).*

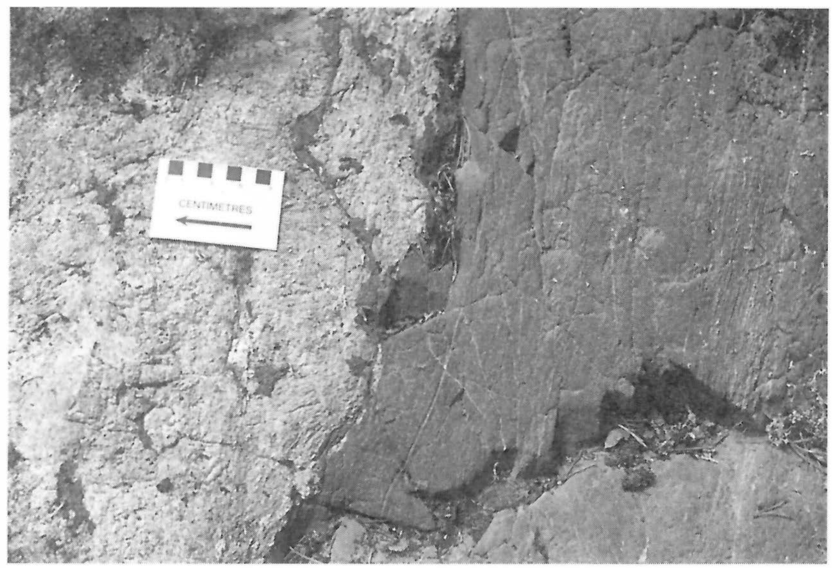

Figure GS-23-7: *Plagioclase phenocrysts from a plagioclase-phyric diabase dyke that intrudes M2 and L2 zone cumulate rocks in the central part of the Pipestone Lake Anorthosite Complex (see text for additional discussion).*

basalt sequence. The geology of the Transition zone and its potential for Ti-V-Fe mineralization should be investigated.

OXIDE MINERALIZATION

Oxide mineralization (unit 7) is developed as disseminated to massive ilmenite and/or vanadium-bearing magnetite (Cameron, 1992). Massive magnetite layers form relatively thin bands (<3 m thick; typically <1 m thick) that are interlayered with disseminated oxide-bearing leucogabbro, gabbro, melagabbro or pyroxenite. Massive magnetite layers forming the Main Central zone are exposed in outcrops along the south shore of Pipestone Lake (Cameron, 1992). In the western part of the PLAC, massive oxide layers rarely crop out, although linear magnetic highs (ground magnetometer survey; Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc.) suggest that three separate zones of massive magnetite are developed in this part of the complex (Fig. GS-23-3). The most continuous magnetic high in the western part of the PLAC occurs along the base of the M1 zone (Figs. GS-23-3, -4) and is correlated with the Main Central zone. Magnetic highs to the south and north of the Main Central zone are correlated with the South zone and North Contact zone, respectively. The development of magnetite-rich rock in association with the North Contact zone is atypical; preliminary drilling of a magnetic anomaly centred at the western end of Pipestone Lake and to the north of the Main Central zone (Fig. GS-23-3) confirms the presence of massive magnetite in this area.

Main Central Zone

To date, most of the drilling conducted by Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc. has focussed on the Main Central zone. At the time of writing, 7 km of the Main Central zone had been intersected at depths of 80 to 100 m by drill holes spaced at 75 m. Drilling coverage extends from the eastern part of Pipestone Lake to the major fault occurring in the western part of the complex (Fig. GS-23-3). Several deeper holes have also been drilled; these indicate that the Main Central zone is continuous to a depth of at least 300 m. Both drilling and mapping confirm that the Main Central zone is a 3 to 10 m thick package of interlayered massive ilmenite-bearing magnetite and oxide-bearing (magnetite and/or ilmenite) gabbroic rocks. The Main Central zone appears to be thickest in the central part of the complex. The zone represents a steeply dipping, tabular Ti-V-Fe deposit that has a strike length of >10 km and a minimum depth of 300 m. A 2 km section of the Main Central zone (central PLAC) contains drill-inferred reserves of >6 million tonnes of massive oxide mineralization having an average grade of 50% Fe_2O_3, 11.5% TiO_2 and 0.7% V_2O_5 (Gossan Resources Ltd., news release, October 13, 1994). Massive oxide layers in the Main Central zone have sharp and wavy contacts with adjacent gabbroic layers. Individual massive oxide layers display considerable variation in their thickness along strike, locally widening to one to two metres or pinching out altogether. It is not clear whether this variation in thickness reflects primary (magmatic) or secondary (tectonic) processes. Despite thickness variations in individual layers, the average oxide abundance within the Main Central zone and its total thickness appear to be remarkably consistent throughout most of the PLAC.

The Main Central zone occurs at the base of the M2 zone (melagabbro) and immediately above the L2 zone (leucogabbro). This setting is intriguing in that it signifies a major change in the liquidus mineral assemblage of the resident magma in the PLAC chamber. It is clear that elucidation of the origin of this change will assist in understanding the genesis of the oxide mineralization in the PLAC. Petrographic descriptions and geochemical analyses for the Main Central zone oxide occurrences are given by Cameron (1992).

Gossan Resources Ltd. collected a 2500 pound bulk sample of massive, ilmenite-bearing magnetite from an outcrop of the Main Central zone (see Cameron, 1992 for a description of Location 1, central PLAC). Metallurgical testing of this sample is being carried out by Dr. W. Dressler of the Department of Engineering, Laurentian University.

Disseminated Zone

Distinct disseminated magnetite and ilmenite mineralization occur immediately above the Main Central zone. Drilling by Gossan Resources Ltd., in conjunction with mapping conducted by the authors, suggests that a magnetite- and ilmenite-bearing section of the M2 zone melagabbro layer immediately and persistently overlies the Main Central zone and is generally <10 m thick. The magnetite-bearing interval grades upward into a much thicker ilmenite-bearing section of the same melagabbro layer, containing between 10 to 15% disseminated ilmenite and only trace amounts of magnetite. Gossan Resources Ltd. refers to the ilmenite-bearing portion of the M2 melagabbro layer as the Disseminated zone. The Disseminated zone is commonly 60 m thick and crops out in many parts of the PLAC. Thin massive ilmenite bands (see analysis for sample 68-94-13-1, Table GS-23-1), up to 20 cm wide, are developed in an outcrop of the Disseminated zone at the south end of Cross Lake.

South Zone and North Contact Zone

To date, little information is available concerning the characteristics of oxide mineralization making up the South and North Contact zones. These occurrences will be examined in detail during the 1995 field season. The South zone appears to have some similarities to the Main Central zone, both in terms of the proportions of Fe, Ti and V and the geological setting (*i.e.,* both zones are developed at or near a leucogabbro-melagabbro contact). However, the magnetic expression of the South zone (Gossan Resources Ltd.) does not extend across the entire PLAC, and merges with the magnetic anomaly associated with the Main Central zone at several locations. The South zone is characterized by the development of a 3 to 8 m thick, semi-massive magnetite layer(s) (40 to 80% magnetite). A series of exposures of the South zone (western part of the PLAC) have been cleared and washed. Preliminary examination of these exposures indicates that an ilmenite-bearing melagabbro, similar to the Disseminated zone, immediately overlies the South zone. The lateral extent and TiO_2 tenor of this ilmenite-bearing layer are not presently known.

Disseminated ilmenite mineralization is present in outcrops of the M3 zone in the western and central parts of the PLAC. Occurrences of ilmenite-bearing melagabbro and leucogabbro from the M3 zone in the western PLAC are tentatively correlated with the North Contact zone. The North Contact zone was only recently tested by drilling. The zone occurs within the upper 100 m of the PLAC and is generally not well exposed. Preliminary field observations and drilling suggest that the North Contact zone contains greater abundances of coarser-grained disseminated ilmenite than the Disseminated zone. The ilmenite occurs within an interlayered sequence of melagabbro, leucogabbro, gabbro and subordinate pyroxenite. An approximately 10 m thick zone of disseminated ilmenite mineralization is developed in a series of outcrops of the M3 zone in the central part of the PLAC. Drilling suggests that melagabbro is the principal rock type in the North Contact zone. One drill hole intersected a 9 m wide (true width) section of the North Contact zone, which returned an average grade of 9% TiO_2 (Gossan Resources Ltd., news release, October 13, 1994). Massive ilmenite bands up to several cm wide have been observed in drill core from the North contact zone (L. Chastko, Gossan Resources Ltd., personal communication, September, 1994). Negligible quantities of Fe and V are reported from the North Contact zone (Gossan Resources Ltd., news release, October 13, 1994). However, the above-mentioned magnetic high adjacent to the western end of Pipestone Lake may signify the local development of massive magnetite in association with the North Contact zone.

Geochemistry

Table GS-23-1 presents whole-rock geochemical data for surface grab samples collected from the PLAC during the current investigation. Most of the oxide-rich samples were collected from outcrops of the M2 zone within the western part of the PLAC. Massive oxide bands were also sampled from a new exposure of the Main Central zone at the eastern end of the complex (stripped outcrop at the southeastern end of Pipestone Lake). One sample of massive ilmenite, collected from a recently stripped outcrop located along the southern shoreline of Cross Lake (western PLAC, Fig. GS-23-2), was also analysed (sample 68-94-13-1, Table GS-23-1).

The analytical results for ilmenite- and magnetite-rich samples are consistent with the results reported by Cameron (1992) and Gossan Resources Ltd. (news releases, March to October, 1994). The maximum TiO_2 abundances are observed from massive oxide samples from the Main Central zone (20.7% TiO_2, sample 68-94-61-1D, Table GS-23-1), and the massive ilmenite sample (44.5% TiO_2, sample 68-94-13-1, Table GS-23-1). As expected, maximum vanadium abundances (1% V_2O_5) occur in massive magnetite samples (Table GS-23-1; see also Cameron, 1992). The analysed samples with disseminated ilmenite mineralization contain between 3.9% and 5.8% TiO_2 - in agreement with Cameron (1992). These results illustrate that the grades and geochemical characteristics of the Fe-Ti-V mineralization developed within the western part of the PLAC are analogous to those of the more thoroughly explored oxide zones from the central part of the complex. Massive oxide occurrences are magnetite-rich and contain significant amounts of TiO_2 and only minor concentrations of undesirable metals (S, Mn, Mg and Cr; Table GS-23-1).

In the oxide-poor samples, TiO_2 abundances are highest in diabase veins and dykes from the A1 and L1 zones (up to 1.64% TiO_2, Table GS-23-1). The diabase samples are also relatively Fe-rich (up to 14.5% FeO, Table GS-23-1). The possibility that these diabase bodies represent feeder magmas to the overlying oxide-rich melagabbro zones (M1 to M3 zones) is being investigated. In contrast to the diabase samples, plagioclase-rich samples are generally impoverished in both TiO_2 and FeO. Anorthosite samples typically contain <0.3% TiO_2 and <2.5% FeO. As the abundance of mafic constituents (Fe, Mg) increases in plagioclase-rich samples (anorthosite and leucogabbro), so too does the TiO_2 abundance (Table GS-23-1). This suggests that oxide crystallization postdated plagioclase crystallization during the formation of the plagioclase-rich rocks that account for most of the cumulate stratigraphy in the PLAC. As such, most of the oxide minerals should reside within the mafic matrix of these plagioclase-rich cumulates, which is what is observed throughout the complex.

SULPHIDE MINERAL OCCURRENCES

Disseminated and locally blebby chalcopyrite and pyrrhotite mineralization is erratically distributed throughout the PLAC. Sulphide mineral abundances reach a maximum of 10% in hand specimens and 1% in outcrop. In the western part of the complex, sulphide mineralization forms rusty weathered areas in outcrops of plagioclase-rich cumulates (Fig. GS-23-8) in both the A1 and L1 zones. Chalcopyrite and pyrrhotite form fine- to medium-grained crystals or aggregates that commonly display an intercumulus habit. The sulphides locally form lensoidal blebs up to 3 cm long. Trace amounts of pyrite are locally associated with the chalcopyrite-pyrrhotite occurrences. The disseminated sulphide mineralization is commonly remobilized into late-stage fractures and forms irregular, thin (<1 cm) quartz-sulphide veinlets.

Representative grab samples of sulphide-bearing and selected additional cumulate rock types from the western PLAC were collected for the purpose of determining their Au, Pt and Pd contents. In addition, 20 drill core samples were submitted for Au, Pt and Pd analyses (1 to 2 m of core per sample). The core samples were collected from Gossan Resources' diamond drill core inventory. Most of the sampled drill holes intersected the M2, L1 and M1 zones in the central and eastern part of the PLAC. The Au, Pt and Pd analyses were undertaken in order to determine whether or not the PLAC sulphides were prospective for precious metals, given the fact that disseminated Fe-Cu-Ni sulphide mineralization in some mafic-ultramafic intrusions represents a primary source for the platinum-group elements (PGE) and Au (*e.g.*, J-M Reef, Stillwater Complex, U.S.A.; Deep Copper Zone, Sudbury Igneous Complex, Ontario). Furthermore, disseminated sulphides from Precambrian layered anorthositic intrusions from central Ontario are known to be strongly enriched in Pd, Pt and Au (Peck *et al.*, 1993).

The analytical results are presented in Table GS-23-2. Whole-rock major and trace element abundances for the surface grab samples are given in Table GS-23-1. The sulphide-bearing rocks are in general, extremely impoverished in both Pt and Pd (all samples contain <20 ppb of Pt and <20 ppb of Pd). However, four samples contain in excess of 50 ppb of Au, with the maximum Au tenor being 505 ppb (sample 68-94-104-1; Table GS-23-2). Three of the anomalously high gold values are associated with disseminated, fine-grained to blebby chalcopyrite + pyrrhotite mineralization (<1%) in gabbro or interlayered leucogabbro/gabbro/pyroxenite cumulates belonging to the L1 zone (drill core samples). One of the Au-enriched samples (68-94-60-1B; Table GS-23-1) was collected from an outcrop of megacrystic anorthosite in the eastern part of the complex. The sample contains <1% disseminated, fine-grained chalcopyrite and pyrrhotite. All of the surface grab samples have low base metal tenors (<420 ppm of Cu and <230 ppm of Ni, Table GS-23-1).

The analytical results indicate that the sulphide occurrences in the PLAC are generally not prospective for PGE, but may be prospective for Au. Gold-enriched sulphide-bearing reefs occur in association with gabbroic and anorthositic cumulates in the Skaergaard Intrusion, Greenland (Bird *et al.*, 1991). Further work is required in order to better characterize the distribution and precious metal tenor of Cu-Fe sulphide occurrences within the PLAC. The low PGE and Cu-Ni tenors of the PLAC sulphides may reflect a prior sulphur saturation event that removed the PGE and Ni (the PLAC cumulates are characterized by having extremely low Ni contents; Cameron, 1992) prior to emplacement of the PLAC parent magmas into the chamber. Two diabase samples collected from the western part of the PLAC were also analysed, in the hope that they may indicate the precious metal tenor of some of the magmas that gave rise to the PLAC cumulates. One of these samples (68-94-46-2) contains relatively high Pd and Pt (17 ppb of each metal), whereas the other sample (68-94-52-2) does not contain detectable quantities of these metals (Table GS-23-2).

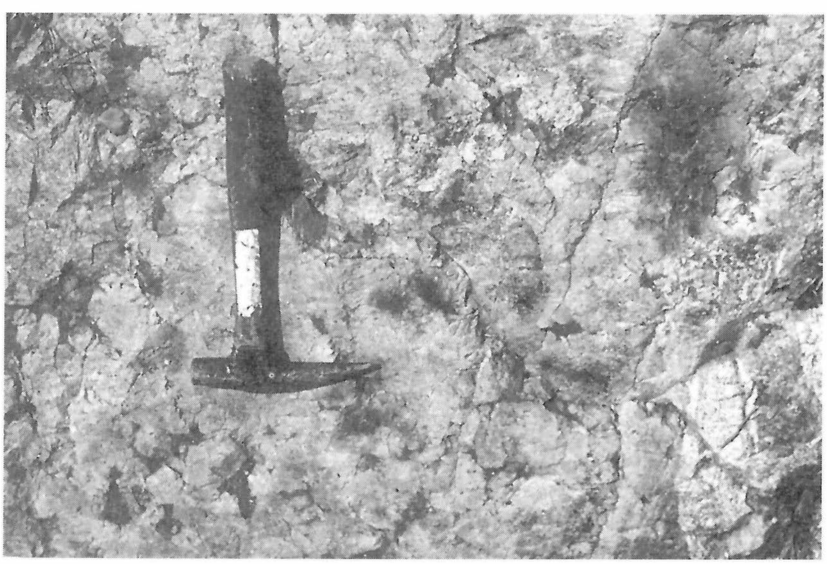

Figure GS-23-8: Oxidation (dark) associated with disseminated chalcopyrite and pyrrhotite mineralization within megacrystic anorthosite from an outcrop of the A1 zone in the western part of the Pipestone Lake Anorthosite Complex.

ACKNOWLEDGMENTS

Both Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc. are thanked for their cooperation. Special thanks are extended to Mr. L. Chastko and Mr. J. Campbell for providing invaluable technical data, helpful suggestions and logistical support. Mr. J.M. Pacey is thanked for preparing the figures.

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GS-24 PRECAMBRIAN DRILLING ALONG THE SUB-PALEOZOIC EASTERN BOUNDARY OF THE THOMPSON NICKEL BELT*

by J.J. Macek and W. Weber

Macek, J.J. and Weber, 1994: Precambrian drilling along the sub-Paleozoic eastern boundary of the Thompson Nickel Belt; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 130-133.

SUMMARY

Four vertical diamond drill holes were cored through the Paleozoic cover into Precambrian rocks in the Williams Lake region to test the inferred eastern boundary of the Thompson Nickel Belt (TNB) (as interpreted from aeromagnetic maps) and explain specific magnetic patterns within the TNB. In addition to logging, thin sections were examined from typical or informative portions of the cores (Table GS-24-1). Selected samples were analyzed for major and and trace elements (Table GS-24-2).

INTRODUCTION

The purpose of this project is (a) to better define the eastern boundary of the southwestern extension of the Thompson Nickel Belt (TNB), which extends underneath Phanerozoic cover toward Lake Winnipegosis - Swan River (Manitoba Mineral Resources Division, 1979), and (b) to provide geological data on lithologies comprising the sub-Phanerozoic TNB.

This project:

- supports exploration for nickel sulphides. Accurate knowledge of the boundary and lithologies of the TNB greatly improves cost-effectiveness of exploration underneath 100 to 300 m (or more) Paleozoic cover.
- provides baseline data for land use management, specifically to provide geological data that will aid in the definition of the limits of a proposed National Park being studied for the Manitoba Lowland region without encroaching on areas with significant mineral potential.

BACKGROUND

The TNB has been an area of active exploration since the 1950's. After the discovery of large nickel deposits at Thompson and the opening of several mines by Inco Limited and Falconbridge Limited along the exposed portion of the TNB, exploration extended into the southwestern extension of the TNB in the 1970's. At that time, the Minago River deposit, which presently owned by Black Hawk Mining Inc., was discovered by Amax. The deposit contains approximately 20 million tonnes with 1.02% nickel (Black Hawk Mining Inc., Annual Report, 1992). In the late 1980's Falconbridge Limited started an exploration program on a 40 x 80 km Special Exploration Permit area 14 km north of Grand Rapids. Over the past five years Falconbridge has drilled 82 holes totalling 42 000 m on this project, with expenditures of $8.5 million. So far, Falconbridge has outlined six nickel occurrences. The most significant is at William Lake, 70 km north of Grand Rapids, where diamond drilling intersected mineralization that assayed up to 3.9% nickel over 3.6 m and 1.6% nickel over 15.1 m. The best intersection from the other occurrences assayed 0.74% nickel over 32 m (Falconbridge Limited, public announcement, 1994).

Cominco Limited has explored for nickel along the TNB extension since 1990, southwest of Falconbridge's permits. Although Cominco has not announced any mineralization, drill intersections of primitive komatiites (Hulbert *et al.*, in prep.) suggest excellent potential for nickel sulphide mineralization.

Based on surface mapping in the exposed portion of the Churchill-Superior boundary zone, the eastern boundary has been defined as the contact between areas with high magnetic signatures of the Pikwitonei granulites and areas of gneisses with much lower magnetic signatures (*cf.* Weber, 1990; Bleeker, 1990). These criteria have been used to infer the location of the eastern boundary of the belt along its southwestern extension beneath Paleozoic cover (*cf.* McGregor and Macek, 1992, 1993).

The gneisses with lower magnetic signatures are interpreted to have been derived from granulites through retrogression and deformation under greenschist to upper amphibolite facies conditions as a result of collision and underplating with the Reindeer zone during the final phases of the Trans-Hudsonian orogeny (Bleeker, 1990). The metamorphic overprint involved hydration of granulite facies assemblages, resulting in the breakdown of orthopyroxene, calcic plagioclase and magnetite and their recrystallization to blue-green amphibole, quartz, sodic plagioclase and biotite. This change of mineralogical composition causes the abrupt change from high to low magnetic signatures along the eastern boundary of the TNB.

In addition, the TNB is characterized by certain lithologies:

a) the Proterozoic Ospwagan Group, including ultramafic flows and sills, in part with spinifex textures;

b) migmatitic gneisses of tonalitic to granodioritic composition, locally with hypersthene relicts (retrogressed and migmatized enderbitic gneisses and enderbites) with inclusions and larger bodies of mafic and ultramafic rocks; and

c) relatively massive Proterozoic granitoids, including pegmatites, and intrusions underlying areas up to 200 km (Machado *et al.*, in press).

Drill hole summaries

Four vertical diamond drill holes were cored by the Geological Services Branch through the Paleozoic cover into the Precambrian in the Williams Lake region, west of the inferred eastern boundary of the TNB. The drilling tested several aeromagnetic patterns delineated on the 1:250 000 scale aeromagnetic map (Geological Survey of Canada, 1969). The location of drill holes are shown in Figure GS-26-1 (this volume). The Precambrian core and thin sections from selected core are described in detail in Table GS-24-1; chemical analyses from selected core samples are listed in Table GS-24-2. The Paleozoic sections of the diamond drilling are discussed in Bezys (GS-26, this volume). The following is a summary and preliminary evaluation of the drilling program.

Drill hole M-1-94 tested one of several magnetically low areas (60 980 γ) with a distinct elliptical shape, which could be caused by a felsic gneiss dome or by a late granitoid intrusion. The hole intersected a weakly foliated granite. Its relatively massive texture and lack of metamorphic overprint suggest that it is a late-Hudsonian granitoid intrusion. N. Machado (Université du Québec à Montréal) plans to obtain a U-Pb age of the granite to test this interpretation.

Drill hole M-2-94 tested a small magnetic elongated anomaly with a peak of 61 100 γ in a magnetically flat (61 040 γ) region. The drill hole intersected a melanocratic rock composed of fine grained, felty aggregates of amphibole, chlorite and epidote. The massive appearance, mineralogy and chemistry suggest that the protolith was probably a mafic massive flow or intrusion, which was recrystallized under greenschist facies conditions during the Hudsonian overprint.

Drill hole M-3-94 tested an irregularly shaped positive magnetic anomaly (61 110 γ) 2 km west of the inferred eastern boundary of the TNB (McGregor and Macek, 1992, 1993). The anomaly was interpreted to be either caused by granulites or rocks of the TNB. The hole intersected a layered metagabbro. Its mineralogy suggests recrystallization under greenschist facies condition, and thus eliminates a granulite interpretation and confirms that the eastern boundary lies east of this anomaly.

Drill hole M-4-94 was located in a magnetically low and featureless region, interpreted to be underlain by a felsic migmatite/gneiss terrane, typical of the TNB. However, the drill hole intersected a mafic

* Funded by Provincial A-Base

schist affected by greenschist facies metamorphism. Although it is extensively recrystallized and carbonatized, a probable relict of microspinifex texture was observed in one thin section. This and its chemistry suggest that the protolith is a Proterozoic ultramafic flow. Its relict texture is similar to those in ultramafic flows intersected by drill holes in the Winnipegosis area (L. Hulbert, pers. comm., 1994).

CONCLUSIONS

1. All four boreholes intersected lithologies that occur commonly in the TNB.
2. This year's drilling confirms that the inferred eastern boundary of the southwestern sub-Phanerozoic extension of the TNB (McGregor and Macek, 1992, 1993) is situated within terrane completely reworked by the Hudsonian Orogen and that the transition zone is actually irregular and may be situated more to the east.
3. The greenschist facies Hudsonian metamorphic overprint observed in the core of holes M2, M3 and M4 may indicate that the underlying area is transitional between subgreenschist facies Hudsonian metamorphism to the south (Hulbert *et al.*, in prep.) and the amphibolite facies Hudsonian metamorphism in the Wabowden-Thompson area.

ACKNOWLEDGMENT

We acknowledge cooperation by P. Tirschmann, Falconbridge Limited in providing the chemical analyses in this report.

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Table GS-24-1

1994 Manitoba Geological Services Branch's diamond drilling program; logs and thin section data. Drill hole intersection in metres. All holes were drilled vertically; size of core BQ. Core is stored at Manitoba Energy and Mines' drill core library in Thompson and is available to the public. Locations of drill holes are shown in Figure GS-26-1

DDH M-1-94

Elliptical magnetic low, informally termed "William Lake dome". Expected rock: Granitoid gneiss.

(metres)

XXX.X-123.6 **PALEOZOIC**

123.6-126.2 **PEGMATITE, kaolinized**

126.2-128.55 **PEGMATITE, pink**

Sample for U-Pb geochronology: 127.3-127.8

128.55-139.4 **BIOTITE GRANITE**

Light gray, medium to fine grained, weakly foliated to non-foliated rock. Biotite flakes (5%) are 1 to 2 mm, mostly randomly oriented and regularly disseminated. The granite is invaded by pink pegmatite veins or diffuse nests 2 to 50 cm thick.

128.5 - 136.5 Granite, weathered, hematized

A few 1 to 20 cm wide kaolinized zones are noted.

Thin section sample: 127.08

Modal analysis	%
Biotite	5
Plagioclase	25
Microcline	25
Quartz	45
Muscovite	Tr
Carbonate	Tr

Samples for U-Pb geochronology: 137.89-138.36
138.56-139.15

DDH M-2-94

Small magnetic anomaly (61 100 γ) possibly related to lithology of the Ospwagan group.

(metres)

121.90-130.35 PALEOZOIC

132.40-142.05 MAFIC MASSIVE ROCK

Dark blue-green, very fine grained, massive rock. Veinlets of quartz and calcite 1 to 15 mm thick irregularly intersect the rock. The rock is also intersected by 10 to 50 cm wide shear zones characterized by pronounced chloritization and hematization.

Interpretation: Pyroxene-rich massive rock containing a small amount of pyroxene (now amphibole) porphyrocrysts (metapyroxenite, metamelagabbro, metapicrite?).

Metamorphic grade: Greenschist facies.

Thin section sample: 137.83

Modal analysis	%
Amphibole (porphyr.)	2
Amphibole (matrix)	60
Chlorite	20
Epidote	10
Quartz and albite	5
Opaques	3

DDH M-3-94

West side of a large anomaly (l61 100 γ) near the projected eastern boundary of the TNB. Granulite or Ospwagan Group lithology expected.

(metres)

147.94-149.50 METAGABBRO, weathered.

Dark green, medium grained, weakly foliated and poorly layered rock.

149.50-162.00 LEUCO - MELAMETAGABBRO.

Light to dark grey, medium grained, weakly foliated and vaguely layered rock; layers are several metres thick. The gabbro displays several compositional and textural varieties: anorthositic or leucocratic gabbro, hornblende porphyroblastic melagabbro, and subophitic gabbro. The contact between melagabbro and leucogabbro is sharp (158.3 m). Fractures with calcite, chlorite and talc.

The primary mineralogy is completely replaced by greenschist facies minerals.

Interpretation: Metagabbro, melanocratic metadiorite or contaminated metagabbro.

Metamorphic grade: Greenschist facies.

Thin section samples:

a) 157.5: Hornblende porphyroblastic gabbro

Modal analysis	%
Hornblende	25
Biotite	15
Epidote	10
Plagioclase+Quartz	50

b) 158.6: Leucogabbro

Modal analysis	%
Biotite	20
Epidote	10
Plagioclase	60
Quartz	10

c) 162.0: Diabasic gabbro

Modal analysis	%
Hornblende	10
Biotite	20
Epidote	20
Plagioclase	30
Quartz	20

d) 161.0: Diabasic gabbro

Modal analysis	%
Hornblende	15
Biotite	20
Epidote	20
Plagioclase	25
Quartz	20

DDH M-4-94

Regional magnetic low (<61 040 γ). Expected rock: TNB gneiss/migmatite.

(metres)

140.00-142.08 **PALEOZOIC**

142.08-147.35 **WEATHERED ROCK**

Grass-green to blue-green, medium grained, weakly foliated and pervasively sheared rock. Mineral composition: kaolin, chlorite and minor hematite. The rock is intersected by 1 to 3 mm thick veinlets filled with calcite or calcite and pyrite. These veinlets occur 5 to 70 cm apart.

147.35-163.40 **ULTRAMAFIC SCHIST**

Light silver-green, fine to very fine grained, weakly foliated rock, pervasively sheared. Mineral composition: amphibole (actinolite-tremolite) > chlorite, biotite, carbonate > quartz. The primary texture is not preserved. The colour varies from silver-green to dark green.

Interpretation: Picrite or pyroxenite massive flow containing a microspinifex texture.

Metamorphic grade: Greenschist facies.

Thin section samples:

a) 156.2 m: Dark green.

Modal analysis	%
Amphibole	75
Chlorite	5
Biotite	2
Carbonate	15
Quartz	3

b) 156.6 m: Medium green.

Modal analysis	%
Amphibole	75
Chlorite	3
Biotite	7
Carbonate	15

c) 159.5 m: Silver-green.

Modal analysis	%
Amphibole	10
Talc	35
Chlorite	35
Carbonate	20

Relict microspinifex texture

d) 162.7 m: Apple-green.

Modal analysis	%
Amphibole	90
Chlorite	5
Carbonate	3
Opaques	2

Table GS-24-2

1994 Manitoba Geological Services Branch's diamond drilling program; chemical analyses (provided by Falconbridge Limited)

	ID WA 35963	**ID WA 35965**	**ID WA 35964**	**ID WA 35966**	**ID WA 35967**
SiO_2, %	74.2	47.8	50.6	44.8	40.5
Al_2O_3, %	14.6	12.7	19.0	7.01	8.98
Fe_2O_3, %	1.27	13.5	8.1	9.98	12.4
MgO, %	0.23	11.6	4.78	22.6	21.3
CaO, %	1.82	9.98	6.77	7.28	7.85
Na_2O, %	4.81	1.98	4.02	0.1	0.12
K_2O, %	2.85	0.11	2.59	0.03	0.04
TiO_2, %	0.15	0.86	1.24	0.41	0.53
P_2O_5, %	0.04	0.07	0.71	0.03	0.04
MnO, %	0.02	0.16	0.08	0.15	0.22
Cr_2O_3, %	<0.01	0.11	<0.01	0.29	0.29
LOI, %	0.39	2.21	1.50	7.29	8.06
SUM, %	100.4	101.3	99.40	100.0	100.3
Cu, ppm	19	50	41	7	18
Co, ppm	<5	76	17	83	98
Cr, ppm	<10	752	<10	1984	1984
Y, ppm	6	20	18	10	13
Zr, ppm	85	51	178	24	30
Zn, ppm	38	68	72	62	73
Pb, ppm	22	<10	<10	<10	<10
Ba, ppm	7848	23	1468	<10	<10
Sr, ppm	302	89	1422	19	28
Rb, ppm	101	<5	46	<5	<5
Ni, %	0.002	0.029	0.002	0.10	0.076
S, %	0.01	0.02	0.12	0.02	0.05

Sample ID WA 35963, DDH M-1-94; 137.47-137.59 m, biotite granite.
Sample ID WA 35965, DDH M-2-94; 137.71-137.83 m, very fine grained mafic rock.
Sample ID WA 35964, DDH M-3-94; 160.62-160.77 m, diabasic gabbro.
Sample ID WA 35966, DDH M-4-94; 160.9-161 m, silver-green ultramafic schist.
Sample ID WA 35967, DDH M-4-94; 162.9-163 m, apple green ultramafic schist.

GS-25 RELOGGED DRILL CORE FROM SUB-PHANEROZOIC PRECAMBRIAN BASEMENT IN NTS 63J*

by C.R. McGregor

McGregor, C.R., 1994: Relogged drill core form Sub-Phanerozoic Precambrian basement in NTS 63J; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 134-135.

INTRODUCTION

Nineteen nonconfidential diamond drill holes that intersected sub-Phanerozoic Precambrian rocks in NTS 63J (Fig. GS-25-1) were relogged in 1994 (McGregor, 1994) in order to identify major lithologic units within the eastern Churchill Province. This project was undertaken in cooperation with Alain Leclair of the Geological Survey of Canada.

Seven of the relogged holes were drilled by Granges Inc. in 1989 and the other twelve were drilled by Manitoba Mineral Resources Ltd. between 1974 and 1986. The core is stored in the Provincial Core Library in The Pas.

The locations of the 1994 relogged holes have been plotted on a 1:250 000 scale map in addition to those done in 1992 (McGregor and Macek, 1992) and 1993 (McGregor and Macek, 1993). The map does not include additional nonconfidential company holes that will be relogged in 1995 and provincial/federal government holes drilled in NTS 63J and 63G. The latter have been previously logged and the results published (GS-24, this volume; Bezys 1993, 1992, 1991, 1990; McCabe, 1983).

A catalogue that contains a summative log, cross section and colour photograph documentation for each drill hole is available to the public for viewing at Manitoba Energy and Mines Library in Winnipeg (McGregor, 1994) and/or reproduction at cost. A detailed evaluation and further interpretation of the core is in progress.

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* Funded by Provincial A-Base

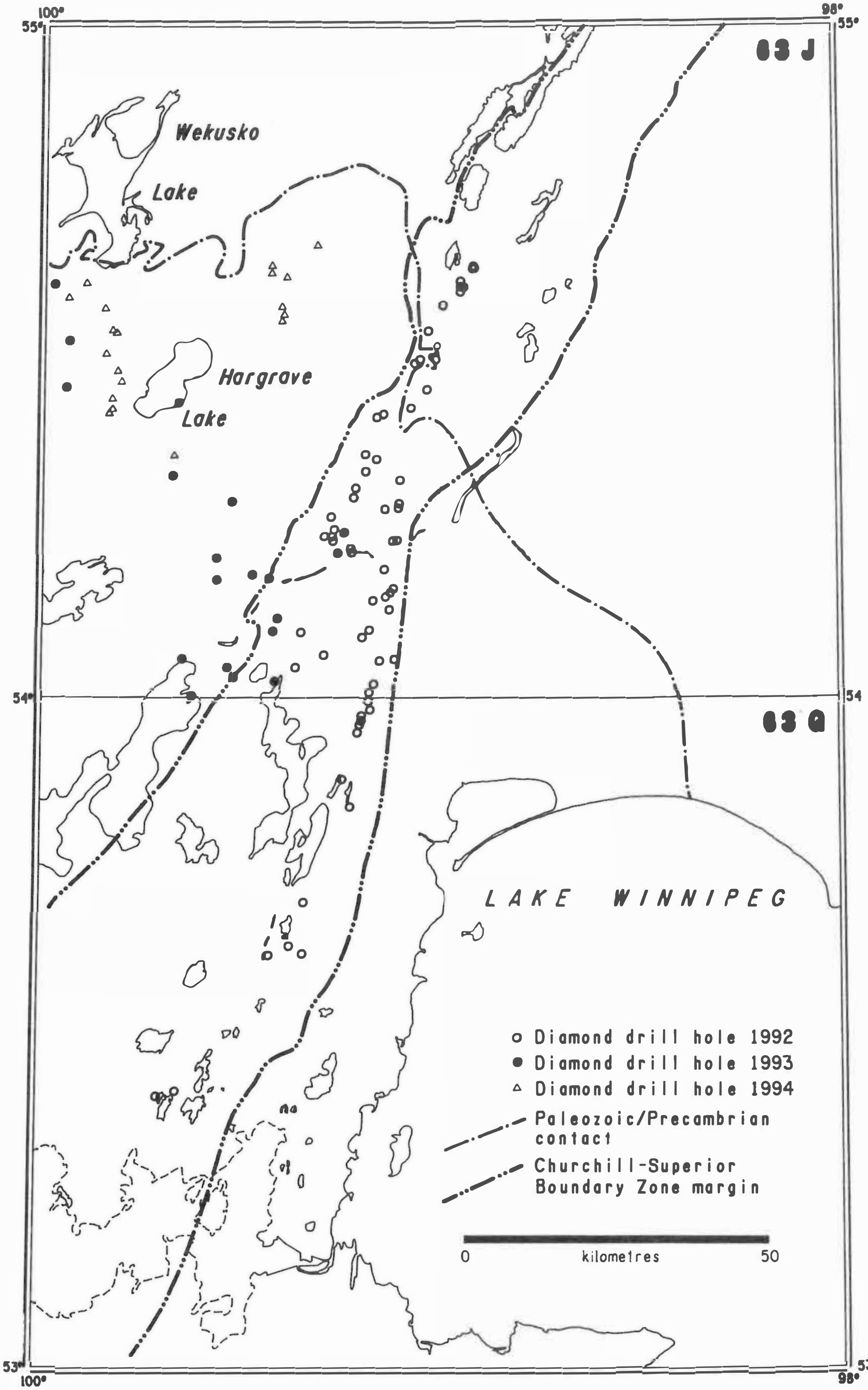

Figure GS-25-1: *Location of relogged sub-Phanerozoic Precambrian diamond drill holes.*

GS-26 STRATIGRAPHIC MAPPING (NTS 63G AND 63F) AND CORE HOLE PROGRAM 1994*

by R.K. Bezys

Bezys, R.K., 1994: Stratigraphic mapping (NTS 63G and 63F) and core hole program 1994; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 136-141.

SUMMARY

A three week stratigraphic mapping program in the vicinity of William and Little Limestone lakes confirmed that the Paleozoic stratigraphy is conformable with regional isopach and structural trends. No evidence of tectonic disturbance affecting Paleozoic strata was observed in outcrop.

The Geological Services Branch's drilling program completed five holes with a total of 621.15 m of core. All holes were drilled to obtain Precambrian core in order to delineate the eastern boundary of the Churchill-Superior Boundary Zone. Paleozoic core information obtained from this program and from mineral exploration holes will be used in the correlation of Ordovician and Silurian stratigraphy in the Grand Rapids area. All stratigraphic data is to be added to the digital Manitoba Stratigraphic Database (MSD), which includes all Lower Paleozoic well tops verified and corrected by the Geological Services Branch.

INTRODUCTION

Four separate stratigraphic projects were carried out in 1994:

1. stratigraphic mapping in the vicinity of William and Little Limestone lakes (Grand Rapids);
2. stratigraphic drilling in the Grand Rapids area;
3. continued core logging of Paleozoic mineral exploration drill core;
4. stratigraphic mapping of Shoulderblade Island (South Moose Lake) (see GS-27, this volume).

Locations of the drill holes are shown in Figure GS-26-1 and a summary of core hole data is presented in Table GS-26-1.

Shoreline outcrops along William and Little Limestone lakes, as well as outcrops along the Reedy Lake Lineament, were mapped. Outcrop pavements north of Honeymoon Lake (Menauhswun Lake) and along the Silurian escarpment were also mapped. In total, 77 stations were examined (Fig. GS-26-2).

STRATIGRAPHIC MAPPING

Stratigraphic mapping in the northern portion of NTS 63G (NTS 63G/11 & G/14) was carried out in the summer of 1994 as a follow-up to previous work in the area (McCabe, 1978, 1979, 1986, 1988; Bezys, 1990). The Paleozoic bedrock in the study area overlies the Churchill-Superior Boundary Zone of the Precambrian basement, and emphasis was placed on observing evidence of recent movement (neotectonism). In the William Lake area, recent mineral exploration drilling has revealed topographic highs as much as 30 m on the Precambrian surface relative to the peneplaned Precambrian surface (Bezys, in prep.).

The bedrock geology consists of the Silurian Interlake Group, specifically the Fisher Branch, Moose Lake, Atikameg, East Arm, and Cedar Lake formations (in ascending stratigraphic sequence) (Fig. GS-26-3). Shoreline outcrops along William and Little Limestone lakes reveal the Moose Lake and Atikameg formations. East of Highway 6, contacts between the Moose Lake, Atikameg and East Arm formations can be discerned and generally follow topographic boundaries. At the base of the Silurian escarpment the Fisher Branch Formation is exposed, as well as portions of the Stonewall Formation (W.D. McRitchie, pers. comm., 1994). This summer's mapping has confirmed that the Paleozoic stratigraphy in this area is conformable with regional isopach and structural trends.

Detailed mapping of the outcrops showed no evidence of disturbed rocks on either William Lake or Little Limestone Lake, as well as the Reedy Lake Lineament. The latter, readily apparent on air photos and topographic maps, may reflect fault structures emanating from the Precambrian basement. Close examination of the east-facing scarp of this lineament near Reedy Lake also revealed no effects of tectonic disturbance.

STRATIGRAPHIC DRILLING IN THE GRAND RAPIDS AREA

The Geological Services Branch's drilling program completed five holes (four to Precambrian) with a total of 621.15 m of core (62.90 m of Precambrian core). Drill targets were chosen from magnetic anomalies to delineate the eastern boundary of the southwestern extension of the Thompson Nickel Belt (*i.e.*, the Churchill-Superior Boundary Zone) (see GS-24, this volume, for a detailed description of this core). Core hole M-1-94 (William Lake northeast) was drilled to test a magnetic low which is informally termed the "William Lake dome"; rock types encountered were pegmatite and granite. Core hole M-1a-94 was drilled to 14.3 m to leave an open hole for future water sampling and testing. Core hole M-2-94 was drilled to test a small magnetic anomaly (61 100 γ), which may be caused by rocks of the Ospwagan Group; a pyroxene-rich ultramafic massive flow was intersected. Core hole M-3-94 was sited over the western part of a large magnetic anomaly ($\geq$61 100 γ) near the projected eastern boundary of the Churchill-Superior Boundary Zone; the drill hole intersected metagabbroic rocks. Core hole M-4-94 targeted a regional magnetic low (<61 040 γ); it encountered a carbonate-bearing actinolite schist, interpreted as a pyroxenitic flow.

Paleozoic stratigraphic and structural information from the core holes, in conjunction with outcrop mapping data, will be used in the correlation of the Ordovician and Silurian stratigraphy in the Grand Rapids area for future compilation maps.

Upon completion of drilling, a Geological Survey of Canada logging truck visited the Grand Rapids area to conduct multiparameter downhole geophysical logging in open core holes. Measurements included natural gamma-ray spectrometry, gamma-gamma density, resistivity, induced polarization (IP), magnetic susceptibility, temperature and temperature gradient. Borehole measurements of core hole M-6-91 in 1992 revealed that the Lower Paleozoic lithologies and stratigraphy were more clearly defined with the use of multiparameter geophysical logs (Mwenifumbo, 1994). Results will be released in Geological Survey of Canada annual reports. Logging of geological core holes in the Grand Rapids area is hampered by the similarity of carbonate lithologies throughout the core. However, variations between geologic formations can be distinguished by their characteristic geophysical signatures. These characteristics will be compared with those from core hole M-6-91 to determine if the geophysical signatures are diagnostic. This will provide better stratigraphic correlations between core holes.

CORE LOGGING OF PALEOZOIC MINERAL EXPLORATION DRILL HOLES

Over the last five years, data from eighty mineral exploration drill holes have been entered into the Manitoba Stratigraphic Database. Recent acquisitions include Falconbridge Ltd.'s data from holes drilled within the extension of the Thompson Nickel Belt. Detailed logging of this core has allowed for better evaluation of possible Precambrian structure that may affect the Lower Paleozoic sequence. Core logs have also been helpful in the preparation of geological compilation maps. Bezys (in prep.) will present a detailed analysis of Paleozoic core from recent drilling by Falconbridge Ltd. in the William Lake area.

ACKNOWLEDGEMENTS

Special thanks are extended to Joanne Shwetz who ably carried out her field assistant duties.

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* Funded by Provincial A-Base

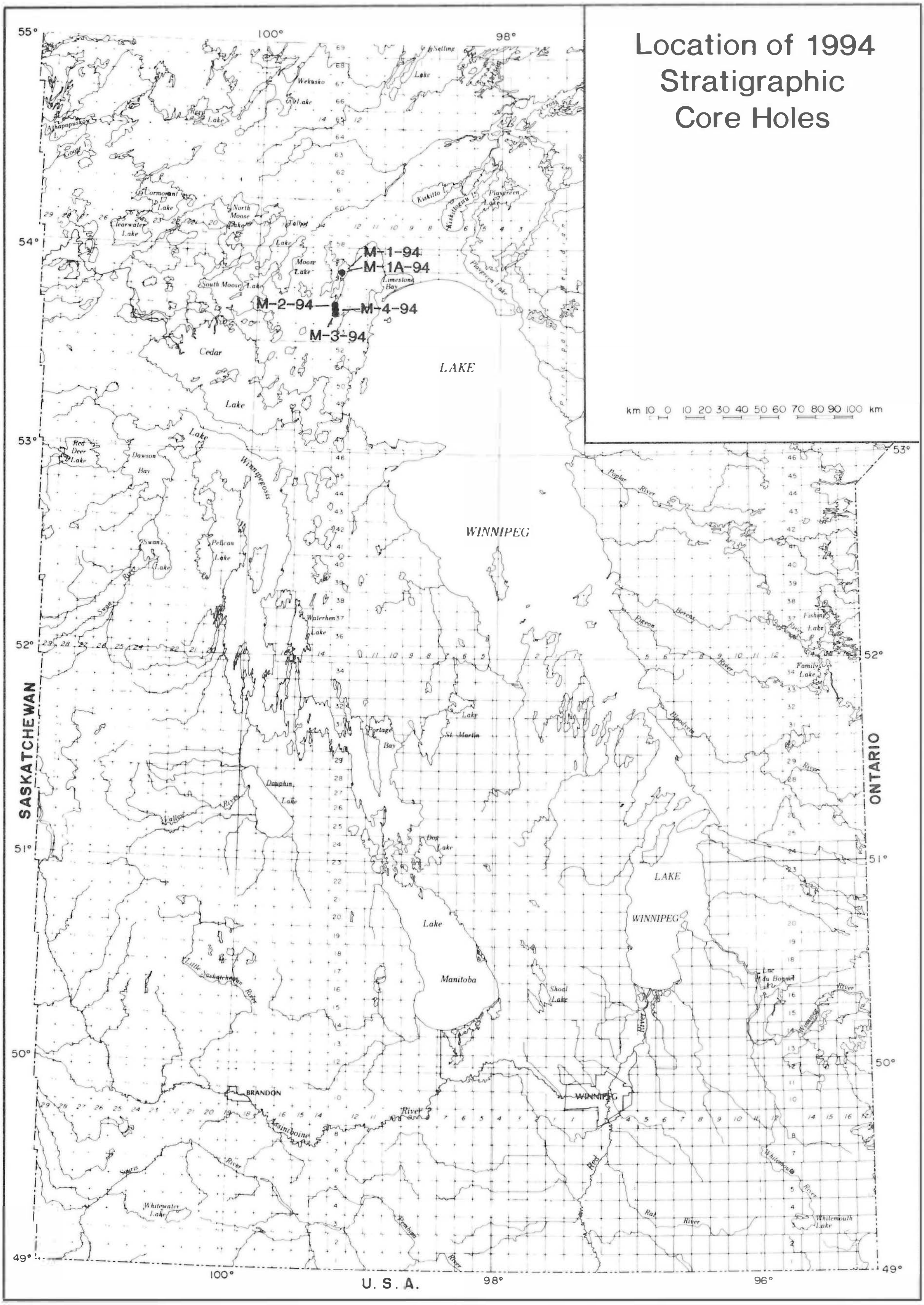

Figure GS-26-1: Core hole locations (1994).

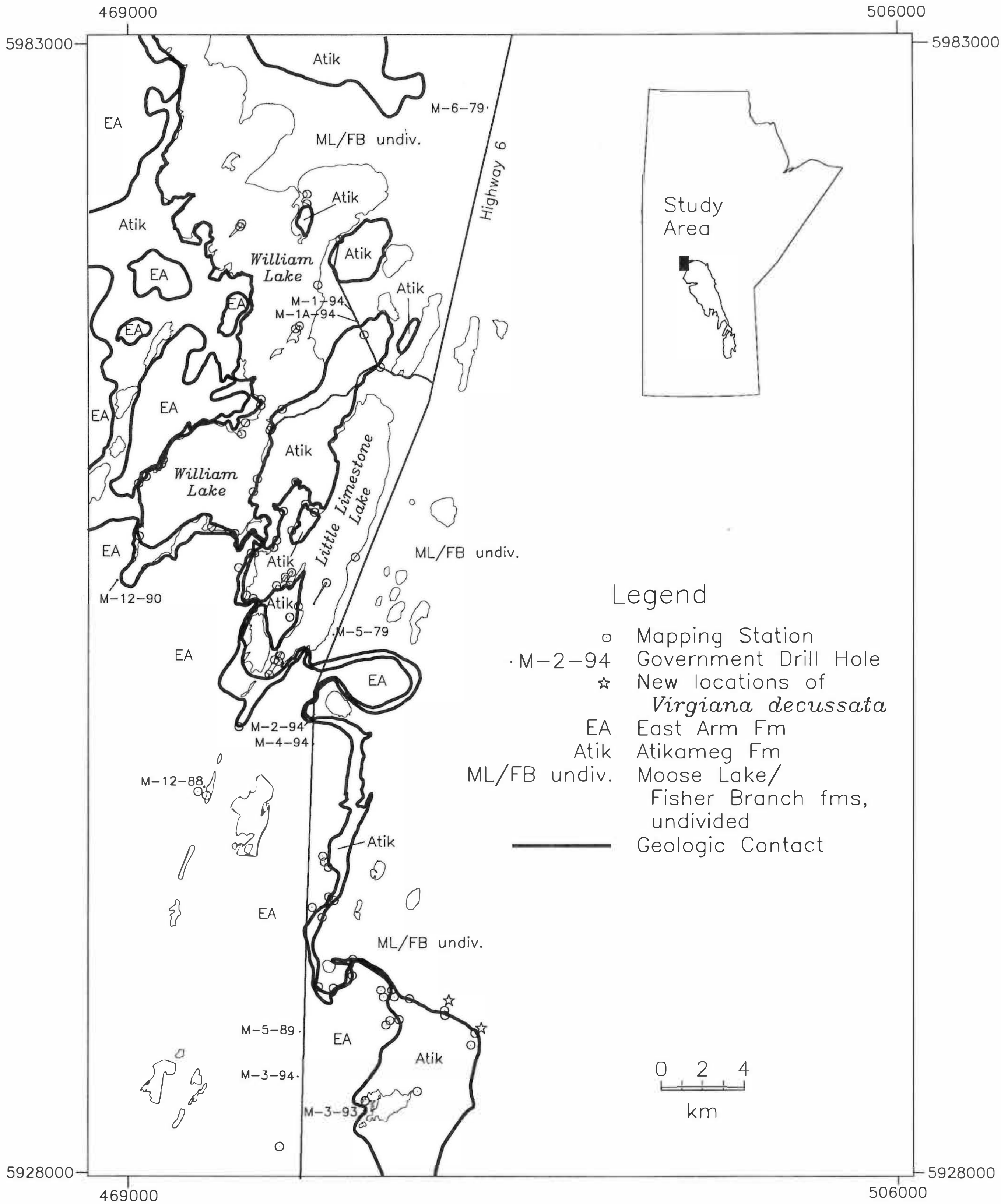

Figure GS-26-2: Geologic base map for the William Lake area, including mapping stations.

GRAND RAPIDS AREA STRATIGRAPHIC COLUMN

ERA	PERIOD	GROUP/FORMATION/MEMBER		BASIC LITHOLOGY
LOWER PALEOZOIC	SILURIAN	INTERLAKE GROUP	CEDAR LAKE FORMATION (0-60m)	Dolomite; yellow-orange to grey, fossiliferous, oolitic, stromatolitic, interrupted by argillaceous marker beds (0-100m).
			– – – v-marker – – –	
			EAST ARM FORMATION (0-10m)	
			– – – u2-marker – – –	
			ATIKAMEG FORMATION (0-8m)	
			MOOSE LAKE FORMATION (0-10m)	
			– – – u1-marker – – –	
			FISHER BRANCH FORMATION (0-15m)	
	– – –	STONEWALL FORMATION – – – t-marker – – –		Dolomite; yellow-grey, sparsely fossiliferous, interrupted by argillaceous zones and marker beds (0-20m).
	ORDOVICIAN	STONY MOUNTAIN FORMATION		Dolomite; yellow-brown, slightly nodular (0-40m).
		RED RIVER FORMATION	Fort Garry Member	Dolomite; mottled, fossiliferous, cherty, overlain by argillaceous dolomite with breccio beds (Fort Garry) (0-50m).
			lower Red River	
		WINNIPEG FORMATION	upper	Quartzose sandstone; interbedded by green, waxy shale with sand and silt interbeds (0-12m).
			lower	
– – –	– – –	– – –	– – –	– – –
PRECAMBRIAN				

– – – – Major unconformities

Figure GS-26-3: Stratigraphic column for the Grand Rapids area.

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Table GS-26-1
SUMMARY OF CORE HOLE DATA 1994

Hole No.	Location and Elevation (m)	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
M-1-94	5969873N	OVERBURDEN	0.00-3.4	
William Lake NE	479804E	SILURIAN - Moose Lake	3.4-10.7	Wackestone, mudstone, some grainstone; medial marker at 7.0-7.6.
	7-34-56-13WPM	(U_1-marker)	10.7-11.4	Mudstone; slightly brecciated.
	280.3	Fisher Branch	11.4-20.7	Boundstone; *Virgiana decussata* and *Paleofavosites* present.
		Stonewall	20.7-23.6	Mudstone.
		(T-marker)	23.6-24.4	Mudstone; distinctively red to grey; brecciated; some sand.
		ORDOVICIAN-Stonewall	24.4-25.3	Mudstone to wackestone.
		(Lower T-marker)	25.3-26.0	Mudstone; grey with red.
			26.0-37.1	Mudstone; some grainstone; *Paleofavosites* present; some chert.
		(Williams Member)	37.1-41.0	Mudstone.
		Stony Mountain	41.0-70.0	Wackestone; some hardground surfaces.
		Red River (Fort Garry)	70.0-80.1	Mudstone; mottled; scattered breccia beds.
		Lower Red River	80.1-113.1	Wackestone to mudstone (at top); burrow mottled; some chert.
		Winnipeg	113.1-123.6	Sandstone, some siltstone; quartzose; very fine to coarse grained; mottled.
		PRECAMBRIAN	123.6-126.2	Pegmatite, kaolinized.
			126.2-128.6	Pegmatite; pink.
			128.6-139.4	Biotite granite with pink pegmatite veins.
M-1a-94	5969449N	OVERBURDEN	0.0-4.2	
William Lake NE	480009E	SILURIAN-Moose Lake	4.2-11.8	Mudstone to wackestone; stromatolitic; medial marker at 8.9-9.4.
	15-27-56-13WPM	(U_1-marker)	11.8-13.0	Mudstone; slight sand.
	285.0	Fisher Branch	13.0-14.3	Grainstone; slightly fossiliferous.
M-2-94	5950341N	SILURIAN-Moose Lake	0.0-10.2	Mudstone to wackestone; stromatolitic; medial marker at 7.0-7.5.
Little Limestone	477865E	(U_1-marker)	10.2-11.2	Mudstone; brecciated.
Lake North	278.1	Fisher Branch	11.2-20.5	Grainstone to packstone; fossiliferous (corals).
		Stonewall (marker)	20.5-23.9	Mudstone; slightly brecciated.
		(T-zone)	23.9-25.6	Mudstone; mottled; no lower T-marker.
		ORDOVICIAN-Stonewall	25.6-38.3	Grainstone, packstone and mudstone; fossiliferous (*Paleofavosites*).
		(Williams Member)	38.3-42.2	Mudstone; laminated.
		Stony Mountain	42.2-71.5	Wackestone; nodular; mottled; some hardground surfaces.
		Red River (Fort Garry)	71.5-83.7	Mudstone; minor breccia beds.
		Lower Red River	83.7-124.9	Wackestone, burrow mottled; cherty; crinoidal.
		Winnipeg	124.9-130.3	Siltstone to sandstone, some mudstone; burrow mottled; quartzose.
		PRECAMBRIAN	130.3-132.4	Weathered Precambrian; claystone to mudstone.
			132.4-142.1	Ultramafic massive flow; veinlets of quartz and calcite; some shear zones with chloritization and hematitization.
M-3-94	5932710N	SILURIAN-East Arm	0.0-6.8	Mudstone, some wackestone; stromatolitic.
Microwave Tower	477089E	(U_2-marker)	6.8-8.2	Mudstone; laminated.
	7-5-53-15WPM	Atikameg	8.2-12.9	Grainstone to packstone; vuggy; scattered salt molds.
	281.6	Moose Lake	12.9-20.3	Mudstone, some wackestone to packstone; stromatolitic.
		(U_1-marker)	20.3-22.0	Mudstone; slightly brecciated.
		Fisher Branch	22.0-31.7	Wackestone to mudstone; vuggy; fossiliferous at base (*Paleofavosites*).
		Stonewall (marker)	31.7-35.7	Mudstone; brecciated.
		(T-marker)	35.7-37.4	Mudstone; blue grey; brecciated; burrowed.
		ORDOVICIAN-Stonewall	37.4-49.6	Mudstone, wackestone to packstone; fossiliferous in places (crinoidal debris, *Pycnostylus*).
		(Williams Member)	49.6-53.1	Mudstone; laminated; mottled.
		Stony Mountain	53.1-83.4	Wackestone; abundant hardground surfaces in lower half; nodular; minor rugose corals.

Table GS-26-1
SUMMARY OF CORE HOLE DATA 1994

Hole No.	Location and Elevation (m)	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
		Red River (Fort Garry)	83.4-96.6	Mudstone; mottled; slightly brecciated; burrowed in places.
		Lower Red River	96.6-139.8	Wackestone; crinoidal; mottled; cherty; burrowed.
		Winnipeg	139.8-146.8	Siltstone and sandstone; mottled; quartzose.
		PRECAMBRIAN	146.8-147.9	Precambrian, weathered?
			147.9-149.5	Metagabbro, weathered; dark green; weakly foliated.
			149.5-162	Leuco-melagabbro; vaguely layered.
M-4-94	5948885N	SILURIAN-East Arm	0.0-7.8	Mudstone to wackestone; stromatolitic.
Little Limestone	477816E	(U_2-marker)	7.8-9.5	Mudstone; blue grey; laminated; slightly sandy.
Lake South	285.8	Atikameg	9.5-14.2	Packstone; mottled; vuggy; fossiliferous (brachiopods and corals); scattered salt molds.
		Moose Lake	14.2-21.4	Grainstone, wackestone to mudstone; stromatolitic; fossiliferous (*Paleofavosites* and coral debris).
		(U_1-marker)	21.4-22.9	Mudstone; laminated; some intraformational breccias; burrow mottled.
		Fisher Branch	22.9-35.4	Grainstone to packstone; fossiliferous (corals and *Virgiana decussata*).
		Stonewall (marker and T-zone)	35.4-48.7	Mudstone, wackestone to packstone; T-zone is not distinctly developed; mottled in places; fossiliferous (*Paleofavosites*, crinoidal); vuggy.
		(Williams Member)	48.7-52.7	Mudstone; laminated.
		Stony Mountain	52.7-81.6	Wackestone; nodular; scattered hardground surfaces; minor chert.
		Red River (Fort Garry)	81.6-93.6	Mudstone; blue grey; brecciated; burrowed.
		Lower Red River	93.6-135.6	Wackestone; fossiliferous (crinoids and corals); cherty; burrowed at top.
		Winnipeg	135.6-142.1	Sandstone to siltstone; quartzose; massive and consolidated.
		PRECAMBRIAN	142.1-147.4	Weathered Precambrian; weakly foliated and pervasively sheared rock; kaolin, chlorite and hematite.
			147.4-163.4	Mafic schist, actinolite schist and talc-chorite schist; carbonate bearing; thin section shows remnants of a microspinifex texture.

GS-27 GEOLOGICAL INVESTIGATION OF THE SHOULDERBLADE ISLAND STRUCTURE, SOUTH MOOSE LAKE, NTS 63F/16*

R.K. Bezys and J.D. Bamburak

Bezys, R.K. and Bamburak, J.D., 1994: Geological investigation of the Shoulderblade Island structure, south Moose Lake, NTS 63F/16; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 142-143.

SUMMARY AND CONCLUSION

A short reconnaissance mapping program was conducted on the Shoulderblade Island structure, South Moose Lake, to investigate unusual Paleozoic outcrops. The circular island is rimmed with dolomite breccia, ranging from fine (<1.0 mm) to very coarse (15.0 m) grained fragments. Baillie (1951) proposed that the breccia were caused by solution collapse. Stearn (1956) interpreted the breccia as reef breccia. McCabe (1988) suggested that the structure may be a diatreme or an impact crater. The present investigation revealed abundant outcrops that occur as large areas of pavement along the eastern shore of the island and within the interior of the island; only 20% of the outcrops were examined in detail. One shoreline outcrop contained a small vertical breccia pipe (0.5 m wide) with small offshoots along country rock bedding planes. Two outcrops located in the northern part of the island consist of breccia with Precambrian clasts. The preliminary interpretation based on this year's field work suggests that Shoulderblade Island represents a possible diatreme breccia.

INTRODUCTION

The 4.9 km^2 Shoulderblade Island is situated within South Moose Lake, 80 km east from The Pas, centred at longitude 100°02'30" and latitude 53°48'00" (NTS 63F/16). It has a distinctive, almost perfectly circular shape with a circular inner lake (see Fig. GS-27-1). During a brief visit to the island in 1993, R.K. Bezys collected several samples. A thin section from a fine grained breccia revealed fine grained carbonate clasts, minor quartz and plagioclase grains, and *very rare, anomalous (1%) mica (possibly margarite, phlogopite or biotite)*. The presence of the anomalous mica prompted a more detailed investigation of the island in 1994.

GEOLOGY

General Geology

The rock surrounding South Moose Lake consists of Silurian carbonate rock, specifically the Interlake Group. The composition of lithic fragments present in the breccia on Shoulderblade Island is similar to rocks of the East Arm Formation (see Fig. GS-26-3, this volume). The formation consists of thinly bedded mudstone and wackestone with minor clay and sand marker beds. The Interlake Group has been completely dolomitized in the South Moose Lake area. Depth to Precambrian is extrapolated to be approximately 150 m below surface elevation based on drilling (core hole M-11-90) conducted 20 km due east of Shoulderblade Island (Bezys, 1990).

Outcrop Distribution

Breccia outcrops dominate most of the island's northern and eastern shorelines. The shoreline is characterized by steep margins and a lack of fringing reefs and shoals. Three minor exposures are present along the northern and western shoreline of the inner lake. In total, 52 stations were mapped on the island, and a visit was made to an island north of Shoulderblade Island (Fig. GS-27-1). Most outcrops have 0.5 to 3.0 m relief and are lenticular in outline (5.0 by 50.0 m). Bedding planes strike parallel to the shoreline and dip approximately 8° toward the centre of the island.

Detailed Geology

Breccia consists predominantly of fine to medium grained, grey to buff, dolomite lithic fragments, cemented by dolomite. Some spectacular outcrops consist of very coarse grained breccia with fragments up to 15 m. The breccia fragments are angular to subrounded and are predominantly matrix supported. Macroscopically, the matrix consists of very fine grained monomict dolomite fragments, minor white tripolized chert and red jasper fragments, and tiny flakes of dark mica similar to biotite (Table GS-27-1). Most dolomite clasts have a mudstone origin, and conversely the matrix contains abundant micrite.

Two outcrops in the northern sector of the island revealed a breccia containing 1 to 2% strongly weathered to altered Precambrian (granitoid) lithic fragments. These fragments consist of altered plagioclase grains, sericite and biotite. Dolomite lithic fragments make up 10 to 25% of the breccia; they are cryptocrystalline to very finely crystalline, <1.0 mm to 4.0 cm, subangular, to rounded, sucrosic and monomict. Quartz grains (5-10%, 0.5-2.0 mm) are frosted and subrounded to subangular. Biotite flakes (1-5%) are usually <1.0 mm. Rare constituents are white, tripolized chert fragments and light green clay fragments. The breccia is matrix supported and has a very low porosity. The matrix is composed of dolomite micrite and is strongly hematized. Colours range from red to yellow to cream.

Table GS-27-1
Description of thin section 88-27-93

Name: Fine grained dolomite breccia, biotite bearing.
Location: SW Shoulderblade Island, South Moose Lake, NTS 63F/16

Modal Distribution:

Clasts:
25% carbonates, <0.1-4.0 mm, subrounded to subangular, lithic with terrigenous components to micritic fragments.
2% plagioclase, <0.5-2.0 mm, subrounded, greenish sericitic alteration and strained albitic twins in some fragments.
<1% quartz, <0.5 mm, subangular.
Matrix:
71% dominantly micritic, laced with late stage hematitic? veinlets.
Authigenics:
1% mica, possibly margarite, phlogopite or biotite.

FUTURE PLANS

The micas and other unusual minerals in the 1993 sample will be analyzed by electron microprobe and additional thin sections will be prepared to aid in determination of the genesis and sequence of events in the brecciation process.

ACKNOWLEDGEMENTS

Special thanks are extended to Joanne Shwetz and Rhandi Nykoluk who ably assisted us in the field and to Joanne who did the thin section description.

* Funded by Provincial A-Base

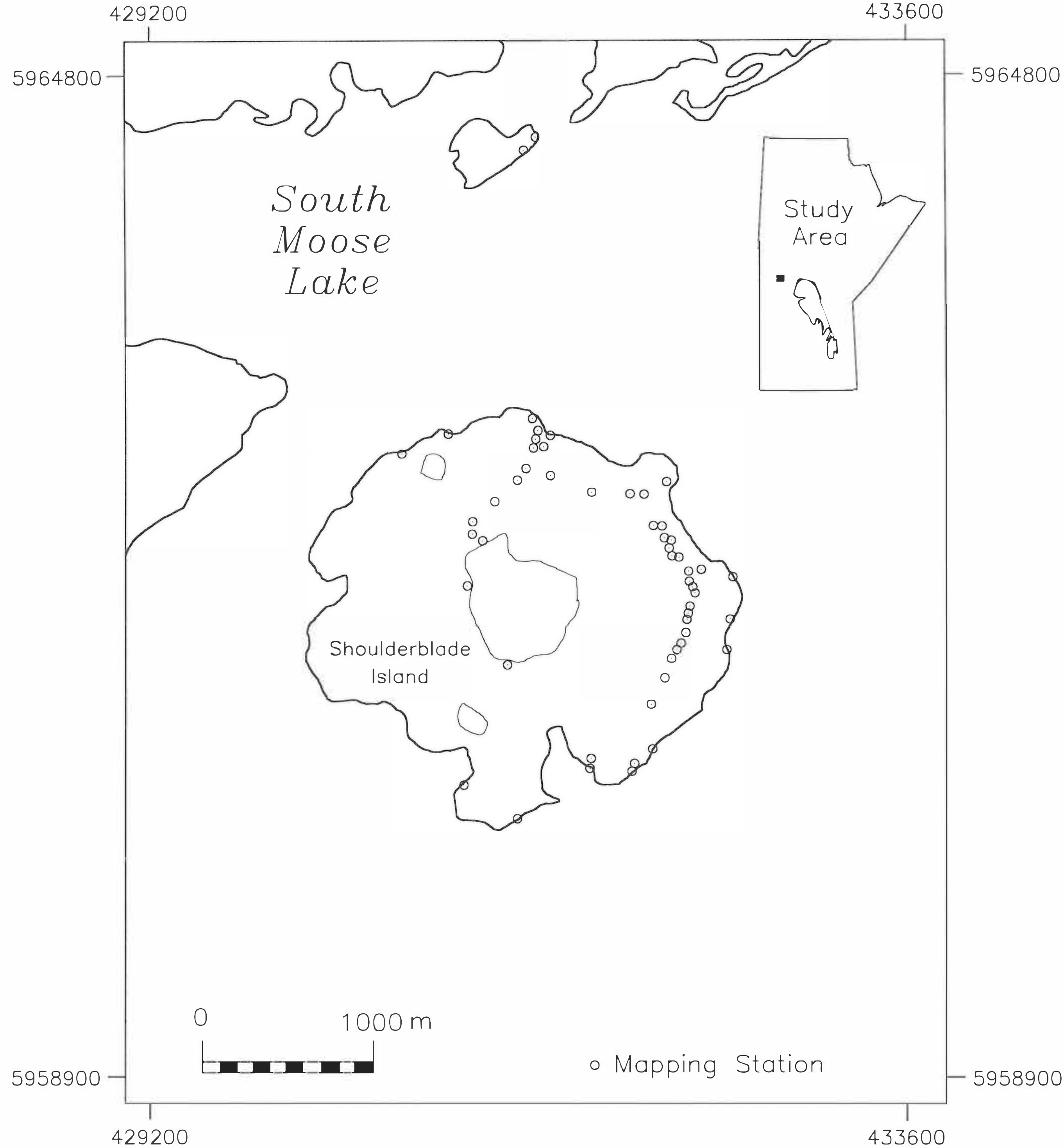

Figure GS-27-1: Location of Shoulderblade Island and mapping stations in South Moose Lake.

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GS-28 STRUCTURAL MAPPING OF THE PALEOZOIC OUTLIER AT LIMESTONE POINT LAKE (NTS 63N/2)

by C. Elliott[1]

Elliott, C., 1994: Structural mapping of the Paleozoic outlier at Limestone Point Lake (NTS 63N/2); in Manitoba Energy and Mines, Report of Activities, 1994, p. 144-147.

SUMMARY

Detailed structural mapping of Limestone Point in Limestone Point Lake has revealed the complex structure of a Paleozoic inlier in the Kisseynew Gneiss Belt. Fossiliferous dolomite contains a locally penetrative, shallowly dipping, spaced cleavege, and decametre-scale, upright folds with variable axial trace orientations. The structural style suggests that deformation did not result from syndepositional deformation, solution subsidence or glacial processes. Tectonic deformation is presently the best explanation for the observed structures, although such a model also has its shortcomings. Two other potentially tectonic deformation features have been described in Paleozoic rocks in Manitoba and Saskatchewan.

INTRODUCTION

Limestone Point and surrounding areas in Limestone Point Lake were mapped at 1:13 000 during six days in June, 1994. Figure GS-28-1 shows an outlier of Paleozoic dolomite exposed over approximately 3 km² in the midst of the Proterozoic Kisseynew gneiss terrane. The dolomites occur approximately 55 km north of the Paleozoic-Precambrian margin and have been folded (Zwanzig and Lenton, 1987; McCabe, 1987). The mapping reported here was undertaken in order to evaluate the structural geometry of the dolomite and to seek an explanation for their presence and their intensely deformed state. The study is part of a larger investigation of Phanerozoic tectonics in Manitoba and Saskatchewan.

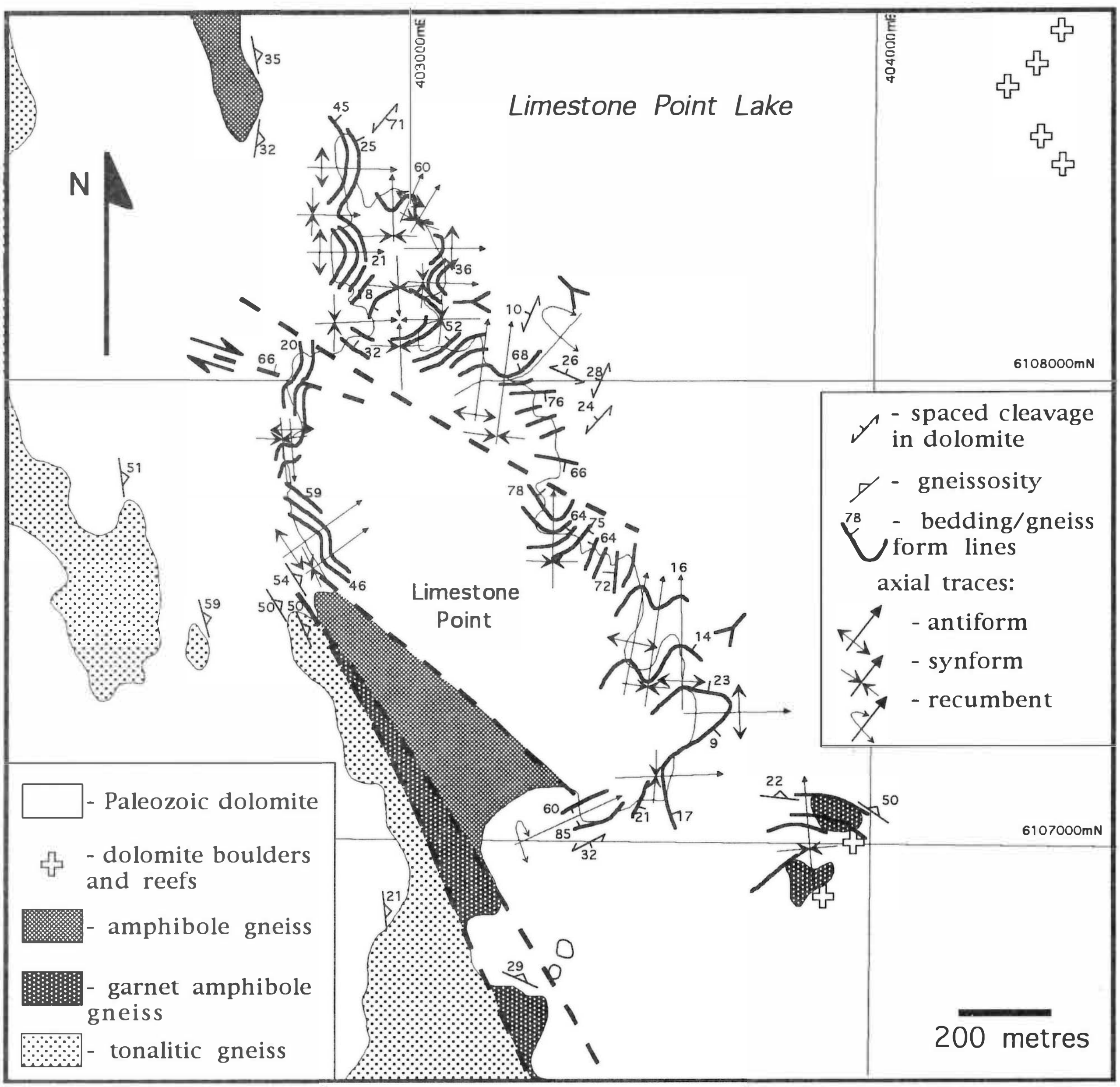

Figure GS-28-1: Geological map of Limestone Point area; Limestone Point Lake (part of NTS 63N/2).

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ROCK TYPES

The general appearance and distribution of the dolomite at Limestone Point were described in some detail by Zwanzig and Lenton (1987) and McCabe (1987). It is generally mottled, white to pink to buff and highly fossiliferous. Bedding, defined by irregular parting surfaces, ranges from centimetres to metres in thickness and is generally well exposed. The only geopetal structures observed, however, were convex-upward algal mats.

Several large exposures consist of unsorted angular dolomite clasts in variably soluble and friable matrix with iron-stained and green clay-filled cavities. These breccia were described by McCabe (1987), and were found during this investigation to be tabular bodies that, where determinable, are parallel to bedding. They are interpreted to be one or more horizons of a depositional breccia.

McCabe (1987) identified the age of the rock at Limestone Point as Ordovician rather than Silurian as had been reported by earlier workers. The strata have many characteristics of the upper Red River Formation Fort Garry Member (McCabe, 1987), which would make the unit lower to middle Ordovician in age.

STRUCTURAL GEOLOGY

Dolomite is well exposed along the shoreline of Limestone Point, and boulders and reefs of dolomite are found in the lake to the east and south of Limestone Point. No outcrops were found away from the lakeshore. The boundaries of the body are not exposed. Outcrop is exposed within 10 m of the contact between amphibole gneisses and dolomite on the west side of Limestone Point, and it appears that this contact is parallel to bedding in the dolomite and to layering in the gneiss. Very little rock is exposed near the southeast contact with the amphibole gneiss, and the orientation of the contact is not clear. Two small islands of flat-lying dolomite to the south (bottom centre, Fig. GS-28-1) are inferred to be in place, suggesting that the contact is at a high angle to gneissosity in the south.

Precambrian gneisses at Limestone Point are poorly exposed. They show strong metamorphic layering defined by compositional and grain size variations. The layering (gneissosity) is commonly crosscut by zones of iron-stained joints that may show sinistral or dextral offsets of up to 10 cm.

Very little evidence of brittle deformation is present in the dolomites. Veins are virtually absent, joints are not abundant, and locally dense fracture sets are not displaced. Shallowly plunging slickensides and cataclastic breccia zones are exposed in a narrow, dextral strike-slip fault zone at the centre of the west side of Limestone Point. The absence of veins is somewhat surprising in light of the intense strain indicated by folding (described below). The absence of cataclastic structures can be explained by abundant gaps in exposure that may coincide with weathered out zones of brittle deformation.

Bedding throughout Limestone Point contains open folds with decametre wavelengths. Mesoscopic upright folds were not observed; rather, bedding changes orientation smoothly across ten or a few tens of metres of continuously exposed dolomite. Folds trend north and east, forming N-S/E-W domes and basins which are best exposed at the north end of Limestone Point (Fig. GS-28-1). Overprinting relationships were not observed, and none of the upright folds have an axial plane cleavage.

In the steeply dipping section along the centre of the east shore of Limestone Point, the limbs of shallowly inclined open folds are bisected by a spaced cleavage. This cleavage is locally penetrative, apparently parallel to the axial surfaces of small open folds (Fig. GS-28-2), at a high angle to bedding, and locally offsets bedding by 1 to 3 mm (Fig. GS-28-3). Preliminary microscopic examination of the cleaved dolomite reveals parallel, Fe-stained solution planes 1 to 2 mm apart. These planes crosscut and truncate earlier irregular stylolitic solution seams that are roughly parallel to bedding. It appears that an early, bedding-parallel, and therefore probably horizontal, solution phase was followed by tilting and another solution phase.

Vertical bedding with a locally strong, shallow-dipping cleavage is the typical expression of recumbent folding in orogenic areas. Inferred axial traces for two possible recumbent folds are indicated on Figure GS-28-1. The spaced cleavage is locally folded (Fig. GS-28-4), suggesting that recumbent folding was early and was followed by upright folding.

GLACIAL FEATURES

The surrounding basement gneisses do not retain glaciated surfaces, but the dolomite at and around Limestone Point display many glaciated outcrop surfaces. Glaciated outcrop surfaces were carefully examined for evidence of post-glacial disruption but none was observed. Abundant glacial striae are all sub-parallel, varying between 185° and 315°. Chatter marks all indicated SSW-directed ice movement.

DISCUSSION

There are four possible explanations for the present location and deformed state of dolomite at Limestone Point.

1. *The strata may be in their depositional location and geometry*. At Limestone Point the dolomites are exposed to within 10 m of their contact on the west side of the point, and the straight contact there appears to be parallel to bedding. However, the contact at the southwest side of the point appears to be oblique to gneissosity or bedding in the dolomite. Furthermore, the stratigraphic position of the upper Red River Formation is some 30 m above the base of the Paleozoic sequence elsewhere in northern Manitoba (McCabe, 1987). The exposure is pervasively folded, and the presence of a dipping spaced cleavage in vertical bedding is a strong argument against syndepositional deformation (Elliott and Williams, 1988).

   McCabe (1987) extrapolated the Precambrian-Paleozoic contact northward from the Shield margin, and concluded that the outlier is probably lower than its depositional position. He proposed a maximum downdrop of approximate 120 m.
2. *Strata may have been carried to their present position and deformed by glacial ice*. It seems unlikely that the temperatures and pressures associated with glaciation could produce the type of plastic deformation observed in the dolomites. This is an aspect that requires more thorough research. No evidence for post-glacial disruption of the dolomite was observed, and all glacial striae measured in the dolomite are subparallel. This indicates that dolomite emplacement predated at least the last glaciation.
3. *The dolomites may have been emplaced and deformed by gravity sliding and cavern solution*. Sliding blocks of dolomite are evident on a small scale where blocks of up to 8 x 8 x 3 m are disjointed from surrounding strata and inclined towards the lake. Large scale solution-related subsidence does not explain the present of upright fold pairs, though it may explain rounded bays along Limestone Point and the basinal fold patterns observed at the north end of the point (Fig. GS-28-1). Bedding planes do not tend to dip towards present low spots, like bays or the centre of Limestone Point Lake. It is concluded that the structure is too complex to be explained by solution and subsidence, particularly in those zones that have vertical bedding and a shallow-dipping spaced cleavage. Furthermore, this kind of cavern formation or gravity sliding has not been described elsewhere in the Lower Paleozoic strata of Manitoba and Saskatchewan.
4. *The dolomites may have been tectonically deformed and transported to their present position*. The model of Limestone Point as a fault basin is, at present, the best explanation for the intensity of deformation in the outlier. Though there are no obvious fault textures near the boundaries of the dolomite, this could be explained by erosion of brittle-deformed dolomite. Exposure of Precambrian rocks near the outlier is poor, and one would expect late faults that crop out. The gneisses are jointed and contain shear fractures that could have been produced or reactivated during deformation of the dolomites.

The geometry of the dolomite is not easily explained by simple one- or two-stage tectonic deformation, nor does the outlier resemble a simple fault-bounded basin. The zones of steep bedding and shallowly dipping cleavage are reminiscent of nappe tectonics, which is very difficult to explain in the context of Paleozoic strata in northern

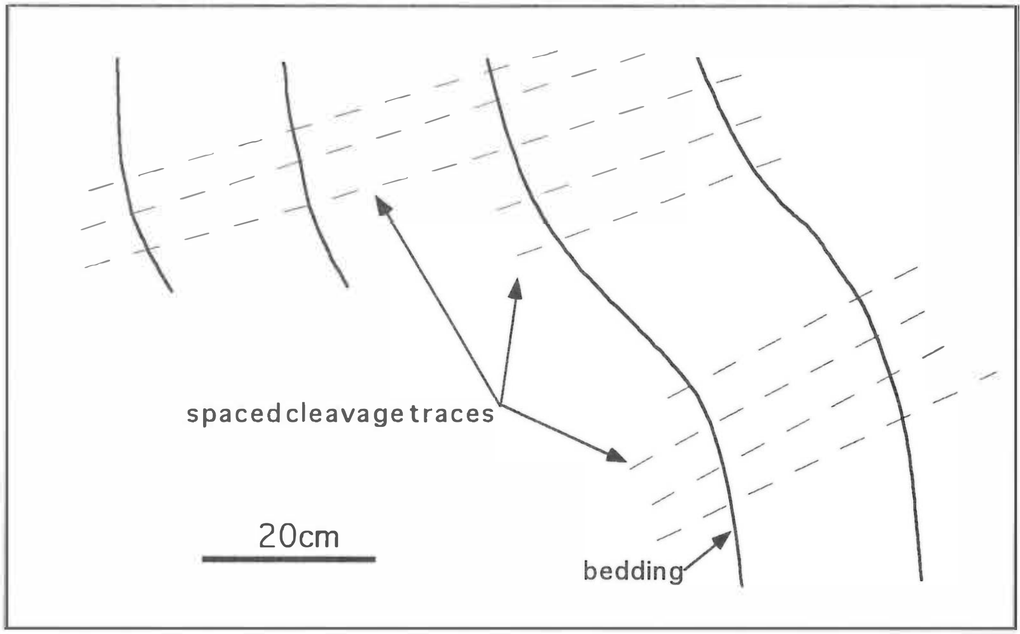

Figure GS-28-2: Field sketch of gently folded dolomite beds. Sketch of vertical NW-trending face on the east side of Limestone Point.

Manitoba. The only other deformed Paleozoic rocks in Saskatchewan and Manitoba are Silurian strata which were mapped by Byers (1962) as cut by the Tabbernor Fault, and probable tectonic breccia in lower and middle Ordovician dolomites, also along the trace of the Tabbernor Fault in Saskatchewan (K. Wilcox, unpublished report; Haidl, 1988). Bezys and Bamburak (GS-27, this report) discovered basement clasts in brecciated Lower Paleozoic carbonate rocks at Shoulderblade Island in South Moose Lake that may have been tectonically generated. Shoulderblade Island lies approximately 220 km SSE from Limestone Point, along strike with the southwestern boundary of the dolomite outlier. Investigation of remotely sensed data may reveal large-scale structures related to the Limestone Point outlier.

ACKNOWLEDGMENTS

The research reported here was funded by LITHOPROBE and NSERC research grants. I was ably assisted in the field by Daniel Giroux of Concordia University. I am particularly grateful to Neill Brandson of Manitoba Energy and Mines for logistical support and for keeping a radio 'eye' on us while we were in the field.

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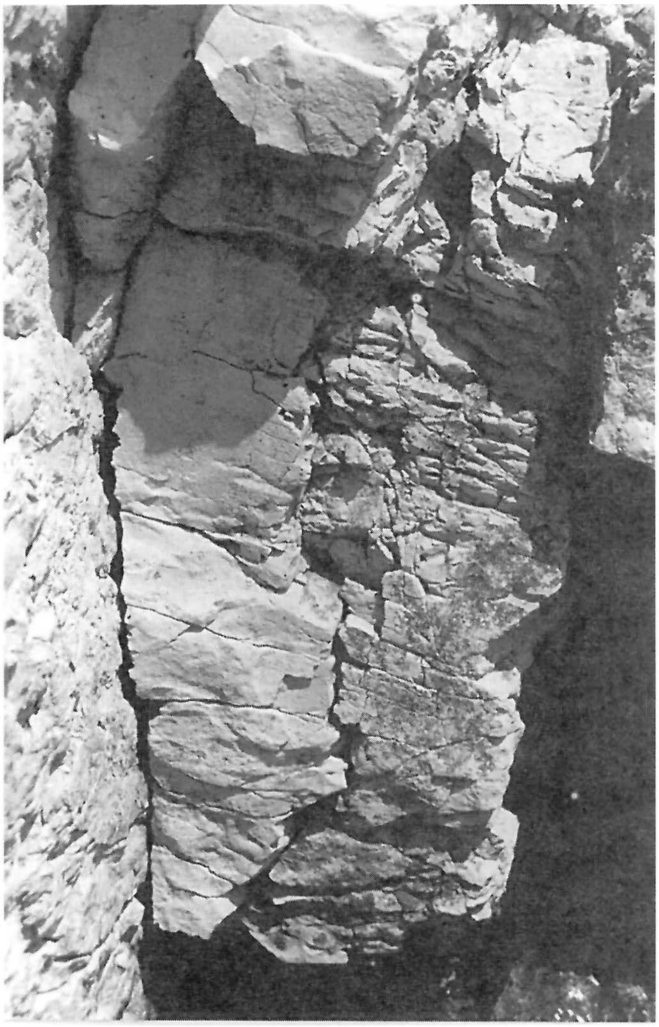
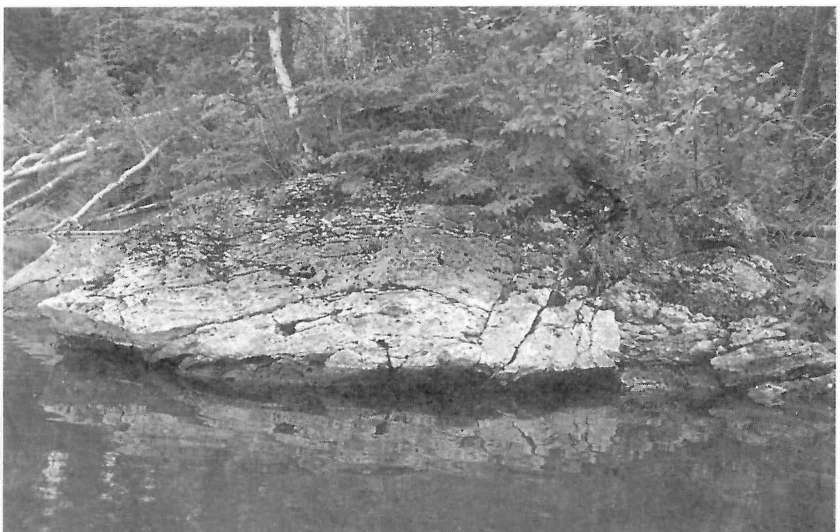


Figure GS-28-3: *Steeply dipping Ordovician dolomite at Limestone Point with shallow south-plunging cleavage. The bedding plane in the centre is approximately 20 cm wide.*

Figure GS-28-4: *Open upright fold in spaced cleavage in Ordovician dolomite at Limestone Point. The photo was taken looking west. Bedding just right of the centre of the photo dips moderately steeply to the south. The outcrop is approximately 5 m wide.*



GS-29 SPRING WATER AND MARL GEOCHEMICAL INVESTIGATIONS, GRAND RAPIDS UPLANDS (NTS 63G)*

by W.D. McRitchie

McRitchie, W.D., 1994: Spring water and Marl geochemical investigations, Grand Rapids Uplands (NTS 63G); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 148-162.

SUMMARY

A spring water and marl geochemical sampling program was conducted in the Grand Rapids area, to determine an optimal sampling medium for detecting elevated metal contents derived from concealed mineralization in Paleozoic carbonate formations of Manitoba's Interlake region. Initial results indicate the marls represent multi-year accumulations of precipitated solutes derived from Paleozoic dolostones up drainage. The regional extent of the marls, from William River south to Mill Ridge, and relatively simple geometry of the subcutaneous drainage system are ideal parameters for conducting a regional geochemical reconnaissance aimed at detecting anomalous metal concentrations originating from (Mississippi Valley type?) mineralization up drainage.

INTRODUCTION

Various approaches have been used to search for indications of Mississippi Valley type (MVT) lead-zinc mineralization in Manitoba's Paleozoic sequences. In 1994 geochemical investigations of spring and stream waters, started in 1989 (McRitchie, 1989), were continued in the Grand Rapids region (Fig. GS-29-1).

Hutt (1926) describes lime or calcium carbonate springs: "Throughout the entire area north of the Dauphin river, there are springs whose waters are highly charged with lime....They are particularly abundant a few miles north of the Dauphin (River) in the muskeg type of country...In many cases there are (a) series of ponds (fed by the springs), one higher than the other, forming steps and slight currents in the connecting channels."

The general geological and topographic attributes of the Grand Rapids Uplands were described in an earlier report (McRitchie, 1989). Exceptional exposures of Silurian and, to a lesser extent, Ordovician bedrock together with a more or less continuous belt of groundwater springs near the base of the east-facing Silurian escarpment provide an ideal area for conducting a geochemical investigation. This year, spring waters were collected from thirty-one sites, principally along the base of the escarpment, and the sampling program was expanded to include an orientation study of marly carbonate-rich sediments from fen pools close to the resurgent points of the groundwaters (Fig. GS-29-2a, -2b). These marly sediments represent multi-year accumulations of precipitated solutes derived from Paleozoic formations up drainage. Consequently if elevated metal contents can be detected in the marls, this could point to the presence of concealed MVT deposits up drainage.

WATER SAMPLING PROGRAM

Spring waters were collected this year from resurgent points north of Sturgeon Gill Road and northeast and east of Menauhswun (Honeymoon) Lake, (Fig. GS-29-3a), six feeder springs to Buffalo Lake (Fig. GS-29-3b), on William Lake, and east of Provincial Highway 6 near Oskatukaw (Jackpine) Lake (Fig. GS-29-4).

Two litre samples were taken at each location, including a 1 L sample, a 500 ml sample acidified with 10 ml of 50% HNO_3, and two 250 ml samples, one of which is scheduled for isotopic analyses coordinated through the provincial Water Resources Branch. Analysis of the waters (Table GS-29-1) was conducted by the provincial Environmental Sciences Centre in Winnipeg. *In situ* pH and temperature readings (Table GS-29-2) were taken at each sampling site using a HACH 1 pH meter, calibrated daily using standard pillow buffer solutions at pH 7.00 and 10.00.

Initial results from the water analyses (Table GS-29-1a) indicate extremely low to below detection levels for all heavy metals (lead, zinc, and nickel), in parallel with the results from earlier surveys (McRitchie 1989). Only one sample (04-30-94) contains what appears to be significantly elevated levels of fluorides (*i.e.,* 0.87 mg/L).

Ion activity products (IAP), thermodynamic equilibrium constants (KT) and saturation indices (SI = Log IAP/KT) were calculated by the provincial Water Resources Branch, using the computer program WATEQF (Plummer *et al.,* 1976). Twenty-five of the 29 spring water samples appear to be supersaturated with respect to calcite and dolomite at their points of emergence (Fig. GS-29-5). Three of the four undersaturated samples were from sites emerging from extensive aprons of beach shingle, and the fourth from a pond of standing water where some CO_2 degassing and precipitation of carbonates may already have taken place. Calcium/magnesium ratios in the analysed waters are tightly clustered between 1.30 and 1.91, which is typical of springs fed by dolomite (Shuster and White, 1971). From Table GS-29-1, it is also evident that the spring waters from the Grand Rapids region contain less dissolved substances than the average of 500 water analyses from Manitoba's southern Interlake (Betcher *et al.,* 1994).

Discussion

The regional geometry of the subsurface drainage system in Manitoba's Interlake region is relatively simple (Fig. GS-29-6). As such, it constitutes an ideal opportunity for investigating the chemistry of Paleozoic bedrock east of the Interlake divide, as it is reflected in the groundwater solutes. The evenly dispersed and more or less continuous belt of springs at the base of the escarpment, together with the supersaturated chemistry of the spring waters, are characteristics of an integrated, diffuse (rather than conduit-controlled) subsurface flow regime (Shuster and White, 1971) with widespread opportunities for interaction between the waters and host dolostones. Furthermore the uniformity of the carbonate bedrock formations should be reflected in a similar consistency in the chemistry of the solutes, making anomalously high metal values (potentially attributable to solute contributions from concealed MVT deposits) readily apparent.

However in the limited strike length of the escarpment sampled thus far, the results of the water sampling program and previous surveys in this region (McRitchie, 1989) consistently return analyses with a relatively high pH; Pb, Zn, and Ni levels at or below detection levels; and tritium levels that confirm a relatively juvenile composition for the groundwaters and short term transport from the recharge areas to the resurgent points.

These factors appear to indicate that the groundwaters may not be ideally suited to detecting anomalous metal contents on a regional scale and some other sampling medium must be targeted to facilitate the investigation.

Marly Fen Pools

The relatively cold spring waters emerging from the base of the main escarpment appear first in clear feeder pools and/or dolostone shingle-lined channels, at a stratigraphic level slightly below (5-10 m) the Fisher Branch Formation. Whether this reflects the presence of an aquitard at this stratigraphic position or simply a coincidence between the regional water table and a specific elevation has yet to be determined. The feeder springs west of Buffalo Lake emerge slightly higher in the stratigraphy near the midpoint of the Moose Lake Formation, evidence that would support the existence of a regional water table whose elevation rises westward toward the Interlake divide. Within 10 to 100 m the streams that emerge from the main escarpment flow into a series of shallow paludal ponds where active precipitation of a creamy white sediment commences, presumably under the influence of elevated temperatures (Table GS-29-2) and CO_2 degassing. Although only a limited number of measurements have been taken, a threshold pH of 7.8 (*i.e.*, the "Limestone Fence" of Krumbein and Garrels, 1952) seems to be necessary before calcite precipitation will begin.

* Funded by Provincial A-Base

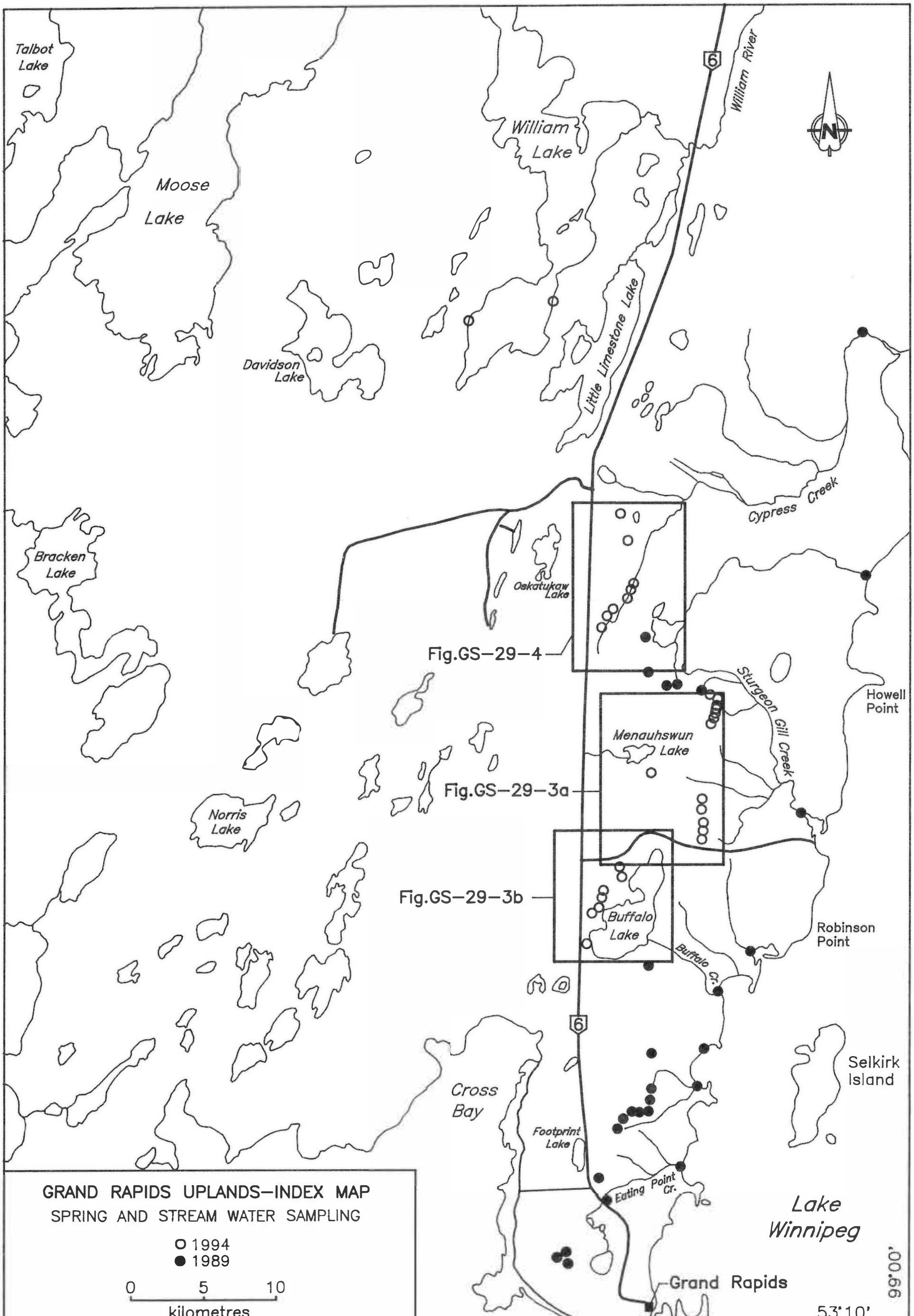


Figure GS-29-1: Spring and stream water sampling, Grand Rapids Uplands - Index Map.

Figure GS-29-2a: Escarpment and marly fen pools, northeast of Menauhswun (Honeymoon) Lake.

The number, size (0.02-8 ha, average 0.5 ha) and shape of the marly fen pools varies extensively (Fig. GS-29-2b). Individual, generally east-trending beaded chains of fen pools, linked by narrow, ephemeral and braided channels, range up to a kilometre in length. The width of the regionally north-trending belt in which precipitates are accumulating ranges from 0.5 to 1.5 km (Fig. GS-29-2b). Water depths in the fen pools range from 0 to 200 cm. Most contain less than 20 cm of standing water, and many dry up completely during periods of low precipitation and run off.

Where the spring waters first begin to pond, the marly fen pools are typically lined with dolostone shingle of various sizes. Carbonate precipitates first appear as sand-sized particles that form lenses intermixed with the shingle. Over the next 10 to 100 m down drainage, the thickness of the coarse granular to fine powdery, very loosely coherent precipitate beds increases to more than a metre, with mushroom-coloured organic-rich mats that float on the surface of the pools and thin, discontinuous felted veneers that blanket the bottom sediments (Fig. GS-29-2c).

At the downstream end of the fen pool chains, the precipitates thin to only a few centimetres of cream and grey carbonate-rich sediment that overlies black organic ooze. Further downstream, the channels and ponds that lead to Lake Winnipeg are devoid of precipitates.

The calcium-rich carbonate sediments accumulating in the fen pools represent reprecipitated groundwater solutes originally derived from Paleozoic dolostones up drainage. The dolostones are constantly subjected to dissolution by meteoric waters that fall on the higher recharge areas west of Lake Winnipeg. The meteoric waters percolate down through the 10 to 20 m thick zone of infiltration (Table GS-29-3), and then move subcutaneously east and west away from the Interlake Divide. Those that emerge from the resurgent points along the eastern side of the divide have significantly lower temperatures than the surface waters. Groundwater temperatures as low as 2.5° C were recorded at some emergent points in mid June. By late August temperatures lower than 6° C were still recorded in some springs (Table GS-29-2). This gives them a greater capacity to contain increased levels of dissolved CO_2, and to dissolve the host rocks in the hinterland.

Significant thicknesses (>1 m) of marly sediment observed in the collection ponds near the head of each beaded chain are consequently thought to represent a multi-year accumulation of precipitates, derived from the hinterland to the west. As such, the marls may constitute an effective geochemical medium for detecting anomalous metal contents derived from concealed mineralization in the eastern segment of the Interlake region. Sampling of the marls would also circumvent irregularities arising from seasonal variations in water composition as demonstrated by Shuster and White (1971).

Studies on the concentration of dissolved zinc in rivers that drain pristine and industrially influenced regions have demonstrated that the solubility of zinc decreases markedly and consistently with increasing pH (Shiller and Boyle, 1985). Nevertheless, low levels of dissolved zinc can be held in solution at pH values between 7 and 8, *i.e.*, within the range exhibited by spring waters in the Grand Rapids region at their emergent points. Subsequently, as spring waters move into warm, marly fen pools and begin to evolve CO_2 and H_2S (?) (Hutt, 1926), the associated increases in pH can be expected to liberate zinc from the waters, along with the marly carbonate precipitates (Fig. GS-29-7). Hutt's reference to hydrogen sulphide is peculiar in that this gas would not normally be expected in this environment where very little SO_4 is available.

On a regional scale the marly fen pools provide a consistently available medium for geochemical sampling throughout the 250 km length of the Interlake region. Marly fen pools occur as far south as Mill Ridge, southeast of Lake St. Martin. Between Lake St. Martin and Long Point the marly fen pools form a linear belt with scattered clusters near Pine Lake, Devils Lake and Dancing Point (Fig. GS-29-8). North of Long Point the fen pools form an almost continuous linear belt as far as William River and latitude 54° N.

SEDIMENT SAMPLING PROGRAM

An orientation survey was conducted this year to determine the composition of the marls from selected fen pools north of the Sturgeon Gill Road. One kg samples were collected from the uppermost 15 cm of sediment in nineteen pools. The sampling array also included two suites of samples taken from five separate pools in each of two chains, to determine whether there is a mineralogical or chemical change in the composition of the marls across the width of the belt in which precipitation occurs (Fig. GS-29-3a). Samples are currently being analysed for major and trace elements by the Geological Services Branch, Analytical Laboratory.

In situ water temperature and pH measurements from the chain of pools at station 04-24-94 (Fig. GS-29-9), display subparallel increases in both parameters downstream for at least 270 m from the point of emergence. Shuster and White (1971) observed the same phenomenon in springs in the Nittany Valley, Central Appalachians, where the CO_2 partial pressure decreased and the pH increased over the first 800 m from the point of emergence before becoming stable.

Given that zinc has a very limited solubility in waters with pH greater than 8.0, geochemical sampling programs aimed at finding zinc in the marls from the Interlake region should be targeted at the very first fen pools in any one chain, rather than subsequent ponds, where the zinc-related solute load is likely to have been depleted. The behaviour of other metals indicative of MVT mineralization is currently being investigated to see if a more aerially extensive zone of potential precipitation can be predicted.

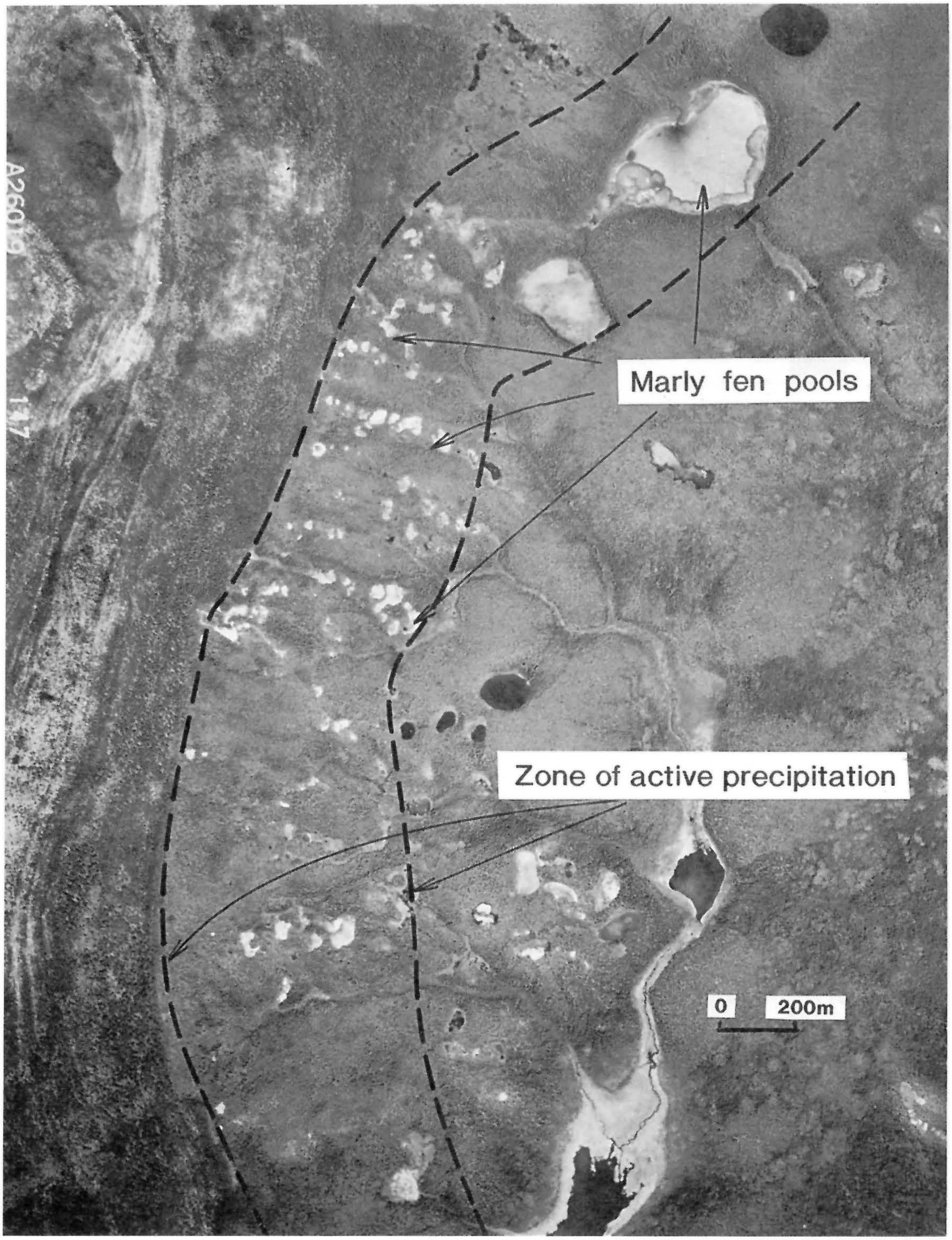


Figure GS-29-2b: *Aerial view of Silurian escarpment (left), beach ridges, and beaded chains of marly fen pools at head of dendritic drainage leading east toward Lake Winnipeg. North of Sturgeon Gill Road, Grand Rapids Uplands.*

Figure GS-29-2c: Marly fen pool with carbonate-rich bottom sediments. Note felted rafts of organic-rich carbonate on surface and bed of pool. West of Buffalo Lake, Grand Rapids Uplands.

Future investigations will attempt to determine vertical changes in chemistry within the marl sequences, pending availability of a coring device. Profiles from the thicker marl deposits will determine the nature and extent of the geologically recent stratigraphic record preserved in the precipitates, as well as longer term fluctuations in metal contents.

ACKNOWLEDGMENTS

Instrument readings and water and sediment sampling in the field were greatly facilitated by Ruth Bezys, Joanne Shwetz and volunteer field assistants Dale Brown, Hugo Copper, Jane Rawluk, and David Wright.

R. Betcher (Water Resources Branch) provided guidance on the water sampling program and assisted in processing the analytical results using WATEQF.

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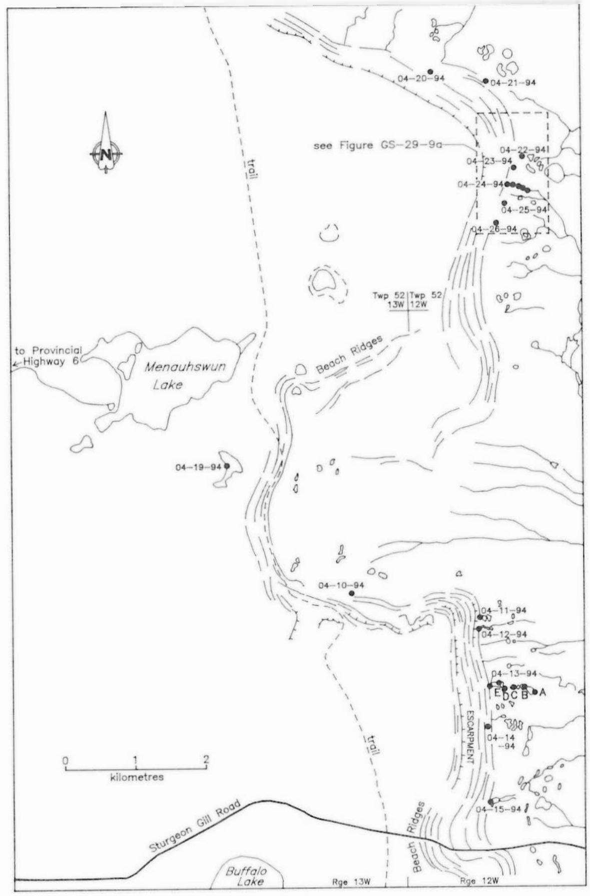
a)



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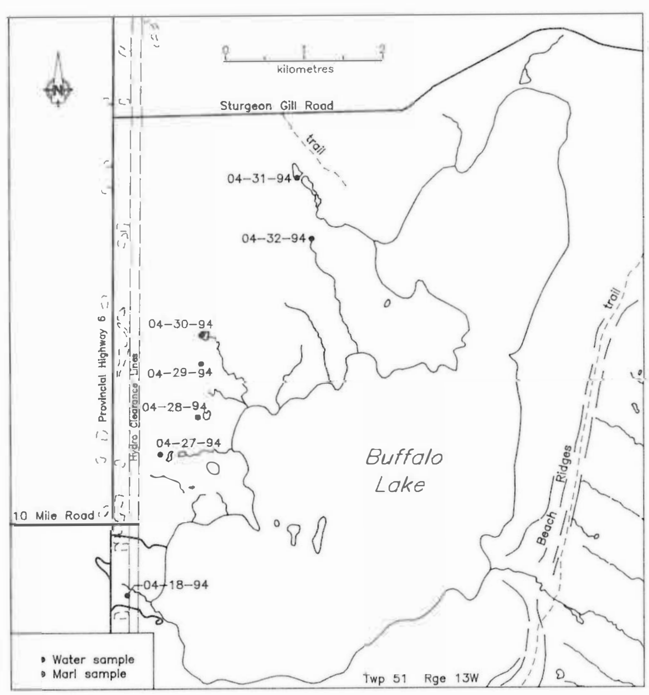

Figure GS-29-3: *Spring water sampling, Grand Rapids Uplands, 1994. a) Menauhswun (Honeymoon) Lake; b) Buffalo Lake.*

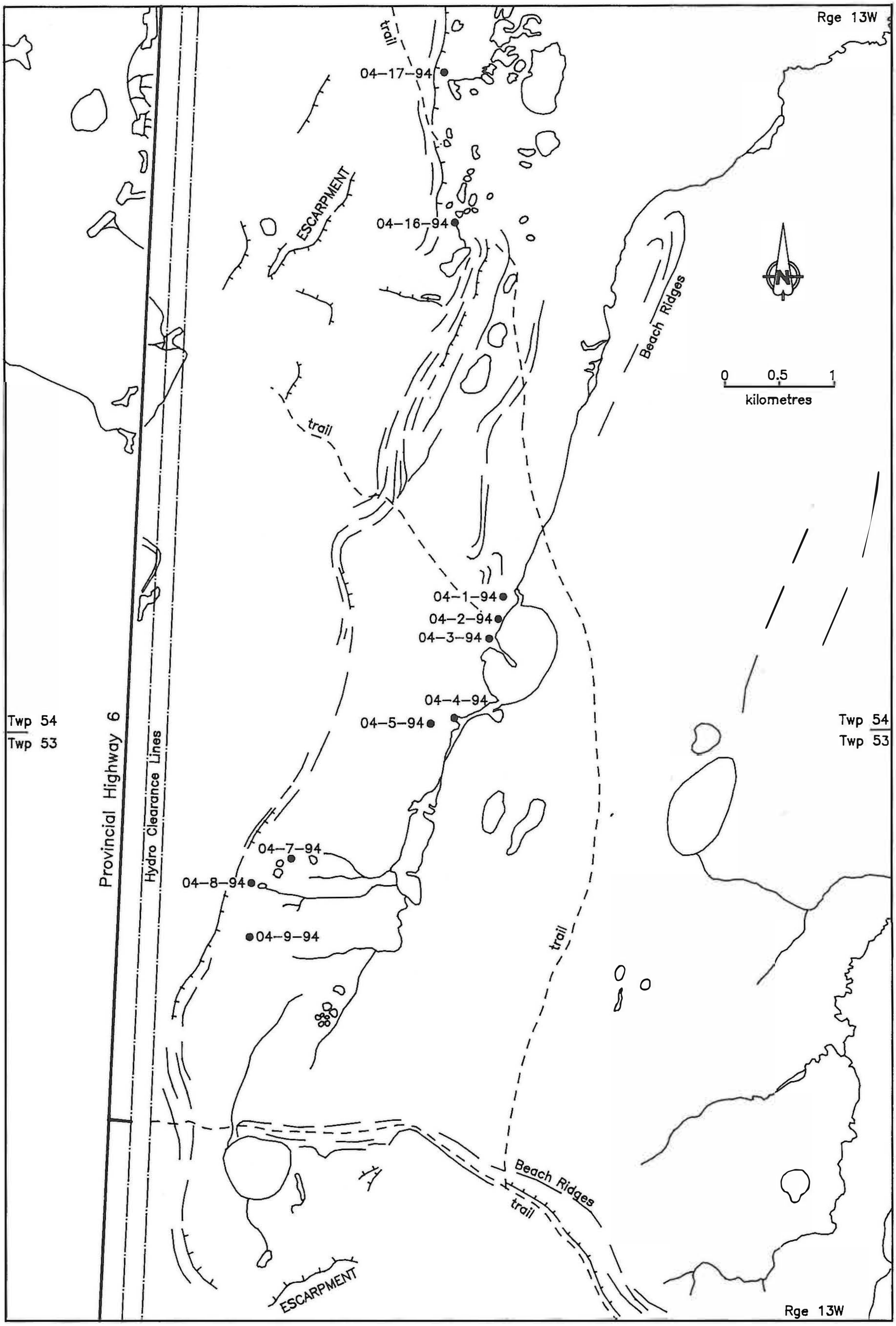

Figure GS-29-4: Spring water sampling, Grand Rapids Uplands, 1994. East of Oskatukaw (Jackpine) Lake.

Table GS-29-1a: Chemical Analyses of Ground/Spring-water Grand Rapids Uplands

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
04-1-94	269	328	<18	<10.2	7.59	0.14	230	<0.05	1.1	0.11	5.2	<10
04-2-94	277	338	<18	<10.2	7.59	0.15	260	<0.05	1.2	0.11	5.2	<10
04-3-94	283	345	<18	<10.2	7.55	0.14	280	<0.05	1.2	0.12	4.9	<10
04-4-94	249	304	<18	<10.2	8.27	0.16	240	<0.05	1.1	0.09	4.3	<10
04-5-94	251	307	<18	<10.2	7.57	0.12	240	<0.05	0.9	0.16	4.5	<10
04-7-94	251	306	<18	<10.2	8.12	0.12	230	<0.05	0.9	<0.01	3.6	<10
04-8-94	250	304	<18	<10.2	7.81	0.14	240	<0.05	1.3	0.16	4.1	<10
04-9-94	244	298	<18	<10.2	7.93	0.12	240	<0.05	1.0	0.06	3.4	<10
04-11-94	251	306	<18	<10.2	7.69	0.15	260	<0.05	<10	0.23	5.3	<10
04-12-94	267	326	<18	<10.2	7.89	0.16	280	<0.05	<10	0.05	5.4	<10
04-13-94	267	326	<18	<10.2	7.71	0.14	280	<0.05	<10	0.06	5.3	<10
04-14-94	266	325	<18	<10.2	7.74	0.12	270	<0.05	<10	0.13	5.3	<10
04-15-94	281	343	<18	<10.2	7.60	0.20	290	<0.05	<10	0.05	5.9	<10
04-16-94	204	248	<18	<10.2	7.59	<0.1	220	0.05	<10	<0.01	7.9	<10
04-17-94	291	355	<18	<10.2	7.45	0.12	300	<0.05	<10	0.07	5.0	<10
04-18-94	290	353	<18	<10.2	7.44	0.14	300	<0.05	<10	<0.15	6.0	<10
04-19-94	268	326	<18	<10.2	7.46	<0.1	80	<0.05	<10	0.15	6.1	<10
04-20-94	248	303	<18	<10.2	7.57	0.18	250	<0.05	0.7	0.18	4.5	<10
04-21-94	241	294	<18	<10.2	7.68	0.12	250	<0.05	0.6	0.65	4.6	<10
04-22-94	258	314	<18	<10.2	7.91	0.21	260	<0.05	0.6	0.29	5.2	<10
04-23-94	254	310	<18	<10.2	7.57	0.16	260	<0.05	0.6	0.09	5.1	39.0
04-24-94	281	343	<18	<10.2	7.90	0.20	270	<0.05	0.7	0.20	5.5	<10
04-25-94	272	332	<18	<10.2	7.94	0.14	280	<0.05	0.6	0.10	5.8	<10
04-26-94	258	315	<18	<10.2	7.92	0.16	260	<0.05	0.7	0.14	5.4	<10
04-27-94	292	356	<18	<10.2	7.68	0.12	300	<0.05	1.5	0.16	5.7	<10
04-29-94	275	336	<18	<10.2	7.82	0.16	290	<0.05	1.5	0.03	4.9	<10
04-30-94	272	332	<18	<10.2	7.55	0.87	280	<0.05	1.2	0.12	4.8	<10
04-31-94	272	332	<18	<10.2	7.64	0.14	280	<0.05	0.8	0.19	5.1	<10
04-32-94	272	332	<18	<10.2	7.56	0.12	270	<0.05	1.0	0.16	4.8	<10
88-1-94	270	329	<18	<10.2	7.64	0.11	300	<0.05	1.4	0.21	5.1	11
88-2-94	327	399	<18	<10.2	7.42	0.13	330	<0.05	0.8	0.13	6.7	<10
CARB/EVAP AQUIFER*	341	415.2	2.0		7.71	0.45	553	0.29	46.4	0.93	11.3	87.9

* Average of approximately 500 analyses from fresh groundwaters in the carbonate-evaporite unit, Betcher *et al.* (1994).

1. Alkalinity - Total ($CaCO_3$) mg/L
2. Alkalinity - Bicarbonate mg/L
3. Alkalinity - Carbonate mg/L
4. Alkalinity - Hydroxide mg/L
5. pH-pH units
6. Fluoride mg/L
7. Residue - Filterable mg/L
8. Boron - soluble mg/L B
9. Chloride - Soluble mg/L
10. Nitrate-Nitrite-N Soluble mg/L N
11. Silica - Soluble Reactive mg/L SiO_2
12. Sulphate - Soluble mg/L SO_4

Sample Numbers	Collection Date
04-1-94 to 04-5-94	4.6.94
04-7-94 to 04-9-94	13.6.94
04-11-94 to 04-15-94	15.7.94
04-16-94 to 04-17-94	16.7.94
04-18-94 to 04-19-94	17.7.94
04-20-94 to 04-26-94	27.8.94
04-27-94 to 04-32-94	28.8.94
88-1-94 to 88-2-94	11.6.94

Table GS-29-1b: Chemical Analyses of Ground/Spring-water
Grand Rapids Uplands

SAMPLE #	13	14	15	16	17	18	19	20	21	22	23	24
04-1-94	<0.001	0.09	54.8	<0.01	0.04	<0.002	34.7	<0.02	<0.005	<5	1.65	<0.01
04-2-94	<0.001	0.09	56.3	0.01	0.03	<0.002	35.9	<0.02	<0.005	<5	1.39	<0.01
04-3-94	<0.001	0.09	57.4	0.01	0.06	0.0025	36.4	<0.02	<0.005	<5	1.37	<0.01
04-4-94	<0.001	0.10	60.4	0.01	0.04	<0.002	32.7	<0.02	<0.005	<5	1.42	<0.01
04-5-94	<0.001	0.07	51.9	<0.01	0.03	<0.002	32.8	<0.02	<0.005	<5	1.58	<0.01
04-7-94	<0.001	0.09	53.4	<0.01	0.03	<0.002	31.8	<0.02	<0.005	<5	1.56	<0.01
04-8-94	<0.001	0.08	52.7	<0.01	0.03	<0.002	32.5	<0.02	<0.005	<5	1.20	<0.01
04-9-94	<0.001	0.07	52.1	<0.01	0.04	<0.002	31.6	<0.02	<0.005	<5	1.43	0.01
04-11-94	<0.001	0.10	46.5	0.01	0.03	<0.002	35.5	<0.02	<0.005	<5	1.27	<0.01
04-12-94	<0.001	0.13	50.3	<0.01	0.03	<0.002	37.3	<0.02	<0.005	<5	1.21	0.01
04-13-94	<0.001	0.14	54.2	0.01	0.03	<0.002	35.7	<0.02	<0.005	<5	1.34	<0.01
04-14-94	<0.001	0.12	52.3	<0.01	0.03	<0.002	34.9	<0.02	<0.005	<5	1.09	<0.01
04-15-94	<0.001	0.11	51.6	0.01	0.03	<0.002	39.5	<0.02	<0.005	<5	1.47	<0.01
04-16-94	<0.001	<0.05	42.7	<0.01	0.06	<0.002	24.8	<0.02	<0.005	<5	<1	<0.01
04-17-94	<0.001	0.08	58.2	<0.01	0.03	<0.002	37.7	<0.02	<0.005	<5	1.30	<0.01
04-18-94	<0.001	0.13	58.5	0.01	0.03	<0.002	36.5	<0.02	<0.005	<5	1.70	<0.01
04-19-94	<0.001	<0.05	59.5	0.01	0.03	<0.002	31.2	<0.02	<0.005	<5	1.18	<0.01
04-20-94	<0.001	0.09	53.2	<0.01	0.02	<0.002	33.4	<0.02	<0.05	<5	1.31	<0.01
04-21-94	<0.001	0.09	52.0	<0.01	0.03	<0.002	32.2	<0.02	<0.05	<5	1.22	0.04
04-22-94	<0.001	0.10	51.0	<0.01	0.03	<0.002	37.2	<0.02	<0.05	<5	1.41	<0.01
04-23-94	<0.001	0.10	50.4	0.01	0.07	<0.002	35.8	<0.02	<0.05	<5	1.50	<0.01
04-24-94	<0.001	0.11	54.9	0.02	0.06	0.0020	40.0	<0.02	<0.05	<5	1.69	0.01
04-25-94	<0.001	0.11	54.2	<0.01	0.07	<0.002	38.5	<0.02	<0.05	<5	1.49	<0.01
04-26-94	<0.001	0.11	52.6	0.01	0.04	<0.002	35.7	<0.02	<0.05	<5	2.15	0.01
04-27-94	<0.001	0.11	62.0	<0.01	0.03	<0.002	38.6	<0.02	<0.05	<5	1.98	<0.01
04-29-94	<0.001	0.14	59.3	<0.01	0.03	<0.002	36.7	<0.02	<0.05	<5	1.55	<0.01
04-30-94	<0.001	0.14	58.2	<0.01	0.04	<0.002	35.8	<0.02	<0.05	<5	1.42	<0.01
04-31-94	<0.001	0.11	60.9	<0.01	0.51	<0.002	38.6	0.02	<0.05	<5	1.42	0.01
04-32-94	<0.001	0.11	57.2	<0.01	0.04	<0.002	36.3	<0.02	<0.05	<5	1.37	<0.01
88-1-94	<0.001	<0.05	57.0	0.01	0.03	<0.002	33.4	<0.02	<0.005	<5	1.32	<0.01
88-2-94	<0.001	0.09	66.9	0.02	0.04	<0.002	40.6	<0.02	<0.005	<5	1.26	0.01
CARB/EVAP AQUIFER *			61.6		1.78		55.6				6.5	53.2

13. Arsenic - Total mg/L
14. Barium - Extractable mg/L
15. Calcium - Extractable mg/L
16. Copper - Extractable mg/L
17. Iron - Extractable mg/L
18. Lead - Extractable mg/L
19. Magnesium - Extractable mg/L
20. Manganese - Extractable mg/L
21. Nickel - Extractable mg/L
22. Potassium - Extractable mg/L
23. Sodium - Extractable mg/L
24. Zinc - Extractable mg/L

Table GS-29-2
Sample/locality descriptions and *in situ* measurements of pH and T°(C)
Spring Water Sampling, Grand Rapids Uplands, 1994

Date	Location	Category	Flow	Base	pH	T°(C)
4/6/94	04-1-94	Brook	Moderate	Shingle	7.85	3.7
	04-2-94	Brook	Moderate	Organic/Marly	7.90	3.6
	04-3-94	Brook	Moderate	Organic/Debris	7.86	3.4
	04-4-94	Pool	Standing	Marl	8.70	17.4
	04-5-94	Brook	Moderate	Shingle	8.00	2.5
13/6/94	04-7-94	Brook	Gentle	Organic/Marl	8.29	11.9
	04-8-94	Rivulet	Moderate	Organic	7.97	5.6
	04-9-94	Rivulet	Slight	Marl	8.27	11.3
17/6/94	88-1-94	Pool	Moderate	Organic	7.92	6.5
	88-2-94	Rivulet	Gentle	Organic/Debris	7.54	5.5
15/7/94	04-11-94	Brook	Moderate	Shingle	7.74	8.2
	04-12-94	Rivulet	Moderate	Organic	8.09	12.7
	04-13-94	Brook	Moderate	Shingle	7.86	9.4
	04-13-94E	Pool	Standing	Marl	8.62	26.5
	04-13-94D	Pool	Standing	Marl	8.49	24.4
	04-14-94	Rivulet	Gentle	Organic	7.86	7.7
	04-15-94	Pool	Standing	Organic	7.93	8.6
16/7/94	04-16-94	Rivulet	Moderate	Shingle	7.68	8.2
	04-17-94	Pool	Gentle	Organic	7.51	6.6
17/7/94	04-18-94	Brook	Moderate	Organic	7.58	4.9
	04-19-94	Rivulet	Gentle	Shingle	7.57	8.4
27/8/94	04-20-94	Brook	Strong	Organic/Woody trash	7.55	6.3
	04-21-94	Brook	Moderate	Organic/Shingle med.	7.55	7.2
	04-22-94	Rivulet	Strong	Organic/Shingle med.	8.17	7.6
	04-23-94	Rivulet	Moderate	Organic	7.63	7.4
	04-24-94	Rivulet	Slow	Organic/Shingle med.	7.92	10.0
	04-25-94	Rivulet	Slow	Organic	8.06	10.5
	04-26-94	Rivulet	Trickle	Shingle sm.	8.13	9.6
28/8/94	04-27-94	Rivulet	Trickle	Organic/Shingle sm.	7.82	8.3
	04-29-94	Rivulet	Trickle	Organic	7.97	11.0
	04-30-94	Pool	Standing	Organic/Woody trash	7.40	8.9
	04-31-94	Rivulet	Trickle	Shingle sm.	7.66	6.4
	04-32-94	Brook	Strong	Organic	7.65	5.8
		Pool/Brook	Strong	Organic/Shingle sm.	7.64	5.7

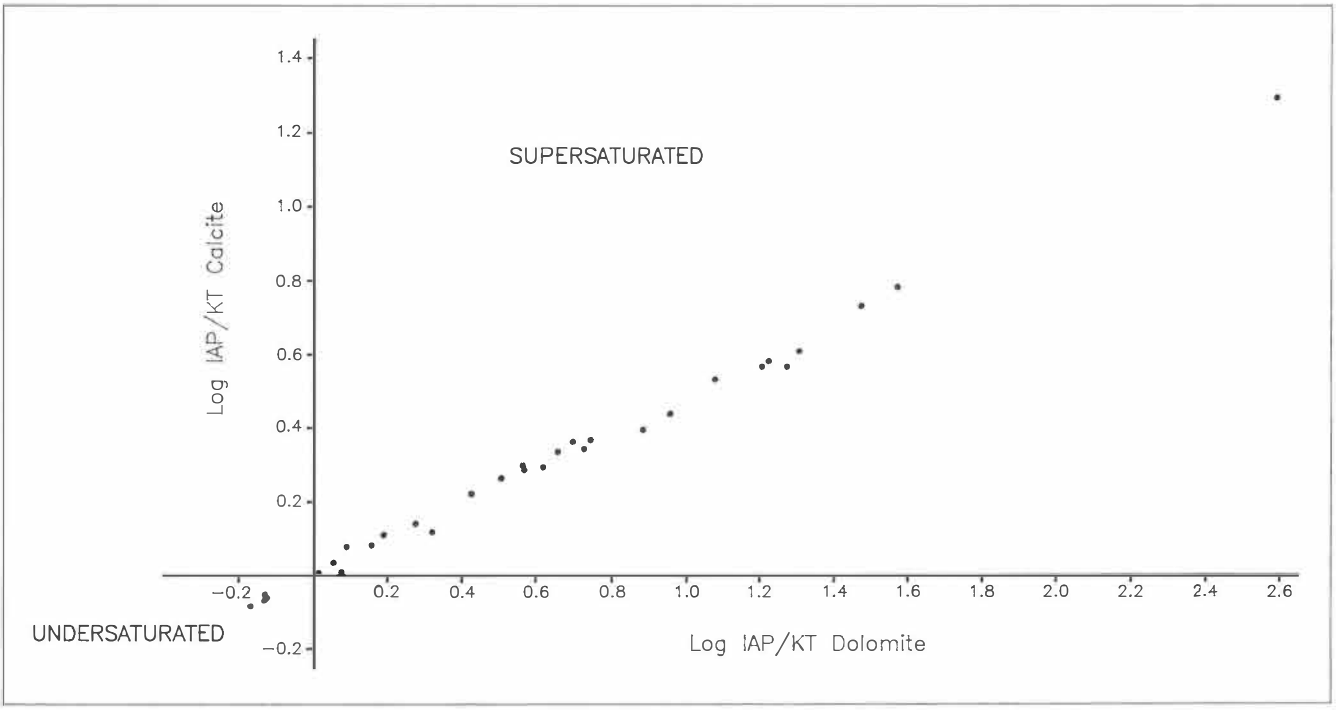

Figure GS-29-5: Calcite and dolomite saturation indices (log IAP/KT) for spring waters in the Grand Rapids Uplands; 1994 sampling program.

Table GS-29-3
Static water levels (m) taken at drillhole locations, Grand Rapids Uplands. Holes drilled by Geological Services Branch
Static Water Level, Measurement Dates

Drillhole		17/5/90	15/10/93	3/6/94	12/6/94	18/6/94	23/6/94	20-22/9/94	26-27/9/94
M-14-88	Road End Lake N.	-	-	-	-	-	-	11.50	-
M-1-89	Footprint Lake	7.20	-	12.80	-	-	-	-	-
M-2-89	10 Mile Road	13.65	13.51	17.68	-	-	-	17.69	-
M-3-89	Cattrail East	8.35	-	-	18.56	-	-	-	-
M-10-90	Davidson Lake	-	-	-	-	-	-	4.85	-
M-3/4-91	Sturgeon Gill W.	-	-	-	21.26	-	-	20.75	-
M-5-91	Cook's Cave S.	-	-	-	-	-	-	5.62	-
M-6-91	Deep Basin	-	9.12	-	-	13.6	-	-	13.05
M-1-93	Cook's Cave N.	-	8.94	-	-	-	-	14.32	-
M-2-93	Road End L.	-	-	-	-	-	-	11.90	-
M-3-93	Menauhswun Lake	-	-	-	-	-	12.30	13.03	-
M-1-94	William L. NE.	-	-	7.10	-	-	-	9.47	-
M-1A-94	William NE. Water	-	-	6.65	-	-	-	-	-
M-3-94	Microwave Tower	-	-	-	17.20	18.20	-	-	-
M-4-94	Little Lst. S.	-	-	12.66	-	-	-	-	-

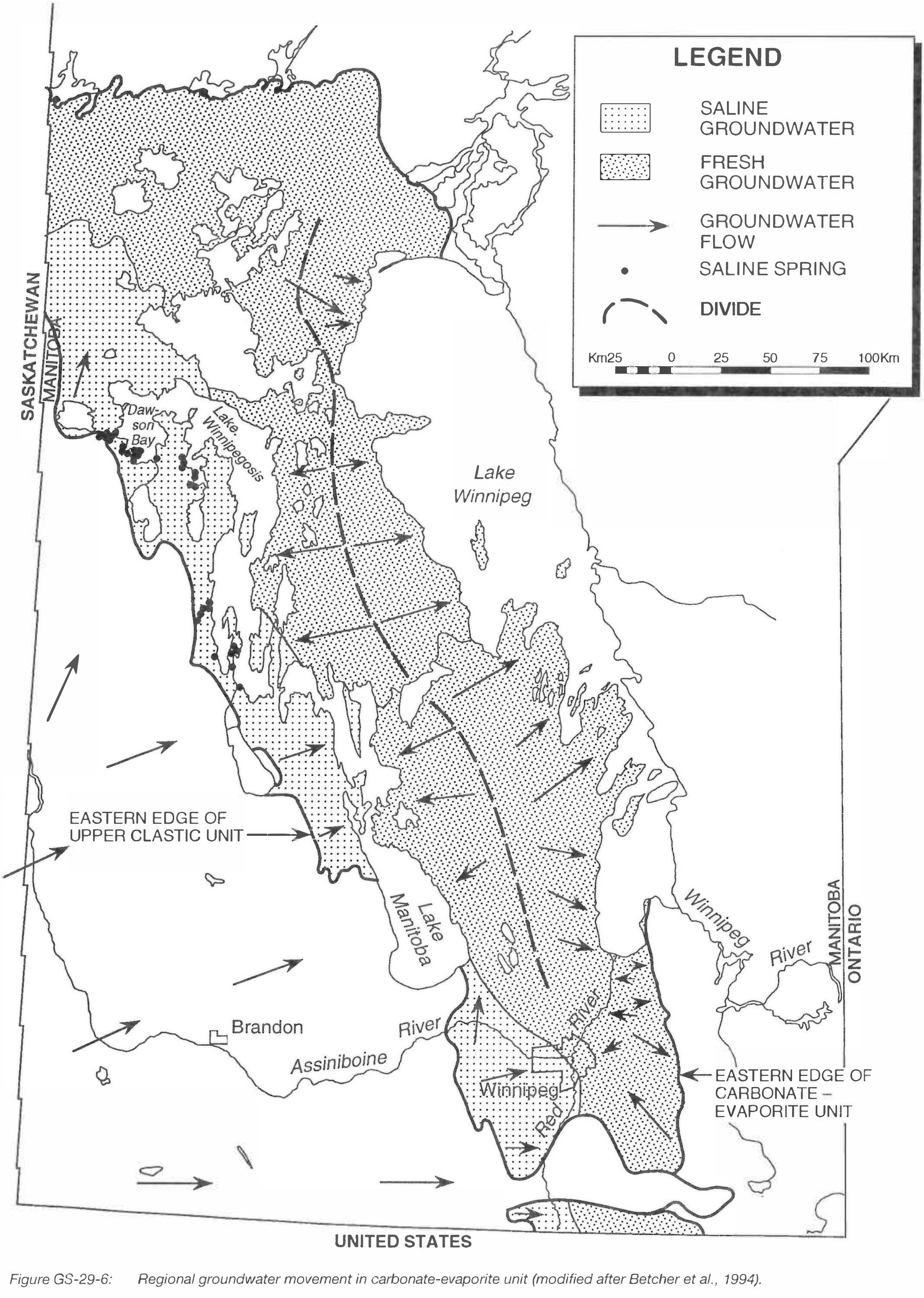

Figure GS-29-6: Regional groundwater movement in carbonate-evaporite unit (modified after Betcher et al., 1994).

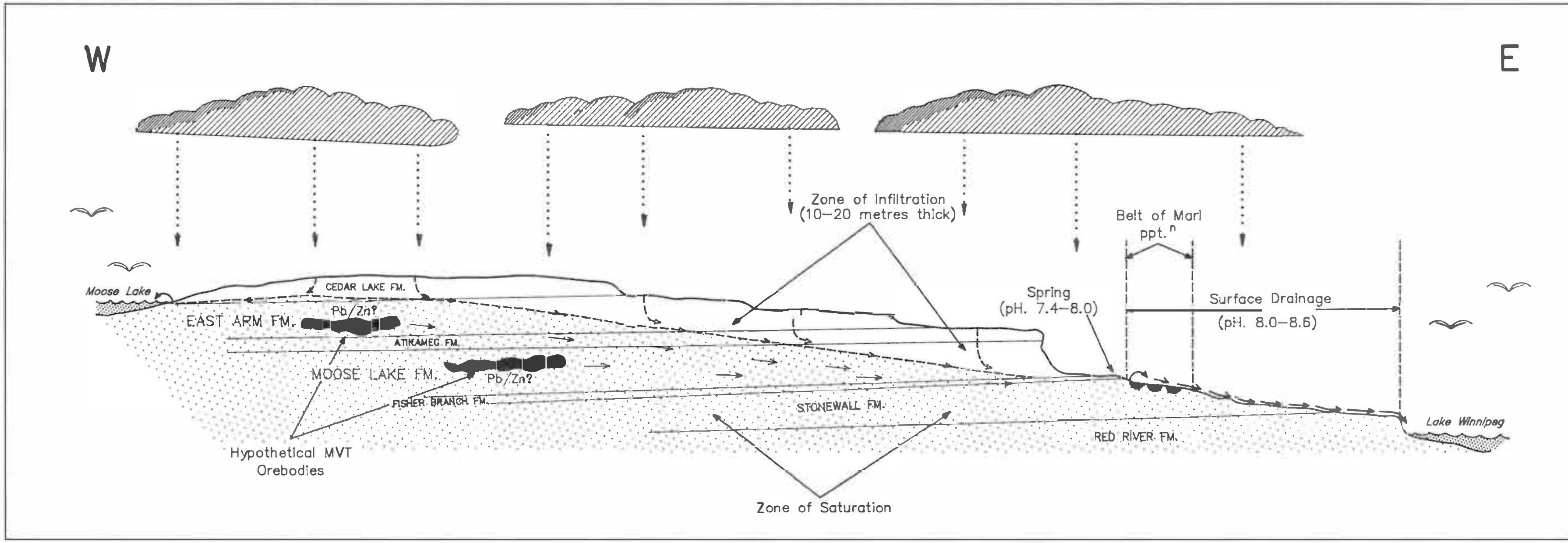

Figure GS-29-7: *Grand Rapids Uplands (not to scale) - Hypothetical model; subcutaneous groundwaters feed springs at base of Silurian escarpment, where CO2 degassing leads to precipitation of marly sediments in fen pools. The marls may contain higher background levels of Zn, Pb, Ba, etc. derived from concealed MVT Pb/Zn deposits up drainage to west.*

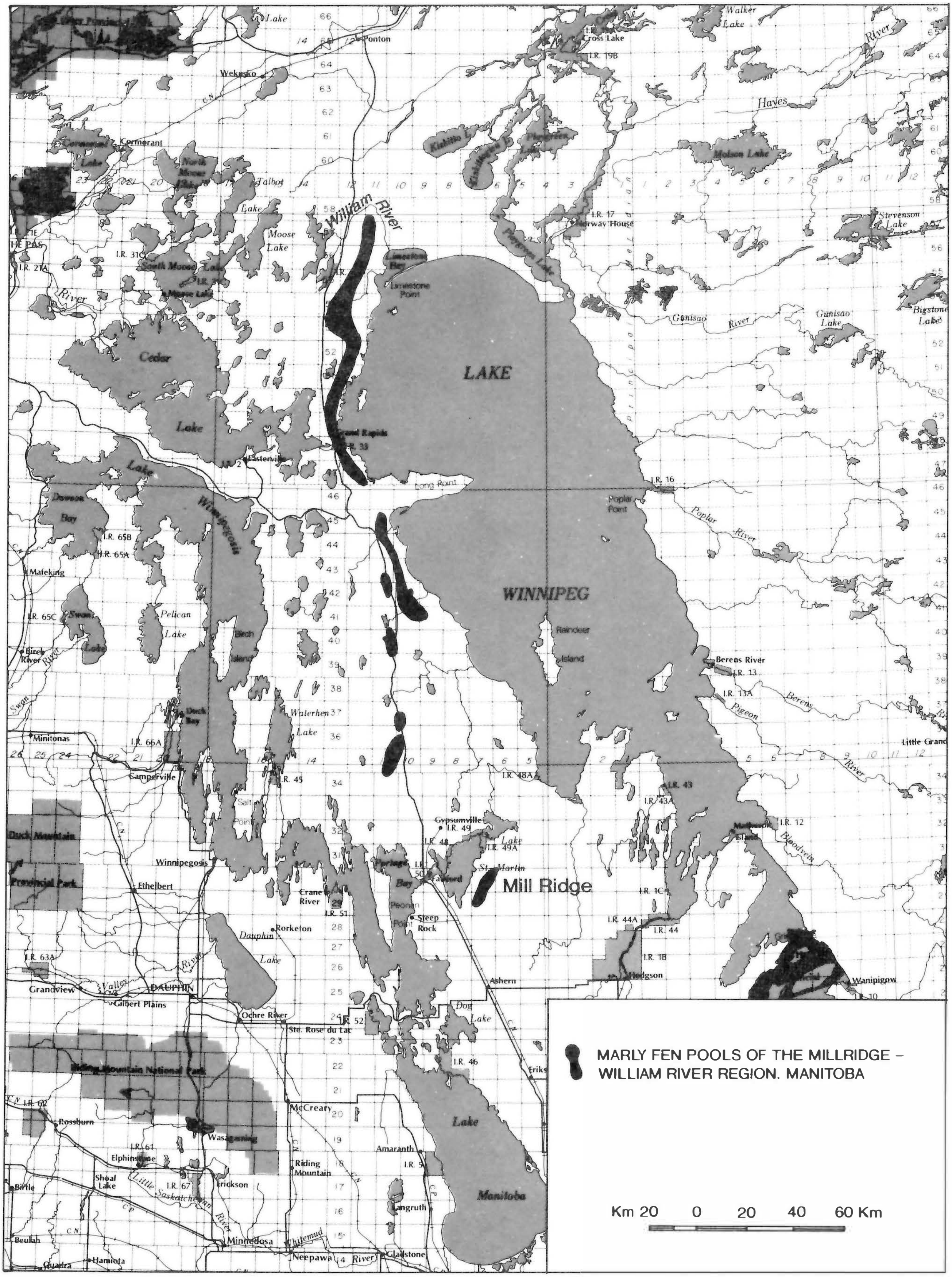

Figure GS-29-8: *Marly fen pools of the Mill Ridge - William River region, Manitoba.*

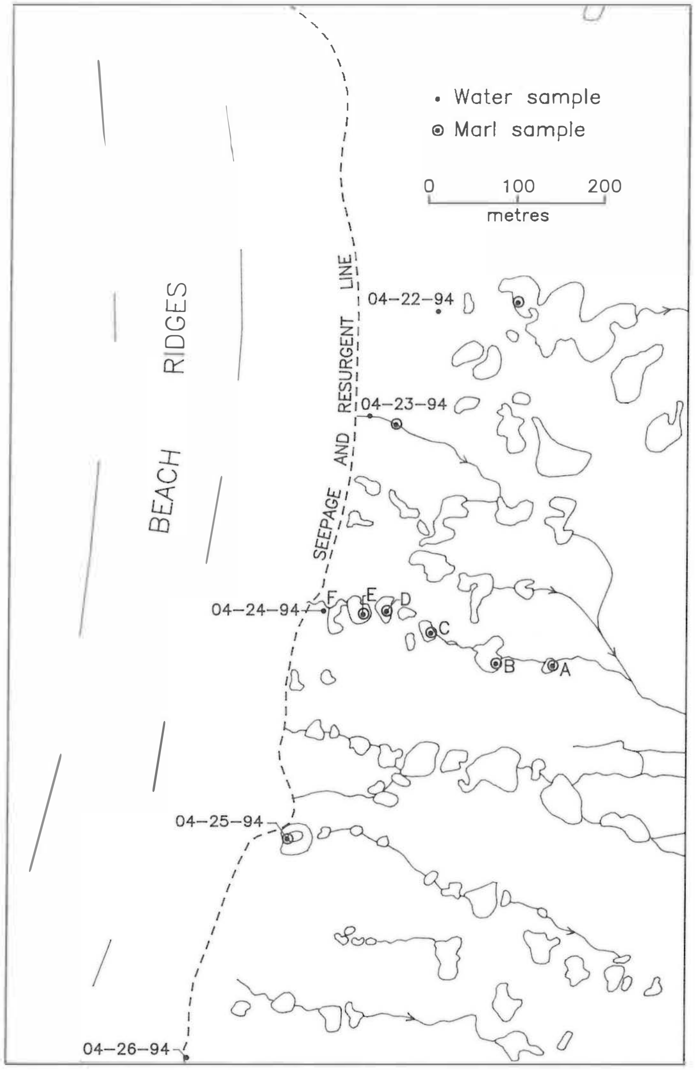

Figure GS-29-9: *a) Serial sampling (F to A), of marls and marly fen pools (pH and T°C) at station 04-24-94, NE of Menauhswun Lake, Grand Rapids (see Fig. GS-29-3a for location).*

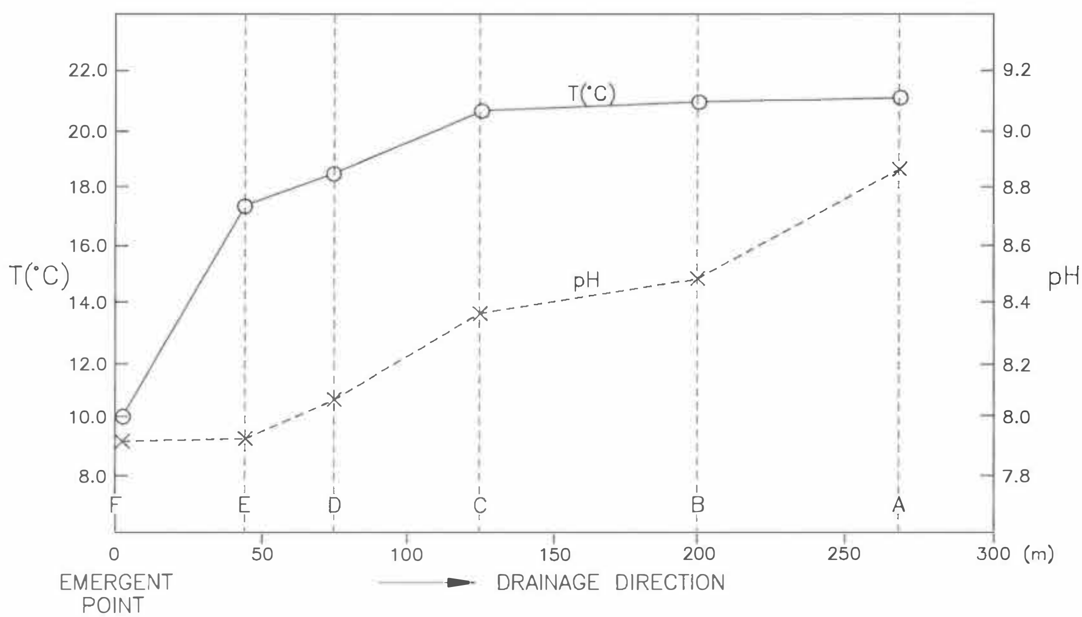

Figure GS-29-9: *b) In situ T (°C) and pH measurements on waters from marly fen pools show increases in both parameters, over the first 270 m downstream.*

GS-30 NEW GEOLOGICAL OBSERVATIONS IN THE RICE LAKE BELT, SOUTHEASTERN MANITOBA (NTS 52M/3,4 AND 52L/14)

by K.H. Poulsen[1], W. Weber, D.F. Garson[1] and R.F.J. Scoates[1]

Poulsen, K.H., Weber, W., Garson, D.F. and Scoates, R.F.J., 1994: New geological observations in the Rice Lake belt, southeastern Manitoba (NTS 52M/3,4 and 52L/14); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 163-166.

SUMMARY

Field work in 1994 has added considerable new knowledge of the geology of the Rice Lake greenstone belt since the last compilation in 1971. This information will be integrated with mineral deposits data in map form to complete this project. Of particular exploration significance are (1) the recognition of hydrothermally altered volcanic rocks prospective for volcanogenic base metal mineralization in the Little Beaver Lake area northwest of Bissett and the Garner Lake segment of the belt, (2) the association of banded iron formation and komatiites north of Garner Lake in a setting conducive to the formation of nickel sulphide deposits, and (3) the presence of strongly carbonatized shear zones that are attractive for gold exploration at Garner Lake.

INTRODUCTION

An initial step in this project (Project C1.108) of the Canada-Manitoba Partnership Agreement on Mineral Development involved the transfer of existing geological and mineral deposit information from various map sources into digital form using Autocad™ software in order to produce a 1:100 000 compilation of the Rice Lake belt. The source maps were produced by several geologists over a period of more than 50 years, so it is understandable that discrepancies were discovered at several locations where existing maps overlap. Therefore, three weeks' field work were conducted in the Rice Lake greenstone belt (Fig. GS-30-1) during August 1994 to verify the location and nature of major lithological and structural boundaries and mineral occurrences. Several important revisions, which also incorporate new U-Pb zircon data obtained earlier in the project (Poulsen *et al.*, 1993; D.W. Davis, unpubl. report), are described below.

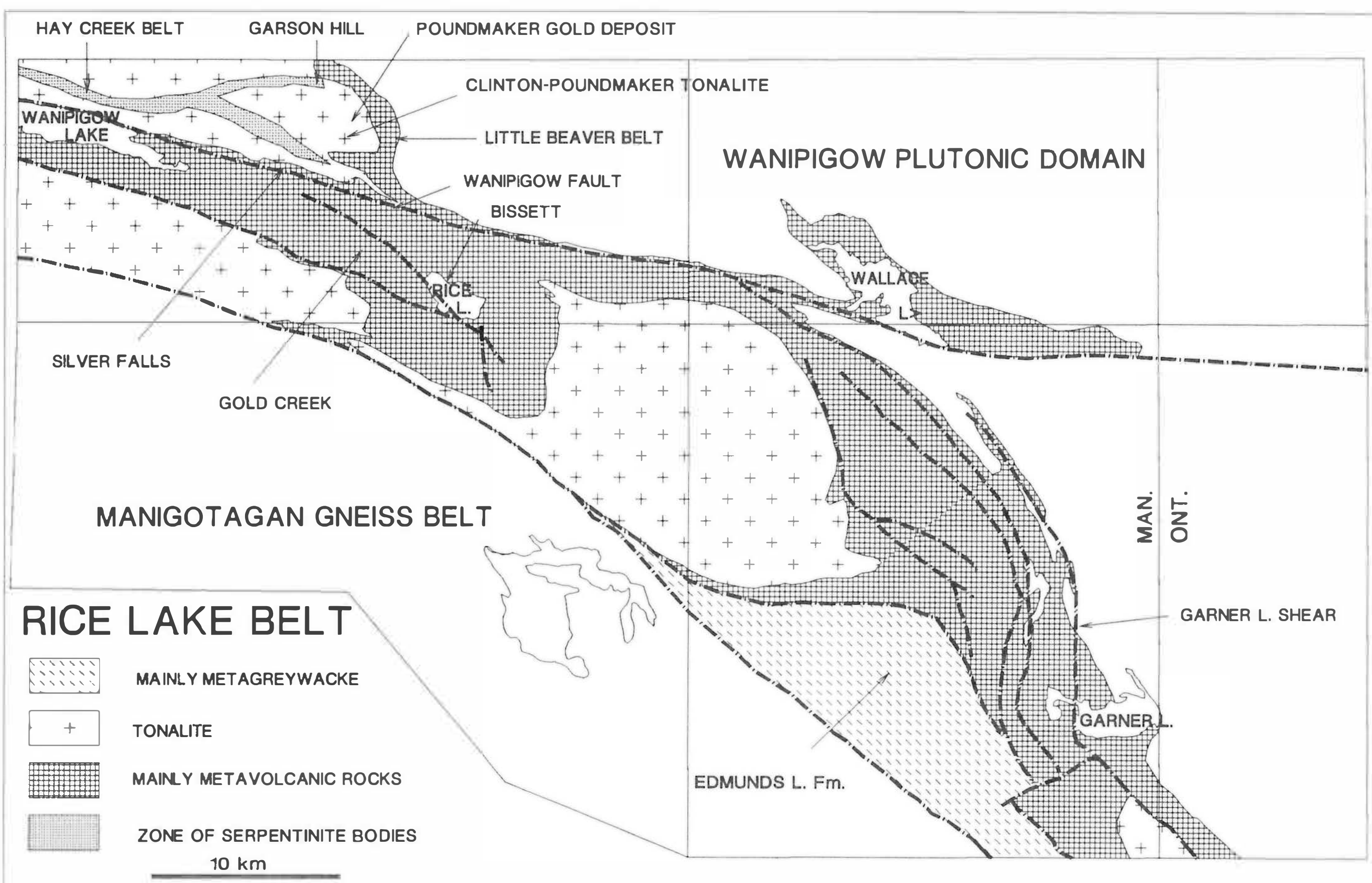

Figure GS-30-1: Geological sketch map of the Rice Lake belt.

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

WANIPIGOW LAKE - LITTLE BEAVER LAKE AREA

A new belt containing ultramafic rocks, coincident with a well defined airborne gradiometer anomaly (Geological Survey of Canada, 1988), was identified northeast of Wanipigow Lake. This belt is the northernmost of two branches which split from the Hay Creek serpentinite belt (Fig. GS-30-1). Massive serpentinite is exposed at Garson Hill west of the logging road to Pointer Lake (north of Garson Hill), but cannot be traced further east, suggesting a fault contact between the east-trending ultramafic belt and a prominent northeast-trending belt of mafic to felsic volcanic rocks through Little Beaver Lake. The contact between these supracrustal rocks of the Little Beaver Belt (LBB) and tonalite to the west is intrusive but pre-tectonic as evidenced by the tectonic transposition of rocks in the contact zone. The supracrustal rocks of the LBB are portrayed on existing maps as metagreywacke (Davies, 1950; Weber, 1971), but based on this year's survey, most of them are interpreted to be intermediate to felsic metavolcanic rocks that have been metamorphosed to amphibolite facies, resulting in a relatively high biotite content. Patchy rusty weathered zones within some felsic metavolcanic units are suggestive of synvolcanic sulphidic stockworks, and the local presence of garnets may reflect a precursor synvolcanic hydrothermal alteration of the type associated with volcanogenic massive sulphide deposits.

The granitoid rocks to the west of the LBB have tonalitic compositions. The Clinton-Poundmaker tonalite (Fig. GS-30-1) is massive and relatively undeformed, whereas its equivalent to the south is foliated between the Hay Creek serpentinite belt and the Wanipigow Fault. The Poundmaker gold deposit occurs in a northwest-striking shear zone with apparent dextral components of movement. Mineralization consists of a 2 to 3 m wide massive quartz vein with local laminated quartz as well as quartz stringers in a mafic schist (foliated mafic dyke?); pyrite, ankerite, fuchsite and siderite occur within the quartz veins.

Iron formation is indicated on several maps (*cf.* Weber, 1971) near the trace of the Wanipigow Fault east of Wanipigow Lake. Its locations also coincide with positive airborne gradiometer anomalies (Geological Survey of Canada, 1988). The iron formation is discontinuous but appears to occupy two spatially and lithologically distinctive positions. The first, as narrow bands of weakly magnetic iron formation, is intercalated with strongly foliated basalt, in part pillowed, directly north of the Wanipigow Fault. The second, not observed in outcrop, is indicated by magnetic anomalies to occur within a poorly exposed band of metasedimentary rocks directly south of the Wanipigow Fault. These metasedimentary rocks are exposed at Silver Falls on the Wanipigow River where a southward-fining clastic sequence includes polymictic metaconglomerate, thick bedded to massive quartz arenite, siltstone and argillite. The magnetic iron formation appears to be associated with this unit. The sedimentary package extends west of Wanipigow Lake (Weber, 1991) where it consists of thick bedded arenite and interlayered argillite, but no conglomerate or iron formation.

There are many uncertainties in correlating this local metasedimentary package on a regional scale. Stockwell (1940) correlated the metaconglomerate with the San Antonio Formation at Horseshoe Lake, the youngest post-volcanic (<2.73 Ga) supracrustal sequence in the Rice Lake belt, but included the finer grained rocks, including iron formation, with Rice Lake Group volcanic rocks. We have seen no evidence that supports separation of the coarse- and fine-grained metasedimentary rocks into separate groups. Thus several interpretations are feasible:

1. The conglomerate, quartz arenite, siltstone, argillite and iron formation are all part of the San Antonio Formation. This would imply that the San Antonio Formation would include more diverse lithologies, such as a distinct subaqueous facies, than are present at the type locality between Rice Lake and Horseshoe Lake. Such diverse lithologies are known from equivalent post-volcanic assemblages in the Superior Province, *e.g.*, in the Island Lake belt (Neale, 1984).
2. The diverse rock types are part of the Conley Formation (McRitchie, 1971) at Wallace Lake, also an association of quartz arenite, conglomerate, argillite and iron formation. This would appear less likely, however, in that the conglomerate at Silver Falls contains abundant volcanic and/or hypabyssal clasts, whereas the conglomerate at Wallace Lake is dominated by plutonic tonalite clasts. Their correlation would imply that the sedimentary rocks at Silver Falls are relatively old (pre-2.9 Ga; D.W. Davis, unpubl. report).
3. The coarse to fine sedimentary sequence is part of the Edmunds Lake Formation, which is known to locally contain all of the same lithologies. This interpretation was adopted by Weber (1971, 1991). The only contrary evidence is that the arenaceous rocks at Silver Falls and west of Wanipigow Lake lack well developed structures typical of turbidites (*e.g.*, rhythmic layering, well developed graded bedding, etc.) that are characteristic for metasediments of the Edmunds Lake Formation; this implies a slightly different facies of the Edmunds Lake Formation.
4. The sedimentary rocks at Silver Falls represent a sequence that is distinct. As this is most convenient, they will likely be portrayed as distinct in the current compilation with the full understanding that any of the above correlations could be valid.

GOLD CREEK AREA WEST OF RICE LAKE

Stockwell's (1945) map shows an isoclinal fold that affects gabbro units in the area west of Rice Lake. Neither the airborne gradiometer anomalies (Geological Survey of Canada, 1988) nor our reconnaissance of selected outcrops support the presence of this fold. The rock sequence is remarkably similar to the homoclinal moderately north-dipping sequence of felsic to intermediate volcaniclastic rocks intercalated with gabbroic sills at Bissett (Poulsen *et al.*, 1986). The presence of this distinct stratigraphic package and probable longitudinal shear zones within the sequence at Gold Creek compare favourably with the stratigraphic and structural setting in the vicinity of the San Antonio mine and further exploration may be warranted.

WALLACE LAKE AREA

Field relationships at Wallace Lake were re-examined in light of new geochronological data (Turek and Weber, 1991; Turek *et al.*, 1989; D.W. Davis, unpubl. report) that establish the metasedimentary rocks of the Conley Formation (McRitchie, 1971) at Wallace Lake as among the oldest rocks in the Rice Lake belt. A well exposed section of the Conley Formation in the vicinity of the Conley shaft shows that quartz arenite was successively intruded by gabbro, diorite, feldspar porphyry and quartz porphyry dykes and sills prior to regional deformation. Zircons from the quartz porphyry yielded a U-Pb age of 2920.6 ± 3 Ma (D.W. Davis, unpubl. report). This has also been demonstrated on a larger scale near the Jeep Mine where a 2880 Ma pre-deformational granodiorite intrudes the Wallace Lake supracrustal sequence. This inferred "older" gabbro-granitoid magmatism appears to be part of the Wanipigow River Plutonic Suite, a term that demands re-evaluation. The "Suite" as it is currently known, consists not only of (a) this "older" gabbro-granitoid magmatism but also of (b) even older pre-Conley Formation plutonic tonalitic "basement" (*ca.* 3000 Ma, Turek and Weber, 1991 and GS-31, this volume; D.W. Davis, unpubl. report) and (c) much younger (2730 Ma) granodiorite that is equivalent in age to the main period of volcanism in the Rice Lake belt. The plutonic rocks north of the Wanipigow River form a "domain" of rocks with diverse crystallization ages rather than a comagmatic plutonic "suite".

Selected exposures of ultramafic rocks at Wallace Lake were briefly examined. There appear to be two distinct varieties: serpentinite and actinolite schist. Serpentinite had been recorded at one locality on the north shore of Wallace Lake (Scoates, 1971), but Theyer (1983) noted that this body is part of a more extensive flow. Our survey verified the presence of an ultramafic body with >1 km strike length in contact with Conley Formation quartz arenite, but was unable to identify spinifex texture. Based on chemical composition and on field characteristics, it is likely, therefore, that this serpentinite is intrusive like those along the Hay Creek belt and at Garner Lake. Actinolite schist (McRitchie, 1971) also occurs as thin concordant lenses in association with the Conley Formation. It has been interpreted as either unusual clay-rich magnesian metasedimentary rocks or as a variety of ultramafic rocks. No features were observed in this survey that would resolve this question. Whole rock chemical analyses (in progress) should allow a comparison with proven komatiites from other locations in the Rice Lake belt.

GARNER LAKE AREA

Brommecker *et al.* (1993) recognized significant volumes of komatiitic rocks between Beresford Lake and the Garner Lake area. Poulsen *et al.* (1993) identified a *ca.* 2870 Ma age for gabbroic pegmatite that cuts the Garner Lake layered ultramafic intrusion, which in turn, cuts older volcanic and sedimentary rocks. This suggests that much of the Garner Lake area is underlain by rocks of the older >2.9 Ga assemblage, which predates 2.73 Ga greenstones comprising most of the Rice Lake belt. The existing maps do not separate this older assemblage from the younger greenstones. One week of field work was spent in the Garner Lake area to answer this question, but this problem could not be resolved. Several discrepancies between existing maps and our survey indicate that the region requires remapping.

The Garner Lake area is transected by numerous north-striking shear zones, along with north-northwest-striking cleavage (D_2)(*cf.* Brommecker *et al.*, 1989) and folds that result in large-scale transposition of originally east-striking units. The Garner Lake Shear Zone, one of the most prominent north-trending structures, divides the Garner Lake area into two geologically distinct eastern and western parts.

The area east of the Garner Lake Shear Zone contains a relatively coherent east-trending stratigraphic package of supracrustal and intrusive rocks that is at least 5 km thick as measured from north to south. The entire sequence has been metamorphosed to amphibolite facies assemblages and includes:

1. a lowermost sequence of intercalated felsic and mafic metamorphic rocks of uncertain origin. Fine grained biotite-bearing felsic rocks predominate; these are either metarhyolite or meta-arenite, but a strong foliation precludes a convincing demonstration of either interpretation. In some cases the felsite contains clasts. The mafic rock is strongly foliated homogeneous amphibolite, which is consistent with a gabbro protolith.
2. the Garner Lake ultramafic intrusion, consisting of alternating layers of serpentinite and pyroxenite (Scoates, 1971), which by their disposition, suggest their fractionation within a sill (or series of sills) that tops to the north. The pyroxenite locally contains metre-wide gabbroic dykes that yielded *ca.* 2870 Ma zircons (Poulsen *et al.*, 1993).
3. a previously unrecorded (≈200 m wide) unit of gabbro with minor pyroxenite that occurs directly north of the ultramafic rocks. It is not certain whether this is a more fractionated phase of the Garner Lake ultramafic intrusion or a separate body. At several locations, modally graded layers from 10 to 50 cm thick are locally interlayered with pyroxenite.
4. gabbro that is overlain by (and probably intrudes) hydrothermally altered volcanic rocks. Adjacent to the Garner Lake Shear Zone the altered volcanic rocks consist mainly of felsic tuff, lapilli tuff and volcanic breccia that were hydrothermally altered before being metamorphosed to assemblages containing biotite, anthophyllite (up to 50%) and possible cordierite. A probable exhalative unit containing pyrite, traces of chalcopyrite and possibly andalusite occurs near the top of the sequence immediately east of the Garner Lake Shear Zone.
5. a sequence of intercalated tholeiitic basalt, komatiitic basalt and komatiite that overlies the felsic volcanic rocks to the north. This sequence locally contains interflow units of banded magnetite iron formation and is capped by a thin iron formation unit. Spinifex texture is common in the komatiite. Basalts are commonly pillowed and indicate tops to the north.

The western part of the Garner Lake area contains several units that are comparable to those in the eastern part, particularly komatiite and banded iron formation, but is structurally more complex due to the greater abundance of north-trending transecting shear zones. In general, the rocks in the western part were metamorphosed at a lower grade. Serpentinite-pyroxenite units that characterize the Garner Lake ultramafic intrusion are absent in the western part and greater volume of gabbro (including pyroxenite and magnetic quartz-ferrogabbro) is present. Gneisses exposed along the southern shore of the east-trending arm of Garner Lake either were derived from quartz-bearing sandstone that nonconformably overlie quartz ferrogabbro and gabbro or are highly sheared variants of these plutonic rocks. This unit has yielded *ca.* 2870 Ma zircons (D.W. Davis, unpublished report) that again indicate an early phase of magmatism in the Rice Lake belt. An erosional nonconformity between such rocks and the overlying komatiite and tholeiite would imply that there is no genetic link between the plutonic and volcanic rocks, contrary to the interpretation of Poulsen *et al.* (1993).

The north-striking shears that punctuate the geology of the Garner Lake area contain zones of intense carbonate alteration characterized by 1 to 3 m wide pods of massive ankerite containing ramifying quartz veinlets. The intensity of carbonatization is unusual for the Rice Lake belt, perhaps reflecting mafic to ultramafic protoliths, but is reminiscent of similar zones in the Cochenour-Balmertown area within a comparable rock sequence in the Red Lake greenstone belt, northwestern Ontario.

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GS-31 THE 3 GA GRANITOID BASEMENT TO THE RICE LAKE SUPRACRUSTAL ROCKS, SOUTHEAST MANITOBA

by A. Turek[1] and W. Weber

Turek, A. and Weber, W., 1994: The 3 Ga granitoid basement to the Rice Lake supracrustal rocks, southeast Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 167-169.

Zircons were separated from a tonalite from the south margin of the English Lake magmatic complex (Fig. GS-31-1) to obtain a U-Pb age. Previous mapping in the English Brook area indicated that this rock unit may be older than supracrustal rocks in the Rice Lake belt (Weber, 1991).

Zircons separated from this tonalite are gem quality, colourless to very slightly pink, euhedral stubby to elongate. They are free of opaques and other inclusions; alteration and fractures are minimal. Some of the long grains show minor surface erosion. Six fractions were analyzed, four fractions (B, C, D, F) were abraded, the other two (A, E) were not abraded. All fractions were upgraded by hand picking.

The analytical results of the zircons are given in Table GS-31-1 and plotted on a concordia plot (Fig. GS-31-2). The regression of the age was done using the Ludwig (1991) program. The indicated age is 3003.2 ± 2.5 Ma and the regression is within experimental error. The U and Pb concentrations determined in these zircons are characteristically low. Fractions B and C, which are very discordant, have a relatively higher U and Pb content than the other four fractions, but they are collinear with the other more concordant data points. The regression of the concordant points D, E, F and the slightly discordant point A, which are all low in U and Pb, yield an age of 3002.9 ± 2.7 Ma, also within experimental error.

This 3003 Ma tonalite is one of the oldest ages obtained from rocks of the Rice Lake belt and the adjacent Berens River domain to the north. Other data indicate that rocks of similar age (3.0 - 3.01 Ga; Turek and Weber, 1991, D.M. Davis, unpubl. report) are the source of detritus for sediments of the >2.9 Ga Conley Formation (D.M. Davis, unpubl. report). This is considered to be part of an older platform assemblage, predating 2.73 Ga volcanic rocks that comprise most of the Rice Lake greenstone belt (Turek and Weber, 1991). This implies that rocks of the dated English Lake magmatic complex are likely basement to the older supracrustal assemblage. Unfortunately, the presence of a faulted contact between the dated unit and plutonic and sedimentary rocks of the Rice Lake belt does not provide additional field evidence, such as a regolith or intrusive relations.

Additional evidence for the presence of 3 Ga basement are the presence of zircons older than 2906 Ma in the Jeep mine granodiorite (Turek *et al.*, 1989), 3.0 and 3.01 Ga detrital zircons in Edmunds Lake Formation metasediments (D.M. Davis, pers. comm., 1994) and a 3.0 Ga component identified in detrital zircons from paragneiss at Black Lake, which are presently being analyzed by A. Turek using the Australian SHRIMP ion microprobe.

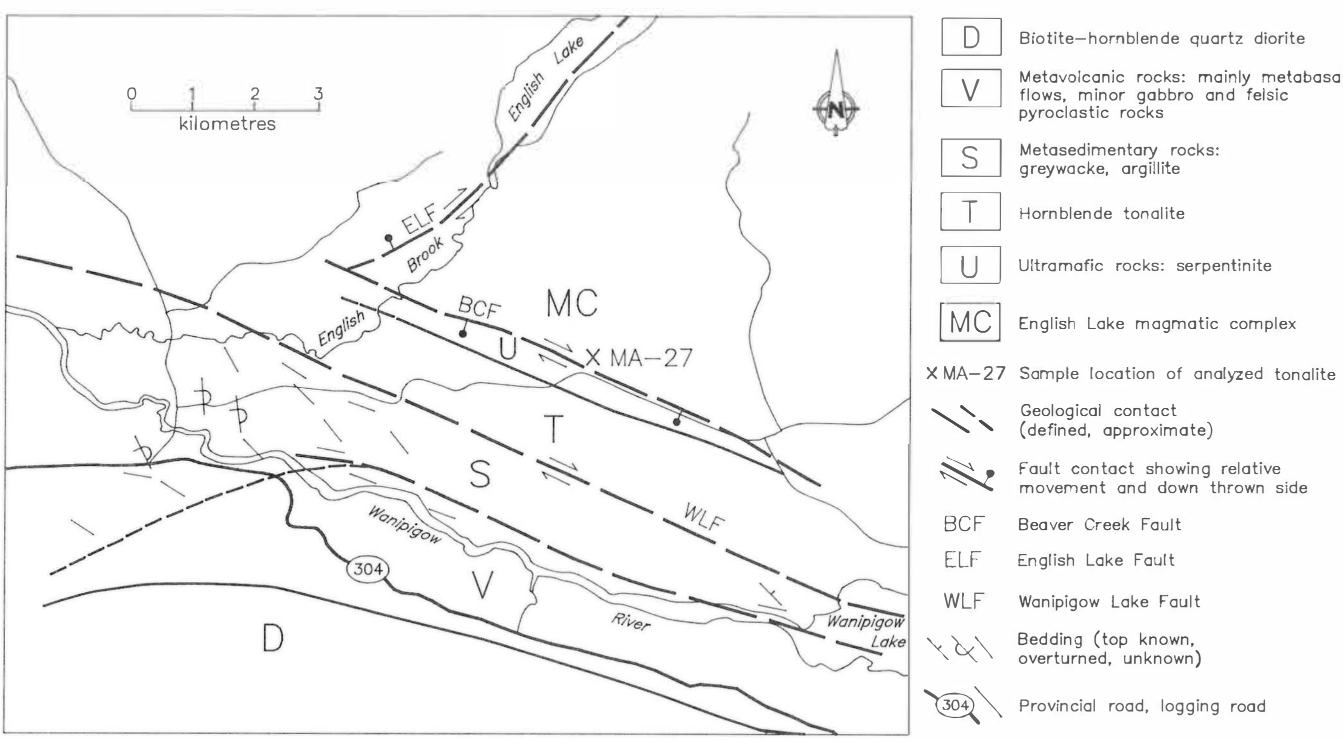

Figure GS-31-1: General geology of the English Brook area with sample location of the analyzed tonalite (MA-27).

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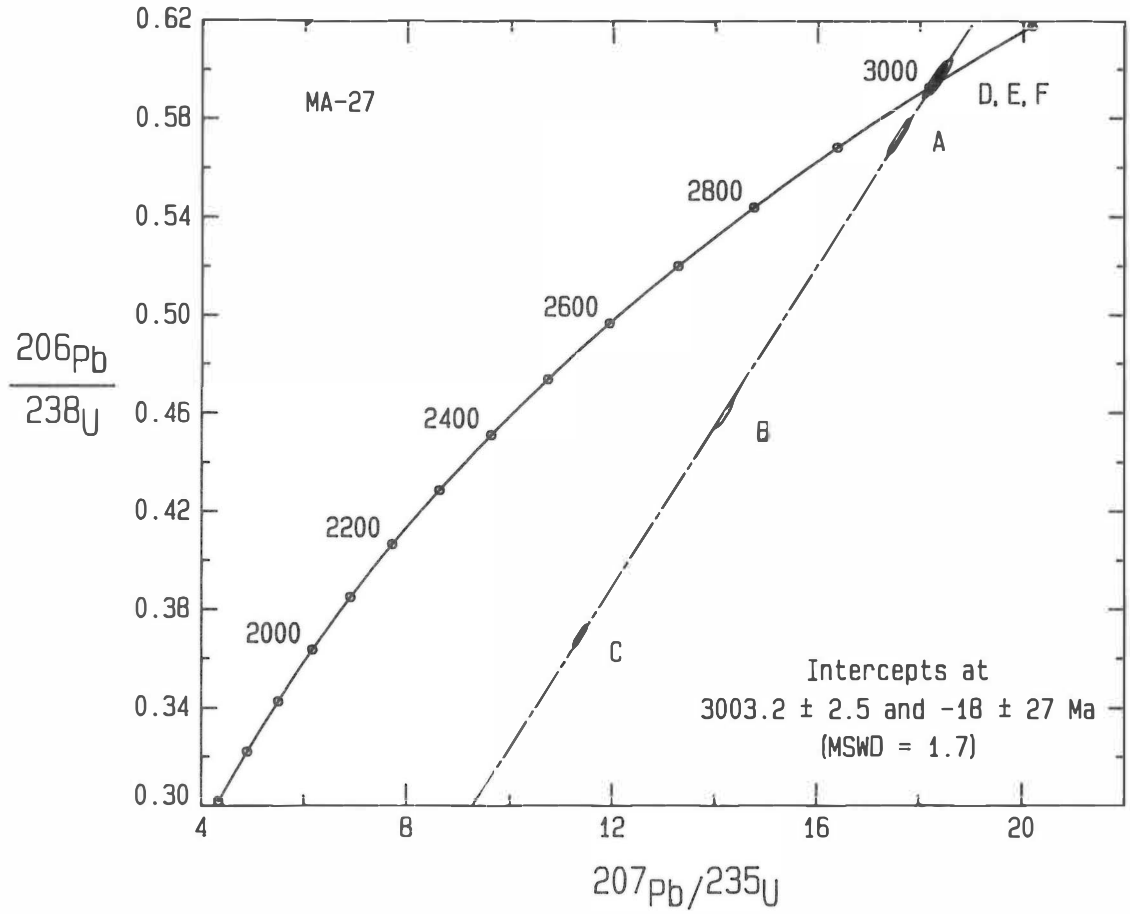

Figure GS-31-2: Concordia diagram for tonalite (MA-27), near English Brook.

Table GS-31-1
Analytical data for zircons from the tonalite of the English Lake magnetic complex, near English Brook, sample MA-27

Sample detail[a]				Concentration		Atomic ratios					Apparent ages(Ma)[e]		
Sample no.	Magnetism	Grain size(μ)	Weight (mg)	(ppm) U	Pb	$^{204}Pb/^{206}Pb^{b}$	$^{208}Pb/^{206}Pb^{c}$	$^{207}Pb/^{206}Pb^{c}$	$^{207}Pb/^{235}U^{d}$	$^{206}Pb/^{238}U^{d}$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
A	m0	188	1.7	15	11	0.00158	0.17971	0.22942	17.602	0.5727	2919	2968	3002
B	m2	114	1.2	66	37	0.00027	0.16657	0.22389	14.198	0.4599	2439	2763	3009
C	m0	62	1.0	74	32	0.00061	0.15846	0.22385	11.372	0.3693	2026	2554	3005
D	m2	114	0.9	26	19	0.00069	0.17212	0.22356	18.403	0.5970	3017	3011	3006
E	m0	62	1.6	26	18	0.00058	0.16208	0.22283	18.308	0.5959	3013	3006	3001
F	m0	114	1.0	29	21	0.00061	0.16770	0.22280	18.289	0.5954	3011	3005	3001

[a] Relative magnetic susceptibility of zircons is reported as m0 (nonmagnetic) to m2 (paramagnetic) and is related to the indicated inclination of the Frantz isodynamic separator using maximum current of 2 A. Grain size is an average; sieves used were 225, 152, 76, 48 μ.

[b] Measured ratio.

[c] Blank corrected.

[d] Blank and nonradiogenic Pb corrected.

[e] Decay constants used; $\lambda^{238}U = 1.55125 \times 10^{-10} year^{-1}$; $\lambda^{235}U = 9.8485 \times 10^{-10} year^{-1}$ (Steiger and Jäger, 1977).

GS-32 QUATERNARY GEOLOGICAL INVESTIGATIONS RELATED TO DRIFT PROSPECTING, RICE LAKE GREENSTONE BELT, MANITOBA (PARTS OF NTS 62P/1, 52M/4, 52M/3 AND 52L/14)*

by P.J. Henderson[1]

Henderson, P.J., 1994: Quaternary geological investigations related to drift prospecting, Rice Lake greenstone belt, Manitoba (Parts of NTS 62P/1, 52M/4, 52M/3 and 52L/14); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 170-171.

SUMMARY

Regional drift sampling and surficial geology mapping in the Rice Lake greenstone belt (NTS 62P/1 and 52M/4) were essentially completed in 1993. The results of the geochemical, mineralogical and lithological analyses of sediment and humus samples have been released as GSC Open File 2910 (Henderson, 1994a). Surficial geology maps are in preparation.

During a short field season, additional bulk till sampling and checking of surficial mapping was conducted in the western portion of the area (NTS 62P/1, 52M/4, 52M/3, 52L/14). This concludes field work for this project, part of the joint Canada-Manitoba Partnership Agreement on Mineral Development. Results of visible gold grain counts obtained by tabling these samples show high numbers of predominantly pristine grains from three sites.

INTRODUCTION

Quaternary geological studies oriented toward mineral exploration through drift prospecting were conducted in the western part of the Rice Lake greenstone belt (NTS 62P/1 and 52M/4) as part of the joint Canada-Manitoba Partnership Agreement on Mineral Development (1990-1995)(Henderson, 1993, 1994b; Henderson *et al.*, 1993). The program has three main objectives: 1) to identify chemical and mineralogical components of till and humus associated with bedrock mineralization, 2) to establish a regional geochemical database as a means of determining background and anomalous concentrations of relevant elements, and 3) to provide a geological framework for interpreting the glacial dispersal of those components of till derived from mineralized bedrock.

DRIFT COMPOSITION

Field Procedures

Drift sampling in the area was focused along a 5-6 km wide corridor parallel to Provincial Road 304 and roughly coincident with the greenstone belt. A total of 210 3-kg sediment samples were collected from hand-dug pits, and natural and man-made exposures. At selected sites, 10 to 12 kg bulk till samples were also collected. Pits were dug to bedrock or 1.0 m depth and, in nearly all cases, samples were collected below the A and upper B horizon.

In addition, a total of 186 humus samples were taken. The well decomposed, dark organic part of the uppermost soil horizon (A_1) was preferentially sampled.

Analytical Procedures

The <0.002 mm (clay) and <0.063 mm (silt and clay) fractions of the original sediment sample were analyzed for trace metal contents. Clay was separated by centrifugation and decantation; silt and clay by dry sieving. Both fractions were analyzed for a suite of elements using inductively coupled plasma atomic emission spectrometry (ICP-AES) after aqua regia partial digestion. Gold, was determined using cold vapour atomic absorption spectrometry (CV-AAS) on the <0.002 mm size fraction. Au, Pt, and Pd concentrations were determined by fire assay/atomic fluorescence spectrometry analysis of the <0.063 mm fraction. In addition, the carbonate content (AAS; <0.063 mm fraction), texture, and pebble composition (4-8 mm fraction) were determined.

Humus samples were air dried and sieved to obtain the <0.0425 mm fraction. This material was analyzed using a commercial ICP-AES multi-element package. Mercury was determined using CV-AAS. The silt and clay fractions and the humus samples were analysed at Chemex Labs Ltd., Mississauga, Ontario.

The 10 to 12 kg samples collected at selected sites were processed by Overburden Drilling Management Ltd., Nepean, Ontario to extract a <2 mm heavy mineral concentrate. Separation was achieved using a shaker table and diluted methylene iodide (s.g.=3.1). Visible gold grains observed on the shaker table and in pans were counted and classified on the basis of size and morphology. Three shape classes (pristine, modified, reworked) reflect the basic appearance and surface texture of the grain and have been used as an indication of distance of glacial transport by Averill and Zimmerman (1986), and DiLabio (1990). The >0.025 mm fraction of the nonferromagnetic heavy mineral concentrate will be examined for kimberlite indicator minerals.

Results

The results of all geochemical and lithological analyses, as well as visible gold counts from bulk till samples collected in 1992 and 1993, are presented in GSC open File 2910 (Henderson, 1994a). Visible gold grain counts from additional bulk till samples collected this past summer within the study area and further east along Provincial Road 304 are listed in Table GS-32-1. Figure GS-32-1 depicts the number of visible gold grains in bulk till samples collected within the study area in 1992, 1993 and 1994.

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* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

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Table GS-32-1
1994 Visible Gold Grain Counts

Sample No.	NTS	UTM			No. of Visible Gold Grains			
		Zone	Easting	Northing	Total	Reshaped	Modified	Pristine
94HJB1005	52M/03	15	328654	5653578	3	0	2	1
94HJB1006	52L/14	15	332624	5650855	4	3	0	1
94HJB1007	52L/14	15	334450	5649500	2	0	2	0
94HJB1008	62P/01	14	677060	5671965	8	3	2	3
94HJB1009	62P/01	14	680900	5674325	1	1	0	0
94HJB1011	62P/01	14	689450	5674300	8	3	2	3
94HJB1012	62P/01	14	689450	5674300	45	10	12	23
94HJB1013	62P/01	14	697480	5668240	4	0	4	0
94HJB1014	62P/01	14	708750	5663800	1	0	1	0
94HJB1015	52M/04	15	316760	5656420	31	0	9	22
94HJB1016	52L/14	15	335400	5647550	0	0	0	0
94HJB1017	52L/14	15	337409	5644917	0	0	0	0
94HJB1018	52L/14	15	336500	5643200	46	2	15	29

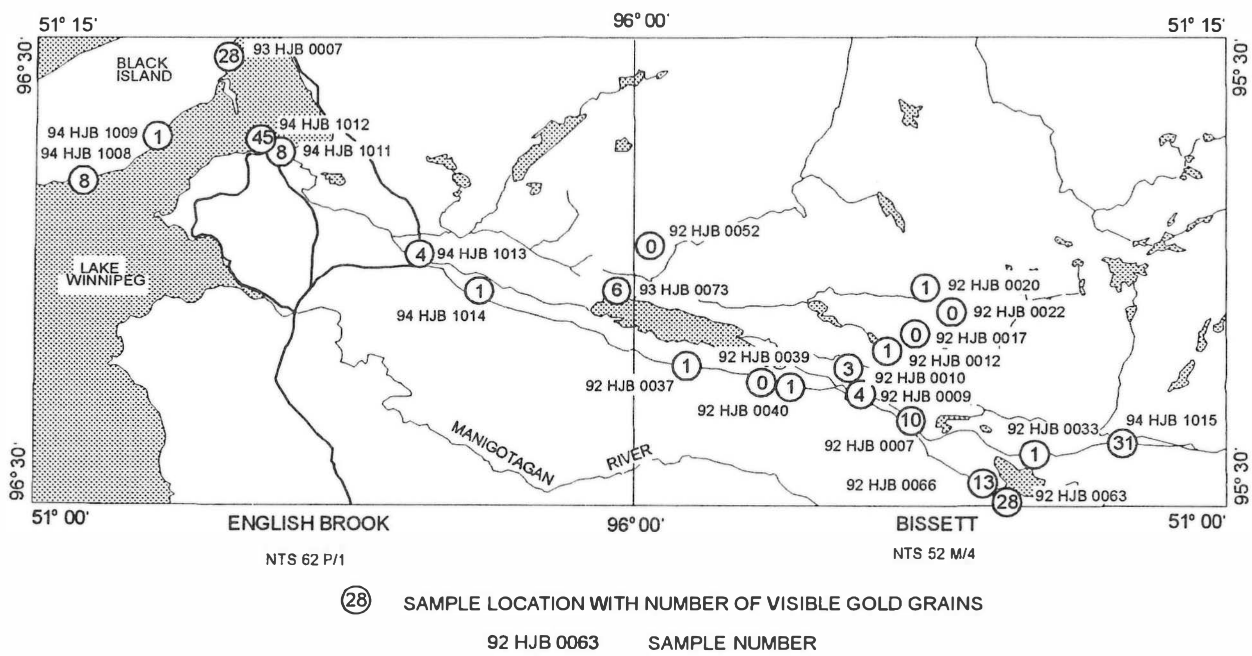


Figure GS-32-1: Visible gold grain counts from bulk till samples collected within the Rice Lake study area.

GS-33 LUMP SILICA INVESTIGATION - SOUTHEAST MANITOBA*

by J.D. Bamburak and W.D. McRitchie

Bamburak, J.D. and McRitchie, W.D., 1994: Lump silica investigation - southeast Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 172-177.

SUMMARY

Detailed mapping of the Quartz Mountain occurrence and a reconnaissance survey and sampling of surrounding occurrences of high-purity quartz were carried out in the Buffalo Lakes region, southeast of Bissett in southeastern Manitoba. Over 300 000 tonnes of high-purity quartz was inferred from this mapping and the potential for additional tonnage was indicated in the immediate vicinity.

INTRODUCTION

Investigation for potential sources of lump silica focussed on the "Quartz Mountain" area near Buffalo Lakes, 130 km northeast of Selkirk on the northern flank of the English River gneiss belt, southeast Manitoba (Fig. GS-33-1).

Quartz vein occurrences in the region were mapped and sampled (Fig. GS-33-2) and the large quartz vein that was examined by Theyer and McRitchie (1993) was mapped in greater detail (Fig. GS-33-3) to provide preliminary estimates of potential reserves.

Mining claims have been staked over the main quartz zone and other veins in the immediate vicinity by Robert and Fred Sellers and by Dave Meek. A timber-cutting chance road, built in the spring of 1994, comes within a kilometre of the Buffalo Lakes region.

BUFFALO LAKES QUARTZ VEINS

Quartz veins with three principal orientations, 000°, 300° and 325° (Fig. GS-33-2), occur with near vertical dip in foliated siltstone, greywacke and shale. Siltstone and mudstone are dominant, however, strongly foliated pelites containing altered andalusite porphyroblasts occur at the northwest fringe of the swamp in the central part of the map area. The veins are parallel to layering and/or foliation, which generally trends northwest (Fig. GS-33-4a). The longest veins are parallel to layers and crosscutting tensional, north-south veins with rafts of brecciated, variably silicified country rock. Veins parallel to layering exhibit pinch and swell structures, with thicker pods lying within fold closures (Locality 3). Oblique veins (azimuth 000°) display a greater and more consistent thickness. Folds within the metasedimentary rocks plunge 017° to the southeast. Axial planes dip at intermediate angles to the northeast.

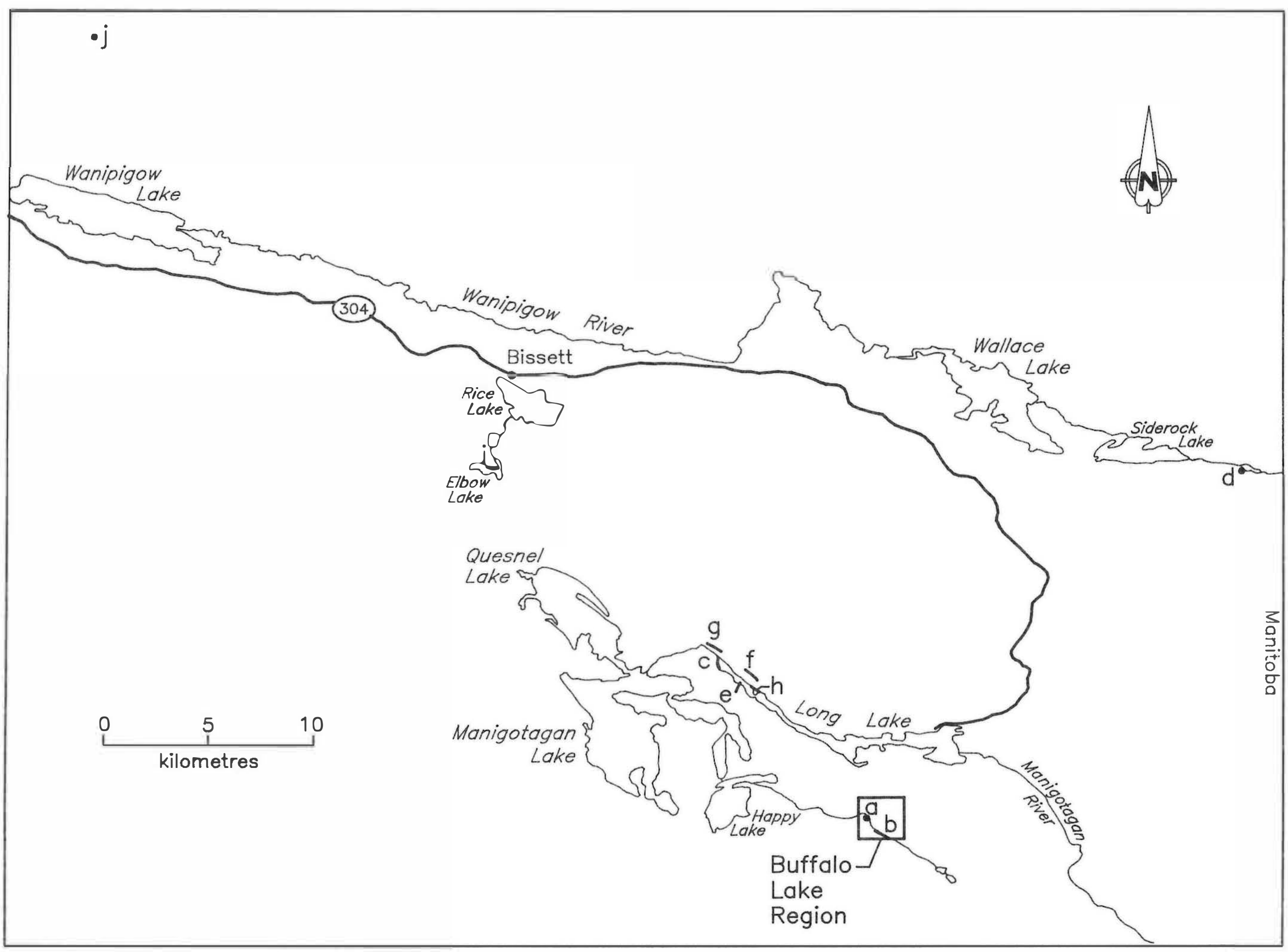


Figure GS-33-1: Regional setting of major quartz veins near Buffalo Lakes, Bissett region. Veins are labelled "a" to "j".

* Funded by Provincial A-Base

MAJOR QUARTZ VEINS BUFFALO LAKES REGION (Near Long Lake)

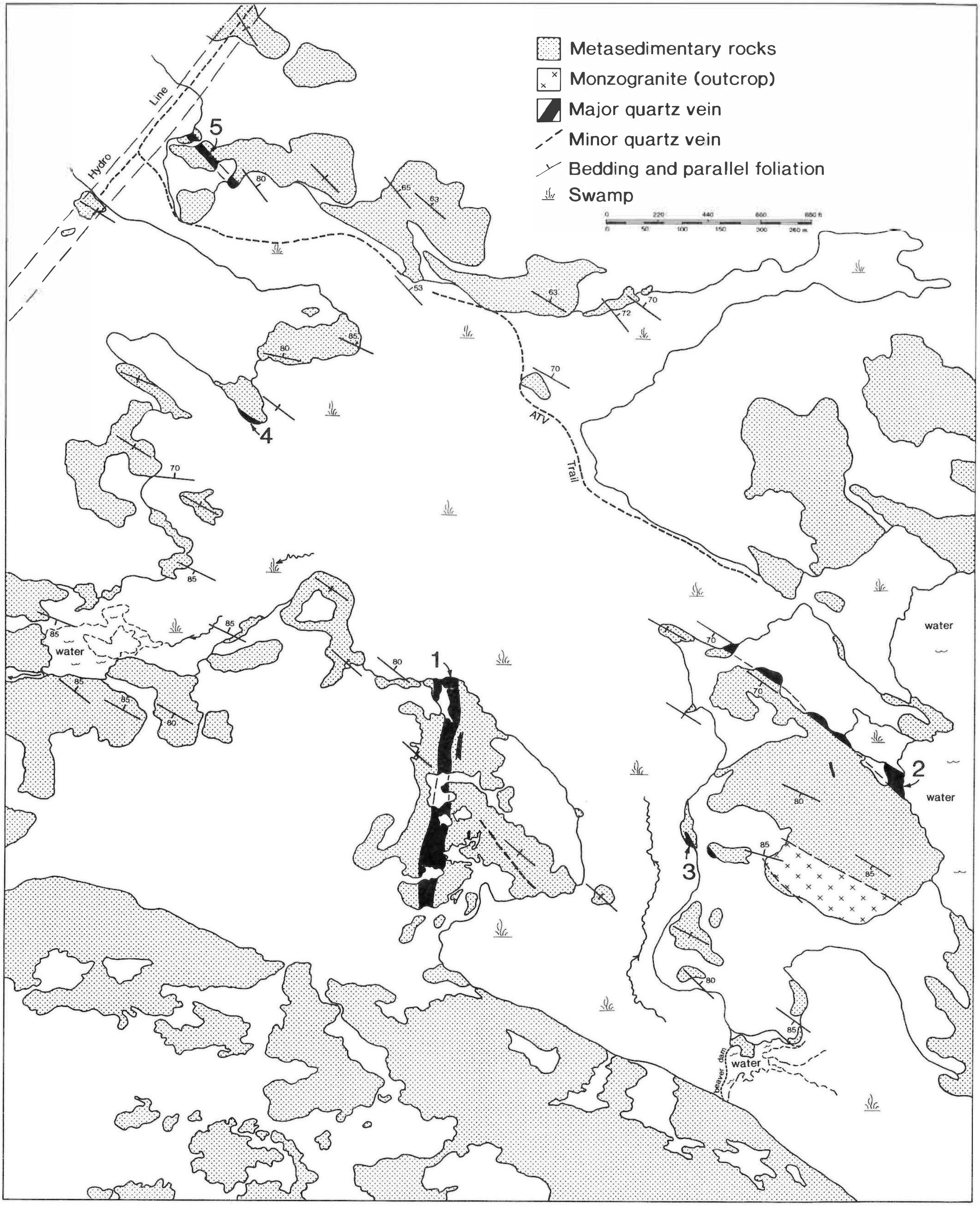


Figure GS-33-2: Major quartz veins in the Buffalo Lakes region, southeast Manitoba.

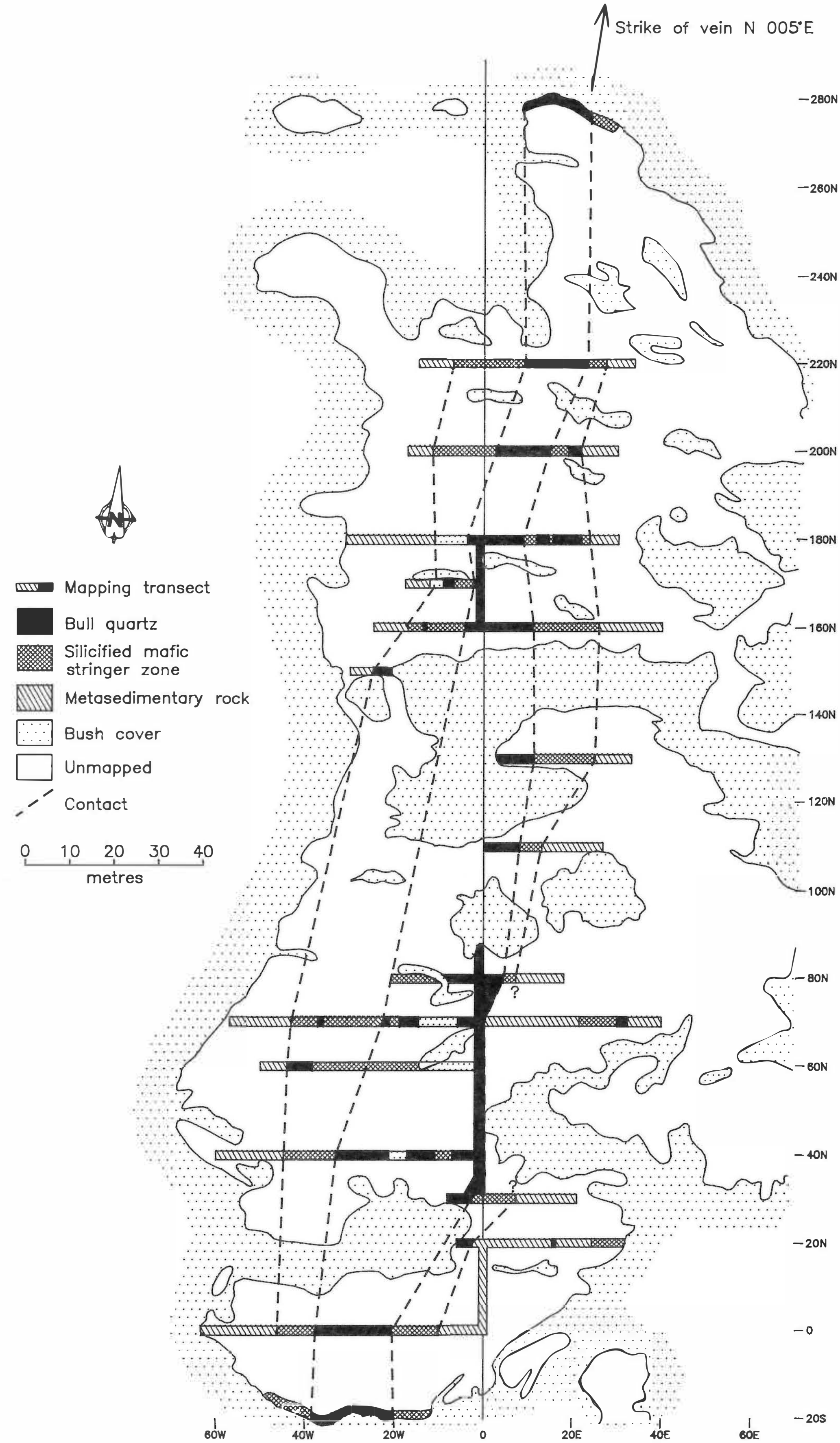
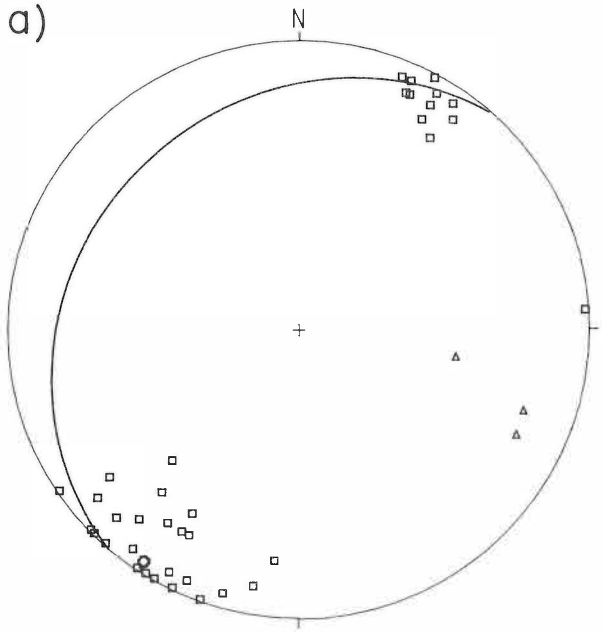


Figure GS-33-3: Detailed map of main quartz vein on "Quartz Mountain".

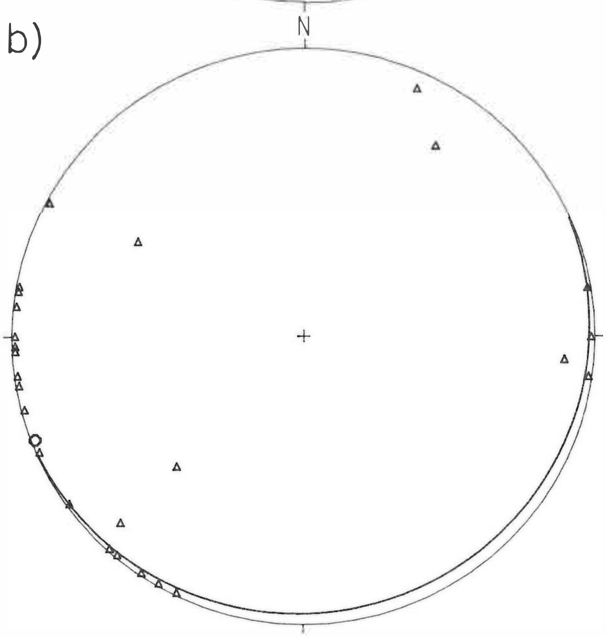
a)



FOLIATION & FOLD AXIS

Projection	Schmidt
Number of sample points	49
Mean lineation azimuth	213.4
Mean lineation plunge	3.0
Great circle azimuth	220.8
Great circle plunge	22.4
1st eigenvalue	42.32
2nd eigenvalue	4.57
3rd eigenvalue	2.11
LN (E1/E2)	2.225
LN (E2/E3)	0.775
(LN (E1/E2)) / (LN (E2/E3))	2.872
Spherical variance	0.5884
Rbar	0.4116

b)



VEINS

Projection	Schmidt
Number of sample points	33
Mean lineation azimuth	248.4
Mean lineation plunge	0.2
Great circle azimuth	65.7
Great circle plunge	4.4
1st eigenvalue	24.52
2nd eigenvalue	7.53
3rd eigenvalue	0.94
LN (E1/E2)	1.180
LN (E2/E3)	2.076
(LN (E1/E2)) / (LN (E2/E3))	0.568
Spherical variance	0.5399
Rbar	0.4601

Figure GS-33-4: Schmidt equal area projections: a) layering/foliation and fold axes; b) poles to quartz veins.

The large veins (>5 m width) (Fig. GS-33-5) have cores of white, massive, saccharoidal bull quartz that commonly exhibit ubiquitous conchoidal fractures. Contaminated zones containing thin elongated rafts of biotite-rich metagreywacke occur sporadically near outer contacts. The quartz veins are flanked by 1 to 3 m thick highly silicified zones containing quartz stockworks and lesser pale green silicified metasedimentary rock. These, in turn, give way to sheared metasedimentary rock latticed by conjugate quartz veinlets with two and commonly three orientations, one lying parallel to the dominant foliation/layering (see Fig. GS-33-4a and -4b). The number of quartz veinlets decreases outward away from the quartz core.

LOCALITY 1 - "QUARTZ MOUNTAIN" MAIN ZONE

Reconnaissance mapping of the main zone in 1993 indicated that there was potential for the presence of >1 000 000 tonnes of high purity quartz. A composite sample consisting of pieces of surface quartz taken across the southern part of the main zone contained 98.9% SiO_2 (Theyer and McRitchie, 1993).

Preliminary mapping in 1994 (Fig. GS-33-3) confirmed that the main zone consists of a core of high-purity white quartz with rare rafts and narrow inclusions of metasedimentary host rocks. It is bounded on both sides by a highly silicified zone with ghosts of metasedimentary country rock. The width of the bull quartz core pinches and swells, but appears to be no less than 20 m wide. The main zone (azimuth 005°), which crosscuts bedding (azimuth 310°-325°), has a minimum length of 310 m, a width of 30 to 50 m and an estimated depth of 30 m.

The high-purity quartz core has an exposed length of about 310 m, a minimum width of 20 m and an observed thickness of 20 m at its south end. If it is assumed that the 20 m depth of the high-purity quartz is continuous along its length, an inferred tonnage of 320 000 tonnes can be calculated using a density of 2.65 t/m^3. The potential for >1 000 000 tonnes of quartz feedstock at this locality is dependent upon the geometry of the zone at depth and the silicon metal production specifications.

SURROUNDING LOCALITIES

Grab samples from three newly documented occurrences (Fig. GS-33-2 and Table GS-33-1; Localities 2 to 5) are being analyzed to determine their composition and purity.

FURTHER WORK

The large size and significant lateral extent of the quartz veins at Localities 1 and 2 support the need for more systematic sampling and drilling of the veins to determine reliable reserves. Veins at Localities 3 and 4 warrant follow-up stripping and trenching to determine their extent, as well as sampling and analysis, should they possess mineable tonnages.

REFERENCES

Theyer, P. and McRitchie, W.D.

1993: High purity lump quartz in southeast Manitoba; **in** Manitoba Energy and Mines, Report of Activities 1993, p. 149-151.

Table GS-33-1
Locality descriptions of vein quartz occurrences in the Buffalo Lakes region, S.E. Manitoba (see Figure GS-33-2)

LOCALITY

1. Major zone of silicification (length 310 m, width 30-50 m) with central vein of high-purity, white, massive quartz flanked by peripheral zone of highly silicified, white and pale green quartz contaminated by altered metasedimentary host rock. Outer zone consists of metasedimentary rocks latticed by conjugate veinlets of quartz, 1-10 cm thick. Main vein (azimuth 005°, near vertical dip) is oblique to planar bedding/foliation in host rocks. Evaluation of the resource potential of this locality is described in detail above (Locality 1 - "Quartz Mountain" Main Zone).

2. Major zone of silicification (length 300 m+, width >10-15 m, azimuth 325°) with central vein of white, massive quartz flanked to south by 1.5 thick zone of silicified, pale green metasedimentary rock and an 8 m thick zone of quartz stringer latticework in metasedimentary rocks. North contact of vein and silicified country rock not exposed. Poor exposures on lakeshore at southeast end indicate potential width of vein quartz exceeding 20 m. Old trench (azimuth 030°) at northwest end exposes 9 m wide cross section of bull quartz. Vein is parallel to layering in host rocks.

3. 13 m wide body of weakly foliated white quartz at edge of swamp in synclinal fold nose plunging at shallow angles to southeast. Quartz and flanking zone of silicified metasedimentary host rocks to north and northwest are strongly iron stained within the core of the fold. Second 3 m wide exposure of massive quartz 70 m along strike (175°) may be the extension of this zone.

4. 4.3 m wide vein of white, pure bull quartz with cm-scale conchoidal fractures throughout. Southwest contact concealed beneath swamp. To the northeast vein is flanked by inner highly silicified zone (4.5 m wide) with dominant quartz veinlets and stringers cutting metasedimentary rock, and outer stringer zone (6.5 m wide) with lattice-work of cm-thick quartz veinlets striking 304° and 352° in yellow, green and grey metasedimentary rock. Exposed strike length of quartz vein >40 m.

5. Approximately 100 m strike length of exposed massive white quartz with minor thin metasedimentary rafts. Width of massive quartz vein is consistently 10 m; both contacts exposed. Flanking zones of silicified country rock (inner) and stringer latticework (outer) of conjugate quartz veinlets in metasedimentary host. This has similar orientation (azimuth 325°) to major vein at Locality #2 and may be a lateral extension. Granitic sills, veinlets/stringers occur within the metasedimentary host rocks 60-80 m to the southwest.

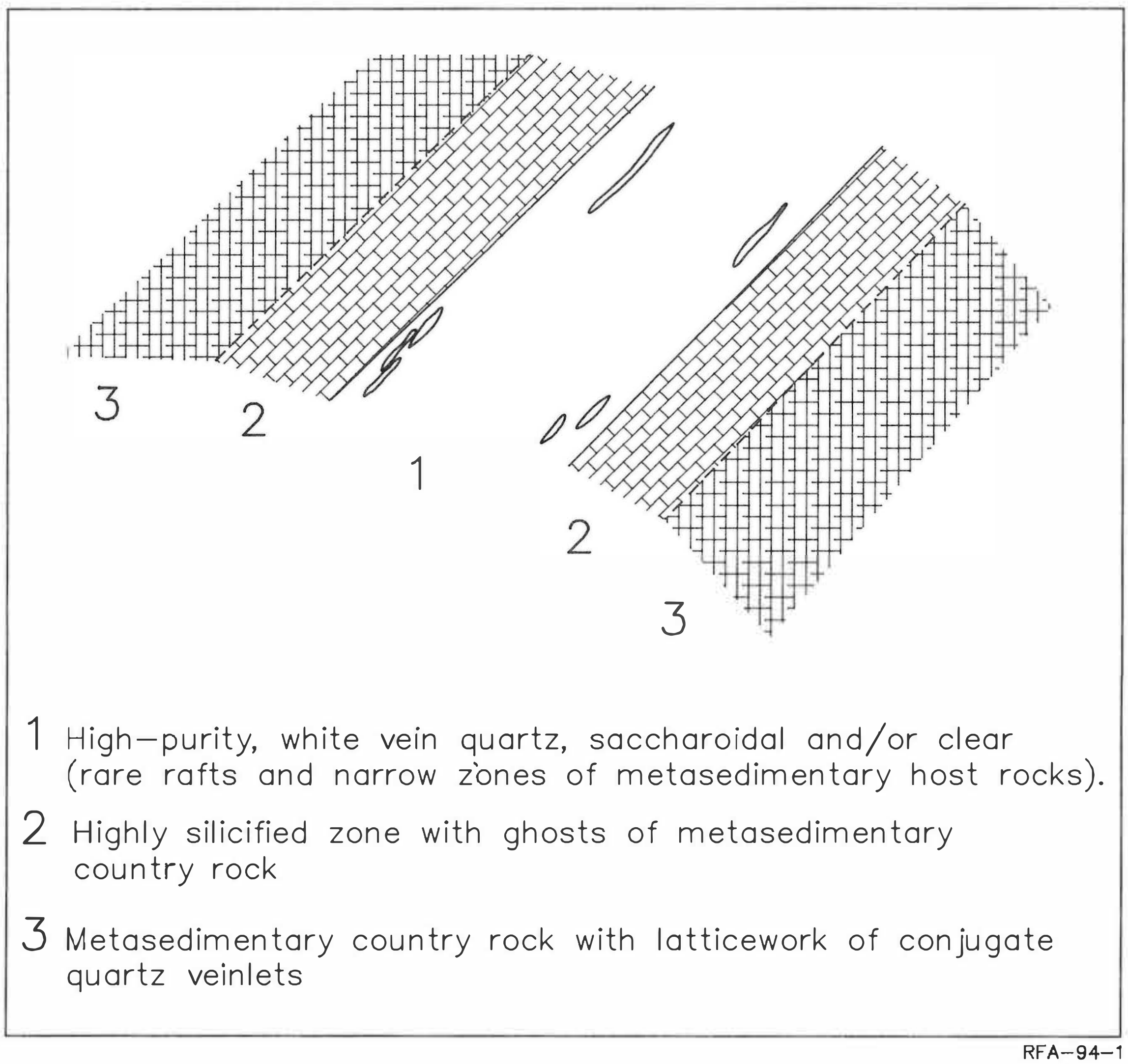


Figure GS-33-5: Sketch of typical zonation associated with silicified zones and quartz veins.

GS-34 AEROMAGNETIC SURVEY OF SOUTHERN MANITOBA

by I. Hosain and D. Teskey[1]

Hosain, I. and Teskey, D., 1994: Aeromagnetic survey of southern Manitoba; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 178.

The Geological Survey of Canada and Manitoba Energy and Mines carried out the fourth phase of the annual aeromagnetic coverage of southern Manitoba. The area covered and the area for future coverage are illustrated in Figure GS-34-1. 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 4, 1994/95 - Virden 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 November, 1995.

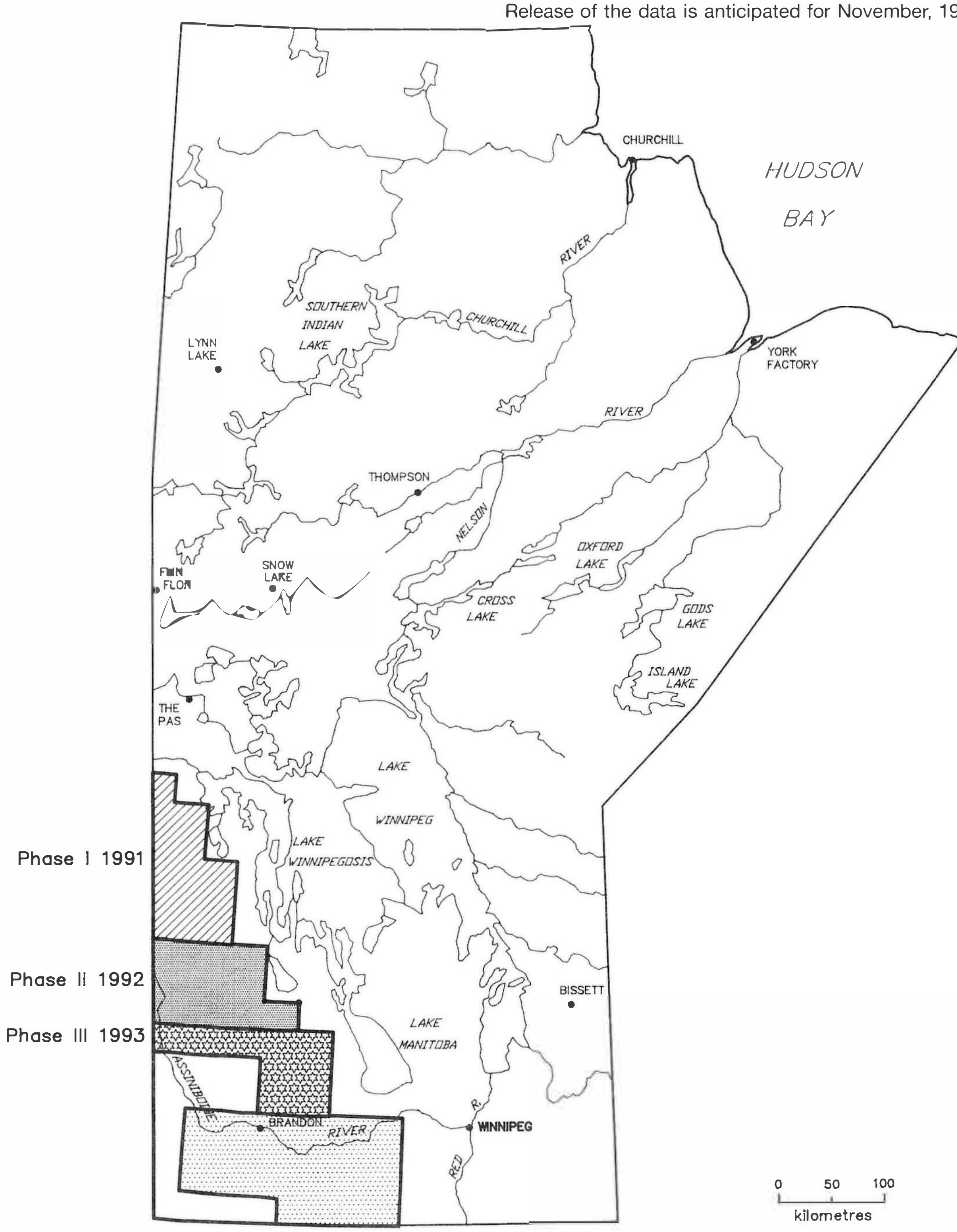


Figure GS-34-1: Aeromagnetic surveys, southern Manitoba.

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GS-35 KIMBERLITE INDICATOR MINERAL FOLLOW-UP PROJECT, WESTLAKE PLAIN, SOUTHWESTERN MANITOBA (NTS 62J, 62K, 62N, 62O and 63C)*

G. Matile and E. Nielsen

Matile, G. and Nielsen, E., 1994: Kimberlite indicator mineral follow-up project, Westlake plain, southwestern Manitoba (NTS 62J, 62K, 62N, 62O and 63C); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 179-181.

SUMMARY

The distribution of G10 garnets from a prairie-wide kimberlite indicator mineral survey suggested that a more detailed survey should be done in the Westlake plain of southwestern Manitoba. A total of 182 bulk till samples, at an average spacing of 100 km², were taken from the area. During the survey, rounded scoriaceous volcanic clasts, suspected of being Mesozoic, were discovered. Sample processing and $^{40}Ar/^{39}Ar$ dating of the volcanic clasts will be carried out as funds become available.

INTRODUCTION

Previous work by Thorleifson and Garrett (1993) indicates that five of the twelve G10 garnets found in the 816 till samples collected from Manitoba, Saskatchewan and Alberta were from the Westlake plain in south-central Manitoba and the area immediately to the south (down-ice). Although little is known about the ice-flow history of this area, especially "large earth moving events", it is assumed that the surface till was deposited by southerly flowing ice as indicated by the orientation of flutes. This would suggest that the G10 garnets were derived from a source(s) close to the north end of Lake Manitoba, the site of the most northerly G10 garnet (Oliver Lake). Alternatively, the G10 garnets were dispersed from sources to the west, possibly in Saskatchewan or Alberta, by preglacial fluvial processes. The preglacial sands and gravels were subsequently incorporated into the near surface tills. The absence of erratics of western provenance in the tills of the Westlake and Interlake plains argues against this, although such erratics are common throughout much of southwestern Manitoba above the Manitoba Escarpment.

Detailed investigations of the surficial sediments in the Manitoba Westlake and Interlake are needed to effectively undertake mineral exploration projects in these areas. This requires an understanding of the composition, distance and direction of glacial transport, and mode of transportation and deposition of the various till components.

The primary objective for the 1994 field season was to undertake detailed till sampling in the Westlake plain area to aid the mineral exploration industry in the search for kimberlites. The spacing between till samples has been reduced from the one sample per 800 km² used by GSC in 1992 to one sample per 100 km². This project, therefore, represents the next level of detail in regional kimberlite exploration.

GLACIAL HISTORY

The Westlake plain extends from the west side of Lake Winnipegosis and Lake Manitoba to the base of the Manitoba Escarpment and from the south shore of Dawson Bay to the Whitemud River (Fig. GS-35-1). It has relatively low relief with an extensive blanket of till and few bedrock outcrops. Glacial Lake Agassiz beach and offshore sand, silt and clay deposits are found in places along the escarpment and in the Swan River valley and Dauphin Lake areas. Thick accumulations of late Holocene sediments occur as alluvial fans along the major rivers at the base of the escarpment. Between Ste. Rose du Lac and Glenella, a long and relatively narrow glaciofluvial ridge similar to Birds Hill trends southward; it is the largest glaciofluvial deposit in the area.

The ice-flow history of the area is poorly known. A fluted, carbonate-rich till sheet is found at the surface throughout the region. The orientation of flutes and a limited number of glacial striae indicate that the ice flowed primarily to the south. In the Swan River and Dauphin re-entrant areas the flutes splay towards the west and southwest, indicating the glacier was in part deflected by Duck and Riding mountains. The lack of confinement by the escarpment at the re-entrants resulted in the ice "spilling" into the two respective valleys. In the northern portion of the area near Pelican Rapids, two sets of glacial striations were measured at several sites along the south shore of Dawson Bay: the oldest set averages 119°, whereas the most prominent set averages 247°. The second set was clearly generated by the same ice that deposited the carbonate-rich till exposed at surface.

Little is known about the drift stratigraphy of the area. The surface till on the Westlake plain is easily differentiated from the surface till above the escarpment by the carbonate content and matrix texture: the surface till on the plain is much higher in carbonate and lower in clay than the till on top of the escarpment. A limited number of drill holes in the area east and northeast of Dauphin indicate that the carbonate-rich surface till of northern provenance overlies till with relatively low carbonate content similar to that on top of the escarpment (Klassen, 1979). This lower till is exposed at the surface in the Swan River and Dauphin re-entrants, where the carbonate-rich till locally pinches out, suggesting that an earlier ice flow from the northwest affected at least parts of this area. This agrees with glacial striation measurements in the Pelican Rapids area. The western limit of the advance that deposited the carbonate-rich till (the Arran advance) is clearly defined in the Dauphin re-entrant by the Petlura and Grifton moraines.

The drift thickness varies from 0 to 80 m. West of Lake Winnipegosis, drift thickness is poorly defined; the few holes that have been drilled in that area indicate that it is generally less than 20 m thick. Between Dauphin Lake and Lake Manitoba, drift thickness increases from north to south. Bedrock outcrops are common in the north, as in the Toutes Aides-Winnipegosis area, whereas in the Ste. Rose du Lac-Ebb and Flow Lake area, thicknesses are commonly 20 to 40 m. West of Lake Manitoba in the McCreary-Gladstone area, drift thickness is generally between 20 and 80 m.

METHODOLOGY AND RESULTS

The Westlake plain was divided into 243 cells, measuring 10 by 10 km using the universal transverse mercator grid, which is defined on 1:250 000 scale NTS maps. Using random numbers generated by R. Garrett of the Geological Survey of Canada, a 1 km² target cell was defined within each 100 km² cell. The objective was to collect a till sample from as close as possible to each 1 km² target cell. Of the 243 original cells, samples were taken from 182 cells; 61 cells were not road accessible or did not have glacial till exposed at the surface.

At each of the 182 sample sites (Fig. GS-35-1), two samples were collected; a 40 L bulk till sample weighing approximately 70 kg and a 3 kg split. The large sample will be processed for kimberlite indicator minerals, and the 3 kg split will be submitted for geochemical analysis.

Samples will be processed at the Saskatchewan Research Council Laboratory in Saskatoon for kimberlite indicator minerals as funds become available. The final hand picking and microprobe analysis of selected indicator minerals will be contracted under the supervision of G. Matile.

EVIDENCE FOR PHANEROZOIC VOLCANISM

During the till sampling survey, numerous scoriaceous clasts between 2 and 10 cm in diameter were found in a gravel pit approximately 14 km northwest of Swan River (Fig. GS-35-1). The clasts are rounded to sub-rounded, light weight, highly vesicular and variously red, brown or black. A thin section of one of the black pebbles indicates that the vesicles are not filled and the surrounding walls are glass. The clasts are therefore not derived from the Shield and a Phanerozoic (possibly Mesozoic) age is suggested. In addition, the vesicular nature of the clasts suggests that they would not withstand long distance glacial transport and a local source in the Swan River area is suspected.

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development, and NATMAP Southern Prairie Project

The volcanic clasts were found in only one of several sand and gravel pits excavated in a prominent Glacial Lake Agassiz spit complex. The spit formed when Glacial Lake Agassiz was at the Upper Campbell level. Longshore drift within the Swan River valley during this period was counterclockwise (Nielsen *et al.*, 1984). The volcanic pebbles may therefore have a source to the northeast, possibly on the south side of Porcupine Hills. A fluvial source from Saskatchewan cannot, however, be ruled out.

Specimens of the volcanic clasts have been submitted for $^{40}Ar/^{39}Ar$ dating and whole rock, rare earth and trace element geochemistry, in an attempt to determine their age and composition.

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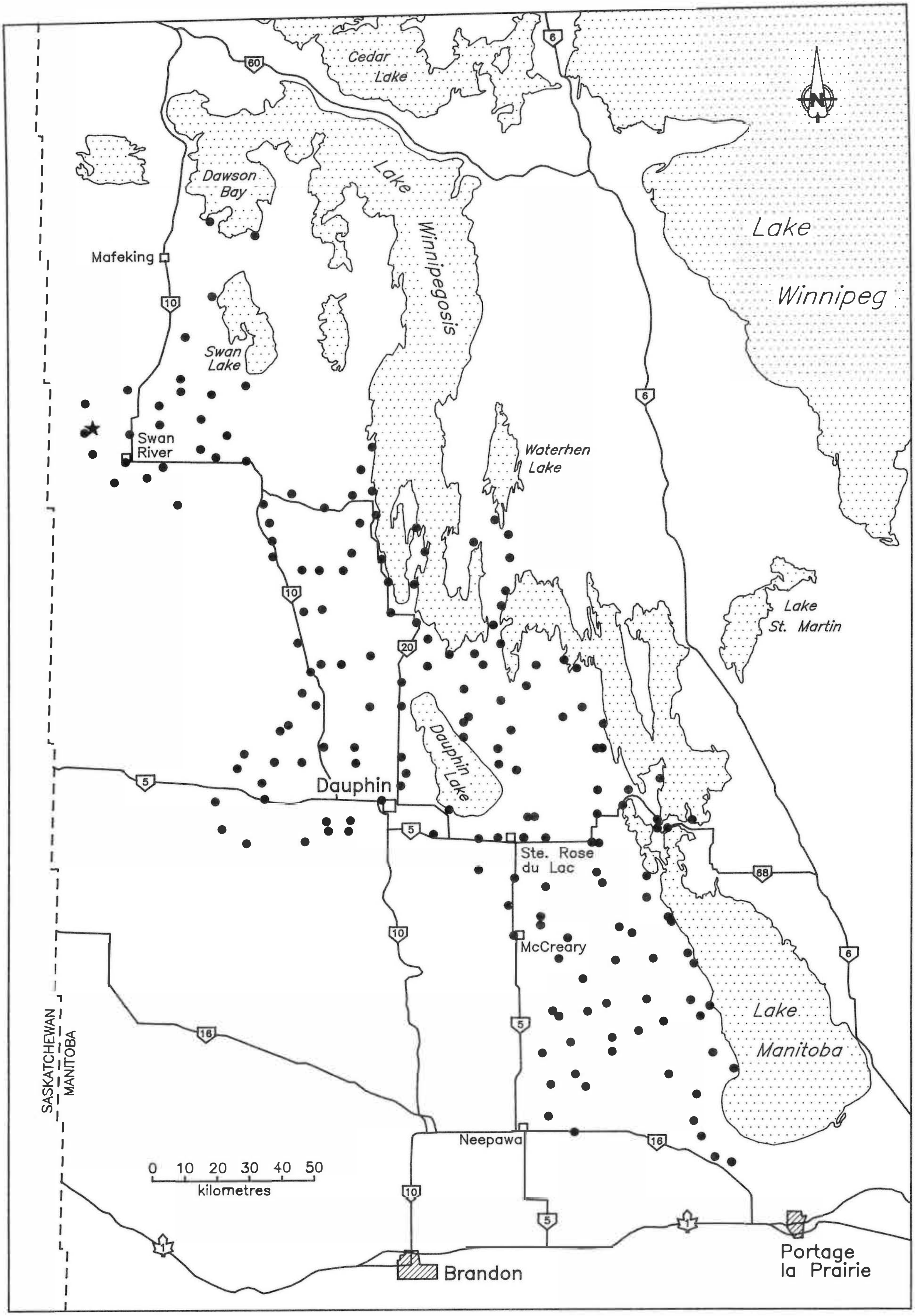

Figure GS-35-1: *Index map showing sample locations. Star indicates the location where the scoriaceous clasts were found.*

GS-36 SOUTHERN PRAIRIE NATMAP, A PROGRESS REPORT*

by G.L.D. Matile and R.J. Fulton[1]

Matile, G.L.D. and Fulton, R.J., 1994: Southern Prairie NATMAP, a progress report; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 182-183.

SUMMARY

Field mapping was completed in the west half of NTS 62H (southeastern Manitoba) and NTS 62F/01, -02, -06, -07, -08 and -11 (southwestern Manitoba) this summer. Data collected emphasized engineering, environmental, and groundwater geology and will be included in a GIS-oriented database. Preliminary results from a biostratigraphical investigation in southeastern Manitoba suggest that a complete Holocene climatic record may be obtained from the Wampum site; subsamples have been taken from the Wampum core for diatom, pollen and macrophyte analysis. In southwestern Manitoba 250 till samples were collected for texture and geochemical analysis; correlation with the Saskatchewan's Quaternary stratigraphy is a primary goal.

INTRODUCTION

During 1994, field and laboratory activity by Manitoba Geological Services Branch staff continued in support of surficial geological mapping and stratigraphic studies initiated in 1991. Much of the activity was carried out under the jointly funded federal/provincial Southern Prairie National Mapping Program (NATMAP). NATMAP is an initiative coordinated by provincial, federal, private sector and academic agencies to develop new mapping methods and enhance interprovincial cooperation. In the Prairie region, two areas have been selected for GIS-oriented Quaternary geological mapping programs: an area in southeastern Manitoba and adjacent Ontario that spans the Prairie/Shield contact and the provincial boundary, and the Virden area in southwestern Manitoba that extends into adjacent Saskatchewan.

SOUTHEASTERN MANITOBA

In 1994, field data collection was completed for the east half of NTS 62H. Emphasis has been on engineering, environmental, and groundwater geology in the portion of the map area that is underlain by Phanerozoic rocks. Work has been carried out in cooperation with H. Thorleifson of the Geological Survey of Canada since 1991.

Field work consisted of drilling 1 m deep dutch auger holes at an average spacing of 1.6 km along all roads on the till plain and every second road on the clay plain. Veneer and surface sediments were described in detail and entered into a database. Approximately 1900 sites were investigated and this information will supplement historical data that was compiled in an electronic database in 1993.

Preliminary drilling in a Glacial Lake Agassiz beach lagoon near Wampum in the fall of 1993 intersected a 8 m thick sequence of organic sediments. A basal radiocarbon date of 10 000 ± 110 years BP (sample number TO-4286) suggests that a complete Holocene record may be obtained at this site. This fall a detailed site investigation was carried out by the Manitoba Geological Services Branch and the University of Manitoba; drilling will be funded by the Geological Survey of Canada and the University of Manitoba.

Follow-up analyses of kimberlite indicator minerals reported in GSC Open Files 2745 and 2750 were released in May, 1994 as GSC OF 2875. As part of this follow-up, heavy mineral concentrates from 465 till samples and 195 sand samples from southeastern Manitoba were visually scanned for kimberlite indicator minerals. A total of 1195 grains were selected for electron microprobe analysis, from which a total of 33 Cr-spinels and seven G9 garnets were recovered. Of the seven G9 garnets, three have nickel values within the diamond stability field (Thorleifson *et al.*, 1994).

SOUTHWESTERN MANITOBA

The Geological Survey of Canada completed field mapping in NTS map areas 62F/01,-02,-06,-07,-08 and -11 during the summer of 1994. In addition, approximately 250 till samples were collected and are currently being analyzed for texture and geochemistry. The analytical data will be used for stratigraphic correlation and will also serve as background data, should questions of pollution arise. A number of observations and discoveries are notable:

1. Mammoth tusk
A mammoth tusk that was recovered from a gravel pit 10 km southeast of Deloraine in 1981 was borrowed from the Moncur Museum in Boissevain and a portion sent for radiocarbon dating. The gravel in which the tusk was enclosed underlies till and is an ice-advance deposit of the last glaciation. The tusk age should date the advance of the last ice sheet. This is the only sub-till organic material that has been collected in the area.

2. Bedrock control on topography and drift
A direct control exists between bedrock and topography in the vicinity of Turtle Mountain. This is not a common phenomenon in the Prairie region because most areas are underlain by uniform shale or thick glacial drift. On the flanks of Turtle Mountain, however, several contrasting bedrock units are present and drift is generally thinner than 20 m. In this area the competent Boissevain Sandstone forms an escarpment that rises approximately 15 m above a flat plain, which has developed on the upper beds of the Pierre Shale (McNeil and Caldwell, 1981). A flat plain is also developed on top of the Boissevain Sandstone, but hummocky terrain characterizes the area of soft Tertiary clays and sands of the overlying Turtle Mountain Formation (Bamburak, 1978).

3. Flat-floored valleys
The Boissevain Sandstone partially controls the morphology of stream valleys in the area flanking Turtle Mountain. In other parts of the area, Holocene valleys are shallow, relatively straight and v-shaped. In the area underlain by Boissevain Sandstone, the valleys are deep, meandering, and flat floored. These anomalously shaped valleys are developed through groundwater sapping that occurs at the contact between the relatively competent sandstone and the underlying shale and siltstone. Springs occurring at the base of the permeable sandstone erode the underlying soft shale and siltstone, undercutting the competent unit. Headward failure of the sandstone leads to the development of steep-walled, flat-floored valleys with a meandering pattern.

4. Whitewater Lake
Lying between Deloraine and Boissevain, Whitewater Lake is sensitive to climatic indicators. The lake basin is shallow (<2 m), but relatively large (≈6 km^2). The basin is ringed by a single, well developed shoreline, but there is no associated outlet channel. Available topographic maps and airphotos, taken as recently as 1978, show Whitewater Lake extending to the shoreline. Presently the lake has virtually dried up. Local residents report that the lake gradually disappeared during the relatively dry 1980's. It seems quite significant that a basin which has no outlet and is this sensitive to climate should have only one Holocene shoreline and that the lake should have been filled to the level of this shoreline a decade ago. The history of Whitewater Lake warrants more detailed research than it will receive during this current study.

5. Connection between Solonetzic soils and the older till that overlies Boissevain Sandstone
A correlation was drawn between an anomalous area of saline soils and surficial geology as an outcome of a field workshop that was

* Funded by NATMAP Southern Prairie Project

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

held with representatives of Agriculture Canada and the Geological Survey of Canada. In the Virden region, saline soils are commonly associated with areas of groundwater discharge and areas where shale is near the surface. Neither of these factors hold true for the area between Deloraine and Boissevain; in this area the thin, relatively loose, highly permeable surface till is underlain by thick, compact, older till. Apparently, this relatively impermeable layer impedes drainage into the underlying permeable Boissevain Sandstone and permits development of saline soils in poorly drained depressions.

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GS-37 THE 1994 LAKE WINNIPEG PHYSICAL ENVIRONMENT SURVEY: CRUISE SUMMARY

B.J. Todd[1], C.F.M. Lewis[2], L.H. Thorleifson[1], E. Nielsen, L. Lockhart[3], V. Isidoro[4]

Todd, B.J., Lewis, C.F.M., Thorleifson, L.H., Nielsen, E., Lockhart, L., and Isidoro, V., 1994: The 1994 Lake Winnipeg physical environment survey: cruise summary; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 184-185.

SUMMARY

A multidisciplinary geoscientific reconnaissance of Lake Winnipeg was carried out from August 4 to August 30, 1994. The primary objectives of the project are to establish major geological boundaries beneath the lake, to investigate properties of the sediment and its pore water, and to interpret the late glacial to present history of the lake to improve understanding of environmental change, including recent sedimentation and chemical contamination, long term lake-level movement, groundwater inflow, and changes in former climatic and hydrological conditions. Over 500 km of high quality geophysical track lines were obtained. Interpretation of these geophysical records will be aided by data acquired from core samples taken along these geophysical tracks. Ten box cores will allow high-resolution study of the last 100 to 200 years of lake history. Thirteen 2 to 8 m gravity and piston cores will provide a longer record of Lake Winnipeg and the Lake Winnipeg/Lake Agassiz transition. Bottom sediment samples were taken from 33 additional sites, and water and biological samples from 24 of those sites; these samples will provide biota data for the lake. The Lake Winnipeg Project was conducted in cooperation with the Canadian Coast Guard from its ship the CCGS *Namao*. The funding partners include the Province of Manitoba, Manitoba Hydro, Fisheries and Oceans Canada, and the Geological Survey of Canada (GSC).

LAKE WINNIPEG

Lake Winnipeg covers a significant area of southern Manitoba, extending 400 km south to north along a poorly defined boundary between sedimentary rocks to the west and the Canadian Shield to the east. In addition to drainage from the Canadian Shield, the lake receives runoff from much of the Prairie region of western Canada and parts of the adjacent United States. The sediments of the immense Glacial Lake Agassiz, the predecessor of Lake Winnipeg, are the base material for many of the agricultural soils of Manitoba and Saskatchewan. Currently, Lake Winnipeg supports commercial, subsistence, and sport fisheries, provides shore lands and recreation, and stores water for hydroelectric energy production by Manitoba Hydro on the Nelson River outlet. It is also the presumed discharge region for groundwater moving through aquifers under southern Manitoba.

GEOPHYSICAL PHASE

The lakebed was mapped with sidescan sonar and its sub-bottom profiled with high resolution (Seistec) and sleeve gun multichannel seismic systems along transects through major basins of the lake, including its remote northern region. A magnetometer and ground penetrating radar (experimental) were operated as well. Air and water samples were acquired along the geophysical track lines for baseline chemical contamination studies by the University of Winnipeg and the Freshwater Institute (DFO).

The geophysical survey data, though limited in coverage compared to the large area of the lake, are generally of high quality. East-west transects, with south-north tie lines, were run in both the south and north basins, as well as in the connecting narrows and islands area. Data were not acquired in the southern part of the north basin owing to high wind and wave conditions that persisted longer than expected. Nonetheless, over 500 km of geophysical track lines were obtained and these reveal many surprises:

1. evidence for substantial westward relocation of the boundary between rocks of Precambrian and Paleozoic age,
2. unexpected rock basins of substantial depth beneath this shallow, flat-bottomed lake, which contain, for example, over 60 m of sediment in the north basin,
3. previously unknown lakebed features such as widespread ice scours, sediment waves over 5 m high indicating high current flow in constricted passages, and many enigmatic linear patterns of unknown origin. The Glacial Lake Agassiz sediment sequence and some ice marginal morainic deposits are clearly imaged. These sediments are truncated and overlain by sediments of postglacial Lake Winnipeg, which commonly reach thicknesses of 9 m or more in the offshore basins. The latter sediments are gas-charged in many places. The regional unconformity capping the Lake Agassiz sequence confirms the previous existence of lower Lake Winnipeg water levels. A mud-buried paleobeach and shoreface were profiled in the northern part of the south basin about 15 m below present lake level.

GEOLOGICAL PHASE

This phase of the CCGS *Namao* cruise focussed on lakebed sampling to investigate sediment sequences and key features. Additional water and sediment sampling was undertaken to contribute to assessment of the biota, limnology and environmental status of the lake by scientists at the Freshwater Institute.

Coring and geological sampling

Seventeen widely spaced sites were occupied. Long gravity and piston cores, ranging in length from 2 to 8 m, were obtained at 13 sites to sample the sediment in order to verify stratigraphy or features identified in the geophysical records.

Samples of the Lake Winnipeg and Lake Agassiz sediment sequences were recovered in both the north and south basins. Three cores sampled sediments in the more constricted central part of the lake. Sand was encountered in the paleoshoreface profiled in the south basin. Two grab samples in "The Narrows" (between the basins) verified the presence of coarse sand and transported detritus in the area of inferred large sand waves.

Studies of recent sedimentation

Ten box cores from widely spaced sites throughout the lake were obtained for high-resolution study of recent (last 100-200 years) sediment accumulation and chemical contamination. The core should permit an evaluation of aerial fallout and sedimentary input from the major rivers, especially the Red, Winnipeg and Saskatchewan rivers. When dated by the Pb^{210} technique, these cores will allow calculation of net fluxes of contaminant for intervals of 10 to 20 years over about 150 years. This information should clarify the sources and dispersal pattern of chemical contaminants, notably mercury and stable organochlorine compounds like PCBs, which are found in Lake Winnipeg fish. These chemicals are known to originate from aerial fallout and local sources of industrial effluents and domestic sewage in the Red/Assiniboine and Winnipeg River systems. The core data will provide insight into two questions:

1. Has the sedimentation rate changed over the period of lake level regulation by Manitoba Hydro?
2. Are elemental chemical contaminants (*e.g.*, mercury, cadmium, lead) of natural or anthropogenic origin? (There is no such doubt about the origin of synthetic organic chemicals like PCBs.)

1 Geological Survey of Canada, Terrain Sciences Division
2 Geological Survey of Canada, Atlantic Geoscience Centre
3 Fisheries and Oceans Canada
4 Canadian Coast Guard, Central Region

Synoptic sampling

Bottom sediment sampling was carried out at 33 stations using a Ponar dredge operated by hand from a small boat launched daily from the ship. These samples will be analyzed using the same methods as those planned for cored sediments, as well as analyzed for toxins at the Freshwater Institute of Fisheries and Oceans Canada. In order to support other programs of the Freshwater Institute, limnological and biological data collection and sampling were also completed at these sites. At 24 of the stations, conductivity and temperature profiles were completed using automated equipment. A Secchi disk measure of water turbidity was taken. Water samples were filtered and refrigerated on board the ship during the evening after collection. A phytoplankton sample and a zooplankton net haul were taken at each site. The dredged bottom sediment remaining after sediment samples were taken was screened and preserved in order to obtain a semi-quantitative sample of benthic invertebrates. High winds prevented sampling in the southern north basin.

GS-38 STATUS OF THE MANITOBA STRATIGRAPHIC DATABASE*

by G.G. Conley

Conley, G.G., 1994: Status of the Manitoba stratigraphic database; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 186.

BACKGROUND AND OBJECTIVES

Development of the Manitoba Stratigraphic Database (MSD) began in 1988 as the stratigraphic component of the Manitoba Oil and Gas Well Information System (MOGWIS). MSD has evolved in that it no longer contains only petroleum related stratigraphic and core storage data, but has been extended to include all relevant Phanerozoic wells in Manitoba.

The MSD will eventually incorporate existing paper and computer stratigraphic databases into one integrated system that will provide rapid access to all subsurface well records for internal users and external clients. The goal of MSD is to assist clients in the exploration and development of the mineral resource and oil and natural gas potential of Manitoba.

A major objective of the MSD is to produce isopach and structure contour maps for Phanerozoic data by extracting data directly from the MSD into a mapping and contouring software package or into a Geographic Information System.

CURRENT STATUS OF THE PROJECT

The schema that is currently being used was modified from PPDM® (Public Petroleum Data Model) version 3.2. PPDM is a relational model developed by a consortium comprising major corporations involved in petroleum exploration, data acquisition and distribution. Recent mergers with the Petrotechnical Open Software Corporation (POSC) and International Business Machines Corporation (IBM) have resulted in many changes to the schema. As these changes are ongoing, the schema may not be finalized for several years.

In 1988, data for all existing oil and gas wells and test wells were purchased from Digitech. Geological Services Branch has verified Kelly Bushing and ground elevation against at least two sources. Location data in the form of UTM coordinates were generated by plotting wells on 1:50 000 topographic maps according to the original land survey descriptions and then by using AutoCad® to digitize the wells and to generate the coordinates.

Geological Services Branch has concentrated on the subsurface stratigraphic picks and core storage information for all Manitoba Phanerozoic wells. Over the past two years, 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. Wherever encountered, the depth to Precambrian basement has also been recorded.

The stratigraphic data stored in a well header table and a well tops table. The well header data include UWI (Unique Well Indicator), well location (UTM and NTS), NTS 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, hydro), source of the data, and date of last update.

The well tops data for each well include stratigraphic picks, isopach values, subsea elevations, geologist responsible for the pick, the date the pick was made or revised, and indicators for faulted, eroded and incomplete formations and for quality of the pick. An incomplete formation is one where the drill has stopped within the formation and has not completely penetrated it. An eroded or incomplete designation indicates that the formation should be excluded from isopach calculation. Data can be displayed in either feet or metres.

This past year, a complete set of isopach and structure contour maps were generated for each formation in order to visually verify the accuracy of the data. The mapping process was accomplished as follows. MSD data is stored in a single user Oracle database. A simple SQL query extracts the data from MSD into an ASCII text file. This file contains UTM easting and northing location data and the subsea or isopach value for the specified formation top. AutoCad® (ver. 12) is then loaded with a template map that contains the necessary provincial and lake outlines and various other reference points. The previously generated text file is then read by Quicksurf® (ver. 4.7) (from within AutoCad®) and the isopach and structure contour surfaces are generated with user specified contours. The contours and data points are then labelled and the map is ready to be plotted.

The mapping program revealed that even with careful handling of the data, some errors were still present. KB's and location data were recorded wrong on certain portions of the original paper database, and some transcription errors were made in data entry, logging and calculation of isopachs. All known data errors have been corrected.

Core storage location data are being maintained by D. Berk as a separate stand-alone database at the Midland core storage facility. The core storage locations are merged into MSD following all major updates. Drill chip sample storage will be added as soon as practical.

In total, 3097 well records with tops data reside in the formation tops database and all nonconfidential wells are available to the public. Of these, 580 Lower Paleozoic wells have been verified.

FUTURE DEVELOPMENTS

Later this year, MSD will be moved onto a centralized database server so that several Geological Services Branch users can simultaneously access the system. This will speed up entry of historical and current data and provide on-line access to the core storage facility. 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 (upon request) in the form of printouts, or digitally in the form of ASCII text or Foxpro®, or dBase IV® database files.

Detailed core descriptions are currently being gathered in a word processor and will be incorporated into MSD once it has been moved onto the server.

As time permits, historical picks maintained by Geological Services will be entered into the database. The historical data include wells primarily picked by H.R. McCabe and other early Manitoba geologists. The picks will cover the entire stratigraphic column in Manitoba and will serve as a valuable permanent reference.

In 1995, a database of selected Precambrian wells and existing detailed log descriptions will also be added to MSD. This database is currently maintained in paper and computer form by C. McGregor.

* Funded by Provincial A-Base

GS-39 GEOLOGICAL INFORMATION SYSTEMS PROJECTS*

by P.G. Lenton and L. Chackowsky

Lenton, P.G. and Chackowsky, L., 1994: Geological information systems projects; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 187.

SUMMARY

The Geoscience Information Services Section of Geological Services Branch deals with geological GIS systems and geological database systems. Projects supported by these activities include NATMAP projects, Manitoba Stratigraphic Database and Stratigraphic Map Series, Survey mapping, resource evaluation and production of analytical maps for land management studies.

NATMAP PROJECTS

Two major geological compilations have been released for the NATMAP Shield Margin Project: a 1:100 000 scale compilation of the south flank of the Kisseynew belt and a 1:50 000 compilation of the Snow-File lakes region (Open File reports OF94-4 and OF94-5).

The Manitoba segment of the cross-border Kisseynew compilation (see report GS-4, this volume) covers approximately 4500 km^2 within map boundaries of 54° 53' and 55° 15' north and 100° 15' and 102° 00' west. The Saskatchewan extension brings the west boundary to 102° 45'. Principal compilers are H. Zwanzig and D. Schledewitz (Manitoba Geological Survey) and K. Ashton (Saskatchewan Geological Survey). The geology was compiled by the provincial geologists and hand drawn manuscripts were transferred to the GSC where they were scanned and vectorized. Map topology was built in ArcInfo® and, after final editing, was printed in Ottawa by the GSC. The compilation contains updated and simplified versions of previous digital maps produced under NATMAP as well as current mapping and re-interpreted older mapping.

The 1:50 000 Snow Lake-File Lake compilation covers approximately 700 km^2. The compilation was done by L. Chackowsky and A. Bailes based on geology by A. Bailes (MGS), A. Galley (GSC) and K. Connors (GSC). Mapping done under the EXTECH program was included in the compilation. The geology was compiled in digital manuscript using PAMAP® GIS software. All compilation, topology building and editing were done by MGS with the finalized digital map transferred to the GSC for conversion to ArcInfo® format and colour printing.

DIGITAL MAPS (NON-NATMAP)

GIS technology is currently used for preliminary map production. The 1:50 000 preliminary map for Iskwasum Lake (Preliminary Map 1994F-1) was produced using AutoCad® and PAMAP® software combined with structural data extracted from the GEODATA databases of field information. A detailed 1:5 000 scale map by A. Bailes for the Photo Lake area (Snow Lake region) was produced using PAMAP® GIS software and GEODATA databases. All of these map products are based on field work done during the 1994 field season.

GIS software, combined with AutoCad®, was used in the production of maps in the Paleozoic Stratigraphic Map Series. The control data was derived from the Manitoba Stratigraphic Database (see GS-38, this volume).

GIS technology is extensively used in land management studies and Endangered Spaces evaluation programs.

MANITOBA MINERALS DATABASE

The initial database schema design of a comprehensive Minerals Database to accommodate information on mineral deposits, industrial minerals occurrences and aggregate resources was completed during the summer. A preliminary design was tested during the summer with data entry. The schema was revised based on this preliminary data entry experience and initial data loading has begun. The current design does not contain all details of aggregate resource documentation.

The system is based on xBase data structures implemented in FoxPro® version 2.6. Several data tables are related by a common linking field made up of a concatenation of the information type (mineral deposit, industrial mineral or aggregate), NTS area and a numeric occurrence number. The data structure includes: occurrence name, location, access, land status, lithostructural and stratigraphic position, primary and secondary commodities, holder, market data, exploration summary and coding information. Location data are supplied in UTM co-ordinates and latitude and longitude for point locations or in township, range, section and LSD for occurrences in surveyed territory or occurrences of significant aerial extent. Land status information will include Crown Land classification codes, park type (where applicable) and whether the ground is open to exploration. Holder and market data can contain production statistics and technical testing data where available. These databases will contain current and historical data on property holders, products and production history information (where available) including mineralization grades and tonnage production figures. Exploration history data includes comprehensive descriptions of geophysical and geochemical surveys, drilling history with pertinent drill log information and descriptions of shafts, pits and trenches. Survey descriptions will include type and extent of survey, spacing, instrumentation and summaries of pertinent results. Geochemical survey descriptions may, where pertinent, contain full results of the survey as tables of analyses as well as sample descriptions and sample type. Geological setting data comprise information on lithostructural environment, age, stratigraphic setting, descriptive geology and geological references. Detailed descriptions of each occurrence will include classification, commodity and grade for primary and secondary commodities, detailed description of mineralization and any significant alteration characteristic of the occurrence.

The principal data source for mineral occurrence descriptions is the Mineral Deposit Series reports. The database will contain most of the text information for each occurrence described in these reports. The reports include descriptive data from assessment reports, mineral inventory cards, description from site examination by geologists, previous reports and comprehensive reference lists. Industrial mineral deposit descriptions are derived from site examination, public domain assessment files and all pertinent reference material.

The Manitoba Minerals Database is designed to run on MS-DOS computers. The MMD will comprise an executable program and one or more sets of database files containing data on mineral occurrences. No special software other than that supplied with the MMD program will be required to access the data. The data will be released by NTS area.

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

GS-40 MARKETING BRANCH ACTIVITIES 1994/1995

by Marketing Branch Staff

Marketing Branch, 1994: Marketing branch activities; in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 188.

The Marketing Branch is responsible for the development of strategies and initiatives that profile and promote the development of Manitoba's mineral, petroleum and energy resource industries in accordance with the principles of sustainable development. The Marketing Branch provides marketing, business development, research, and information distribution services to the public. In addition, the Marketing Branch is also responsible for in-house ministration of editorial, cartographic, publishing, and library services.

BUSINESS DEVELOPMENT

The mandate of the Business Development Section of Manitoba Energy and Mines is to assist individuals and companies in Manitoba's minerals industry by the provision of marketing, applied mineralogy and metallurgical expertise. In addition, the Business Development Section provides access to a wide range of information on government services, programs and regulations. Emphasis of the Business Development Section has historically been placed on commodities not currently produced by established mineral companies in Manitoba. Commodities traditionally produced in Manitoba, such as gold and base metals, that have not been exploited due to difficulties with recovery or refractory ore mineralogy, will now be considered. The Business Development Section is responsible for overseeing the Province's activities under Sector "C" (Economic Development) of the Canada/Manitoba Partnership Agreement on Mineral Development.

Examples of projects that the Business Development Section is involved in are:

a) Pipestone Lake titanium-vanadium-iron project, in conjunction with the Pipestone Lake Joint Venture. A mineralogical study of the massive oxide zone at Pipestone Lake has been completed and a metallurgical study of the beneficiation of the massive oxide zone is underway.

b) Arborg kaolin project, in conjunction with Arborg Kaolin Ltd. A pilot-plant scale study of the Arborg kaolin has been completed by the North Carolina State Minerals Research Laboratory. Tests of the purified kaolin are ongoing at the Pine Falls Paper Co. Ltd. mill at Pine Falls. A two-part marketing study of kaolin in Manitoba has been completed and published as Open File Reports OF94-1 and OF94-2.

c) Graham Avenue Transit Mall project, in conjunction with the City of Winnipeg, Government of Canada, and Canital Granite Ltd. The first phase of the granite curbing installation, from Vaughan Street to Eaton Place, was done during the summer of 1994. The second phase, from Eaton Place to Main Street, will be completed during the summer of 1995.

d) High-purity magnesium dolomite project in Manitoba's Interlake region. Open File Report OF92-4 on the chemistry of the dolomite has been published. Samples of the dolomite have been provided to private industry for testing as a raw material for magnesium refractories.

e) Stainless steel masteralloy project in conjunction with Chrome Corporation of America. A study of the economics of a stainless steel masteralloy has been completed.

f) High-purity silica project in conjunction with Selkirk Silica Ltd. An economic study of sodium silicate manufacture and bench scale tests on the high-purity silica to determine the efficiency of sodium silicate manufacture has been proposed.

g) Potash project in conjunction with Potash Mining of Canada Inc., a wholly-owned subsidiary of the EMC Group of France. A 3-D seismic study has been completed on the potash leases of the Manitoba Potash Corporation.

h) Dolomite marble at Wekusko Lake in conjunction with Wekusko Marble Inc. A market study for this type of red marble is underway.

MINERAL EXPLORATION AND DEVELOPMENT INCENTIVE PROGRAMS

The Marketing Branch worked in partnership with Manitoba Industry, Trade and Tourism, Manitoba Finance, and other government departments to facilitate a competitive investment and business climate for the minerals and energy sectors. This business climate is enhanced by a number of incentive programs. These include: *Tax Holiday for New Mines, Mining Tax Exploration Incentive Program, New Investment Credit, Processing Allowance, Reduction of Sales Tax on Electricity Usage, Prospectors Assistance Program, and Mineral Exploration Incentive Program (MEIP)*.

MARKETING OUTREACH ACTIVITIES

The Marketing Branch promotes the mining, petroleum and energy industries in Manitoba through various extension (outreach) programs. Direct contacts with the mining and petroleum industries are established and maintained at conventions and shows. The presence of marketing representatives at mining trade shows throughout North America is part of the Branch's overall strategy to ensure that mineral and petroleum development opportunities are profiled to attract new investors to Manitoba. Information on Manitoba exploration projects, provincial taxation changes for the mining industry, and programs within Manitoba Energy and Mines to assist mineral exploration and mine development are presented. Forums such as Scitrek '94 are used to distribute information of a more general nature to the public and secondary school students.

The Manitoba Mining, Minerals and Petroleum Convention, held in November of each year, provides an ideal forum for the identification, promotion and facilitation of economic development opportunities. Over 500 delegates from industry, the investment community and government attended the 1993 convention, heard presentations by expert guests from both government and private industry, and discussed opportunities to promote investment in Manitoba's minerals and petroleum industries.

An information centre and a library are maintained in the Winnipeg office. The information centre provides all written information distributed by Manitoba Energy and Mines. It stocks booklets, reports, maps and fact sheets on Manitoba's minerals, geology and petroleum resources, mineral inventories, corporate data, energy conservation literature, alternative energy resources and transportation literature.

The library operates as a resource centre that offers research and reference services to industry, departmental staff and the general public. In a continuing effort to improve service, the library has:

a) become the provincial depository for Geological Survey of Canada publications;

b) made additional on-line resources available through Internet and GEOSCAN;

c) installed Inmagic Plus to provide improved access to the library's automatic catalogue of holdings;

d) catalogued the Department's video cassette recordings and produced a bibliography to provide access to the collection; and

e) initiated an update to the *Bibliography of Manitoba Geology*.

* Funded by Canada-Manitoba Partnership Agreement on Mineral Development

GS-41 STRUCTURE OF THE SQUALL LAKE AREA, SNOW LAKE (NTS 63K/16)*

by J. Kraus[1] and P.F. Williams[1]

Kraus, J. and Williams, P.F., 1994: Structure of the Squall Lake area, Snow Lake (NTS 63K/16); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 189-193.

SUMMARY

The study area displays a deformation sequence of F_1 to F_4. F_1 and F_2 isoclinal folds are dismembered by the McLeod Road thrust during southwest-directed transport. The macroscopic F_2 McLeod Lake synform has a curved hinge and is interpreted as a sheath fold. The relative age of the Birch Lake and Snow Lake faults, which are broadly parallel to the McLeod Road thrust, is uncertain. Both structures appear to postdate F_1 folding. The thrust and faults appear to cut up and down section along ramps. Folding and thrusting interaction lead to the formation of two "triple junctions", where Amisk Group is in contact with File Lake Formation and Missi Group. The McLeod Lake synform, McLeod Road thrust and both faults are overprinted by the north-northeast-trending F_3 Threehouse synform and associated folds such as the Squall Lake antiform. The F_3 Squall Lake antiform, cored by the Squall gneiss dome, is a periclinal fold with a curved axis dipping shallowly in northerly and southerly directions. F_4 is locally developed. Around Angus Bay, F_4 appears as a tight east- to southeast-trending structure, which refolds the McLeod Road thrust and McLeod Lake synform. F_1 and F_2, which are separated in time by at least 20 Ma, are believed to have formed during southwest-directed shearing related to the convergence of the Flin Flon and Kisseynew domains. Shearing was accompanied by continued rotation of folds towards parallelism with the transport direction. F_3 is interpreted to be either a result of subhorizontal compression or of superposition of a northwest-southeast shortening component during continued southwest-directed transport as a result of the oblique collision between the Superior and Churchill provinces along the Thompson Nickel Belt. F_4 represents the waning stages of the Flin Flon-Kisseynew domain convergence after the Superior-Churchill collision had ceased.

INTRODUCTION

During the 1994 field season structural mapping was carried out in the area between Snow Lake, Squall Lake and McLeod Lake, north of Squall Lake and around Angus Bay on Herblet Lake (see maps of Harrison, 1949; Russell, 1957; Froese and Moore, 1980). Although the outcrop quality is, with few exceptions, poor, the area was chosen because of its abundant metasedimentary lithologies. In the greater Snow Lake area, Amisk Group volcanic and volcaniclastic rocks have proven to be unsuitable for the determination of the deformation sequence due to their mostly massive character, lack of primary features, and again, poor quality of exposure. The objective of the field study was to delineate:

- the internal structure of a thrust-bound sliver of File Lake metaturbidites between Snow Lake and Squall Lake. Why does this sliver increase considerably in thickness in this area?
- the nature of the File Lake Formation-Missi Group-Amisk Group "triple point" *ca.* 1 km southeast of Squall Lake and the role of the McLeod Road thrust in this respect.
- the geometry of the Squall gneiss dome.
- the significance of the divergence of the File Lake metaturbidite/ Missi boundary and the McLeod Road thrust at Angus Bay and the nature of a >180° curvature of the McLeod Road thrust in the area north of Snow Lake.

Kraus and Williams (1993b) established a deformation sequence of F_1 to F_3 for the area between Snow Lake, Bart Lake and west Wekusko Lake based largely on studies in the File Lake metaturbidites. They described tight to isoclinal F_1 folds in the thrust bound sliver of metaturbidites in the hinge zone of the F_3 Threehouse synform at Snow Lake. At this location, F_1 folds are overprinted by a generally clockwise crosscutting S_2 cleavage that wraps around peak metamorphic minerals (Kraus and Williams, 1993b, in press), but the authors were unable to correlate this fabric with large scale F_2 structures. On the broadly north-dipping eastern limb of the F_3 Threehouse synform, S_2 is crenulated by F_3 with the axial planes of the crenulations being parallel to the axial plane of the Threehouse synform. All fold generations and other linear features are coaxial plunging moderately to steeply to the northeast (Kraus and Williams, 1993a, 1993b, in press). Crenulations of S_1 preserved as inclusion trails in porphyroblasts suggest that the peak of metamorphism occurred during early F_2 (Kraus and Williams, 1993b, in press). Metamorphic grade in the Snow Lake area increases to the north. However, temperature remained close to peak metamorphic conditions during F_3 as indicated by kink band boundary migration along the axial planes of F_3 crenulations in mica (Kraus and Williams, in press). The metaturbidite sliver is bounded by the McLeod Road thrust and Snow Lake fault to the north and south, respectively; it disappears along Snow Creek east of Snow Lake, where the McLeod Road thrust and Snow Lake fault coalesce. The McLeod Road thrust and Snow Lake fault have previously been considered to be coeval with F_2 (Kraus and Williams, 1993b). The thrust-bound sliver of metaturbidite continues from the hinge area of the F_3 Threehouse synform at Snow Lake north to Squall Lake. Approximately 1 km southeast of Squall Lake, the metaturbidites are in contact with Missi Group arkose. The sequence of metaturbidites and arkose continues northeast parallel to the east shore of Squall Lake, curves around the north end of the Squall gneiss dome and Ham Lake pluton, and extends into the File Lake area (see map of Harrison, 1949).

STRUCTURE OF THE METASEDIMENTARY SUCCESSION BETWEEN SNOW LAKE, SQUALL LAKE AND MCLEOD LAKE

Detailed mapping of this section revealed a macroscopic parasitic F_3 S-fold on the west limb of the F_3 Threehouse synform. The F_3 S-fold refolds two isoclinal fold generations, F_1 and F_2. The sequence contains at least one large scale isoclinal F_1 syncline as described by Kraus and Williams (in press) from Snow Lake. The F_1 syncline cannot be traced further north, as the metaturbidites display a schistose character with a distinct lack of sedimentary features due to a higher degree of recrystallization. The Missi Group rocks occupy the core of an F_2 synform, which was previously referred to as the McLeod Lake syncline by Harrison (1949). Its axis plunges shallowly northeast at the File Lake Formation-Missi Group contact. Both limbs are perfectly parallel in map view around McLeod Lake, but dip at moderate to shallow angles towards the axial trace. The F_2 axis must become, therefore, subhorizontal to the northeast. Along the axial plane to the south, S_0/S_2 intersections in the "underlying" metaturbidites parallel to the F_2 axis become increasingly steeper, plunging moderately to steeply to the northeast in Snow Lake; thus, the F_2 fold hinge is curved. It is therefore suggested that the McLeod Lake synform is a sheath fold. In the vicinity of the Missi-metaturbidite contact, its axial plane dips steeply to the southeast. The McLeod Lake synform is associated with a well developed S_2, which fans around the hinge and dips moderately to steeply to the southeast. The Missi rocks in the hinge contain an earlier S_1 biotite foliation parallel to S_0. S_2 in Missi rocks can be correlated with the prominent S_2 in the metaturbidites (Kraus and Williams, 1993b, in press). Although S_2 fans through the hinge of the McLeod Lake synform in Missi rocks, it consistently intersects S_0 clockwise in the metaturbidites, as reported by Kraus and Williams (in press) from Snow Lake. An exception is the immediate vicinity south and east of the F_2 closure in the Missi Group, where the S_0/S_2 relationships are reversed to anticlockwise. The

* Funded by NATMAP Shield Margin Project

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anticlockwise S_0/S_2 relationships are not persistent along the trend of the metaturbidites subparallel to the McLeod Road Thrust towards the Snow Lake town site. This indicates that the majority of the exposed metaturbidites are part of the western limb of the F_2 McLeod Lake synform. Hence, between Snow Lake and Squall Lake, the McLeod Road thrust cuts through folded strata to the north, from the western limb of the McLeod Lake synform through the axial plane to the eastern limb. The McLeod Road thrust must therefore postdate F_2 folding. It is interpreted to have dismembered an S-asymmetric F_2 fold pair along the short limb in the late stage of F_2. F_1 and F_2 transport was to the southwest with a shallow to moderate plunge (*e.g.*, Norman *et al.*, in press; Kraus and Williams, in press). Therefore, the change of tectonostratigraphic level takes place along a lateral or oblique-lateral ramp in metaturbidites in the hinge zone of the McLeod Lake synform. The F_2 axial plane of the McLeod Lake synform and the ramp of the McLeod Road thrust are folded by F_3 and F_4. Since the fold hinge has been dismembered along a discordant thrust segment and subsequently folded, (a) a "triple junction" and (b) apparent amplification of F_4 folding of the McLeod Road thrust have resulted.

File Lake Formation-Missi Group Relationships

The contact between File Lake Formation metaturbidites and Missi Group arkose is not exposed. In the vicinity of the contact, the Missi Group is intruded by a *ca.* 150 m thick mafic sill (see map of Harrison, 1949) that consists mainly of coarse amphibole and plagioclase. The sill contains conformable (*i.e.*, unrotated) xenoliths of Missi rocks. Both the sill and xenoliths have been deformed by F_1 and F_2. In the sill, S_2 is defined by a shape fabric of plagioclase. Locally, an S_1 parallel to the boundary is preserved. The metaturbidites near the contact do not appear to be intruded by the sill. Metaturbidite is contained in mafic rock only at one isolated location close to the contact; it cannot be demonstrated that it is the same sill described above. The Missi core of the McLeod Lake synform contains numerous smaller and larger sills. Mafic sills in the metaturbidites are rare, but where they occur they resemble their counterparts in the Missi. It might be possible, therefore, that the Missi Group and File Lake Formation constitute significantly different crustal levels. However, it cannot be said with certainty whether the sill has intruded an originally conformable contact or marks a fault. Missi beds with well preserved crossbeds consistently young away from the contact. That is, if the File Lake Formation-Missi Group contact were conformable, then the Missi Group would be younger than the File Lake Formation. As there is no evidence of large scale F_1 folds within the Missi package, the McLeod Lake synform might be a true syncline.

MCLEOD ROAD THRUST

The McLeod Road thrust forms a prominent ridge along the trail from the Snow Lake town site to Squall Lake and can be traced as far north as Angus Bay on Herblet Lake, displaying a curvature of more than 180°, the significance of which will be discussed below (see map of Froese and Moore, 1980). This segment of the thrust forms the boundary of monotonous Amisk Group metabasalt with File Lake metaturbidites and Missi arkose (*ibid.*). Due to the contrast between basic and acid rocks on both sides of the thrust, its trace can be identified by differences in vegetation: poplar trees and a combination of jack pine and spruce grow on metabasalt and metaturbidites, respectively. Along the trail to Squall Lake, a zone of intense ductile deformation in the overlying basalt is up to 150 m wide and dips moderately to steeply in northerly directions. Within this zone high strain domains from 20 cm to several m wide are generally associated with synkinematic carbonate impregnation parallel to the shear zone foliation. The carbonate itself is strongly foliated and contains S-folds whose axes are parallel to the prevalent stretching lineation plunging moderately to steeply northeast. Locally, the folds are transposed and cut by the shear zone fabric during progressive deformation. The shear zone fabric anastomoses around peak metamorphic garnet and abundant dm-scale low strain domains. In the immediate footwall, metaturbidites of the Corley Lake member (Bailes, 1980) do not show any local increase in bulk strain. For example, F_2 pressure shadows between staurolite porphyroblasts in S_2 (Kraus and Williams, in press), which is at a low angle to S_0, are not more intense than elsewhere in the metaturbidite sequence. Deformation is concentrated in dm-wide high strain zones up to 20 m underneath the contact. These zones exhibit small-scale sheath folds and Z-asymmetric refolded folds with axes parallel to the regional lineation. The direction of movement along the McLeod Road thrust is therefore interpreted as toward to the southwest. Progressive deformation gave rise to reorientation of axes of synkinematic small scale structures into the transport direction. The northwest-trending segment of the McLeod Road thrust along the trail to Squall Lake appears to be subparallel to S_1 and S_0 in the overlying basalt and in the metaturbidites, respectively. Southeast and east of McLeod Lake, the McLeod Road thrust dips moderately to the southeast and, hence, in the opposite direction to the underlying Missi rocks. The thrust uses the S_2 foliation as a movement surface, since it is the best developed pre-existing anisotropy in the underlying Missi sill (see above). Whether the McLeod Road thrust is a true thrust fault or has a strike-slip component cannot be determined at this point: generally, a fault has a strike-slip component, where the stretching lineation in the fault fabric systematically deviates from the direction of dip. This is only applicable for subsequently undeformed faults. If a true thrust is folded, as in this case, by F_3 (and locally by F_4), and it is assumed for convenience that the F_3 axis is parallel to the stretching lineation, then the stretching lineation remains constant after F_3 folding. However, the orientation of the thrust plane, and hence, the direction of downdip, have changed during F_3 at any point except the one where the thrust plane is intersected by the F_3 axial plane. At this one location, F_3 rotation of the thrust plane is zero. Thus, the relationship between the downdip direction and stretching lineation might lead to a false interpretation of contradictory sinistral and dextral strike-slip components on opposite limbs of the F_3 fold. For this reason, previous interpretations by Galley *et al.* (1988) and Kraus and Williams (1993a, 1993b) based on observations of the thrust in the eastern limb of the F_3 Threehouse synform around Snow Lake appear to be problematic. In order to delineate the nature of the McLeod Road thrust, the downdip-stretching lineation relationships must be examined in the F_3 hinges of the folded thrust plane. Alternatively, the original orientation of the thrust plane has to be restored by "unfolding" F_3; this is not possible. The chosen example of F_3 being parallel to the stretching lineation in the McLeod Road thrust seems to hold true. Also, the S_0/S_2 intersection lineation in the metaturbidites along the McLeod Road thrust south of McLeod Lake plunges consistently northeast regardless of the orientation of S_0. The same reasoning must also be applied to the Birch Lake and Snow Lake faults (see below).

BIRCH LAKE FAULT

Exposure of the Birch Lake fault (Galley *et al.*, 1988) in the study area is restricted to the type locality northeast of Snow Lake. The fault runs subparallel to the McLeod Road thrust; its trace exhibits a similar degree of curvature. The Birch Lake fault juxtaposes Missi Group arkose on top of Amisk Group basalt. At the type locality a mafic sill in the Missi occupies the immediate hanging wall of the fault. There, a zone of ductile deformation at least 5 m wide shows synkinematic carbonate impregnation as observed in the McLeod Road thrust zone. A moderately northeast-dipping synkinematic foliation contains an amphibole stretching lineation, which plunges perfectly or close to downdip. A microstructural study is required to determine the nature of the fault, as the poor outcrop quality obscures microstructures. If the Birch Lake fault is a compressional structure such as the McLeod Road thrust, then it can only emplace younger (Missi) over older (Amisk Group) rocks when the sequence had previously been folded. The Birch Lake fault is folded by F_3 and F_4.

SNOW LAKE FAULT

The Snow Lake fault forms the southern termination of the sliver of File Lake Formation running from Squall Creek, *ca.* 7 km east of Snow Lake, through Squall Lake around the Squall gneiss dome to the north. It continues into the File Lake and Batty Lake areas as the Loonhead Lake fault (*e.g.*, Zwanzig, 1992, Connors and Ansdell, 1994). Originally, the fault was identified as the Kisseynew lineament by Harrison (1951) and Robertson (1951), who discussed its significance as the structural contact between rocks of the Amisk Group and Kisseynew gneiss belt that extend west into Saskatchewan. The Snow Lake fault is not exposed north of Snow Lake and is only poorly exposed at the east narrows of Snow Lake, where it cuts off Amisk Group rocks at a low angle. Here, the fault zone dips steeply to the north and forms an escarpment. Like the McLeod Road thrust and the Birch Lake fault, the Snow Lake fault contains synkinematic carbonate veins. An amphibole (actinolite?) lineation plunges moderately to the northeast. At the southern end of Squall Lake, the Snow Lake fault is stitched by a syn- to post-peak metamorphic pegmatite, which contains inherited garnet and staurolite from the surrounding metaturbidites. Thus, the relative age of the Snow Lake fault is ambiguous. It postdates F_1 folding, as it cuts off an F_1 syncline at a low angle in Snow Lake, and it is folded by F_3. Two interpretations seem plausible. The Snow Lake fault could be late-F_1, dismembering an F_1 fold pair along its short limb in a similar fashion to the McLeod Road thrust, which shears off the eastern limb of the McLeod Lake synform. Alternatively, it is late-F_2, broadly coeval with the McLeod Road thrust and therefore postdates the peak of metamorphism. The first hypothesis is supported by the fact that the fault appears to be truncated by the 1830 Ma Ham Lake pluton (Connors and Ansdell, 1994; Figure 1 in Harrison, 1951). The Ham Lake pluton predates the peak of metamorphism, which is believed to have occurred between 1815 Ma and 1810 Ma (Gordon *et al.,* 1990; Machado and David, 1992). An F_1 age for the Snow Lake fault implies that it was subsequently folded by the McLeod Lake synform. However, towards its eastern termination at Snow Creek, the fault does not turn around the F_2 hinge. Therefore, a late-F_1 Snow Lake fault as a marker on the west limb of the F_2 McLeod Lake synform would be a measure of the amount of thickening of the metaturbidites in the hinge area. As a marked difference to the McLeod Road thrust, the Snow Lake fault seems to be generally nonparallel to primary layering. This is illustrated by the divergence of the Snow Lake fault and the McLeod Road thrust between the west narrows of Snow Lake and Squall Lake, resulting in a distinct broadening of the thrust bound metaturbidite sliver. The Snow Creek fault is interpreted as having been overridden by the McLeod Road thrust at Snow Lake leading to the disappearance of the metaturbidites to the east. Thus, the Snow Lake fault appears to be older than the McLeod Road thrust.

GEOMETRY OF THE SQUALL GNEISS DOME

The Squall gneiss dome is the smallest of four domes north of the Squall Lake-Herblet Lake area. It consists of pink gneiss overlain by layered felsic and mafic gneisses and thus constitutes a true mantled gneiss dome *sensu* Eskola (1949). A gneissosity in core and mantle rocks is generally shallowly to moderately outward dipping. The gneissosity wraps around garnet and is therefore suggested to be F_2 age, coeval with peak metamorphism. There is no evidence of an earlier S_1 in either core and mantle rocks. In the southern part of the dome the original character of the protolith cannot be determined as the pink gneiss is fine to medium grained and relatively homogeneous. Lack of mafic minerals such as biotite results in poorly developed gneissosity. Further north, towards the middle of the dome, mafic biotite-rich layers are up to 1 cm thick. In the northern half, the gneiss has a coarse granitic character and contains chunks of magnetite. Transition from augen gneiss with attenuated quartz augens to a layered gneiss can be observed. Towards the northern end of the dome, the gneiss is migmatized with quartz-feldspar leucosomes aligned parallel to the gneissosity. The leucosomes are coated by biotite-enriched layers. The gneiss dome forms a periclinal F_3 antiform on the west limb of the Threehouse synform with a slightly curved fold axis that plunges shallowly to the north and southwest at its northern and southern limits, respectively. Prior to folding, the granitoid might have been a tabular body. The S_2 gneissosity contains a shallow L_3, which plunges subparallel to the fold axis. In the southern hinge area, the lack of a distinct gneissosity emphasizes L_3 and gives the pink gneiss an LS-character. The Squall Lake antiform refolds the F_2 McLeod Lake synform and is itself gently folded by an approximately east-trending F_4 fold. It is evident that F_3 and F_4 are not coaxial.

STRUCTURE OF ANGUS BAY ON HERBLET LAKE

Southeast of Angus Bay on northwest Herblet Lake, the McLeod Road thrust again cuts up section from Missi Group rocks into metaturbidites at another prominent "triple junction" (see map of Froese and Moore, 1980). Towards Angus Bay, the Missi-File Lake boundary and the McLeod Road thrust diverge by almost 90°. S_2 in the File Lake metaturbidites follows both the contact with Missi rocks around a closure of an east- to southeast-trending F_4 fold and the east-southeast-trending McLeod Road thrust along the southwest shore of Angus Bay (*ibid.*). Around this fold closure the File Lake metaturbidites constitute a monotonous sequence of sillimanite-garnet-biotite schists. Primary features have been obliterated by metamorphism and an S_2 schistosity is subparallel to parallel to S_0 as established on the limbs of the F_2 McLeod Lake synform in equivalent lower grade rocks. Missi Group rocks appear as coarsely layered biotite gneiss with a well developed S_2 gneissosity. Incipient partial melting is abundant in rocks of the Missi Group. Where migmatitic bands are conformable with the gneissosity, they are asymmetrically boudinaged along shear bands formed during sinistral F_3 shearing. The contact of the Missi Group and File Lake Formation is folded into a macroscopic pre-F_4 S-fold (see map of Russell, 1957). Long limbs dip at intermediate angles, short limbs at high angles in easterly and westerly directions, respectively. The axial plane dips steeply east. As outcrop is far from coherent, the attitude of the fold axes cannot be determined. The S-fold is parasitic to a southwest-closing anticline cored by metaturbidites. Since the structure has the wrong asymmetry to be a parasitic fold on the McLeod Lake synform and is cut off by the McLeod Road thrust in the "triple junction", it must be F_1 age. Along the southeast-trending southern shoreline of Angus Bay, the metaturbidites dip consistently inland. At the southeast end of the bay, metaturbidites and McLeod Road thrust disappear in the lake and do not reappear along strike (see maps of Froese and Moore, 1980; Russell, 1957). On the eastern shore and north of Angus Bay, Froese and Moore (1980) interpret the unexposed File Lake Formation-Amisk Group contact as non-tectonic. Applying the observations from the "triple junction" in the vicinity of the McLeod Lake synform hinge southeast of Squall Lake and from field observations, it is concluded that the File Lake metaturbidites that outcrop along the shoreline of Angus Bay form a tightened thickened F_4 hinge. Therefore, the McLeod Road thrust must turn around at the southeast end of Angus Bay and form the contact between metaturbidites and Amisk Group rocks along the trend of the McLeod Lake synform to the northwest. It might be argued that the structure cannot be a fold, because on two sides of the bay, and thus on the two possible fold limbs, the McLeod Road thrust is structurally overlain by different Amisk Group lithologies (see maps of Froese and Moore, 1980; Russell, 1957). This pattern is, however, possible if the McLeod Road thrust has sheared off folded Amisk lithologies along the axial plane or limb or has cut unfolded Amisk stratigraphy at a low angle. The discordant nature of the McLeod Road thrust, the presence of incompetent metaturbidites sandwiched between high grade Missi and Amisk Group gneisses, and the presence of the Squall gneiss dome as a rigid obstacle might have led to the development of a macroscopic F_4 fold and its amplification in the metaturbidites at this location. The fact that the F_4 axial trace trends east in Missi rocks around the northern end of McLeod Lake, but trends southeast in the bay itself, might be related to a space problem with the adjacent rigid Herblet gneiss dome during F_4 convergence (see map of Froese and Moore, 1980). Although obscured by the waters of Angus Bay, the McLeod Road thrust appears to cut up and down section to the north along a pair of ramps. As the thrust appears to stay in a higher tectonostratigraphic level north of Angus Bay, assuming that it forms the contact between the File Lake Formation and the Amisk Group, the ramp pair must be asymmetric. At the southern limb of the F_4 Angus Bay structure, lineations in the metabasalt, which structurally overlie the metaturbidites in the hanging wall of the McLeod Road thrust plunge to the southwest (Figure 2 in Harrison, 1949). The lineations are interpreted as having been reoriented during F_4. Towards the west, in the Missi Group, F_4 is more open and the hinge is only slightly thickened (see map of Froese and Moore, 1980). In the F_4 hinge area, the original northeast plunge of the lineations has been preserved. The fold eventually dies out at the west end of the Squall Lake dome.

SYNTHESIS AND CONCLUSIONS

The study area between Snow Lake, Squall Lake and Herblet Lake shows a complete deformation sequence of F_1 to F_4. F_1 folds are overprinted by the F_2 McLeod Lake synform, which has been dismembered along its short limb by the McLeod Road thrust. The F_2 McLeod Lake synform, McLeod Road thrust and Snow Lake fault are folded by the F_3 Threehouse synform and the F_3 Squall Lake antiform. The Squall Lake antiform and McLeod Lake synform are overprinted by east-trending open to tight F_4 folds. These interference patterns lead to the arcuate trace of the McLeod Road thrust and Birch Lake fault. Two "triple junctions" of Missi Group, File Lake Formation and Amisk Group rocks represent the cutting effect through the McLeod Lake synform hinge and a lateral or oblique-lateral ramp of the McLeod Road thrust south and east of McLeod Lake, respectively. F_1 to F_3 folds and associated lineations are coaxial. F_2 and F_3 axes become progressively shallower to the north along the trend of the fold's axial trace. Shallowing of the F_2 McLeod Lake synform axis from intermediate to steep angles in Snow Lake to subhorizontal at Squall Lake suggests a sheath fold geometry. It also explains the continuation of the McLeod Lake synform over tens of kilometres to the west. As the orientation of F_3 axes is controlled by the attitude of layering prior to F_3 and thus by F_2 folding, the axis of the F_3 Squall Lake antiform plunges shallowly north and southwest. Isoclinal F_1 and F_2 folding and associated thrusting appear to have taken place in the same kinematic framework. Convergence of the Kisseynew domain and the Flin Flon-Snow Lake greenstone belt (*e.g.,* Norman *et al.,* in press) resulted in southwest-directed overthrusting of Kisseynew lithologies (File Lake Formation and Missi Group) over Amisk Group rocks of the Flin Flon-Snow Lake belt. Associated with this convergence was complex interfolding and thrusting of the two domains; linear features were reoriented towards parallelism with the transport direction. However, as F_1 folds at west Wekusko Lake are stitched by the 1836 Ma Wekusko pluton (the folds have been interpreted previously based on style as being F_3 by Kraus and Williams, 1993b) and F_2 is postdated by the peak of metamorphism (1815-1810 Ma), both isoclinal fold generations are separated by 20 Ma. F_3 formation can be explained simply by means of horizontal compression related to the oblique collision of the Churchill Province and Superior plate along the Thompson Nickel Belt (*cf.* Kraus and Williams, in press). Connors and Ansdell (in press) provide a similar explanation in one of their models for the F_3 deformation on east Wekusko Lake. Alternatively, the Churchill-Superior collision might have lead to the superposition of a northwest-southeast shortening component during ongoing convergence of the Kisseynew domain and Flin Flon-Snow Lake belt. As a consequence of the resulting constrictive strain, F_3 folds might have formed with axes close to parallel to the F_1-F_2 stretching direction (*cf.* Nicolas and Boudier, 1975). The latter hypothesis does not seem realistic, as a continued southwest transport should have had a sufficient component of stretching parallel to the composite F_1 to F_3 linear fabrics that would have reoriented the subhorizontal F_2 segment of the McLeod Lake synform (=sheath fold cap). Regardless of the coaxiality of linear F_1 to F_3 features the F_1 to F_3 deformation is not progressive. F_4 may have taken place during the waning stages of the Kisseynew domain-Flin Flon belt convergence after the Churchill-Superior collision had ceased. It occurs only at places where layering was at a high angle to the F_4 deformation vector and is clearly not coaxial with F_1 to F_3 north and east of Squall Lake.

ACKNOWLEDGEMENTS

The summer of 1994 was J.K.'s third and final field season towards a Ph.D. at the University of New Brunswick. He would like to thank Al Bailes for introduction to the area and guidance throughout the field work. Geological discussions with him, Steve Lucas, Karen Connors, Al Galley and Dan Ziehlke are much appreciated. J.K. also thanks Al Bailes, Mark Fedikow and Paul Gilbert in Snow Lake and Neill Brandson in Flin Flon for their hospitality. Logistical support was provided through P.F.W.'s NSERC grant, the GSC, Hudson Bay Mining and Smelting Co. Ltd. and by private sources. Additional air photos were supplied by Gary Ostry. J.K. would like to emphasize the incredible help of Mike and Sylvia Botten, their son Michael and many others in Snow Lake. TVX Gold Inc. is thanked for their cooperation and interest. Competent assistance through the field seasons by Sergio Alvarado and Rowenna Gilbertson is gratefully acknowledged.

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GS-42 BROADLEAF RIVER MINERAL ASSESSMENT (NTS 52M/3)*

by W. Weber and W.D. McRitchie

Weber, W. and McRitchie, W.D., 1994: Broadleaf River mineral assessment (NTS 52M/3); in Manitoba Energy and Mines, Minerals Division, Report of Activities, 1994, p. 194-196.

INTRODUCTION

The Province's commitment to the Endangered Spaces Campaign has prompted a reassessment of current land use designations throughout Manitoba. The Atikaki Wilderness Park, east of Lake Winnipeg, is one of several areas tabled for consideration as a potential Endangered Space, in which mining, forestry and hydroelectric development would be precluded in the future. A brief field investigation was undertaken in 1994 to evaluate the accuracy of geological mapping in the potentially prospective area between the Gammon River and Wallace Lake and to interpret the southern Atikaki region's residual exploration potential.

BACKGROUND

Along the southern fringe of the Atikaki Wilderness Park, in the Wallace-Siderock lakes area, mineral exploration for gold and base metals has focussed principally on the better documented metavolcanic and metasedimentary lithologies of the Rice Lake greenstone belt and contained shear zones and quartz veins. The greenstone belt trends east from Lake Winnipeg to the Ontario border and ranges in width from <1 km at the border to >4 km at the west end of Wallace Lake. Numerous claims are in good standing, and new geological interpretations of the older segments of the greenstone belt (GS-30, this volume) indicate significant potential for base metals (nickel) and gold. More recently the eastern segment of the greenstone belt near Siderock and Crystal lakes is being explored for sources of lump silica. Accordingly, a strong case can be made for excluding this segment of Atikaki Wilderness Park from Endangered Spaces candidacy.

North of the well defined greenstone belt, the existing geological database is based on two reconnaissance surveys (Russell, 1948; Ermanovics, 1970) which documented several narrow belts of iron formation and volcanic-derived rocks in a dominantly granitoid terrane. The more aerially extensive belts are shown halfway between Wallace Lake and Aikens Lake near Kosteck Lake by Russell (1948). Accordingly, Kosteck Lake was used as a base to re-examine the belts of interpreted supracrustal rocks to the north and south of Kosteck Lake, and to define their residual mineral prospectivity.

KOSTECK LAKE WEST AND NORTHWEST

Ground traverses west of Kosteck Lake (Fig. GS-42-1) located three distinct north- and northwest-trending belts of mafic metavolcanic rocks, in contrast to the single belt (unit 6a) of Russell (1948). The belts are relatively thin (≈100 m) and the mafic units strongly recrystallized, folded and metamorphically layered. Epidote-rich pillow cores, pillow selvages, and pillow shapes are readily recognizable in the central belt (Fig. GS-42-2). Elsewhere, the mafic units appear more as massive and even-textured diorites. South of "Northwest Lake" coarsely recrystallized, massive hornblende-rich phases occur as rafts in a contaminated granitic matrix and as a distinct unit that is over 30 m in width.

White to grey weathering, coarse grained hornblende tonalite is widespread throughout this region. Pink porphyritic granite with 2 cm alkali feldspar phenocrysts is common near the Broadleaf River. Both granitoid units are variably foliated. The mafic supracrustal units are typically intruded by one or other of the granitoid phases.

Typically, metamorphic layering (2-10 cm) in the metabasalt units is highly folded. Some belts pinch out locally and reappear along strike in the manner of fold keels. In such cases the rafted xenoliths are commonly rootless fold blocks and the host granitoids penetrate the axial planes.

The region west and northwest of Kosteck Lake contains a higher abundance of metavolcanic rocks than identified on earlier maps. Russell's unit 6b "gneisses derived from metasedimentary rocks, *lit-par-lit* gneiss" may in part represent areas with metavolcanic belts that were not individually mapped. However, metasedimentary rocks were not identified during this assessment in the area surveyed. The term "iron formation" is also not appropriate and appears to refer to strongly, metamorphically layered amphibolite, derived from pillow basalt.

The region contains a higher percentage of metavolcanic rocks than was previously shown, suggesting a higher residual prospectivity for gold and base metals than was initially indicated.

KOSTECK NORTHEAST AND EAST

Russell (1948) identified two narrow belts of mafic units (unit 8a) that trend in a southeasterly direction, south and west of Aikens Lake.

The southern belt was examined north of Kosteck Lake (Fig. GS-42-1), where it occurs as a narrow belt in a region dominated by coarse grained, homogeneous, weakly foliated hornblende tonalite to granodiorite. Pink zoned aplite/pegmatite dykes are ubiquitous in the tonalite.

The mafic unit is hornblende-rich with minor feldspar. Retrograde biotite is common and is associated with a later foliation. The main mafic unit is flanked by anastomosing networks of the mafic phase, several metres wide, in the host tonalite. This apparently intrusive relationship suggests that the mafic unit was injected as a dyke into a granitoid batholith.

No other supracrustal rocks were observed in the region north and east of Kosteck Lake, confirming the generally low residual prospectivity inferred from previous mapping and appraisals by explorationists.

The new information strongly supports the existence of a boundary condition in the Kosteck Lake area with low exploration potential batholiths to the north and east, and medium exploration potential metavolcanic/granite complexes to the south and west. The inferred boundary (Fig. GS-42-1) can be extrapolated to the northwest and southeast using airborne magnetic trends and signatures derived from federal surveys (Geological Survey of Canada, 1966a, b; Shives, 1993).

CONCLUSIONS

The high residual prospectivity for precious and base metals in the region underlain by metavolcanic and metasedimentary rocks of the Rice Lake belt between the Ontario border and the west end of Wallace Lake is well established (Segment A, Fig. GS-42-1). A brief reappraisal of the region between Wallace and Aikens lakes indicates a hitherto unrealized moderate residual prospectivity for the region south and northwest of Kosteck Lake (Segment B, Fig. GS-42-1), and a low residual prospectivity for base and precious metals between Kosteck Lake and the Gammon River (Segment C, Fig. GS-42-1). Aeromagnetic maps of the region show no anomalies diagnostic of kimberlite pipes.

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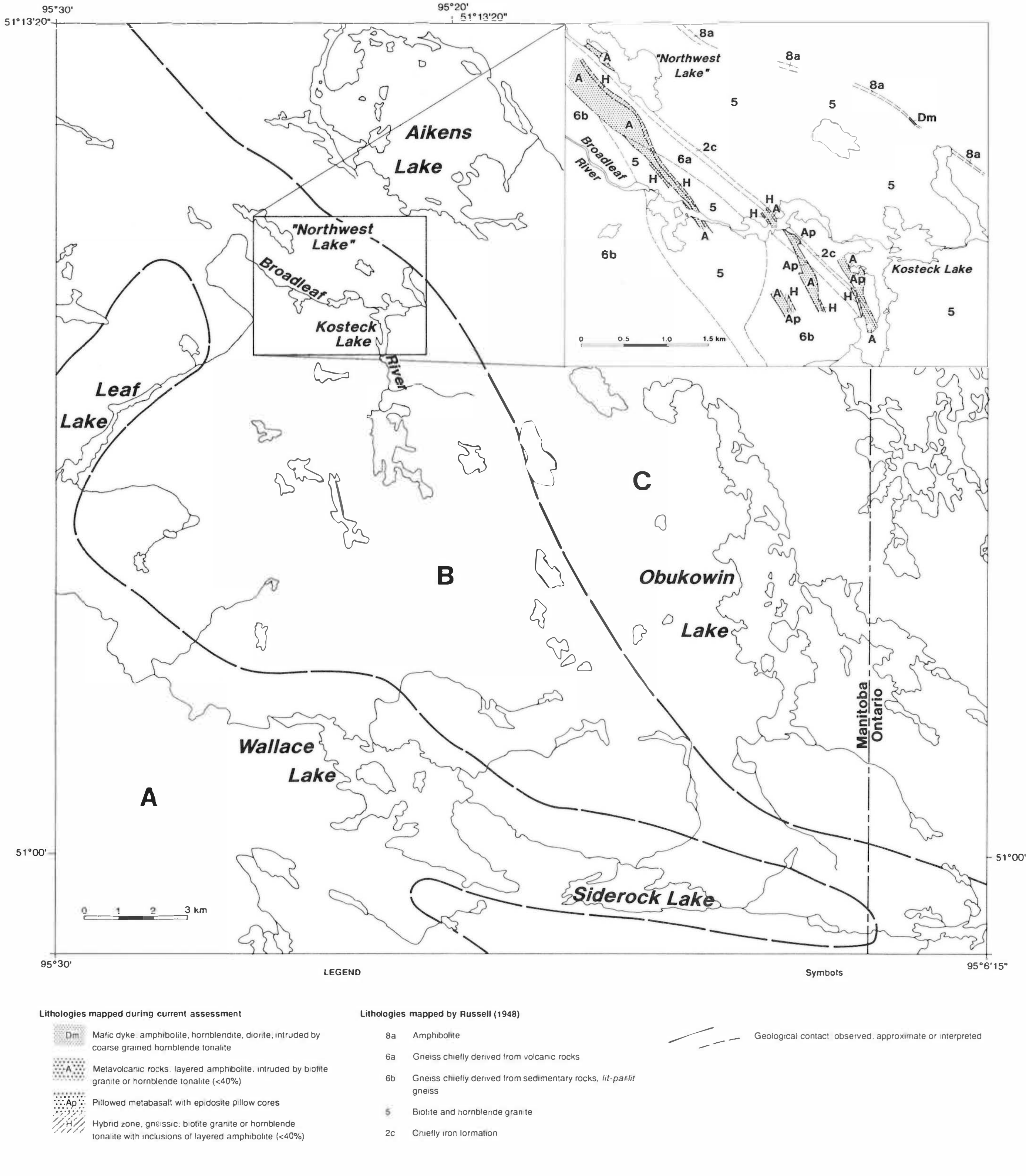

Figure GS-42-1: *Gammon River-Wallace Lake region, showing subdivision into zones of contrasting prospectivity for base and precious metals; A - highly prospective; B - moderately prospective; C - low prospectivity. Geology in inset after Russell (1948) with additions from current assessment.*

Figure GS-42-2: *Pillowed metabasalt with epidosite in pillow cores, northwest of Kosteck Lake.*

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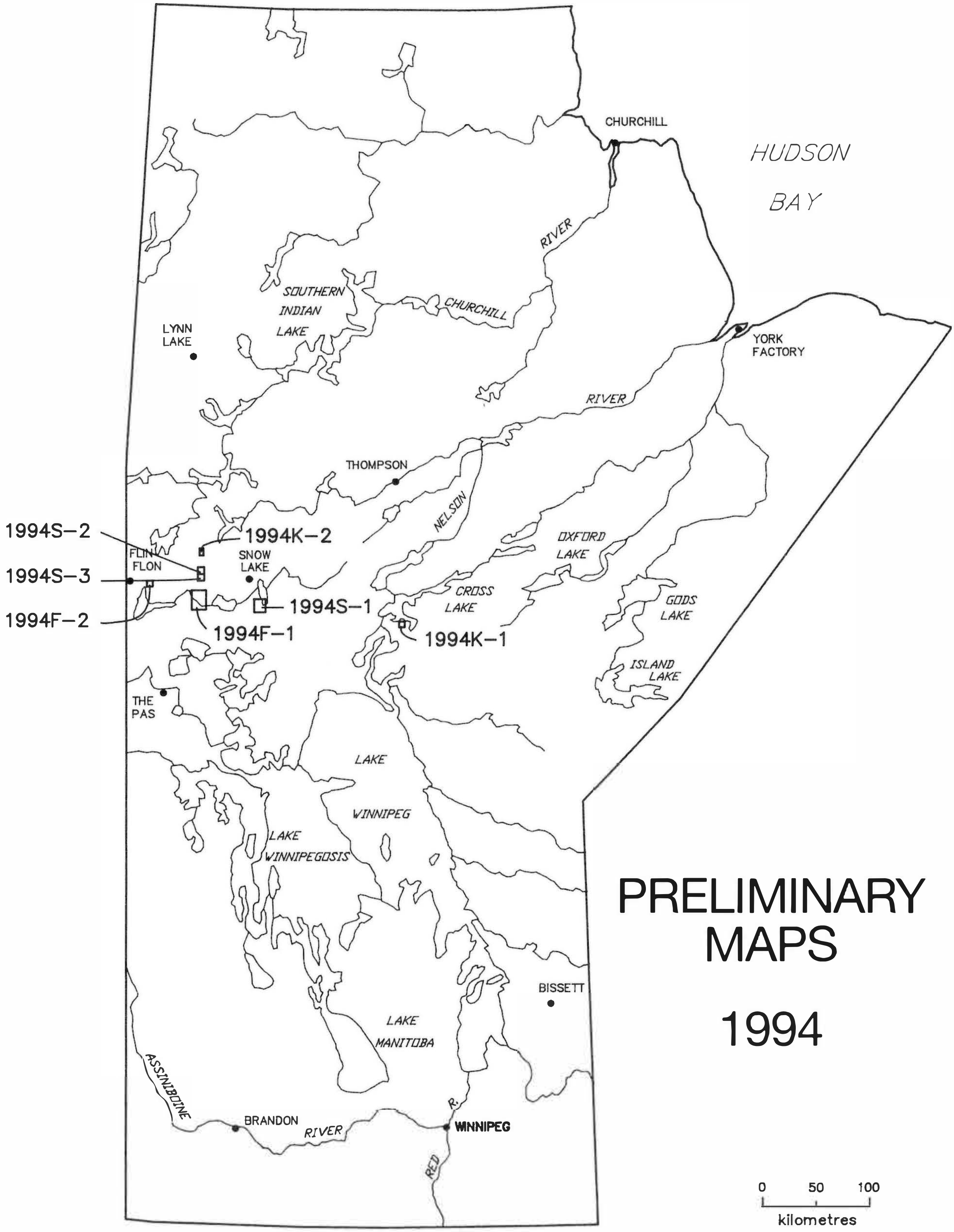
PRELIMINARY MAPS 1994

GEOLOGICAL SERVICES BRANCH		SCALE
1994F-1	Iskwasum Lake (NTS 63K/10W) by E.C. Syme and D. Morrison	1:50 000
1994F-2	Baker Patton Felsic Complex (Parts of NTS 63K/13 and 63K/12) by G.H. Gale, L.B. Dabeck, D.E. Prouse and L.I. Norquay	1:10 000
1994K-1	Geology and Mineral Occurrences in the Western Part of the Pipestone Lake Anorthosite Complex (Parts of NTS 63I/4 and 63I/5) by D.C. Peck, H.D.M. Cameron and M.T. Corkery	1:5 000
1994K-2	Nokomis Lake (Part of NTS 63N/3) by H.V. Zwanzig and J.V. Shwetz	1:10 000
1994S-1	Wekusko Lake, Southwest (NTS 63J/12) by H.P. Gilbert	1:20 000
1994S-2	North Star Lake (NTS 63K/15NE4) by L.I. Norquay, D.E. Prouse and G.H. Gale	1:10 000
1994S-3	North Star Lake (NTS 63K/15SE4) by L.I. Norquay, D.E. Prouse and G.H. Gale	1:10 000



PRELIMINARY MAPS

1994

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
	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, Iskwasum 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 bedrock compilation maps
Phanerozoic Geologist	R.K. Bezys	Southwest Manitoba, Hudson Bay Lowlands, and Interlake
Mineral Investigations:		
Senior Mineral Deposit Geologist	Dr. G.H. Gale	Flin Flon and Snow Lake
Mineral Deposit Geologist	K. Ferreira	Mineral Deposit Series; Editorial 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; Iskwasum Lake
	L. Norquay	North Star Lake
Resident Geologist NE (Thompson)	Dr. P. Theyer	Poplar River
Resident Geologist NW (Thompson)	Dr. D. Peck	Nueltin & Topp Lakes, Pipestone, Lynn Lake
Staff Geologist	H.D.M. Cameron	Pipestone, Nueltin & Topp Lakes
Industrial Minerals Geologists	B.E. Schmidtke	Silica; industrial mineral inventory
	J.D. Bamburak	High-magnesium dolomite; building stone; High-calcium limestone, Lump silica
Geoscience Information Services:	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/Geophysicist	I.T. Hosain	SW Manitoba/Interlake
Geochemist	Dr. M.A.F. Fedikow	Snow Lake/Southeast Manitoba
Quaternary Geologists	Dr. E. Nielsen	Elbow Lake, Naosap Lake
	G. Matile	Southern Manitoba

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