Report of Activities 1996

EXPLORE *in* MANITOBA

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Manitoba
Energy and Mines
Geological Services

REPORT OF ACTIVITIES 1996

1996

This publication is available in large print, audiotape or braille on request

Minister of
Energy and Mines
Minister responsible for Manitoba Hydro

Room 314
Legislative Building
Winnipeg, Manitoba, CANADA
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Last year we officially launched our new mineral strategy as part of an overall goal to make Manitoba the best place in Canada, and possibly the world, to invest in mining.

We introduced changes to the taxation structure, initiated new geological survey programs, released a complete guide to gold mines and deposits in the province and began offering "one window permitting" with simple, transparent and fixed time frames, making it easier to do business in Manitoba. We also replaced the Mineral Exploration Incentive Program with the Mineral Exploration Assistance Program (MEAP). Under the new program, $3.7 Million in fianancial assistance has been allocated resulting in nearly $16 Million of exploration activity.

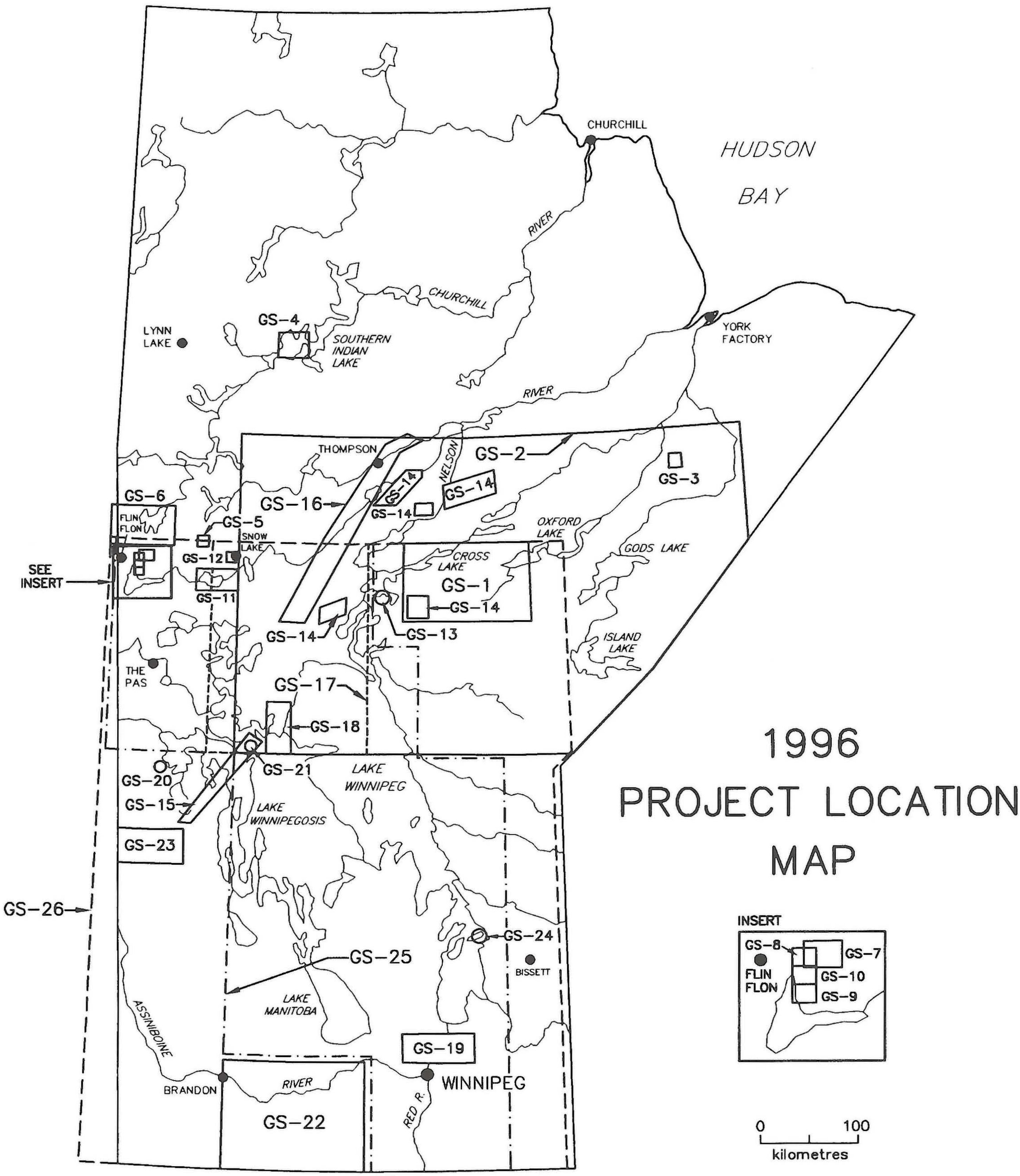
I am pleased to note that 18 new companies are conducting work in the province and two new gold mines have gone into production recently. Although this year is not over, 1997 already looks exciting. Another gold mine is scheduled to begin production shortly and the construction of a cesium formate chemical plant at one minesite marks an important step in value added production. We also expect a continued expansion of Manitoba's other exploration opportunities.

I look forward to meeting you at this year's Manitoba Mining and Minerals Convention to discuss these and other Manitoba mining initiatives.

Darren Praznik

Darren Praznik

JEUX DU
CANADA
GAMES
BRANDON '97



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MANITOBA GENERAL

INTRODUCTORY SUMMARY

by W. D. McRitchie

McRitchie, W.D., 1996: Introductory summary; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 1-4.

GENERAL

The Department of Energy and Mines has moved rapidly over the last two years to introduce a broad array of new initiatives designed to stimulate increased investment in Manitoba's mineral sector. These have included more favourable taxation policies, an enhanced Mineral Exploration Assistance Program, Prospector assistance, one window permitting procedures and increased funding for geological surveys to build the database that the exploration industry needs to target its efforts. The budget during 1996/97 was expanded to $3.7 million and reporting lines for the Flin Flon and Thompson regional offices were transferred to the Geological Services Branch.

During the winter of 1995/96, the GSB tabled a broad array of programs for review by the Mineral Exploration Liaison Committee (MELC). Feedback was used to expand the range of geological programs mounted by the Branch giving special emphasis to improving geological documentation in the relatively underexplored northern Superior Province. Under the general name Operation Superior, these initiatives included new geological mapping in the Stull-Kistigan region, multimedia geochemical surveys of the greenstone complexes and intervening granitoid terranes (Geological Survey of Canada-GSC), upgrades to the mineral deposits database with special focus on gold mineralization, an intensive evaluation of anorthosite complexes with their attendant potential to contain titanium and vanadium oxide concentrations, and an evaluation of past geophysical surveys. This review included an assessment of the residual mineral potential for selected areas that may become candidates for Endangered Spaces designation. During the Summer, geological mapping was initiated on Edmund and Margaret lakes, the anorthosite investigation sampled and mapped bodies on Cauchon, Hairy, Butterfly and Cuthbert lakes, amongst others, and a new staff geologist assigned to the Thompson Office conducted an initial reconnaissance of gold occurrences in selected areas as a precursor to a more intensive program planned for 1997. A new NATMAP program in the cross border region between Manitoba and Ontario is also being planned for initiation in 1997 and active discussions between the Ontario Geological Survey and the GSC are taking place.

Elsewhere in the province, considerable emphasis was given to concluding the initial five year thrust of geological mapping in the Flin Flon/Snow Lake region in support of base and precious mineral exploration. This Shield Margin federal/provincial National Mapping program has made remarkable advances in improving the geological database and resulted in radical changes to the understanding of this region's mineral potential and how the major concentration of greenstone belts was assembled. This cooperative effort has proved highly productive with a prolific flurry of new reports, technical papers and maps, many of which were released in symposia, poster sessions, short courses and field tours at the joint annual general meeting of the Geological Association of Canada and Mineral Association of Canada in Winnipeg in May. Currently an emphasis is being placed on compiling the results from this program with staged publication of results planned in November 1996, in the Spring of 1997 and CD ROM releases later in 1997.

During the Summer, geological projects concluded mapping at Dow/Martell, North Kississing Lake, Webb Lake, and Reed Lake and a cooperative endeavour with HBED at Photo Lake was completed. New mapping commenced in the Lac Aimée/Naosap area. Liaison and field tours took place with numerous prospectors in the region as well as Canmine Resources and Aur Resources. Discussions were held with TVX to lay the foundation for detailed geological mapping, mineral deposit studies and structural work between Squall and Snow lakes in 1997.

With strong encouragement from Senior exploration companies active in the Thompson Nickel Belt (Inco, Falconbridge, Cominco and HBED), a series of discussions and planning sessions have developed a longer term strategic plan for improving geological mapping along the Churchill/Superior Boundary. Over the next three years, emphasis is being given to developing a new 1:50 000 geological map for much of the region between Moak and Gormley lakes using detailed surface mapping, conducted by the GSB, together with subsurface drillhole and geophysical information provided by the companies. A broad array of geochronological, isotopic, structural and petrological investigations is planned that would involve the GSC and Universities, with overall coordination provided potentially through MITEC.

Compilation of drill core from the sub-Paleozoic basement, to upgrade documentation of the Nickel Belt extension in the Ponton region as well as the adjacent Kisseynew gneisses and Snow Lake greenstones in NTS area 63J, continued.

Mapping of Silurian and Ordovician carbonates continued in the Grand Rapids region. Spring water and marl geochemical sampling was concluded and augmented by a regional structural study that compared fractures in the Paleozoic dolostone exposures with those inferred in the underlying basement. South of The Pas Moraine, several new holes were drilled to basement in an area of generally sparse information. Additional holes were drilled in the Stonewall and Garson areas to provide depth to bedrock and other information required to improve resource documentation in the Capital Region area.

In the south of the province, field investigations upgraded the inventory of bentonite occurrences in the Pembina Valley region, and generated new maps for the Capital Region north of latitude 50° as part of a broader strategy to improve land-use decision making in a region of rapid urban expansion.

Field work and compilation activities, focussed on surficial deposits, continued in the southwest and southeast corners of the Province under the federal/provincial Southern Prairies initiative. New GPS elevations were determined for several Lake Agassiz beaches in order to improve the constraints governing the rate of post-glacial rebound. The GSC also conducted geophysical surveys in selected areas to evaluate the ability of new instrumentation to detect and map near-surface irregularities in the carbonate bedrock, including karst channels, structural anomalies on the Precambrian surface and post-Paleozoic faults.

The Geological Survey of Canada completed Phase II of the Lake Winnipeg Survey, adding substantially to the geophysical database initiated in 1994. This year's cruise provided new information from the north and south basins, as well as new lake bottom sediment samples and near-shore profiles that will add significantly to the understanding of shoreline erosion processes.

The new surge of field programs has been supported by rapid increases in the Branch's ability to process the data using new GIS capabilities. Acquisition of an ARC/INFO system in late 1995 followed by subsequent in-house training of key personnel has permitted the Branch to produce a broad array of new digital full colour geological compilation maps in support of the final drive to complete work in the Shield Margin region. This enhanced capability also enabled the Branch to complete four new compilation maps published this year as an integral component of Gold Deposits Of Manitoba released by the Marketing Branch in conjunction with the September MINExpo Convention in Las Vegas.

Work on the 1:1 000 000 Wetlands Map, produced in concert with the University of Alberta and LINNET corporation, is near completion, with release scheduled for early 1997.

Good progress was made in completing reports in the Mineral Deposit Series that cover the exposed and Shield marginal sectors of the Churchill Province. Compilation of information was initiated for parts of the Superior Province as a backdrop to field programs planned for 1997.

The ongoing Bedrock Geology Compilation program has brought the Cross Lake (NTS 63I) compilation to completion. Work is continuing on the Norway House (NTS 63H) and Selkirk (NTS 62I) sheets. A digital

GIS-based 1:500 000 scale compilation of the northern Superior has been added to the program in support of Operation Superior programming.

A new Intergovernmental Geoscience Accord governing the future roles and relationships of the federal and provincial survey organizations was signed at the Mines Ministers Conference in Yellowknife, September 17th. This and Bilateral Accords between the GSC and each of the provinces will replace the coordinating mechanisms that guided geological programming in Canada under the recently demised Mineral Development Agreements. Discussions toward developing a new strategic plan for coordinated geological programming in Manitoba, together with industry input channeled through the Mineral Exploration Liaison Committee, are well advanced.

Throughout the year Branch staff provided ongoing advice to other agencies and clients on a broad range of mineral-related matters. These included land-use issues, the new Parks' Systems Plan, the Mineral Exploration Assistance Program and Manitoba Hydro's search for new rip-rap at Grand Rapids. The Branch also continues to work closely with the Marketing Branch and the private sector (Arborg Kaolin, Gossan Resources) on matters pertaining to industrial minerals, such as peat, potash and ilmenite.

Field tours of recently mapped mineral deposits were given for various companies and prospectors, and new geochemical sampling procedures were demonstrated in the Osborne Lake and Lynn Lake regions, the latter to assist Black Hawk (Granduc) Mining.

As an adjunct to its main programs, Branch staff also devoted time to investigating the potential for new mineral deposit types. Samples of black shales from Precambrian and more recent settings were collected, and carbonate exposures in the Mafeking area were investigated with staff of the GSC familiar with Prairie Gold type mineralization, recently recognized in Alberta.

The Regional Offices at Flin Flon and Thompson continued to be active, by conducting geological mapping programs, mineral deposit investigations, and property evaluations, as well as responding to inquiries and requests from local explorationists. Staff at Thompson have been especially active in developing a new strategic plan for survey work in that region, a task that has entailed in-depth discussions with industry explorationists as well as the GSC and university researchers in various parts of Canada. The Flin Flon Office continued to provide claim status, registration and consultative and advisory services to the mining and mineral exploration industries. The library of publications available for research continues to be expanded and the claim status service has been upgraded with the installation of the LINNET Geomatics Windows 95-based Claims Enquiry program in a dedicated PC to replace the old UNIX-based terminal and system. At the Centennial site, the new heated drill core examination facility and unheated short-term core storage area that also houses a diamond saw, were completed matching services provided at Thompson. The regional geologist at The Pas moved to Flin Flon to replace one staff person who resigned early in the year.

The GSC and coworkers from the universities of Regina and Saskatchewan and the GSB continued work on the interpretation of seismic profiles across the Thompson Nickel Belt conducted in 1994 under the LITHOPROBE Trans Hudson Orogen Transect initiative. New insights into the three dimensional geometry of the Churchill/Superior boundary zone and the age and structural relationships of the major crustal elements under this region, from the Superior Craton to the neighbouring juvenile components of the Hudsonian Orogen, are being developed.

TECHNICAL RESULTS

Lynn Lake Region

Toward the end of the Summer a brief period was spent with Black Hawk Mining personnel, to demonstrate sundry geochemical sampling techniques as an aid to detecting zones that might be enriched in gold near the T1A deposit.

Flin Flon

In the Dow Lake-Martell Lake area, newly acquired geochemical data and new mapping provided clearer definition of structural units on the south flank of the Kisseynew belt. Gently northeast-dipping structural panels of highly metamorphosed ocean-floor and island-arc volcanic rocks, younger basinal sedimentary rocks and successor arc plutons are identified as the northern continuation of similar units in the Flin Flon-Snow Lake belt. Their variable mineral potential controls and strongly influences the distribution of deposits and showings in the gneissic and low-grade terranes.

The geological mapping project on the northern fringe of Kississing Lake was concluded with examination of drill core from Canmine Resources Corp. property on Yakushavich Island. Brief visits were also made to new clear-cut outcrops in the Syme Lake and Fay Lake areas.

In the Lac Aimée area, where a new mapping program is being started, lithologies principally comprise aphyric- to phyric- (plagioclase and pyroxene) basalt and related breccia with arc geochemical signatures. North of Alberts Lake, greywacke-siltstone turbidite is intercalated with this basalt. These rocks trend NE to E, in contrast to north- to northwest-trending Mikanagan ocean- floor basalt to the west. The boundary between the two basalt types consists of a major block-bounding fault at the KD mineralized zone that extends due south from the southwest extremity of Lac Aimée. Mikanagan basalt has relatively higher TiO_2 and FeO compared to Lac Aimée basalt and is devoid of intercalated breccia and turbidite, consistent with a deeper water environment.

Stratigraphic and structural problems arising from the compilation of the Baker Patton Complex area were re-examined prior to completion of the final map. On-going geochemical investigations include additional sampling to refine stratigraphic correlations and the preparation of an M.Sc. thesis at the University of Regina that will investigate the alteration associated with the Leo Lake VMS deposit. Mapping in the Cleaver Lake area, south of the Baker Patton Complex, was completed. The supracrustal rocks consist predominantly of subaqueous mafic volcanic rocks and minor rhyolite flows and intrusions. Several oxide and sulphide facies iron formations occur in the central part of the area.

Several units of mafic rocks delineated in the Baker Patton Complex have been traced northwards into the Alberts Lake area as part of a newly initiated project. Felsic volcanic rocks are tentatively correlated with subaqueous rhyolites at Baker Patton. The Alberts Lake gold deposit and several occurrences of quartz vein-hosted gold-sulphide mineralization are spatially and genetically associated with a regional northeast-trending zone of brittle-ductile deformation, the Alberts Lake Deformation Zone.

Follow-up analytical geochemical and structural work in the Reed Lake area has built on the field work completed in 1995 and has resulted in a more thorough interpretation of rock units and their structural relationships. The Fourmile Island arc assemblage, identified in the field by its compositional and stratigraphic heterogeneity, has the geochemical signature of oceanic island arc tholeiites, similar to VMS-hosting arc rocks at Flin Flon and Snow Lake. The Northeast Reed ocean-floor assemblage, a monotonous sequence of pillowed basalts, is geochemically an N-type MORB with a weak arc signature and is similar to other units in the Flin Flon belt that have been interpreted as back-arc basin basalts.

Mapping of the Photo Lake area completed a cooperative project between HBED and GSB, begun in 1994. This 1:5000 scale mapping project is designed to accelerate exploration in this newly discovered Cu-Zn mining area and to link this area to the more completely understood and mapped Chisel Lake region to the south. In addition to identifying the geological setting of the Photo Lake Deposit, the goal of the project is also to define the geological parameters underpinning the copper (and gold) rich nature of the orebody as opposed to the zinc-rich mineralization at Chisel Lake.

Northern Superior Province

Following extended planning sessions, a series of new projects were initiated in the Northern Superior Province to stimulate increased levels of exploration by the private sector. This part of the Superior Craton contains a high proportion of linear, west-trending greenstone terranes that are continuous along strike with those in Ontario. However, an extensive veneer of glacial surficial deposits, over much of the region, blankets much of the bedrock and restricts exposures to lake and river shorelines. Accordingly, although detailed geological mapping is warranted in selected areas of good exposure and more recently burnt over areas, emphasis has been placed on upgrading the geochemical database for the entire region using a multimedia approach to target anomalous metal concentrations in bedrock, and other media, as well as indicator mineral concentrations in basal tills associated with down-ice dispersion fans.

216 multimedia geochemical sampling sites were visited in the Carrot River, Munro Lake, and Echimamish River greenstone belts. Helicopter-supported sampling of outcrop, till, B-horizon, humus and vegetation was undertaken on 1 km spacings resulting in the collection of 991 samples. Multi-element geochemical databases are currently being developed for each sample type in order to assess the potential for diamonds, and base and precious metal mineralization in these belts. A regional till sampling program based on one sample per 40 km^2, was initiated by the GSC in the intrusion-dominated terranes that separate the Archean greenstone belts.

Geological mapping was initiated at the southeastern end of Margaret Lake in a 5-6 km wide greenstone belt that extends northwestwards from Stull Lake in Ontario. This supracrustal belt is dominated by pillow basalt flows intruded by four varieties of felsic dykes and two small plutonic bodies. A major, linear, 315° trending deformation zone is an extension of a similar zone at Stull Lake that contains associated gold showings. Small areas of felsic volcanic and arkosic rocks occur in proximity to this zone.

A regional study of mafic and ultramafic intrusions in the northwestern part of the Superior Province was initiated with field investigations at Bear Head Lake, Butterfly Lake, Cauchon Lake, Cuthbert Lake, Landing Lake, Paint Lake, Partridge Crop Lake and Wintering Lake. Investigations focussed on Archean anorthositic intrusions and metagabbro to metapyroxenite bodies within or immediately adjacent to, the Pikwitonei Granulite Domain. Systematic bedrock sampling was completed in order to provide petrographic and geochemical data to classify the rocks, and establish their petrogenetic evolution and potential for hosting magmatic sulphide and oxide mineralization.

Detailed mapping in the central part of the Pipestone Lake Anorthositic Complex was completed as part of an ongoing M. Sc. thesis (University of Manitoba) concerned with the geological setting and genesis of the Ti-V-Fe deposits that occur in the complex (currently being evaluated by Gossan Resources Ltd. and Cross Lake Mineral Exploration Ltd.). A second M. Sc. thesis, to be initiated next year, will compare the petrology, geochemistry and oxide occurrences at Pipestone Lake with those of the West Channel (Nelson River) anorthosite complex.

In preparation for mineral deposit studies planned for 1997, field notes from previous mapping programs in the Superior Province were retrieved from archives and examined for records of mafic or felsic volcanic samples that could be used in a first pass geochemical characterization of their paleotectonic settings. This preliminary geochemical data will facilitate correlation of mineral deposits and tectonic environments of formation as a regional guide to exploration.

Work commenced on interpreting and compiling all geophysical data from open assessment files relating to past exploration in the northern Superior Province. The outcome of this project will consist of two reports with accompanying maps, outlining areas requiring further exploration. The first report, encompassing the southern portions of NTS areas 53K, 53L and 63I (north and south), is in final preparation.

Thompson Belt

Extensive discussions with companies active in the Nickel Belt (and its southwestern extension) have led to the development of a major cooperative project to be conducted over the next three year period. The principal products stemming from this work will be an enhanced understanding of the geology of the belt based in large part on a new and thoroughly revised 1:50 000 geological map of the Churchill/Superior Boundary Zone from Moak Lake southwest to The Pas moraine and in the longer term Swan Lake. During 1996 work began on the map, in close cooperation with INCO Limited and Falconbridge Limited. The new map will merge two decades of regional and detailed mapping by the GSB with the latest understanding of the lithostratigraphic sequences and structural evolution. In addition, the map will include information obtained from detailed relogging of drill core collected by the companies together with extrapolation based on a hitherto unavailable geophysical database. Both companies are providing access to technical information and support by technical staff in undertaking this task, which will be conducted under an accelerated timeframe.

In the southwestern extension of the Nickel Belt between Cedar and Swan lakes, stratigraphic, lithologic and geochemical studies were initiated on core from four bore holes from Cominco's Rabbit Point property. The intrusive and extrusive spinifex-bearing ultramafic rocks and associated sulphide-bearing pelite, sulphide facies iron formation and dolomite indicate a potential to contain komatiite-hosted Ni-Cu deposits. The geochemical investigations, conducted in cooperation with researchers from Laurentian University and the University of Alabama, will be guided by the detailed stratigraphy in these subgreenschist facies rocks.

South and southeast of Wekusko Lake confidential sub-Phanerozoic drill core supplied by exploration companies was relogged in order to further delineate basement lithologies in the area. This year's relogging program resulted in a comprehensive catalogue of 30 cores in NTS areas 63J-SW and 63K-SE.

Southern Manitoba- Interlake Region

A three week stratigraphic mapping program in the Cross Bay area (Cedar Lake, Grand Rapids) was conducted to trace contacts within the upper portion of the Silurian Interlake Group. An anomalous feature at Ochre Lake northeast of Cross Bay, may represent a post Paleozoic structural disturbance that affected the Silurian strata. Supplemental stratigraphic data was gathered from logging 25 mineral exploration drill cores in the Grand Rapids region.

The spring water and marl sampling program, to detect signs of MVT mineralization north of Grand Rapids, was completed this year. Six springs west of Mechiso Lake, one north of Buffalo Lake and the Karst Spring at Iskwasum Lake were sampled and analysed. Check resampling of a single anomalously high fluoride result from northwest of Buffalo Lake failed to duplicate earlier results. Fracture orientations in the carbonate bedrock were collected at 37 distributed sites from Iskwasum Lake to Garson as part of a regional study to compare fractures in the basement with those in the carbonate rocks at or near surface.

This year the GSB drill program completed nine holes with a total of 738.32 metres of core. Three deep holes were drilled in a north-south transect between Cross Bay (Cedar Lake) and Tan Creek (north of St. Martin junction) to provide stratigraphic control in a region with very sparse data. The other six holes were drilled in the Stonewall region and near Garson to provide depth to bedrock and industrial mineral information as part of the Capital Region study. All stratigraphic core hole information is being added to the Manitoba Stratigraphic (digital) Database which also includes 1355 lower Paleozoic well tops verified by relogging. The Database currently contains information from 5346 wells, and is being used to generate new stratigraphic maps for southwestern Manitoba. Several products that are readily reproducible and of interest to explorationists include overburden thickness and depth to Precambrian.

All water wells drilled to bedrock in the north half of the Capital Region are being inventoried for input into the digital database (structure contour and isopach maps will be produced from this data). All mineral inventory cards for each quarry were updated and stratigraphic columns for each quarry have been drafted and are in final form.

Data acquisition has also begun from the City of Winnipeg drillhole log database. This highly condensed information set, when standardised and reinterpreted, will ultimately be used to generate detailed depth to bedrock and other maps covering areas within the Perimeter Highway for use by engineering and environmental studies.

Mapping of Upper Cretaceous calcium bentonite seams along the edge of the Manitoba Escarpment and within the Pembina Valley in the Brandon area demonstrated the lateral continuity of the seams as well as that of the overlying and underlying formations and members. At least 11 bentonite seams ranging in thickness from 1-30 cm, are typically separated by black shales. Although many of the seams along the Escarpment west of Miami and Morden have been extracted, additional potential exists to the north and south and within the Pembina Valley.

The Lake Winnipeg Phase II project funded by the GSC and Manitoba Hydro, was carried out between August 5 and September 5. The northeast geophysical survey resulted in approximately 400 km being surveyed. This was followed by a southbound coring and sampling cruise that resulted in 24 gravity and 24 piston cores being taken, for a cumulative length of 100 m. As part of the Lake Winnipeg project and as a joint project with the University of Manitoba, the elevation of the upper and lower Campbell beaches of Lake Agassiz were determined along the Manitoba Escarpment, as were the elevations of beach polygons falling within the southeast Manitoba Prairie NATMAP region.

In addition to the principal programs of the Branch, short visits were made to several localities as part of a new initiative to explore for new deposit types. At Black Island, hydrated iron sulphate minerals mantling the black shale within the Ordovician Winnipeg Sandstone were found to contain Rozenite, Szomolnokite and Magnesiocopiapite. These crusts were produced as a result of groundwater leaching of a gold-bearing, sediment hosted iron formation intersected during diamond drill testing of the hematite occurrence on Black Island.

The geological setting of microdisseminated gold and associated base metals has been confirmed in the Upper Devonian Point Wilkins Member of the Souris Formation exposed in the CBR cement quarries at Mafeking. Mineralization was identified with scanning electron microscopic techniques as micron-sized particles in solution chimneys developed within both high-calcium limestone and overlying strongly oxidized dolomitic limestone. A modern day example of this deposit type has been documented from the Red Deer River salt spring, north of Mafeking. Regional controls on this type of mineralization are considered to be the coincidence of the Churchill/Superior Boundary Zone and the dissolution front or edge of the Prairie Evaporite. The recognition of this new gold deposit type opens up an exciting exploration opportunity for Manitoba's Phanerozoic rocks.

Abundant pieces of multicoloured red, orange, mauve and yellow noncalcareous breccia with interleaved clasts and glassy, gas-bubble texture were found in a gravel pit on the south side of the Swan River Valley, on the northeastern slopes of Duck Mountain. This brecciated "meltrock" is distributed throughout the quarry along with cobbles of Precambrian granitic rocks and Paleozoic carbonates, and in four "oversize" piles. Although the "meltrock" has not been recognized *in situ* within the sand and gravel deposits in the walls of the pit the fragile nature of the specimens and their slightly rounded surfaces suggests limited transportation. The lithology of the breccia clasts consists of baked fragments of shale, silt and sand that are not unlike the undisturbed Cretaceous sediments exposed in the valley walls. The "meltrock" characteristics suggest sudden heating and cooling of the sedimentary rocks, but the origins of this process are unknown at this time.

Thanks are extended to staff of the GSB who provided summaries on their summer investigations.

Sept. 17, 1996

GS-1 OPERATION SUPERIOR: MULTIMEDIA GEOCHEMICAL SURVEYS IN THE ECHIMAMISH RIVER, CARROT RIVER AND MUNROE LAKE GREENSTONE BELTS, NORTHERN SUPERIOR PROVINCE, MANITOBA (NTS 53L AND 63I)

by M.A.F. Fedikow, E. Nielsen and E. Sailerova

Fedikow, M.A.F., Nielsen, E. and Sailerova, E., 1996: Operation Superior: multimedia geochemical surveys in the Echimamish River, Carrot River and Munroe Lake greenstone belts, northern Superior Province, Manitoba (NTS 53L and 63I); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 5-8.

SUMMARY AND CONCLUSIONS

A total of 991 multimedia samples were collected from 216 sites within the Carrot River, Munroe Lake and Echimamish River greenstone belts in the northern Superior Province during the months of June and July, 1996. Rock, till, b-horizon, humus and vegetation samples collected at each site will be analyzed by a variety of analytical techniques to develop a multi-element geochemical database for application to mineral exploration.

INTRODUCTION

Belt and reconnaissance scale geochemical surveys have a long history of application to mineral exploration and mineral resource assessment. Published articles (Coker and Dilabio, 1989; Ketola, 1989; Beaumier, 1989) describe the relative merits of rock, till and lake sediment geochemical surveys at various scales where prospecting and mineral exploration have been impeded by significant overburden cover. In overburden obscured volcano-sedimentary belts the mineral potential of the belt is initially assessed using geological comparisons with similar-aged belts where revenue generating commodities have been discovered and exploited.

In previous studies designed to assess mineral potential in greenstone belts, relatively few sample types have been collected and analyzed to geochemically examine favourable structures, lithologies or geophysical conductors. A recent example of this approach has been developed and described by Wright and Bonham-Carter (1996) in a multidisciplinary study of the residual mineral potential of the Proterozoic Snow Lake greenstone belt. In this study geology, geophysics, lake sediment geochemistry, known mineral deposits and related alteration zones were used to predict "high potential" areas for mineral exploration.

The five year helicopter and fixed wing-assisted multimedia geochemical surveys being conducted under the Operation Superior initiative in northeastern Manitoba will utilize a wide range of geochemical sample media. These include rock, till (<2μm and <63μm size fractions) b-horizon soil, humus and vegetation (black spruce crowns and outer scaly bark; jack pine new growth). The derived multi-element analytical data will initially be used to establish metal-rich zones and areas of diamond potential. Subsequently the data will be integrated with geological and geophysical information to provide a multilayered assessment of potential for numerous commodity types.

Concurrent with the first year of the multimedia sampling program a short term research project was initiated to attempt to quantify seasonal metal flux in vegetation by measuring the changes in metal content and root water uptake in black spruce trees. A satisfactory resolution of the quantification of seasonal metal flux in vegetation would permit a broader comparison over time of vegetation geochemical data in the project area.

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

A two-tiered approach will be implemented for northern Superior Province multimedia geochemical sampling. Belt-scale sampling will be conducted by the Manitoba Geological Services Branch on 1 km centres within and down-ice from the known limits of Archean greenstone belts. The Geological Survey of Canada will undertake reconnaissance scale till sampling on approximately 40 km centres in the intrusion-dominated terrane between the greenstone belts (Matile and Thorleifson, GS-2 this volume). Both scales of sampling will utilize fixed wing and/or helicopter support.

At each sampling site two samples were collected from hand dug pit. One till sample (12 litre pail) was collected for diamond indicator mineral assessment. The second 1 kg till sample will have the <2μm and <63μm size fractions analysed for base and precious metal contents using neutron activation (NA) and inductively coupled plasma (ICP) techniques. A b-horizon sample was collected from each till sample pit and will be assessed using a variety of analytical techniques including atomic absorption spectrometry (AAS), neutron activation (NA) and inductively coupled plasma-mass spectrometry (ICP-MS/enzyme leach). Humus sample to fill a medium sized ZIPLOC bag was collected from the immediate vicinity of the till/b-horizon pit and will be analyzed by NA and ICP methods. Where possible, representative outcrop chip samples were collected from within 50-100m of the overburden sample pit generally after significant moss and lichen were removed from the outcrop. These samples consisted of 1-2 kg of 5-6 cm rock chips. Silicate whole rock analysis and multi-element analysis (AAS, ICP, NA) will be undertaken as deemed necessary. Vegetation samples were collected from burned and non-burned environments. Samples of outer scaly bark and the upper 45 cm (the 'crown') of black spruce were collected from both environments. Where black spruce was unavailable in burned areas, current years twig growth from 3-8 year old jack pines was collected. Subsequent to drying, the outer scaly bark, the twin portions of the black spruce crowns and the jack pine twigs will be ashed (470°C) and analysed by NA and ICP. A thin cross sectional slice of tree trunk was collected with a saw from each black spruce tree for age determination.

QUALIFICATION OF METAL FLUX IN VEGETATION

A two month study of closely monitored changes in transpiration rates and metal flux of black spruce trees growing in a variety of substrates and other environmental conditions was undertaken in the general area of Jenpeg. The study was designed to determine whether geochemical data generated from an 8 week vegetation sampling survey could be compared over the term of the survey by quantifying metal flux in crown twigs. The experiment will assess whether measurements of the rate of root water uptake can be correlated with crown twig metal concentrations. The twig portions of the black spruce crowns were selected for study because 1) the tissue will be collected regionally during Operation Superior, and 2) the apparent acropetal tendency for higher metal concentrations to occur in the crowns (Fedikow and Dunn, 1996). The extent of the relative effects of certain environmental criteria on root water uptake and parallel metal accumulation in crowns will be investigated. These criteria include; (1) exposure of the tree to direct sun and wind, (2) general patterns of trends in the weather and their effects on metal uptake, (3) the number of photosynthesizing and transpiring branches on the sampled tree affecting both water uptake rate and metal redistribution. This includes an assessment of the size of the root system on metal enrichment given the apparent positive correlation between the size of a root and shoot system (4) physical characteristics of tree crown including the length of the crown leader as a potential indicator of the rate of metal accumulation. The length of the leader should be reflecting the metabolic activity of the apical meristematic tissue and possibly the metal uptake rate into this tissue type, and (5) soil drainage characteristics.

Reproducibility of the method will be assessed by comparing geochemical results for sample sets of one, two and five crown samples collected every five or six days over the term of the 1996 sampling season. The relative impact of the above listed factors on metal accumulation in black spruce crowns will be determined so that criteria for selecting a tree at a particular sampling site can be established. This should increase the reproducibility of vegetation geochemical data between sampling sites, as well as provide the basis for better field data interpretation.

RESULTS

A total of 991 samples were collected from 216 sites in the Carrot River, Munroe Lake and Echimamish River greenstone belts during 1996 from a base situated near the Manitoba Hydro Jenpeg generating station (Fig. GS-1-1). Figure GS-1-2 provides the location of the sampling sites in relation to the boundaries of the greenstone belts. The sample breakdown for each greenstone belt is provided in Table GS-1-1.

Analyses are unavailable at the time of writing. Preparation of all sample-types is in progress.

ACKNOWLEDGMENTS

We greatly acknowledge the considerable skills of Mr. C. Taylor, Provincial Helicopters, (Lac du Bonnet) in safely accessing sample sites for the 1996 season. Manitoba Hydro is thanked for access to facilities at its Jenpeg generating station with particular acknowledgment of the efforts of Mr. Darrell McKay for assistance with access to fuel storage facilities, campsite and general advice. Mr. Samir Hathout is thanked for able assistance during the sampling program.

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Table GS-1-1

Summary of sample types collected from greenstone belts surveyed in 1996. Till is subdivided into samples collected for diamond mineralogical and indicator mineral geochemical assessment ("Diamond") and for base and precious metal geochemistry ("Geochem")

	Rock	Till		Horizon	Humus	Vegetaton Black Spruce/Jack Pine		
		Diamond	Geochem			Crowns	Outer Sclay Bark	Current Year Growth
Carrot River Belt (Sites 71)	34	58	58	70	71	70	67	3
Munroe Lake Belt (sites 33)	23	23	25	33	32	34	34	0
Echimamish River Belt (sites 112)	91	934	88	111	106	99	96	13

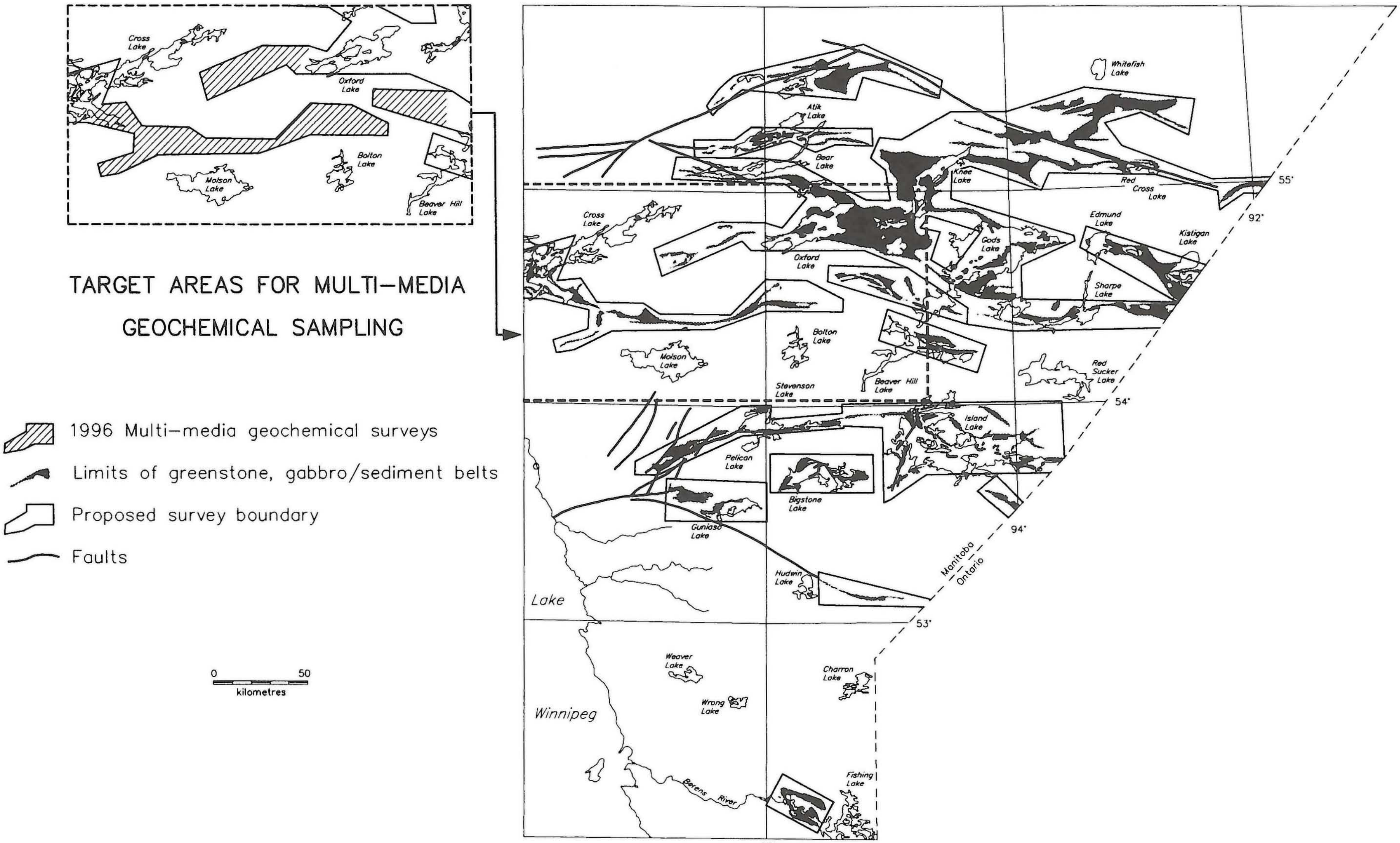

Figure GS-1-1: Location map for Superior Province greenstone belts sampled in the 1996 Operation Superior multimedia geochemical survey.

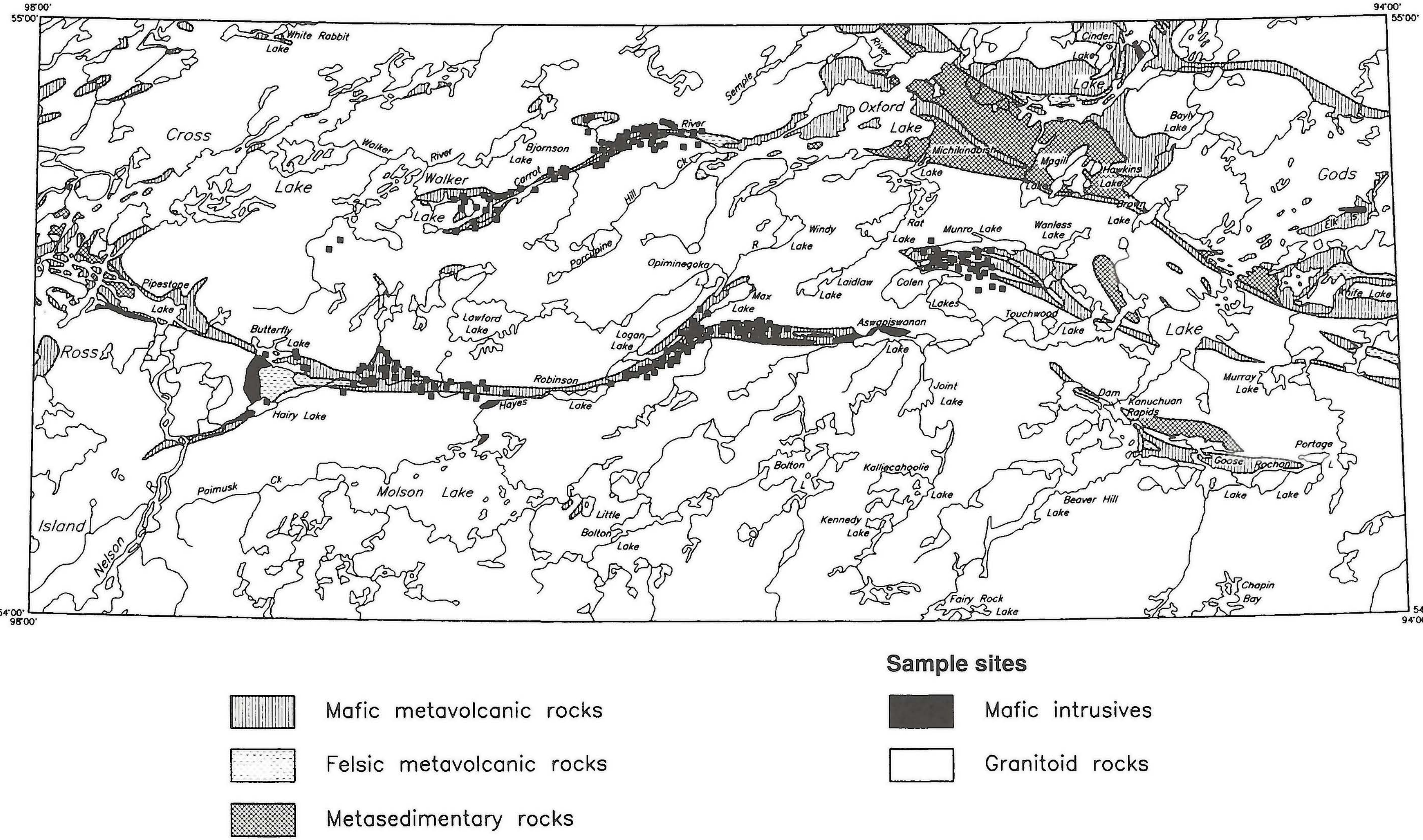

Figure GS-1-2: Location of multimedia geochemical sampling sites in relation to the boundaries for the greenstone belts surveyed in 1996.

GS-2 REGIONAL TILL COMPOSITIONAL TRENDS, NORTHEASTERN MANITOBA

by G. L. D. Matile and L. H. Thorleifson[1]

Matile, G.L.D. and Thorleifson, L.H., 1996: Regional till compositional trends, northeastern Manitoba; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 9-10.

INTRODUCTION

The Superior Province of the Canadian Shield in northeastern Manitoba is a region with high potential for discoveries of base metal, precious metal, and gemstone deposits. The Manitoba Geological Services Branch (MGSB) and the Geological Survey of Canada (GSC) have therefore initiated geoscience programs designed to enhance the knowledge that supports mineral exploration in this area. Mapping of regional geochemistry and indicator mineral trends is being conducted on two scales. Multimedia geochemical sampling at 1 km spacing within greenstone belts is being coordinated by Fedikow *et al.* (GS-1, this volume). This paper summarizes progress on an accompanying project that is based on till sampling at 40 km spacing. This work is designed to map major features in sediment composition and hence drift provenance, and to provide a reference set of data for background geochemical and indicator mineral trends.

STUDY AREA

The study area (Figure GS-2-1) covers the Manitoba portion of the area between 53°N and 56°N and from 92°W and 100°W, an area meant to cover a portion of the northwestern Superior Province with a high frequency of greenstone belts. The area was extended westward in order to overlap with earlier surveys (McMartin *et al.*, 1996; Kaszycki *et al.*, 1996; Thorleifson *et al.*, 1994). For example, numerous Cr-diopsides have been found in sediments west of Lake Winnipeg (Thorleifson *et al.*, 1994). The present project will enable these observations to be tested, and will determine whether the area of Cr-diopside abundance extends to the northeast.

Precambrian rocks in the region consist largely of granitic and high grade metamorphic rocks with intervening east-west trending greenstone belts that include low grade metavolcanic and metasedimentary rocks. The northeastern and southwestern corners of the study area are underlain by the Hudson Bay Lowland and Williston Basin, respectively, where Paleozoic sedimentary rocks dominated by carbonate are present. In the northwest, the area extends into the Churchill Province of the Canadian Shield. The Churchill/Superior boundary and associated Thompson Nickel Belt are located in the west-central part of the area.

In the northeast, southwestward ice flow deposited a continuous, fluted sheet of calcareous till derived from carbonates and reworked marine sediments in the Hudson Bay Lowland. The northwestern, central, and southeastern parts of the area are underlain by noncalcareous, sandy till. Locally-derived calcareous till is prevalent in the area west of Lake Winnipeg.

Also present are well developed eskers that trend southwest, as well as east-west trending moraines. Silty glaciolacustrine sediments are extensive, particularly in the central and west-central portions of the area. Extensive peatlands are present, and perennially frozen soils are increasingly common to the north.

[1] Geological Survey of Canada

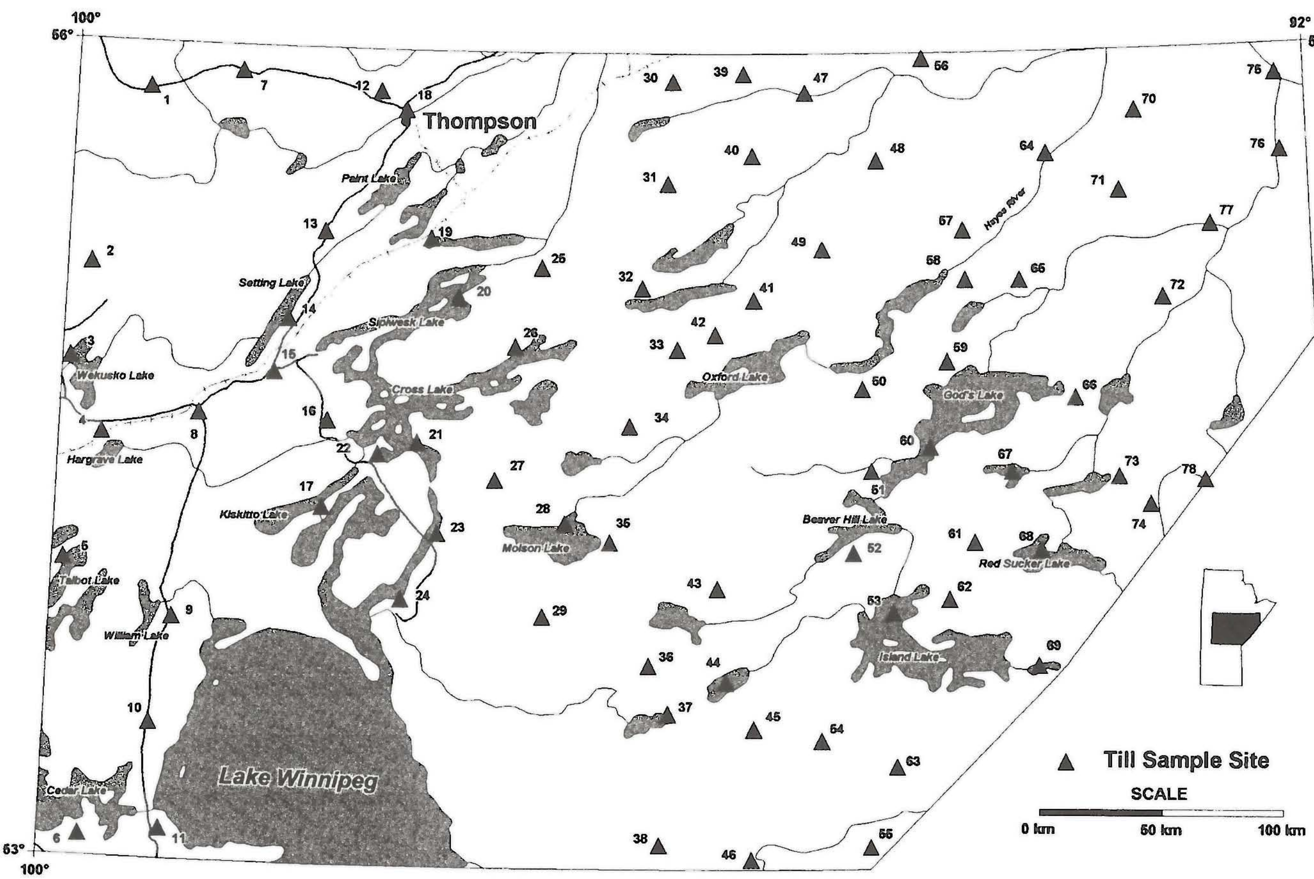

Figure GS-2-1: Location of till sampling sites.

SAMPLING

Till was chosen as the sample medium for the regional survey, due to the role that till plays as the source of other clastic sediments and a major control of geochemical trends in media such as soil. Furthermore, sampling of till permits the analysis of indicator minerals and their correlation to the composition of other fractions of the till. Till samples also permit the lithological analysis of the gravel fraction, in order to trace the provenance of the sediments to bedrock sources.

A 40 km spacing was considered adequate to define major features of the sediment, such as the southwestern limit of carbonate derived from the Hudson Bay Lowland, and trends in background for geochemical and indicator mineral variables.

At 78 sites, a 12 litre till sample was collected below the B horizon at an existing exposure such as a road cut or river bank, or from a shovel hole. Data on location, sampling depth, Munsell colour, reaction to HCl, texture, structure, and moisture content were recorded at the site. Samples were obtained at 21 road-accessible sites by the first author during a four day period in late July. At 57 sites, till was sampled by the second author from shovel holes or river cuts at sites accessed by Cessna 206 float planes based at Norway House, Thompson, and Gods Lake Narrows. The latter work was completed over 6 days in late July and 7 days in mid August, with as many as 8 sites sampled per day.

ANALYSES

Three 0.3 litre subsamples will be removed from each 12 litre sample, an archive split, a split for recovery of the <0.002 mm fraction by centrifugation for geochemical and clay mineralogical analysis, and a split for determination of moisture content and preparation of the <0.063 mm fraction by dry sieving for geochemical and carbonate mineralogical analysis. Sediment remaining after removal of splits, >11 litres, will be disaggregated and screened at 2 mm. The >2 mm fractions will be washed, dried, weighed, and retained for lithological analyses. The <2 mm fraction will be examined for visible gold grains using a shaker table and panning. Preconcentration of heavy minerals will be completed using a shaker table procedure designed to enhance recovery of coarse silicate heavy minerals. Plans call for final concentration of a heavy mineral concentrate to be completed using methylene iodide diluted with acetone to a specific gravity of 3.2, as well as removal of ferromagnetic minerals. The 0.25-2.0 mm fraction will be visually examined for indicator minerals derived from kimberlite and metamorphosed massive sulphide, and selected minerals will be analyzed by electron microprobe. The <0.25 mm nonferromagnetic concentrate will be analyzed by nondestructive instrumental neutron activation analysis (INAA).

FUTURE WORK

Data obtained from the 78 till samples collected in 1996 will be released over a period of about one year following completion of field work.

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GS-3 GEOLOGY OF THE EDMUND LAKE AREA (53K/11NE)

by M.T. Corkery

Corkery, M.T., 1996: Geology of the Edmund Lake area (53K/11NE); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 11-13.

SUMMARY

The northern half of the map area is underlain by a sequence of Archean supracrustal rocks. These form a portion of the Stull Lake greenstone belt that extends in a west-northwest direction from Stull Lake in Ontario, terminating to the west of Edmund Lake (Figure GS-3-1). The eastern end of the Gods Lake Greenstone belt occurs 10 km further west along strike.

In the map area the supracrustal belt forms a gradually westward-thinning east-plunging homocline. It is flanked by tonalite and granite terranes to the north and south.

The supracrustal belt is dominated by pillowed and massive basalt flows that have historically been assigned to the Hayes River Group (Downie, 1938). The basalts are intruded by gabbro and felsic dykes and two small plutonic bodies. A major linear shear zone trends 310° across the map area. This is an extension of the shear zone, and its associated gold showings, in the Little Stull Lake area. The deformation zone ("Wolf Bay" shear zone) divides the belt into a northern and southern basalt series. Interlayered felsic and mafic volcaniclastic rocks, iron formation and sedimentary rocks occur sporadically along the north edge of the shear zone. Downie (1936) assigned these rock types to the Oxford group. Numerous gossan zones occur both within these units and to the south within the shear zone.

INTRODUCTION

The Edmund Lake map area represents the first in a series of geological mapping programs within the Archean greenstone belts in the Stull Lake map sheet - NTS 53K. The area straddles the Ontario/Manitoba border between latitudes 54° and 55° north.

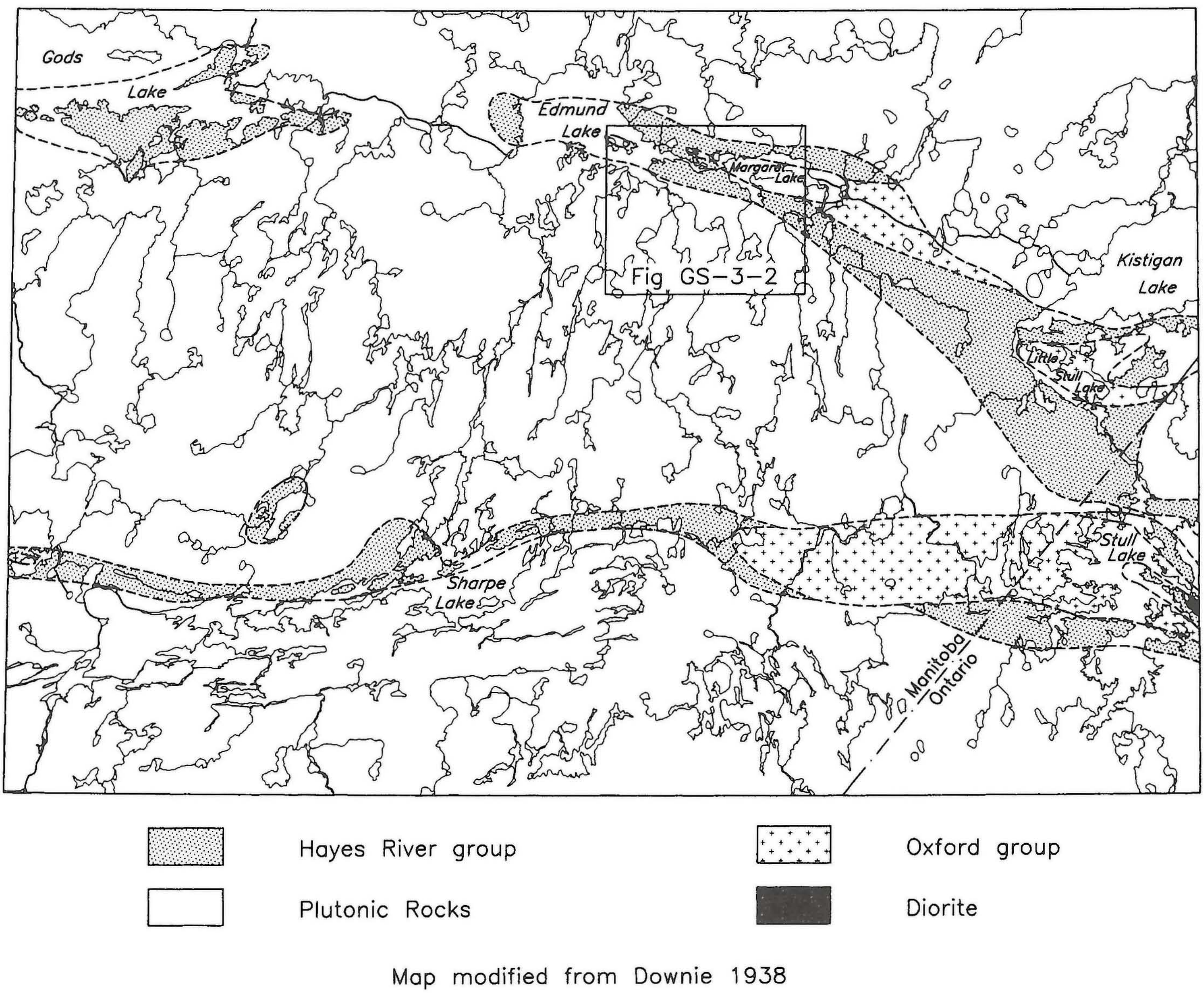

Figure GS-3-1: Location and general geology of the Stull Lake area.

The project entails 1:20 000 scale geological mapping of supracrustal belts and plutonic rocks within selected portions of the 1:250 000 NTS sheet in Manitoba. Mapping programs are planned for the Edmund - Margaret lakes area, the Little Stull - Kistigan lakes area and the Sharpe Lake area. The geological database for the area does not compare with that for elsewhere in the province because it consists only of the 1:250 000 coverage by Downie (1936).

Mapping of the supracrustal rocks in 1996 centred on the south eastern end of Edmund Lake and Margaret Lake (53K/11NE) at 1:20 000 scale (Manitoba Energy and Mines Preliminary Map 1996S-1). There is significant exposure of the supracrustal belt in the Edmund Lake area, however, it is to a large extent obscured by lichen and moss cover.

The Hayes River group and Oxford group terminology has been retained in this report to avoid confusion. However, an evaluation and reworking of the existing nomenclature is expected to develop as a result of detailed mapping programs conducted under Operation Superior.

SUPRACRUSTAL BELT ASSOCIATIONS

Hayes River group

The supracrustal rocks in the Edmund Lake area (Manitoba Energy and Mines Preliminary Map 1996S-1) are dominated by pillowed and massive basalt flows (unit 1). Fine grained aphyric and porphyritic gabbro dykes and sills (unit 2) intrude the volcanic pile throughout the entire sequence. Large coarse grained layered gabbro-pyroxenite sills (unit 3) occur only on the south flank (base) of the sequence. There is a lack of the interbedded greywacke, iron formation or tuff layers that are common in the Hayes River group in the Gods Lake area (Theyer, 1992). The monotonous sequence of basalt flows with layered gabbro sills at the base, and feldspar porphyritic basalt flows near the top, is similar in character to the Pipestone Lake Group in the Cross Lake area. Based on physical and chemical characteristics the Pipestone Lake Group is interpreted as a back arc basin association (Corkery *et. al,* 1991). Geochemical analysis is underway to test the geochemical signature of the basalts at Edmund Lake.

Although entirely composed of basalt or basaltic gabbro the volcanic sequence in the Edmund - Margaret lakes area has been divided into six subunits. The dominant flows in the southern series are dark green to green- grey aphyric pillowed and massive basalt flows (unit 1a) interlayered with pale green to blue- green aphyric pillowed and massive basalt flows (unit 1c). Unit 1c flows are interpreted to be slightly more siliceous, and possibly of basaltic andesite composition. Pale green to blue- green feldspar porphyritic pillowed and massive basalt flows (unit 1d) - rarely with mafic aggregates of amphibole - occur in the upper portion of the section and form a northwest- trending marker that continues into the "Wolf Bay" shear zone (Fig. GS-3-2). Dark green to green-grey hornblende porphyritic massive and pillowed basalt flows (unit 1b) are rare and show an irregular distribution in the section. All of these basalts contain abundant chlorite and pale green amphibole. North of the "Wolf Bay" shear zone, basalts have similar primary characteristics and consist of dark grey to black aphyric flows (unit 1e) and amphibolite derived from pillowed and massive basalt flows (unit 1f). These are interpreted to be higher metamorphic grade equivalents of unit 1a.

Primary layering and top indicators are rare in the basalts. However, where present they indicate a moderately northeast dipping- northwest trend at an acute angle to the strongly developed west-northwest regional fabrics. The consistent angular relationship of primary layering to the fabric and the linear distribution of the only marker horizon (feldspar porphyritic basalt - unit 1d) indicate a homoclinal northeast- facing sequence. Large scale folding has not been documented in the belt. Although few primary relationships were observed in the northern series - northeast of the "Wolf Bay" shear zone - the few north- facing top directions that were observed are consistent with those documented in the southern series.

Fine grained aphyric (unit 2a) gabbro dykes and sills that form about 10% of the section intrude the basalts throughout the area. They occur as small 1 to 2 m aphanitic dykes and as discontinuous fine- to medium-grained sills up to tens of meters thick. They are commonly composed of 0.5 to 1.0 mm anhedral to subhedral feldspar in a chlorite-amphibole matrix. Feathery radiating, 3 to 7 mm aggregates of mafic

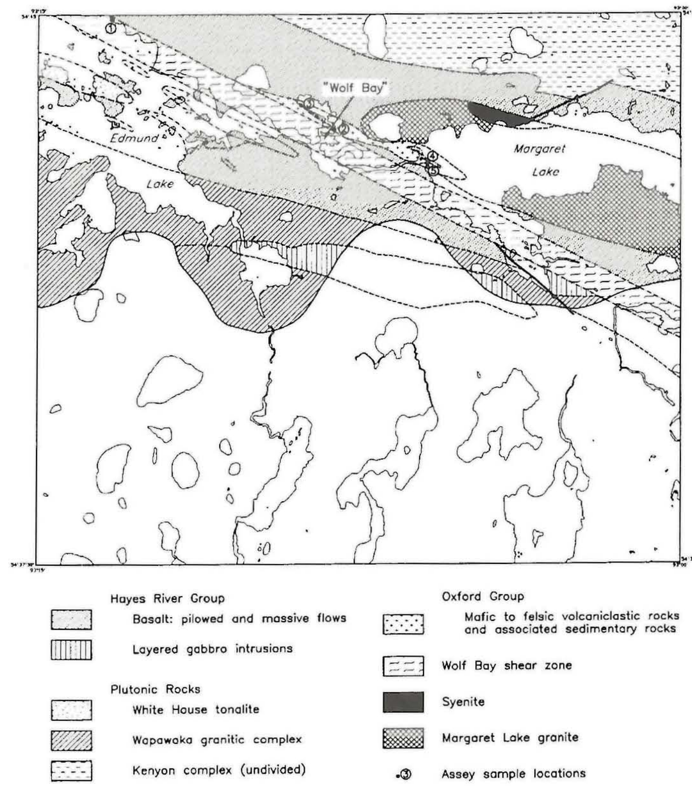

Figure GS-3-2: Simplified geological map of the Edmund- Margaret lakes area.

minerals (actinolite?) form mafic clots in thicker sills. Where contact relationships are not exposed these dykes and sills are difficult to distinguish from thick massive basalt flows that display similar textural characteristics. Hornblende porphyritic gabbro (unit 2b) forms a minor dyke phase commonly associated with unit 1c. Plagioclase porphyritic and/or glomeroporphyritic gabbro (unit 2c) is associated with unit 1d.

Oxford group

A highly diverse sequence of volcaniclastic and sedimentary rocks forms a narrow discontinuous band up to 500 m thick along the north flank of the "Wolf Bay" shear zone. These units are well exposed only in "Wolf Bay" and on the west shore of Margaret Lake. They pinch out to the west along the "Wolf Bay" shear zone and plunge beneath the Margaret Lake granite (unit 9) to the east. In general these rocks are strongly flattened and foliated and transposed parallel to the shear zone, but some outcrops retain delicate primary depositional features.

Felsic massive and fragmental volcanic rocks (unit 7a) are the dominant lithologies in this group. Where least deformed and recrystallized they consist of pale green to light green-beige aphyric rhyodacite to rhyolite. Most are massive with a vague internal banding defined by colour variations or, rarely, they are fragmental with a range of angular fragments from coarse ash to lapilli and rarely larger. These units are commonly strongly altered along fractures that results in a light grey and black mottled fresh surface with muscovite and sulphides along the fractures. Many suphide-bearing gossan zones occur in these units. Black to dark grey volcaniclastic and epiclastic shoshonitic basaltic rocks (unit 7b) occur in "Wolf Bay" and at the west end of Margaret Lake.

Sedimentary rocks (unit 8) are interlayered with the volcaniclastic rocks (unit 7). Arkosic sandstone and polymictic pebbly sandstone (unit 8a) are exposed as isolated outcrops and in one 30 m thick section. Bedding ranges from thin silty beds and bed sets up to thick pebbly beds. An outcrop area, with well preserved primary features, at the west end of Margaret Lake contains several 10 to 20 cm thick sandy beds that display graded bedding that tops to the northeast. The sandy matrix is typically plagioclase rich and quartz poor. Clasts are typically felsic volcanic or chert iron formation with rare mafic volcanic clasts. Interbeds of 7 to 10 cm thick, fine grained, mafic lithic greywacke (unit 8 b) occur in the arkosic sandstone and felsic fragmental rocks. Thinly bedded greywacke, becomes dominant in association with the chert-magnetite iron formation (unit 8c).

PLUTONIC ROCKS

Supracrustal belt intrusives

Two small oval granitic bodies and a small syenite intrude the greenstone belt (Figure GS-3-2)

The "White House "tonalite (unit 4) intrudes the greenstone belt in the central part of Edmund Lake area. This strongly foliated intrusion is dominated by light grey, fine- to medium-grained, equigranular biotite tonalite (unit 4a). Along the southern margin the main phase is intruded by a younger plagioclase porphyritic biotite tonalite (unit 4b). Locally this phase contains quartz phenocrysts. Throughout the intrusion both phases show variable alteration of the biotite to chlorite, with significant epidotization of the adjacent feldspars.

The larger Margaret Lake granite (unit 10) is a fine- to medium-grained, equigranular, pale pink, biotite leucogranite. In most exposures the biotite is partially to completely altered to chlorite and nearby feldspars are variably epidotized. It is generally weakly to nonfoliated, even in close proximity to the northwest-trending "Wolf Bay" shear zone and in line of the southwest-trending shears on the north side of Margaret Lake. In one outcrop, on an island at the west end of Margaret Lake, granitic dykes interpreted to be Margaret Lake granite cut highly deformed volcaniclastic rocks of the Oxford Group and the feldspar porphyritic phase of the rhyolite dykes. At this location the granite, although foliated, appears to postdate the major regional deformation and either postdates, or is synchronous with, the "Wolf Bay" shear zone.

Along the north shore of Margaret Lake, pyroxene syenite (unit 9) intrudes the basalts (unit 1e & 1f) and are in turn intruded by the Margaret Lake granite. This rock weathers dark grey to rosy- pink grey, is medium grained, equigranular, with a variable percentage of dark green pyroxene (aegirine-augite) in a microcline rich matrix.

Major granitic terranes

The supracrustal belt is flanked to the north and south by plutonic terranes. On the north side of the belt, granitic rocks (unit 6a) of the Kenyon Complex intrude layered amphibolite (unit 1f) derived from basalt. This pink, medium grained, biotite granite forms a major intrusion north of Margaret Lake. To the south of the main granite, numerous 1 to 5 m thick southwest-trending dykes crosscut extremely deformed southwest-trending amphibolitized pillowed basalts and associated mafic phyllonite. Subsequent deformation produced an east-west foliation in both units.

The Wapawaka Intrusive Complex flanks the belt on the south side, and is in fault contact with the supracrustal belt. The dominant intrusive phases consist of coarse grained, sparsely porphyritic, leucocratic-biotite tonalite (unit 5c) intruded by medium- to coarse-grained, light grey, biotite tonalite (unit 5b). They are invariably strongly foliated, with an augen fabric developing around phenocrysts in unit 5c. The tonalite is intruded by coarse grained, weakly foliated, pink, biotite granite (unit 5a) .

Late dykes

Three variations of felsic to intermediate younger dykes intrude all units within the greenstone belt with the exception of the Margaret Lake granite and the syenite. The dominant two sets consist of fine grained feldspar porphyritic and feldspar- quartz porphyritic rhyolitic dykes. Both weather light grey to beige and are pale grey- green, very fine grained to aphanitic rhyolite. Grey weathering, dark grey, feldspar porphyritic dacitic or andesitic dykes are cut by both types of rhyolitic of dykes.

"Wolf Bay" shear zone

The "Wolf Bay" shear zone and related shears dominate the structural pattern of the supracrustal belt. The main shear zone forms a 700 m thick extremely linear deformation zone that trends 310° across the map sheet (Fig. GS-3-2). Related east-trending shears in the southern series basalts generally deflect to the southeast into the 310° trend, except in the northwestern corner of the map area where 270° trending mafic phyllonites offset northeast-trending sheared gabbro in the "Wolf Bay" shear zone.

Extrapolation of magnetic trends to the southeast indicates continuity of the zone to the shear zone on Little Stull Lake. It is less clear how the zone extends to the northwest or west.

The predominant rocks within the shear zone are annealed mafic cataclastic rocks and fault breccia (unit 9a), and highly schistose and laminated mafic phyllonitic (chlorite - carbonate schist) tectonite and mylonite (unit 9b). However, the strain intensity within the shear zone is highly variable. Lens-shaped domains of less-deformed rock are common in the shear zone and range in size from a few metres to tens of metres across. These are generally rhombic in outcrop section and truncated by highly strained rock in the dominant 310° and 270° trends.

Porphyritic dykes within the shear zone are common and highly strained to form felsic phyllonite.

Economic Considerations

The "Wolf Bay" shear zone is interpreted to be an extension of the deformation zone to the southeast on Little Stull Lake. In that area, iron formation, felsic volcaniclastic rocks and altered sheared basalt host significant gold resources. The association of similar lithologies in proximity to the shear zone in the Edmund- Margaret lakes area, in association with significant alteration and sulphide gossan zones, may indicate a potential exploration target. Several samples (locations on Figure GS-3-2) were submitted for routine assay (Table GS-3-1). Although none of these values is excessively high, the sample from silicified mafic tectonite on the north shore of Edmund Lake (sample 1) shows significant levels of gold.

Table GS-3-1
Assay Values

Sample	Unit	Au (ppb)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Cr (ppm)	Co (ppm)
1	Unit 9b	50	204	171	<5	41	20	11
2	Unit 9b	11	151	133	<5	53	162	45
3	Unit 7a	<6	44	19	<5	60	20	8
4	Unit 8C	<5	108	33	<5	16	37	14
5	Unit 7a	<6	59	33	14	53	30	14

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GS-4 PALEOMAGNETISM OF THE PALEOPROTEROZOIC BALDOCK BATHOLITH, MANITOBA (NTS 64B/14)*

by D.T.A. Symons[1], M.T. Lewchuk[1] and M. J. Harris[1]

Symons, D.T.A., Lewchuk, M.T., and Harris, M.J., 1996: Paleomagnetism of the Paleoproterozoic Baldock Batholith (NTS 64B/14); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1996, p. 14-20.

SUMMARY

Paleomagnetic analysis has been done on 143 specimens from 14 sites in granites of the Baldock batholith exposed on the shores of Southern Indian Lake for about 35 km north of the town of South Indian Lake. The specimens were tested using alternating field and thermal step demagnetization methods and saturation isothermal remanent magnetization methods. These tests show that the characteristic remanent magnetization (ChRM) is carried primarily by pseudosingle to multidomain magnetite with minor pyrrhotite. Twelve sites give mean ChRM directions that cluster to form a unit mean direction of D = 33.7°, I = 84.6°, a_{95} = 6.2° and k = 50.5 (declination, inclination, radius of cone of 95% confidence, and precision parameter). This mean gives a pole position for the Baldock granite of 84.7°W, 65.2°N (dp = 12.1°, dm = 12.2°) (longitude, latitude (semi-axes of oval of 95% confidence)). This pole indicates that the granite is not part of the huge 1855 ± 5 Ma Wathaman-Chipewyan batholith that was emplaced at low paleolatitudes. Rather the granite is part of a Paleoproterozoic superterrane that formed at polar paleolatitudes near the Archean Superior craton from ~1910 to ~1775 Ma and incorporates all of the exposed Trans-Hudson orogen to the southeast of the Wathaman-Chipewyan batholith.

INTRODUCTION

As part of an extended series of paleomagnetic studies in the Trans-Hudson orogen (THO) sponsored by LITHOPROBE, a study has been done on a collection from the Baldock granite batholith exposed on the shores of Southern Indian Lake just north of the town of South Indian Lake (Fig. GS-4-1, 2). On recent geologic maps of Manitoba, this granite is shown to be part of the Chipewyan batholith in the Chipewyan domain (*e.g.* Syme *et al.*, 1993). It, in turn, is part of the Wathaman-Chipewyan batholith that has an arcuate shape, trending northeastward through Saskatchewan and then swinging to eastward through Manitoba (Fig. GS-4-1). Overall the Wathaman-Chipewyan batholith in >900 km long and is possibly the largest Precambrian batholith exposed on Earth (Fumerton *et al.*, 1984). The paleomagnetic pole position for its northeast-trending arm has been reported by Symons (1991). The original purpose of this study was to determine the pole position for its east-trending arm to see if the arcuate shape was a primary or secondary feature. Such knowledge would significantly constrain models for the geotectonic evolution of the THO. As it turns out, this paleomagnetic study indicates that the Baldock batholith should be assigned to the Lynn Lake-La Ronge or Leaf Rapids domain of the THO rather than to the Wathaman-Chipewyan batholith. The purpose of this paper is to report fully on the paleomagnetic data from the collection and to comment briefly on their geotectonic significance. A full geotectonic discussion will be given when data from two collections in the Kisseynew domain to the south are available.

GEOLOGY

The study area was mapped geologically at a scale of 1:50 000 by Frohlinger (1972) and Cranstone (1972). It is in the middle of an extensive felsic plutonic terrane that extends for tens of kilometres in most directions with a few enclaves of moderately to highly metamorphosed host rocks (Manitoba Energy and Mines, 1986). The sampled granites are grouped with the "younger plutonic rocks" because of their massive character. Thus they are presumably younger than foliated "older plutonic rocks" some 35 km southwest of site 1 (Fig. GS-4-1) that intrude metavolcanic rocks that have yielded an U/Pb-zircon age of 1878 ± 3 Ma (Baldwin *et al.*, 1987). Some tens of kilometres to the east the Baldock batholith has given a Rb-Sr whole rock date of 1930 ± 50 Ma (Clark, 1981) and a U-Pb zircon date of 1855 ± 30 Ma (W.R. Van Schmus, personal communication to H.V. Zwanzig, in Halden *et al.*, 1990). Further the Baldock granites are uniformly calc-alkaline in composition, comprised mostly of megacrystic granite with minor hornblende and biotite or leucocratic biotite granite. It has a much narrower range of compositions and significant isotopic and trace element differences from the adjacent Chipewyan batholith (Halden *et al.*, 1990). The latter batholith has given U-Pb zircon ages of 1860 ± 17, 1857 ± 9 and 1855 ± 10 Ma (Zwanzig *et al.*, 1985; Van Schmus and Schledewitz, 1986) with a mean of 1857 ± 3 Ma. The Baldock granite has been mapped as intrusive into the Ridge tonalite which has given an unpublished U-Pb zircon age of 1852 ± 5 Ma (W.R. Van Schmus, personal communication to H.V. Zwanzig). The granites in the study area are not known to be cut by younger dikes or other intrusions.

Given the lack of diagnostic geologic relationships and radiometric age dates for the granite at South Indian Lake, it is understandable that the study area has been assigned to various domains. For example, in the past decade it has been classified with the Southern Indian domain (Manitoba Energy and Mines, 1986), the Chipewyan domain but

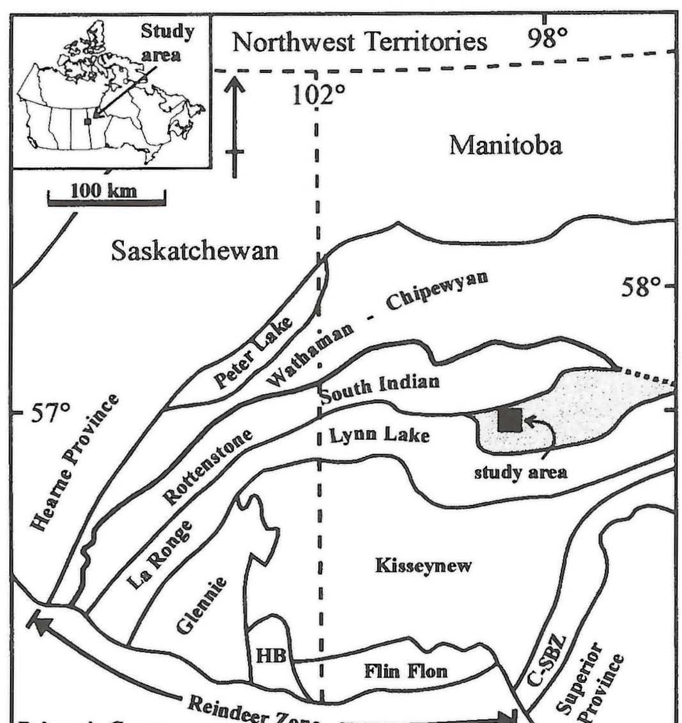

Figure GS-4-1: Location of the study area in the Baldock Batholith (gray tone) of the Trans-Hudson orogen (THO). C-SBZ, Churchill-Superior boundary zone. HB, Hanson Lake Block. ■, study area. Dash line, proposed main suture in the THO.

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not part of the Baldock batholith (Corkery and Lenton, 1990; Halden *et al.*, 1990), the Chipewyan batholith and domain along with the Baldock batholith (Zwanzig and Schledewitz, 1994), part of the Lynn Lake-La Ronge domain along with the Baldock batholith (White *et al.*, 1993), and split between the Southern Indian and Chipewyan domains (Syme *et al.*, 1993). Examination of the aeromagnetic map for Manitoba (Broome, 1995) indicates that the granite at South Indian Lake is part of the Baldock batholith, but that there is no particular reason to believe that it is part of the Wathaman-Chipewyan batholith.

SAMPLING

Five cores were drilled, oriented and collected from each of 14 sites along the shore of Southern Indian Lake (Fig. GS-4-2). The sites are widely distributed over an area of about 35 km by 10 km. Twelve of the sites are located in megacrystic coarse grained biotite granite and two in seriate leucocratic biotite granite. Two ~2.5 cm right-cylindrical specimens were sliced from most cores with either three or one from the few remaining cores, yielding a total of 143 specimens (Table GS-4-1).

NATURAL REMANENT MAGNETIZATION

The natural remanent magnetizations (NRM) of all specimens were measured on an automated Canadian Thin Films model DRM-420 cryogenic magnetometer. All measurements were done inside a magnetically-shielded room with an ambient field of about 0.2% of the Earth's magnetic field intensity. For the specimens from the Baldock granite, the NRM intensity ranges from 4 x 10^{-4} to 3 x 10^{0} A/m with a median of 9.7 x 10^{-2} A/m and with 90% of the values between 1.4 x 10^{-3} and 9.5 x 10^{-1} A/m.

STEP DEMAGNETIZATION

Alternating field (AF) demagnetization was done in 11 steps up to 130 mT on one specimen from each site using a Sapphire Instru-

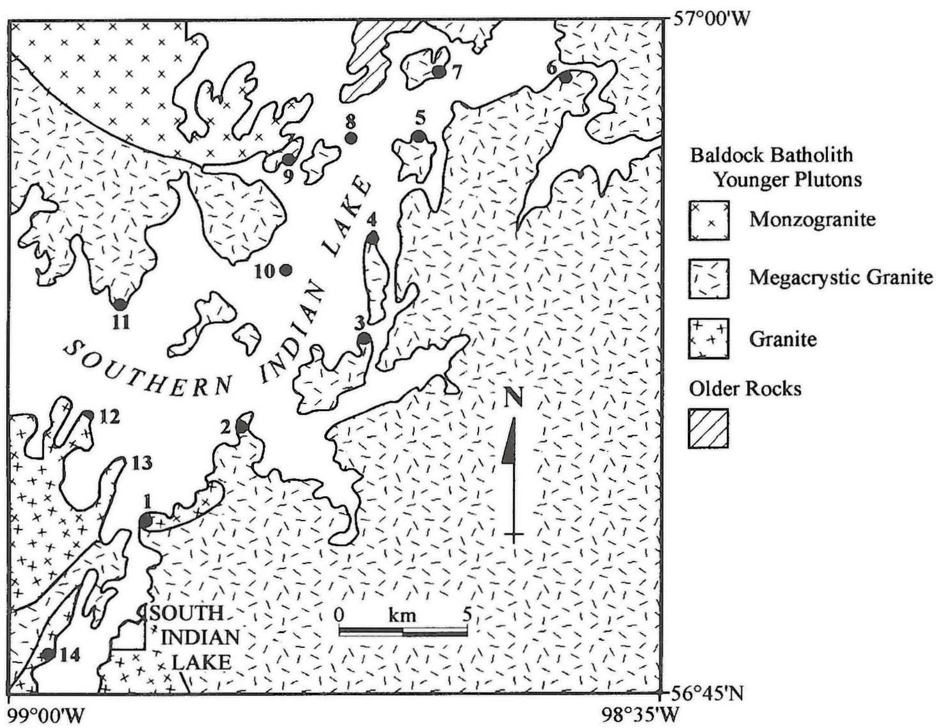

Figure GS-4-2: Site locations and geology simplified from Manitoba Energy and Mines (1986).

Table GS-4-1
Remanence Data

Site	Number s	Number e	Demagnetizing Steps Range mT	Demagnetizing Steps Range °C	Decl.	Mean Remanence Incl.	a_{95}	k
2	12,	12	20 - 130	245 - 575	8.2	75.6	15.0	9.4
3	11,	10	10 - 50	245 - 500	26.8	70.5	5.9	77.1
4	10,	10	20 - 130	245 - 500	27.6	76.9	5.3	85.8
5	10,	10	10 - 110	245 - 500	43.2	75.0	6.2	61.8
6*	11,	11	20 - 70	245 - 575	251.8	5.8	12.1	15.2
7	9,	9	20 - 130	245 - 500	348.6	78.6	8.4	38.7
9	10,	8	10 - 70	245 - 500	30.4	80.4	12.0	22.4
10	10,	10	10 - 130	245 - 500	145.9	82.2	9.4	27.3
11*	10,	8	20 - 50	245 - 550	190.1	-5.9	25.7	5.6
12	8,	6	20 - 70	245 - 575	166.6	81.4	8.2	67.0
13	10,	7	10 - 70	245 - 525	127.6	80.3	14.4	18.6
14	8,	7	20 - 130	245 - 500	284.3	82.0	11.7	23.2
MEAN	(12)				33.7	84.6	6.2	50.5

Notes: Asterisks indicate sites excluded from the MEAN as deviant or insufficiently coherent; number of specimens measured (s) and yielding end points used in the mean (e); demagnetization steps used in mean in millitesla (mT) and degrees Celcius (°C); mean remanence is given by its declination (Decl.), inclination (Incl.), and radius of cone of 95% confidence (a_{95}) in degrees and precision parameter (k) (Fisher, 1953).

ments model SI-4 demagnetizer. The median destructive field for all specimens is about 5 mT, showing that the granite retains a large viscous remanent magnetization (VRM). This is true despite the fact that the specimens were stored in the shielded room for about four months prior to measurement to permit much of the VRM to decay. By 20 mT about 34% of the NRM intensity remains as the characteristic remanent magnetization (ChRM). Most specimens define steeply-downward ChRM vectors between about 20 mT and 60 mT (Fig. GS-4-3a, b). A few specimens show a very slow decay of their NRM intensity on AF demagnetization (Fig. GS-4-3c).

Thermal demagnetization was done on one specimen from each site at steps of 245, 285, 325, 500, 525, 550, 575 and 600°C using a Magnetic Measurements model MMTDI demagnetizer. Again the rapid decay of VRM is seen with only 39% of the NRM intensity remaining after the 245°C step. Evidence of pyrrhotite is seen in some specimens which are preferentially unblocked in the diagnostic 285 to 325°C range (Fig. GS-4-4 a, c) with a further sharp drop to ≤1% of the NRM between 525°C and 575°C that is indicative of a magnetite ChRM (Fig. GS-4-4 b, c). For most specimens the ChRM direction is steeply downward.

Depending on the behaviour of the ChRM in the initial AF and thermally demagnetized specimens, remaining specimens for each site were AF step demagnetized following one of three regimes: a) 20, 25, 30, 40 and 50 mT for sites 1, 3, 6, 8, 9, 11 and 13; b) 20, 30, 40, 50 and 60 mT for sites 2, 5, 10 and 12; and, c) 20, 30, 40, 60, 90 and 120 mT for sites 4, 7 and 14.

SIRM ANALYSIS

Saturation isothermal remanent magnetization (SIRM) analysis was done on eight representative specimens using a Sapphire Instruments model SI-6 pulse demagnetizer. Five specimens from sites 1, 4, 5, 7 and 8 show rapid acquisition of magnetization to saturation by 300 mT which is the expected behaviour for both pyrrhotite and magnetite, and one from site 14 shows steady acquisition to 900 mT which is indicative of hematite, and two specimens from sites 12 and 13 show the dominance of magnetite or pyrrhotite with minor hematite (Fig. GS-4-5a). AF demagnetization of the SIRM shows that the magnetite and/or pyrrhotite carriers are mostly in the pseudosingle to multidomain size range (Fig. GS-4-5b). This result is consistent with the finding of large VRM components on step demagnetization. The curves for sites 12 and 13 show a minor contribution from hematite from the flattening of the curve at about 50 mT and the curve for site 14 shows that only hematite is present.

STATISTICAL ANALYSIS

The demagnetization data for each specimen was analyzed using the method of Kirschvink (1980), requiring that the maximum angular deviation (MAD) angle be <15° for acceptance of a characteristic remanent magnetization (ChRM). The relatively high median MAD value of 6.5° reflects the relatively large VRM that must be removed before the ChRM is isolated. Nevertheless reliable end-point ChRM directions were determined for most specimens, and 128 of them or 90% were used to calculate the site mean remanence directions using Fisher (1953) statistics (Table GS-4-1). Twelve of the 14 site mean directions form a coherent cluster (Fig. GS-4-6) with a unit mean direction of D = 33.7°, I = 84.6°, a_{95} = 6.2°, k = 50.5 (declination, inclination, radius of cone of 95% confidence and precision parameter of (Fisher 1953)). All 12 of these sites have a_{95} values of ≤15°.

Sites 6 and 11 both gave mean directions that were aberrant from the unit mean direction, and site 11 in addition had an unacceptably large a_{95} value of 25.7°. The reason for the discordance of these sites is uncertain; however, sites 6 and 11 have the most intense median NRM vector intensities of 2.5 x 10^{-1} and 1.7 x 10^{0} A/m, respectively, suggesting that they may have come from outcrops that have been struck by lightning.

Applying the dipole formula to the unit mean direction gives a pole position for the Baldock granite of 84.7°W, 65.2°N (dp = 12.1°, dm = 12.2°) (longitude, latitude (semi-axes of the oval of 95% confidence)).

DISCUSSION

The purpose of this study was to determine the pole position for the east-west arm of the Wathaman-Chipewyan batholith in Manitoba and to compare it with the known pole for the northeast-southwest arm in Saskatchewan (Symons, 1991) in order to estimate oroclinal deformation in the batholith. Given the size, petrologic uniformity and massive character of the batholith, such deformation would be expected to be about an almost-vertical axis. Further, given the large size of the areas sampled on both "limbs" in these paleomagnetic studies, a consistent but localized rotation or tilt about an horizontal or inclined axis would be unlikely. The obvious observation is, however, that the ChRM directions of the two "limbs" are radically different and incompatible

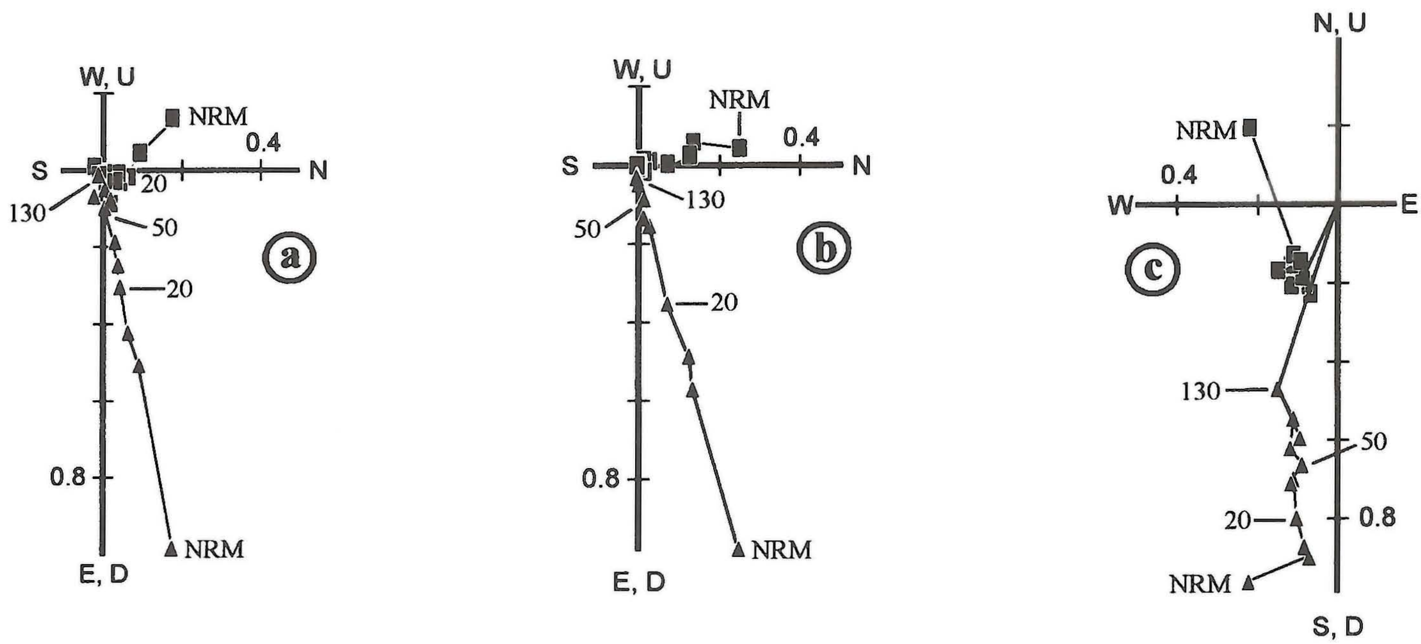

Figure GS-4-3: Orthogonal alternating-field step demagnetization diagrams for representative specimens from: a) site 3, J_0=1.03 x 10^{-1} A/m; b) site 7, J_0=1.42 x 10^{-1} A/m; and, site 14, J_0=3.99 x 10^{-3} A/m. Circles and triangles denote projections on the horizontal (N, E, S, W) and vertical (U, N, D, S or U, E, D, W) planes, respectively. The axis unit is normalized to the NRM intensity (J_0) and some demagnetization field intensities are shown in millitesla.

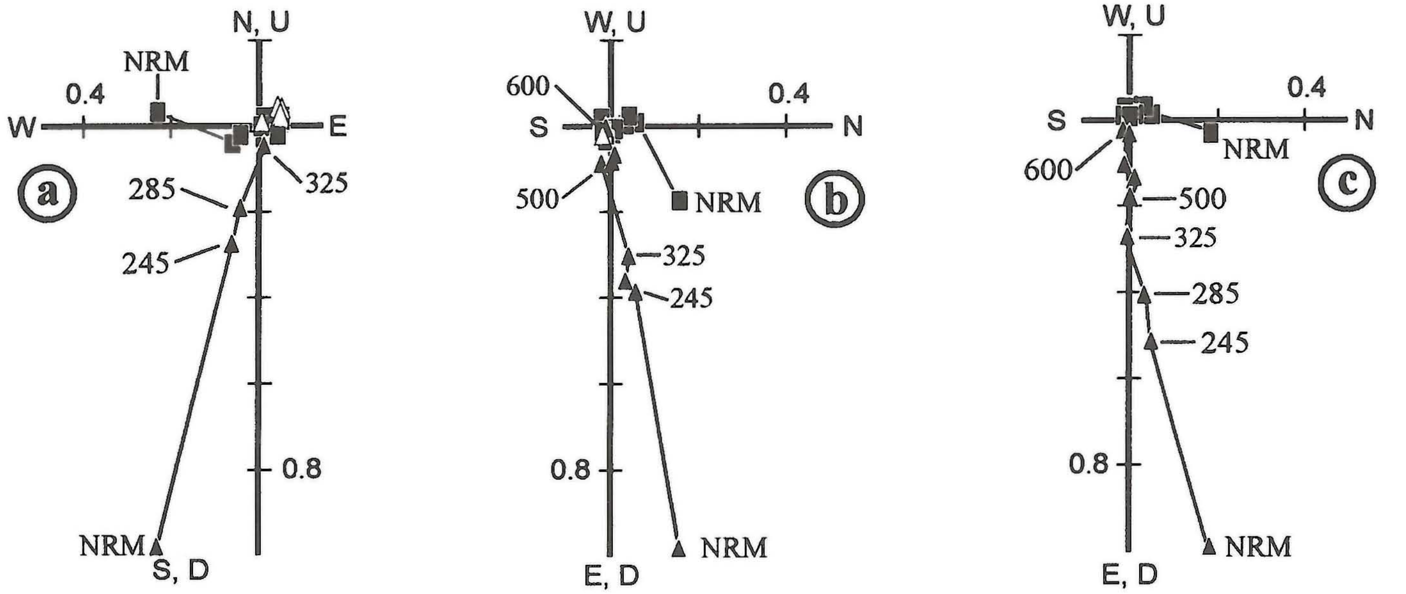

Figure GS-4-4: Orthogonal thermal step demagnetization diagrams representative specimens from: a) site 1, J_0=8.51 x 10^{-3} A/m; b) site 7, J_0=1.67 x 10^{-1} A/m; and, c) site 12, J_0=8.11 x 10^{-2} A/m. Conventions are as given for Figure GS-4-3, except that the step values are in °C. In (a) and (c) note marked intensity between 285°C and 325° indicating pyrrhotite, and in (b) and (c) unblocking temperatures up to 525° to 575°C indicating magnetite.

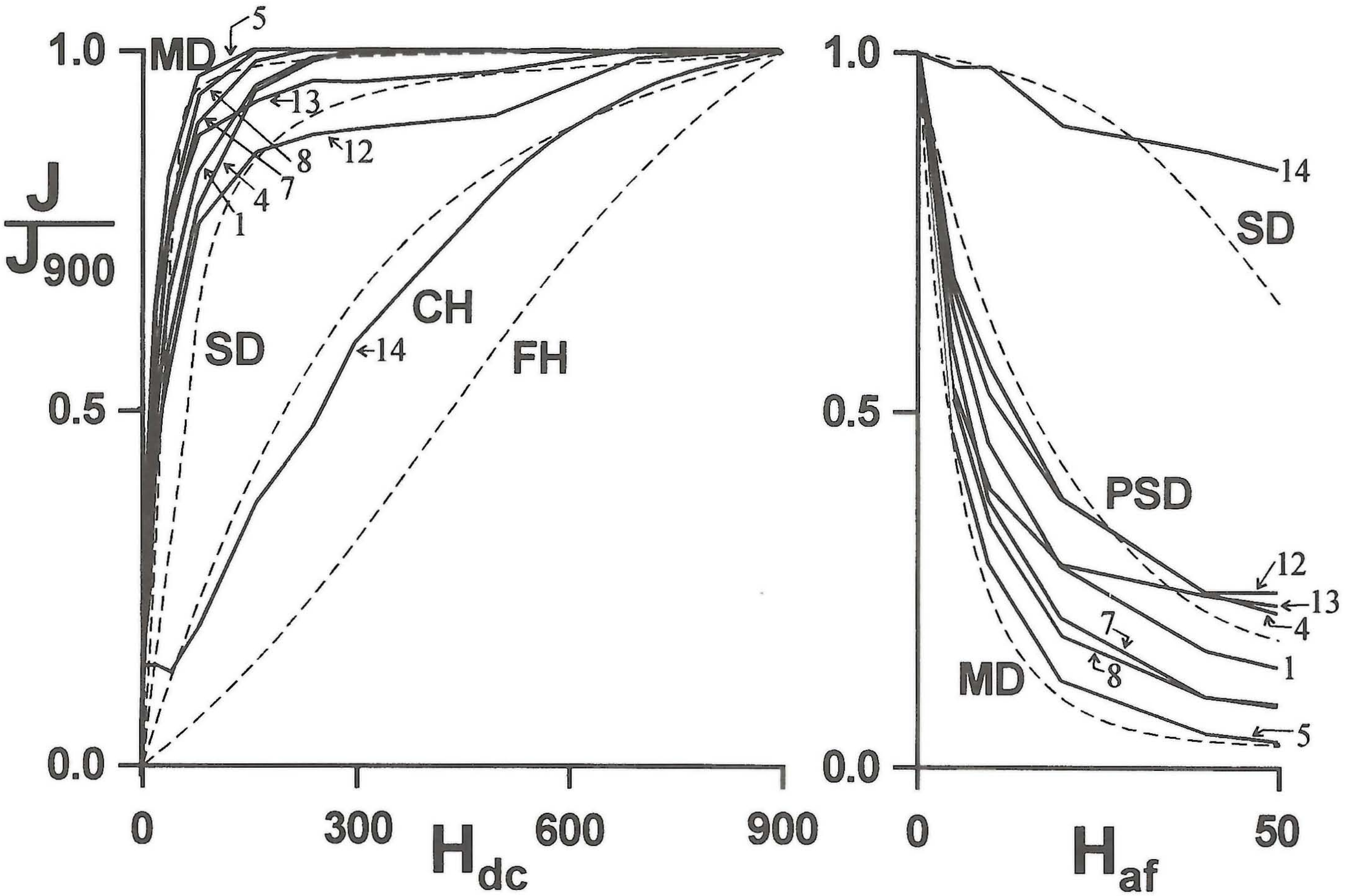

Figure GS-4-5: Saturation isothermal remanent magnetization (SIRM) curves for representative specimens showing direct field (H_{dc}) acquisition up to 900 mT and subsequent alternating field (H_{af}) demagnetization. Shown are typical curves for single, pseudosingle and multidomain magnetite (SD, PSD, MD) and for coarse and fine-grained hematite (CH, FH). Specimen curves are identified by their site number.

with a vertical-axis rotation. The ChRM of the northeast-southwest arm is directed at D = 134.6°, I = 54.1°, a_{95} = 3.5° that gives a pole position at 67°W, 9°N (dp = 3°, dm = 5°) (Fig. GS-4-7), and that indicates that the batholith was emplaced at a subtropical paleolatitude of 35°. In addition, coeval rocks in the adjacent Peter Lake domain and Slave-Rae-Hearne craton to the northwest of the Wathaman batholith also give subtropical paleolatitudes of 21° and 23°, respectively (Symons, 1994). All three give similar poles in present-day northern South America that indicate that they formed part of a continental plate at ~1850 Ma (Symons, 1994). Rotation of the northeast-southwest arm on the continental plate about a vertical axis will not change their paleolatitude. In contrast the ChRM of the Baldock granite shows that it was emplaced at a high polar paleolatitude of 80°. This result provides clear evidence that the Baldock batholith is not part of the Wathaman-Chipewyan batholith.

Several paleomagnetic results have been reported recently from plutonic rocks in most terranes of the THO on the southeastern side of the Wathaman-Chipewyan batholith. They have consistently given polar paleolatitudes with similar pole positions in northern North America, as have coeval rocks from the abutting Archean Superior craton. They include paleolatitudes of 88° for the 1867 Ma Davin Lake complex in the Rottenstone domain (Radigan, 1993; Symons *et al.*,1994a), of 67° for the 1849 Macoun Lake granite pluton in the Lynn Lake-La Ronge domain (Lohnes, 1993; Symons *et al.*, 1994b), of 71° for the 1844 Ma Hanson Lake diorite pluton and of 80° for the Jan Lake pluton in the Hanson Lake block (Gala *et al.*, 1994, 1995), of 66°, 71° and 75° for the 1837 Ma Phantom Lake granite, 1840 Ma Boot Lake gabbro, and 1851 Reynard Lake grandiorite, respectively, in the Flin Flon domain (MacKay 1992: Symons, 1995), of 67° for the norite and granophyre of the 1850 Ma Sudbury irruptive complex in the Superior craton (Morris, 1984), and of similar values for several other units in the other THO domains that are currently being analyzed. The paleolatitude and pole position for the Baldock batholith fit with this polar population.

The contrast between the subtropical position of terranes on the northwest side of the THO at ~1850 Ma and the polar position of terranes on the southeast side has been attributed to the presence of an ~5000 km wide ocean — the Manikewan Ocean (Stauffer, 1984; Dunsmore and Symons, 1990). In a recent overview of paleomagnetic data for the THO and environs, Symons *et al.*, (1995) noted that the main part of the ocean at that time was between the Wathaman-Chipewyan batholith and the Rottenstone domain. In their model, the batholith was formed along the margin of the Rae-Hearne craton on one side of the ocean, similar to the formation of the Coastal batholith — a good geological analogue (Meyer *et al.*, 1992) — along the margin of the South American craton some 70 Ma ago with the open Pacific Ocean offshore.

In contrast the terranes on the southeastern side of the Wathaman-Chipewyan batholith were assembled by compressional accretion of allochthonous island arcs with Archean remanents into one or more superterranes which were attached to the Superior craton, much the same as found today in the equatorial western Pacific. Within this geotectonic framework for the THO, the Baldock granite's pole falls closest to preliminary poles for the 1840 Ma Boot Lake and 1837 Ma Phantom Lake plutons in the Flin Flon domain (MacKay, 1992) (Fig. GS-4-7). The inference from this comparison is that the massive granite of the Baldock batholith was emplaced at about 1838 Ma also or that there was a significant difference in post-emplacement translation distances between the Baldock batholith and the Flin Flon domain. Ages of ~1855 or ~1838 Ma for the Baldock granite agree in that they are younger than the 1878 ± 3 Ma age determined for the adjacent older foliated granites (Baldwin *et al.*, 1987) and that they fit in the 1855 ± 30 Ma age bounds for the batholith as known at present, but they are equivocal with respect to intrusion into the younger 1852 ± 5 Ma Ridge tonalite. Clearly there is need for better radiometric age dating of the Baldock batholith to help resolve its place as a large piece in the geotectonic puzzle that is the THO.

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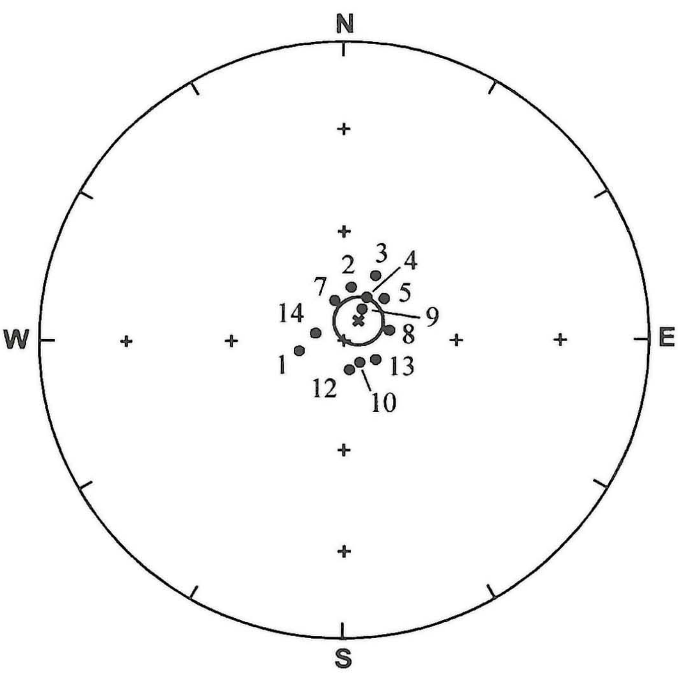

Figure GS-4-6: Lower hemisphere of an equal-area stereogram showing the 12 accepted site mean remanence directions (circles) and their overall mean (X) circumscribed by its circle of 95% confidence (Fisher, 1953).

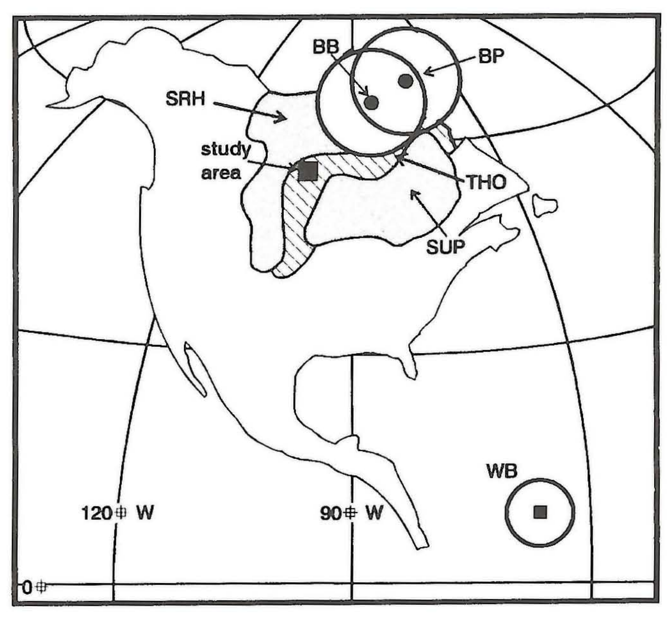

Figure GS-4-7: Pole position for the Baldock batholith (BB) relative to the poles for the Wathaman batholith (WB) (Symons, 1991), and the Boot Lake Phantom Lake complex (BP) combined (MacKay, 1992). Also shown are the Slave-Rae-Hearne craton (SRH), Trans-Hudson orogen (THO) and Superior craton (SUP).

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GS-5 GEOLOGY OF THE DOW LAKE - MARTELL LAKE AREA (PARTS OF NTS 63K/15 AND 63N/2)

by H.V. Zwanzig

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SUMMARY

New mapping and newly acquired geochemical data in the Martell Lake - Dow Lake area provide a simple tectonic classification of structural units on the south flank of the Kisseynew belt. Gently northeast-dipping structural panels of highly metamorphosed ocean-floor and island-arc volcanic rocks, younger basinal sedimentary rocks and successor arc plutons are identified as the northern continuations of equivalent units in the Flin Flon - Snow Lake belt. Preliminary geochemical data from volcanic-derived amphibolite, mafic tectonite and younger plutons are comparable to data from better preserved rocks northwest and southeast of the area. Panel-bounding faults and shear zones are traced into regional structures up to 100 km long. Their early history entailed the assembly of the Amisk collage southeast of Dow Lake. Younger basinal sediments and additional volcanic rocks were subsequently juxtaposed along structures that extend across the Dow Lake area. The geometry of these various tectonic assemblages controls the distribution and types of mineral deposits and showings in the gneissic and low-grade terranes.

INTRODUCTION

In the vicinity of Flin Flon 1.92-1.88 Ga volcanic-arc and ocean-floor assemblages were accreted in the Amisk collage and intruded by 1.87-1.83 Ma successor arc plutons (Lucas *et al.*, 1996). Some of the volcanic assemblages, early accretionary structures and the arc plutons extend north into the Kisseynew gneiss belt where they were involved in recumbent folding and high grade metamorphism (Zwanzig and Schledewitz, 1992; Zwanzig, 1995a). The 1.9 Ga volcanic assemblages in the Snow Lake area also extend into the Kisseynew belt. These were juxtaposed with the Amisk collage and the early successor arc plutons during and after the deposition of the Burntwood suite turbidite and Missi suites nonmarine sediments at 1.85-1.83 Ga (Syme *et al.*, 1995; Machado *et al.*, 1996). Prominent structures also mark this period of accretion, collision and crustal thickening. The structures extend across the Snow Lake belt and across part of the Kisseynew belt, some for a distance of more than 100 km (Fig. GS-5-1). They control the geometry of the various tectonic assemblages and the distribution of mineral deposits. Plutons, which range in age from 1.84 to 1.83 Ga, locally cut

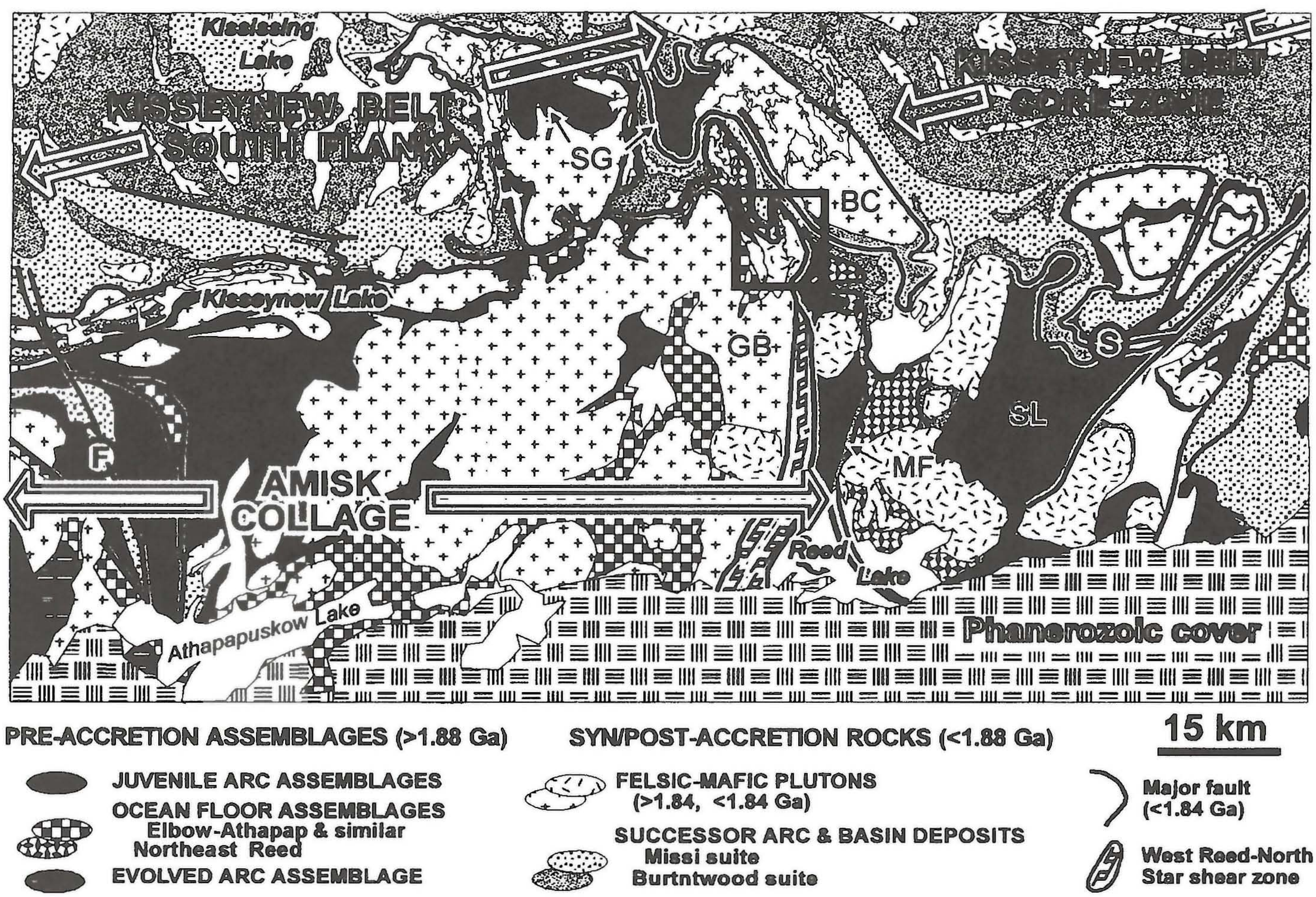

Figure GS-5-1: Major tectonic assemblages and plutons in the Flin Flon - Snow Lake belt and southern Kisseynew belt, Manitoba. The location of the Dow Lake - Martell Lake area is indicated (heavy rectangle). BC: Batty Lake complex; GB: Gants Lake batholith; MF: Morton Lake fault zone; SG: Sherridon gneiss; SL: Snow Lake assemblage; ***F****: Flin Flon;* ***S****: Snow Lake. The geology of the Flin Flon belt is after Syme et al. (1995).*

these structures and constrain their ages (Connors and Ansdell, 1994; David, *et al.*, in press). The regional geochemical variation of these plutons may provide a tectonic model for the youngest major period of magmatism in Trans-Hudson orogen.

The Dow Lake - Martell Lake area lies at the juncture of the Flin Flon, Snow Lake and Kisseynew belts. The local structure is dominated by large folds, thrust faults and shear zones that separate structural panels of different volcanic assemblages and intrusive rocks (Fig. GS-5-2). The new mapping and lithogeochemistry have helped to trace these panels and the bounding structures south to Reed Lake and northwest into the Kisseynew domain, thus defining regional structures. Extensive belts of sedimentary rocks were involved in the deformation north and east of Dow Lake. Narrow belts of predominantly turbidite were involved in the Snow Lake - Reed Lake area (Syme *et al.*, 1995). At Dow Lake and farther north the early structures were overturned to the southwest and refolded several times during the main stages of continental collision in Trans-Hudson orogen (Zwanzig, 1996a). The early fabrics were annealed during the metamorphism. Structural attenuation in reactivated shear zones has locally cut out major units and reversed early kinematic indicators.

TECTONOSTRATIGRAPHY AND GEOCHEMISTRY

The lithologies in the Dow Lake - Martell Lake area were defined during regional mapping (Zwanzig and Schledewitz, 1992) and in follow-up mapping (Zwanzig, 1995a). Tectonic origins are assigned to the these units in Table GS-5-1. Subunits are arranged from ultramafic to felsic rather than in chronological order, which is only partly known.

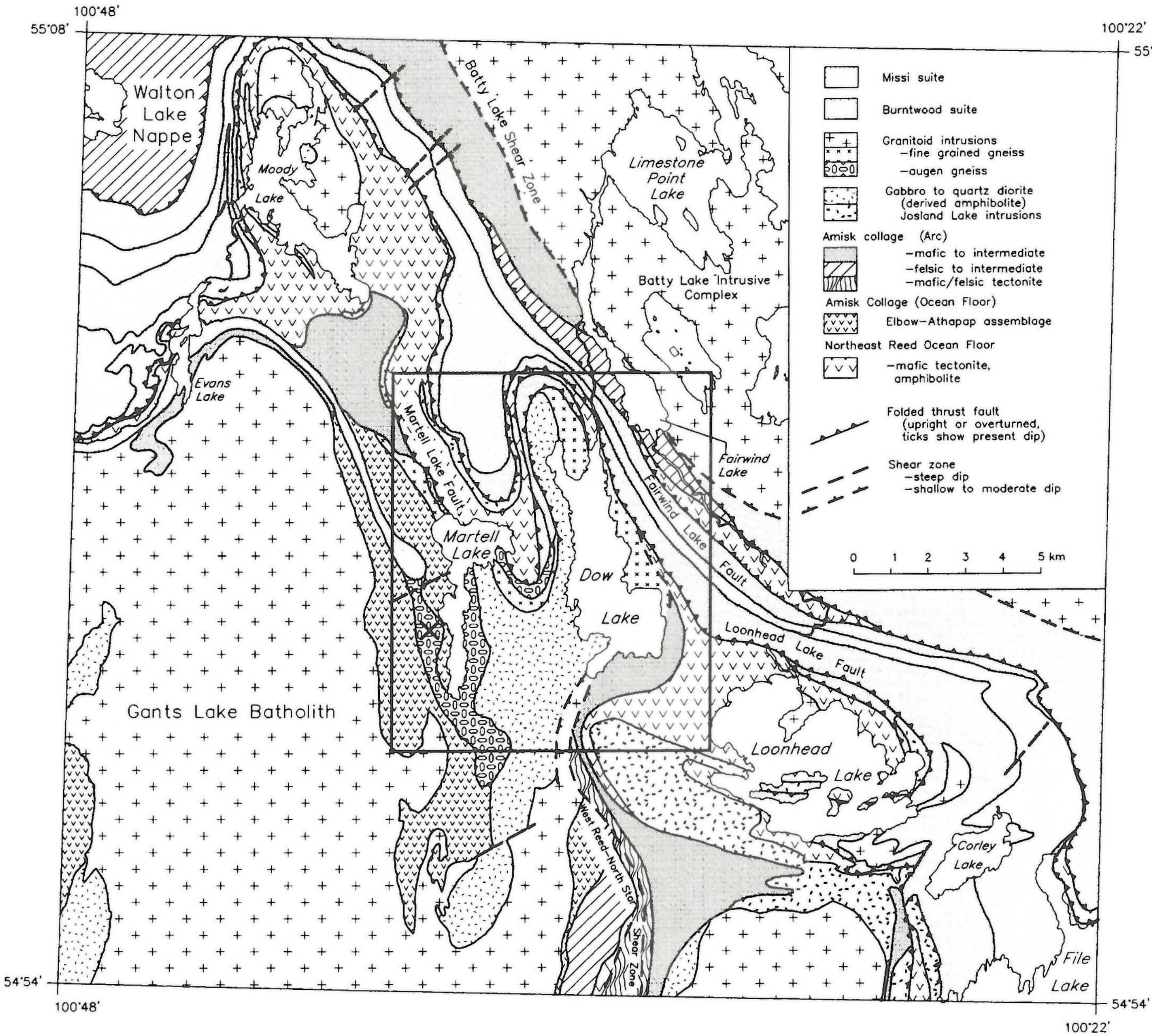

Figure GS-5-2: Simplified geology and structural interpretation of the Dow Lake - Martell Lake area and its surroundings on the boundary zone between the Flin Flon - Snow Lake and Kisseynew belts, modified after Zwanzig (1995a). Also shown is the location of the Martell Lake gold occurrence (X).

Table GS-5-1
Tectonostratigraphy

INTRUSIVE ROCKS	
Synkinematic (collisional) intrusions, <1.82 Ga	
20b	Granite pegmatite
Magmatic arc and ocean floor plutons, 1.82-1.9 Ga	
15-19e	Ultramafic to granitic intrusions and orthogneiss
LATE VOLCANIC ARC AND BASINAL DEPOSITS	
Missi Suite, 1.83-1.85 Ga	
10-14	Metasedimentary and minor volcanic rocks
Burntwood Suite, 1.84-1.85 Ga	
9	Metagreywacke, mudstone
JUVENILE ARC VOLCANIC ROCKS, ~1.9 Ga	
Sherridon Gneiss	
5b-7a	Layered felsic gneiss
Amisk Collage	
3b-4d	Mafic to intermediate porphyritic volcanic rocks, fine grained amphibolite, tectonite
OCEAN FLOOR VOLCANIC ROCKS, ~1.9 Ga	
Northeast Reed Assemblage	
2a-2b	Fine grained amphibolite
Elbow-Athapap Assemblage (Amisk Collage)	
1b	Fine grained amphibolite, mafic tectonite

Previous descriptions of the map units were based on field characteristics, petrology and the presence of structural breaks (Zwanzig, 1995a). However, the amphibolites assigned to units 2 to 4 could not be adequately differentiated in the high-grade metamorphic terrane without geochemistry. These units are all dark grey-green weathering, fine- to medium-grained and have similar mineral contents and secondary structures. Their primary differences are seen only on a few clean outcrops of unusually well preserved rocks. Nevertheless, newly acquired geochemical data and the new mapping provide a simple subdivision of the amphibolite that is generally consistent with the previously mapped units and with the tectonic classification of less highly deformed rocks in adjoining areas. Four main divisions of amphibolite have been assigned to regional assemblages as existing and new units. They occur from southeast to northwest as given below.

- Elbow-Athapap assemblage (Stern *et al.*, 1995): ocean-floor amphibolite (unit 1b) and ultramafic rock (unit 15) in the lowest structural panel;
- Martell Lake metagabbro and quartz diorite: medium grained amphibolites with biotite ± garnet ± quartz (units 16 and 17) intruded at the top of the lowest structural panel;
- Mafic to intermediate volcanic arc assemblages: recognizable volcanic rocks and tectonites (units 3b, 3c and 3d) in a central structural panel;
- Northeast Reed assemblage (Syme *et al.*, 1995): ocean floor amphibolites (units 2a and 2b) in a higher panel.

The lower supracrustal units (1b and 3b-3d) are interpreted as part of the Amisk collage. The higher units (2a and 2b) extends into assemblages in the Snow Lake region. Units 16 and 17 are identified as post-Burntwood intrusive rocks, which have overwhelmed unit 1b. Unit 16a, differentiated gabbro, which typically intrudes unit 2a, is correlated with Josland Lake gabbro (Bailes, 1980) and with identical sills in the Kisseynew belt. These interpretations are still preliminary and based partly on major element chemistry and Rb, Sr, Ba, Y, Zr, Nb done by XRF (2 ppm trace element detection limit) on 12 fine grained and 16 intrusive samples. In this report the chemical distinction of the amphibolites is based mainly on contents of TiO_2, Zr and Nb to avoid mobile element variation due to metamorphism. Precision trace element chemistry is in preparation.

The newly correlated volcanic assemblages and lithologies not fully described in Zwanzig (1995a) are discussed below.

Elbow-Athapap assemblage (units 1b and 15)

South and west of Martell Lake ~300 m thick screens of strongly foliated fine grained amphibolite (unit 1b) occur between east-north-east-dipping intrusive sheets. Locally the mafic tectonites form straight gneiss with felsic layers. Sheared selvages, resembling deformed pillow rinds, are restricted to a few outcrops near the west shore of Martell Lake. There is also abundant uniform amphibolite interpreted as metagabbro and diabase.

Three samples of unit 1b from the largest screens have a subalkaline basaltic composition (Fig. GS-5-3a) with contents of TiO_2

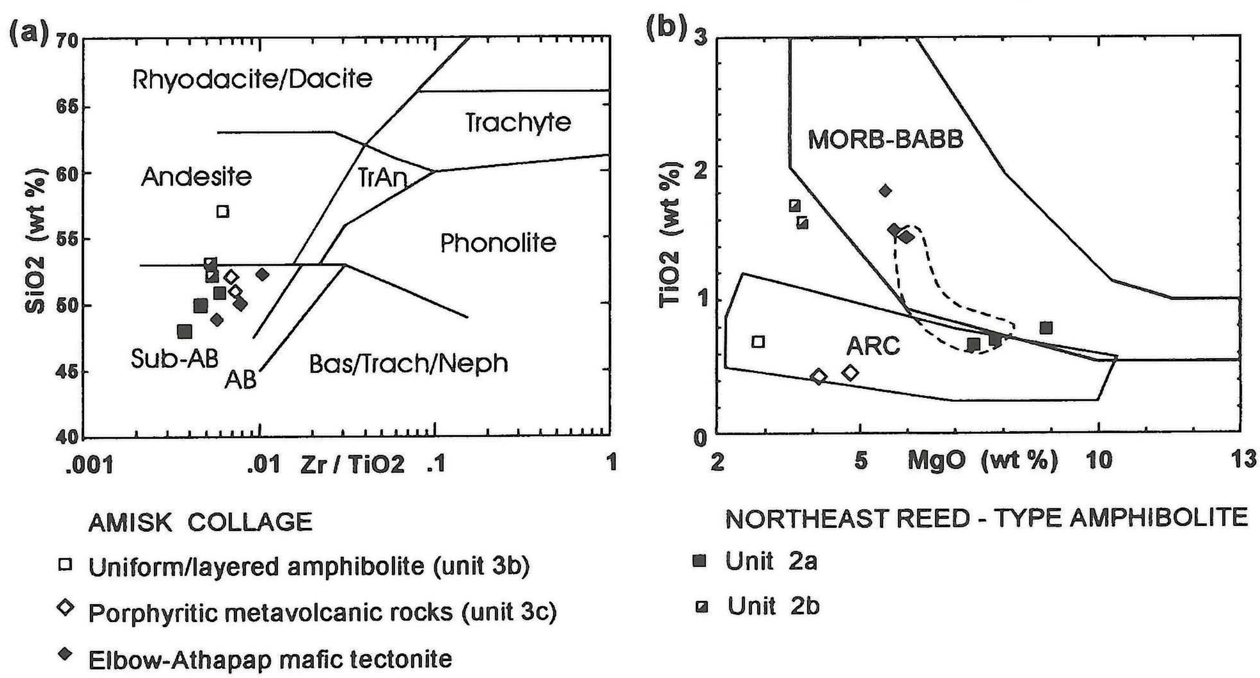

Figure GS-5-3: Discrimination plots of fine grained amphibolites in the Dow Lake - Martell Lake area, interpreted to be derived from sub-alkaline basalts and andesite; (a) SiO_2 vs Zr/TiO_2 showing fields of common volcanic rocks after Winchester and Floyd (1977); (b) TiO_2 vs MgO showing fields of mid-ocean ridge basalt - back-arc basin basalt (MORB-BABB), arc volcanics (ARC), and Moody Lake basalt - Evans Lake amphibolite (dashed outline).

(Fig. GS-5-3b) and Zr (80-190 ppm) in the range of ocean floor basalt.

Several tectonic lenses of ultramafic intrusive rock (unit 15), <100 m thick, occur in younger intrusions to the east and in adjacent shear zones. The best preserved parts of these lenses consist of metapyroxenite and olivine metapyroxenite. They have the same composition and occur in the same shear zone as the layered ultramafic Reed Lake complex, which has been interpreted as oceanic cumulate rock (Syme *et al.*, 1995).

The mafic and ultramafic rocks are considered to be remnants of the Elbow-Athapap back-arc basin floor, which apparently extends northeast across the Gants Lake batholith (Fig. GS-5-1).

Northeast Reed assemblage (units 2a and 2b)

The higher structural panel of purely basaltic amphibolite provided three samples (unit 2a) with relatively low absolute contents of Zr (30-40 ppm) and Nb (2-4 ppm), and moderate TiO_2 (Fig. GS-5-3b). The rocks extend to the northwest into the chemically similar Moody Lake basalt and Evans Lake amphibolite (Zwanzig, in prep.). They are tentatively correlated with part of the Northeast Reed assemblage from File Lake, interpreted to be ocean floor basalt (Syme *et al.*, 1995), but detailed trace element work is required. Unit 2a appears to be cut out and then reappears along the shear zone on the east shore of Dow Lake (Fig. GS-5-2).

South of Dow Lake a second unit of amphibolite (2b), which has higher Ti and trace element contents may be defined structurally above unit 2a.

Volcanic arc assemblage (units 3b, 3c and 3d)

Mafic to intermediate amphibolite occurs between the two panels of ocean floor. The lower contact of this amphibolite is a shear zone but the contact with unit 2a is not exposed.

A single aphyric sample (unit 3b) represents andesite. The rock has weak layering locally, but no primary structures. Porphyritic volcanic rocks (unit 3c) comprise basalt with possible pillows (two samples) and breccia (probably andesitic). Tectonites derived from these rocks are assigned to unit 3d. All units have low Ti (Fig. GS-5-3b), Zr (30-40 ppm) and Nb (3-5 ppm). They are interpreted as an island-arc volcanic assemblage in the Amisk collage.

Sherridon gneiss (units 5b-7a)

Coarsely garnetiferous felsic to intermediate gneiss at Fairwind Lake has not been sampled for chemical analysis. However, the rock is traced northwest into the Walton Lake nappe (Zwanzig, 1994a) where better exposure and unpublished geochemical data indicate that the felsic units contain metarhyolites similar to those in the arc assemblages of the Flin Flon-Snow Lake belt. The gneiss occupies the uppermost structural panel of volcanic-derived rocks.

Josland Lake gabbro (units 15a and 16a)

Strongly differentiated layered intrusions of tholeiitic gabbro (Bailes, 1980) occur north and west of Reed Lake in Amisk collage and Northeast Reed assemblage (Syme *et al.*, 1995). One of these bodies extends northwest towards Dow Lake, as a mafic to ultramafic phase (unit 15a) that intrudes unit 2b. Differentiated metagabbro sills with locally preserved layering intrude unit 2a along the south flank of the Kisseynew belt. They have been correlated with the Josland Lake gabbro (Zwanzig, 1994b). The sill (unit 16a) at the contact between unit 2a and the Burntwood suite north of Martell Lake may also be a Josland Lake gabbro.

An AFM plot of 30 analyses, collected from mafic to felsic differentiated sills over a distance of 50 km along the Kisseynew south flank, lies exactly on the strongly tholeiitic Fe-enrichment trend of data from the type area of Josland Lake gabbro (Fig. GS-5-4a). The mafic samples from the Kisseynew belt also scatter along the same Ti-enrichment trend as the type Josland Lake gabbro (Fig. GS-5-4b). These rocks are distinguished from other mafic to intermediate intrusions at Dow Lake and from farther north by their low K_20 content (Fig. GS-5-4c) and their sodic fractionate of leucotonalite.

Martell Lake sill complex (units 16 and 17)

Gabbroic to fine grained amphibolite (unit 16) and intermediate intrusive rocks (unit 17) with minor felsic rock form a large folded sheet that extends across the map area. This deformed intrusive complex dips gently east. Southeast of Martell Lake it has a lens-shaped body of the most mafic unit (16) at the structural base. East of this body, clean exposures of unit 17 consist of weakly differentiated quartz gabbro to quartz diorite sills, some with narrow sheets of tonalite at the top. Similar compositional variations elsewhere suggest that the whole intrusive complex consists of sills.

Major shear zones occur at the top of the sill complex, where unit 17 contains long narrow rafts of the Burntwood suite. These field relationships indicate that units 16-17 were emplaced in subhorizontal fault zones after juxtaposition of the volcanic assemblages with the Burntwood suite metaturbidites. The intrusions are apparently coeval with the youngest members of the successor arc plutons. They are not part of the Amisk collage as previously thought (Zwanzig, 1995a). However, they are sheared, highly metamorphosed, folded and cut by syncollisional pegmatite.

The mineral contents and geochemistry of the sill complex are distinctive. Some of the mafic rocks contain garnet. The intermediate rocks are relatively rich in garnet and biotite with accessory magnetite, titanite and apatite. This is reflected in high to moderate contents of Fe (Fig. GS-5-4a) and Ti (Fig. GS-5-4b), and moderate K over a wide range of SiO_2 (Fig. GS-5-4c). Zr varies from 72 to 366 ppm. (The two samples with the lowest alkali and Zr contents may be remnants of older intrusions.) The scatter of K_2O values is typical of alkali element mobility in high-grade metamorphic rocks. However, an overall chemical distinction is still apparent between the Martell Lake sill complex and other relatively young intrusive suites from adjacent areas.

Gants Lake tonalite to quartz-diorite gneiss (unit 17c)

The Gants Lake batholith (Whalen, 1993) extends across the Flin Flon belt north towards Martell Lake (Fig. GS-5-1). There, it comprises dark grey gneissic quartz diorite and light grey interlayered tonalite. The rocks are considered to be part of an early successor arc.

The quartz diorite is seriate porphyritic with 3-8 mm plagioclase phenocrysts (15-30%). It grades into tonalite with mafic inclusions and locally into porphyritic gabbro. All intrusive phases are progressively finer grained, more commonly porphyritic and more contaminated with xenoliths towards the margin of the composite pluton. Quartz diorite dykes occur in the adjacent supracrustal rocks, attesting to the preservation of the intrusive contact of the main body. Rhyolite dykes cut the quartz diorite.

Batty Lake tonalite gneiss (unit 18d)

Light grey weathering quartz-rich (30-35%) tonalitic gneiss exposed northeast of Fairwind Lake is one of the main phases of the Batty Lake complex (Zwanzig and Schledewitz, 1992). This orthogneiss is cut by 1-10 cm veins of pegmatite. It is locally garnetiferous and contains patches of coarser mobilizate. It has a straight, sheared southwest contact, which is parallel to the underlying supracrustal assemblages.

Sheared tonalite to granodiorite and porphyry to augen gneiss (units 18h, 18e and 19e)

Deformed intrusive sheets of granodiorite, tonalite and feldspar porphyry <500 m thick occur at Martell Lake and south of Dow Lake. Their composition includes tonalite (unit 18h) and granodiorite to granite (units 18e, 19e). Textural types range from strongly foliated equigranular rock (18e) to augen gneiss and porphyry (unit 19e). Augen gneiss contains rounded feldspar porphyroclasts, locally with asymmetric tails. Porphyry with 20% phenocrysts of feldspar (7 mm long) in a fine grained matrix occurs in the least deformed central part of the sheet south and west of Martell Lake. Potassic alteration, quartz veins and gold showings occur west of Martell Lake on the east side of the porphyry zone. This intrusive sheet is truncated at the Missi unconformity, a relationship that indicates an older age than units 16-17. Contacts between the mafic and granitoid rocks are not exposed but the narrow body of unit 16 east of Martell Lake is best interpreted as a dyke cutting unit 18e.

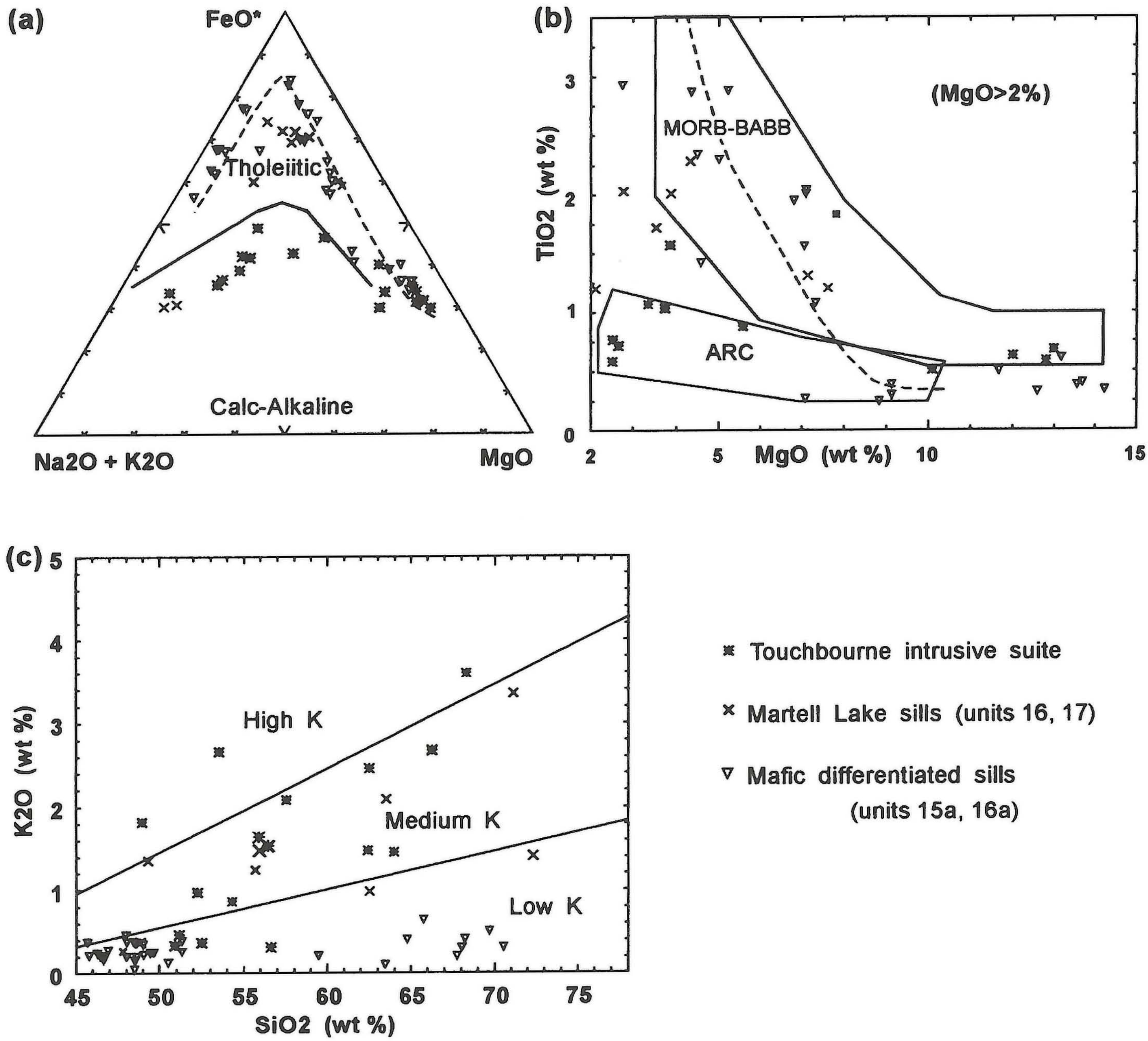

Figure GS-5-4: Discrimination plots of intrusive rocks in the Dow Lake - Martell Lake area and Kisseynew belt; (a) AFM plot with boundary (solid line) after Irvine and Baragar (1971) and trend of Josland Lake gabbro from the type area (Bailes, 1980); (b) TiO_2 vs MgO showing fields of mid-ocean ridge basalt - back-arc basin basalt (MORB-BABB), arc volcanics (ARC), and trend of type Josland Lake gabbro; (c) K_2O vs SiO_2.

Dow Lake felsic rock (unit 18g)

Elongate lenses, <180 m thick, of fine grained quartzofeldspathic rock (Dow Lake gneiss) were described by Zwanzig (1995a) and interpreted as intrusions. The country rock of a thin dyke of unit 18g is presently interpreted as unit 17, a relationship that indicates a younger age for 18g.

Burntwood and Missi suites (units 9 to 14)

Field relationships (above) indicate that the gneisses derived from predominantly sedimentary rocks are younger than the volcanic assemblages and all of the intrusive rocks except units 16, 17, 18g and probably 18h. Unpublished geochemical data from volcanic rocks in the Missi suite outside the Dow Lake area suggest that the volcanics may belong to the same period of magmatism as the younger intrusions.

In the lowest structural panel, which is part of the Flin Flon belt, the meta-arenite (unit 12) and basal conglomerate (unit 11) of the Missi suite overly the Amisk collage and early intrusions with profound angular unconformity. In all higher structural panels, which lie on strike with the Snow Lake belt, Burntwood suite metaturbidite (unit 9) is faulted against metavolcanic rocks and is conformably or disconformably overlain by the Missi suite.

A gradation between the Burntwood and Missi suites is apparent in the narrow belt of metasedimentary rock between Martell Lake and Dow Lake, herein called the Martell Lake fault zone. Where best exposed the zone is symmetrical, with Missi suite in the centre and Burntwood suite on the margins. The sediments are interpreted to be in fault contact with the amphibolites on either side of the zone. A unit (10a) that is gradational between the graphitic garnet-biotite gneiss (Burntwood suite) and magnetite-bearing quartz-feldspar-rich gneiss (typical Missi suite) comprises protoquartzite ± sillimanite ± garnet, pelitic garnet-biotite schist and garnet-magnetite-bearing quartzofeldspathic rock. Unit 10a occurs locally throughout the Kisseynew south flank and has been interpreted as shallow a marine basin facies at the bottom of the Missi suite (Zwanzig, 1994a).

STRUCTURE

Zwanzig (1995a) has divided the area between the Gants Lake batholith and the Batty Lake intrusive complex into four structural panels. The gently northeast-dipping contacts between the panels were interpreted to be early faults (D_1) and shear zones. These structures were overturned during D_2 and annealed under high-grade metamorphic conditions. Rocks within the panels acquired a strong S_2 foliation. This was refolded about shallow- to moderately east-dipping axial planes during D_3. The large north-plunging S-shaped fold pair that extends across Dow Lake, and the southeast-plunging synform south of the lake were formed at that time. During D_4 these structures were warped to their present canoe shape and east-northeast-trending domes were formed.

Detailed mapping, this year, has shown that there are additional, narrow, discontinuous structures with Missi suite in the core and Burntwood suite in the limbs. These structures and the previously mapped shear zones separate the various panels of ocean-floor, volcanic arc and intrusive rocks that are partly distinguished by their geochemistry. Many of these fault slices are interpreted to extend tens of kilometres along strike beyond the map area. The inferred strike faults were intruded by differentiating sills, an indication that the faults were subhorizontal.

The regional structural units and major faults are summarized in Table GS-5-2 from northeast to southwest (structural top to bottom). Intrusive rocks dominate the southwest half and the most northeastern part of the map area. Supracrustal rocks extend northwest across the area in attenuated structural panels that were folded into the large S-shaped F_3 structure. This fold pair dies out to the north such that the panels adjacent to the Batty Lake complex are planar (Fig. GS-5-2).

Table GS-5-2
Structural units and bounding fault zones

Batty Lake tonalite gneiss complex
- *Batty Lake shear zone*
  - contains a syncline with Burntwood and Missi suite

Walton Lake nappe (Sherridon volcanic gneiss)
- *Fairwind Lake fault*

D_1 syncline with Burntwood and Missi suite metasedimentary rocks
- *Loonhead Lake fault*
  - intruded by gabbro to quartz diorite (Josland Lake sills?)

Northeast Reed ocean floor assemblage
- *Martell Lake fault zone*
  - contains Burntwood and Missi suite intruded by Martell Lake quartz diorite to gabbro

Volcanic arc assemblage (Amisk collage)
- *West Reed-North Star shear zone*
  - contains gneissic granodiorite, tectonites and ultramafic lenses (Reed Lake complex) intruded by Martell Lake quartz diorite to gabbro and Dow Lake felsic gneiss

Elbow-Athapap ocean floor assemblage (Amisk collage), mafic screens that are country rock to augen granodiorite, unconformably overlain by the Missi suite
- *Intrusive contact with pre-Missi rocks*

Gants Lake quartz diorite-tonalite
- -intruded by rhyolite dykes

Southwestern structural panel

The deepest structural level is considered to be part of the Flin Flon belt. It is dominated by plutonic rocks that intrude the Elbow-Athapap ocean-floor assemblage of the Amisk collage. The presence of weakly foliated quartz diorite dykes in mafic tectonite suggests that strong deformation of the Amisk collage has preceded the intrusion of the Gants Lake batholith. The unconformity at the base of the Missi Suite indicates uplift of the early successor arc before deposition of the sediments and further accretion of volcanic rocks.

The upper part of this structural panel features shear zones and faults intruded by the Martell Lake sill complex and Dow Lake gneiss. The shear zones extend south into the West Reed - North Star shear zone.

West Reed - North Star shear zone

Gently curved, narrow valleys occur between the intrusive rocks of the southwestern structural panel and the volcanic-arc-derived amphibolites to the east. These valleys contain a few low outcrops of mafic to mixed tectonite and strike north into recrystallized mylonite on the shore of Dow Lake. The tectonites are the northern extension of the West Reed - North Star shear zone (Fig. GS-5-2).

The lenses of Reed Lake ultramafic complex and apophyses of the Gants Lake batholith in the zone indicate that the West Reed - North Star shear zone started as an early structure during the accretion of the Amisk collage. The zone was reactivated as suggested by Syme *et al.* (1995). At Dow Lake it was annealed and locally obliterated during later deformation. It was intruded by the post-Burntwood (<1.85 Ga) Martell Lake sills and Dow Lake gneiss. Rolled porphyroclasts, annealed mylonite and extensional shears suggest a history of early sinistral slip followed by southwest-directed transport during D_3 (after peak metamorphism).

Martell Lake fault zone

The structurally lowest zone that contains metasedimentary rocks (Burntwood and Missi suites) is called the Martell Lake fault zone in this report. It extends from the northeast shore of Dow Lake along the S-shaped D_3 structure and across the northern part of Martell Lake. It appears to cut off or join the West Reed - North Star shear zone.

The Martell Lake zone is interpreted as a fault-bounded D_1 syncline that contains metasedimentary rocks in the core. Its upper bounding fault is the contact of fine grained amphibolite, Northeast Reed ocean-floor assemblage (unit 2a) and mafic tectonite (unit 3b). The Burntwood suite on the structurally lower side of the Martell Lake zone is heavily intruded by the Martell Lake sills, an indication that the fault zone was part of a system of thrusts or low-angle normal faults in its early history. Repetitions of the Burntwood and Missi suites in the zone suggest thrusting. The sedimentary rocks apparently served as detachment between overriding panels of igneous rocks during the D_1 juxtaposition of the Amisk collage and the Northeast Reed assemblage, somewhat like the Morton Lake fault zone (Syme *et al.*, 1995).

Loonhead Lake fault

The contact between the Northeast Read assemblage and the Burntwood suite to the northeast has been mapped as the Loonhead Lake fault (Connors, in press). On the east side of Dow Lake this contact is obscured by later shearing and poor exposure. However, the fault is inferred to extend along the S-shaped structure northwest of the lake. There, the amphibolite adjacent to the fault is intruded by mafic sills (unit 16a) interpreted as Josland Lake gabbro. Similar structural relationships exist on Loonhead Lake and for 50 km west of Martell Lake. Exposures of the fault, which were encountered west of Martell Lake, are complicated by younger shear zones and intrusions. The fault is interpreted as a D_1 thrust that may have been inverted during D_2 and refolded during D_3 (Zwanzig, 1995b).

The wide regional extent of the fault has been discussed (Zwanzig, 1995a). The unique geochemistry of units 2a and 16a, which allows the Northeast Read ocean-floor assemblage to be traced for 50 km west of Dow Lake, also suggests that the Loonhead Lake fault system extends that far. The fault is taken as part of the structural boundary of the Kisseynew belt.

D_1 syncline

The metasedimentary rocks bounded by the Loonhead Lake fault in the southwest and the Fairwind Lake fault in the northeast occupy a syncline, which contains Missi suite in the core and Burntwood suite on the limbs. The fold has been mapped as a D_1 structure at File Lake (Bailes, 1980). It probably extends 80 km from Snow Lake northwest toward Kississing Lake (Fig. GS-5-1). It was cut by S_2 (Connors, in press) and refolded during D_2, D_3 and D_4 (Zwanzig, 1994a).

Fairwind Lake fault

Above the Burntwood suite the contact zone of Walton Lake nappe marks an abrupt change from the basinal metasediments to gneisses derived from a volcanic arc. This zone also contains rare mafic-ultramafic lenses, possibly ocean floor. It is tentatively interpreted as a D_1 fault, folded about the D_2 Walton Lake nappe (Zwanzig, 1994a).

Batty Lake shear zone

The structurally uppermost fault-bounded syncline containing Burntwood and Missi suites is along the southwest contact of the Batty Lake complex. Late shearing has obliterated signs of early faulting and cut out the sedimentary rocks northwest of Fairwind Lake.

Regional tectonic and economic implications

A pattern has emerged from the detailed mapping and preliminary geochemistry at Dow Lake and Martell Lake that fits well with the tectonic relationships and ages established in the Flin Flon - Snow Lake belt and the Kisseynew belt.

Southwest of Dow Lake, Amisk collage comprises 1.9 Ga arc and ocean-floor assemblages separated by long-lived shear zones and intruded by mainly 1.87-1.84 Ga successor arc plutons. These rocks are unconformably overlain by the Missi suite, commonly with a thick basal conglomerate. They formed a composite terrane that extends 140 km from the Morton Lake and Martell Lake fault zones west to the Sturgeon-weir shear zone (Lucas *et al.*, 1996). In Manitoba, gneissic equivalents of these rocks extend north to Kississing Lake.

The Snow Lake area and the Kisseynew belt are interpreted to form a second composite terrane as suggested by the structural and stratigraphic continuity between them. Southeast of Dow Lake, roughly wedge-shaped blocks of 1.9 Ga arc and ocean-floor volcanics are separated by narrow fault-bounded panels of Burntwood suite metaturbidite (Fig. GS-5-1). The structures converge northwest from Reed Lake and Snow Lake to Dow Lake, but extend beyond Dow Lake into the Kisseynew belt. The Northeast Reed ocean-floor assemblage, the intruded Josland Lake gabbro and the overlying Missi suite occupy a thrust sheet that may extend to Kississing Lake. The thrust sheet is separated from volcanic arc-derived (Sherridon) gneisses to the north by the large D_1 syncline of Burntwood suite with conformably overlying Missi suite. The syncline and its bounding faults also extend from Snow Lake nearly to Kississing Lake. The regional involvement of the sedimentary rocks and dated plutons indicates that terrane assembly and amalgamation with the Amisk collage occurred 1.85-1.83 Ga.

All the fault-bounded panels of sedimentary rocks, including the Martell Lake and Batty Lake zones, are synclines. The sedimentary rocks apparently formed footwall synclines that served as detachment zones for overriding panels of igneous rocks. The convergence of the zones towards the Kisseynew gneiss belt suggests that they were originally linked at depth. They probably formed an imbricate array of faults that was later overturned during backfolding.

The expanded collage was intruded by 1.84-1.82 Ga plutons during assembly, continued sedimentation, volcanism and continued D_1 deformation. The intrusions are abundant in the Kisseynew belt, in the Snow Lake area and farther south and east. They include the Touchbourne intrusive suite (Manitoba Energy and Mines, 1988), which is locally enderbitic and is hosted exclusively in the Burntwood suite. The Touchbourne suite has a medium-K calc-alkaline chemistry (Fig. GS-5-4a-c) that suggest arc magmatism migrated into the Kisseynew belt during D_1. The Josland Lake and Martell Lake sills, which are associated with D_1 faults in the contact zone with the Amisk collage, are Fe-tholeiites, possibly related to subduction rollback (Zwanzig, 1996b).

The similar geology of the Snow Lake area and the adjacent part of the Kisseynew belt is consistent with the distribution pattern of precious- and base-metal deposits in the low-grade rocks and the gneisses. The mineral potential can be determined for the individual tectonic assemblages, some of which provide a good target for mineral exploration (Zwanzig, 1995a). An understanding that the assemblages form thrust sheets and lenses involved in later recumbent and upright folding is required to tracing them in the Kisseynew belt. Geochemical finger printing, especially of the mafic rocks, is also critical to the mapping.

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GS-6 PERSPECTIVES ON THE STRUCTURAL GEOLOGY ALONG THE NORTH MARGIN OF THE FLIN FLON VOLCANIC BELT

by D.C.P. Schledewitz

Schledewitz, D.C.P., 1996: Perspectives on the structural geology along the north margin of the Flin Flon volcanic belt; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1996, p. 29-31.

SUMMARY

Isolating the effects of pre-to late-metamorphic deformation provides a new perspective on the boundary between the Kisseynew gneiss belt and Flin Flon belt. The concepts of accretionary tectonics have been established with the identification of major fault boundaries that predated regional Hudsonian metamorphism. These accreted terranes and their bounding faults were variably modified during syn-to late-metamorphic deformation. The pre-metamorphic tectonic boundary between the Kisseynew south flank and the north margin of the Flin Flon belt, from Annabel Lake, Saskatchewan to Ponton Lake, Manitoba, is highly sheared. The deformation is syn-to post-peak of metamorphism and the shear zones that lie within the north margin of the Flin Flon belt are truncated by a system of late metamorphic normal faults. The high degree of syn-metamorphic strain has obscured the nature of the pre-metamorphic boundary conditions and the late metamorphic normal faulting has partially obscured the extent of the syn-to post-metamorphic shearing in the north margin of the Flin Flon belt.

INTRODUCTION

The north margin of the Flin Flon volcanic belt is delineated by a marked geological change from a supracrustal belt with relatively well preserved metasedimentry, volcanic and igneous rocks (Flin Flon belt) to a gneissic belt (Kisseynew gneisses). How to interpret this change has been a focus of attention since the first mapping that documented the geology north of Flin Flon into the Kisseynew Lake region (Dowling, 1902). The interpretations have covered the geological spectrum from a northerly continuation of the Flin Flon belt, lithologies with a south to north increase in metamorphic grade, to the possibility of a major fault that juxtaposed regions of different lithologies and metamorphic grades. The term "Kisseynew Lineament" (Harrison, 1951) came into common usage to delineate a break between gneissic rocks and less metamorphosed terrane extending from Amisk Lake, Saskatchewan to Wekusko Lake, Manitoba. The failing of these concepts lies in the fact that there is no single or unique solution. There is instead a complex deformation path with each subsequent phase of deformation variably affecting earlier structures. The following discussion focuses on the north margin of the Flin Flon belt from Annabel Lake, Saskatchewan to Ponton Lake, Manitoba (Fig. GS-6-1).

This geologically problematic area has been re-examined as part of regional and detailed mapping programs in Saskatchewan and Manitoba. The results have been coordinated and combined with the Lithoprobe Trans-Hudson Orogen Seismic transect and the NATMAP Shield Margin Project. This coordinated multidisciplinary, multi-agency program has greatly advanced the understanding of the evolution of the Flin Flon volcanic belt and its crustal setting (Lucas *et al.*, 1994; Stern *et al.*, 1996). The proposed aspects of a subduction and continental collision model while not fully constrained nor testable provides an appropriate context and scale for the magnitude of the cumulative strain recorded in the rocks of the Kisseynew gneiss belt and the Flin Flon belt. The concepts of accretionary tectonics have been established with the identification of major fault boundaries that predated regional Hudsonian metamorphism. These accreted terranes and their bounding faults were variably modified during syn-to late-metamorphic deformation.

The steps in the deformation path include an accretionary process that assembled the Flin Flon belt from diverse island arc and ocean floor assemblages along transcurrent and thrust faults. Many of these structures have been reactivated during subsequent episodes of deformation. A period of major thrust faulting postdated deposition of post-accretionary, basin sedimentary rocks (Burntwood suite), subaerial sedimentary rocks and volcanic rocks (Missi suite) and igneous intrusions. This period of thrust faulting predated regional metamorphism and established fundamental structures that impact on the interpretation of the Kisseynew gneiss belt. A crustal scale accretionary thrust fault carried the Snow Lake volcanic belt over the Flin Flon belt. Basin sedimentary rocks (Burntwood suite) occur as slices in the thrust zone (Syme *et al.*, 1995). Thrust faults of this age also carried basinal Burntwood suite rocks over parts of the Flin Flon belt and the Snow Lake belt producing a tectonic complex of interleaved volcanic, sedimentary and igneous rocks of various ages and affinities. This type of tectonically interleaved zone is considered to be a precursor to the gneisses and migmatites of the Kisseynew south flank, a subdivision of the Kisseynew gneiss belt (Fig. GS-6-1). Synchronous deformation in the Flin Flon belt unaffected by this basin overthrusting produced upright folds and steeply dipping fault zones.

NORTH MARGIN OF THE FLIN FLON BELT- ANNABEL LAKE TO PONTON LAKE

Subsequent syn-to post-metamorphic deformation have variably overprinted the tectonic boundaries between the regions affected by basin overthrusting, and the areas of the Flin Flon belt that escaped overthrusting. The sinistral reverse Annabel Lake shear zone (TASZ) (Fig. GS-6-1) is interpreted as an accommodation structure related to late continental collision that allowed ductile rocks of the Kisseynew south flank to slide southwestward past low-grade rocks of the Flin Flon belt (Ashton and Lewry, 1994). This high strain zone lies within rocks of the Flin Flon belt. The rocks north of the TASZ, that lie above the sillimanite isograd, are more highly foliated. The shallow to moderately northerly dipping contact zone between the Flin Flon belt and Kisseynew south flank lies 10 km north of the easterly-trending 1 km wide Annabel Lake section of the TASZ. The Tartan Lake segment of the TASZ in Manitoba trends easterly to southeasterly and is truncated by a region of steeply dipping east-northeast-trending shear zones.

Lithoprobe seismic data has provided the first indication of structure at depth across the boundary zone between the Flin Flon belt and the Kisseynew south flank. The seismic profiles cross the TASZ in Saskatchewan and the highly strained rocks immediately northeast of the TASZ in Manitoba. Projection of the geology from surface into the subsurface along the north margin of the Flin Flon belt using the Lithoprobe data, which defines reflectors of intermediate northerly dips, places foliated seismically reflective Flin Flon belt rocks beneath the Kisseynew south flank gneissic complex. The steeply dipping contacts and fabrics measured at the surface clearly become shallower at depth. The southern extension of the foliated and seismically reflective Flin Flon belt terrane is truncated abruptly against a poorly imaged region. The well defined reflection seismic discontinuity dips steeply to the south and is readily traceable to a depth of 18 km. This apparent normal fault clearly postdates the development of the tectonic lamination in the more highly metamorphosed rocks of the Flin Flon belt and the Kisseynew south flank to the north. The surface projection of this discontinuity along the northwest side of Naosap Lake lies within a northeasterly-trending fault system which appears to be a part of the Northeast Arm shear zone (NASZ). The syn-to late-metamorphic NASZ is interpreted to have a young transcurrent dextral sense of shear(Lucas *et al.*, 1995). The NASZ appears to have acted as a late metamorphic accommodation structure that allowed normal fault movement to take place on the more easterly-trending system of younger normal faults from Naosap Lake to Ponton Lake (Fig. GS-6-1).

ECONOMIC IMPLICATIONS

The results of detailed studies and geochronology in the area of the Tartan Lake gold deposit (Fig. GS-6-1) indicate mesozonal shear-zone related gold deposition that postdated the peak of metamorphism

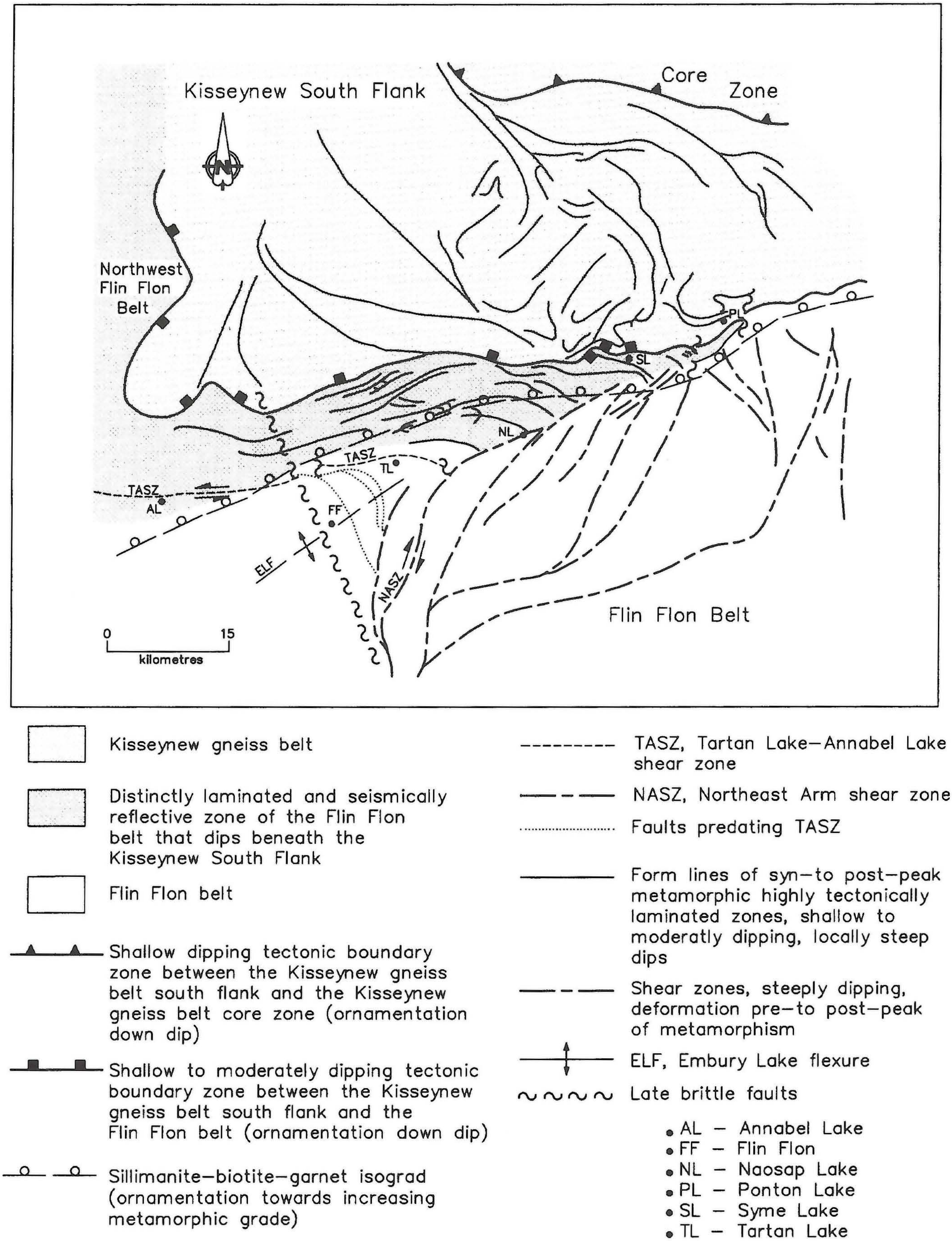

Figure GS-6-1: Simplified plan view of late-collisional structural relationships along the north margin of the Flin Flon belt and the south boundary of the Kisseynew south flank.

(Fedorowich *et al.*, 1991). The timing of the late normal faulting and resulting reactivation of the TASZ and the NASZ is consistent with the age of vein hosted gold deposits. The scale of the late metamorphic faulting, a minimum of 18 km depth (present day) and strike length of over 100 km is appropriate as a mechanism to produce wide spread second order faults and fractures along its trend. Metamorphically derived gold-bearing fluids could be channeled from deeper seated areas to be deposited in vein systems at a higher level in the crust.

The deposition of gold-bearing veins at Tartan Lake is interpreted to be focused by the ductility contrasts of the gabbroic intrusions during deformation. Vein hosted gold deposits of similar style and age occur at Contact Lake (Fayek and Kyser, 1995) and Star Lake (Ibrahim and Kyser, 1991) in Saskatchewan. The host rocks in these deposits are intrusive rocks of intermediate composition. Clearly the composition of the host intrusive rocks is not a limiting factor. The effects of the late metamorphic fault system extend along an area from Tartan Lake to Ponton Lake. The potential for deposition of gold-bearing veins can be extended to a variety of host rocks with suitable ductility contrasts that produced fracture patterns to focus gold bearing fluids and allow deposition at appropriate conditions of temperature, pressure and resultant changes in fluid properties.

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GS-7 GEOLOGY OF THE LAC AIMÉE-NAOSAP LAKE AREA (63K/13SE AND 63K/14SW)

by H.P. Gilbert

Gilbert, H.P., 1996: Geology of the Lac Aimée-Naosap Lake area (63K/13SE and 63K/14SW); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 32-39.

SUMMARY

The area mapped consists mainly of massive and fragmental mafic volcanic rocks, with subordinate felsic volcanic and/or intrusive units, and minor greywacke-siltstone turbidite (Amisk collage, Syme 1995; Table GS-7-1). Tonalitic and gabbroic intrusive rocks occur in the northeast part of the area. A major F_2 anticline-syncline pair (Lac Aimée anticline and syncline) extends northeast through the map area. North of Naosap Lake, disrupted isoclinal folds attributed to D_1 are refolded by later F_2 folds. F_3 resulted in broad open folding of F_2 folds and produced east-southeast- to southeast-trending strain slip cleavage.

Table GS-7-1
Formations for the Lac Aimée-Naosap Lake area

LATE INTRUSIVE ROCKS*	9	Granodiorite, granite, aplite.
	8	Diabase, aphyric to plagioclase phyric.
		INTRUSIVE CONTACT
	7	Gabbro, amphibolite; minor pyroxenite.
INTRUSIVE ROCKS*	6	Felsite; plagioclase ± quartz porphyry.
	5	Tonalite, leucotonalite, quartz diorite, leucodiorite; minor diorite.
		INTRUSIVE CONTACT
		Aimée arc-type volcanic and related sedimentary rocks (2-4).
	4	Greywacke, siltstone, minor cherty siltstone.
	3	Rhyolite, plagioclase ± quartz phyric; minor felsic tuff and related breccia.
AMISK	2a	Basalt, basaltic andesite, aphyric to plagioclase ± pyroxene phyric; related volcanic breccia, diabase and gabbro.
	2b	Mafic tuff, crystal tuff; minor lithic tuff.
	2c	Intermediate to mafic heterolithic breccia, minor tuff.
		FAULT CONTACT
		Mikanagan ocean-floor basalt (1).
COLLAGE	1	Basalt, aphyric; minor variolitic and plagioclase ± pyroxene phyric basalt; related diabase and gabbro.

*Note. The relative ages of units within 'late intrusive' and 'intrusive' rock groups are not determined.

A network of anastamosing north- to northeast-trending faults (D_4) is inferred from topographic lineaments and localized shear zones. Animus Lake and Sourdough Bay faults mark the boundaries between the Mikanagan Lake, Lac Aimée, and Sourdough Bay blocks respectively. Major faults are inferred parallel to the northwest and southeast shorelines of Lac Aimée. Volcanic rocks in the Lac Aimée block trend mainly northeast to east whereas Mikanagan basalt trends north to northwest.

The supracrustal rocks in the Lac Aimée block are lithologically and stratigraphically similar to arc-type volcanic suites elsewhere in the Flin Flon granite-greenstone belt (Stern *et al.*, 1995). In contrast, the Mikanagan Lake block is characterized by ocean-floor basalt and related mafic intrusions.

Mineralization at the 'KD zone' southwest of Lac Aimée consists of pyrite with minor Cu (and trace Zn, Au and Ag) in silicified basalt intruded by quartz veins and felsic porphyry. At the Sap claims in the northeast part of the map area, pyrite mineralization (with trace Au) occurs in gabbro within a basalt section that contains conspicuous felsic units.

Mapping of the project area will be completed in 1997. Geochemical investigations, integration of field data in the NATMAP database and preparation of a 1:20 000 scale map and report will be undertaken during and after final mapping in the Lac Aimée-Naosap Lake area.

INTRODUCTION

A geological mapping program was initiated in the Lac Aimée-Naosap Lake area as part of the regional NATMAP program in the Flin Flon granite-greenstone belt (Fig. GS-7-1). Field mapping was carried out at a scale of 1:15 840 in a panel extending through the central part of the project area (Fig. GS-7-2). The objectives of the project are as follows:

a) to upgrade existing 1:63 360 scale maps (Bateman and Harrison, 1943; Kalliokoski, 1949) and to provide critical information for the 1:50 000 and 1:100 000 NATMAP compilation maps.
b) to identify the geochemical affinity of the volcanic rocks, using whole rock, trace, and rare earth element analytical data, to delineate and extend the boundary between arc and ocean-floor volcanic terranes in the area west of Lac Aimée.
c) to investigate the stratigraphy and structure of the supracrustal rocks.
d) to investigate all mineralized localities and assess their economic significance.

STRUCTURE

The F_2 Lac Aimée anticline and syncline extend northeast through the map area, broadly conformable with the trend of Lac Aimée (Fig. GS-7-2). These tight to isoclinal major folds are defined by top indicators in pillow basalt and turbidites, and are locally delineated by deformed felsic volcanic units. The regional S_1 foliation wraps around the fold closures of the F_2 folds. F_2 minor folds plunge moderately to steeply southwest and northeast (Fig. GS-7-3). In the northeast part of the project area, the hinge lines of the Lac Aimée anticline and syncline are convergent toward a highly attenuated, gneissic zone north of Naosap Lake. To the southwest, the folds trend south-southwest toward the west margin of the Lac Aimée block.

North of Naosap Lake, disrupted isoclinal folds attributed to D_1 are refolded by F_2 folds (Fig. GS-7-4). Later D_3 deformation resulted in broad open folding of the axial traces of major F_2 folds, and produced strain slip cleavage that trends southeast to east-southeast (Fig. GS-7-5). Parasitic Z-folds on the limbs of Lac Aimée syncline that are displayed by the rhyolite unit south of Lac Aimée are attributed to dextral shear associated with D_3.

The Lac Aimée-Naosap Lake area is dominated by an anastamosing network of north- to northeast-trending faults attributed to late brittle deformation (D_4). The most significant structures are the block-bounding Animus Lake and Sourdough Bay faults that mark the boundaries between Mikanagan, Aimée and Sourdough Bay blocks respectively (Fig. GS-7-6). The Sourdough Bay fault is a major regional structure that extends southwest and south through Alberts Lake to Sourdough Bay in the north arm of Athapapuskow Lake (Bailes and Syme, 1989); this fault is marked at one locality near the west end of Naosap Lake by a 45 m wide tectonic breccia that contains diverse angular blocks of foliated felsic porphyry, basalt, and related schist and gneiss up to 1 m across. Animus Lake fault appears to be offset approximately 650 m by sinistral displacement on the Lac Aimée fault (Fig. GS-7-6). Within major fault blocks, numerous subsidiary faults are inferred from topographic lineaments or localized intense shearing.

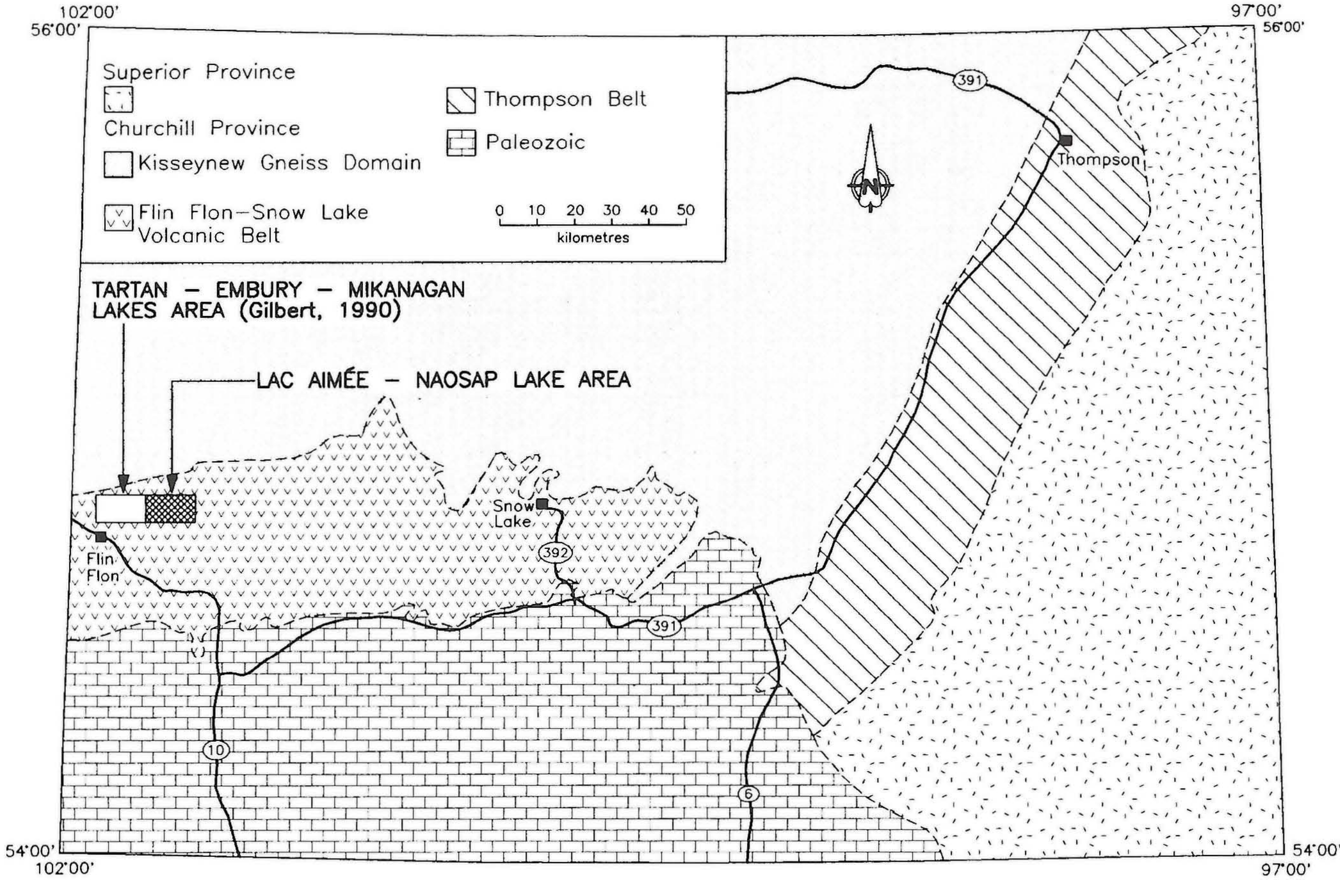


Figure GS-7-1: Map of geological domains showing the location of the Lac Aimée-Naosap Lake area.

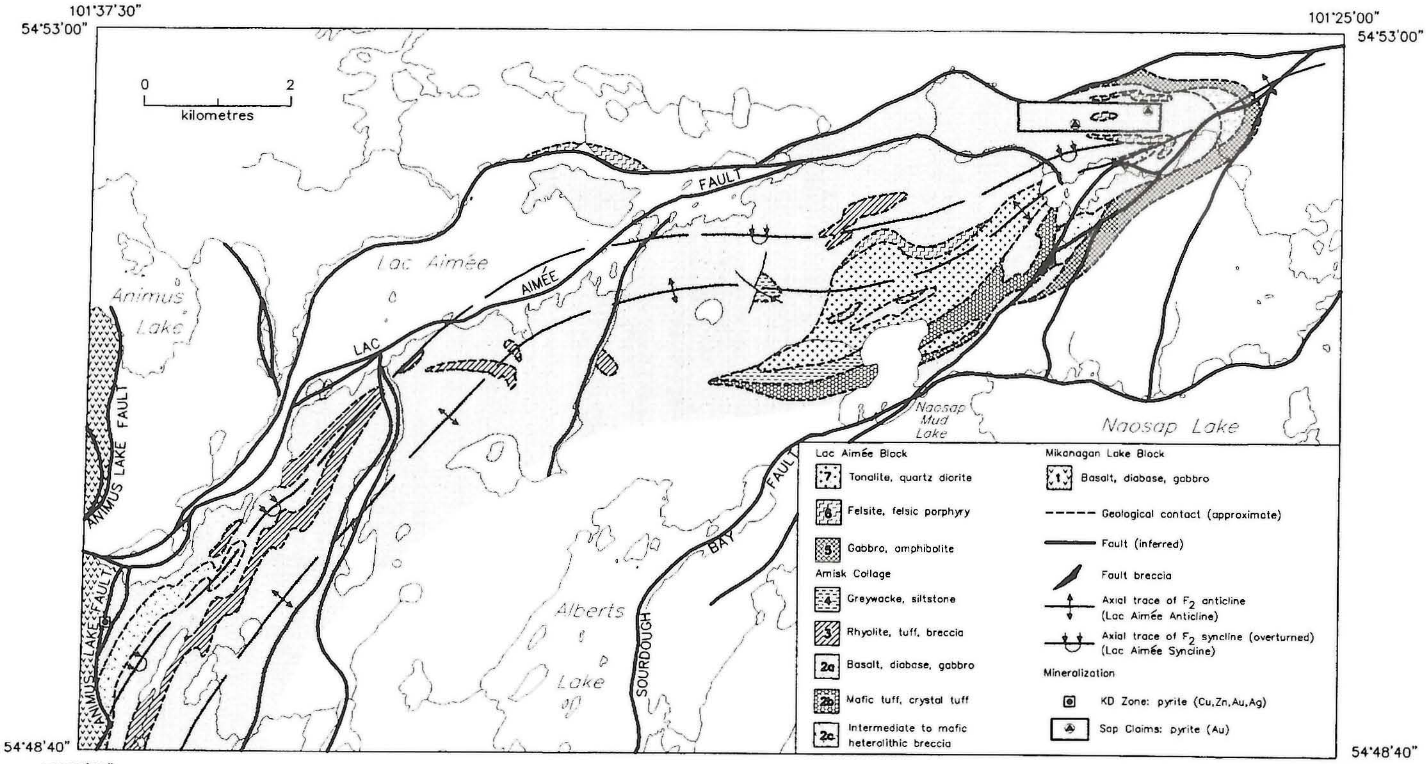


Figure GS-7-2: Generalized geology of the Lac Aimée-Naosap Lake area.

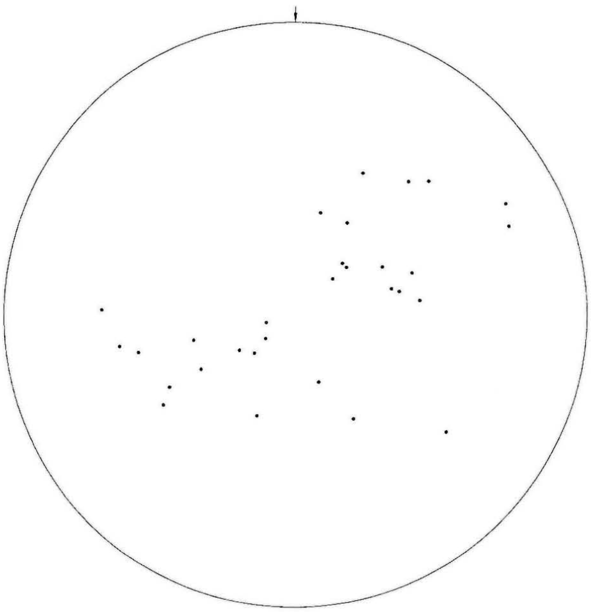


Figure GS-7-3: Lower hemisphere stereographic plot of F_2 minor folds in the Lac Aimée-Naosap Lake area.

Figure GS-7-4: Gneissic amphibolite showing disrupted F_1 minor folds refolded by F_2.

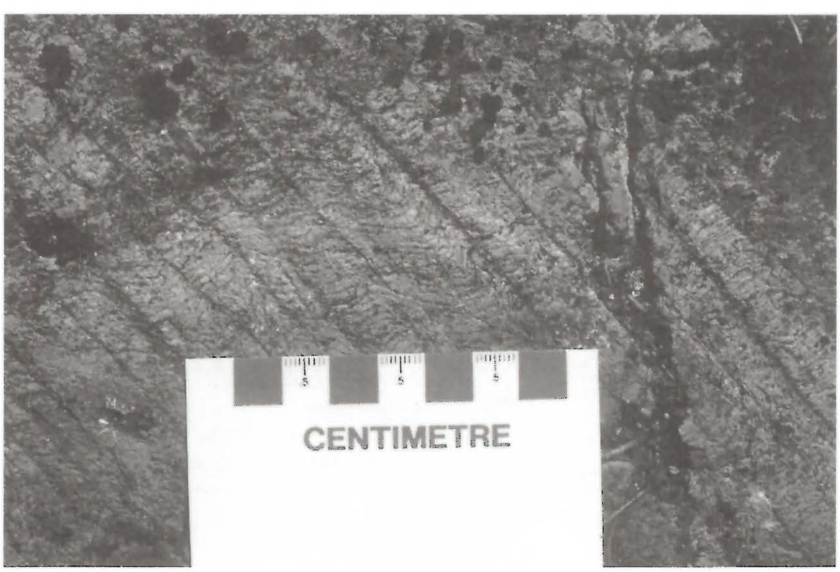


Figure GS-7-5: S_3 strain slip cleavage in porphyritic rhyolite.

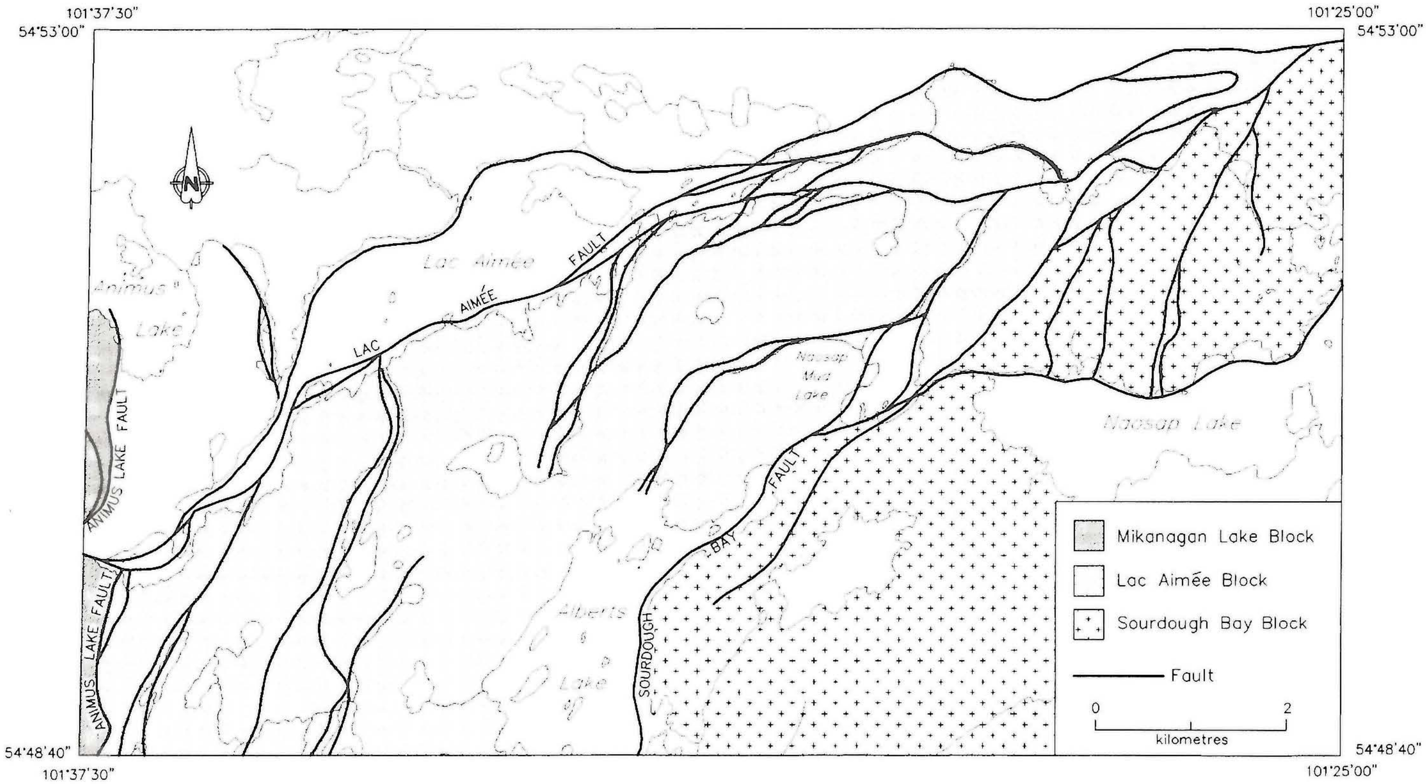


Figure GS-7-6: Major faults and structural blocks in the Lac Aimée-Naosap Lake area.

STRATIGRAPHY

The Mikanagan Lake block, located directly to the west and extending into the southwest corner of the project area, consists largely of ocean-floor basalt and subordinate related gabbro. Mikanagan basalt (1) (Table GS-7-1) is massive to pillowed and largely aphyric; several variolitic flows (up to 35 m thick) occur close to the west margin of the fault block. In contrast to arc basalt, Mikanagan basalt is devoid of intercalated flow breccia and vesicular/amygdaloidal textures are not conspicuous, consistent with an inferred deep water depositional environment.

Lac Aimée block consists largely of massive basalt to basaltic andesite, with minor intercalations of related tuff and volcanic breccia. At least two stratigraphically distinct units of rhyolite and two units of turbiditic greywacke/siltstone occur within the mafic volcanic section (Fig. GS-7-7). Heterolithic volcanic breccia and tuff occur in the northeast and southwest parts of the project area.

Pillowed to massive Aimée arc-type basalt (2a) is aphyric to plagioclase ± pyroxene phyric (pyroxenes are altered to hornblende). Quartz ± plagioclase amygdales occur sporadically in massive flows and are abundant in intercalated breccia. Epidote is common in pods, stringers and patchy alteration zones. Concentric cooling fractures occur in several units. Pillows (0.5-1.5 m) are well preserved in the southwest part of the project area, but elsewhere are attenuated or largely obliterated by deformation. Synvolcanic diabase dykes include aphyric to porphyritic types texturally similar to associated mafic flows, and a densely porphyritic phase with up to 40% hornblende pseudomorphs after pyroxene.

Mafic tuff and crystal tuff (2b) locally display primary bedding (1-12 cm) defined by alternating pale/dark grey-green units and/or very fine laminae (1-5 mm) that are differentially weathered. Tuff is generally slightly finer grained than associated basalt. Plagioclase phenoclasts are subangular to ovoid and locally graded in mafic crystal tuff. Sporadic lithic crystal tuff units associated with volcanic breccia (2c) contain mafic lithic granules and sporadic lapilli, in addition to plagioclase phenoclasts.

Intermediate to mafic heterolithic breccia (2c) at least 200 m thick, interpreted as debris flow deposits, occurs in the axial zone of the southwest part of Lac Aimée syncline and on the limb of Lac Aimée anticline in the northeast part of the project area. Breccia units (1 to >10 m) are unsorted, and contain subangular lapilli and volcanic blocks (up to 75 cm) in a tuff matrix. Clasts are mainly mafic volcanic, aphyric to plagioclase ± pyroxene phyric, and commonly amygdaloidal; subordinate fragment types include altered mafic, intermediate, and felsic volcanic lithologies. In the northeast part of the project area, heterolithic breccia is highly attenuated and altered to amphibolitic schist and gneiss. Epidotic or siliceous alteration occurs sporadically in both massive and fragmental mafic volcanic rocks throughout the mapped area.

Porphyritic rhyolite units (3) up to 220 m thick occur in a zone that extends northeastward for over 10 km through the project area. The rhyolite is typically massive and contains 5-25% plagioclase (± quartz) phenocrysts. Sporadic tuff units and minor felsic breccia zones are intercalated with massive rhyolite at a scale of 25 cm to 1.5 m. A rhyolite lobe with primary flow lamination was observed at one locality (Fig. GS-7-8). Some flows display diffuse 5-25 cm colour lamination (cream/pale to medium grey) that may also be due to flow. The ubiquitous sericitic foliation is locally crenulated into S_3 strain slip cleavage (Fig. GS-7-5). Late brecciation and chloritic alteration along fractures is common in the rhyolite.

Fine grained feldspathic greywacke and siltstone (4) in the core of Lac Aimée anticline west of Naosap Mud Lake are interlayered at a scale of 10 cm to 2 m in cyclic turbidite units. The sedimentary rocks, which are over 100 m thick, are massive to laminated and locally graded; finely laminated cherty siltstone occurs at the top of some turbidite cycles. Similar turbidite deposits, approximately 200 m thick, occur on the south limb of the anticline 1 km west of Naosap Mud Lake. Graded bedding, rip-ups and parallel lamination are characteristic of ADE Bouma turbidite cycles (Fig. GS-7-9). The turbidite deposits, which occur within a sequence of massive basalt and tuff, are interpreted to be derived mainly from intermediate to mafic tuff.

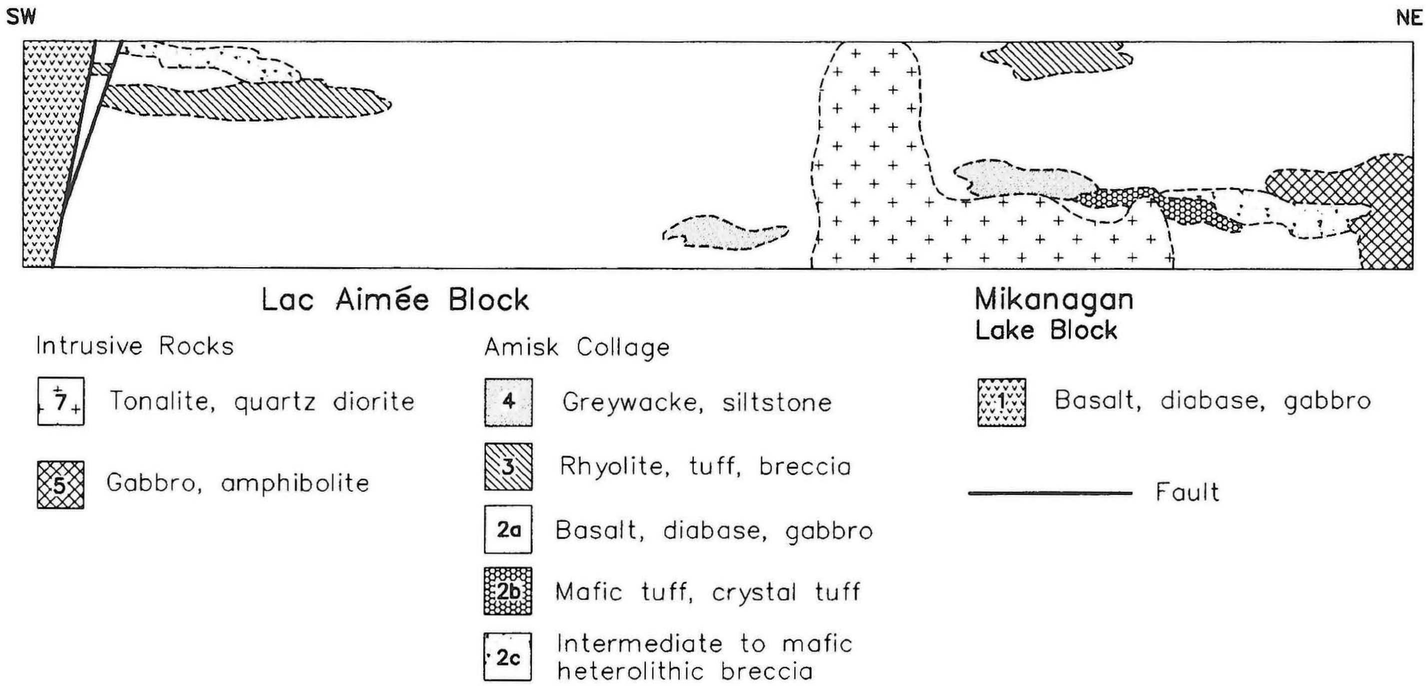
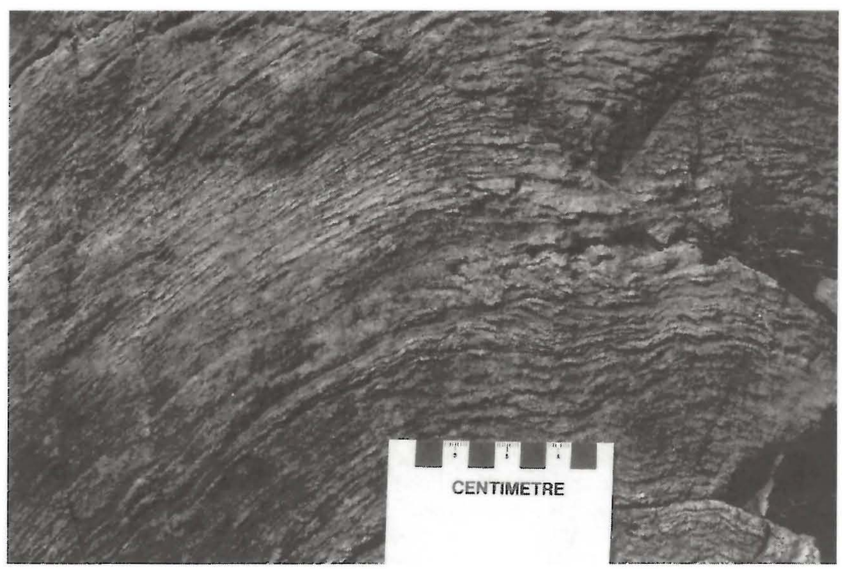


Figure GS-7-7: Schematic SW/NE transverse section showing the main stratigraphic units in the Lac Aimée block.

Figure GS-7-8: Primary flow lamination at the margin of a rhyolite lobe.



INTRUSIVE ROCKS

A pear-shaped leucotonalite to quartz diorite stock (5), up to 1.4 km wide and 4 km long, is emplaced in the axial zone of Lac Aimée anticline north of Naosap Mud Lake. The granitoid rocks are medium grained, equigranular to hypidiomorphic, with fine grained, locally porphyritic zones toward the margins of the intrusion. Sporadic felsic porphyry dykes are emplaced in the stock. Minor dioritic phases are attributed to contamination by basaltic host rocks at the margins of the stock. The intrusion is overprinted by the regional S_1 foliation and is interpreted as early, possibly of subvolcanic origin.

Minor felsitic dykes (6), mostly 50 cm to 10 m wide, are widespread in the northeast part of the mapped area. Unit 6 includes early (synvolcanic) and later, pluton-related minor intrusions; different phases of felsic porphyry are distinguished by phenocryst type (plagioclase, quartz) and grain size (medium grained, coarse grained). Conspicuous felsitic units are intercalated with basalt and gabbro in the vicinity of the Sap claims north of Naosap Lake (Fig. GS-7-2) where the strongly foliated felsite and plagioclase porphyry units (5-40 m thick) are locally characterized by diffuse zones of hornblende metasomatism.

Medium grained gabbro and related amphibolite (7) extend along the southeast margin of the volcanic sequence north of Naosap Lake. The massive, mesocratic to melanocratic rock is homogeneous except in localized marginal zones that are contaminated by basaltic host rocks. Porphyroblastic hornblende (up to 5 mm) is common close to the intrusive margin. A minor phase of coarse grained pyroxenite that occurs locally in the gabbro as sporadic xenoliths and remnant bodies (up to 5 m) is interpreted as an early intrusive phase coeval with the gabbro. Further north at the Sap claims, where gabbro is mineralized with pyrite (± trace Au), the rock is massive to strongly foliated and locally altered to hornblende-chlorite schist.

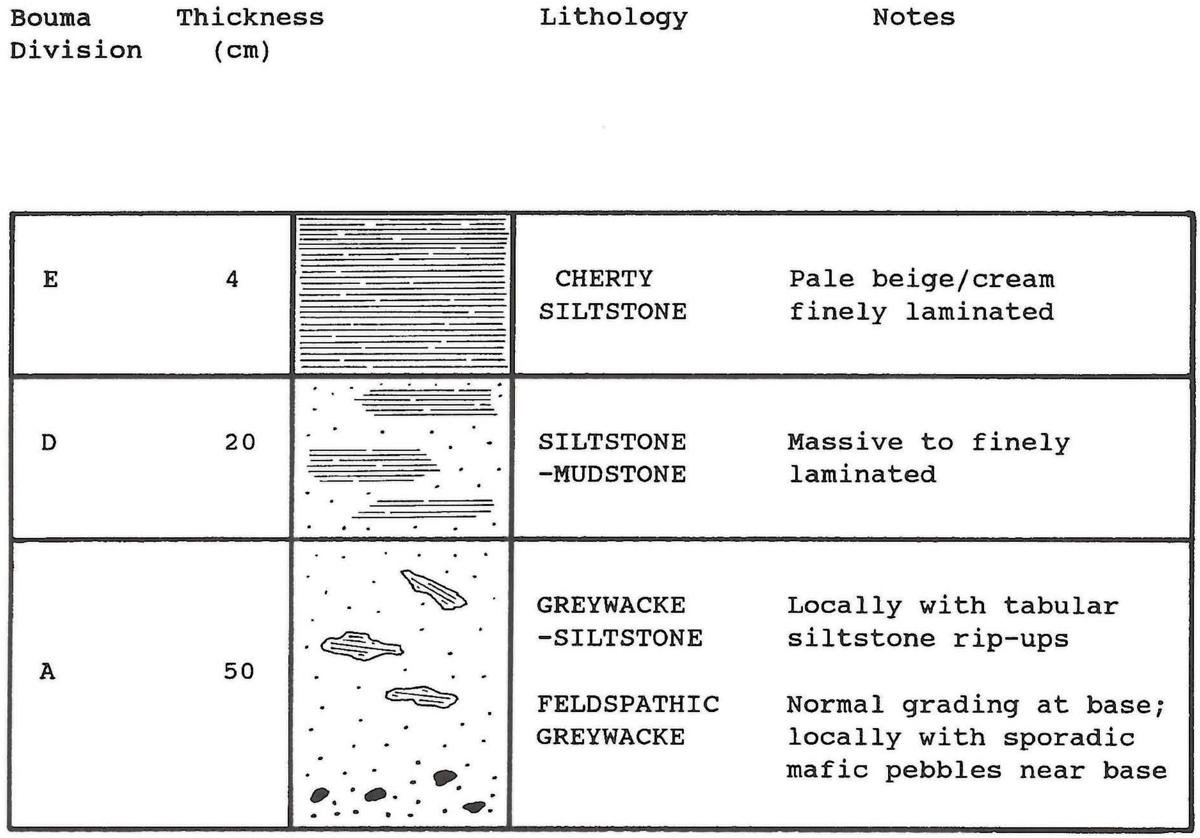


Figure GS-7-9: Greywacke-siltstone turbidite unit on the south limb of Lac Aimée anticline west of Naosap Mud Lake.

Post-tectonic intrusions include both diabase (8) and granitoid dykes (9). Late, aphyric to plagioclase phyric massive diabase dykes are emplaced in volcanic rocks (Amisk collage) and in the tonalitic stock (5) north of Naosap Lake. Post-tectonic aplite veins postdate the gabbro intrusion (7) north of Naosap Lake; granodiorite/granite dykes (9) intrude late fault breccia within the Sourdough Bay fault.

GEOCHEMISTRY

Mafic volcanic rocks in the Lac Aimée block are compositionally similar to juvenile arc basalt elsewhere in the Tartan-Embury-Mikanagan lakes area (Table GS-7-2). Ocean-floor basalt in the Mikanagan Lake block is distinguished from arc basalt by relatively higher levels of REE and HFSE, especially TiO_2 and Zr, and higher FeO^{total} and MgO (Fig. GS-7-10, 11). Aimée basalt displays a calc-alkalic trend, whereas Mikanagan basalt is tholeiitic (Fig. GS-7-12). Relatively higher average Cr levels in arc basalt, and Cr enrichment in one of the Aimée mafic flows (Fig. GS-7-11) reflect the local abundance of Cr-bearing (altered) pyroxene phenocrysts in some arc flows.

The geochemical data confirm the tectonic/stratigraphic distinction between the Lac Aimée and Mikanagan Lake blocks and indicate analogies with volcanic rock suites elsewhere in the Flin Flon belt (Stern *et al.*, 1995; Gilbert, in prep.). Recognition of the tectonic origin of the various rock suites has important implications for the exploration industry because VMS deposits in the Flin Flon belt are hosted only by 1.9 Ga arc-type volcanic rocks (Syme and Bailes, 1993).

Table GS-7-2
Average TiO_2, FeO^{total}, MgO, Ni and Cr of Mikanagan basalt compared to a representative Aimée basaltic andesite flow. Combined averages and the compositional range of arc basalt suites elsewhere in the Tartan-Embury-Mikanagan lakes area are shown for comparison

Volcanic rock suite	TiO_2 (%)	FeO^{total} (%)	MgO (%)	Ni (ppm)	Cr (ppm)
		OCEAN-FLOOR BASALT			
Mikanagan Lk.(E-type)	1.59	11.90	6.24	48	111
		ARC BASALT			
Lac Aimée	0.90	5.21	2.24	9	13
Tartan-Embury-Mikanagan lakes area	0.44	8.96	5.75	43	213
Compositional range (Tartan-Embury-Mikanagan lakes area)	*0.2-0.9*	*4.2-12.1*	*1.7-13.5*	*0-397*	*18-1870*

ECONOMIC GEOLOGY

Mineralization in the 'KD zone' at the southwest extremity of Lac Aimée has been explored periodically for over seventy years since it was first staked as the Copper King claim in 1921. Mineralization at a locality at the north end of the zone was examined by the author in July, 1996. Pyrite with minor Cu and traces of Zn, Au and Ag occurs in a 3.5 m wide, strongly sheared zone of silicified basalt; massive sulphide veins comprise 10 to 25% of the mineralized zone, which is veined by quartz and felsic porphyry. At least two porphyry phases, defined by variable plagioclase, quartz and hornblende phenocrysts, intrude the basaltic host rocks at this locality.

Mineralization at the Sap claims north of Naosap Lake consists of pyrite (with trace Au) in a sequence of gabbro and amphibolite intruded by quartz and felsitic veins. Sulphide stringers occur in all the above rock types, especially gabbro and related hornblende-chlorite

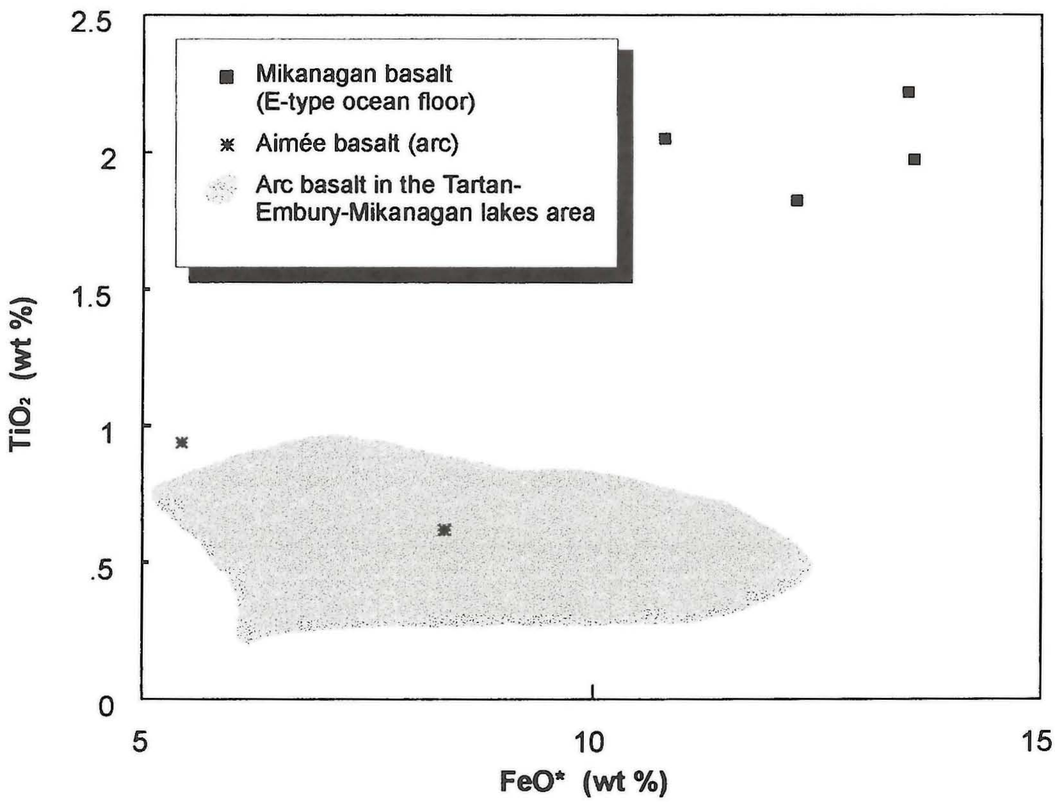


Figure GS-7-10: FeO^{total}/TiO_2 plot of Aimée (arc) basalt and Mikanagan (E-type ocean-floor) basalt, compared with the field of all arc basalts in the Tartan-Embury-Mikanagan lakes area.

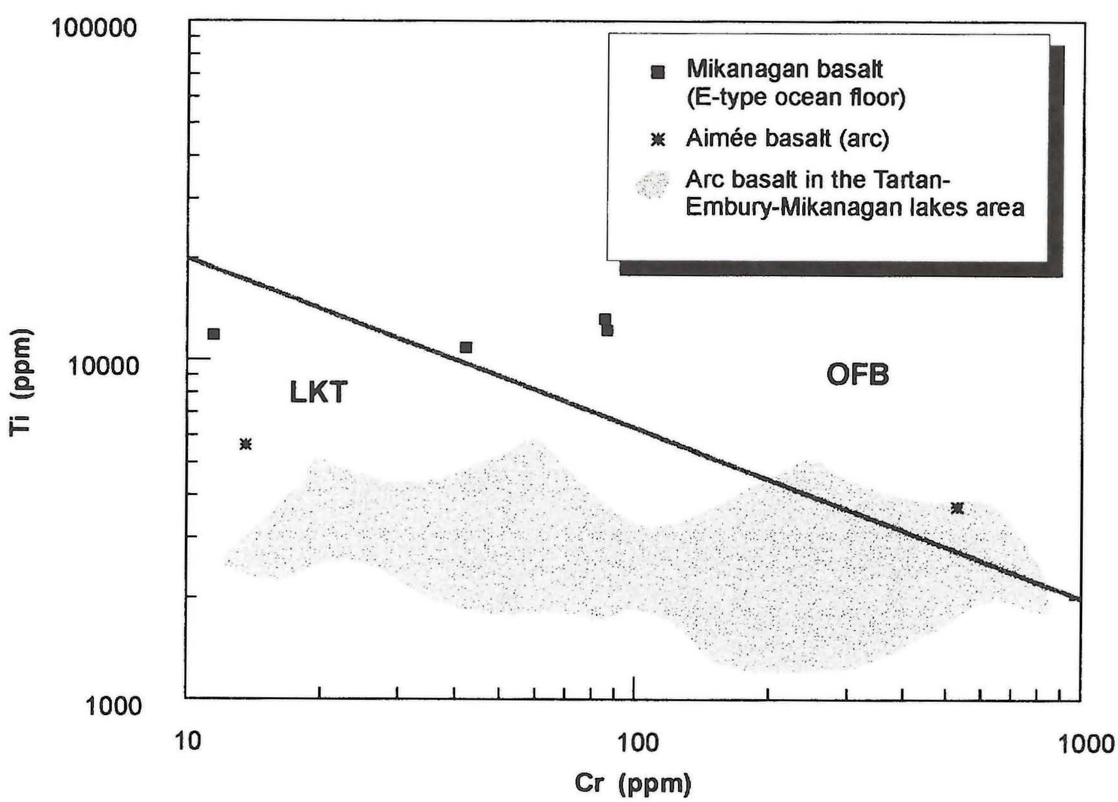


Figure GS-7-11: Ti vs Cr diagram (Pearce, 1975) of Aimée (arc) basalt and Mikanagan (E-type ocean-floor) basalt, compared with the field of all arc basalts in the Tartan-Embury-Mikanagan lakes area. Compositional fields of modern low-K tholeiite (LKT) and ocean-floor basalt (OFB) are from Pearce (1975).

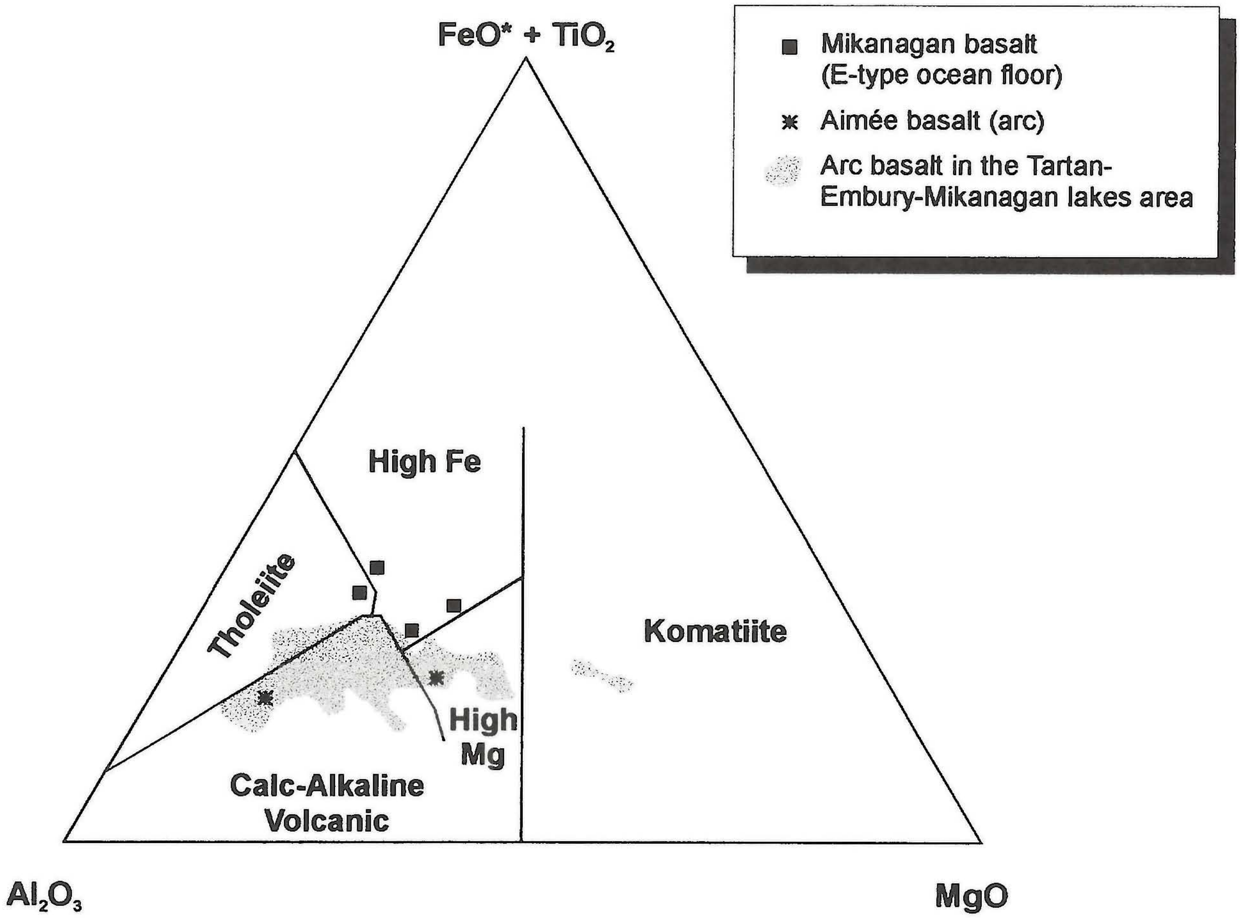


Figure GS-7-12: Jensen (1976) cation plot of Aimée and Mikanagan basalts, compared with the field of all arc basalts in the Tartan-Embury-Mikanagan lakes area. Aimée (arc-type) basalt displays a calc-alkalic trend whereas Mikanagan basalt (E-type ocean-floor) is characterized by a tholeiitic trend.

schist that locally contain up to 15% pyrite in irregular 1 to 2 cm aggregates. The Sap claims occur within a strongly attenuated zone in the northeast part of the project area in which primary structures are largely obliterated by deformation.

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GS-8 GEOLOGY OF THE ALBERTS LAKE AREA, FLIN FLON (NTS 63K/13)

by T.H. Heine

Heine, T.H., 1996: Geology of the Alberts Lake Area, Flin Flon (NTS 63K/13); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1996, p. 40-42.

SUMMARY

The west side of Alberts Lake is predominantly underlain by a series of mafic and felsic volcanic rocks. A gabbro intrusion forms the southern boundary of the map area. The area to the north of this intrusion is underlain by a supracrustal sequence that consists of mafic and felsic volcanic flows and fragmental intervals, heterolithologic breccia, and minor chert. No stratigraphic top indicators were noted. Some rhyolite flows at the north end of the lake show identical characteristics to those in the main part of the Baker Patton felsic complex, suggesting that they may be part of the same volcanic sequence. In addition to the major gabbro in the southern part of the map area, the sequence has been intruded by quartz-phyric rhyolite and a granitic to tonalitic body that contains distinctive blue-grey quartz grains. Thin mafic dykes are a common feature in some parts of the sequence. Intrusion breccia is exposed on a small island at the north end of Alberts Lake.

The main structural feature of the area is the Alberts Lake deformation zone. This heterogeneous interval of mafic and felsic phyllonites and fragmented rocks trends northeast along the northwest side of the lake. Discrete shear strands of this zone up to 2 m thick have been noted along the shoreline. Some of these strands contain quartz veins that have been extensively sampled, presumably for their gold content. The deformation zone is up to approximately 500 m thick.

Two areas of possible economic significance were located. One has intervals that contains up to 5% disseminated barren sulphide (pyrite) in altered fragmental rhyolite. The other has an area of discordant chloritic alteration associated with minor disseminated pyrite. No exploration work appears to have been performed on these occurrences.

INTRODUCTION

The area mapped during this project is located in the southeast quadrant of NTS sheet 63K/13 (Flin Flon) along the west side of Alberts Lake. Access is by Little Spruce Lake Road north from Provincial Highway 10 and via a trail starting along the northwest side of Flintoba Creek.

Outcrops are abundant in some parts of the area, but away from lake shorelines rock textures are almost completely obscured by lichen and moss cover, making it difficult or impossible to interpret textural features and lithologic relationships.

The geology of the Alberts Lake area was most recently mapped in 1941 by J.D. Bateman and 1943 by J.M. Harrison, and published as a map with marginal notes (Bateman and Harrison, 1945). Mineral occurrences in the area were described by Gale and Eccles (1988). Results of the geological investigations on the sequence to the south and southwest of the mapped area have recently been reported by Gale *et al.* (1994) and Gale and Dabek (1995).

GEOLOGY

The lithologies present in the area appear to represent the extension of the supracrustal sequence of the Leo Lake-Flintoba Lake area to the south and southwest. Because of the poor understanding of the structural geology of the area, it is not possible at this time to propose a stratigraphic sequence for the units described in this contribution. The supracrustal sequence is characterized by rapid lithologic changes both along and across strike, making the correlation of individual units difficult at best. The locations of the units described below are shown on Figure GS-8-1.

Supracrustal Sequence

Basalts and related mafic volcanic rocks occur throughout the supracrustal sequence. Several distinctive lithologic varieties are present. Pillows and associated subaqueous eruption features are generally uncommon, and pillow selvages occur in only a few exposures.

The most distinctive basalt (Unit 1a) contains up to 10% single phenocrysts and glomerophyric aggregates of white feldspar to 2.0 mm. Quartz-filled amygdules are rarely present, and selvages were not noted. Fragmental equivalents to this basalt are locally present; some exposures contain feldspar-phyric fragments and domains that may represent larger blocks hosted by aphyric mafic rock (basalt?). No contacts were observed between the massive and fragmental parts of this unit.

An amygdaloidal basalt (Unit 1b) that is characterized by small (0.5-3.0 mm) quartz-filled vesicles and locally contains up to 20% vesicules occurs in the northern part of the map area. Pillow selvages and amoeboid flow breccia are locally present, but no unequivocal top indicators were recorded. To the east of this basalt, the sequence is dominated by massive basalt that contains sparse amygdules up to 45 mm. Pillows and amoeboid pillow breccia are fairly common constituents of this unit.

A large proportion of the mafic rocks in the area cannot be differentiated based on field characteristics and they make up a dominantly mafic volcanic and volcaniclastic assemblage (Unit 1). These rocks are generally aphyric, and quartz-filled amygdules can be locally prominent. Amoeboid and angular flow breccia and tuff layers are also present locally.

Felsic volcanic rocks are present throughout most of the sequence examined. It is unclear what proportion of these rocks represent supracrustal accumulations as opposed to intrusions. In some exposures the fragmental character of the rhyolite is apparent, but in adjacent exposures this rock is massive. Contacts with enclosing units are generally sharp.

Tuff, lapilli tuff and massive rhyolite that shows lobe and flow structures, and locally preserved polygonal joints, make up Unit 2a. The rhyolite is typically quartz-phyric, but aphyric and quartz-feldspar phyric units are also present.

Massive aphyric to quartz phyric rhyolite (Unit 2b) is probably intrusive in part, and forms sills within the enclosing sequence. A significant proportion of this rock type may be extrusive, but additional work is required to confirm this.

An unfoliated rhyolite intrusive unit that contains white quartz phenocrysts to 5 mm (Unit 2c) occurs at a number of locations in the southern part of the map area. It has an aphanitic red-brown matrix, contains minor disseminated magnetite, and has intrusive relationships to the enclosing units.

Unit 3 consists of rhyolite fragments in a mafic matrix. The rhyolite fragments average 10 to 20 cm long and are flattened in the plane of the dominant schistosity. In some areas it is clear that the character of this unit is due to fragmentation of felsic layers by shear associated with the Alberts Lake deformation zone described below. In other areas, subrounded to subangular equant rhyolite fragments are contained within a mafic matrix, and represent a primary accumulation. The proportion of these units within this sequence remains unclear.

Several concordant chert layers (Unit 4) up to 2 m thick occur on an island located approximately half way up the northwest side of Alberts Lake. These consist of white silica and contain minor disseminated pyrite. This chert has been evaluated for its precious metal content; several overgrown trenches are located on the main layer, and mark the gold occurrence shown on the map of Bateman and Harrison (1945), and described by Gale and Eccles (1988) as their Location 21. The aphanitic, even-textured character of the silica, as well as the lack of lithic fragments, suggests that the chert layers represent supracrustal chemical precipitates rather than quartz veins.

The mapped area. Most of these have been grouped under Unit 5a, and consist of fine grained sedimentary rock, grits, greywacke and fine grained tuff. Some magnetite-bearing sedimentary rocks are present within the sequence. Beds are generally only poorly developed and top indicators were not noted. The variability in the composition of the clastic intervals reflects the variety of volcanic rock types present in the area; compositions range from felsic to mafic.

Heterolithic breccia (Unit 5b) occurs in several areas. It consists of a variety of fragments of dominantly volcanic rock types in a fine grained

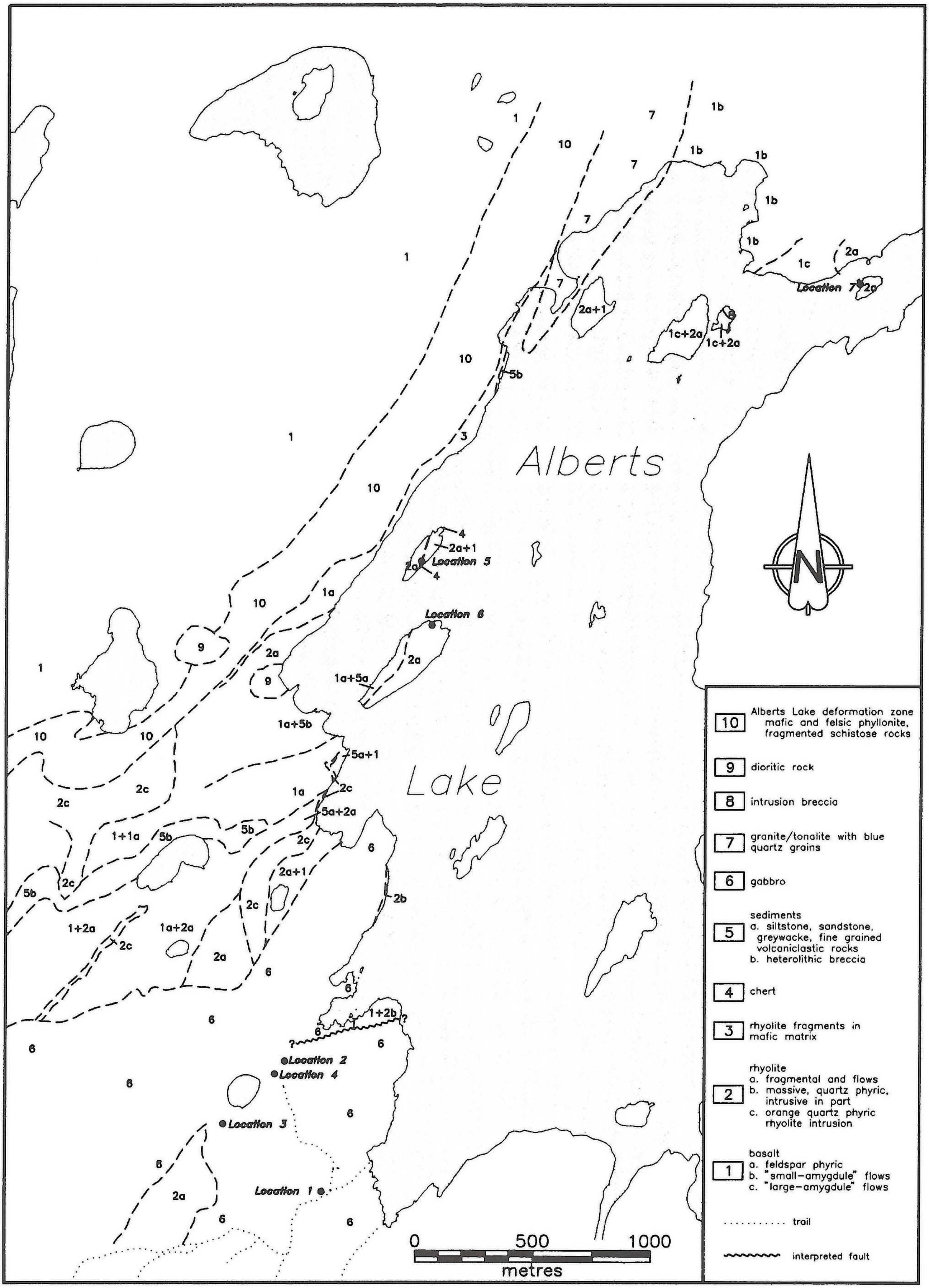

Figure GS-8-1: Location and geology of the Alberts Lake area.

mafic matrix. Clasts consist of rhyolite, aphyric and feldspar-phyric massive and amygdaloidal basalt. The clasts typically are not sorted, are matrix supported and range from approximately 5 to more than 30 cm across.

Intrusions

A massive gabbroic rock (Unit 6) forms the southern boundary of the map area. It is medium grained (to 3 mm), massive and composed of approximately 60% feldspar and 40% amphibole. It consists of two phases, one magnetite-bearing and the other magnetite-free. Contacts between the two phases were not observed. The magnetite-bearing phase is clearly visible on total field and vertical gradient magnetic maps (1983a, b). The contact with a rhyolite in the southern part of the map area is subvertical, but exposures in the eastern part of Elbow Lake show the gabbro overlying felsic volcanic rocks in a horizontal attitude.

A granitic/tonalitic intrusion that contains distinctive blue-grey quartz grains (Unit 7) occurs in the northern part of the map area. It consists of approximately 65% feldspar, 25% chlorite (after amphibole?) and 10% quartz; the quartz and feldspar forming an equigranular matrix. This intrusion is generally unfoliated, with thin, schistose intervals that represent sheared areas.

Several outcrops expose an intrusion breccia (Unit 8) in the north part of Alberts Lake. Angular fragments to 60 cm are hosted by a matrix that is somewhat more melanocratic than the rhyolite fragments; it is dark medium green and contains few blue quartz grains.

The mafic rocks to the west of the intrusion breccia have undergone extensive patchy feldspar metasomatism. Euhedral, white feldspar porphyroblasts to 2 mm compose up to 7% of the rock. The distribution of the feldspar cuts across lithologic boundaries and porphyroblasts are equally well-developed in the central portion of pillows as in the selvages. The distribution of feldspar is patchy, and some areas are free of porphyroblasts. Feldspars also occur in interflow sedimentary rock. The relationship of the intrusion breccia to a metasomatic event, if any, is uncertain.

Fine grained massive dioritic intrusions (Unit 9), show a scattered distribution in the central part of the map area. It is unclear if these represent a phase of one of the larger intrusions in the area, or a separate intrusive episode.

STRUCTURAL GEOLOGY

The Alberts Lake deformation zone (Unit 10) is the main structural feature of the area. It is represented by mafic and felsic phyllonites and fragmented rocks. Reliable shear movement indicators were not observed and therefore the sense of displacement along this feature is not known. The primary schistosity within this deformation zone trends northeast and is steeply dipping. Deflection of the main schistosity in one area into a fold with possible Z-asymmetry suggests dextral offset along this structure, but more evidence is required to confirm this interpretation. Local minor folds within the deformation zone show S-asymmetry. Several exposures of northeast-trending schist mark discrete fault strands of the Alberts Lake deformation zone.

Discrete east-trending shears occur in the gabbro. In addition to mafic schist, the shear locally contains quartz and calcite veins with angular chloritic rock fragments. The apparent offset of the gabbro at the south end of the lake may be a result of sinistral offset along one of these structures.

ECONOMIC GEOLOGY

Four gold occurrences occur north of Leo Lake within the gabbro in the south part of the map area (Locations 1, 2, 3 and 4, Fig. GS-8-1). Quartz veins in shears within the gabbro carry gold values. At Location 3, Granges Ltd. outlined a deposit of 400 000 tonnes averaging 7.3 gm Au/t (Gale and Eccles, 1988). The detailed structural setting of these occurrences remains to be determined.

At Location 5 a gold occurrence is hosted by a two metre thick white chert layer. A grab sample from one of the trenches returned 5 ppb Au (Gale and Eccles, 1988). The chert contains only very minor quantities of disseminated pyrite.

Abundant disseminated pyrite occurs at the northeast end of the island at Location 6 (Fig. GS-8-1). It is associated with an altered, fragmental felsic unit that contains rhyolite lobes. Along the shoreline to the west, felsic and mafic rocks commonly show chloritic and lesser sericitic alteration. Minor radiating aggregates of anthophyllite (?) are widely scattered throughout this sequence, and may represent an area of hydrothermal alteration.

At Location 7 (Fig. GS-8-1), along the northwest shoreline of the island, polygonally-jointed rhyolite lobes occur in rhyolite lapilli tuff. Within this assemblage one area has been intensely hydrothermally altered. Black Mg-chlorite (?) contains net-textured subangular lithic fragments whose outlines have been almost completely obliterated. Although sulphides were not observed within the alteration zone, limonitic areas are common along the southeast shore on the island. No work appears to have been performed at any of these locations.

CONCLUSIONS

The suggestion that the Baker Patton Felsic Complex continues to at least the north end of Alberts Lake appears to be reasonable based on the field evidence obtained during this summer's program. Some of the physical characteristics of the felsic flows are identical to those observed in the main Baker Patton area, however, this needs to be confirmed.

Felsic volcanic rocks (mainly rhyolites) form an appreciable proportion of the supracrustal stratigraphic assemblage. In several areas they have been hydrothermally altered (chlorite and possibly sericite), and contain up to 10% disseminated pyrite. Additional work needs to be done to more fully evaluate the economic potential of this assemblage.

The northeast-trending Alberts Lake deformation zone is the major structural feature of the area. Its relationship to deformation zones in the Baker Patton area needs to be established. Some of the phyllonite strands are the loci for the emplacement of quartz veins, some of which have been evaluated for their gold content.

ACKNOWLEDGMENTS

Dr. George Gale is thanked for providing insight into various aspects of the supracrustal sequence exposed in the Alberts Lake and surrounding area. Ms Panagiota Athanasopoulos provided competent assistance throughout the field season. Aur Resources Incorporated is thanked for providing electronic maps for the Alberts Lake area.

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GS-9 THE HOTSTONE - PERSIAN LAKE PROJECT, NORTH ARM, LAKE ATHAPAPUSKOW, (NTS 63K/12)

by D.E. Prouse

Prouse, D.E., 1996: The Hotstone - Persian Lake project, North Arm, Lake Athapapuskow, (NTS 63K/12); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 43-46.

SUMMARY

Detailed mapping of the area between the North Arm of Lake Athapapuskow and Persian Lake has been completed at 1:5 000 scale. The preliminary geological map is published at 1:10 000 scale (Prouse, 1996).

The west portion of the map area is underlain by a thick bimodal sequence of mafic and felsic volcanic flows and syn-volcanic dykes. Detailed mapping east of Thompson Bay in 1995 outlined a number of previously undocumented rhyolite units.

A large diorite dyke and massive basaltic andesite flows that have been subjected to contact metamorphism predominate in the central part of the area. Volcanic rocks west of Persian Lake consist of massive felsic and intermediate flows with lesser amounts of mafic flow material. Late mafic and felsic intrusions cut the volcanic sequences in the central and eastern portions of the map area.

Volcanic rocks in the western part of the map area include northeast-to east-trending flows that are overprinted by a north-northeast-trending schistosity. Volcanic flow units near Persian Lake have a northerly trend that becomes northeasterly in the west. Schistosities are poorly preserved and are overprinted with a prevalent north-northeast shear foliation. Rock units through-out the map area have been subjected to significant stress that produced faults in the North Arm area and faults and shears in the central part and the Persian Lake area.

Mineralization is commonly associated with shears and faults throughout the map area. Thin oxide and sulphide facies iron formations are poorly exposed in the Persian Lake and in the central part of the map area. Rhyolitic rocks have been subjected to iron-magnesium alteration in the south-central part of the map area and west of Persian Lake.

INTRODUCTION

Geological mapping in 1996 continued east of Sharpe Bay on the North Arm of Lake Athapapuskow and extended to the east side of Persian Lake. The project was initiated in 1994 when preliminary mapping (Gale *et al*., 1994) east of the Hotstone mineral occurrence (Gale and Eccles, 1992) outlined the presence of felsic volcanic rocks in a previously undifferentiated sequence (Buckham, 1944). Mapping was conducted using cut grid lines in the Thompson Bay area of Lake Athapapuskow. The balance of the area was mapped using 1:5 000 scale airphotos.

The project area constitutes a portion of the Bakers Narrows Block (Bailes and Syme, 1989). The project area is bounded to the west by the North Arm Fault; to the north by the fault bounding the southern margin of the Baker Patton Felsic Complex; and to the east by the granitic intrusion at Persian Lake and Pothook Lake (Fig. GS-9-1).

Those areas of the project previously mapped by Bailes and Syme (1989) will not be discussed in detail in this report. It should also be noted that due to lack of clean exposures a detailed description of volcanic flow sequences was difficult to establish.

Detailed mapping conducted by M. Guttman of Sherritt Gordon Mines Ltd. (Cancelled Assessment File 93014) and Falconbridge Ltd. (Unpublished data) will be used to assist in preparation of the preliminary geological map for the area southwest of Persian Lake.

WRIGHT BAY-SHARPE BAY AREA

The east shore of Wright Bay and the peninsula that separates Wright Bay and Sharpe Bay is underlain by a sequence of subaqueous basalt and basaltic andesite flows with intercalated felsic to intermediate flows. Two distinct basalt flow units with volcaniclastic and massive portions alternate with felsic to intermediate flows resulting in a strong bimodal sequence (Bailes and Syme, 1989). These flow units have a northeast trend, face southeast and have well preserved volcaniclastic textures. This sequence has an approximate stratigraphic thickness of 1 100 m. The true thickness is not known because some flows are not fully exposed.

A presumed fault that extends from central Sharpe Bay north-northeast to the southern boundary of the Baker Patton Complex makes it difficult to extend the volcanic sequences in the Wright Bay-Sharpe Bay area further east to the central map area. Age and displacement for this fault are not known.

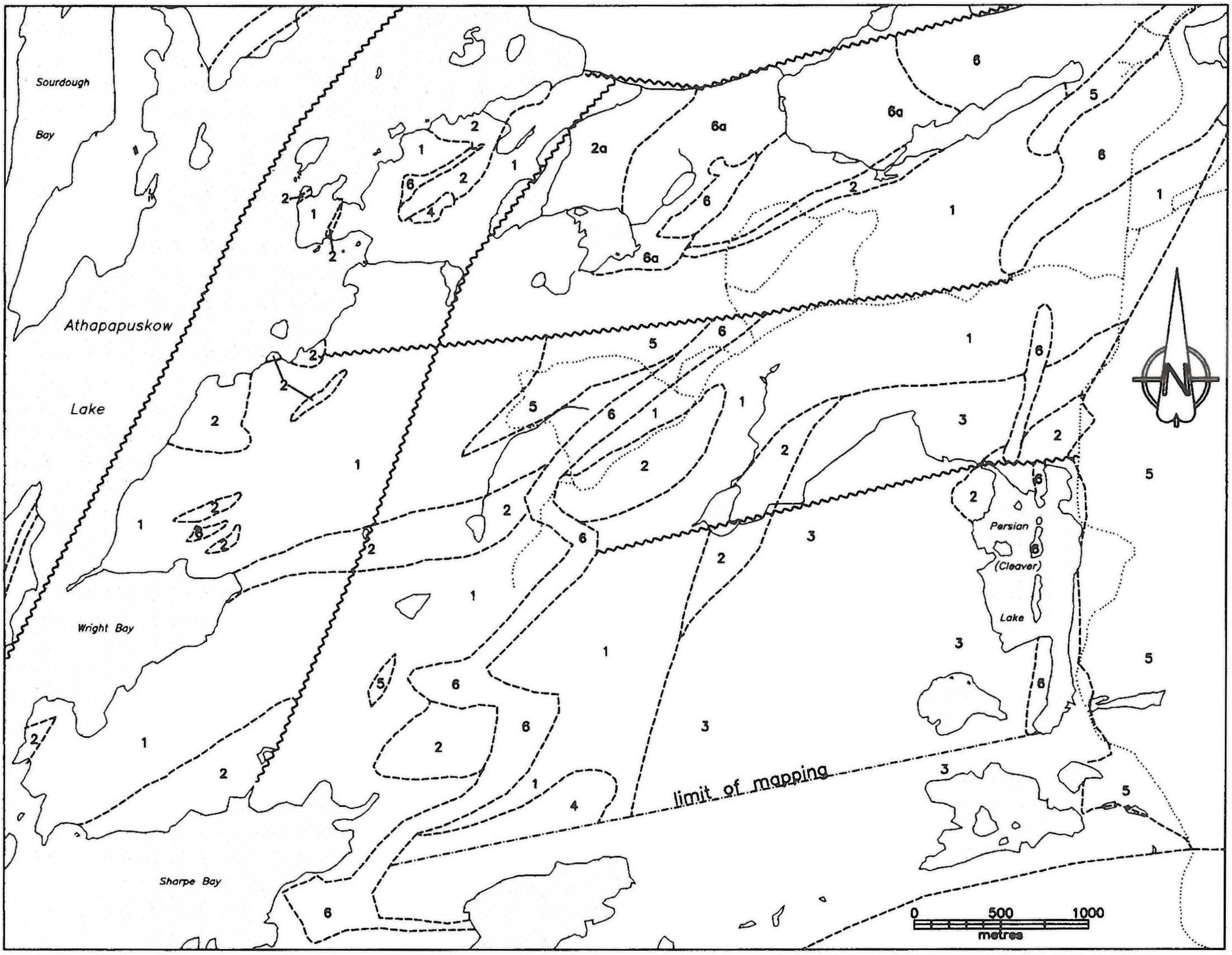
The northeast shore of Wright Bay is underlain by massive fault brecciated quartz phyric rhyolite with a strong south-southwest-trending shear foliation. Further northeast this rhyolite unit contains lobes and flow breccia sections with chloritized matrix. East of the presumed northeast trending fault from Sharpe Bay, massive 1-2% quartz phyric rhyolite is strongly sheared and brecciated and contains up to 10% chlorite clots and 1-2 cm concordant quartz veins and discordant tension gashes. Further east, on the east side of another presumed north-northeast-trending fault, there is a distinctive white rhyolite with amoeboid shaped massive chlorite domains <1 to 6 cm diameter stretched in a shear foliation plane. On the weathered surface the chlorite domains impart a "spotted" texture to the rhyolite. Massive rhyolite and rhyolite tuff breccia are truncated by the large diorite dyke in the central area 100 m further northeast.

The northeastern shore area of Sharpe Bay is dominated by a bimodal sequence of mafic and felsic massive flows and volcaniclastic rocks. Narrow poorly exposed outcrops of aphyric basaltic andesite are intercalated with thin rhyolite tuff, breccia and massive flows, as well as massive dacite flows. Thin diorite dykes cut the volcanic sequence. Volcanic flows appear to have a northeast trend. The area is extensively sheared with a north-northeast orientation in the central Sharpe Bay area, which changes to an east-northeast direction at the east end of Sharpe Bay.

Approximately 500 m north of the east end of Sharpe Bay a sequence of basaltic andesite flows contains intercalated rhyolite flow breccia, massive rhyolite or rhyolite lobes. Mafic flows consist of 5-10 m of matrix supported flow breccia overlain by 12-15 m of poorly developed pillowed flow and pillow fragment breccia that is overlain by a thick massive flow section. These flows trend northeast. The facing direction is not known. Rhyolites in this sequence are 2-3% quartz phyric, trend north-east and are composed of an approximate 10 m massive section, 5-10 m of rhyolite lobes and a thicker flow brecciated section with 10-15 cm angular to subround fragments. Sulphide facies iron formation is exposed in a trench near the presumed rhyolite-basalt contact. The iron formation has been strongly sheared and chert has been recrystallized to sugary textured subround quartz fragments, 1 to 2 cm, in a foliated chloritic matrix. The unit contains 5-7% pyrite stringers and blebs and trace chalcopyrite. This sequence of mafic and felsic flows trend northeast to the central part of the map area where they are also truncated by a large diorite dyke.

The area of Sharpe Bay is underlain by massive aphyric basaltic andesite flows with plagioclase phyric zones. Rhyolite and rhyodacite tuff and flow breccia are intercalated with mafic flows. Massive aphyric rhyolite dykes with quartz phyric areas cut the volcanic sequence. Basaltic flows are sheared in the near shore area and contain veinlets and domains of quartz and epidote. Rhyolite lapilli tuff is medium green on the weathered surface with subround fragments up to 1 cm. Rhyodacite tuff and breccia contain lapilli size to 10 cm lenticular fragments in a gritty matrix. Foliations in this area have a general west-southwest orientation.

A medium-to coarse-grained diorite dyke approximately 110 m thick intrudes the mafic sequence 200 m east from the east shore of Sharpe Bay. This unit has a northerly strike where it enters the southern part of the map area, but meanders in a general northeast direction to the north.



6	gabbro/diorite a. gabbro with mafic volcanic rocks
5	felsic intrusions
4	rhyolite dykes/intrusions
3	interlayered felsic and intermediate volcanic rocks
2	rhyolite a. rhyolite with mafic dykes
1	basaltic andesite

roads and trails

faults

Figure GS-9-1: General Geology of the Hotstone-Persian Lake project area.

East of the diorite dyke unit, a synvolcanic rhyolite intrusion and dyke swarm cut through massive aphyric and pyroxene plagioclase phyric basaltic andesite. Mafic xenolith layers and large irregular masses have been hornfelsed and contain mm scale silica veinlets. The rhyolite intrusion is typically light grey with 1% quartz phenocrysts, 3-4% metasomatic k-feldspar crystals and approximately 1% fine grained disseminated magnetite. This unit corresponds with an ovoid shaped magnetic high east of Sharpe Bay on the aeromagnetic vertical gradient map (1983). The rhyolite has a prominent 40-60° trend. The west margin consists of a repetitive sequence of rhyolite dykes from <1 to 10's of metres in thickness with basaltic andesite xenolith sheets and blocks. A distinctive quartz porphyry similar to that in the "Hotstone" area occurs near the west contact of the rhyolite dyke unit. To the east, mafic xenolith content decreases and rhyolite intrusions become thicker. Narrow (5-10 m) diorite dykes intrude the rhyolite unit and are generally concordant to dykes and xenolith layers. Massive basaltic andesite on the north and east periphery of the rhyolite intrusion contain rhyolite dykes, and quartz-carbonate and k-feldspar rich zones.

CENTRAL MAP AREA

The central part of the project area is easily accessible by logging road from the Kississing Road north of Cleaver Lake. The area contains a large (150 m thick) diorite/gabbro dyke that trends northeast from the Sharpe Bay area. The diorite varies from medium-to coarse-grained and is fine grained on its margins. The unit typically contains 40% hornblende, 55% plagioclase, 5% k-feldspar ± quartz, pyrite and magnetite. This unit truncates mafic and felsic volcanic units that trend northeast from the Sharpe Bay-Wright Bay area. It postdates all units except the Nisto Lake intrusion to the east.

In the south central area, a 300 m thick massive green brown 1-5% K-feldspar phyric basaltic andesite contains minor poorly preserved tuff/breccia zones. These mafic volcanic flows have been hornfelsed and contain small zones of epidote. Facing direction for this sequence is unknown. Foliations strike northeast and have moderate to steep dips to the southeast.

Faults are common in the south central map area. North-east and easterly trending fault zones (occupied by creeks and swamp) make stratigraphic correlation difficult. The majority of these faults are suspected to postdate intrusion of the diorite.

Outcrop exposure in the area north and east of the diorite dyke is sparse due to extensive sand and muskeg cover. Scattered exposures of massive rhyolite and rhyodacite flows with minor tuff sections compose an approximately 400 m thick unit, which is considered to be the continuation of the rhyolite unit that trends northeasterly from Wright Bay. These rhyolites have a light grey weathered surface and are 1-2% quartz phyric. They have been extensively sheared and altered and contain sulphide mineralized zones up to 5 m thick with 2-5% pyrite and trace chalcopyrite. One of the better exposed outcrops contains an approximate 20 m thick altered zone containing 10-20% chlorite ± sericite and <1% garnet adjacent to a mineralized shear zone.

East of the altered rhyolites there are large exposures of massive aphyric to slight plagioclase phyric hornfelsed basaltic andesite with intercalated dacite flow. A 30 m thick diorite dyke cuts one large outcrop of mafic flow material, which has a number of narrow shears. The hornfelsed mafic rocks are hard massive bodies with silica veinlets, quartz veins and quartz filled tension gashes. An easterly trending fracture cleavage is prominent in these hard massive rocks.

THE PERSIAN LAKE AREA

The area west of Persian Lake is underlain by an approximate 1 200 m thick sequence of intercalated felsic and intermediate volcanic flows with lesser amounts of massive mafic volcanic flows. West of the intercalated sequence, an approximately 350 m thick massive rhyolite is sheared and altered on its western, swamp bounded margin. Volcanic rocks have been intruded by diorite/gabbro and intermediate porphyritic sills and dykes. The east margin of the volcanic rocks is bounded by the large granodioritic intrusion that extends from Pothook Lake southwest-wards to the Neso Lake area.

Volcanic rocks west of Persian Lake consist of massive aphyric and <1 to 2% quartz phyric rhyolite with an aphanitic groundmass of quartz, feldspar and minor biotite. Rhyolite is intercalated with medium to dark green fine grained aphyric to weakly feldspar phyric dacite. Rhyolite and dacite form a repetitive interlayered sequence with layers varying from 10 cm to 10's of metres in thickness. This layering is suspected to be a tectonic feature. Massive to weakly foliated green-brown aphyric basaltic andesite flows make up a small proportion of the volcanic sequence and are more abundant near the southwest end of Persian Lake. The volcanic rocks approximately 500 m west of central Persian Lake extend northeastwards. These rocks have been moderately to strongly hornfelsed and are typically fine grained, aphanitic and hard.

A 60 m thick north-trending, well foliated diorite dyke with gabbroic sections intrudes the volcanic sequence in the middle of Persian Lake. This intrusion is composed of 60% hornblende, 30% plagioclase ± K-feldspar and quartz. Other dyke-like bodies of massive gabbro and diorite intrude the volcanic sequence west and southwest of Persian Lake. A distinctive porphyritic intermediate intrusion occurs on the southwest side of Persian Lake. This unit is composed of 10-15% 1-3 mm white to greenish subhedral plagioclase phenocrysts in a weakly foliated matrix of hornblende, chlorite and plagioclase.

A thin, rusty, sheared sulphide facies iron formation is poorly exposed on the northeast shore of Persian Lake.(pers. comm. S. Masson, 1996). This unit is hosted by sheared and carbonate altered rhyolite. A four m thick isoclinally folded oxide facies iron formation occurs 700 m west of the north end of Persian Lake. The iron formation occurs within a hornfelsed basaltic andesite unit with quartz phyric rhyolite. Magnetite rich mafic layers alternate with <1 cm thick recrystallized chert layers. The minor fold has an approximate due west axial plane and a moderate plunge to the east.

Approximately 1200 m west of Persian Lake there is a 350 meter thick unit of primarily massive, aphyric to 2% quartz phyric, rhyolite. This unit contains a number of northeast-southwest trending mineralized and altered shear zones. The west margin of the rhyolite is bound by a swamp and a small lake where northeasterly-and-northerly trending presumed faults are considered to intersect. A large rhyolite outcrop just east of the swamp consists of sheared flow breccia, lobes and thin tuff layers that contain abundant chlorite and carbonate alteration stringers and localized zones.

The area west of the south end of Persian Lake was not covered during this mapping program. However, a portion of this area was mapped in detail by Falconbridge in 1974. Their map indicates a thick sequence of intermediate flows and siliceous flows with minor rhyolite flows and mafic dykes. East of the Falconbridge property, primarily hornfelsed massive mafic volcanic flows have been intruded by synvolcanic rhyolite. Further field investigations and petrographic studies are required to differentiate these rocks.

Volcanic sequences at Persian Lake have northerly-trending flows that change to a northeasterly trend west of the lake. Late northeast trending sinistral faults with a small strike slip component cut the sequences at Persian Lake.

The area west of Persian Lake is structurally complex and is suspected to be effected by at least two fold events although supporting evidence is lacking. Outcrop patterns 700 m west of Persian Lake suggest the presence of a fold hinge with a northeast-trending axial plane. This structure is not obvious in the field. Contact metamorphism has obliterated most primary textures thus facing directions are difficult to determine. Hornfelsed rocks generally display a prominent moderately dipping to flat lying fracture cleavage with an east-southeast orientation west of Persian Lake. Schistosities throughout the area are usually strongly overprinted by a north-northeast trending shear foliation. A weak foliation (S?), with an approximate orientation of 60 or 240° is defined by minor biotite content in felsic volcanic rocks and chlorite and hornblende in mafic to intermediate rocks.

ECONOMIC GEOLOGY

A number of known documented mineral occurrences exist within the project area (Gale and Eccles, 1992), the majority are concentrated in the central part of the map area. These occurrences primarily consist of stratabound massive sulphide deposits with minor chalcopyrite and some form of associated alteration zone. Nearly all the occurrences are hosted within felsic to intermediate volcanic rocks that are commonly sheared and silicified. These occurrences have been tested by shallow to intermediate level (75-150 m vertical depth) drill holes and trenching. Most have been adequately tested, but given the structural complexity, lack of facing indicators and abundance of alteration it is unlikely that all alteration zones have been tested to their stratigraphic tops. Potential also exists for zones of alteration that have not been adequately drill tested. The "spotted" chlorite alteration in massive rhyolite situated west of the central map area is a good example. This type of alteration is typically found in the footwall of massive sulphide deposits; it appears to lie beneath occurrence #81 of Gale and Eccles (1992). A 5.4 m intersection of well mineralized pyrite and pyrrhotite with scattered chalcopyrite were encountered in DDH 1 at this occurrence. As well, DDH 1 and 2 intersected "approximately 40 m of chloritic schist, schistose rhyodacite and sulphide-rich rock." Other zones of chlorite alteration and a garnet-anthophyllite alteration zone with associated sulphide mineralization warrant additional investigation.

As noted, there are many known and presumed faults and shear zones throughout the map area. Many of these have associated quartz veins and silicification. Most of the exposed quartz veins observed are narrow (<0.5 m), barren, or contain only minor pyrite or pyrrhotite. There are however large areas of swamp and overburden cover which overlie presumed fault zones and it is unlikely that these have been tested by induced polarization surveys.

Sulphide facies iron formation in the central map area and west of Persian Lake are potential hosts for gold deposits. However, the iron formations observed have relatively narrow thickness and moderate to low sulphide content. Sulphide bearing chert layers up to 15 m in thickness, are exposed in the central map area. An approximately 0.5 m thick chert layer exposed in an overgrown trench contains 3-4% fine grained arsenopyrite needles and blebs associated with 1-2 mm chlorite veinlets. There is no known documentation for this occurrence.

West of Pothook Lake, in the north central map area, an occurrence of stringers and blebs of pyrite, pyrrhotite, chalcopyrite and sphalerite occurs within a quartz porphyry intrusion (Gale and Eccles, 1992). The quartz porphyry intrusion cuts mafic and intermediate volcanic rocks. One of the samples assayed from this occurrence contained 6.0 g/t gold. A larger faulted mass of this intrusion exists west of the central map area.

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GS-10 THE BAKER PATTON COMPLEX (PARTS OF 63K/12 AND 63K/13) - RHYOLITES, DACITES AND RARE EARTH ELEMENT CHEMISTRY

by G.H. Gale and L.B. Dabek[1]

Gale, G.E. and Dabek, L.B., 1996: The Baker Patton Complex (parts of 63K/12 and 63K/13) - rhyolites, dacites and rare earth element chemistry; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 47-51.

SUMMARY

The Zr/TiO_2 vs Nb/Y discriminant diagram of Winchester and Floyd (1977) is not suitable for classifying the Baker Patton Complex (BPC) rhyolites because they have Zr/TiO_2 ratios below 0.09. Rhyolites with similar low Zr/TiO_2 ratios are the host rocks at the Flin Flon, Ruttan, Brunswick No. 12, Corbet and Ansil Mines. Rhyolite flows that have the lowest REE contents and the largest Eu depletion are those that are most extensively altered. There is some evidence to suggest that Eu is depleted in alteration zones and redeposited in associated exhalite; if substantiated, this will be a valuable guide for distinguishing cross-cutting alteration zones from mineralogically similar exhalites.

INTRODUCTION

Compilation of the BPC final map necessitated remapping selected portions to address specific stratigraphic and structural problems arising from a preliminary perusal of the geochemical data. New findings from this work suggest that there are several late parallel to subparallel brittle structures; not one major structure through the Sourdough Bay area. These faults disrupt and offset known massive sulphide deposits and their alteration zones (Fig. GS-10-1).

A preliminary synthesis of the geochemical data collected in 1994 and 1995 has led to several observations that may have a direct bearing on exploration for massive sulphide deposits not only within the BPC, but also within the Flin Flon-Snow Lake belt and elsewhere.

RHYOLITE *vs* DACITE

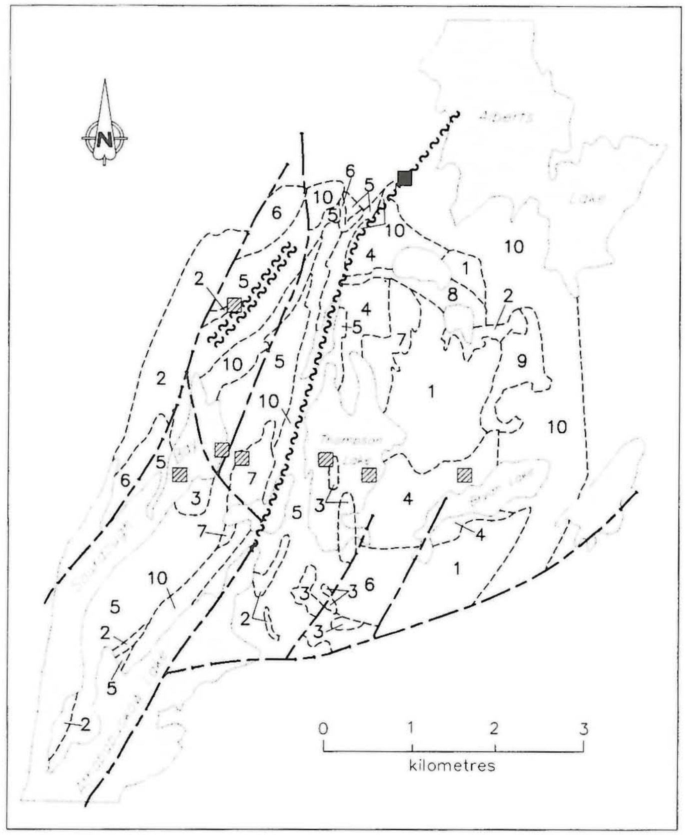
On the basis of SiO_2 vs Zr/TiO_2 plots, felsic flows of the BPC plot across the fields for dacite and rhyolite (Fig. GS-10-2) whereas these rocks plot well within the dacite-rhyodacite field on the Zr/TiO_2 vs Nb/Y discriminant diagram (Fig. GS-10-3). This can be interpreted as either these rocks are all dacites and some have been silicified, or the discriminant diagram is not suitable for classifying BPC rhyolites.

The samples plotted on (Fig. GS-10-2a) that fall within the rhyolite field were collected from flows that comprise massive lobes and variable amounts of hyaloclastite tuff, lapilli tuff and breccia. All of the analyses (Table GS-10-1) that plot in the rhyolite field were derived from massive lobes whereas the interlobe material from the same flows plots in the rhyodacite-dacite field (Fig. GS-10-2b). A plot of TiO_2 vs Zr (Fig. GS-10-4a, b) indicates that these elements are conserved and that the lobes and enclosing hyaloclastites are comagmatic, *i.e.* they have the same TiO_2/Zr ratio and fall on a line that passes though the origin (Madeisky and Stanley, 1993). These diagrams also illustrate that the flow with both lobe and hyaloclastite material plotting in the dacite field (Fig. GS-10-2b) has a TiO_2/Zr ratio that falls between the ratios for andesite and the rocks that fall within the rhyolite field (Fig. GS-10-2a).

Although flows with >72% SiO_2 lobes occur stratigraphically above and below basalt and/or andesite, there is no chemical or physical evidence of silicification in the mafic rocks. In addition, high silica lobes are distributed throughout the BPC and are not restricted to a 'centre of silicification'. Consequently, there is no physical or chemical evidence that there has been a widespread silicification of the entire BPC. Admittedly, it is feasible, but highly improbable, that each flow behaved as a local 'silicification centre'. Consequently, some of the felsic flows in the BPC with Zr/TiO_2 ratios <0.09 are considered to be altered rhyolite.

Rocks in the vicinity of the Flin Flon mine that are classified as rhyolite (Bailes and Syme, 1989) have Zr/TiO_2 ratios similar to those of the BPC rocks and also plot in the dacite field of Figure GS-10-3.

Rare earth element (REE) chondrite normalized plots (Fig. GS-10-5) for rhyolite flows with alkali depletion index (The Flin Flon Index = [1-(Na_2O+K_2O)/Al_2O_3 as molecular proportions times 100%]; Madeisky, 1996) of less than 50% are parallel and define a narrow field for both the heavy REE (HREE) and the light REE (LREE). The spread in REE patterns shown on Figure GS-10-5 is probably due to the change in mass due to alteration rather than initial magmatic contents because comagmatic tuff and lobes from the same flows have significantly different REE contents (Fig. GS-10-6).



10	Gabbro	2	Basalt
9	Tonalite	1	Quartz-feldspar rhyolite
8	Quartz porphyry	------	Geological contact (approximate)
7	Quartz crystal tuff	∿∿∿∿	Shear zone
6	Quartz phyric rhyolite	— — —	Fault
5	Aphyric rhyolite	▨	VMS
4	Aphyric and quartz phyric	■	Au
3	Andesite		

Figure GS-10-1: General geology of the Baker Patton Complex.

REE patterns for rhyolite flows with a Flin Flon Index greater than 50% exhibit a considerably greater spread in data than flows that have lower Flin Flon Indices (*cf.* Figs. GS-10-5 and GS-10-7). On Figure GS-10-7 the flows that have the lowest REE contents and the largest Eu depletion are those that are most extensively altered, *i.e.* the highest Flin

[1] University of Regina, Regina, Saskatchewan

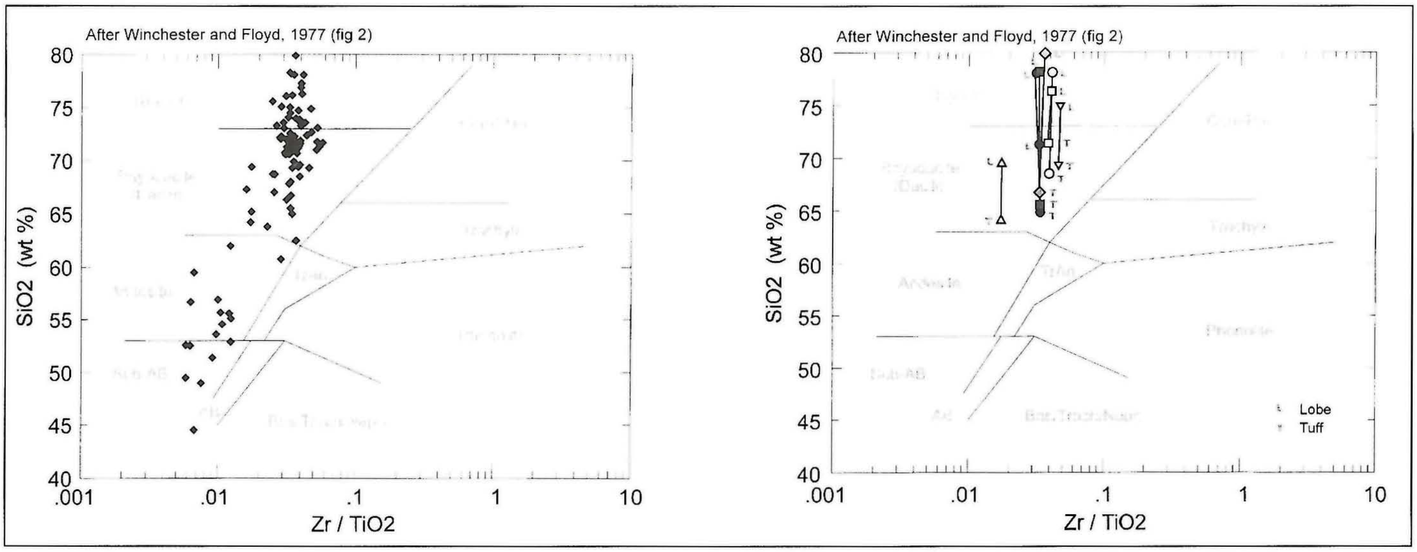


Figure GS-10-2: SiO_2 vs Zr/TiO_2 discriminant diagram, field boundaries from Winchester and Floyd (1977): a. volcanic rocks from the BPC, b. hyaloclastite and lobes from individual flows reported in Table GS-10-1.

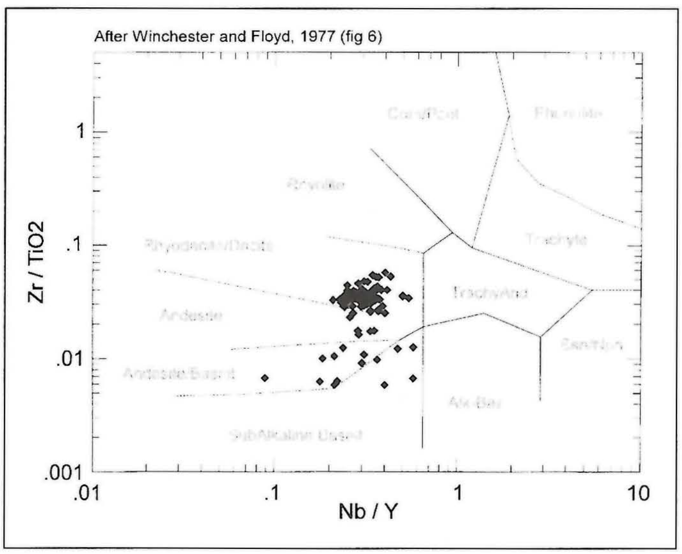


Figure GS-10-3: Zr/TiO_2 vs Nb/Y for volcanic rocks of the BPC.

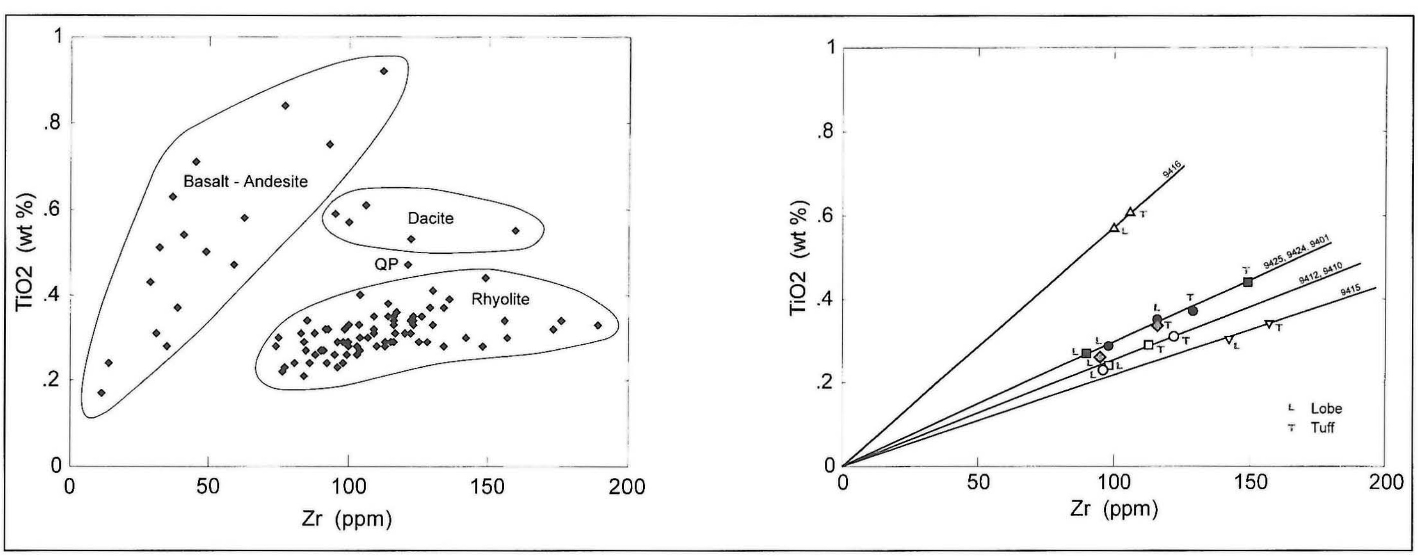


Figure GS-10-4: a. TiO_2/Zr plot for volcanic rocks of the BPC; b. TiO_2/Zr plots for hyaloclastite and lobe for felsic flows in the BPC reported in Table GS-10-1.

Table GS-10-1
Major and trace element chemistry of hyaloclastite and lobe material from individual subaqueous rhyolite flows.
9401-flow 9401, H-hyaloclastite, L- lobe

Sample	SiO_2	Al_2O_3	$Fe_2O_3^T$	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	S (LOI)	Total	Rb	Sr	Zr	Ba	Y	Nb	Ga	Flin Flon Index
9401H	65.0	13.84	7.05	0.66	3.55	1.25	4.60	0.37	0.08	0.07	3.5	99.97	61	23	129	394	29	8	20	49
9401L	71.3	12.34	5.29	0.45	1.73	4.81	1.01	0.35	0.08	0.05	1.8	99.21	10	73	116	215	24	9	16	27
9401L	78.2	9.59	1.42	0.79	0.90	2.44	2.83	0.29	0.08	0.02	1.7	98.26	40	41	98	637	23	7	14	26
9410L	78.1	9.64	3.13	1.47	0.81	4.20	0.23	0.23	0.05	0.06	1.5	99.42	6	61	96	94	20	7	10	26
9410H	68.5	12.17	7.40	3.58	1.96	0.46	3.23	0.31	0.05	0.11	2.2	99.97	44	448	122	1100	26	8	16	65
9412H	71.4	11.94	5.33	1.00	2.02	1.81	3.29	0.29	0.05	0.08	2.6	99.81	38	52	113	911	23	7	13	45
9412L	76.3	10.00	4.19	0.93	1.38	3.56	1.31	0.24	0.06	0.05	1.6	99.62	10	60	98	424	20	6	14	27
9415H	69.3	13.25	6.72	0.48	1.98	2.33	3.10	0.34	0.06	0.09	2.6	100.25	36	32	157	805	35	10	13	46
9415L	74.9	11.12	4.07	0.73	1.22	3.81	1.79	0.30	0.07	0.08	2.0	100.09	18	43	142	596	28	9	14	26
9416H	64.2	12.70	9.55	1.42	3.02	2.19	2.71	0.61	0.11	0.10	4.0	100.61	30	38	106	551	24	8	16	49
9416L	69.4	11.37	6.84	1.44	1.97	3.62	1.60	0.57	0.09	0.08	3.0	99.98	16	69	100	371	20	7	14	32
9424H	66.7	13.12	6.91	0.71	3.76	1.87	3.44	0.34	0.10	0.03	3.5	100.48	34	41	116	534	24	8	17	48
9424L	79.9	9.65	1.67	0.40	0.79	3.55	1.81	0.26	0.12	0.01	1.1	99.26	23	51	95	463	20	7	9	19
9425H	65.5	14.97	7.65	0.50	2.37	0.26	4.58	0.44	0.08	0.05	3.5	99.90	77	13	149	938	33	9	28	64
9425L	78.3	9.14	1.62	2.21	0.26	2.65	1.65	0.27	0.06	0.05	2.7	98.91	31	108	90	488	19	7	12	33
9317H	73.60	12.27	3.44	0.73	1.43	3.33	2.74	0.29	0.04	0.05	2.0	99.92								31
9317L	74.40	11.99	3.24	0.78	1.40	3.87	2.16	0.28	0.04	0.05	2.0	100.21								27

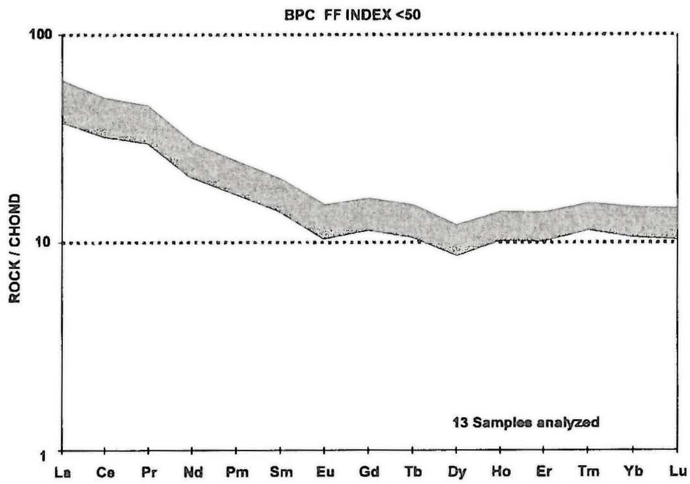


Figure GS-10-5: Chondrite normalized REE patterns for rhyolites from the BPC with Flin Flon Index <50%.

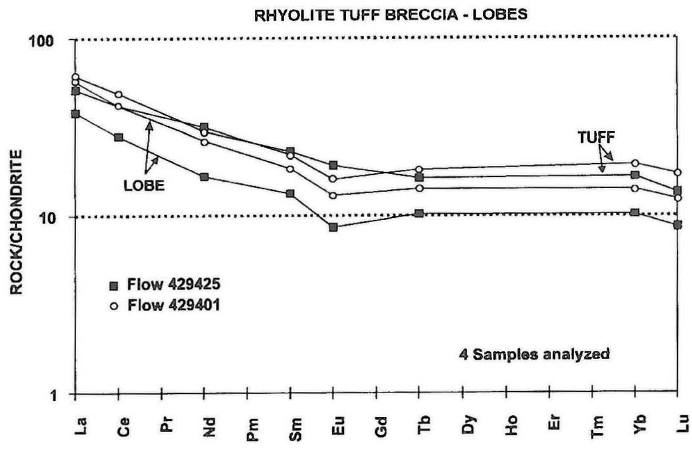


Figure GS-10-6: Chondrite normalized REE patterns for comagmatic hyaloclastite and lobe portions of two rhyolite flows from the BPC.

Flon Indices.

DISCUSSION

Some analyses of subaqueous felsic flows within the BPC plot within the fields of dacites on discriminant diagrams, despite having >70% SiO_2 contents in their massive lobes. Because these rocks have the physical and chemical characteristics of altered rhyolite and there is no physical or other chemical evidence to indicate local or regional silicification these rocks are considered to be rhyolite. The comagmatic hyaloclastite material associated with the lobes has up to 15% less SiO_2 than the lobes. The magnitude of the decrease in SiO_2 appears to be correlatable with the fragment size of the associated hyaloclastite material, *i.e.*, it is greatest in tuff and least in breccia. This is interpreted as desilicification resulting from the reactions of hot rock with seawater during initial flow activity.

Even though it appears from a plot of TiO_2 vs Zr that both of these elements are conserved, *i.e.*, have not undergone losses or gains during the alteration processes, the BPC rhyolites plot in the discriminant field for dacite as defined by Winchester and Floyd (1977). The failure of these rocks to plot in the rhyolite field is a result of low Zr values, which affects their position on the Y-axis in a Zr/TiO_2 vs Nb/Y plot. Other rhyolites from the Flin Flon area also plot in the dacite field because of their low Zr/TiO_2 ratios (Bailes and Syme, 1989; E.C. Syme, pers. comm., 1996). This can be attributed to the anomalously low Zr contents of source rocks from which the volcanic rocks in the Flin Flon area originated (Stern *et al.*, 1995). It appears from these data that the Winchester and Floyd (1977) discriminant diagram Zr/TiO_2 vs Nb/Y is not suitable for distinguishing rhyolite and dacite in the BPC and other parts of the Flin Flon area.

Similar low-Zr/TiO_2 subaqueous rhyolites are spatially associated with the Flin Flon, Callinan and Ruttan massive sulphide deposits (Bailes and Syme, 1989; Ames and Taylor, 1996). Rhyolites associated with the Brunswick Mine (Lentz and Goodfellow, 1992), Inmont property (Barrett and MacLean, 1991), the Ansil Mine (Barrett *et al.*, 1991), and the Corbet Mine (Barrett *et al.*, 1993) also have low Zr/TiO_2 ratios. Although it is beyond the scope of this article, a line of research that should be investigated is whether rhyolites spatially associated with massive sulphide deposits elsewhere in the Flin Flon area and in other mining camps are also low Zr/TiO_2 rhyolites.

REE data from massive rhyolite lobes indicate that, in general, the BPC rhyolites exhibit a narrow range in both LREE and HREE. Altered rhyolites exhibit the greatest deviation from the values obtained from the lobes although there is only minor deviation from the 'Lobe' patterns in the HREE there is a marked but variable depletion in the LREE and in Eu. The largest depletion in Eu is correlatable with extensive alkali alteration *i.e.* Flin Flon Index >75%.

Campbell *et al.* (1984) documented the mobility of REE in alteration zones beneath massive sulphide deposits and that at the Kidd Creek Mine the greatest loss in Eu occurred in the most altered samples in the footwall alteration zone. This suggests that greatest Eu depletion occurs in the most intensely altered portions of a massive sulphide deposit alteration zone. Such a relation could be a useful tool in distinguishing the central/vent portions of hydrothermal alteration zones from peripheral marginal alteration.

Eu depleted in an alteration vent should be redeposited at the seawater-rock interface together with other hydrothermally derived products. Evidence that supports this idea has been presented by Leighat and MacLean (1992) who observed a positive Eu anomaly in exhalites from the Matagami Key Tuffite and Siddaiah *et al.* (1994) who document a positive Eu anomaly in gold-bearing exhalite and associated iron formation. We are currently investigating the rare earth element contents of tuffites in the Flin Flon area to follow up on the idea of Eu depletion in alteration zones and its deposition in associated chemical sedimentary rocks. If this association can be substantiated, then it will provide a valuable tool for explorationists in distinguishing disseminated mineralization in cross-cutting alteration zones from mineralogically similar exhalite.

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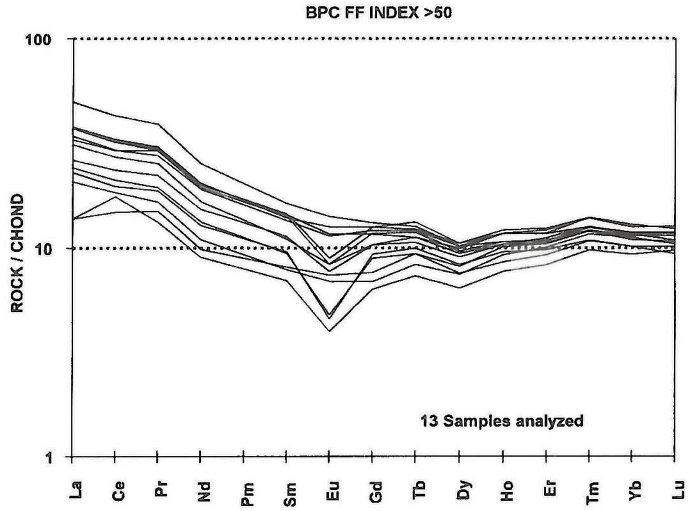

Figure GS-10-7: Chondrite normalized REE patterns for rhyolites from the BPC with Flin Flon Index >50%.

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GS-11 GEOCHEMISTRY OF ARC AND OCEAN-FLOOR METAVOLCANIC ROCKS IN THE REED LAKE AREA, FLIN FLON BELT

by E.C. Syme and A.H. Bailes

Syme, E.C. and Bailes, A.H., 1996: Geochemistry of arc and ocean-floor metavolcanic rocks in the Reed Lake area, Flin Flon belt; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996. p. 52-65.

SUMMARY

Follow-up geochemical and structural work in the Reed Lake area has added detail to the lithological information resulting from 1:50 000 reconnaissance mapping conducted in 1995. Precise (XRF, ICP-MS) geochemistry of *ca.* 1.9 Ga volcanic assemblages confirms earlier field interpretations that a heterogeneous sequence of arc affinity volcanic rocks (Fourmile Island assemblage) is juxtaposed against oceanic-affinity basalts (Northeast Reed assemblage) by the Morton Lake fault zone (<1.842 Ga). The Fourmile Island assemblage ranges from basaltic andesite to rhyolite in composition, and has trace element characteristics similar to arc rocks elsewhere in the Amisk collage. Basalts in the Northeast Reed assemblage are N-type MORBs with weak arc signatures, interpreted as back-arc basin basalts.

INTRODUCTION

The Reed Lake area (parts of NTS 63K/9 and 10) lies in the eastern past of the Paleoproterozoic Flin Flon greenstone belt, 30 km southwest of Snow Lake (Fig. GS-11-1). The area was mapped in reconnaissance 1:50 000 fashion during a joint Manitoba-GSC project in the summer of 1995 (Syme *et al.*, 1995a, b). Follow-up geochemical and structural studies are reported here.

The geology of the Reed Lake area (Fig. GS-11-2) was reported in Syme *et al.* (1995a). In summary, a major (kilometres wide), regionally extensive tectonite belt exposed on western Reed Lake (West Reed-North Star shear zone) juxtaposes rocks of oceanic affinity on the west (Reed Lake mafic-ultramafic complex) with rocks of presumed arc affinity on west-central Reed Lake (Fourmile Island assemblage). The Reed Lake map area is split into two domains by the Morton Lake fault zone (MLFZ), which juxtaposes a footwall (autochthonous) domain, comprising the Fourmile Island assemblage, West Reed-North Star shear zone and Reed Lake mafic-ultramafic complex, and a hanging wall (allochthonous) domain, consisting of basalts of the Northeast Reed assemblage, the composite Reed Lake pluton, and the Snow Lake arc assemblage. The fault zone itself includes a slice of File Lake Formation greywacke turbidites. These relations are significant in that they suggest that the Snow Lake arc assemblage is contained in a southwest-

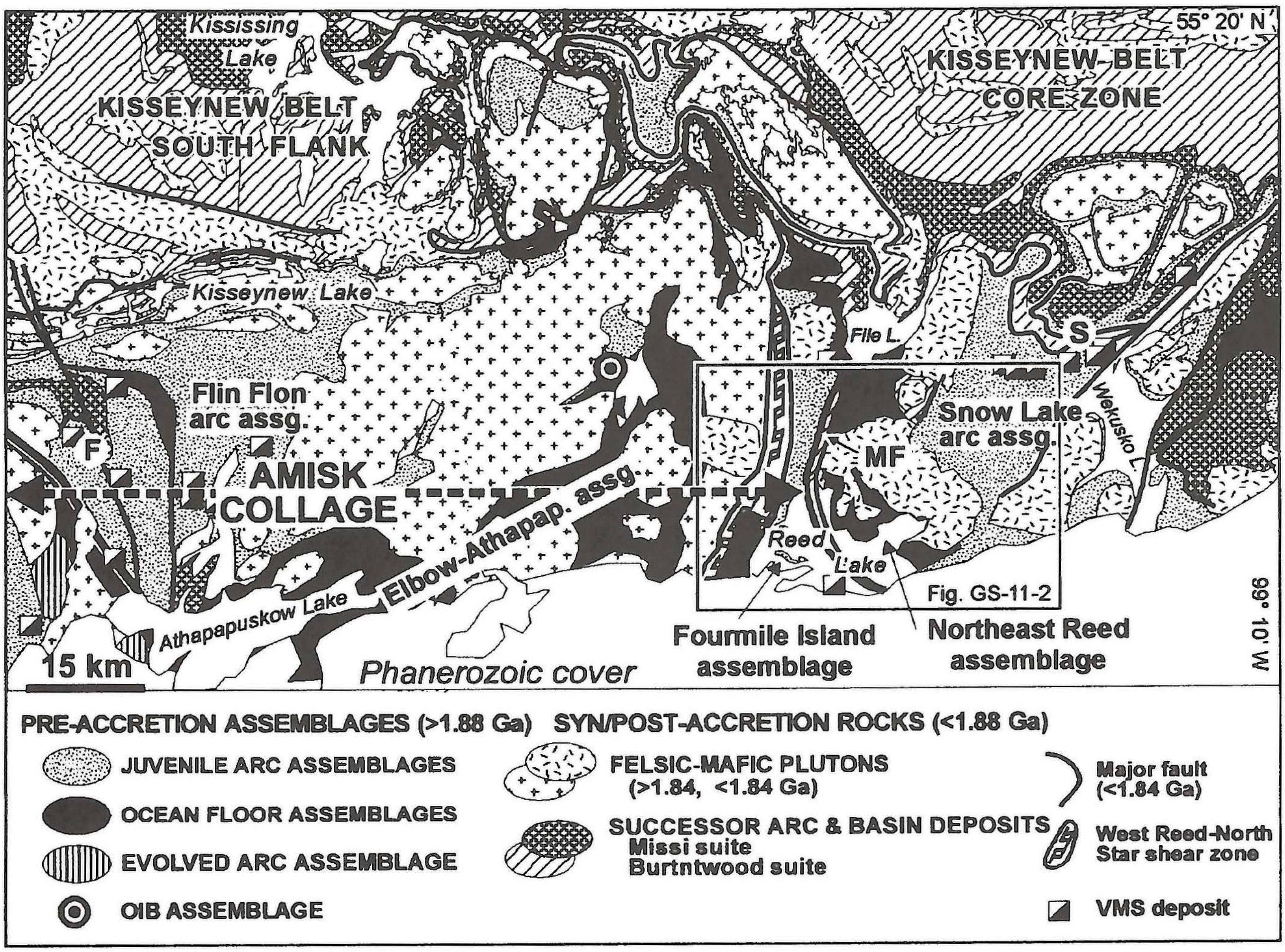


Figure GS-11-1: Simplified geological map of the central portion of the Flin Flon belt, showing the Amisk collage, major tectonostratigraphic assemblages and plutons, and location of mined VMS deposits. F: Flin Flon; S: Snow Lake; ML: Morton Lake fault. Outlined area shows location of map in Figure GS-11-2.

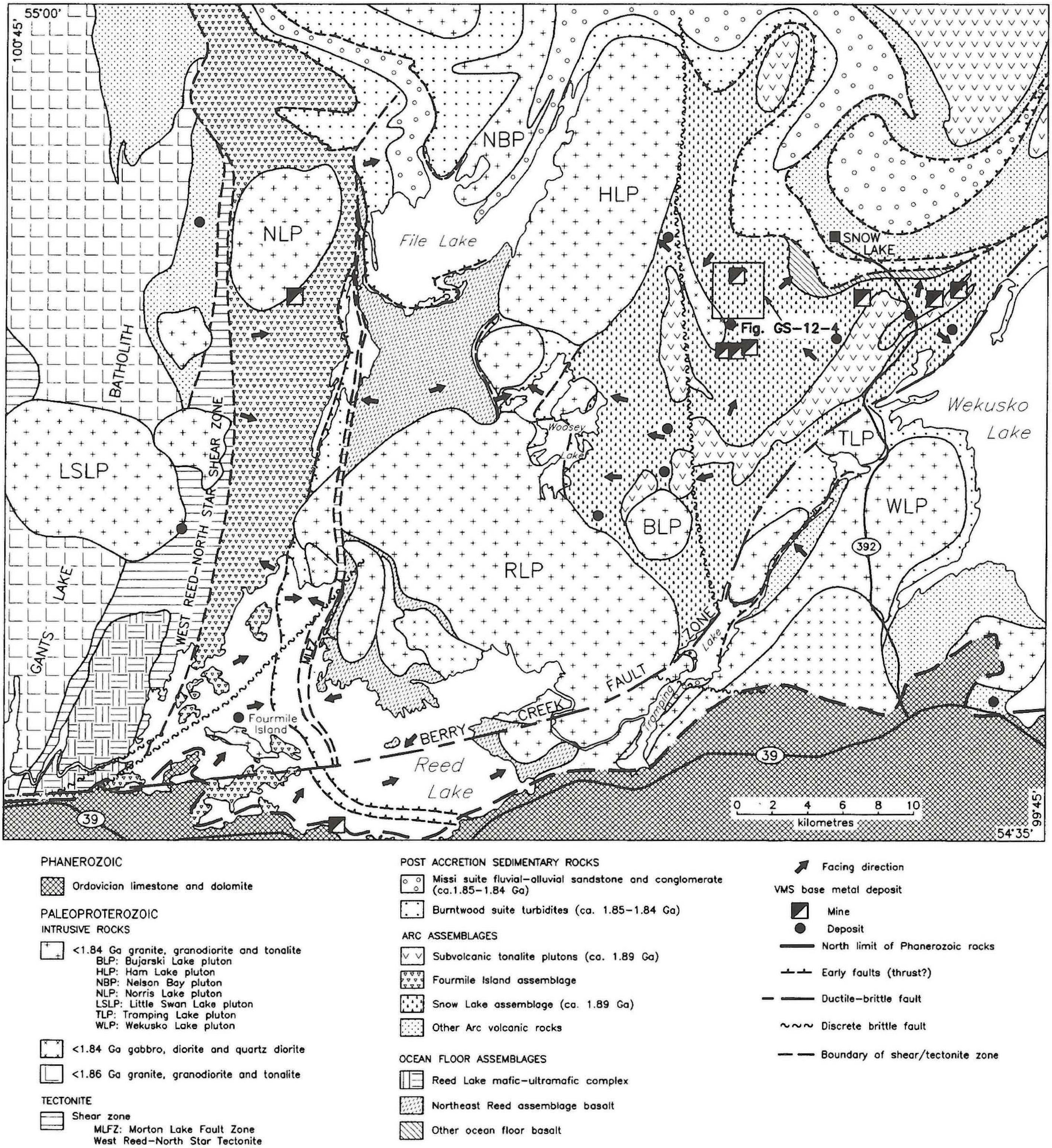


Figure GS-11-2: Simplified geology of the Reed Lake-Morton Lake-Tramping Lake area, after Syme et al. (1996b), Morrison et al. (1996), Bailes 1980), Stanton (1945) and Rousell (1970). Intrusive rocks: RLC: Reed Lake mafic-ultramafic complex; JLS: Josland Lake sill; LSLP: Little Swan Lake pluton; NLP: Norris Lake pluton; RLP: Reed Lake pluton; HLP: Ham Lake pluton; WLP: Wekusko Lake pluton; MLFZ: Morton Lake fault zone. S: Spruce Point Cu-Zn deposit. Locations of stratigraphic sections shown in Figure GS-11-3 are labeled W, F and S.

verging allochthon emplaced after deposition (*ca.* 1.84 Ga) of the File Lake Formation. This structural interpretation is consistent with earlier suggestions (based on lithologic, geochemical and isotopic criteria) that the Snow Lake and Flin Flon VMS camps are unrelated and represent remnants of different and distinct volcanic arcs that have been structurally juxtaposed.

The tectonic affinity of metavolcanic rocks in the Reed Lake area was assigned on the basis of field characteristics (Table GS-11-1), compared to metavolcanic rocks of known tectonic affinity elsewhere in the Flin Flon belt. Geochemical analyses were conducted on a representative suite of samples so that a more rigorous determination of affinity could be made.

Sampling and analytical methods

Samples were collected specifically for geochemical analysis and represent the mesoscopically least-altered rocks encountered during the mapping. The samples were trimmed to remove weathered surfaces, joints, veinlets, etc., and none contain significant numbers of amygdales.

Major elements, Rb, Sr, Y, Zr, Nb and Ba were analysed by XRF at XRAL Laboratories. Trace and rare earth elements (Sc, V, Cr, Ni, Rb, Sr, Y, Zr, b, Mo, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Tl, Pb, Bi, Th and U) were analysed by acid digestion ICP-MS at the University of Saskatchewan. Comparison of XRF and ICP-MS data suggested that HFSE elements were incompletely placed into solution during acid digestion, and accordingly a sinter ICP-MS method was utilized to re-analyze for Y, Zr, Hf and Th. Major- and trace-element data are listed in Appendices GS-11-1 and 2.

GEOCHEMISTRY

Northeast Reed assemblage

The Northeast Reed assemblage includes an areally extensive sequence of pillowed basalt on northern Reed Lake and similar rocks exposed on Morton, File and Woosey lakes (Fig. GS-11-2). These sequences are distinguished by lithologic homogeneity and are similar in field character to basalts in the Elbow-Athapapuskow ocean floor assemblage (Syme, 1994, 1995; Stern *et al.*, 1995b; Fig. GS-11-1; Table GS-11-1).

The Northeast Reed assemblage is composed entirely of basalts that have a restricted major-element compositional range (*e.g.*, SiO_2 47-50 wt.% (one anomalous sample at 54.6%); MgO 4.6-8.7 wt.%; Fig. GS-11-4; Table GS-11-2). Like basalts in the Elbow-Athapapuskow

Table GS-11-1
Field characteristics of Fourmile Island and Northeast Reed assemblages

	Fourmile Island assemblage (arc)	Northeast Reed assemblage (back-arc)
Composition	Heterogeneous (mafic-felsic), dominantly mafic	Homogeneous (basalt)
Lithologies	Lithologically variable: pillowed and massive aphyric and porphyritic mafic flows, felsic exogenous domes, heterolithologic breccias, tuff, synvolcanic mafic-felsic dykes and sills, iron formation.	Lithologically simple: dark green, pillowed, aphyric and subordinate plagioclase phyric flows, rare massive flows, synvolcanic diabase dykes and sills.
Stratigraphy	Complex stratigraphy.	Monotonous basaltic piles.
Environment	Subaqueous; possible subaerial source for subaqueous debris flows. Pillowed flows variably amygdaloidal.	Subaqueous. Thin pillow selvages, few amygdales, rare radial pipe amygdales.
Facies	Proximal volcanic constructs, intra-arc depositional basins (evidence of intra-arc extension?).	Proximal?
Alteration	Widespread synvolcanic hydrothermal alteration (*e.g.*, silicification, pervasive epidotization).	Limited seafloor alteration. Interpillow chert.
VMS deposits	Spruce Point mine, Reed Lake deposit. Dickstone Mine probably in equivalent strata.	No economic deposits to date.

Table GS-11-2
Geochemical characteristics of Fourmile Island and Northeast Reed assemblages

	Fourmile Island assemblage (arc)	Northeast Reed assemblage (back-arc)
Affinity	low-K arc tholeiites	tholeiitic N-type MORB with arc signature
SiO_2	54-76% (basaltic andesite - rhyolite)	47-50% (basalt)
MgO	0.60-5.7%	4.6-8.7%
TiO_2	0.17-0.92%	0.89-1.68%
Chondrite-normalized REE patterns	Highly variable for the entire assemblage, but individual stratigraphic units have uniform patterns. LREE-enriched, flat, and LREE-depleted: - $[La/Yb]_n$ = 0.5-4.4 - $[Gd/Yb]_n$ = 0.8-1.4	Two narrow ranges: 1) convex-up (Northeast Reed basalt) - $[La/Yb]_n$ = 0.8-1.4 - $[Gd/Yb]_n$ = 1.4-2.0 2) LREE-depleted (File, Woosey and Morton basalts) - $[La/Yb]_n$ =0.6-0.8 - $[Gd/Yb]_n$ = 0.7-1.2
Ti/V (MgO>5%)	20	15-26
Mg/Ni (MgO>2%)	2036-13803	328-698
Th/Nb	0.16-0.68	0.07-0.15
Nb/Y	0.05-0.18	0.05-0.19
Zr/Y	2.1-3.2	2.2-4.4
Zr/Nb	14.3-49.9	14-52
Ti/Zr	36-138	86-137

ocean-floor assemblage (Stern *et al.*, 1995b) Northeast Reed basalts are subalkaline (hypersthene+quartz normative), tholeiitic (Figs. GS-11-4, 5) and somewhat fractionated, with Mg#'s 0.42-0.64 and Ni contents 50-125 ppm (Fig. GS-11-4). Samples plot in the fields of modern ocean-floor basalts (Fig. GS-11-6), and are similar to ocean-floor basalts elsewhere in the Flin Flon belt (Fig. GS-11-4). They overlap the field of contemporaneous Flin Flon MORB-OIB mantle estimated from compositions of ocean-floor rocks in the Amisk collage (Fig. GS-11-6).

Plots using ratios of immobile trace elements demonstrate that Northeast Reed basalts are exclusively N-type (similar to normal MORB) basalts (Fig. GS-11-6). MORB-normalized trace element diagrams display consistent, flat, MORB-like patterns, lacking the negative anomalies at Zr and Ti that characterize arc suites (Figs. GS-11-7, 8). They have Th/HFSE and Th/Yb ratios intermediate between **primitive** N-type MORBs and arc rocks (Fig. GS-11-6). The slightly elevated Th/Nb ratios exhibited by these rocks (0.07-0.15, average 0.10) are similar to those in some members of the Elbow-Athapapuskow assemblage. Stern *et al.* (1995b) interpret these ratios as a subduction signature, rather than a result of crustal contamination; such MORB-like basalts with weak arc signatures suggest affinities with modern back-arc basin basalts (Stern *et al.*, 1995b).

Northeast Reed assemblage basalts have trace element ratios (Nb/Y, Zr/Y, Zr/Nb; Table GS-11-2) similar to basalts in the Elbow-Athapapuskow ocean-floor assemblage (Stern *et al.*, 1995b), and within the range of modern MORBs. They have slightly lower Ti/Zr ratios (86-137) than most Elbow-Athapapuskow assemblage basalts (100-130).

The Elbow-Athapapuskow assemblage contains a number of distinct basalt sequences probably equivalent to stratigraphic formations (Stern *et al.*, 1995b; Syme, 1995). Similarly, the Northeast Reed assemblage clearly contains two geochemically and geographically distinct 'formations': 1) basalts on Reed Lake, and 2) basalts in the File Lake - Morton Lake - Woosey Lake area (Fig. GS-11-2). Reed Lake basalts have consistently higher Zr, Hf, and Ti contents than File-Morton-Woosey basalts, and, except for one sample, also have higher Nb contents (Figs. GS-11-7, 8). Chondrite-normalized REE patterns (Fig. GS-11-9) of the basalts on Reed Lake have a concave-downward or 'humped' pattern, peaking at Sm-Gd and decreasing to both La and Yb ($[La/Yb]_n$ = 0.8-1.4, $[Gd/Yb]_n$ = 1.4-2.0). These basalts have neutral, slightly positive or slightly negative Eu anomalies (Eu/Eu* = 0.9-1.1). Basalts from File, Morton and Woosey lakes have LREE-depleted patterns with no enrichment of the middle REE ($[La/Yb]_n$ = 0.6-0.8, $[Gd/Yb]_n$ = 0.7-1.2), and virtually no Eu anomalies (Eu/Eu* = 1.0-1.1).

The contact between the Reed Lake and File-Morton-Woosey basalts is occupied by the Reed Lake pluton (Fig. GS-11-2), so primary contact relations are unknown. Most basalt 'formations' within the Elbow-Athapapuskow assemblage are faulted (Syme, 1995).

Fourmile Island assemblage

The Fourmile Island assemblage comprises all of the metavolcanic rocks lying between the West Reed-North Star shear zone and the MLFZ, as well as metavolcanic rocks exposed south of the Berry Creek shear zone on southwestern Reed Lake (Fig. GS-11-2). Stratigraphy is dissected by faults and intruded by major tholeiitic sills, so as a result there is no single, complete stratigraphic section through the Fourmile Island assemblage. Three semi-continuous sections through the assemblage are shown on Figures GS-11-2 and 3: one in west-central Reed Lake (section 'W'), one south of Fourmile Island (section 'F'), and one south of the Berry Creek shear zone (section 'S'). Following the mapping in 1995 these three sections were correlated on the basis of gross stratigraphic similarity, pending geochemical confirmation (Syme *et al.*, 1995). The follow-up work reported below adds no new information to the correlation of sections W and F, but clearly indicates that the

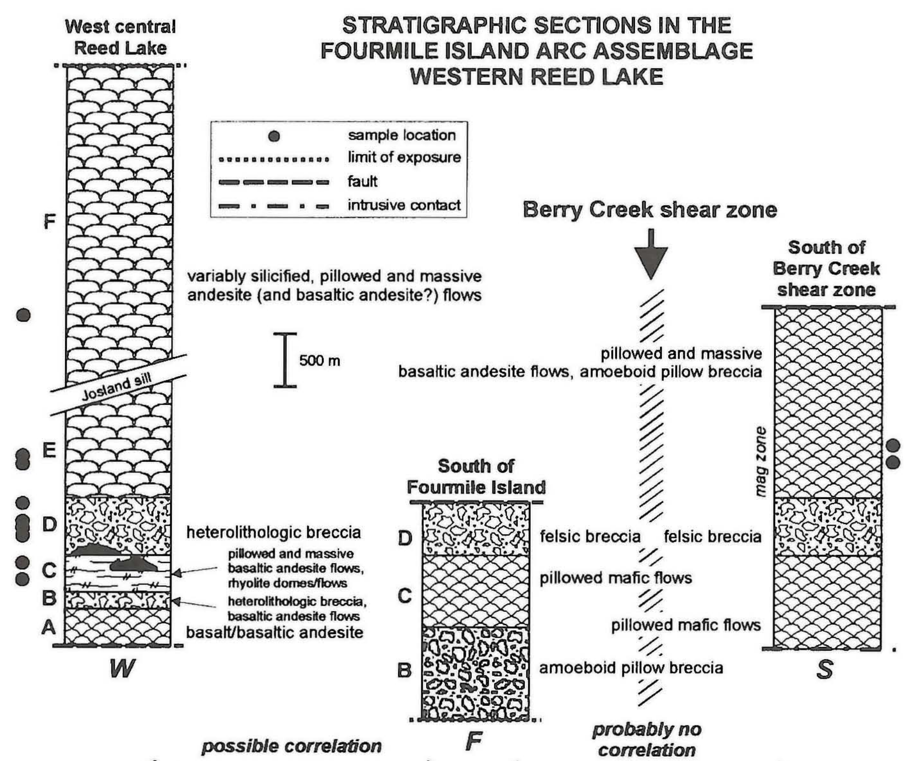


Figure GS-11-3: Stratigraphic sections through the Fourmile Island arc assemblage, western Reed Lake (see Fig. GS-11-2 for locations). The west-central section (W) is separated by a fault from the sequence south of Fourmile Island (F). The Fourmile Island section is in turn transected by the dextral Berry Creek shear zone (BCSZ). A probable stratigraphic correlation exists between sections W and F, based on gross lithologic similarity. The illustrated section south of the BCSZ (section S) is exposed on and south of Bartlett Point; mafic flows with a high magnetic response are designated 'mag zone'. Geochemical differences between Unit 'E' rocks in section W and superficially correlative rocks in section S suggest that no stratigraphic correlation can be made across the Berry Creek shear zone.

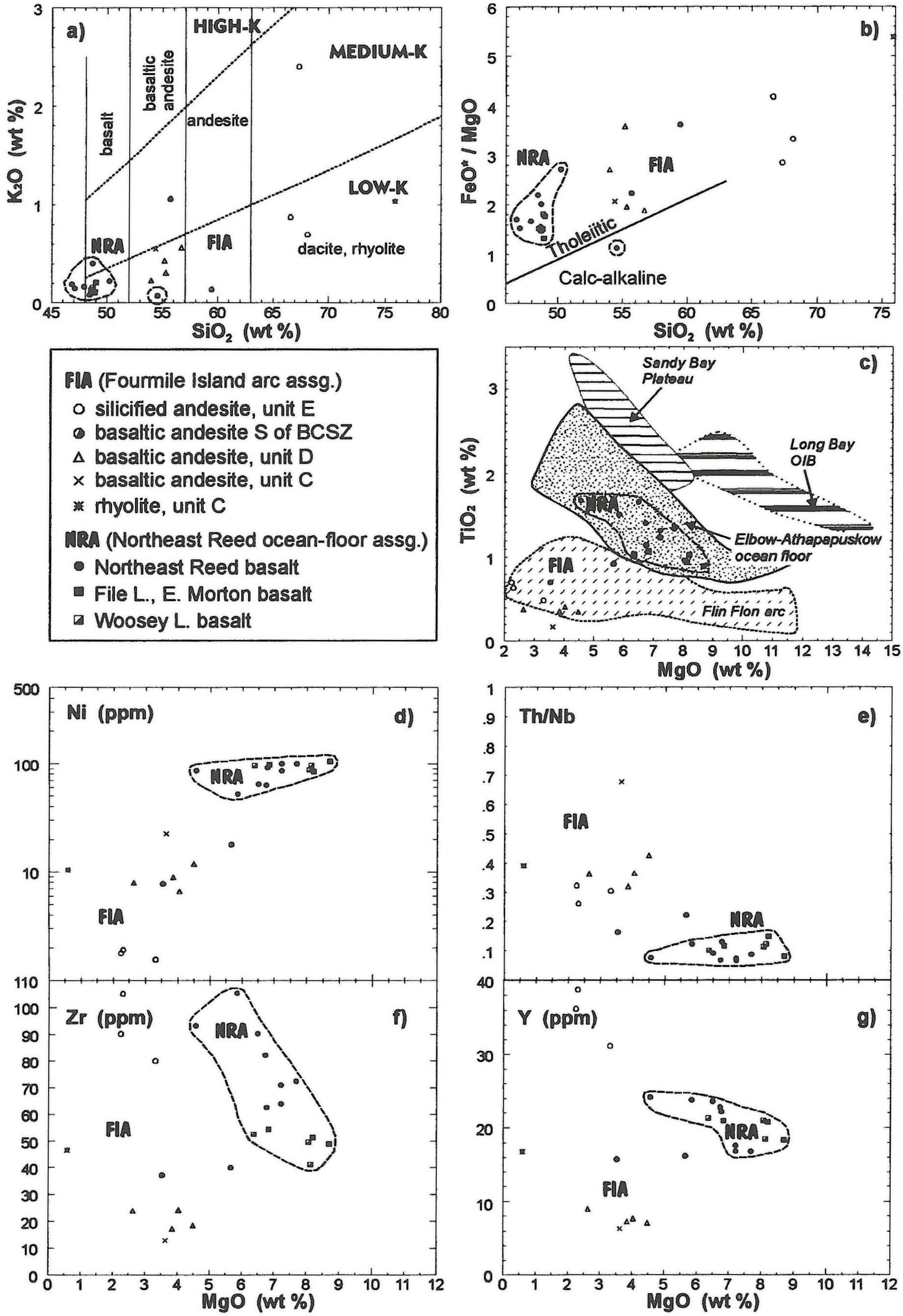


Figure GS-11-4: (a) SiO_2 vs. K_2O; boundaries from LeMaitre (1989); (b) SiO_2 vs. FeO/MgO: Northeast Reed and Fourmile Island assemblages plot in the tholeiitic field; boundaries from Gill (1981); (c) MgO vs. TiO_2, comparing Reed Lake data with geochemical data from elsewhere in the Flin Flon belt (fields from Stern et al., 1995a, b); (d-g) selected trace elements vs. MgO.*

volcanic rocks south of the BCSZ (section S) are geochemically distinct from those north of the shear zone. The stratigraphic sections and their relationships are shown in Figure GS-11-3, together with locations of analysed samples.

The Fourmile Island assemblage exhibits considerable lithologic and stratigraphic diversity, in distinct contrast to the more homogeneous Northeast Reed assemblage (Table GS-11-1). Lithologic heterogeneity in the Fourmile Island assemblage is borne out by the major and trace element data. These rocks range in SiO_2 from 54-76 wt.% (basaltic andesite to rhyolite), showing essentially no overlap with the range of SiO_2 exhibited by Northeast Reed basalts (Fig. GS-11-4; Table GS-11-2). Major element contents and compositional trends are consistent with these rocks being termed low-K arc tholeiites (Figs. GS-11-4, 5), although the distinction between tholeiitic and calc-alkaline magma series is ambiguous (*e.g.*, compare Figs. GS-11-4b and 5a). On balance, the relatively Fe-enriched nature of the assemblage suggests affinities with tholeiitic suites. As a group, Fourmile Island assemblage rocks have arc signatures on MORB-normalized trace element diagrams (Figs. GS-11-7, 8), characterized by positive Th and negative Nb anomalies, depleted Zr-Hf, and troughs at Ti. They plot in the arc fields on discrimination diagrams based on modern volcanic rocks (Fig. GS-11-6a, c), and within the field of Flin Flon arc assemblage rocks (Figs. GS-11-4c, 6c, 6d; Stern *et al.*, 1995b). Thus the Fourmile Island assemblage has a clear oceanic arc affinity, similar to the arc rocks at Flin Flon and Snow Lake.

Not all of the stratigraphic units in the Fourmile Island assemblage were sampled during this reconnaissance study (Fig. GS-11-3). Units are discussed separately below.

Unit 'C'

Unit 'C' is a highly heterogeneous unit 365 m thick dominated by thin, pillowed, aphyric and plagioclase phyric, buff-brown weathering, intermediate-mafic flows and related amoeboid pillow breccia. The flows are cut by synvolcanic (locally pillowed) dykes of similar composition. The sequence includes a thick (150 m) unit of coarsely quartz-feldspar phyric rhyolite interpreted as an exogenous felsic dome (Fig. GS-11-3). A sample for U-Pb geochronology was collected from the rhyolite, but unfortunately it proved to contain insufficient zircon for analysis.

One sample of a pillowed, plagioclase phyric mafic flow and one sample of the porphyritic rhyolite dome were collected for geochemical analysis. The flow is basaltic andesite in composition, with high Al_2O_3 (20.5 wt.%) reflecting its abundant phenocrystic plagioclase. This rock is characterized by the lowest HFSE and REE abundances exhibited by the Fourmile Island assemblage (Figs. GS-11-4, 7, 8, 9). It has the highest Th/Nb ratio of any rock in the Fourmile Island assemblage, but nevertheless plots within the general field of Flin Flon arc assemblage rocks (Fig. GS-11-4).

The rhyolite (75.9 wt.% SiO_2) has a slightly LREE-enriched chondrite-normalized REE pattern (Fig. GS-11-9) similar to rhyolites elsewhere in the Flin Flon arc assemblage (Fig. GS-11-6e). Rhyolites associated with the Flin Flon massive sulphide deposit (M and S, Fig. GS-11-6e) have flat REE patterns similar to the Fourmile Island assemblage rhyolite, but at significantly higher REE concentrations.

Unit 'D'

Unit 'D' (550 m thick) is dominated by intermediate to felsic fragmental rocks (Fig. GS-11-3). The contact with underlying Unit 'C' is gradational. The base of Unit 'D' at least locally is a quartz-feldspar phyric rhyolite flow or dome that grades upward into a well defined felsic breccia. The basal part of Unit 'D' also contains thin pillowed flows of mafic-intermediate composition. The proportion of rhyolite clasts decreases up section, with an increasing abundance of plagioclase phyric mafic clasts. Felsic clasts comprise only about 10% of the uppermost part of the volcaniclastic section. The breccias are matrix supported and thick bedded, suggesting that they were deposited from subaqueous debris flows, possibly shed from a subaerial volcanic centre into an adjacent basin.

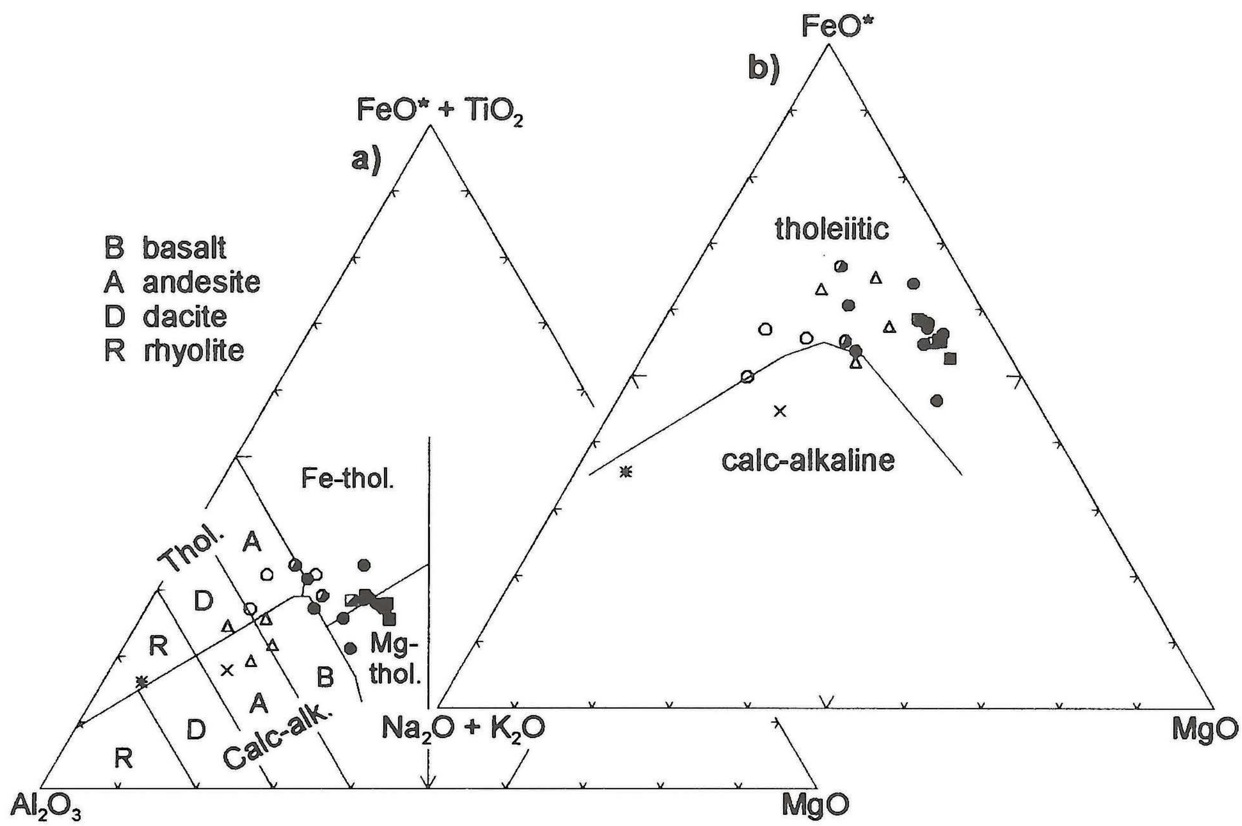
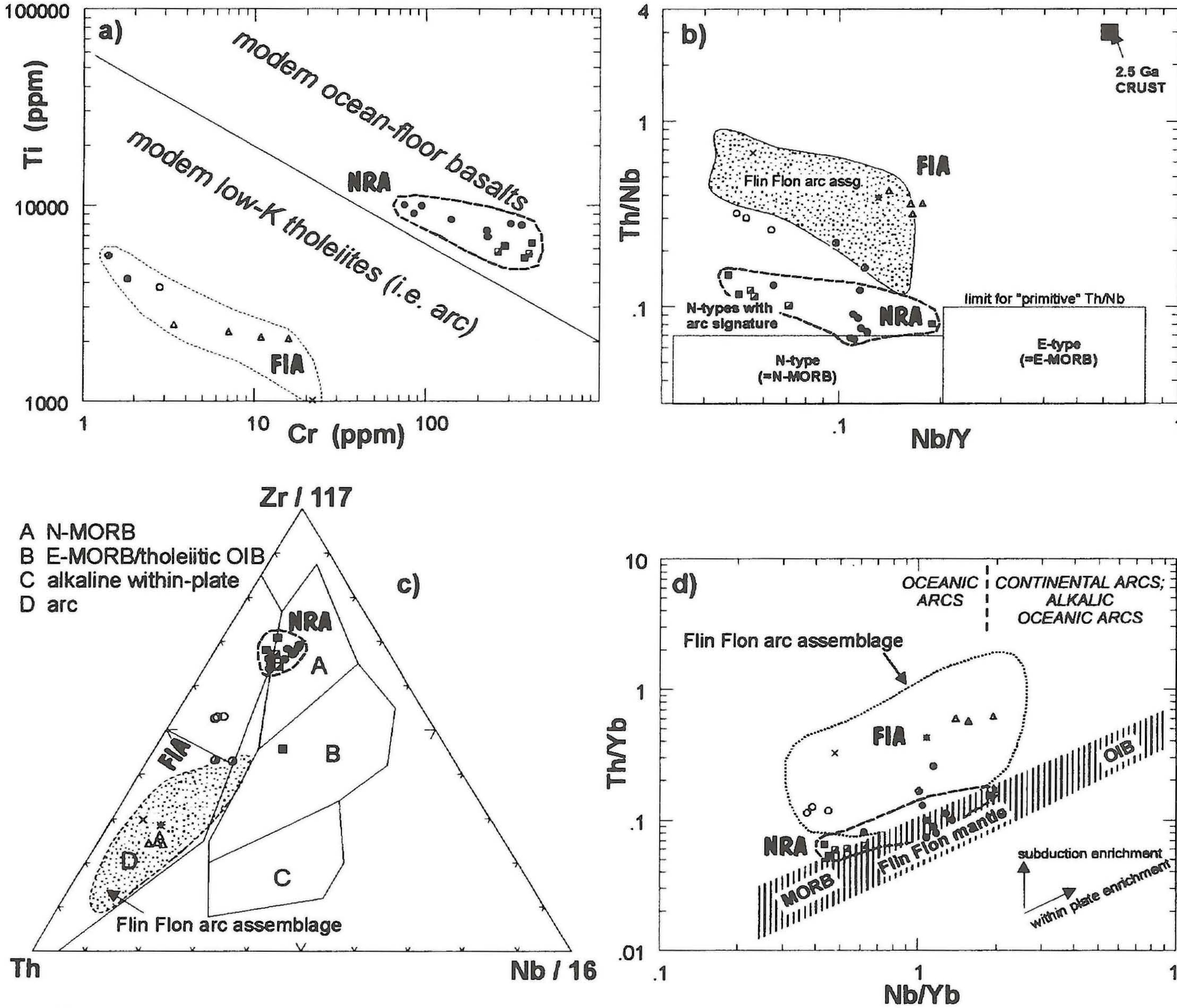


Figure GS-11-5: (a) Jensen (1976) ternary diagram (oxides in cation %); (b) Irving and Baragar (1971) AFM ternary diagram (oxides in wt. %). Legend as in Fig. GS-11-4.



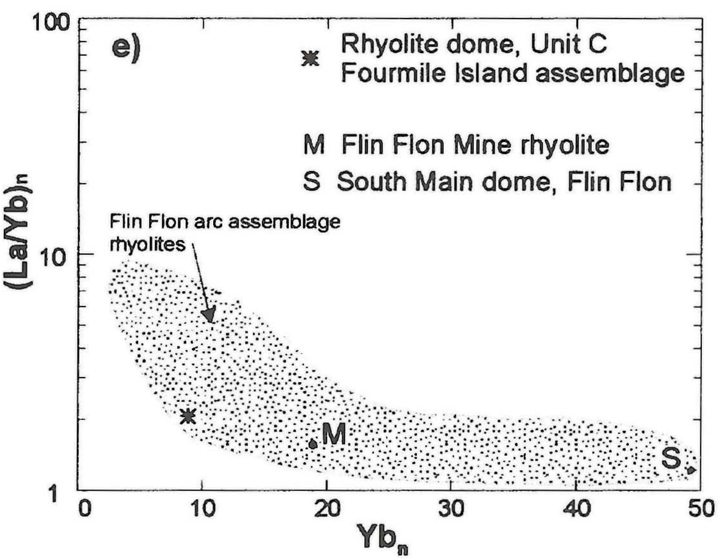


Figure GS-11-6: (a) Cr vs. Ti, discriminating ocean-floor basalts from low-K (arc) tholeiites; fields from Pearce (1975); (b) Nb/Y vs. Th/Nb, showing fields of primitive N- and E-type MORBs, Flin Flon assemblage arc rocks (from Stern et al., 1995b). Northeast Reed basalts are similar to some basalts in the Elbow-Athapapuskow ocean-floor assemblage in that they are N-type basalts with arc signatures. (c) Th-Zr/117-Nb/16 discrimination diagram (Wood, 1980). Fourmile Island assemblage rocks plot in the arc field and Northeast Reed assemblage basalts plot in a field overlapping N-MORB and arc; note that Unit E flows plot outside the range of Flin Flon arc assemblage rocks; (d) Nb/Yb vs. Th/Yb (see text for discussion); (e) Yb_n vs. $[La/Yb]_n$, rhyolites. Legend as in Fig. GS-11-4.

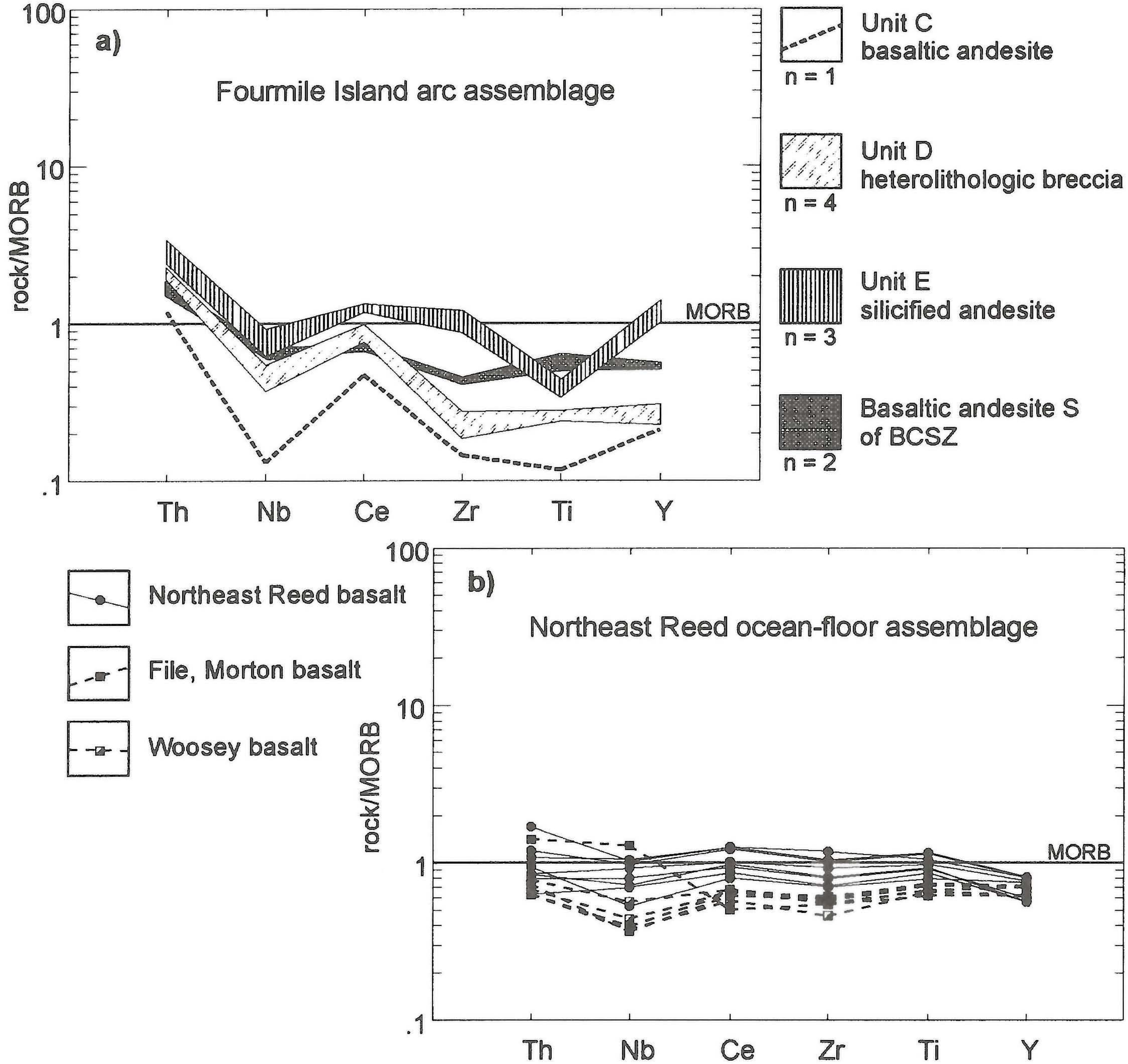


Figure GS-11-7: N-MORB-normalized (Pearce, 1996) diagrams. (a) Relative to N-MORB, Fourmile Island assemblage stratigraphic units C, D, and E have arc signatures characterized by enriched Th and depleted Nb (resulting in high Th/Nb ratios), and depleted Zr, Ti, (Y). (b) Northeast Reed assemblage basalts have flat patterns with minor Nb anomalies.

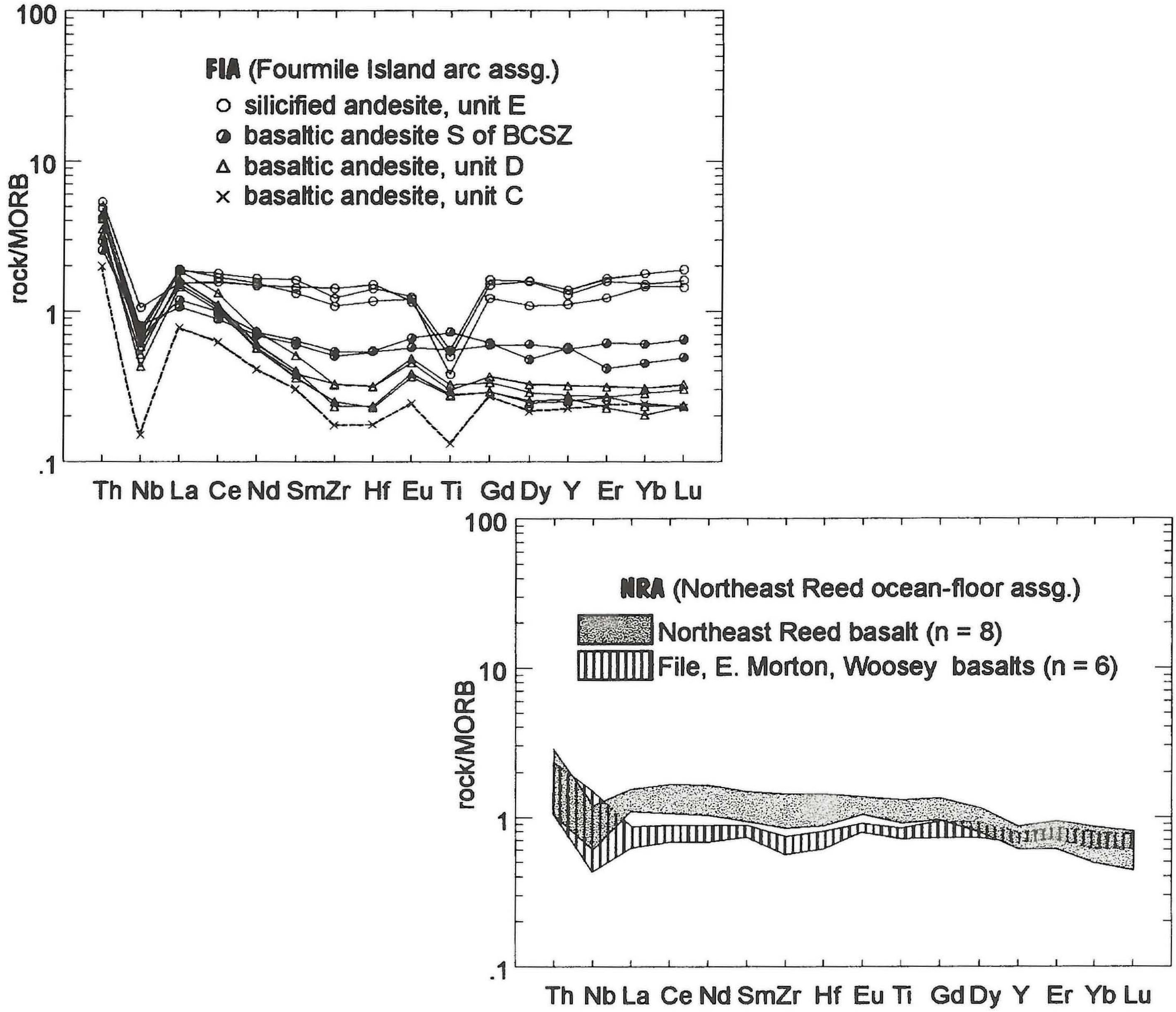


Figure GS-11-8: N-MORB-normalized incompatible element diagrams, with elements arranged in order of increasing incompatibility in MORB-source mantle from right to left (after Sun and McDonough, 1989). (a) Fourmile Island assemblage rocks have arc signatures characterized by elevated Th and depleted Nb, and depleted HFSE. Note that each stratigraphic unit has a distinctive trace element pattern. Bulk incompatible element content increases up-section (i.e., from unit C to unit E). (b) Northeast Reed assemblage basalts have flat MORB-normalized patterns with minor positive Th and negative Nb anomalies. Basalts from Northeast Reed Lake have higher incompatible element contents than basalts from File, Morton and Woosey lakes.

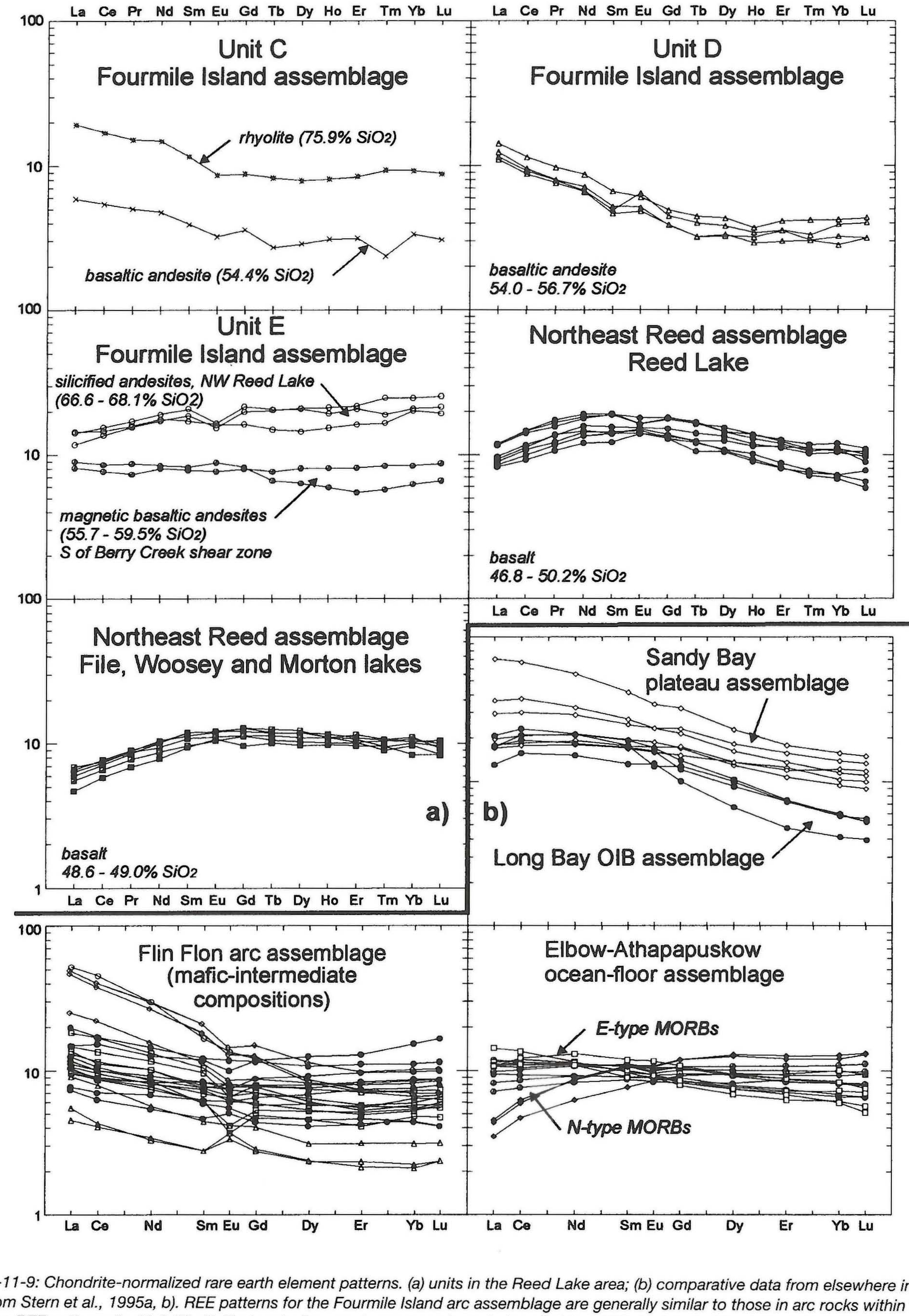


Figure GS-11-9: Chondrite-normalized rare earth element patterns. (a) units in the Reed Lake area; (b) comparative data from elsewhere in the Amisk collage (from Stern et al., 1995a, b). REE patterns for the Fourmile Island arc assemblage are generally similar to those in arc rocks within the Amisk collage. The REE patterns for Unit 'E' silicified andesites are, however, unique, being slightly LREE-depleted with relatively high REE concentrations. Northeast Reed assemblage basalts display two distinct REE pattern types (see text for discussion): basalts on File, Morton and Woosey lakes are similar to N-type MORBs in the Elbow-Athapapuskow assemblage, whereas basalts from Reed Lake have a convex-upward REE pattern intermediate between MORBs and OIB.

Four samples were collected from Unit 'D': one of the matrix, near the top of the section, and three different mafic clasts. All similar in composition: basaltic andesites with a distinct arc signature (high Th/Nb ratios, and low Ti, Zr; Fig. GS-11-4d, 4e, 6, 7, 8). The compositional homogeneity between clasts and matrix suggests the mafic clastic material was derived essentially from a single source. Rare earth contents are relatively low (Yb_n = 3-4; Fig. GS-11-9), and chondrite-normalized patterns are smoothly dish-shaped and LREE-enriched ($[La/Yb]_n$ = 2.9-4.4). Weak positive Eu anomalies in three samples (Eu/Eu* = 1.1-1.4) probably reflect the presence of plagioclase phenocrysts.

Unit 'E'

Unit 'E' is at least 700 m thick, composed of grey-green to green weathering, aphyric, pillowed and massive flows. These flows abruptly overlie unit 'D' and contain no intercalated andesitic volcaniclastic rocks. The 'D'-'E' contact therefore signals an abrupt change in volcanic style and composition. Pillowed flows in the sequence are commonly characterized by large (metre-scale) pillows with carbonate-filled amygdales; massive flows have amoeboid pillow breccia flow tops. Some the flows in unit 'E' display selective silicification of pillow margins (Fig. GS-11-10). The top of unit 'E' is defined arbitrarily as the base of the overlying, concordant Josland Lake sill.

The major element data reveals some unexpected results in terms of rock classification for Unit 'E' (open circles on Fig. GS-11-4). These rocks have SiO_2 contents in the dacite range (67-68 wt.%), but have the weathering colours and flow morphology of mafic (basaltic andesite) flows. Unit 'E' flows have low MgO (2.3-3.3 wt.%), Ni (<2 ppm), Cr (<3 ppm) and V (1-25 ppm) contents, the lowest transition metal contents of any of the rocks analysed from Reed Lake (Fig. GS-11-4d; Appendix GS-11-2). The flows have high FeO*/MgO ratios and thus plot in the tholeiitic fields of major-element discrimination diagrams (Figs. GS-11-3, 4). Locally intense silicification is present throughout much of the exposed part of Unit 'E' (Syme *et al.*, 1995), but obviously altered rocks were not sampled during this study.

Are the sampled flows pervasively silicified mafic rocks, or do their present compositions relict primary magmatic compositions? The low MgO and transition metal contents in Unit 'E' are consistent with a more siliceous composition than the basaltic andesites in the Fourmile Island assemblage. Concentrations of trace elements least likely to have been mobile during hydrothermal alteration (Ti, Zr, Nb, Y, REE, Th) are uniform and form smooth patterns on normalized plots, suggesting alteration has not significantly affected trace element distribution. Unit 'E' flows display a clear arc signature (high Th/Nb ratios, 0.32-0.43), but are enriched in Zr and Y relative to other arc rocks (Figs. GS-11-4, 7, 8). They plot in the arc field on a Th - Zr/117 - Nb/16 diagram, but well outside the field of Flin Flon arc assemblage rocks (Fig. GS-11-6c). Chondrite-normalized REE patterns are elevated overall (Yb_n = 20-25) and slightly LREE depleted ($[La/Yb]_n$ = 0.5-0.7; Fig. GS-11-9a); again, they are unlike any other arc assemblage rocks in the Flin Flon belt (*cf.* Fig. GS-11-9b). Weak negative Eu anomalies in two samples (Eu/Eu* = 0.8; Fig. GS-11-9a) suggests that some plagioclase fractionated from the primary magmas. The trace element evidence suggest that the samples Unit 'E' flows are unique, fractionated, evolved rocks with elevated incompatible element contents. Given the presence of silicification in Unit 'E', a conservative interpretation is that the rocks may be somewhat silicified andesites. The sample set for Unit 'E' is too small (only 3 samples, from two flows at two separate localities) to conclude that all of Unit 'E' is similarly andesitic in composition.

Basaltic andesite S of BCSZ

Volcanic stratigraphy south of the Berry Creek shear zone can be related in a general sense to that to the north (Syme *et al.*, 1995; Fig. GS-11-3). South of the shear zone, the stratigraphic sequence trends northwest and tops to the northeast, as it does to the north. The sequence consists of (from oldest to youngest) >900 m of mafic flows, 550 m of felsic breccia and synvolcanic felsic dykes, and >1800 m of massive and pillowed mafic flows. Direct correlation of units across the Berry Creek zone is hampered by poor exposure and high strain. Massive flows correlated with the base of Unit 'E' in the west-central section (W) display a distinctive high magnetic signature on a vertical gradient map (Geological Survey of Canada, 1983). In outcrop, this 600-700 m thick zone corresponds with a sequence of grey-green- to green-weathering, thick, aphyric, massive mafic flows with strongly amygdaloidal flow tops and prominent flow-top amoeboid pillow breccias. This unit of magnetically anomalous, massive mafic flows has no direct equivalent north of the Berry Creek shear zone. Two samples for geochemical analysis were collected from these flows in order to test the correlation of stratigraphy across the BCSZ.

The flows have SiO_2 contents in the basaltic andesite to andesite range, with 3.5-5.7 wt.% MgO (Fig. GS-11-4). They plot in the arc fields on trace element discrimination diagrams (Fig. GS-11-6), and have an arc signature on MORB-normalized trace element diagrams (Fig. GS-11-7, 8). They are, however, quite distinct from all other members of the Fourmile Island assemblage in that they have a flat chondrite-normalized REE pattern ($[La/Yb]_n$ = 1.0-1.4) with relatively low REE abundances (Yb_n = 7-9) and no Eu anomalies. These rocks also have the lowest Th/Nb ratios of any of the arc rocks (Fig. GS-11-4), intermediate between the Northeast Reed ocean-floor assemblage and Fourmile Island rocks with a strong arc signature.

Figure GS-11-10: Selective silicification of pillow margins, Unit 'E' andesites, Fourmile Island assemblage (partially underwater).

The sampled basaltic andesites differ substantially from the 'silicified andesites' in Unit 'E', with which they were provisionally correlated (Syme *et al.*, 1995). The available geochemical data thus do not support stratigraphic correlation across the BCSZ (Fig. GS-11-3). The question of how Fourmile Island assemblage rocks south of the BCSZ relate to strata north of the BCSZ is unknown, and awaits more detailed geochemical and geochronological work.

ECONOMIC IMPLICATIONS

The 1.9 Ga assemblages forming the Amisk collage include juvenile arc rocks (~60% of the exposed supracrustal rocks), juvenile ocean-floor/back-arc rocks (~30%), and minor (<10% total) ocean plateau, ocean island basalt and 'evolved' plutonic arc (Fig. GS-11-1). All economic VMS deposits that have been, or are currently being, exploited in the Flin Flon belt are hosted by arc assemblage rocks (Syme and Bailes, 1993; Bailes and Galley, 1996): no economic Cu-Zn deposits have been found in the voluminous back-arc basaltic sequences. The first-order association between juvenile arc rocks and VMS deposits provides a powerful screen to evaluate less well-known areas of the Flin Flon belt and its sub-Phanerozoic extension. The demonstration here that the Fourmile Island assemblage in western Reed Lake has arc affinity suggests that this area is highly prospective with respect to VMS deposits. Major sulphide deposits in the Reed Lake area (Spruce Point Mine, Dickstone Mine, Rail Lake deposit, Reed Lake deposit) are all within the Fourmile Island assemblage, suggesting that, like the Flin Flon and Snow Lake arc assemblages, the Fourmile Island assemblage is also mineralized. On the other hand, the area underlain by Northeast Reed ocean-floor assemblage rocks has empirically less potential to host VMS deposits, although Cu showings in Northeast Reed basalts are known.

The available geochemical data do not support the correlation of Fourmile Island assemblage stratigraphy across the Berry Creek shear zone, although the data from south of the shear zone is limited. Accordingly, at this time there is no clear indication of how the stratigraphy that hosts the Spruce Point VMS deposit relates to the arc rocks on west central Reed Lake. Further work is required to more fully characterize the geochemical characteristics of volcanic rocks south of the BCSZ, so a more definitive statement of correlation can be made.

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Appendix GS-11-1: Major element data for whole-rocks, Reed Lake

Sample	Unit	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	P_2O_5	Cr_2O_3	LOI	Mg #
Fourmile Island assemblage														
52-95-480-A	Flow, S of BCSZ	55.7	16.19	2.58	5.67	3.57	1.05	14.06	0.11	0.92	0.16	<.01	5.25	0.47
52-95-486-A	Flow, S of BCSZ	59.5	14.23	4.72	3.54	2.77	0.14	14.23	0.13	0.70	0.08	<.01	3.80	0.35
07-95-1020-1-2	silicified basalt	56.7	21.04	9.59	3.70	4.97	0.45	2.94	0.03	0.41	0.06	0.09	3.80	0.73
52-95-295-A	Unit C, flow	54.4	20.52	7.09	3.64	5.12	0.55	8.37	0.10	0.17	0.02	<.01	2.05	0.49
52-95-293-A	Unit C, rhyolite	75.9	11.86	2.45	0.60	4.25	1.03	3.61	0.06	0.18	0.06	<.01	0.45	0.27
52-95-289-A	Unit D, breccia matrix	54.0	18.32	8.80	4.04	1.70	0.23	12.22	0.20	0.41	0.05	<.01	3.50	0.42
52-95-572-A	Unit D, clast	55.3	17.63	10.14	4.49	1.73	0.31	9.77	0.17	0.35	0.06	<.01	5.15	0.50
52-95-572-C	Unit D, clast	55.2	18.05	10.04	2.65	2.47	0.43	10.53	0.17	0.37	0.07	<.01	3.60	0.36
52-95-572-B	Unit D, clast	56.7	17.69	10.27	3.86	2.27	0.56	8.07	0.14	0.35	0.07	<.01	4.70	0.51
52-95-320-B	Unit E, massive flow	67.3	10.54	3.24	3.32	1.86	2.40	10.53	0.12	0.48	0.17	<.01	5.70	0.41
52-95-336-A	Unit E, massive flow	66.6	12.29	2.19	2.31	4.12	0.87	10.72	0.11	0.63	0.14	<.01	3.45	0.32
52-95-320-A	Unit E, massive flow	68.1	12.68	2.31	2.25	4.60	0.70	8.33	0.12	0.70	0.18	<.01	3.55	0.37
Northeast Reed assemblage														
52-95-400-A	Reed Lake basalt	46.8	14.76	14.24	7.22	1.53	0.19	13.72	0.20	1.24	0.08	0.02	1.40	0.54
52-95-410-A	Reed Lake basalt	47.1	14.15	14.88	7.69	1.31	0.15	13.10	0.20	1.34	0.09	0.02	1.20	0.56
52-95-496-A	Reed Lake basalt	47.9	14.15	13.84	7.22	1.64	0.17	13.42	0.21	1.32	0.09	0.03	2.00	0.54
07-95-1007-1-1	Reed Lake basalt	48.7	15.67	13.56	6.73	1.86	0.12	11.67	0.19	1.41	0.11	<.01	1.70	0.56
52-95-494-A	Reed Lake basalt	48.4	13.80	11.83	6.49	1.48	0.08	15.87	0.22	1.66	0.12	<.01	2.30	0.47
52-95-415-A	Reed Lake basalt	48.7	17.61	8.62	5.85	3.89	0.40	13.08	0.21	1.51	0.14	<.01	0.60	0.50
07-95-1004-1-1	Reed Lake basalt	50.2	15.54	10.40	4.56	3.26	0.23	13.79	0.20	1.68	0.11	<.01	0.40	0.42
07-95-1107-1-2	Reed Lake basalt	54.6	14.47	12.18	6.77	2.03	0.07	8.51	0.15	1.15	0.09	0.01	0.65	0.64
07-95-1287-1-1	Morton Lake basalt	49.0	13.89	13.58	6.84	1.63	0.21	13.48	0.19	1.07	0.08	0.03	2.75	0.53
07-95-1286-1-1	File Lake basalt	48.8	14.01	12.02	8.20	1.68	0.11	13.80	0.22	1.03	0.08	0.03	0.75	0.57
07-95-1285-1-1	File Lake basalt	48.9	14.49	12.20	8.69	1.61	0.11	12.82	0.18	0.89	0.07	0.03	0.55	0.60
07-95-1219-1-1	Woosey Lake basalt	48.7	14.13	12.67	8.13	1.57	0.16	13.40	0.21	0.94	0.07	0.03	1.20	0.57
07-95-1218-1-1	Woosey Lake basalt	48.6	14.25	12.27	8.07	1.85	0.14	13.62	0.20	0.96	0.07	0.02	0.60	0.57
07-95-1217-1-1	Woosey Lake basalt	48.9	14.29	14.50	6.37	1.71	0.10	12.84	0.21	1.03	0.07	0.02	0.80	0.52

All by XRF; major elements (wt.%) calculated to 100% volatile free; total iron as Fe_2O_3. Mg# calculated assuming $Fe^{2+}/(Fe^{2+}+Fe^{3+})=0.9$

Appendix GS-11-2 : Trace element data (ppm) for whole-rocks, Reed Lake

	Cr	Ni	Sc	V	Pb	Rb	Cs	Ba	Sr	Ta	Nb	Hf	Zr	Y	Th	U	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Fourmile Island assemblage																														
52-95-480-A	1	17	28.7	276	1.90	6.88	0.19	206.3	77.4	0.30	1.49	1.05	37.60	15.17	0.33	0.19	2.78	6.95	1.06	4.98	1.57	0.64	2.12	0.31	2.04	0.43	1.16	0.19	1.29	0.21
52-95-486-A	2	7	37.4	352	2.19	0.89	0.04	12.2	145.4	0.57	1.78	1.05	35.32	14.90	0.29	0.11	2.53	6.29	0.90	4.80	1.50	0.56	2.09	0.36	2.62	0.59	1.73	0.28	1.75	0.28
07-95-1020-1-2	869	188	56.2	290	2.85	5.42	0.09	54.9	190.4	0.51	0.79	0.51	18.99	8.09	0.13	4.40	2.23	5.90	0.92	4.58	1.12	0.54	1.65	0.24	1.54	0.30	0.80	0.11	0.61	0.09
52-95-295-A	21	22	34.3	160	1.47	6.99	0.27	89.6	83.9	0.36	0.34	0.35	12.50	6.10	0.23	0.15	1.87	4.54	0.63	2.90	0.77	0.24	0.96	0.13	0.95	0.23	0.68	0.08	0.71	0.10
52-95-293-A	5	10	19.5	36	3.10	19.74	0.76	267.0	145.6	1.48	2.15	1.26	45.65	16.39	0.84	0.42	6.18	14.25	1.92	9.10	2.29	0.65	2.37	0.40	2.64	0.61	1.86	0.32	1.98	0.29
52-95-289-A	3	6	43.6	221	2.80	2.15	0.06	25.4	168.4	0.44	1.29	0.61	22.98	7.28	0.47	0.26	3.58	7.53	0.97	3.97	0.95	0.47	1.17	0.19	1.24	0.25	0.76	0.11	0.82	0.13
52-95-572-A	15	11	40.1	248	2.57	3.73	0.04	75.3	276.5	0.32	0.94	0.44	17.42	6.66	0.40	0.20	3.41	7.09	0.92	3.88	0.89	0.35	1.01	0.15	1.05	0.23	0.75	0.10	0.67	0.10
52-95-572-C	7	7	46.7	264	3.02	3.52	0.05	46.1	303.7	0.36	1.38	0.61	22.60	8.44	0.50	0.24	4.41	9.36	1.19	5.15	1.27	0.44	1.28	0.21	1.40	0.27	0.88	0.14	0.88	0.14
52-95-572-B	10	8	28.8	198	2.18	5.67	0.06	172.1	278.7	0.41	1.13	0.45	16.19	6.82	0.36	0.16	3.81	7.72	0.97	4.19	0.99	0.37	1.00	0.15	1.07	0.21	0.63	0.10	0.58	0.10
52-95-320-B	1	1	23.0	1	1.08	11.61	0.02	39.8	26.7	0.56	1.55	2.23	74.52	29.00	0.47	0.32	4.41	11.68	1.91	10.33	3.21	1.15	4.17	0.69	4.60	1.10	3.38	0.54	4.14	0.61
52-95-336-A	3	2	30.2	25	0.62	6.54	0.17	102.4	64.6	0.65	2.34	2.94	99.99	36.90	0.61	0.36	3.68	11.17	1.92	10.26	3.60	1.12	5.23	0.97	6.87	1.56	4.68	0.83	5.17	0.82
52-95-320-A	1	2	28.5	20	0.70	3.09	0.02	17.6	48.1	0.54	1.71	2.74	85.35	34.23	0.55	0.38	4.39	12.65	2.10	11.35	4.01	1.20	5.63	0.97	6.79	1.41	4.43	0.63	4.36	0.69
Northeast Reed assemblage																														
52-95-400-A	213	82	36.2	282	1.33	1.48	0.06	26.5	146.4	0.62	1.79	1.76	61.03	16.07	0.12	0.05	2.66	8.21	1.44	8.08	2.70	1.03	3.39	0.50	3.42	0.66	1.72	0.25	1.51	0.21
52-95-410-A	290	95	51.3	377	0.61	1.56	0.01	24.2	286.5	0.90	1.83	1.95	69.13	16.02	0.16	0.06	2.92	9.24	1.70	8.74	2.68	1.10	3.58	0.58	3.48	0.68	1.74	0.24	1.42	0.19
52-95-496-A	336	95	46.9	361	1.09	2.66	0.04	19.4	159.0	0.60	2.04	2.08	67.70	16.78	0.15	0.07	2.78	8.89	1.51	8.55	2.75	1.08	3.37	0.57	3.52	0.74	1.87	0.26	1.50	0.25
07-95-1007-1-1	133	60	35.6	304	2.24	0.73	0.04	27.8	187.9	0.86	2.35	2.17	78.21	21.66	0.16	0.11	3.03	9.57	1.67	9.42	2.98	1.11	3.94	0.66	4.32	0.86	2.38	0.34	2.17	0.31
52-95-494-A	91	62	44.6	387	2.41	0.41	0.01	16.0	170.4	0.40	2.51	2.56	87.08	22.74	0.23	0.10	3.67	11.71	1.95	10.79	3.71	1.33	4.79	0.79	4.70	1.01	2.67	0.37	2.32	0.29
52-95-415-A	72	84	47.3	427	0.94	0.90	0.03	64.8	175.8	0.89	2.73	2.48	90.48	23.46	0.21	0.27	3.80	12.13	2.10	11.22	3.71	1.21	4.76	0.81	4.73	0.96	2.59	0.36	2.36	0.33
07-95-1004-1-1	216	88	64.9	425	2.20	0.46	0.00	45.0	131.4	0.64	1.37	1.70	60.10	21.31	0.18	0.20	2.60	7.62	1.33	7.27	2.37	1.02	3.52	0.59	4.10	0.84	2.43	0.37	2.21	0.34
07-95-1107-1-2	82	51	45.8	373	1.90	11.87	0.26	61.1	166.1	0.55	2.67	2.85	102.3	23.12	0.33	0.19	3.73	12.21	2.18	11.69	3.80	1.21	4.71	0.78	5.09	1.02	2.74	0.40	2.55	0.36
07-95-1287-1-1	387	94	63.6	429	0.85	0.73	0.00	21.1	136.6	0.43	1.02	1.57	52.22	20.07	0.12	0.05	2.01	6.16	1.10	6.27	2.19	0.88	3.37	0.56	3.87	0.85	2.34	0.35	2.25	0.32
07-95-1286-1-1	270	81	50.2	323	0.66	1.29	0.21	21.5	139.3	0.38	0.94	1.52	49.30	19.89	0.14	0.06	1.88	5.91	1.06	6.07	2.29	0.89	3.18	0.56	3.87	0.81	2.18	0.35	2.15	0.34
07-95-1285-1-1	351	101	44.6	307	0.64	0.94	0.03	4.4	149.0	0.45	3.32	1.34	47.02	17.60	0.27	0.09	1.48	4.83	0.86	4.75	1.83	0.79	2.54	0.48	3.18	0.72	2.07	0.32	1.76	0.27
07-95-1219-1-1	372	92	50.9	326	0.62	1.68	0.07	26.2	162.4	0.37	0.97	1.19	39.41	17.63	0.12	0.07	1.75	5.46	0.97	5.25	1.87	0.77	2.95	0.50	3.34	0.74	2.17	0.30	2.02	0.27
07-95-1218-1-1	248	84	44.2	298	0.60	1.88	0.14	32.1	179.9	0.34	1.14	1.33	47.74	20.18	0.13	0.07	2.18	6.29	1.09	5.66	2.11	0.82	2.98	0.54	3.60	0.81	2.30	0.32	2.13	0.31
07-95-1217-1-1	274	93	49.6	335	0.48	1.25	0.04	26.6	157.6	0.68	1.47	1.48	50.81	20.59	0.15	0.12	2.10	6.47	1.13	6.15	2.32	0.90	3.39	0.60	4.04	0.81	2.49	0.36	2.34	0.30

All by ICP-MS; Y, Zr, Hf and Th by sinter ICP-MS

GS-12 SETTING OF CU-ZN-AU MINERALIZATION AT PHOTO LAKE (PART OF 63K16)

by A.H. Bailes

Bailes, A.H., 1996; Setting of Cu-Zn-Au mineralization at Photo Lake; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 66-74.

SUMMARY

Mapping of the Photo Lake area at 1:10 000 scale was completed during a four week field season. This concludes a cooperative mapping program by Manitoba Energy and Mines (MEM) and Hudson Bay Exploration and Development (HBED) begun in 1994 (Bailes and Simms, 1994). The project was designed to facilitate exploration and development on the Photo Lake property after the 1994 discovery of a Cu-Zn-Au rich volcanic-hosted massive sulphide (VMS) zone, now the Photo Lake mine. At stake was the future economic viability of the mining community at Snow Lake.

The 1:10 000 scale map of the Photo Lake area (Bailes *et al.*, 1996a) covers a 25 km² area, and shows that the Photo Lake VMS deposit occurs within a different stratigraphic setting than other VMS deposits at Snow Lake area. This is significant as it suggests a potentially new and relatively unexplored target for further investigation. Mapping at Photo Lake has identified the VMS 'mine horizon' and several areas of strongly altered rocks that are likely related to the Photo Lake 'mineralizing event'. The mine-hosting stratigraphy trends north of the map sheet indicating that this area has considerable VMS potential.

INTRODUCTION

Supracrustal rocks at Snow Lake are part of the Flin Flon greenstone belt, one of the largest Paleoproterozoic VMS districts in the world. Recent investigations have shown that the central Flin Flon greenstone belt consists largely of 1.92-1.88 Ga tectonostratigraphic assemblages that were amalgamated to form an accretionary collage ('Amisk collage') prior to emplacement of 1.87-1.83 Ga granitoid plutons (Lucas *et al.*, 1996; Fig. GS-12-1). Juvenile *ca.* 1.89 Ga arc volcanic rocks in the eastern Flin Flon belt at Snow Lake are isotopically distinct from those at Flin Flon (Stern *et al.*, 1992) and probably developed separately from those at Flin Flon, possibly upon an Archean microcontinental fragment (Stern *et al.*, 1995; Lucas *et al.*, 1996).

The eastern Flin Flon assemblages are currently interpreted by Syme *et al.* (1995) to have been tectonically juxtaposed against already accreted rocks of the 'Amisk collage' during 1.84-1.80 Ga southwest-directed collision of rocks of the Kisseynew domain with those of the

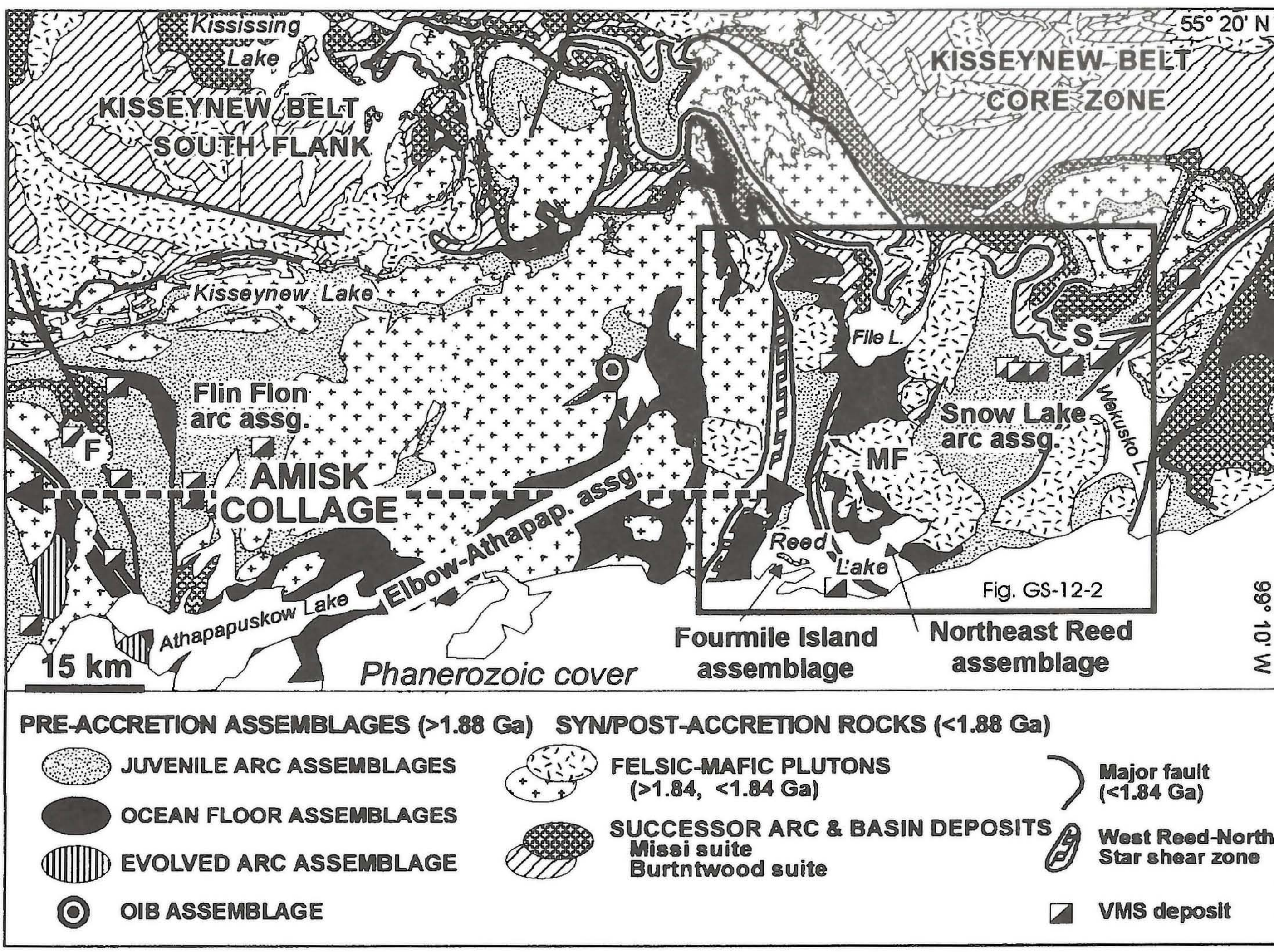

Figure GS-12-1: Simplified geological map of the central and eastern portion of the Flin Flon belt showing major tectonostratigraphic assemblages and plutons, and locations of mined VMS deposits. F: Flin Flon, S: Snow Lake, ML: Morton Lake fault zone. Rectangle shows outline of area depicted in Figure GS-12-2.

Flin Flon belt. The VMS-hosting Snow Lake arc assemblage (Fig. GS-12-2), in which the Photo Lake area occurs, is interpreted to be one of several allochthons in a thrust stack formed during the 1.84-1.80 Ga deformational event (Syme *et al.*, 1995, 1996).

The >6 km thick VMS-hosting oceanic arc sequence at Snow Lake records, in its stratigraphy and geochemistry (Bailes and Galley, 1996), a temporal evolution from a relatively more primitive to an evolved arc (Fig. GS-12-3). VMS deposits at Snow Lake can be subdivided into Cu-rich, Zn-rich and Cu-Zn-Au types. Cu-rich deposits, mainly at Anderson and Stall lakes, occur in a flow-dominated, bimodal (basalt-rhyolite) sequence dominated by primitive arc tholeiite. Zn-rich types (*e.g.* Chisel Lake) occur in a volcaniclastic-dominated, relatively more evolved sequence. The recently discovered Cu-Zn-Au rich VMS deposit at Photo Lake also occurs in the more evolved arc sequence but within a rhyolite-dominated section. The relationship between the evolved arc-hosted Photo Lake Cu-Zn-Au rich and the Chisel Lake Zn-rich mineralization is not known, although Bailes and Simms (1994) tentatively suggest that the Photo Lake deposit may be hosted by younger strata than those at Chisel Lake. Mapping in 1996 at Photo Lake was undertaken to fill a gap between 1:5000-1:10 000 scale coverage of the Chisel Lake (Bailes *et al.*, 1995b) and the Photo Lake (Bailes *et al.*, 1996a) areas.

PHOTO LAKE GEOLOGY

The Photo Lake area (Bailes *et al.*, 1996a; Fig. GS-12-4) consists largely of *ca.* 1.89 Ga metavolcanic and associated synvolcanic intrusive rocks, intruded by the synkinematic Chisel Lake layered mafic to ultramafic pluton. All rocks are overprinted by lower to middle almandine amphibolite facies mineral assemblages produced during a *ca.* 1.81 Ga regional metamorphic event that reached approximately 5 kb and 535° C at Photo Lake (Menard and Gordon, 1995). Although all rocks are metamorphic those that have recognizable primary features are referred to by their original names without metamorphic prefixes.

The volcanic and sedimentary rocks at Photo Lake include an 'older' and 'younger' sequence. The 'older' sequence consists largely of felsic flows, volcaniclastic rocks and gneisses whereas the 'younger' sequence comprises dominantly mafic voclaniclastic rocks of the Threehouse formation.

Bailes and Simms (1994) report evidence for a potential unconformity at the base of the younger Threehouse sequence, which they suggest explains angular truncation of 'older ' stratigraphic units at its base. A corollary of this interpretation is that the pre-Threehouse rocks must have been tilted (deformed) and eroded prior to deposition of the Threehouse sequence raising the possibility that the Photo Lake 'mine horizon' could be truncated at the base of this sequence.

Older volcanic rocks

Older volcanic rocks at Photo Lake occur on the north limb of a major east southeast trending syncline (Fig. GS-12-4) that is cored by the younger Threehouse formation. The older volcanic rocks consist mainly of massive felsic volcanic rocks and lesser amounts of heterolithologic mafic and felsic breccia, with minor amounts of mafic flows and local synvolcanic bodies of quartz and quartz-feldspar porphyry. No reliable stratigraphic section for these rocks has been recognized, in part due to a combination of poor quality outcrops (moss and lichen covered), massive monotonous lithologies, absence of reliable facing directions, and obliteration of subtle primary features during widespread synvolcanic hydrothermal alteration and subsequent regional metamorphism. This is in sharp contrast to comparable pre-Threehouse strata on the south limb of this syncline that at Chisel Lake display a well defined, dominantly north facing stratigraphy with many volcaniclastic units and ubiquitous facing criteria. The dramatic contrast between the older, pre-Threehouse section, on the south limb of the syncline (at Chisel Lake) and on the north limb of the syncline (at Photo Lake) is a significant, but as yet unexplained, feature of Snow Lake geology.

In the absence of a well defined stratigraphy, the legend for pre-Threehouse strata in the Photo Lake map area (Bailes *et al.*, 1996a; Fig. GS-12-4) is arbitrarily given in order from mafic to felsic compositions. The following description of units is also given from mafic to felsic, without regard to stratigraphic order.

Undivided basalt, basaltic andesite and fine grained amphibolite

Mafic flows are a minor rock lithology in the Photo Lake map area. The only volumetrically significant unit is centred on Bolloch Lake. It consists mainly of massive aphyric basalt and basaltic andesite flows with lesser pillowed flows and amoeboid pillow breccia. These flows typically contain 1-10%, 2-30 mm quartz amygdales. Locally the flows are intercalated with thin, volumetrically minor volcaniclastic units including heterolithologic mafic breccia, mafic scoria lapilli tuff and mafic wacke. Bedding in the mafic wacke indicate the Bolloch Lake basalt to be a steep dipping, south to southwest facing unit. The Bolloch Lake basalt varies in width from less than 300 m wide at the north border of the map sheet to 1.3 km east of Bolloch Lake. This over 7 km long unit is abruptly truncated 3 km east of Bolloch Lake by a north trending fault. Offset on this fault is significant as the Bolloch Lake basalt is not repeated in the map area to the east. The presence of large amygdales in the basalt and intercalation with scoria lapilli tuff suggest that it is more likely to have been deposited in a moderately shallow environment than in a deep water environment.

One other unit of basalt occurs in the pre-Threehouse sequence, and it is exposed only in a single tiny exposure 4.3 km northeast of Bolloch Lake. The main significance of this porphyritic pillowed basalt unit is that it is in the middle of the monotonous felsic sequence that hosts the Photo Lake VMS deposit and provides the only reliable facing direction (SE) available in this economically important volcanic section.

Undivided mafic volcaniclastic rocks

Thick units of mafic heterolithologic breccia occur in three localities in the Photo Lake map area: northeast of Bollock Lake, stratigraphically overlying the Bolloch Lake basalt, and stratigraphically overlying the Photo Lake mine 'horizon'. Minor amounts of mafic volcaniclastic rocks, including mafic wacke and scoria lapilli tuff, are also intercalated with the Bolloch Lake basalt.

The unit of breccia northeast of Bolloch Lake is composed dominantly of plagioclase phyric mafic volcanic fragments. Over 50% of this mafic breccia is silicified and feldspathized. Altered breccia has a bleached appearance, resembles an intermediate to felsic rock, and contains 10-40% acicular 2 to 7 mm amphibole porphyroblasts. Fragments in the altered breccia are commonly nebulous, and in most strongly altered varieties are no longer distinguishable from the matrix. The mafic breccia forms a >600 m wide unit that trends north of the map area an undetermined distance and is truncated to the southeast by a body of fine grained felsic rocks and a north-trending fault. The domain of fine grained felsic rocks is cored by quartz-feldspar porphyry. Because these felsic rocks cut across stratigraphy they may be intrusive; however, at outcrop scale they are indistinguishable from fine grained felsic rocks that elsewhere are mapped as extrusive.

Up to 200 m of mafic heterolithologic breccia outcrop south of, and stratigraphically above, the Bolloch Lake basalt. They are composed mainly of aphyric basalt and basaltic andesite fragments, with lesser amounts of aphyric mafic scoria blocks and rare angular rhyolite and porphyritic basalt clasts. Many of the aphyric basalt clasts contain large quartz amygdales, and are similar in appearance to quartz amygdaloidal basalt flows in the stratigraphically underlying Bolloch Lake basalt. Portions of this unit of mafic breccia are silicified and feldspathized. This alteration varies from selective alteration of individual fragments to widespread alteration of sections up to 70 m thick.

A north-trending, up to 90 m wide, unit of heterolithologic mafic breccia occurs in the middle of the felsic section that hosts the Photo Lake VMS deposit. The breccia has a highly variable clast population that is dominated by aphyric and plagioclase phyric basalt and basaltic andesite. These mafic clasts display a wide range in both phenocryst and amygdale size and abundance. Mafic scoria lapilli and blocks, although a minor component in the breccia, indicate derivation from a source terrane that included pyroclastic material. The mafic breccia is relatively unaltered, in contrast to strong alteration of felsic rocks to the west. This is significant because it indicates that the hydrothermal event that affected the felsic rocks to the west ceased before deposition of the mafic breccia. We suggest that the alteration that effects the felsic rocks to the west was likely produced by the hydrothermal event responsible for the Cu-Zn-Au sulphide mineralization at the Photo Lake mine. A corollary of this is that the unexposed interval between the unaltered mafic breccia and the altered felsic rocks is the Photo Lake 'mine horizon'.

Undivided dacite, andesite flows

Medium to dark grey green weathering, massive, aphyric, quartz amygdaloidal volcanic rocks occur within the dominantly felsic domain directly east and northwest of Ghost Lake. They display irregular and often gradational contacts with the felsic rocks, and are internally variable in colour and composition. In the past these rocks have been mapped as mafic to intermediate flows (Harrison, 1949; Williams, 1966; Bailes and Galley, 1992) but chemical analyses indicate that they are typically dacitic in composition. Their irregular distribution, gradational contacts and internal variability is consistent with them being altered rocks, with one interpretation being that they are simply chloritized equivalents of the bounding rhyodacite and rhyolite lithologies. This interpretation is also consistent with their high alkali contents. The question then is whether this lithology is a discrete map unit or whether the characteristically high vesicle and gas cavity content simply controlled primary permeability and, consequently, a higher degree of alteration by through-going hydrothermal fluids.

Powderhouse dacite

An up to 250 m wide unit of plagioclase phyric dacite tuff and lapilli tuff outcrops 1.8 km southwest of Bolloch Lake. The dacite and an associated heterolithologic breccia are identical to the 'Powderhouse dacite' that forms the stratigraphic footwall to the Chisel Lake area Zn-rich VMS deposits. The dacite tuff northwest of Bolloch Lake is typically massive, pale buff weathering and characterized by 5-15%, 0.5-3 mm plagioclase phenocrysts and small plagioclase phyric felsic fragments. The up to 60m wide unit of breccia to the northeast is composed of a mixture of felsic and mafic clasts. Felsic fragments in this breccia are commonly plagioclase phyric and texturally identical to the fine grained massive dacite tuff. Although no facing directions were identified in the Powderhouse dacite southwest of Bolloch Lake, the unit likely tops to the southwest. This is because bounding mafic wacke units top to the southwest and because the heterolithologic breccia, which is near the base of the type Powderhouse section south of Chisel Lake, is located on the northwest side of the unit.

Many of the dacite and the associated heterolithologic breccia outcrops are strongly altered. Altered dacites are characterized by 5-30% garnet and 10-60% amphibole porphyroblasts; the most altered outcrops locally contain up to 5% disseminated pyrite. Because this unit forms the stratigraphic footwall to the Zn-rich VMS deposits in the Chisel Lake area, this alteration may be economically significant.

There are some structural and stratigraphic problems with the section that underlies the Powderhouse dacite southwest of Bolloch Lake. The major problem is that the mafic wacke unit that apparently underlies the Powderhouse dacite appears to correlate with the younger Threehouse sequence. Bailes and Simms (1994) speculate that the section may include layer-parallel faults.

Undivided rhyolite, dacite and felsic metavolcanic gneiss

The older volcanic sequence at Photo Lake is dominated by felsic volcanic rocks. Most of these felsic rocks are aphyric to sparsely porphyritic nondescript massive units, that locally include portions that are distinctly quartz phyric, or include minor breccia and quartz amygdales. The two largest domains of undivided felsic volcanic rocks occur in the vicinity of Bolloch and Ghost lakes. The relationship of these felsic rocks to the Photo Lake rhyolite, host to the Photo Lake Cu-Zn-Au VMS deposits, is not known as they are separated by faults with indeterminate offsets.

At Bolloch Lake the undivided felsic rocks form approximately half of an over 1.3 km thick sequence, with the remainder of the sequence consisting of intercalated units of the previously described Bolloch Lake basalt and a variety of heterolithologic mafic volcaniclastic units. Distribution of the intercalated mafic volcaniclastic rocks indicates an overall northwest strike to the stratigraphy, that is also recorded more subtly in the distribution of felsic units. Rare facing directions in the Bolloch Lake section are consistently to the southwest, but interpreting the entire section as southwest facing is risky due to the scarcity of top indicators. The abundance of felsic rocks increases to the northwest of Bolloch Lake reflecting an along strike thinning of the intercalated basalt and heterolithologic mafic breccia units. There is also a less pronounced, southwest (upward?) increase in felsic rocks. Primary structures and phenocryst are typically not well preserved in massive felsic units north of Bolloch Lake due to strong recrystallization during regional metamorphism. Units south of Bolloch Lake, which are less strongly recrystallized, can locally be demonstrated to consist of domains (lobes?) of massive rhyolite and intervening domains of monolithologic breccia (microbreccia?). In general the felsic volcanic rocks in the Bolloch Lake area are aphyric to sparsely porphyritic. Alteration of the felsic volcanic rocks is common, but is most prominent in the area just north of Bolloch Lake. Amygdaloidal 'dacites' north of Chisel Lake may represent altered equivalents of the undivided felsic rocks at Bolloch Lake.

At Ghost Lake the undivided felsic rocks are similar to those that occur in the Bolloch Lake area north of Chisel Lake. They are typically aphyric to sparsely porphyritic massive rhyolite with interspersed irregular domains of amygdaloidal 'dacite'. The rhyolite locally contains domains with prominent quartz amygdales, supporting an interpretation that the amygdaloidal 'dacites' are simply altered equivalents of the rhyolites.

Photo Lake rhyolite, felsic metavolcanic gneiss

The Photo Lake rhyolite consists of a monotonous sequence of massive aphyric to sparsely porphyritic felsic rocks and derived felsic gneisses. They locally contain quartz amygdales and quartz-filled gas cavities. This, and local observation of massive lobes and intervening microbreccia, is consistent with the rhyolites being mainly flows. This unit hosts the Cu-Zn-Au rich Photo Lake VMS deposit.

No internal subdivisions of the Photo Lake rhyolite were mapped and no facing directions for these strata were observed. The only indication of the strike of units is provided by a north-northwest trending unit of heterolithologic mafic breccia. The rhyolites are tentatively interpreted to top to the east-northeast on two imperfect criteria. One indication of topping direction is that rhyolites to the west of the unit of heterolithologic mafic breccia are strongly altered whereas the mafic breccia is relatively unaltered. This suggests that the mafic breccia was deposited after the hydrothermal event that effects the western rhyolite package. This topping direction is consistent with the occurrence of strongly altered 'footwall' rocks on the southwest side of the Photo Lake VMS (pers. com. HBED geologists, 1994).

Although Photo Lake rhyolites appear the same in the field, they comprise two suites; one with low Zr contents (averaging 25 ppm), and another with high Zr contents (averaging 85 ppm). The two suites show no systematic distribution. Both suites display the same elevated LREE contents, weak Eu depletion anomalies and flat HREE profiles.

Many outcrops of the Photo Lake rhyolite display the effects of alteration. Altered rocks contain prominent porphyroblasts of garnet, acicular amphibole, biotite and chlorite. A prominent zone of altered rhyolite occurs 700 m northwest of the Photo Lake VMS deposit. These altered rocks typically contain 15-30%, 2-12 mm garnet and 5-40%, 1-6 mm dark green amphibole porphyroblast in irregular patches and anatomosing veins. They also contain 2% sulphides, mainly pyrrhotite with some pyrite and rare chalcopyrite. This zone of alteration has been traced over 1 km to the north in a series of widely spaced, generally small outcrops. Rocks in three small outcrops in this zone, at the north edge of the map area, consist entirely of garnet, chlorite and biotite; they closely resemble 'pipe-like' alteration that is normally found only in the immediate footwall of massive sulphide deposits elsewhere in the Snow lake area. Other zones of altered rocks, present north and west of the Photo Lake deposit, are much weaker, typically composed of sucrosic felsic rocks with 1-3%, 0.5-1 mm garnet and 2-8%, 1-4 mm pale green amphibole porphyroblasts.

Heterolithologic felsic breccia

Only one mappable unit of heterolithologic felsic breccia occurs in the Photo Lake area. This 150 m wide unit outcrops northwest and east of Bolloch Lake, and is bounded to the northeast and southwest by undivided felsic rocks. It is composed dominantly of felsic clasts,

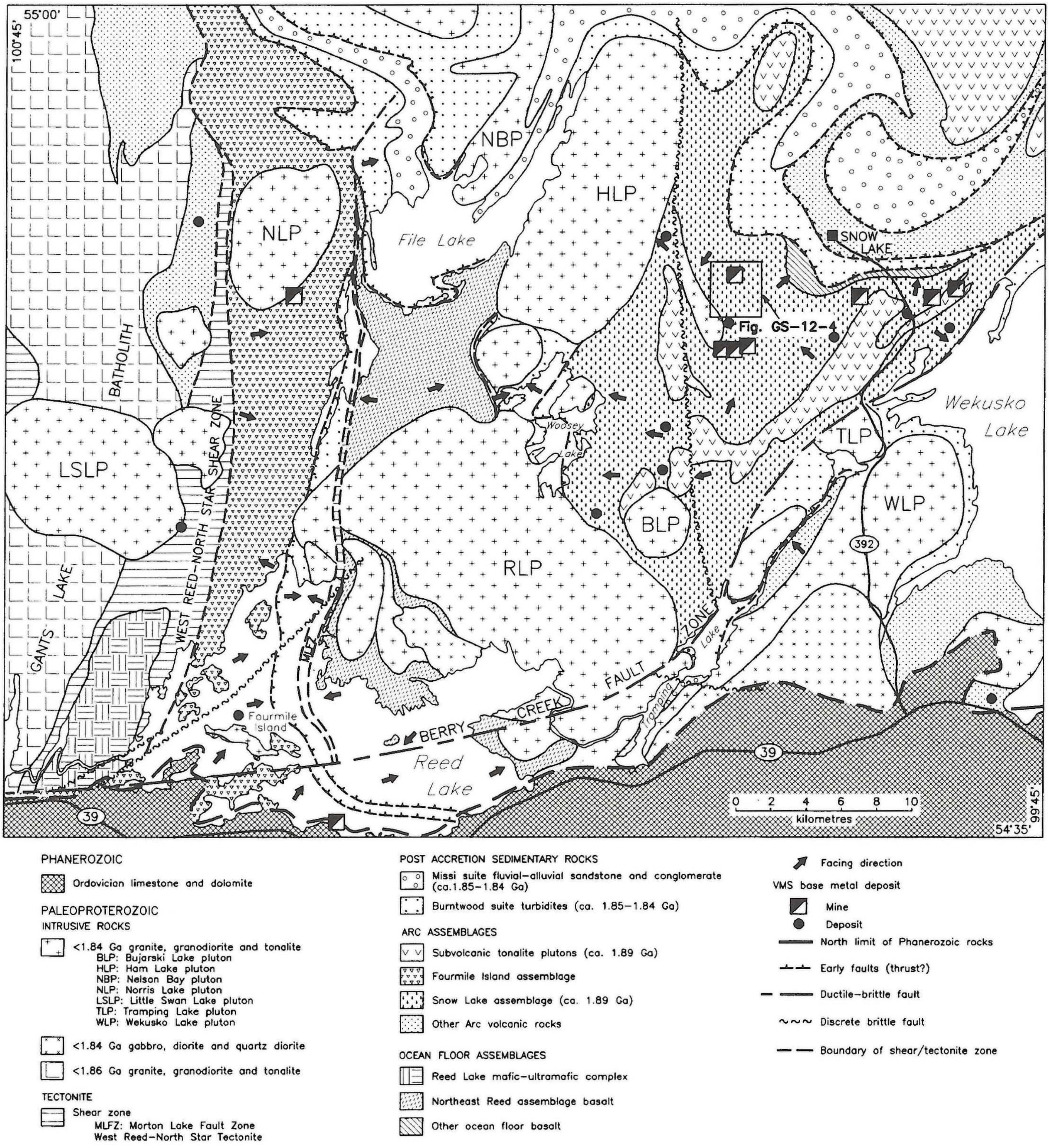

Figure GS-12-2: Simplified geology of the Reed Lake-Wekusko Lake area, modified from Syme et al. (1995,1996), Morrison et al., (1996), Bailes et al. (1994), Froese and Moore (1980), Rousell (1970), Harrison (1949) and Stanton (1945). The Morton Lake fault zone (MLFZ) is interpreted to be the structural contact between the Amisk collage and various tectonostratigraphic assemblages of the Snow Lake area. Rectangle shows outline of the Photo Lake map area. Simplified geology of the Photo Lake map area is shown in Figure GS-12-4.

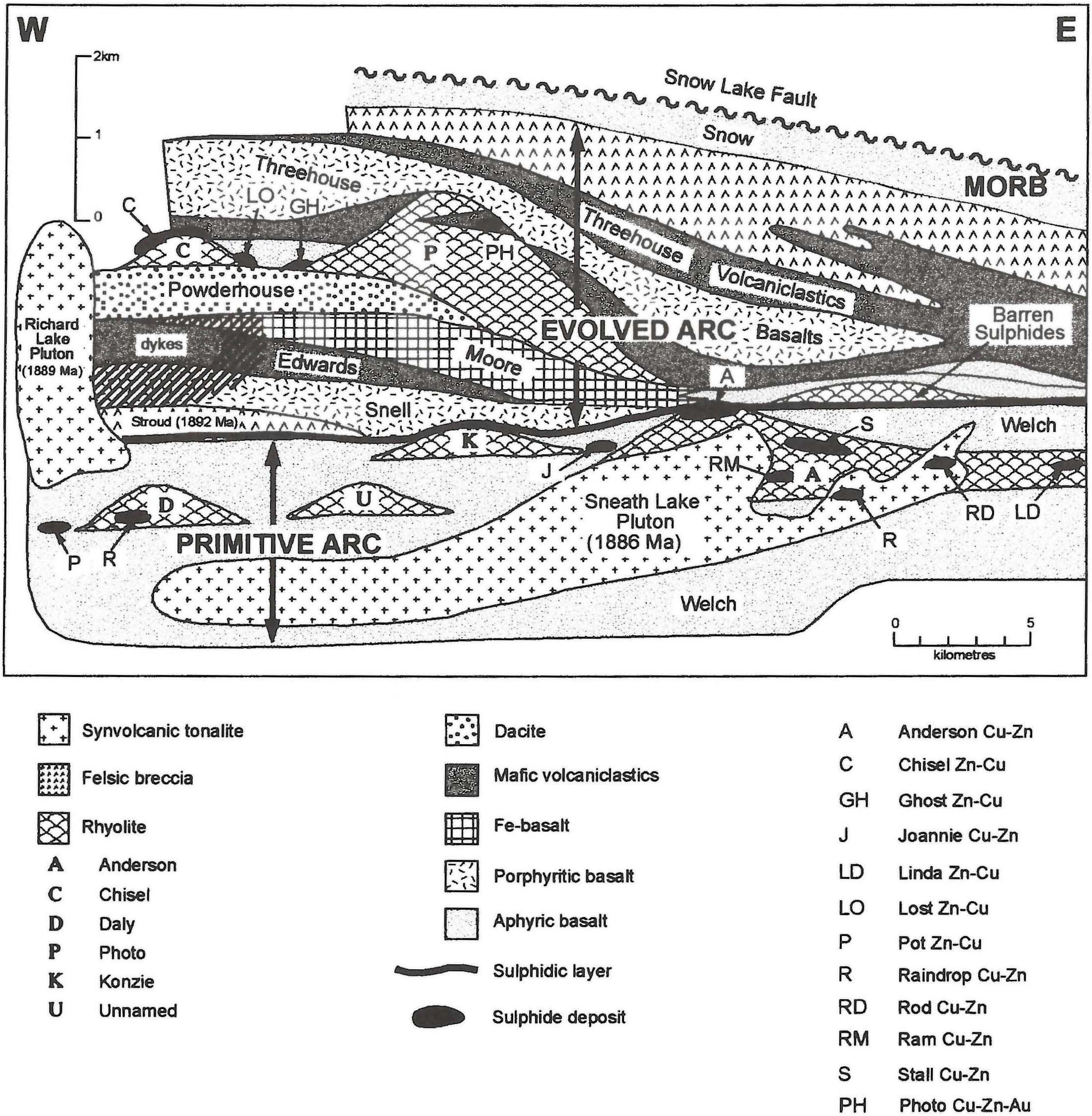

Figure GS-12-3: Schematic geological cross section of the Snow Lake arc assemblage. The Snow Lake arc assemblage is subdivided into a Primitive (or Proto) arc and Evolved arc, and is overlain by basalts with N-MORB geochemistry. The Primitive arc is a bimodal basalt-rhyolite sequence that includes the subvolcanic Sneath Lake tonalite intrusive complex. The Evolved arc is a more heterogeneous sequence, with up to 50% volcaniclastic detritus, that includes a prominent subvolcanic dacite dyke complex and the Richard Lake tonalite pluton.

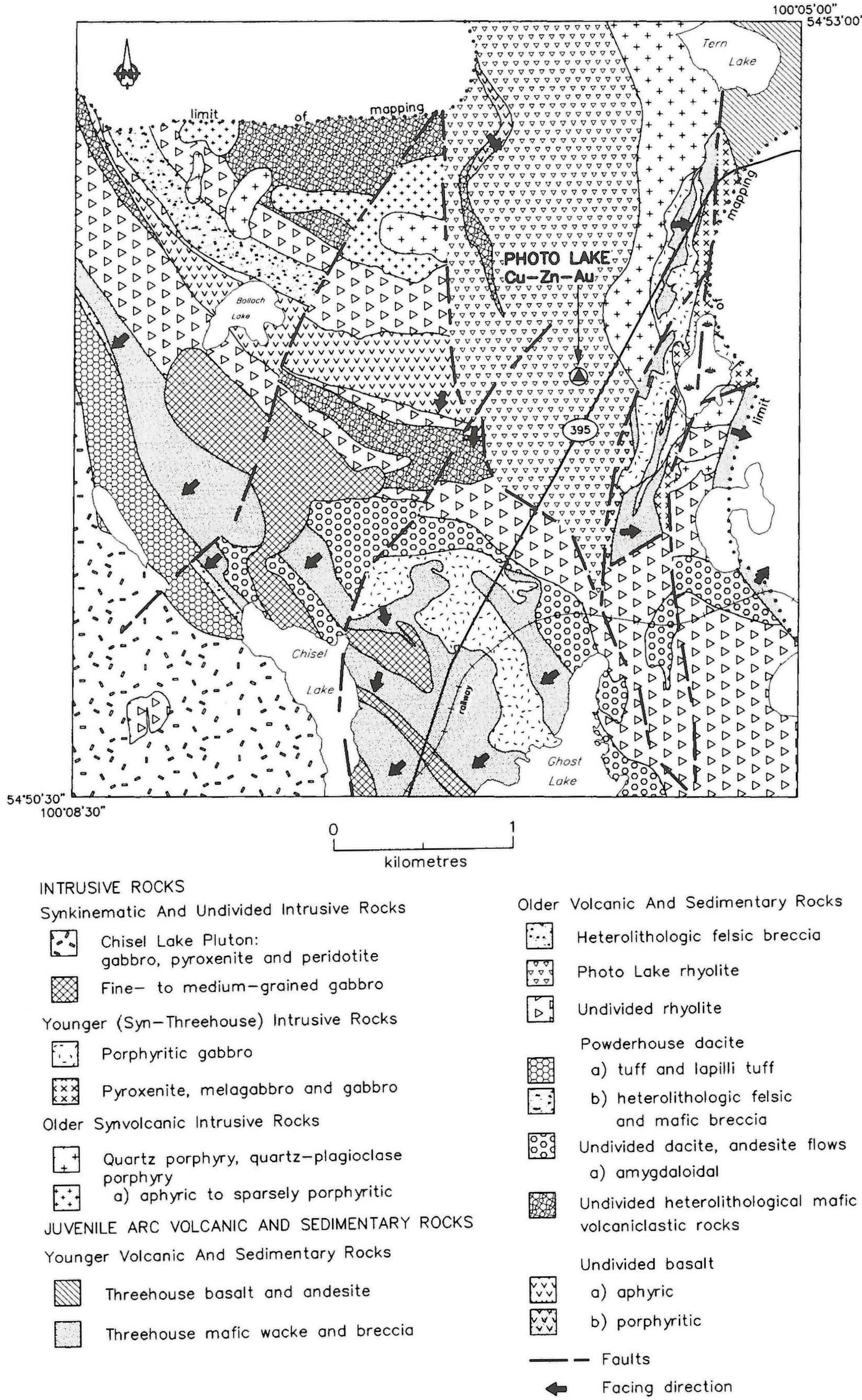

Figure GS-12-4: Simplified geology of the Photo Lake area from Bailes et al. (1996a).

most of them coarsely quartz phyric, but does include up to 10% mafic clasts. The quartz phyric clasts, which contain 5-7%, 1-5 mm quartz phenocrysts, texturally resemble the quartz porphyry that intrudes undivided felsic rocks and the heterolithologic mafic breccia to the northwest. This suggests that the quartz porphyry bodies were shallow, synvolcanic intrusions.

Quartz porphyry, quartz-plagioclase porphyry

Plugs and sills of quartz and quartz-feldspar porphyry occur throughout the Photo Lake area. The largest single body is a sill-like intrusion over 350 m wide and over 2 km long located north of the Photo Lake VMS deposit. Most other intrusions occur north of Bolloch Lake where they form bodies up to 300 m in diameter. Although the quartz porphyry and quartz-plagioclase porphyry bodies may vary in age, most of them appear to be early, possibly synvolcanic, as they are cut by gabbro intrusions that can be linked to overlying extrusive volcanic rocks.

The sill-like intrusion north of the Photo Lake VMS deposit is a massive, featureless, fine grained rock with 4-8%, 1-6 mm quartz and 1-4%, 0.5-3mm plagioclase phenocrysts. The pre-Threehouse age of this intrusion is evident from: 1) rare cobbles of this intrusion in the overlying Threehouse mafic wackes, and 2) cross cutting porphyritic gabbro dykes that are demonstrably synvolcanic with overlying Threehouse basalt. The eastern margin of this intrusion is commonly rusty weathering.

Small stocks and plugs of quartz porphyry and quartz-feldspar porphyry north of Bolloch Lake are considered to be synvolcanic. This is consistent with the presence of clasts of these intrusions in overlying heterolithologic felsic breccia to the southwest. We suggest that much of the spatially related alteration in the section of volcanic rocks near Bolloch Lake may be due to emplacement of these synvolcanic felsic intrusions. Zones of disseminated pyrite are common in these intrusions; some have prominent exploration trenches.

The origin of massive fine grained felsic rocks spatially associated with the Bolloch Lake quartz porphyry and quartz-feldspar porphyry intrusions is uncertain. Although these rocks are indistinguishable from extrusive aphyric to sparsely porphyritic felsic volcanic rocks, their irregular contacts and apparent cross-cutting distribution suggest that they may be in part intrusive. They contain zones of disseminated pyrite comparable to that occuring in the porphyritic intrusions.

Younger volcanic, sedimentary and intrusive rocks

In the Photo Lake area the younger volcanic sequence consists of mafic wacke, mafic breccia, pillowed porphyritic basalt\basaltic andesite, and synvolcanic gabbro intrusions. These rocks are exposed along the south and east margins of the map area. Those at the south margin of the map area occur in a northwest-trending synclinal fold interference structure, 6 km long and 2.5 km wide (locally known as the Chisel basin). Those exposed east of the Photo Lake mine site are at the base of an over 0.5 km thick homoclinal sequence that mainly outcrops east of the map area. In both domains, Threehouse mafic rocks are relatively unaltered and, thus, postdate the prominent synvolcanic hydrothermal event that effected the underlying 'older' volcanic rocks. Since the hydrothermal event is interpreted to be related to the mineralizing episode that produced the Chisel Lake and Photo Lake area base metal sulphide deposits, the Threehouse formation in the Photo Lake map area is not considered prospective for VMS deposits. At Chisel Lake the Threehouse mafic wackes directly and conformably overlie the Chisel Lake mine horizon. Near Photo Lake they appear to unconformably overlie and possibly truncate the Photo Lake ore-hosting stratigraphy (Bailes and Simms, 1994).

Threehouse mafic wacke and breccia

Well bedded mafic wacke forms almost all of the Threehouse formation in the 'Chisel basin', whereas it composes only the basal 100 m of this formation east of Photo Lake. The mafic wacke displays excellent graded bedding, load structures, scour channels and A, AB and ABE Bouma bed zonation, consistent with deposition in a subaqueous environment from turbulent density currents. Inconsistent with this environment of deposition, Bailes (1987) reported the presence of accretionary lapilli in the Threehouse mafic wackes in the Chisel basin. Re-examination of the 'accretionary lapilli' during this project indicates that these structures are post depositional as they locally overprint laminations in the mafic wacke. They are either diagenetic or metamorphic in origin.

Upward coarsening of the Threehouse mafic wacke sequence in the Chisel basin, recorded by a gradual increase in both grain size and bed thickness, indicates a likely increase in topographic relief of the source terrane. Rare preservation of scoria clasts, abundant prominently amygdaloidal basalt clasts in coarser beds, and limited compositional and textural range of detritus suggests that the source may have been a volcanic construct, possibly in part erupted under shallow water to subaerial conditions. The upward coarsening of the sequence could reflect growth of this volcanic construct. Clasts in breccia beds are texturally indistinguishable from intercalated pillowed mafic flows.

Threehouse basalt and basaltic andesite

Pillowed basalt and basaltic andesite flows dominate the upper part of the Threehouse section east of Photo Lake, but only occur sporadically in the Chisel basin section. They include both pyroxene and pyroxene-plagioclase phyric flows that are texturally identical to clasts preserved in breccia beds in Threehouse mafic volcaniclastic rocks, suggesting a common magmatic source for both rock lithologies.

East of Photo Lake the Threehouse section is dominated by mafic flows, whereas in the Chisel basin section it is dominated by mafic volcaniclastic rocks. One interpretation is that the section east of Photo Lake preserves a more proximal portion of this unit than that in the Chisel basin.

Threehouse mafic intrusions

Irregular bodies of porphyritic gabbro and melagabbro are common in Threehouse mafic wackes north of Chisel Lake and east of the Photo Lake mine site. These intrusions include plagioclase phyric gabbro, plagioclase and pyroxene phyric gabbro, melagabbro and pyroxenite. Most intrusions are composed of texturally and compositionally uniform gabbro, but some intrusions show textural and compositional variations that likely reflect crystal settling in a single body. The textural and compositional variation in these intrusions is comparable to those in the overlying Threehouse pillowed basalt and basaltic andesite flows.

Shallow emplacement of the gabbro intrusions is suggested by scattered (<1%) 1-3 mm quartz amygdales and by local prominent zones of quartz amygdales. For example, one of the large intrusions in the Chisel basin has a highly vesicular 3-5 m wide contact phase in which there are 20-30% 2-7 mm quartz amygdales that occur both randomly and in bands. A synvolcanic emplacement of the gabbro intrusions is conclusively demonstrated by the local presence of pepperites. A particularly well developed pepperite is located 30 m east of Photo Lake at the contact of a melagabbro-pyroxenite body with Threehouse mafic wacke. The gabbro displays contorted and amoeboid contacts at all scales, including chilled selvage-like contacts. The gabbro is also present as highly irregular fragments in the mafic wacke, and bedding in the mafic wacke is disrupted and contorted in contact with the gabbro. Theses features are consistent with the gabbro being intruded into unconsolidated, water-saturated Threehouse mafic wacke.

Threehouse formation plagioclase and plagioclase-pyroxene phyric gabbro intrusions at Photo Lake are different in size and shape within the Photo Lake rhyolite and quartz-feldspar porphyry than they are in the adjacent Threehouse mafic wacke. In the competent Photo Lake rhyolite and quartz-feldspar porphyry they are present as 10-30m wide dykes that cut 'stratigraphy' at a high angle, whereas in the Threehouse mafic wacke they form irregular sill-like bodies up to 100 m thick and 1.5 km long. This suggests that after exiting dykes in the underlying competent rock, the mafic magmas ponded in shallow chambers in the unconsolidated water-saturated Threehouse mafic wackes.

The presence of the gabbro intrusions at the base of the Threehouse sequence at Photo Lake and related feeder dykes in the underlying Photo Lake rhyolite indicates that these sequences are structurally intact. A further consequence of this line of reasoning is that angular truncation of the Photo Lake stratigraphy and the quartz-feldspar porphyry intrusion at the base of the Threehouse mafic wackes is most logically interpreted to have been a consequence of an unconformity at the base of the Threehouse formation (Bailes and Simms, 1994). Rare cobbles of the quartz-feldspar porphyry near the base of the Threehouse formation support an unconformable contact.

STRUCTURE

Folds

Recent structural studies in well bedded sedimentary rocks and derived paragneisses (*e.g.* Kraus and Williams, 1995) suggests the following folding episodes have effected rocks of the Snow Lake area between 1840-1800 Ma: F_1 tight isoclinal folds with an associated muscovite cleavage, F_2 folds with a cleavage that is syn- to post-regional metamorphism, F_3 open folds (NNE trending) with an axial planar crenulation cleavage, and rare F_4 folds that are restricted to an area north of Snow Lake. Because the massive rhyolites at Photo Lake do not generally display internal layering or obvious facing directions, the presence or absence of these folds (particularly F_1 or F_2 isoclinal folds) is not immediately obvious. However, we suggest that significant F_{1-2} folds have not affected rocks in the immediate vicinity of the Photo Lake mine because synvolcanic Threehouse gabbro dykes in the Photo Lake rhyolite sequence are relatively undeformed.

Despite the apparent absence of large scale early isoclinal folds in the immediate vicinity of the Photo Lake mine, the host volcanic rocks are strongly deformed. This deformation is recorded by well developed schistosities and prominent stretching lineations. Two prominent cleavages are recognized; an earlier cleavage that generally strikes west-northwest and dips moderately to shallowly to the north-northeast and a younger cleavage that strikes north-northeast and dips steeply. The earlier cleavage is locally deformed by open F_3 folds whereas the younger cleavage is axial planar to the F_3 folds. In well bedded Threehouse mafic wackes of the 'Chisel basin' the early cleavage is locally axial planar to northwest moderate plunging isoclinal (F_{1-2}?) folds. The prominent, ubiquitous stretching lineation in Photo Lake rocks, which is probably a product of combined F_{1-2} and F_3 deformation, plunges moderately to shallowly to the north-northeast.

Faults

Faults locally offset the stratigraphy in the Photo Lake area, but because they have little or no expression in outcrop and occur in monotonous sequences, their along strike definition is poorly constrained. Although most of the faults have only minor offset, and simply jostle the units, the north-trending fault in the centre of the map area separates two very different successions. To the west of this fault there is a south- to southwest-facing mixed-lithology package, whereas to the east there is an east- to northeast-facing rhyolite-dominated package. Recognition of this fault is important as it truncates and offsets the ore-hosting Photo Lake rhyolites.

SETTING OF PHOTO LAKE VMS DEPOSIT

The Photo Lake Cu-Zn-Au VMS deposit occurs within a different stratigraphic setting than other VMS deposits in the Snow Lake area and therefore represents a potentially new and relatively unexplored target. Previous exploration at Snow Lake has targeted either Anderson\Stall-type Cu-rich VMS mineralization, hosted by primitive arc rhyolite bodies, or Chisel-type Zn-rich VMS deposits, spatially associated with evolved arc rhyolite bodies. Photo Lake mineralization is different as it is hosted by evolved arc rhyolite, but is characterized by very high Cu and Au contents.

The Photo Lake deposit is hosted within the largest rhyolite domain in the Snow Lake area, the Photo Lake rhyolite. Until the discovery of the Photo Lake deposit, this domain of rhyolite was generally considered to have low VMS potential. The impact of this discovery was of immediate economic significance to the local economy of the town of Snow Lake, but it is perhaps more important to the local mining community as an indication that this rhyolite domain is much more prospective for economic VMS deposits than was previously considered.

Mapping in the Photo Lake area has identified the location of the Photo Lake VMS 'mine horizon' and several areas of strongly altered rocks that are likely related to the Photo Lake 'mineralizing event' (see above). The map (Bailes *et al.*, 1996a) shows that the mine-hosting stratigraphy trends north of the map sheet indicating that this area has considerable VMS potential. We recommend that a careful approach to tracing VMS mineralization in the Photo Lake area is required as ubiquitous faults may offset the 'mine horizon' and an unconformity at the base of the Threehouse formation may truncate favourable stratigraphy.

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GS-13 DETAILED GEOLOGICAL MAPPING IN THE CENTRAL PORTION OF THE PIPESTONE LAKE ANORTHOSITE COMPLEX

by L.S. Jobin-Bevans[1], D.C. Peck and N.M. Halden[1]

Jobin-Bevans, L.S., Peck, D.C. and Halden, N.M., 1996: Detailed geological mapping in the central portion of the Pipestone Lake Anorthosite Complex: **in** Manitoba Energy and Mines, Mineral Resources Division, Report of Activities, 1996, p. 75-84.

SUMMARY

The Pipestone Lake Anorthosite Complex (PLAC) is a Late Archean (2758 ± 3 Ma; U-Pb zircon age determination, Corkery *et al.*, 1992), sill-like layered intrusion that is currently being examined for its potential as a source of titanium, iron and vanadium. Detailed mapping of the PLAC (1:200 scale) was carried out over a period of four weeks during the 1996 field season as part of an M.Sc. Thesis (University of Manitoba). The purpose of the detailed mapping is to refine previously completed 1:2500 scale mapping (Peck *et al.*, 1994b and Jobin-Bevans *et al.*, 1995) and to obtain a better understanding of the relationships between individual layers and/or lithostratigraphic zones of the PLAC. Three areas in the central portion of the PLAC were chosen: (1) a northern area covering the mid- to upper-portion of the M2 zone (Disseminated Zone), the leucocratic L3 zone, and the lower portion of the M3 zone (North Contact Zone); (2) a region within the centre of the PLAC incorporating the upper portion of the M1 zone and the leucocratic L2 zone; and, (3) a southern area that encompasses the lower portion of the A1 zone. Detail area 1 (DA-1) was chosen because it offers the best exposure of the cryptic magnetite-ilmenite layering in the M1 zone and the mineralized North Contact Zone. Detail area 2 (DA-2) offers excellent exposure of the contacts between individual layers in the PLAC and provides evidence for magma chamber dynamics. Detail area 3 (DA-3) was chosen because it is the only area where 'football' anorthosite is exposed.

IINTRODUCTION

The PLAC, one of several anorthosite bodies that occurs within, or proximal to, the Cross Lake greenstone belt, is currently being explored for Ti-Fe-V oxide mineralization (Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc.). This report describes the results of detailed geological mapping (1:200 scale) that focused on three outcrop areas in the central portion of the PLAC (Fig. GS-13-1). The aim of this program is to obtain a better understanding of the relationships between individual layers and/or lithostratigraphic zones in the PLAC, thereby gaining a better understanding of the petrogenesis of the intrusion.

The PLAC is interpreted to be north-facing based on several observations, including truncation of layering and size-graded layers. The general stratigraphy of the PLAC has been described in previous reports (Cameron, 1992; Peck *et al.*, 1994a; Jobin-Bevans *et al.*, 1995). The stratigraphy has been subdivided into mappable and internally consistent zones (Peck *et al.*, 1994a and 1994b). Detailed descriptions of the geology of the PLAC, as well as descriptions of type lithostratigraphic sections and individual rocks types are provided by Cameron (1984, 1985, 1986, 1992), Peck *et al.* (1994a), and Jobin-Bevans *et al.* (1995). Rock names are based on field observations and characteristics and are pending petrographic and geochemical confirmation.

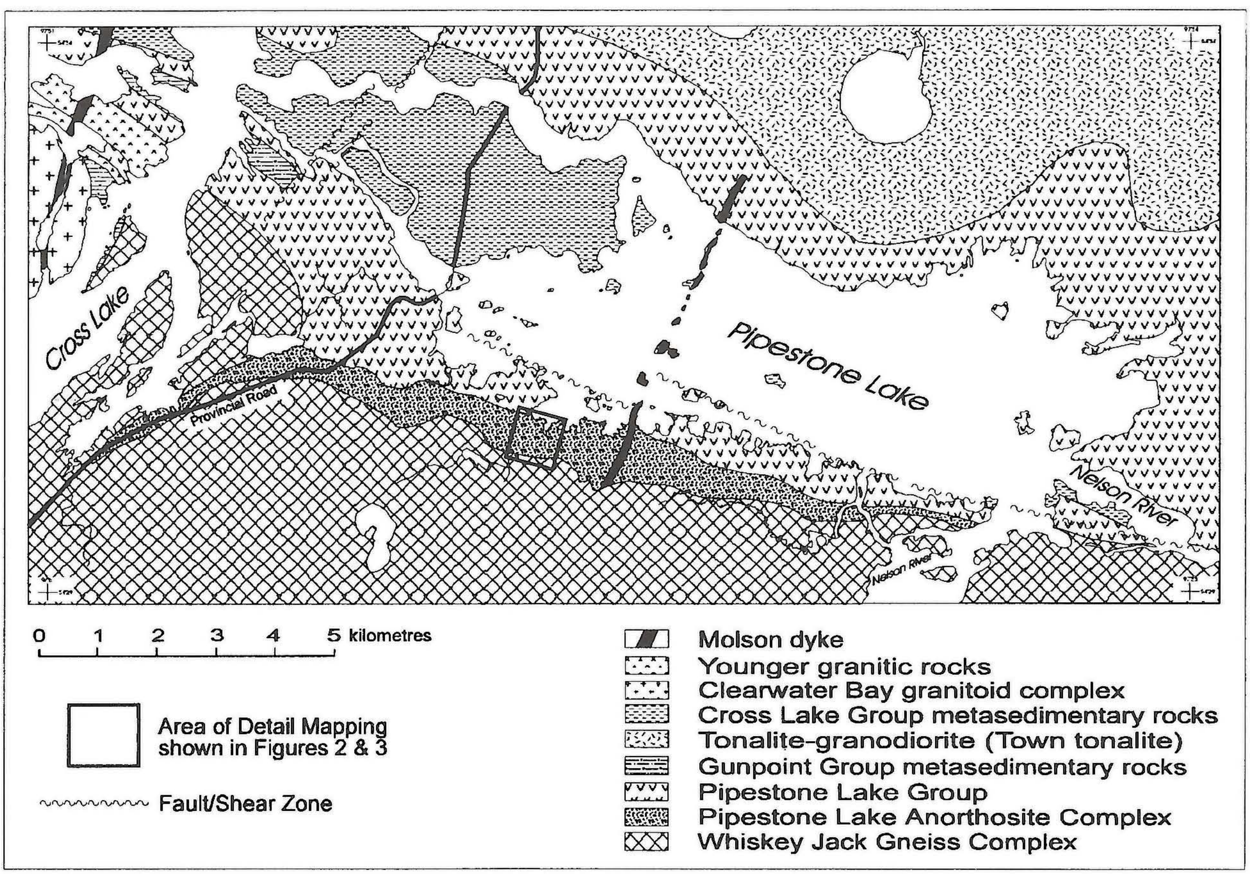

Figure GS-13-1: General geology of the Pipestone Lake area showing the locality in which detailed mapping was carried out (modified after Cameron, 1992).

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DETAIL MAP AREA 1

Detail area 1 (DA-1; Fig. GS-13-2) offers the best exposure of the mineralized Disseminated and North Contact Zones (NCZ) and includes rock types from the M2, L3 and M3 lithostratigraphic zones. Rock units within the exposed M2 zone include; ilmenite- and magnetite-bearing melagabbro, modally layered pyroxenite-gabbro-leucogabbro, modally layered pyroxenite-melagabbro-gabbro and a plagioclase-phyric diabase dyke. A general stratigraphic section through the M2 zone is shown in Figure GS-13-3. The ilmenite-magnetite bearing melagabbro is representative of the mineralized Disseminated Zone and consists of fine- to medium-grained oxide-bearing melagabbro with narrow (<1 cm to 5 cm), discontinuous layers of pyroxenite and rare patches of coarse grained plagioclase pyroxenite. The northernmost occurrence of the oxide-bearing melagabbro exhibits a high ilmenite:magnetite ratio with only patchy and sporadic magnetism. Conversely, the southernmost portion of this unit consists of melagabbro that displays cryptic variation in the ilmenite:magnetite ratio. Although the M2 zone dominantly comprises ilmenite-bearing melagabbro, there are at least 5 distinct layers of magnetite-dominant melagabbro, the contacts of which are defined by distinct changes in magnetism. These changes in the ilmenite:magnetite ratio likely represent changes in the chemistry and/or oxygen fugacity of the magma during crystallization.

A single plagioclase-phyric diabase dyke occurs in the lowermost portion of the exposed M2 zone. The dyke, with a maximum exposed width of 7.0 m and strike length >15 m, comprises pale-brown weathering, subhedral, plagioclase phenocrysts (<5 to 10%) <1 mm to slightly >1 cm across. Contacts with the oxide-bearing melagabbro unit are sharp and planar, and well-developed chilled margins occur within the dyke. This dyke is similar to many of the others described within the PLAC (*e.g.* Jobin-Bevans *et al.*, 1995) that were emplaced following solidification of the M2 zone (melagabbro) magma. The contact between the M2 and overlying L3 zone is poorly exposed and appears to be defined by a narrow east-west trending shear zone.

Rock units within the exposed L3 zone include massive leucogabbro and massive anorthosite. The massive leucogabbro consists of medium grained plagioclase and amphibole with <10% total oxides (ilmenite > magnetite). A generalized stratigraphic section through the exposed L3 zone is shown in Figure GS-13-4. Cross-cutting the near-massive anorthosite are veins and clots of ilmenite-bearing pyroxenite. The oxide-rich veins pinch and swell, are up to 5 cm in width, generally east-trending, and increase in frequency northward toward the contact with the overlying melanocratic M3 zone. In general, the oxide-rich clots consist of interdigitated, coarse grained, euhedral plagioclase and ilmenite within a medium grained mafic (amphibole) matrix (Fig. GS-13-5). The veins and clots appear to have been derived from the overlying oxide-bearing melanocratic zone (M3 zone) and precipitated from fluids that penetrated the anorthosite along fractures.

The contact between the leucocratic L3 and melanocratic M3 zone is sharp and scalloped. A thin layer (<15 cm) of medium grained gabbro that occurs at the stratigraphic top of the L3 zone, is locally truncated by the overlying pyroxenite of the M3 zone (Fig. GS-13-6). This provides evidence for a north-facing intrusion and a northward younging of the upper portion of the L3 and M3 zones.

Rock units within the melanocratic M3 zone include; ilmenite-rich pyroxenite ± garnet-amphibole schist, modally layered leucogabbro-gabbro, modally layered garnetiferous pyroxenite-gabbro-melagabbro and massive anorthosite. A generalized stratigraphic section through the exposed M3 zone is shown in Figure GS-13-4.

The ilmenite-rich pyroxenite, modally layered leucogabbro-gabbro and modally layered, garnetiferous pyroxenite-gabbro-melagabbro are representative of the mineralized North Contact Zone. Concentrations of oxides (>30% oxides with ilmenite > magnetite) occur along the contact between the massive anorthosite and gabbro of the L3 zone. Massive- to semi-massive ilmenite, as pods and blebs up to 5 cm wide, appear to be concentrated within topographic lows along the scalloped contact with the L3 zone. In general, the upper portion of the M3 zone displays crude rhythmic layering with cyclicity approximated by pyroxenite →melagabbro →leucogabbro, as well as an overall increase in plagioclase feldspar, northward. Dispersed throughout these cyclic layers are medium grained, red to pink, subhedral garnets (up to 30%) and approximately 20% disseminated oxides (ilmenite > magnetite).

DETAIL MAP AREA 2

Detail area 2 (DA-2) is located along the western shoreline of Sakimesak Bay (Fig. GS-13-2). This detail area is underlain by rock types from the M1 and L2 lithostratigraphic zones and offers some of the best exposed and accessible outcrops in the complex. A generalized lithostratigraphic section is shown in Figure GS-13-7.

Major rock units within the M1 zone include oxide-bearing melagabbro and oxide-bearing gabbro. Locally, oxide concentrations approach 50% where they have become tectonically concentrated in pyroxenite along the M1-L2 contact. Where exposed, the M1-L2 contact is sheared.

The L2 zone consists of several major rock units including: magnetite-bearing leucogabbro, poikilitic anorthosite with localized and discontinuous layers of megacrystic anorthosite, oxide-enriched poikilitic anorthosite, megacrystic anorthosite, and leucogabbro. The lowermost magnetite-bearing leucogabbro occurs at the contact with the M1 zone. This unit is medium grained, contains up to 10% disseminated magnetite > ilmenite and is gradational into poikilitic anorthosite. The oxide-enriched poikilitic anorthosite comprises patches and discontinuous layers of near-massive magnetite > ilmenite. A near-massive to semi-massive layer of oxide-rich pyroxenite is continuous for over 30 m in strike length and has a maximum thickness of up to 0.5 m. The predominant rock types in DA-2 are megacrystic anorthosite that has a dominantly mafic matrix, and megacrystic anorthosite that has a dominantly leucocratic matrix. In both of these units, the megacrysts display flow orientation with the majority of the long axes of the megacrysts oriented in a east-west direction. Overlying these megacrystic units is a medium grained leucogabbro interlayered with relatively continuous layers of megacrystic anorthosite, up to 1.0 m in width.

A disrupted block, 2 metres wide and about 4 metres in length, occurs within the central portion of DA-2 (Fig. GS-13-8). This block consists of several layers that can be correlated with the major rock types in the detail area including magnetite-leucogabbro, poikilitic anorthosite, magnetite-rich poikilitic anorthosite including a semi-massive magnetite layer, and megacrystic anorthosite. The block is bordered on the east, west and north by a megacrystic unit that has a garnet-amphibole- and oxide-rich matrix. This surrounding megacrystic unit possesses distinct flow textures and oriented megacrysts. The position of the block and its relationship with the surrounding lithologies suggests that the block was separated during the intrusion of a younger magma pulse.

Other evidence of magma dynamics is a scour located within the megacrystic and poikilitic anorthosite of the L2 zone (Fig. GS-13-9). The scour occurs at the contact between the underlying megacrystic anorthosite and a garnet-amphibole-rich megacrystic unit. The scour is concave-north, suggesting a northward younging direction in this area.

DETAIL MAP AREA 3

Detail area 3 (DA-3) is located about 50 m north of the southern contact between the A1 zone of the PLAC and the Whiskey Jack Gneiss Complex (Fig. GS-13-10). This area is underlain by megacrystic 'football' anorthosite, megacrystic gabbro, and tonalite-granodiorite dykes. The only exposure of megacrystic 'football' anorthosite in the PLAC occurs in this area. The 'football' anorthosite unit consists of >95% euhedral, plagioclase feldspar megacrysts, that range from about 6.5 cm to 32.5 cm (average 13 cm) in diameter. A few of the larger megacrysts (<5%) appear to be glomeroporphyritic. Crude size grading is displayed by an overall decrease in the megacryst diameter (from 32.5 cm to 3.0 cm), northward. This size decrease is accompanied by an increase in the frequency of gabbroic patches within the matrix material (Fig. GS-13-11). Oxide mineralization that occurs as massive blebs of magnetite > ilmenite is common throughout the mafic matrix. Flow differentiation, defined by the concentration of megacrysts into parallel layers up to 20 cm in width (Fig. GS-13-12), occurs in the megacrystic gabbro. White- to grey-weathering, tonalitic- to granodioritic-dykes crosscut the foliation of the megacrystic gabbro.

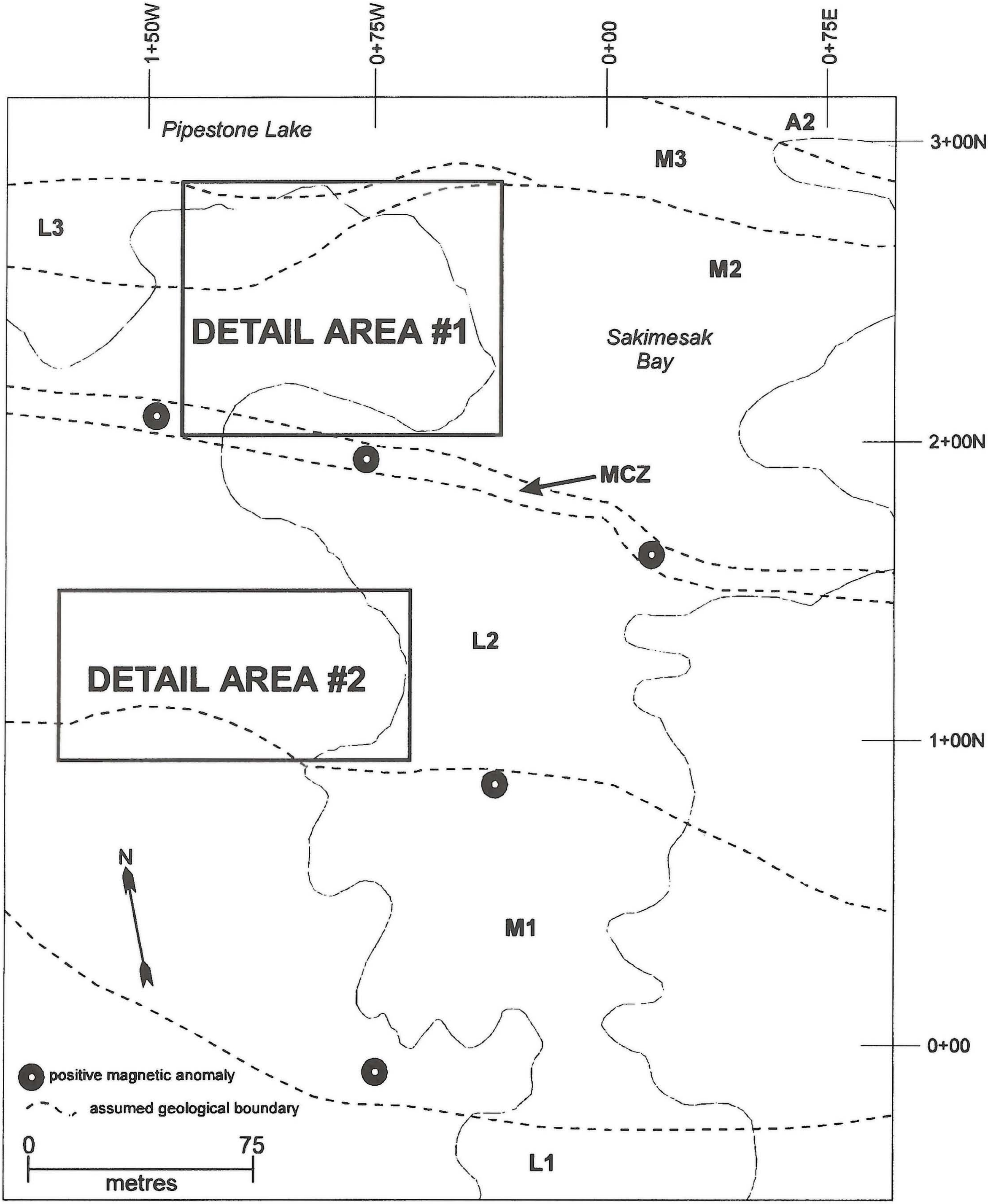

Figure GS-13-2: Location of detailed map areas DA-1 and DA-2 within the central portion of the Pipestone Lake Anorthosite Complex. Zone boundaries and nomenclature are based on Jobin-Bevans et al., 1995.

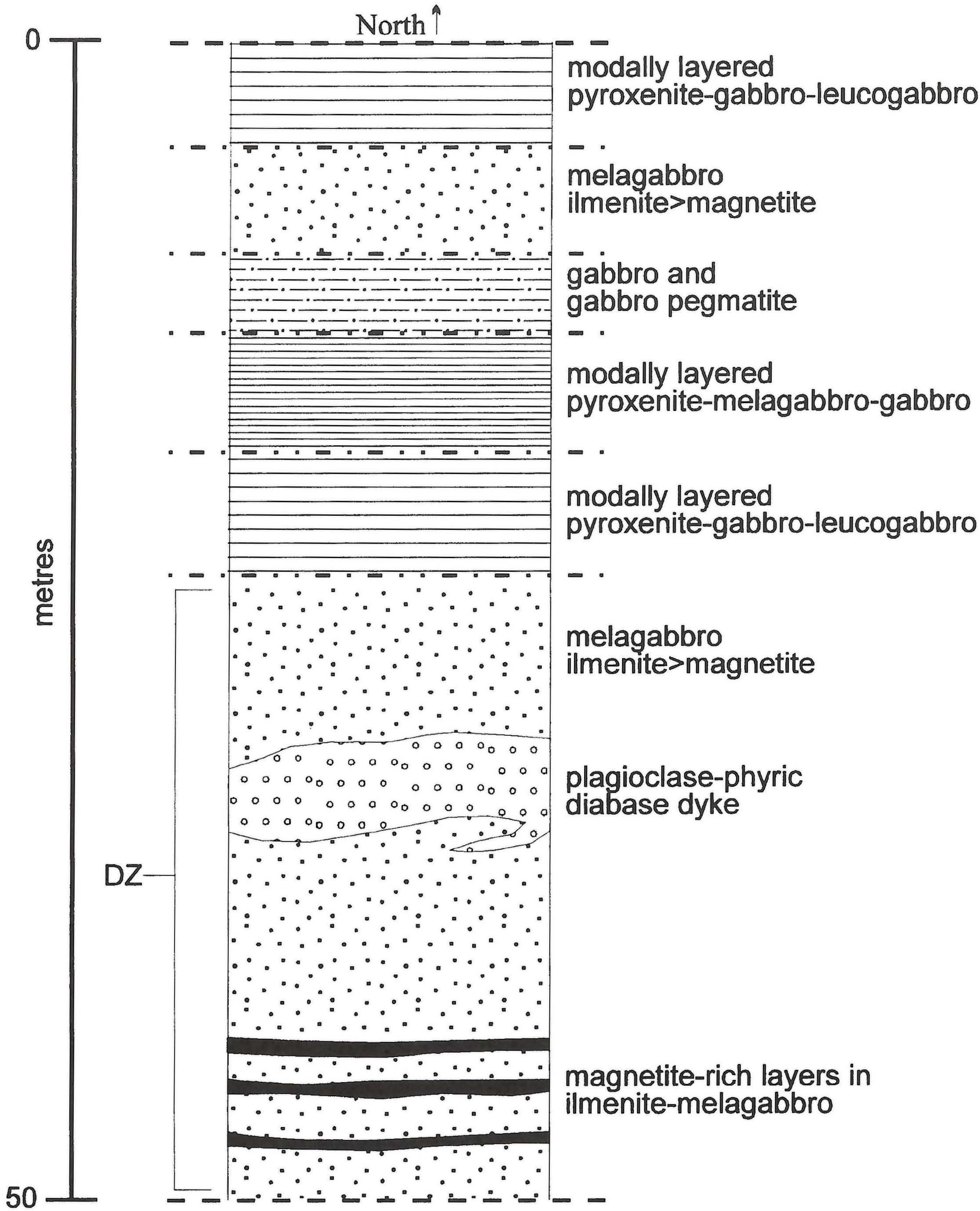

Figure GS-13-3: Simplified stratigraphy of the M2 zone based on the exposure in detail map area 1. DZ = Disseminated Zone.

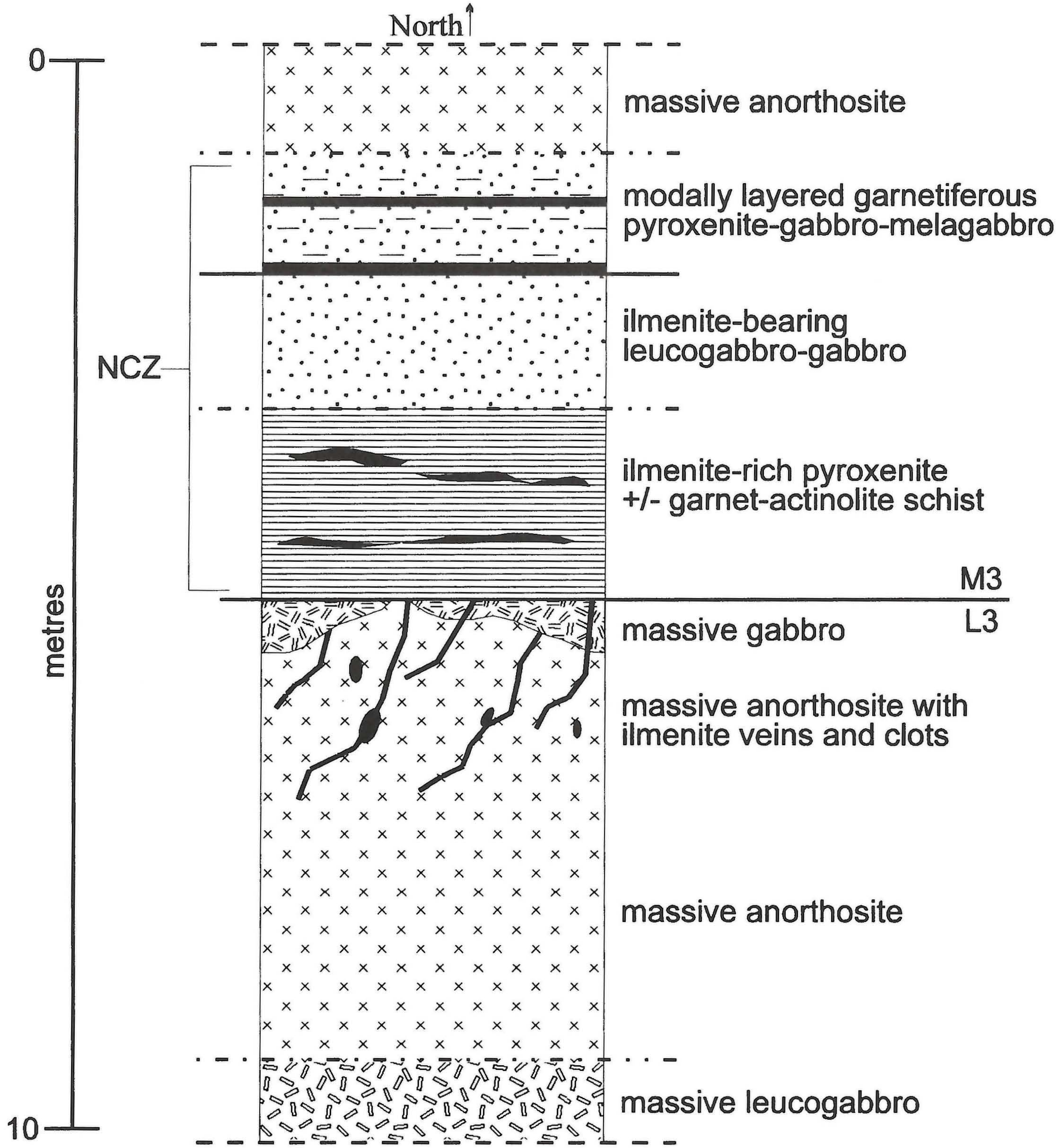

Figure GS-13-4: Simplified stratigraphy of the leucocratic L3 and melanocratic M3 zones, based on the exposure in detail map area 1. NCZ = North Contact Zone.

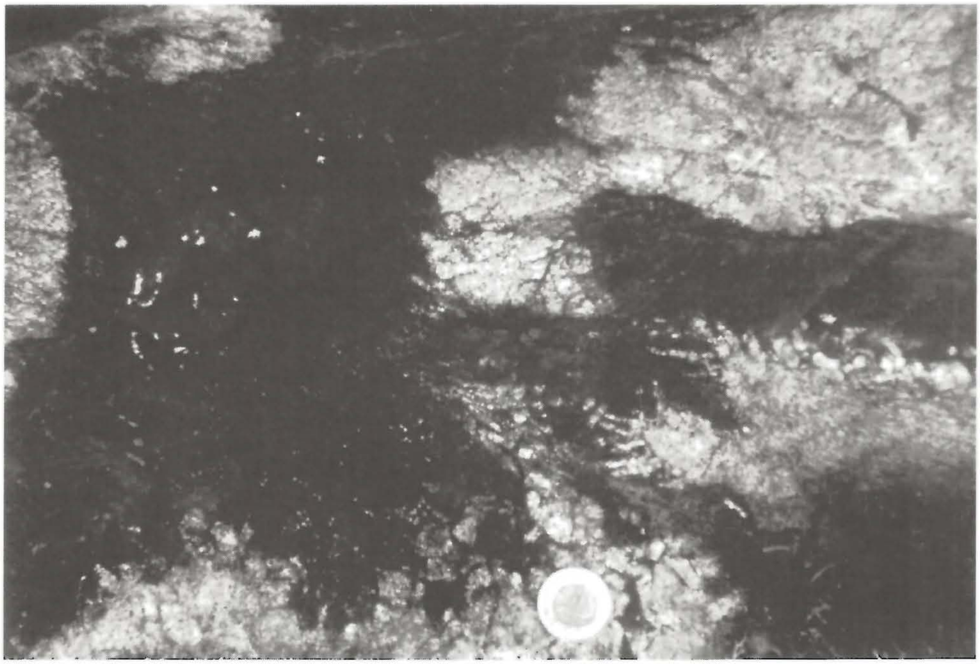

Figure GS-13-5: Oxide-rich (ilmenite > magnetite) mafic clots and veins within massive anorthosite of the L3 zone, detail area 1. Note the coarse-grained, plagioclase feldspar penetrating the mafic and oxide-rich vein material in the central clot.

Figure GS-13-6: Sharp, scalloped contact between the leucocratic L3 and melanocratic M3 zones. Note the narrow layer of gabbro, occurring at the stratigraphic top of the L3 zone, that is locally truncated by pyroxenite of the overlying M3 zone.

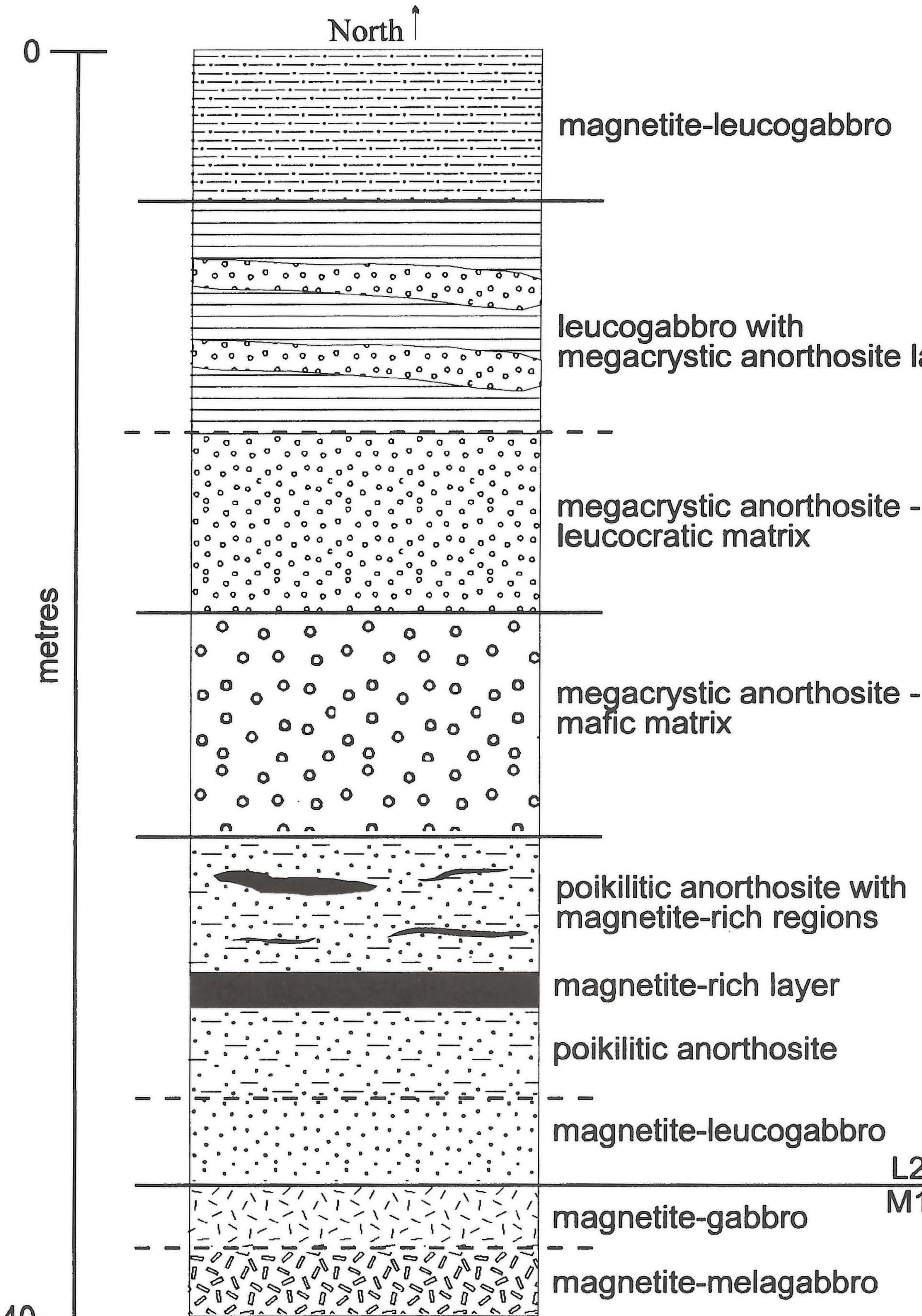

Figure GS-13-7: Simplified stratigraphy of the melanocratic M1 and leucocratic L2 zones, based on the exposure in detail map area 2.

Figure GS-13-8: Disrupted layering in the L2 zone, detail area 2. The continuity of the layers in the block can be traced to the southeast and southwest within the surrounding lithologies. The block is isolated on three sides by a megacrystic plagioclase-bearing unit with a garnet-amphibole-rich matrix.

Figure GS-13-9: Megacrystic anorthosite and poikilitic anorthosite of the L2 zone, detail area 2. Primary igneous contacts are preserved, along with a garnet-amphibole-rich scour (dark central area in the photograph). North is to the left of the photograph.

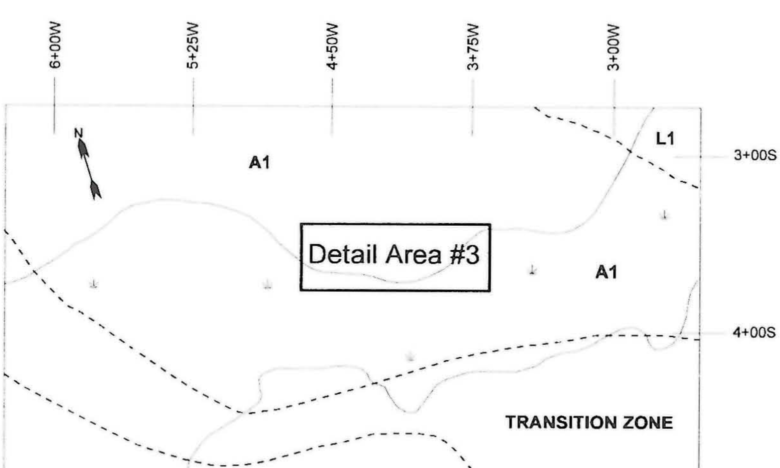

Figure GS-13-10: Location of detail map area DA-3 within the central portion of the Pipestone Lake Anorthosite Complex. Zone boundaries and nomenclature are based on Jobin-Bevans et al., 1995.

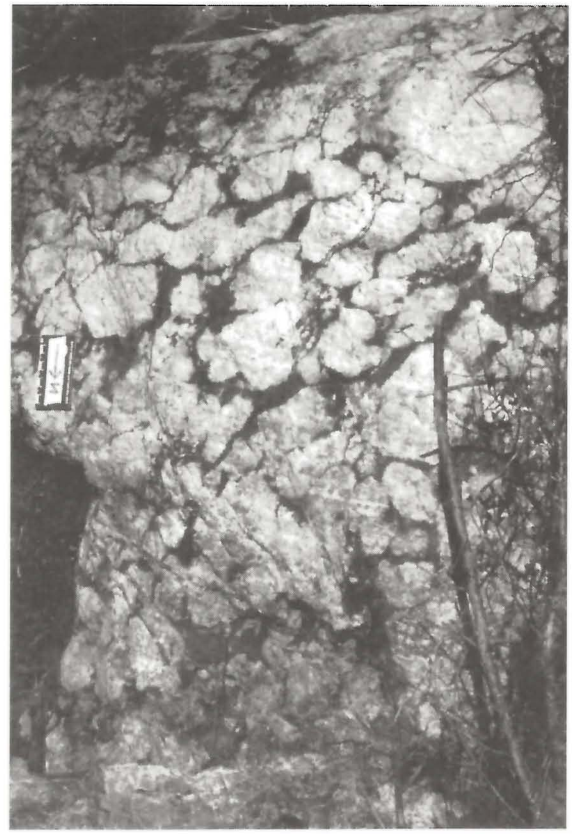

Figure GS-13-11: 'Football' anorthosite of the A1 zone. Crudely developed size-grading is present, with an overall decrease in the megacryst diameter (from 32.5 cm to 3.0 cm), northward. This size decrease is accompanied by an increase in the frequency of gabbroic patches within the matrix material.

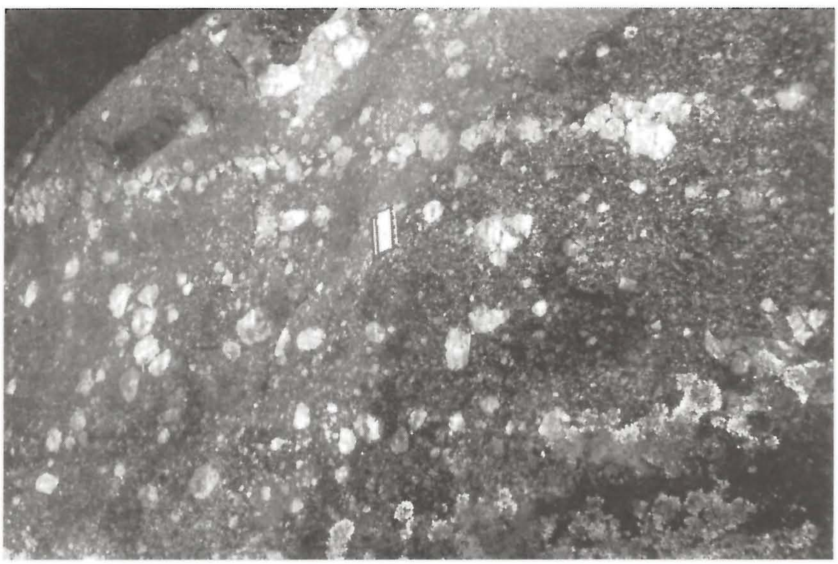

Figure GS-13-12: Megacrystic gabbro of the lowermost A1 zone. Flow differentiation is present, defined by the concentration of megacrysts into parallel layers up to 20 cm in width.

The megacrystic 'football' anorthosite is exclusive to the central portion of the intrusion and occurs near the base of the A1 zone, within the thickest portion of the complex. This, along with its spacial association with the megacrystic gabbro, implies that these units may have settled and/or crystallized within a topographic low in the magma chamber. The large megacrysts may have accumulated or pooled within this topographic low and continued to crystallize until their present size was attained. The size grading also provides further support for a north-facing intrusion or at least a northward younging direction in the A1 zone.

CONCLUSIONS

Observations recorded during the detailed mapping indicate the complex is north-facing and formed from multiple magma pulses in a dynamic magma chamber. Size-graded layering and truncation of layers support the interpretation that the complex is north-facing. Evidence to support a dynamic magma chamber includes the form of disrupted layers and crystal flow differentiation, and changing younging directions within individual lithostratigraphic zones suggest multiple magma pulses.

During the mapping, a previously unrecognized oxide-rich layer (magnetite > ilmenite) was also identified. Through continuing analytical work (electron microprobe and proton induced x-ray emissions (PIXE)), including the mineral chemistry of the plagioclase, oxides (ilmenite-magnetite) and amphibole, we aim to identify any differentiation trends that may be present in the lithostratigraphic units of the PLAC.

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GS-14 GEOLOGICAL INVESTIGATIONS OF ANORTHOSITE, GABBRO AND PYROXENITE OCCURRENCES IN THE PIKWITONEI GRANULITE DOMAIN AND THE CROSS LAKE REGION (PARTS OF NTS 63I/6, 63J/7, 63J/8, 63P/5, 63P/6, 63P/7, 63P/8, 63P/9, 63P/11 AND 63P/12)

by D. C. Peck, H.D.M. Cameron, D. Layton-Matthews and A. Bishop

Peck, D.C., Cameron, H.D.M., Layton-Matthews, D. and Bishop, A., 1996: Geological investigations of anorthosite, gabbro and pyroxenite occurrences in the Pikwitonei granulite domain and the Cross Lake region; **in** Manitoba Energy and Mines, Minerals Division, Report of Field Activities, 1996, p. 85-90.

SUMMARY

A two month field program focusing on petrologic, geochemical and mineral potential studies of Archean mafic and ultramafic intrusive rocks in the northwestern part of the Superior Province was completed. Geological investigations were concentrated on anorthosite suite rocks that occur in the Pikwitonei granulite domain and the Cross Lake region, in order to establish possible petrogenetic relationships between these anorthosites and the layered anorthosite-gabbro intrusions at Pipestone and Kiskitto lakes. Several metagabbro and metapyroxenite occurrences within and adjacent to the Pikwitonei granulite domain were also investigated. Field observations suggest very limited mineral potential in either the anorthositic occurrences or the metagabbro and metapyroxenite occurrences because of limited differentiation and a dearth of visible sulphide and oxide mineralization. Geochemical studies (in progress) will aid in characterizing the magmatic history of the intrusions and provide constraints on the behaviour of base and precious metals during crystallization and subsequent deformation.

INTRODUCTION

Continued interest in magmatic Ni-Cu-PGE deposits and continued exploration for magmatic Ti-V-Fe oxide deposits in the Cross Lake region has prompted a re-evaluation of the mineral potential of mafic and ultramafic intrusions that occur within the northwestern part of the Superior Province. This year's field investigations were directed toward anorthosite suite rocks and metagabbro and metapyroxenite intrusions, within or immediately adjacent to, the Pikwitonei granulite domain and the Cross Lake region (Fig. GS-14-1). The objectives of the field work included: (1) documentation of the petrologic characteristics of each intrusion, *e.g.* primary layering, sulphide and oxide mineral occurrences, and degree of tectonic reworking; and, (2) collection of representative bedrock sample suites from each intrusion for detailed lithogeochemical studies. Anorthosite occurrences at Bear Head and Cauchon lakes (areas 1 and 2, Fig. GS-14-1; Fig. GS-14-2) and Butterfly and Hairy lakes (area 7, Fig. GS-14-1; Fig. GS-14-3) were investigated to better characterize their geology and mineral potential and develop a petrographic and geochemical database that affords a regional comparison of Archean anorthosites in the northwestern Superior Province. These investigations relate to detailed mapping and genetic studies of oxide mineralization in the Pipestone Lake anorthosite complex (see Jobin-Bevans *et al.*, this volume), and recent exploration of the West Channel anorthosite complex at Kiskitto Lake by Gossan Resources Ltd. (Fig. GS-14-3). Metagabbro and metapyroxenite occurrences at Landing, Wintering, Cuthbert, Partridge Crop and Paint lakes were also investigated. Sampling for whole-rock geochemical analysis was completed in order to determine whether these gabbroic bodies are part of a single, cogenetic suite and the extent to which their primary compositions have been modified by metamorphism and deformation.

CAUCHON LAKE

Cauchon Lake, situated approximately 90 km east-southeast of Thompson, straddles the boundary between the Pikwitonei granulite domain and the God's Lake granite-greenstone domain (Figure GS-14-2). The geology of the Cauchon Lake area is described by Weber (1976a, 1987) and shown on three preliminary maps (Weber, 1976b-d). Weber (1976a, 1977, 1987) describes an approximately 25 km long by 0.5 to 1.5 km wide, linear, northeast-trending body of layered anorthosite that contains subordinate leucogabbro and rare gabbroic to ultramafic layers, in the northern part of Cauchon Lake. The anorthosite occurs to the north of the "orthopyroxene-in" isograd that separates the granulite facies rocks to the north from amphibolite facies rocks to the south (domain boundary on Fig. GS-14-2). The geology of the Cauchon Lake area, as described by Weber (1976a, 1977), comprises amphibolite facies tonalite, tonalitic gneiss and metamorphically banded pyroxene-bearing amphibolites (metavolcanics) in the south, and predominantly granulite facies enderbite gneiss, hypersthene-bearing dioritic gneiss, schollen enderbite with abundant mafic to ultramafic inclusions, layered anorthosite and minor mafic to intermediate pyroxene ± garnet gneiss (metavolcanics?) in the central and northern parts of the lake. Late granitic pegmatites and north-northeast or east-northeast striking mafic dykes (Fig. GS-14-2) correlated with the Molson dyke swarm (Weber, 1987) are the youngest rock types exposed in the Cauchon Lake area. Weber (1976a, 1977) identified two prominent Archean metamorphic events in the Cauchon Lake area. The earliest event (M_1) was associated with the development of layered migmatites under amphibolite facies conditions. The second event (M_2) was associated with the development of west-southwest-trending fold axes and associated planar foliations under granulite facies conditions. Late cataclastic deformation (Hudsonian?) produced southwest-trending shear zones and local retrograde metamorphism of the granulites to the amphibolite facies.

High water levels during the field season obscured many of the shoreline outcrops mapped by Weber (1976), and extensive drift cover affords little or no bedrock exposure inland. During the current study, the entire 25 km strike length of the anorthosite body was investigated. Outcrops were examined for evidence of primary layering structures and sulphide or oxide mineralization. Approximately 60 bedrock samples were collected from the anorthosite body for petrographic and whole-rock geochemical analysis. Additional samples were collected from many of the Molson dykes identified by Weber (1976b,d) in order to characterize their chemical and mineralogical compositions.

The principal rock type encountered within the Cauchon Lake anorthosite body is megacrystic anorthosite, typically comprising >90% plagioclase megacrysts and <10% interstitial, medium- to coarse-grained amphibole and/or pyroxene. Accessory minerals include fine- to medium-grained plagioclase and magnetite. Rare, coarse grained, clotty magnetite (<5%) is locally present in the megacrystic anorthosite. Plagioclase megacrysts locally display labradorescence, compositional zoning and both Carlsbad and polysynthetic twinning. The least deformed megacrysts have blocky, spherical or pseudohexagonal crystal shapes and range in size from <1 cm to 15 cm, but are typically 2 to 5 cm in length.

Megacrystic anorthosite is locally interbanded with coarse grained massive anorthosite and leucogabbro. Relict poikilitic textures, involving skeletal pyroxene or amphibole oikocrysts up to several cm long, are locally preserved within leucogabbro layers. Leucogabbro also occurs as tectonized leucocratic gneiss in which mineralogical banding involving <1 cm to 10 cm wide monomineralic plagioclase bands and thinner pyroxene-bearing amphibolite bands are interleaved. Contacts between leucogabbro, massive anorthosite and megacrystic anorthosite are generally tectonized.

Less than 5% of the Cauchon Lake anorthosite body is represented in outcrop by fine- to medium-grained mafic bands (principally gabbro, but including melagabbro and pyroxenite) that have sharp but irregular boundaries with the enclosing anorthosite. Similar mafic bands also occur entirely within tonalite and enderbite gneiss, both to the north and south of the anorthosite body. Within the anorthosite, mafic bands are either foliated or display a compact, granular texture. The bands are typically 5 cm to 30 cm thick and several metres long. No laterally continuous mafic or ultramafic layers were identified from the Cauchon Lake anorthosite, and no evidence was found for a presumed "mafic to ultramafic base" along its southern margin (Weber, 1977). The origin of the mafic bands is equivocal. Locally, they appear to be min-

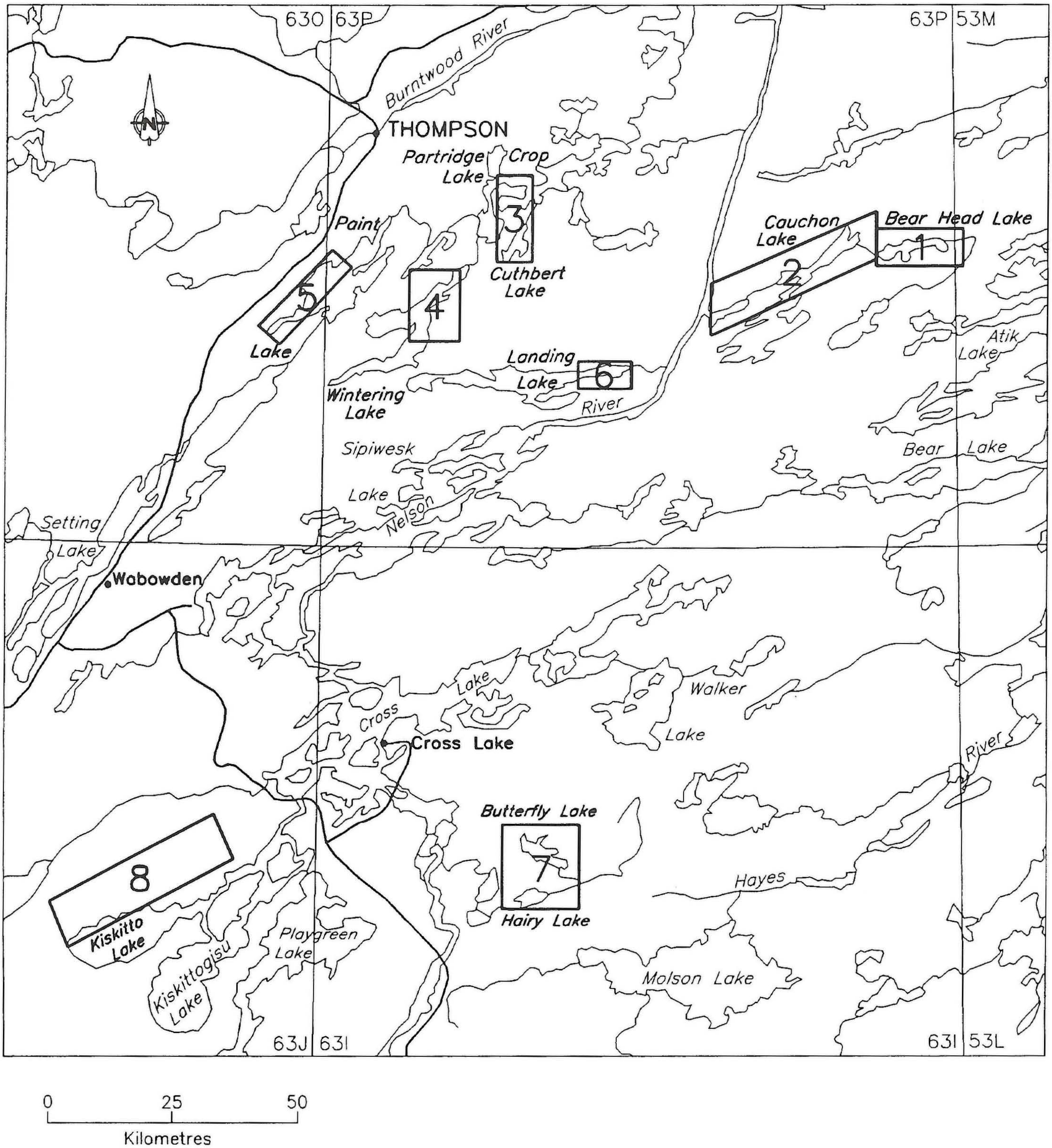

Figure GS-14-1: Location of the areas investigated.

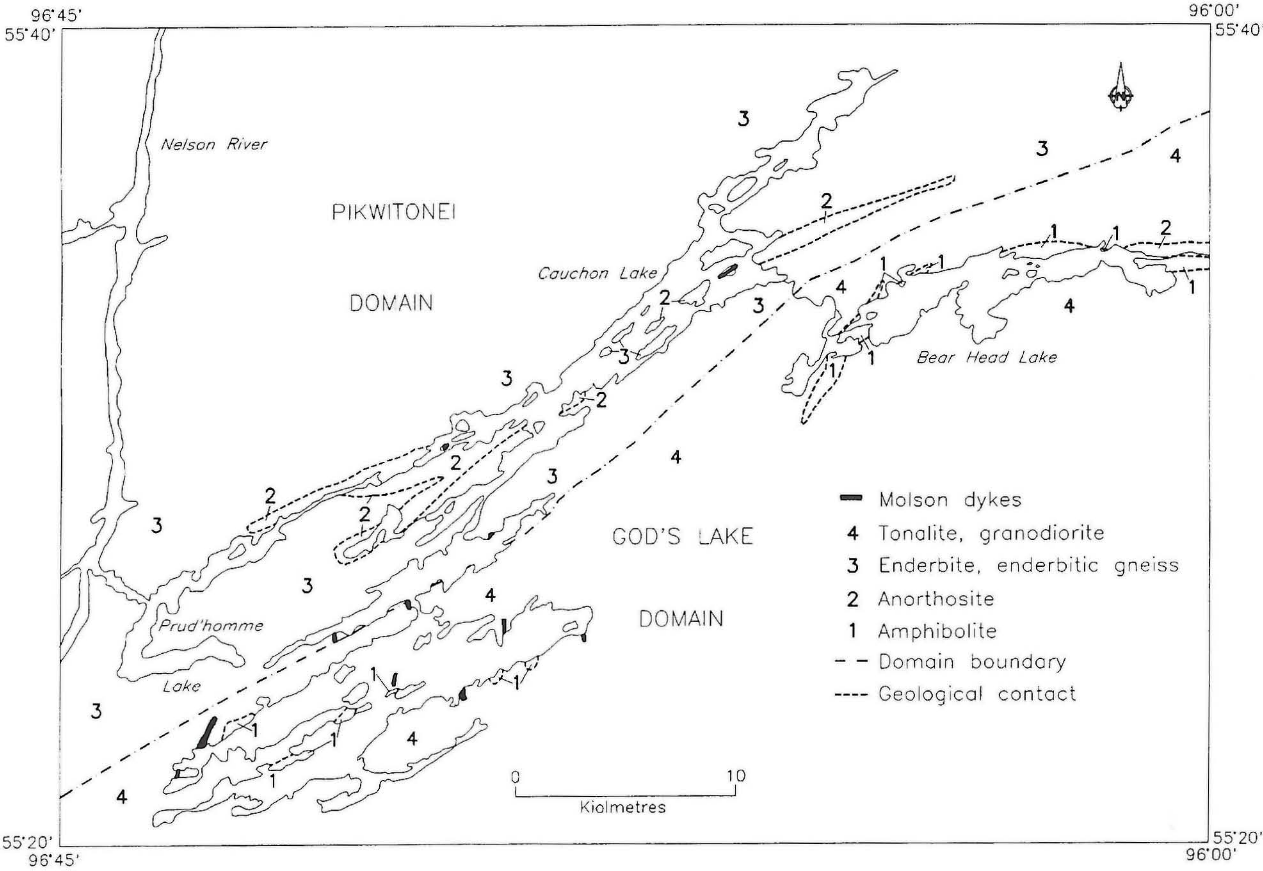

Figure GS-14-2: Simplified geological map of the Cauchon Lake and Bear Head Lake areas showing distribution of anorthosite (unit 2). Modified after Weber (1976b-d; 1987).

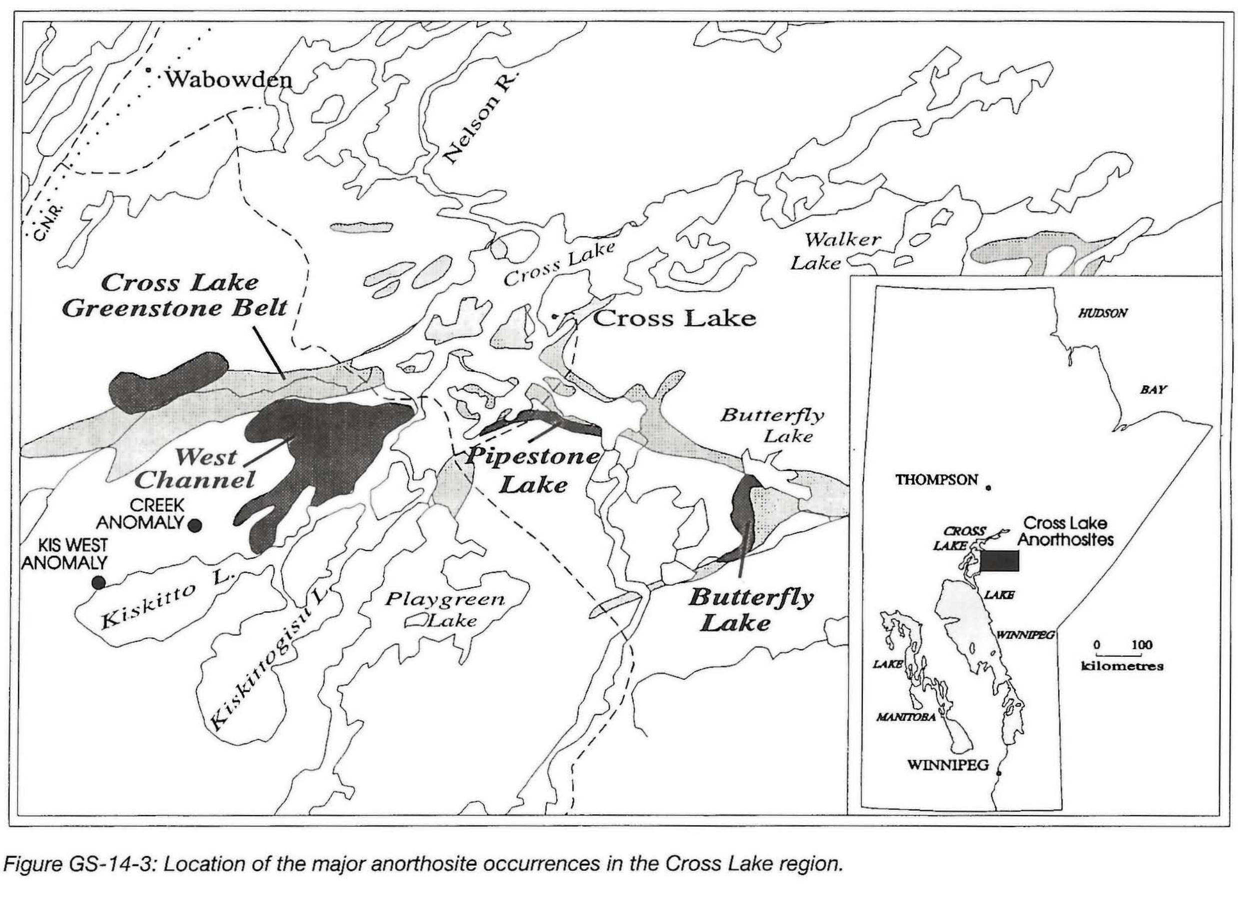

Figure GS-14-3: Location of the major anorthosite occurrences in the Cross Lake region.

eralogically and texturally similar to the matrix of the megacrystic anorthosite and coarse grained leucogabbro, and may reflect redistribution of these matrix constituents during deformation. In other areas, they appear to represent discrete, albeit disrupted, gabbroic layers. Some of the fine grained mafic bands could represent inclusions of older metavolcanic rocks or diabase dykes.

Unequivocal, primary modal or textural layering was rarely observed in the Cauchon Lake anorthosite, and no indication of facing directions was obtained. At one locality, dendritic gabbroic pegmatite is developed as irregular veins and pods within megacrystic anorthosite. The pegmatite contains pyroxene dendrites up to 20 cm long. These veins likely represent mafic residual liquids formed during the final stages of crystallization of the enclosing anorthosite.

Throughout the Cauchon Lake anorthosite body, a strong tectonic fabric is developed, including: (1) a penetrative cataclastic foliation in which all of the original plagioclase megacrysts have been granulated to mosaics of 1 mm to 3 mm grains; (2) augen gneiss, in which lenticular bands of preserved megacrystic anorthosite, <5 cm to 1 m thick, are separated by finer grained granulated anorthosite and thinner, discontinuous mafic bands; and, (3) schollen anorthosite, comprising subangular, metre sized blocks of megacrystic and massive anorthosite invaded by irregular veins of tonalite and enderbite gneiss. Granulation and metamorphic differentiation likely account for much of the subtle modal variations within the anorthosite, and clearly explain the development of thinly banded anorthositic gneiss. Metamorphic fabrics generally strike southwesterly and dip moderately to the north. In contrast, Weber (1976b) indicates predominantly southerly-dipping metamorphic foliations in the northern part of Cauchon Lake

Although primary features within the Cauchon Lake anorthosite body have been extensively modified by metamorphism and deformation, it is unlikely that all evidence of rhythmic layering could have been obliterated. The paucity of layering is therefore considered to be a primary feature that reflects emplacement of the Cauchon Lake anorthosite body as a relatively homogeneous batch of plagioclase laden magma that experienced little or no *in situ* differentiation. Geochemical data will be used to constrain the composition of the primary magma from which the anorthosite was derived. Primary intrusive relationships between the anorthosite and older country rocks were not observed. This reflects the extensive invasion of the anorthosite by younger tonalite and enderbite gneiss. Weber (1976a) observed an increase in the proportion of enderbite and tonalite gneiss toward the southern margin of the Cauchon Lake anorthosite body. Our observations suggest that the entire anorthosite body was invaded by granitoid melts prior to granulite facies metamorphism (M_2).

Weber (1987) reported that some of the mafic bands within the Cauchon Lake anorthosite are enriched in ilmenite (up to 5.4% TiO_2). Similar oxide enrichment is noted in ilmenite-bearing melagabbro layers in the Pipestone Lake anorthosite complex (Cameron, 1992). However, the lack of primary differentiation within the Cauchon Lake anorthosite, in contrast to the rhythmically layered Pipestone Lake anorthosite complex (Cameron, 1992), contra-indicates the presence of significant stratiform oxide layers. Magnetite is the principal oxide mineral recognized in the Cauchon Lake anorthosite. Rarely does the magnetite abundance exceed 1%, and this only occurs in thin, discontinuous mafic bands. Even if oxide-rich layers were developed in the Cauchon Lake anorthosite, it is unlikely that they could have any significant lateral continuity given the intensity of tectonic disruption in the area.

Sulphide mineralization is extremely scarce within the Cauchon Lake anorthosite. Fine grained pyrrhotite and pyrite are present in trace amounts in a few of the mafic bands examined, and rarely in association with interstitial magnetite and pyroxene in megacrystic anorthosite. One outcrop of intercalated megacrystic anorthosite and tonalite gneiss contains a <50 cm wide sulphide-bearing pyroxenite band that carries 15% disseminated, fine grained pyrrhotite. No blebby, magmatic sulphides were recognized within the anorthosite body. Structurally controlled, disseminated, fine-to medium-grained pyrite ± pyrrhotite mineralization is locally developed in or adjacent to narrow (<20 cm thick) quartz veins and southwest-trending shear zones within anorthositic, gabbroic and tonalitic gneiss exposed along the narrows linking Cauchon Lake and Prud'homme Lake (Fig. GS-14-2). Rusty weathering, garnet-rich, biotite-hornblende gneiss, possibly derived from Fe-rich sedimentary rocks, is locally developed along the northern shoreline of Cauchon Lake. This unit locally carries small amounts of disseminated pyrite that is commonly associated with graphite and magnetite (up to 25%).

BEAR HEAD LAKE

One week was spent at Bear Head Lake, 110 km east of Thompson, to investigate anorthosites reported by Weber (1987) and shown on the 1:250,000 compilation map for NTS 63P. The Bear Head Lake area occurs to the south of the southern boundary of the Pikwitonei granulite domain in an area dominantly underlain by amphibolite, tonalite and granodiorite. Anorthositic rocks occur at several locations on the north shore at the east end of the lake, within an area approximately 0.5 km wide and 8 km long (Fig. GS-14-2). The anorthosite is flanked to the north and south by basalt derived amphibolite. Contacts between the amphibolite and the anorthosite are not exposed.

The anorthosite occurrences at Bear Head Lake are less deformed than those at Cauchon Lake. They comprise approximately equal amounts of massive to foliated, interlayered megacrystic anorthosite and coarse grained leucogabbro. Layer contacts are planar and abrupt to gradational. Plagioclase megacrysts are typically 2 cm to 4 cm in maximum dimension. Leucogabbro locally contains 2 cm wide schlieren and 3 cm by 5 cm inclusions of coarse grained amphibolite. No gabbro or melagabbro layers were found within the anorthositic body, although gabbroic rocks occur as scattered xenoliths in pegmatites and as nebulitic inclusions in gneissic granodiorite and tonalite, immediately to the west of the anorthosite. There is no indication of massive or disseminated oxide or sulphide mineralization in the anorthositic rocks. They are intruded by sills and veins of coarse grained to pegmatitic biotite-bearing tonalite and granodiorite that account for approximately 50% of the exposures within the area underlain by anorthositic rocks.

Amphibolites derived from basaltic sequences are exposed to the north and south of the anorthosite. The rocks are fine grained, massive to foliated, thinly banded (1 to 30 cm) and locally contain flattened pillow remnants. They commonly occur as 2 m to 3 m thick layers separated by 20 cm to 3 m thick sills of tonalite and granitic pegmatite.

BUTTERFLY AND HAIRY LAKES

Two weeks were spent investigating and sampling anorthosite occurrences in the Butterfly Lake area (area 7, Fig. GS-14-3), situated 25 km east of Pipestone Lake (Fig. GS-14-3). Previous work by Bell (1962), Weber (1979), Weber and Chase (1980) and Corkery (1986a, b) described an area of anorthosite, exposed on the southwest shore of Butterfly Lake, extending south to Hairy Lake (Fig. GS-14-3). The anorthosite is on strike with the Pipestone Lake anorthosite complex (PLAC; Cameron, 1992). An aeromagnetic high of up to 3 500 γ extends south from Butterfly to Hairy Lake, and is adjacent to the area mapped as anorthosite (Corkery, 1986b). Similar linear magnetic features are associated with disseminated to massive magnetite and ilmenite mineralization in both the PLAC and the West Channel anorthosite complex (Cameron, 1992; Cameron and Peck, 1995).

The anorthosite occurrences at Butterfly Lake are relatively undifferentiated in comparison to those in the PLAC. They comprise interlayered bimodal porphyritic gabbroic anorthosite, megacrystic anorthosite, massive anorthosite and subordinate medium grained leucogabbro. Contacts between these units are typically gradational. No gabbro or melagabbro was found and there was no indication of any oxide mineralization associated with the anorthositic rocks. Bimodal porphyritic gabbroic anorthosite contains 2 populations of plagioclase phenocrysts, *viz.*: (1) <30% plagioclase megacrysts, up to 4 cm in length; and, (2) matrix plagioclase, 2 mm to 2 cm (average 4 mm) in length, and intergrown with hornblende. Minor amounts of disseminated, fine grained pyrite is locally present in the gabbroic anorthosite. Megacrystic anorthosite contains >90% 2 cm to 5 cm subrounded to ovoidal plagioclase megacrysts that locally form aggregates up to 10 cm in diameter, and up to 10 per cent interstitial hornblende. The megacrystic anorthosite commonly forms anorthosite cataclasite where it is intersected by east-southeast-trending shear zones.

Amphibolites derived from the Pipestone Lake Group pillow basalts (Corkery, 1986b) occur to the east and north of the anorthositic rocks at Butterfly Lake. The contact between the volcanic rocks and the anorthosite is not exposed. Hornblende porphyritic gabbros interlayered with the Pipestone Lake Group basalts were sampled for comparison to gabbros in the PLAC and similar gabbros occurring within the basalts on the south shore of Pipestone Lake (Cameron, 1992).

At Hairy Lake, anorthositic rocks are represented by bimodal gabbroic anorthosite that contains small veins and pods of massive anorthosite. An inclusion of megacrystic anorthosite was observed on one outcrop of pink pegmatitic granite.

The north-trending aeromagnetic high between Butterfly and Hairy lakes is overlain by swamp and drift. Bell (1962) shows a single outcrop of anorthosite approximately halfway between the two lakes. Layering in the anorthosites on Butterfly Lake trends northwesterly and there is no indication of south-trending layering that might follow the aeromagnetic high. The source of the magnetic anomaly remains uncertain.

KISKITTO LAKE

Gossan Resources Ltd. completed three additional diamond drill holes on their Kiskitto Lake Ti-V-Fe property during the early part of 1996. Previous drilling had delineated significant disseminated ilmenite and magnetite mineralization in layered leucogabbro (Cameron *et al.*, 1995). Geochemical and petrographic studies of drill core from the "Kis West" and "Creek" magnetic anomalies within the western extension of the West Channel anorthosite body (Fig. GS-14-3) have been initiated. The recent drilling has intersected up to several hundred metres of steeply-dipping, modally- and phase-layered, hornblende-bearing leuconorite/norite emplaced into older tonalitic gneiss. The noritic rocks are granulites that contain abundant hypersthene, some of which appears to have replaced olivine. Oxide mineralization occurs as disseminated medium grained ilmenite and magnetite intergrown with hornblende and interstitial to coarse grained cumulus plagioclase and hypersthene. Results from the drill core studies will be incorporated into an M.Sc. thesis, to be initiated in 1997 (Laurentian University and University of Manitoba), that will compare the chemostratigraphy and oxide mineralization of the Pipestone Lake and West Channel anorthosite complexes.

WINTERING LAKE

Three days were spent investigating and sampling metagabbro and metapyroxenite occurrences mapped by Hubregtse *et al.* (1978) in the northeastern part of Wintering Lake (area 4, Fig. GS-14-1), approximately 35 km southeast of Thompson. Some of the occurrences are associated with Fe-Cu-Ni sulphide mineralization (Dawson, 1952). Hubregtse (1977) reported that the least deformed gabbroic bodies in the Wintering Lake area locally preserve centimetre scale rhythmic layering and more diffuse compositional variations from picrite to gabbro. Samples were collected from several outcrops of metagabbroic rocks. Most of the outcrops examined contain medium grained gabbroic gneiss that display compositional variations from gabbroic anorthosite to pyroxenite. Metagabbro outcrops contain minor amounts of tonalite gneiss that form *lit* or discrete veins within the mafic bands. Centimetre- and metre-scale banding in the gabbroic gneiss is likely derived from preexisting primary layering. Irregular mafic pegmatite veins are present in some of the gabbroic outcrops.

Sulphide occurrences at Wintering Lake are associated with metapyroxenite and garnet + plagioclase + hornblende ± biotite gneiss (metagabbro) and are described by Dawson (1952). Most of the outcrops that expose the sulphide showings were submerged because of very high lake levels during the current field season, and detailed mapping of the occurrences was not possible. Two sulphide occurrences associated with metagabbro/metapyroxenite bodies exposed in the northeastern part of Wintering Lake were briefly examined (A and B showings, Dawson, 1952). The A showing consists of schistose zones of disseminated to semisolid pyrite + pyrrhotite + chalcopyrite, up to a metre wide, developed along the contact between thin metapyroxenite layers or metagabbro layers and garnet-rich plagioclase-hornblende gneiss that may have been derived from pyroxenite. One pyrrhotite-rich sample collected from the walls of a partly submerged trench contains 1300 ppb Pd and 130 ppb Pt (analysed by X-Ray Assay Laboratories, Don Mills, Ontario). These anomalously high PGE values suggest a magmatic affinity for the sulphide mineralization.

The B showing occurs on a small peninsula along the eastern shore of Wintering Lake, approximately 3 km to the south of the north end of the Lake. Dawson (1952) reports that the B showing was explored as early as 1928, and has been the site of extensive trench and drilling (E. Chaboyer, prospector, personal communication, August, 1996). Several trenches (overgrown) and two shafts are developed in an approximately 30 m wide, metamorphosed gabbro-pyroxenite body that has been sheared and invaded by quartz veins. Sulphide mineralization occurs in narrow zones (approximately 3 m wide; Dawson, 1952) that contain disseminated to semisolid pyrrhotite and subordinate pyrite and chalcopyrite within hornblende + plagioclase ± biotite gneiss. The mineralization appears to be developed along the contact between gabbroic gneiss (mineralized) and garnetiferous pyroxenitic gneiss (not mineralized), but insufficient exposure was available to confirm either the extent or orientation of the mineralization. Dawson (1952) reports up to 25% magnetite and minor molybdenite in association with the sulphides. A maximum of 53 ppb Pd, 12 ppb Pt and 3 ppb Au were obtained from two pyrrhotite-rich mineralized samples collected during the current study (analyses performed at X-Ray Assay Laboratories, Don Mills, Ontario).

CUTHBERT AND PARTRIDGE CROP LAKES

One week was spent at Cuthbert and Partridge Crop lakes (area 3, Fig. GS-14-1), 35 km southeast of Thompson, to map and sample anorthosite, gabbro and noritic rocks identified by previous workers (Weber and Malyon, 1978). Lake levels were about 2.5 metres higher than normal, and very little outcrop remained above water. The geology of the Cuthbert Lake and Partridge Crop Lake areas is described by Weber (1978). Anorthosite was not found and only tonalite to granodiorite gneiss, locally containing up to 20% fine- to coarse-grained mafic xenoliths, was observed in the areas mapped as noritic rocks. Coarse grained, layered gabbroic rocks, with local garnetiferous zones, were observed at a few locations at Cuthbert and Partridge Crop lakes, but do not correspond to the norites mapped by Weber and Malyon (1978). Some of the gabbroic rocks appear to be intrusive into enderbitic gneiss, whereas coarse grained and fine grained amphibolite and gabbro occur as inclusions, up to 4 m long, in enderbitic gneiss in the southern part of Partridge Crop Lake. Anastomosing 1 cm to 4 cm wide pyroxenite veins are developed in one of the layered gabbro outcrops examined. Remnants of medium grained leucogabbro layers, that locally contain gabbroic inclusions, also occur in the enderbitic gneiss. Sulphide mineralization was not observed in the layered gabbroic rocks.

Samples were taken from several north-northeast-trending Molson dykes exposed in the area, including large, differentiated ultramafic dykes (Cuthbert Lake dykes; Weber, 1978) exposed on islands and along the shoreline of Cuthbert Lake. The dykes trend about 030°, have maximum widths of approximately 250 m, and can be traced for a distance of over 30 km (Weber and Malyon, 1978). The dykes examined are medium- to coarse-grained and mafic to ultramafic in composition, and typically display a distinctive mottled greenish brown to dark green appearance on weathered surfaces. Rock types encountered include peridotite and pyroxenite. Gabbroic pegmatite pods up to 30 cm x 50 cm in size, are locally developed within the dykes. Contacts between the dykes and older granitoid gneiss were not exposed.

LANDING LAKE

Two days were spent investigating and sampling anorthosite and metagabbro occurrences reported from the eastern end of Landing Lake (Hubregtse and Charbonneau, 1978), located approximately 70 km southeast of Thompson (area 6, Fig. GS-14-1), and within the eastern boundary of the Pikwitonei granulite domain (Hubregtse, 1978). The major lithologies present in the area are tonalite and enderbite gneiss (locally garnet-bearing), plagioclase + quartz + pyroxene ± hornblende gneiss and granofels, mafic granulite and amphibolite (Hubregtse and Charbonneau, 1978). Anorthositic rocks were recognized in only two areas, occurring as highly deformed, plagioclase-rich gneiss that display intense grain size reduction and segregation of plagioclase and hornblende into nearly monomineralic layers. Metagabbroic rocks are exposed in several shoreline outcrops in the eastern end of Landing Lake. These rocks occur as strongly deformed medium- to coarse-grained mafic gneiss that are locally intruded by tonalite and quartz veins, and as small metre- to centimetre-sized inclusions in tonalite and enderbite gneiss. Indistinct, metre scale modal layering (leucogabbro to melagabbro) and small amphibolite (metapyroxenite) bands, up to 30 cm wide, are locally developed in the mafic gneiss. Trace amounts of disseminated, fine grained pyrrhotite and/or pyrite are rarely present within the metagabbroic units.

PAINT LAKE

Two days were spent collecting samples of metagabbroic and related ultramafic rocks from the western and southwestern parts of Paint Lake (area 5, Fig. GS-14-1), located approximately 30 km south of Thompson. Samples were collected for whole-rock geochemical analysis from a metagabbroic complex shown by Charbonneau and Sutherland (1979a, b) and described by Macek and Russell (1978). The metagabbroic complex comprises metapyroxenite, layered metagabbro and anorthositic metagabbro, layered amphibolites and mafic gneiss (Macek and Russell, 1978). The gabbroic rocks are exposed on small, shoreline outcrops and occur in an area dominated by retrogressed enderbitic gneiss, migmatite and late granitic intrusions (Macek and Russell, 1978). The gabbroic rocks are medium- to coarse-grained, commonly contain two pyroxenes, and are interlayered with garnet + hornblende + plagioclase gneiss on a scale of several tens of cm. Biotite and uralite alteration of pyroxene occurs in some of the pyroxenite outcrops examined. Garnet is locally developed as medium- to coarse-grained porphyroblasts within gneissic metagabbro. The gabbroic rocks are strongly foliated and have been variably injected by quartz + plagioclase + hornblende gneiss. Sulphide mineralization was not observed in the metagabbroic outcrops investigated.

IMPLICATIONS FOR MINERAL EXPLORATION

With the exception of the sulphide occurrences associated with metagabbroic rocks at Wintering Lake, no significant sulphide mineralization was observed in any of the intrusions investigated. The paucity or absence of ultramafic layers, disseminated sulphides, S-rich country rocks and primary layering in the investigated intrusions suggests that the conditions necessary for the generation of magmatic sulphide deposits (*e.g.* assimilation of sulphur from external sources by high temperature ultramafic magmas, or mixing of S-saturated and S-undersaturated magmas) did not exist. Anorthositic rocks at Cauchon, Bear Head and Butterfly lakes appear to have formed from relatively homogeneous, plagioclase-rich magmas that did not undergo significant differentiation following emplacement. The lack of primary layering in these bodies contrasts with the well-layered and oxide-enriched Pipestone Lake and West Channel anorthosite complexes.

ACKNOWLEDGMENT

J.M. Pacey prepared the figures that accompany this report.

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GS-15 Stratigraphy and lithologies of selected drill core from the sub-Paleozoic portion of the Thompson Nickel Belt (Parts of 63B, 63C and 63G)

by P. Theyer

Theyer, P., 1996: Stratigraphy and lithologies of selected drill core from the sub-Paleozoic portion of the Thompson Nickel belt (parts of 63B, 63C AND 63G); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1996, p. 91-92.

SUMMARY

Stratigraphic and lithologic investigations on the core of five holes drilled by Cominco Ltd. in the sub-Paleozoic southern extension of the Manitoba Nickel Belt may aid in directing mineral exploration in that area.

INTRODUCTION

Detailed stratigraphic investigations were undertaken on the core of five holes drilled by Cominco Ltd. at their Rabbit Point property (Special Permit 90-1). Cominco Ltd. Rabbit Point property extends from Cedar Lake in the northeast to Swan Lake in the southwest including part of the sub-Paleozoic southern extension of the Thompson Nickel Belt (Fig. GS-15-1).

Geological investigations on core from Cominco's Rabbit Point drilling program and Falconbridge's William Lake drilling program (unpublished company reports) demonstrated the existence of spinifex-textured olivine- and pyroxene-bearing komatiites in parts of the ultramafic rocks of the sub-Paleozoic domain of the Thompson Nickel Belt. These rock types, and the existence of thick sulphide-rich iron formations and slates, imply a potential for the existence of komatiite-hosted Ni Cu deposits and suggest that application of appropriate deposit models may aid in the exploration of these areas.

STRATIGRAPHY

Drillhole RP 11 is 584.1 m long and intersects an approximately 300 m "thick" (uncorrected core length) weakly differentiated (peridotite to pyroxenite) layer of ultramafic rocks. Several centimetre to metre thick, altered fracture zones that are characterized by cm-sized rectangular to subrounded pseudobreccia in a pseudomatrix may be interpreted as flow top breccia:

From (m)	To (m)	Lithology
0.00	99.35	Overburden
99.35	245.4	Limestone (Silurian/Ordovician)
245.4	263.2	Sandstone (Winnipeg Formation)
263.2	265	Regolith (altered,unidentified rocks)
265.0	269	Feldspathic peridotite
269.0	328	Pyroxenite and minor peridotitic interlayers
328.0	565.7	Peridotite and pyroxenite (intense hematiti zation in places)
565.7	584.1	Light green sheared mafic volcanic rocks

Drillhole RP 12 is 501.4 m long and intersects an approximately 235.7 m "thick" (uncorrected core length) weakly differentiated (peridotite to pyroxenite) layer of ultramafic rocks. Two, several cm thick layers of plumose pyroxene spinifex (at 310 m and 351.75 m) provide the only evidence of a possibly extrusive origin for the ultramafic rocks intersected in this hole.

From (m)	To (m)	Lithology
0.00	78.0	Overburden
78.0	172.82	Limestone (Silurian)
172.82	245.7	Limestone (Ordovician)
245.7	263.8	Sandstone (Winnipeg Formation)
263.8	265.4	Regolith
265.4	501.1	Pyroxenite and peridotite

Drillhole RP 15 is 500 m long and intersects an approximately 192.85 m "thick" (uncorrected core length) sequence of spinifex textured peridotitic and pyroxenitic flows separated from each other by flow top breccia and graphitic sedimentary layers.

From (m)	To (m)	Lithology
0.00	15.5	Overburden
15.5	221.45	Limestone (Paleozoic)
221.45	237.53	Sandstone (Winnipeg Formation)
237.53	245.5	Regolith
245.5	438.35	Abundant pyroxenitic and peridotitic flows interlayered with flow top breccia and graphitic sedimentary layers.
438.35	500.0	Argillite, dolomite and siltstone.

Drillhole RP 16 is 683.3 m long and intersects an approximately 380 m "thick" (uncorrected core length) sequence of peridotite and pyroxenite layers separated from each other by plagioclase-bearing ultramafic to gabbroic layers and by olivine and pyroxene spinifex bearing layers.

From (m)	To (m)	Lithology
0.00	56.0	Overburden
56.0	261.4	Carbonates (Paleozoic)
261.4	277.5	Sandstone (Winnipeg Formation)
277.5	660.0	Peridotite and dunite layers with spinifex layers separated by flow top breccia, pyroxenite and gabbro.
660.0	683.3	Argillite, basalt and phyllite.

Drillhole RP 23 is 579 m long and intersects an approximately 30 m "thick" (uncorrected core length) sequence of peridotite grading down the hole into gabbro and anorthosite.

From (m)	To (m)	Lithology
0.00	3.0	Overburden
3.0	196.7	Carbonates (Paleozoic)
196.7	212.0	Sandstone (Winnipeg Formation)
212.0	245.5	Peridotite and dunite
245.5	247.2	Increasing amounts of feldspar displace olivine.
247.2	579.0	Argillite, dolomite and tonalite.

ACKNOWLEDGEMENT

Cominco Ltd. provided access to the core and proprietary information. M. Pacey prepared the figure for this report.

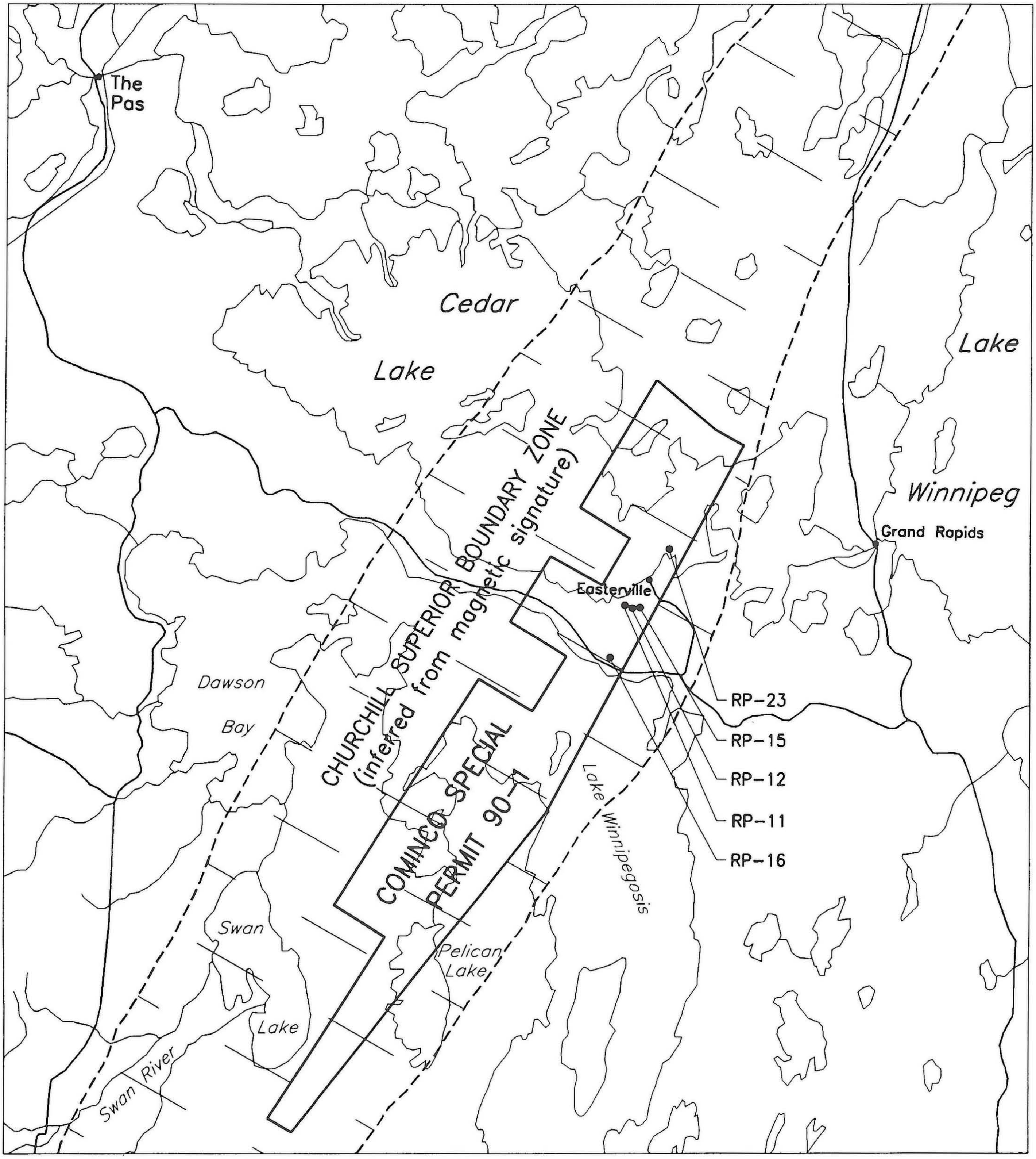

Figure GS-15-1: Location of the Churchill Superior Boundary zone, Cominco Ltd. Special Permit 90-1 and of the investigated drillholes.

GS-16 THOMPSON NICKEL BELT PROJECT: A NEW COMPILATION MAP

by J.J. Macek

Macek, J.J., 1994: Thompson Nickel Belt Project: A new compilation map; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1996, p. 93.

SUMMARY

Representatives of Cominco Limited, Falconbridge Limited, Inco Limited, Mitec, Manitoba Energy and Mines, and Geotop Laboratory of the UQAM met in May 1996 to discuss the need for close and well organized cooperation in future geoscientific studies in the Thompson Nickel Belt (TNB). All participants have agreed that an accurate compilation map of the TNB is essential and should be created as soon as possible.

Manitoba Energy and Mines and Inco Limited have agreed to initiate the work on the compilation map in the Pipe Lake-Mystery Lake area (Fig. GS-16-1, area A) because of a relative abundance of exposures, high density of drillhole data and advanced understanding of geological details in this area. The initial work has focused on examination of pertinent drill core and re-examination of exposures at Mystery Lake, Burntwood River and Nichols Lake areas. The work will continue next year in the Moak Lake and Joey Lake-Brostrom Lake areas (Fig.GS-16-1, area B).

It is expected that in following years the compilation work will proceed in the southern part of the exposed TNB in the Setting Lake-Gormley Lake area (Fig. GS-16-1, area C), with close cooperation of Falconbridge Limited.

It is hoped that the compilation work will eventually include the sub-Paleozoic extension of the TNB (Figure GS-16-1, area D) in cooperation with Cominco Limited, HBED Limited and others. The final result will be an accurate 1:50 000 compilation map of the TNB.

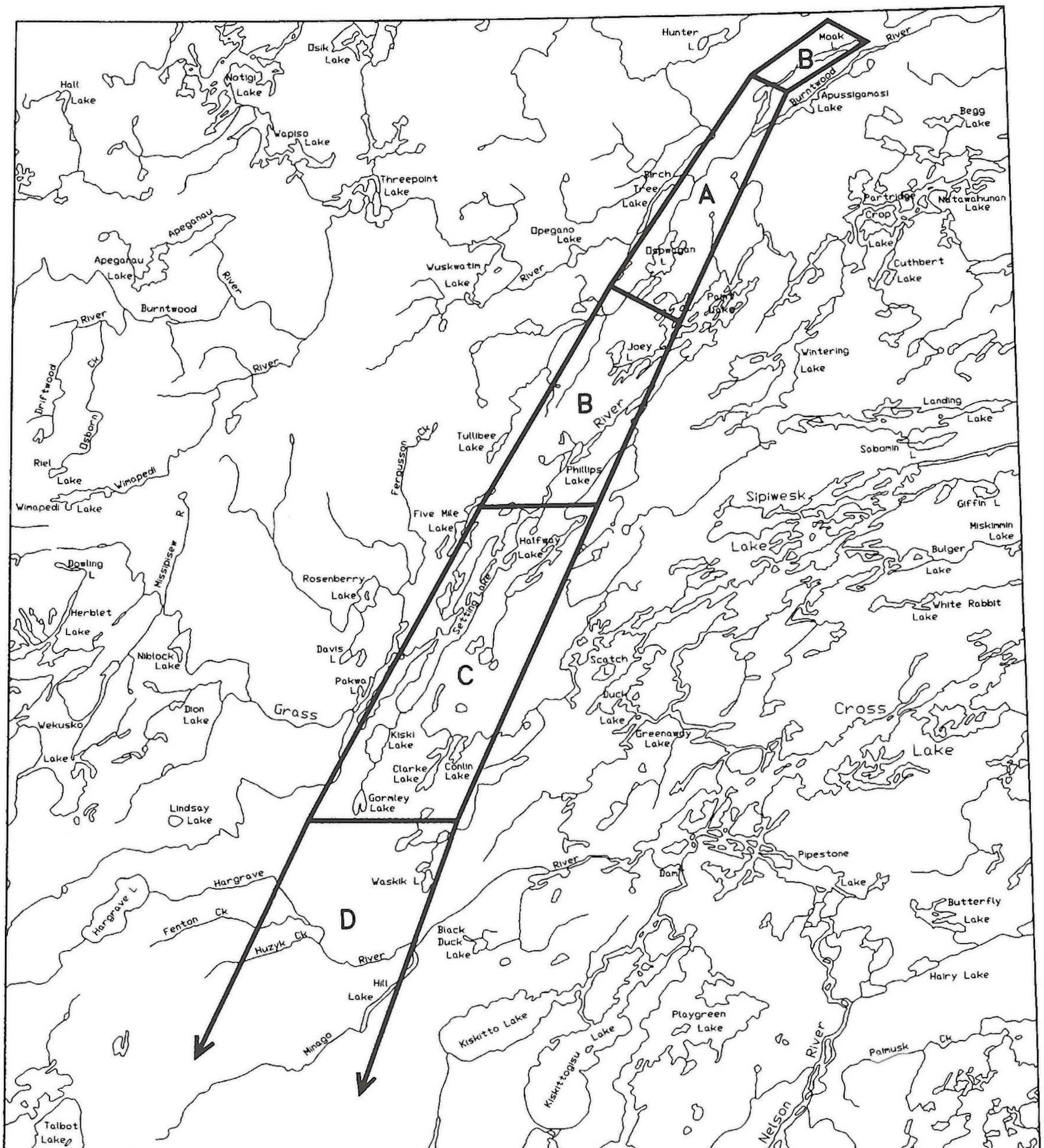

Figure GS-16-1: Compilation sequence in the Thompson Nickel Belt.

GS-17 RELOGGED DRILL CORE FROM SUB-PHANEROZOIC PRECAMBRIAN BASEMENT IN NTS 63J/SW AND PARTS OF NTS 63K/SE

by C.R. McGregor

McGregor, C.R., 1996: Relogged drill core from sub-Phanerozoic Precambrian basement in NTS 63J/SW and parts of NTS 63K/SE; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 94-95.

SUMMARY

As part of an ongoing relogging project initiated in 1992 (McGregor and Macek, 1992), 30 confidential sub-Phanerozoic Precambrian diamond-drill cores (Fig. GS-17-1) were logged in 1996 (McGregor, 1996). The core, drilled by exploration and mining companies, comes from drillholes located in NTS 63J/SW and the eastern part of 63K/SE and was analyzed in order to further describe the lithologic units within the eastern Churchill Province.

ACTIVITIES

Eleven of the diamond-drill holes logged in 1996 were drilled by Hudson Bay Exploration and Development Company Ltd. between 1989 and 1993; 17 by Southern Era Resources Limited in 1994; and the other two by Miranda Industries Inc. in 1995. The Hudson Bay Exploration and Development core is stored in the company's Flin Flon and Snow Lake core facilities and the other core remains in the field.

Preliminary Geological Report PR 96-1 (McGregor, 1996) is a catalogue of the core logs in the same format as those done in previous years (McGregor and Macek, 1992, 1993; McGregor, 1994, 1995). It contains a summative log, cross section and colour photographs for each drillhole that has been relogged. This report is available for viewing at Manitoba Energy and Mines Library in Winnipeg or can be reproduced at cost. A detailed evaluation and further interpretation of the core is in progress.

Report PR 96-1 contains Preliminary Map No. PR96-1-1 that shows the locations and intersected host and target lithologies of the holes relogged in 1996 at 1:250 000 scale in addition to those done in 1992 (McGregor and Macek, 1992; Macek and Nagerl, 1992); 1993 (McGregor and Macek, 1993); 1994 and 1995 (McGregor, 1994; 1995).

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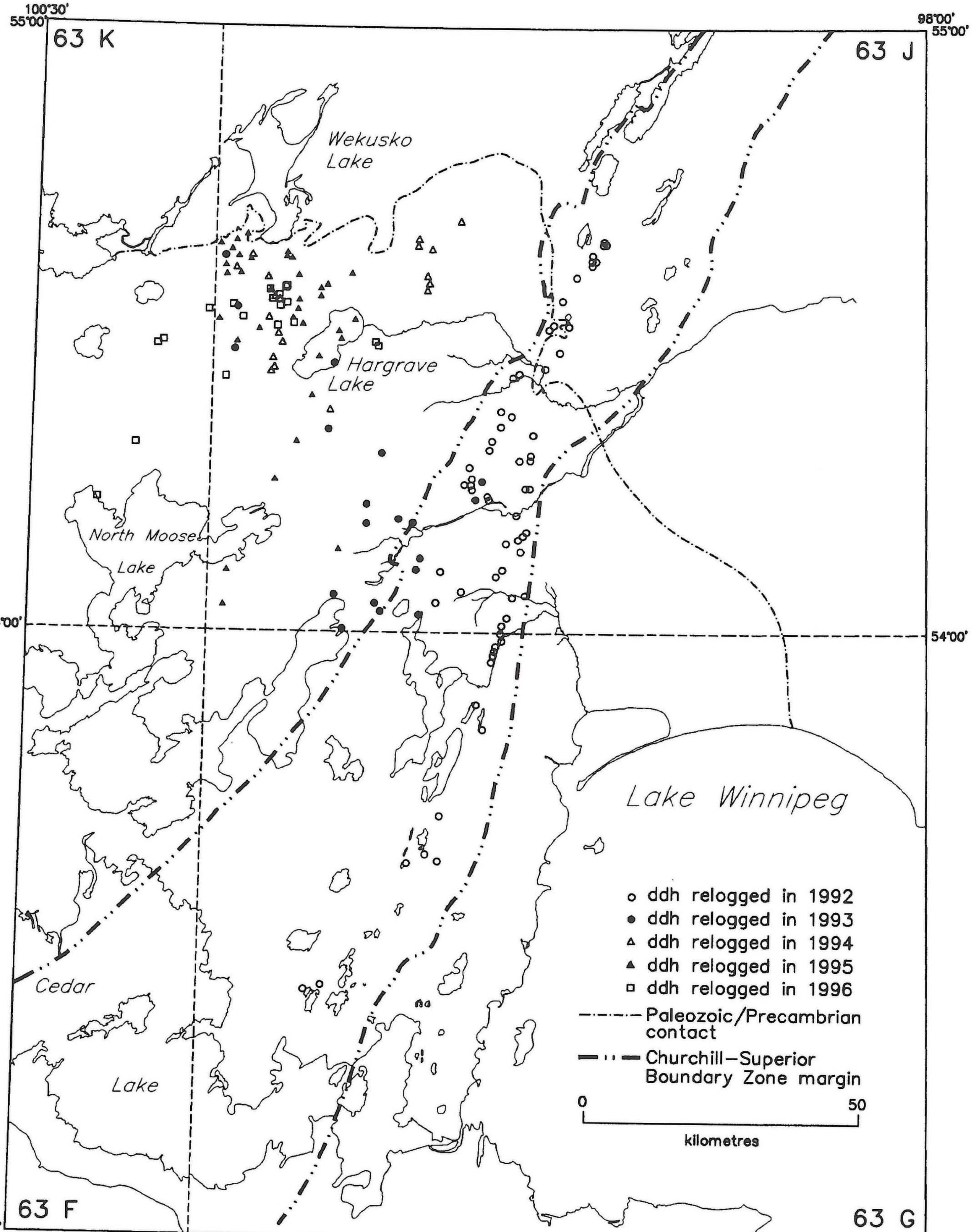

Figure GS-17-1: Location of relogged sub-Phanerozoic Precambrian diamond-drill holes in NTS 63J and part of NTS 63K/SE.

GS-18 STRATIGRAPHIC MAPPING (NTS 63G) AND COREHOLE DRILLING PROGRAM 1996

by R.K. Bezys

Bezys, R.K., 1996: Stratigraphic mapping (NTS 63G) and corehole drilling program 1996; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 96-102.

A three week stratigraphic mapping program in the vicinity of Cross Bay, Cedar Lake, confirmed that the Paleozoic stratigraphy is conformable with regional isopach and structural trends. The Geological Services Branch's drilling program completed nine holes with a total of 738.2 m of core. Three holes were drilled to extend the Grand Rapids area stratigraphy to the southern Interlake area. Two of these holes intersected the Precambrian. Six industrial mineral coreholes were drilled to determine the lateral extent of the Stony Mountain Formation (Gunton Member) in the Stonewall area and the Selkirk Member of the Red River Formation in the Garson area. The Paleozoic core information obtained from this program will be used in the correlation of Ordovician and Silurian stratigraphy in the Grand Rapids and Interlake areas. All stratigraphic data are to be added to the digital Manitoba Stratigraphic Database (MSD), which includes all well tops verified and corrected by the Geological Services Branch.

INTRODUCTION

Five stratigraphic projects were carried out in 1996:

1. Stratigraphic mapping in the vicinity of Cross Bay (Cedar Lake - Grand Rapids);
2. Stratigraphic drilling in the Grand Rapids and northern Interlake area and industrial mineral drilling in the Stonewall and Garson areas;
3. Corehole logging of Paleozoic mineral exploration drill core;
4. Capital Region resource evaluation project (NTS 62H and 62I) (see GS-19, Bamburak and Bezys, this volume); and
5. Detailed mapping of the Mafeking Quarry (NTS 63C/14) for Prairie-type micro-disseminated Au mineralization (see GS-20, Fedikow *et al.*, this volume).

Locations of the stratigraphic and industrial mineral coreholes and are shown in Figure GS-18-1 and a summary of corehole data is presented in Table GS-18-1.

In total, 30 stations were examined in NTS 63G/3, 63G/5, 63G/6 and 63G/11, primarily in the vicinity of Cross Bay (Cedar Lake) (Fig. GS-18-2). Detailed mapping of the Mafeking Quarry was also carried out this summer. Nine stratigraphic and industrial mineral coreholes were drilled and core logged (total: 738.2 m). An additional 25 mineral exploration drill holes were logged (total: 4871.2 m).

STRATIGRAPHIC MAPPING

Stratigraphic mapping continued in 1996 in the western half of NTS 63G as a follow up to previous work in the area (McCabe, 1978, 1979, 1986, 1988; Bezys, 1990, 1994, 1995). Emphasis was placed on documenting regional stratigraphic correlations. The Paleozoic bedrock in the study area overlies the Churchill-Superior Boundary Zone of the Precambrian basement.

The bedrock geology consists of the Silurian Interlake Group. Outcrops in the Cross Bay (Cedar Lake) area are dominated by the Cedar Lake and East Arm formations (Fig. GS-18-2). Stratigraphic cross section A-A' (Figs. GS-18-1,3), extending north from Gypsumville to William Lake, depicts clastic and carbonate deposition on a peneplained Precambrian surface. The marked isopach thickness of the Winnipeg

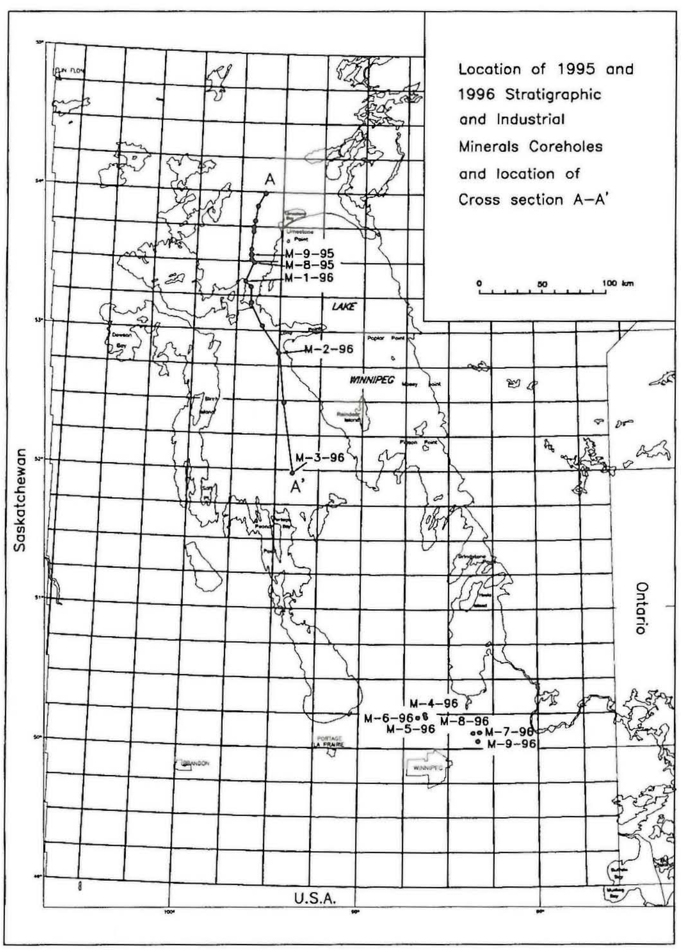

Figure GS-18-1: Location of 1995 and 1996 stratigraphic and industrial minerals coreholes and cross section A-A'.

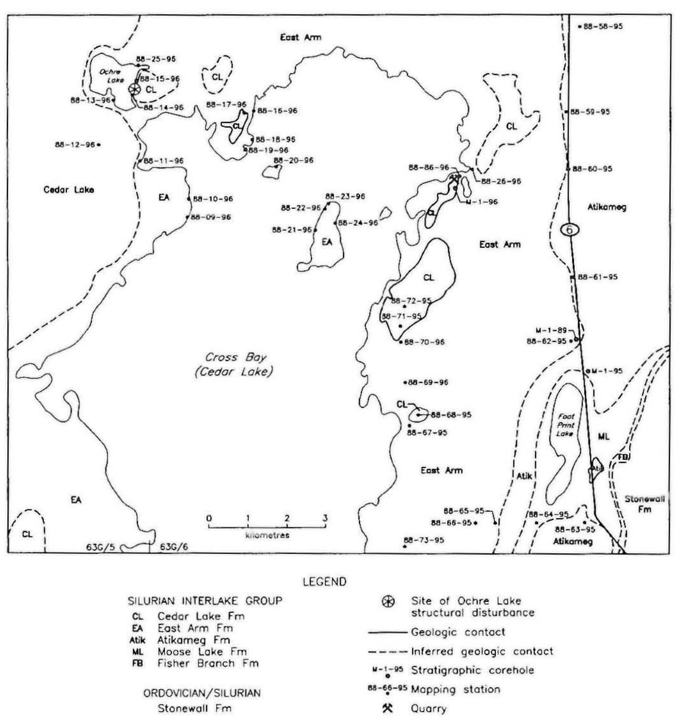

Figure GS-18-2: Location of 1996 mapping stations, coreholes, geological contacts and Ochre Lake site in the Cross Bay area.

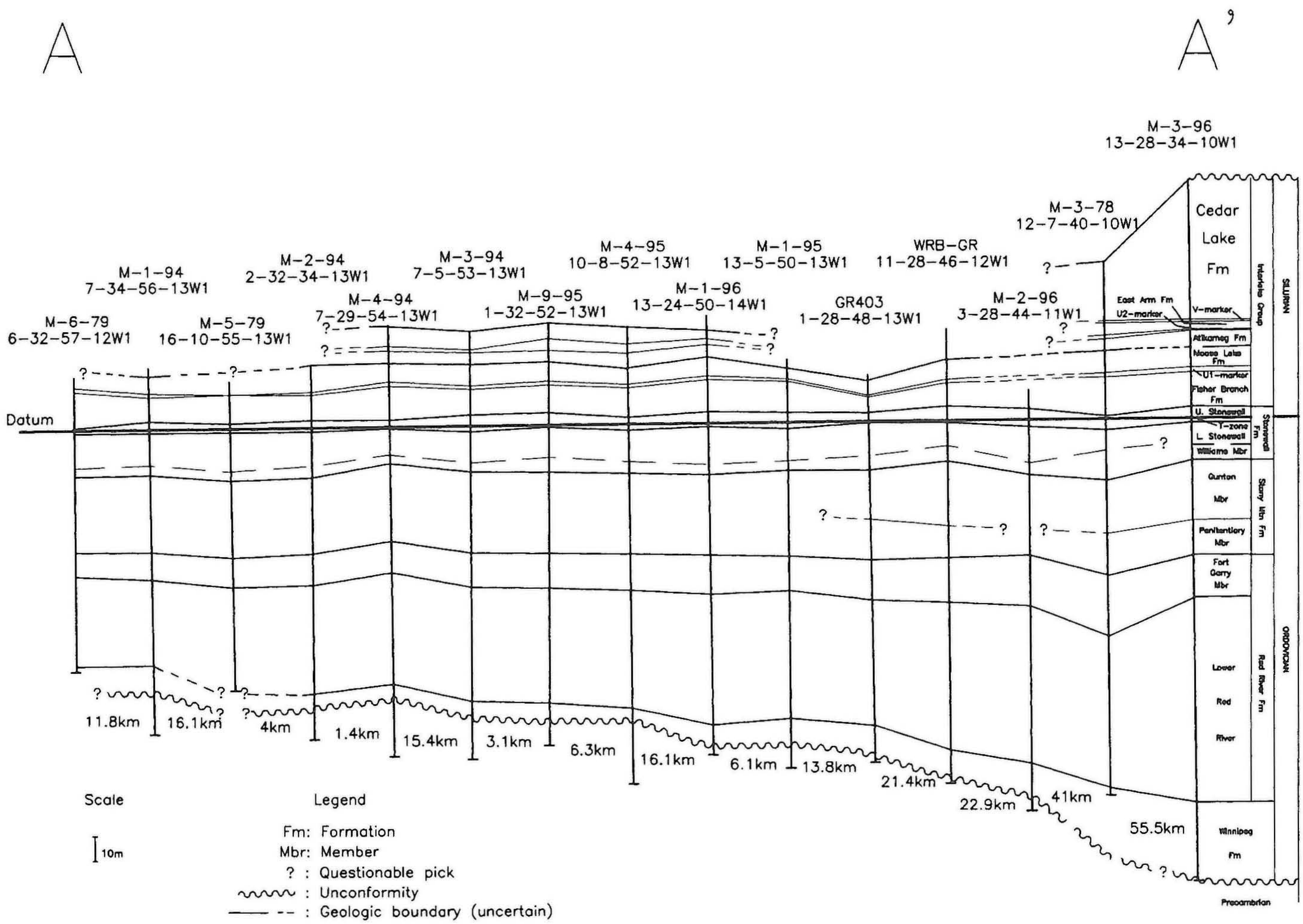

Figure GS-18-3: Stratigraphic cross section A-A'.

and Red River formations represents basinward, depositional thickening. Structural cross section A-A' (Fig. GS-18-4) depicts truncation and erosion of the Silurian Interlake Group, due to uplift. The Precambrian surface has been uplifted significantly in the north compared to the southern profile, but the section shows no major post-Paleozoic abnormalities.

An anomalous feature that was discovered at Ochre Lake (small lake northeast of Cross Bay) (Fig. GS-18-2) may represent a structural disturbance that affected the Silurian bedrock. The outcrop ridge is 4-4.5 m high and consists of transitional beds of the East Arm and Cedar Lake formations (dolomudstone and dolowackestone, respectively). Bulbous stromatolites occur toward the top of the section. From airphotos and topographic maps, it appears the outcrop ridge is lineament controlled and trends approximately 15°. The Reedy Lake Lineament (Bezys, 1996), 33 km to the north of Ochre Lake, trends in a similar direction (18-20°) and is within the CSBZ.

The area of disturbance is approximately 100 m wide (Fig. GS-18-5). Dolomite beds that flank this feature dip approximately 15-25°N. North of the disturbed area, dolomite beds are light brownish tan and extremely jointed. Proximal to the disturbed zone, dolomites become orange to yellowish brown, brecciated and contain veins of calcite and silica. Large siliceous boulders (sinters) are present throughout the disturbed area and have very dense cores with sponge-like rims. Sideritized carbonate breccia is also present within this zone. The siderite envelops dolomite clasts (wall rock) or is present as the matrix within breccia fragments. Some of these breccia fragments display vesicle-like voids in the matrix.

Throughout the disturbed area, clay is abundant. Colours are predominantly yellow-orange-brown (ochre-like) to grey and blue green. The clay may represent secondary oxidation of Mesozoic infill material which may be the Cretaceous Swan River Formation.

Although altered *in situ* rind material was not found at the Ochre Lake site, as it was in the solution chimneys at the Mafeking Quarry (see Fedikow *et al.*, GS-20, this volume), many features at both sites are similar, *e.g.* sideritized carbonate and siliceous sinters. The Ochre Lake site may represent an ancient brine spring source, but the presence of structurally disturbed *in situ* carbonate beds implies a tectonic event: possibly a fault-controlled feature or a diatreme structure. Thin section investigations and geochemical analysis and palynological dating of clay infill material will be carried out on samples from the site.

The mapping of solution chimneys in the Devonian Souris River Formation within the Mafeking Quarry was also conducted this year with staff from the Geological Survey of Canada (Calgary) (see Fedikow *et al.*, GS-20, this volume). This was a follow-up to earlier findings of Au and base metal mineralization in rocks associated with a solution chimney and modern day brine springs. These recently discovered examples of Prairie-type Au mineralization in Manitoba underscores the need to review the metallogenetic potential of Phanerozoic strata.

STRATIGRAPHIC DRILLING

The Geological Services Branch's drilling program completed three stratigraphic coreholes (total: 591.2 m) (two to Precambrian) in the Grand Rapids area and northern Interlake areas. Also, two coreholes to Precambrian were drilled late last year in the Grand Rapids area and

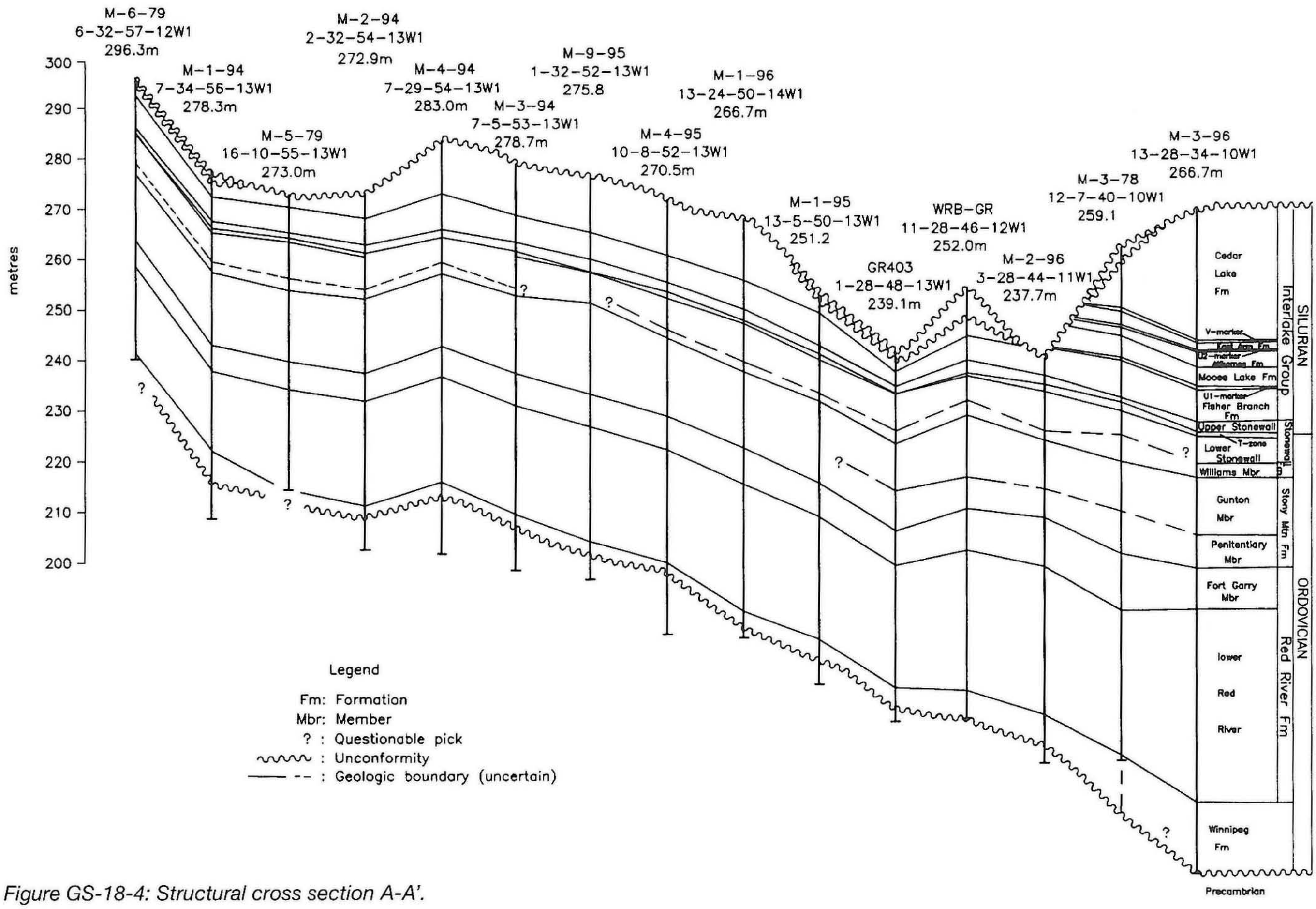

Figure GS-18-4: Structural cross section A-A'.

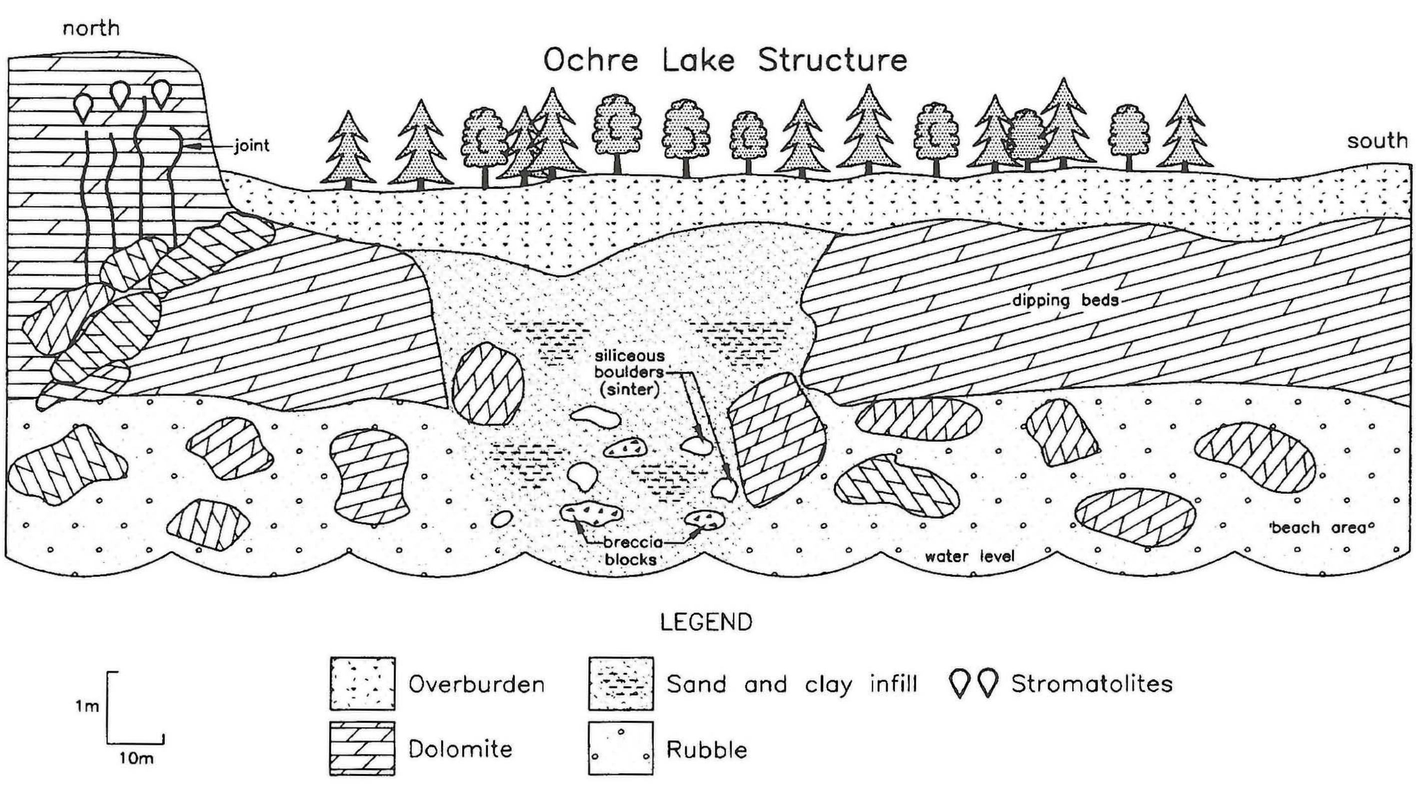

Figure GS-18-5: The Ochre Lake structure.

were excluded from the Report of Activities in 1995 (total: 318.3 m). These and the 1996 coreholes area included in Table GS-18-1.

Coreholes M-8-95 and M-9-95 were drilled to basement to determine the proximity of the eastern edge of the Churchill-Superior Boundary Zone. Corehole M-8-95 intersected 13.4 m of Precambrian melagabbro-ultramafic and corehole M-9-95 encountered 9.3 m of Precambrian weathered biotite gneiss.

Corehole M-1-96 was drilled near the north dike at Cross Bay, Cedar Lake. This hole was drilled to determine the stratigraphy of the bedrock in the area and to establish the existence of the Cedar Lake Formation in outcrop. This corehole encountered 5.5 m of Cedar Lake Formation at the top of the hole (see Bezys (1996) for a review of local stratigraphy). Corehole M-1-96 intersected 3.1 m of Precambrian grey diorite. Corehole M-2-96 was drilled south of Grand Rapids on Highway 6 to establish southward correlation of the Grand Rapids Silurian stratigraphy to the northern Interlake area. The sequence is conformable (Fig. GS-18-2) and the Precambrian encountered is a granodiorite. M-3-96, drilled near Tan Creek, north of Gypsumville, was drilled to 265.1 m. As with M-2-96, M-3-96 was drilled to correlate coreholes from the northern Interlake area to the southern Interlake area. The stratigraphic picks in M-3-96 are conformable, although the Red River Formation becomes calcareous at 166.8 m and the Winnipeg Formation is distinctly discoloured with vivid red orange browns to greenish reds. The calcareous Red River Formation may represent the transition zone from predominantly calcareous facies in the south to dolomitic facies in the north. The vivid colour change in the Winnipeg Formation may be the result of the effects of the Lake St. Martin impact structure: the limit of structural disturbance is only 6.5 km away to the southeast. The limit of structural disturbance of the structure may be much greater than previously estimated. The corehole could not be completed to Precambrian due to the unconsolidated nature of the Winnipeg Formation.

Six industrial minerals coreholes were drilled for the Capital Region Study. See Bamburak and Bezys (GS-19, this volume) for further information.

All corehole data will be compiled into the Manitoba Stratigraphic Database (MSD) to be used for the production of regional structure contour and isopach maps.

CORE LOGGING OF MINERAL EXPLORATION DRILL HOLES

Twenty-five mineral exploration drillholes from the Grand Rapids area were core logged (Cominco and Falconbridge holes) and all pick data will be entered into the MSD. In total, the MSD contains 688 confidential and nonconfidential mineral exploration drillhole data. One drillhole logged this year, Cominco RP-96-21, drilled near Easterville, encountered accretionary lapilli beds within strata of possible Cretaceous age (see Bezys *et al.*, GS-21, this volume). This may provide the first evidence of Cretaceous volcanism within Manitoba.

ACKNOWLEDGMENTS

The assistance of Karla Horsman, Robert Carter and Steve Kullman is gratefully acknowledged.

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Table GS-18-1
Summary of Stratigraphic and Industrial Minerals Corehole Data 1995 and 1996

Hole No.	Location and Elevation (m)	SYSTEM/Formation/ (Member)	Interval (m)	Summary Lithology
M-8-95	9-4-52-13W1	SILURIAN/Interlake Group/Atikameg	0.0 - 5.3	Buff yellow wackestone; minor breccia
N. Sturgeon	5923540N	Moose Lake	5.3-12.3	Brown mudstone; fossiliferous
Gill Rd.	479900E	(U_1-marker)	12.3-13.8	Grey brown mudstone
	260.6 m	Fisher Branch	13.8-24.7	Brown to tan wackestone to packstone; *Virgiana decussata* at the base
		Stonewall	24.7-50.5	Brown mudstone
		(T-zone)	28.3-28.9	Dark grey mudstone
		ORDOVICIAN - Stonewall	28.9-50.5	Brown mudstone/wackestone
		(Williams)	42.2-50.5	Grey to brown algal mudstone
		Stony Mountain	50.5-76.3	Brown mottled wackestone
		Red River	76.3-136.6	
		(Fort Garry)	76.3-90.6	Grey to dark grey wackestone
		(lower Red River)	90.6-136.6	Silty wackestone
		Winnipeg	136.6-144.2	Green grey shale and quartzose sandstone
		PRECAMBRIAN	144.2-145.9	Regolith
			145.9-157.6	Melagabbro-ultramafic
M-9-95	1-32-52-13W1	SILURIAN/Interlake	0.0-6.0	Buff mudstone
W. Honeymoon L	5930900N	Group/East Arm		
	478250E	(U_2-marker)	6.0-10.2	Green grey mudstone
	275.8 m	Atikameg	10.2-14.7	Buff orange mudstone; rare salt casts
		Moose Lake	14.7-22.0	Buff orange mudstone
		(U_1-marker)	22.0-23.6	Mudstone
		Fisher Branch	23.6-33.8	Wackestone; rare Virgiana decussata at the base
		Stonewall	33.8-50.4	Brown, mottled wackestone
		(T-zone)	38.4-39.0	Mudstone
		ORDOVICIAN		
		Stony Mountain	50.4-87.5	Brown wackestone
		Red River	87.5-144.6	
		(Fort Garry)	87.5-99.2	Dark grey mudstone; brecciated
		(lower Red River)	99.2-144.6	Mottled wackestone; Hecla Beds at the base
		Winnipeg	144.6-151.4	Dark grey siltstone and sandstone
		PRECAMBRIAN	151.4-160.7.	Regolith (weathered biotite gneiss)
M-1-96	13-24-50-14W1	SILURIAN/Interlake	0.0-5.5	Orange yellow to buff packstone/grainstone
N. Dike Rd.	5909450N	Group/Cedar lake		
	474500E	East Arm	5.5-9.4	Light brownish tan mudstone; stromatolitic
	266.7 m	(U_2-marker)	9.4-11.4	Grey mudstone
		Atikameg	11.4-15.8	Light brownish tan wackestone
		Moose Lake	15.8-23.7	Light brownish tan mudstone/packstone/grainstone
		(U_1-marker)	23.7-24.8	Grey mudstone
		Fisher Branch	24.8-36.6	Brown tan wackestone/packstone; *Virgiana decussata* at the base
		Stonewall	36.6-60.4	Brown mudstone
		(T-zone)	40.5-42.0	Grey mudstone
		Ordovician-Stonewall	42.0-56.8	Brownish tan mudstone and wackestone;
		(Williams)	56.8-60.4	Brown mudstone
		Stony Mountain	60.4-90.6	Brownish tan mudstone wackestone; fossiliferous
		Red River	90.6-155.4	

Hole No.	Locationl and Elevation (m)	SYSTEM/Formation/ (Member)	Interval (m)	Summary Liothology
		(Fort Garry)	90.6-106.0	Blue grey to brown mudstone
		(lower Red River)	106.0-155.4	Brown tan wackestone; fossiliferous; Hecla Beds at the base
		Winnipeg	155.4-163.8	Tan to white quartzose sandstone at the base
		PRECAMBRIAN	163.8-164.8	Regolith
			164.8-166.9	Grey diorite
M-2-96	3-28-44-11W1	SILURIAN/Interlake	0.0-6.9	Brown wackestone; slightly fossiliferous
Three Rivers Creek	5851569N	Group/Fisher Branch		
	499851E	Stonewall	6.9-32.5	Grey and brown mudstone and wackestone
	237.7 m	(T-zone)	11.3-14.1	Blue grey to orange yellow mudstone
		ORDOVICIAN-Stonewall	14.1-32.5	Brown mudstone
		(Williams)	28.0-32.5	Blue grey to brown mudstone
		Stony Mountain	32.5-63.1	Brown tan wackestone; fossiliferous
		Red River	63.1-141.6	
		(Fort Garry)	63.1-81.9	Grey to brown mudstone minor breccia
		(lower Red River)	81.9-141.6	Brown tan wackestone; fossiliferous
		Winnipeg	141.6-154.6	Grey to brown mudstone/siltstone and sandstone;
		PRECAMBRIAN	154.6-158.4	Regolith
			158.4-159.6	Grey granodiorite
M-3-96	13-28-34-10W1	SILURIAN/Interlake	0.0-52.5	Brown to tan, orange to yellow mudstone/ wackestone/floatstone; minor
Tan Creek	5756159N	Group/Cedar Lake		reef-like material
	511948E	(V-marker)	52.5-54.0	Brownish tan to green mudstone
	256.1 m	East Arm	54.0-56.7	Brown tan mudstone to wackestone; stromatolitic
		(U_2-marker)	56.7-57.4	Grey to green mudstone
		Atikameg/Moose Lake	57.4-70.2	Tan to brown mudstone to wackestone
		(U_1-marker)	71.2-72.5	Brown to tan mudstone
		Fisher Branch	72.5-85.7	Brown to buff wackestone
		Stonewall	85.7-106.6	Light tan mudstone; very broken core
		(T-zone)	90.0-92.0	Mudstone
		ORDOVICIAN-Stonewall	92.0-106.0	Brown mudstone/wackestone
		(Williams)	(?)	
		Stony Mountain	106.0-141.8	Light tan mudstone to packstone
		Red River	141.8-235.5	Mudstone and wackestone (limestone between 166.8-235.5)
		Winnipeg	235.5-265.1	Reddish brown orange mudstone and sandstone
M-4-96	4-29-14-2E	OVERBURDEN	0.0-10.0	
Jackfish Creek	5563350N	ORDOVICIAN/Stony Mountain/(Penitentiary)	10.0-14.1	Green to red mudstone (dolomitic); mottled with zones of discolouration,
(Stonewall)	621475E			fossiliferous
	245.4 m			
		OVERBURDEN		
M-5-96	4-20-14-2E	ORDOVICIAN/Stony Mountain/(Gunton)	0.0-4.5	
Jennifer Creek	5561725N	(Penitentiary)	4.5-5.9	Brown to buff wackestone (dolomitic)
(Stonewall)	621450E		5.9-8.1	Purple red to green mudstone (dolomitic); burrowed
	224.1 m			
		OVERBURDEN		
M-6-96	4-23-14-1E	ORDOVICIAN/Stony Mountain/(Gunton)	0.0-6.5	Till with boulders
Lait NW (Stonewall	5561625N	(Penitentiary)	6.5-17.7	Light brown to yellow buff wackestone (dolomitic); slightly fossiliferous
NW)	616625E		17.7-19.6	Mottled reddish green mudstone (dolomitic); burrowed
	250.5 m			

Hole No.	Locationl and Elevation (m)	SYSTEM/Formation/ (Member)	Interval (m)	Summary Liothology
M-7-96 Tyndall N	16-14-13-6E 5552850N 667480E 244.4 m	ORDOVICIAN/Red River/(Selkirk)	0.0-5.0	Rubble-like Tyndall Stone (lost 5 m of core)
			5.0-12.4	Light brownish tan to grey wackestone (limestone); slightly fossiliferous; dolomite bed present at 8.6-8.8 m; cherty from 8.3 m down
		(Cat Head)	12.4-14.1	Dark brown wackestone (dolomite); fossiliferous
		(Dog Head)	14.1-17.5	Light bluish grey to brown mottled wackestone; rare stylolites
M-8-96 Tyndall NW	2-22-13-6E 5552875N 665360E 240.1 m	OVERBURDEN	0.0-3.7	
		ORDOVICIAN/Red River/(Selkirk)	3.7-10.1	Light brownish tan wackestone (limestone); Tyndall Stone; burrowed and fossiliferous; becoming bluish grey towards the base
		(Cat Head)	10.1-20.1	Dark brown to grey dolomite wackestone; mottled and cherty
		(Dog Head)	20.1-63.1	Light brownish tan wackestone (limestone); mottled and fossiliferous; at 52.4-55.5 is a zone of calcite healed fracturing/brecciation
		(Dog Head)	63.1-70.7	Hecla Beds: light blue to grey to white, interbedded limestone and shale
		Winnipeg	70.7-72.3	Greenish grey laminated shale
M-9-96 Tyndall S	14-26-12-6E 5446300N 666640E 245.1 m	ORDOVICIAN/Red River/(Selkirk)	0.0-8.2	Light brownish tan rubble-like Tyndall Stone (may have been blasted?)
			8.2-15.6	Tyndall Stone: light brown tan to blue grey wackestone (limestone); mottled and stylolitic

GS-19 CAPITAL REGION STUDY: UPDATE 1996 (NTS 62H AND 62I)

by J.D. Bamburak and R.K. Bezys

Bamburak, J.D. and Bezys, R.K., 1996: Capital region study: update 1996 (NTS 62H and 62I); in Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 103-107.

SUMMARY

Four quarries were visited this year and added to the inventory of twenty-two quarries, in total, in the Capital Region Study. All data pertaining to the quarries have been entered into a computer database. A total of six industrial mineral coreholes were drilled: three north of Stonewall in the Rockwood area and three in the Garson area. The drill program north of Stonewall extended the area of known aggregate resources (Gunton Member) 6 km to the northwest of a hole drilled in 1980. In the Garson area, the presence of dimension stone (Selkirk Member, Tyndall Stone) was confirmed 3 km to the southeast of the operating quarry.

Data from all water wells in the river lots area within the Capital Region Study area have been downloaded from GWdrill (Natural Resources, Water Resources Branch digital water well database). From this set of data, all water wells to bedrock have been identified and will be plotted on to 1:20 000 and 1:50 000 scale topographic maps.

Industrial mineral inventory cards for each quarry in the Capital Region Study area were updated and stratigraphic sections for each quarry have been drafted in final form.

Depth to bedrock, regional geology and mineral potential maps will be compiled to assist in the production of municipal development plans for the Capital Region.

INTRODUCTION

A mineral resource and land-use assessment of Manitoba's Capital Region (Winnipeg and surrounding municipalities, Fig. GS-19-1) is being conducted by the Mines and Geological Services branches in response to the Capital Region Strategy under development by the Manitoba Round Table (1996). The purpose of this assessment is to provide mineral resource data for use in municipal development plans for the Capital Region that will legally protect high quality quarry minerals.

Sand, gravel and crushed stone in the Capital Region is in demand by the construction industry. Production of these commodities in the province (as well as some dimension stone) totalled over $47 million in 1994 (Table GS-19-1). The extraction of this material forms the largest mining sector by volume produced and land acreage disturbed in the province.

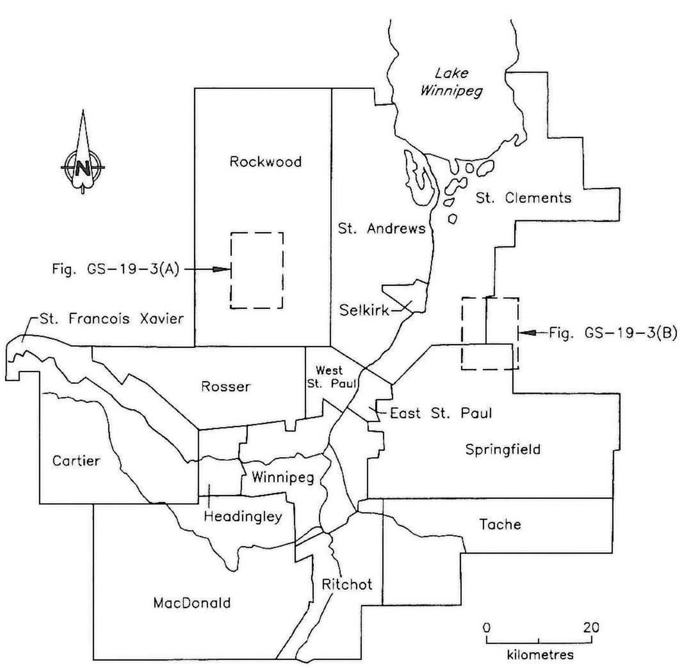

Figure GS-19-1: Capital Region map.

Table GS-19-1
Stone and Sand and Gravel Production in Manitoba
1991-1995

Commodity	1991 $000	1992 $000	1993 $000	1994 $000	1995P $000
sand & gravel	28 355	35 239	33 679	35 486	36 012
stone					
- limestone	5 922	6 243	8 318	10 170	7 999
- granite	5 101	1 510	2 597	1 775	1 444
- shale	-	17	33	87	104
Total	39 378	43 009	44 627	47 518	45 559

Notes:

P = preliminary.

In Western Canada, the largest use of sand and gravel is for the surface of road beds, followed by concrete aggregate, asphalt aggregate, and fill. Production values also include natural silica sand and crushed quartz or silica rock.

Source: Canadian Minerals Yearbook, 1992 to 1995.

In 1995, the Rockwood area (map sheet, UTM AN35) within the Capital Region was mapped at 1:20 000 scale (Bamburak and Bezys, 1995, Fig. GS-29-2). This area was selected because it contains nine active quarries that produced almost 2 million tonnes of crushed stone worth about $10 million in 1994 (Table GS-19-2). This amounts to hundreds of crushed stone truckloads per hour transported mainly from Stonewall to Winnipeg during the summer months. Historically, building stone and dolomitic lime were also produced from the Rockwood area.

For the purposes of this study, the eastern margin of the Capital Region area has been extended a few kilometres to the east in the vicinity of Garson to include the operating Tyndall Stone quarry at Garson and adjacent near-surface bedrock. The economic importance and use of this stone in the Winnipeg area cannot be overstated. Over the last 100 years, Tyndall Stone has been utilized across Canada in building construction worth billions of dollars and has been recognized in many trade publications. Production from Gillis Quarries Limited's Garson quarry was worth $2.5 million in 1993.

Preliminary results of last summer's investigations were also released in a presentation and poster display at the Manitoba Mining and Minerals Convention '95. Another poster display was presented at GAC-MAC Joint Annual Meeting in Winnipeg in May 1996.

Table GS-19-2
Crushed Stone Production in the Rockwood Area, 1992-1994

	1992 tonnes	1993 tonnes	1994 tonnes
Stony Mountain	38 105	99 948	55 028
Stonewall East	1 422 206	1 677 145	1 942 422

Note:

Assuming a minimum value of $5 per tonne for crushed stone, almost $10 million worth of stone was produced in 1994; and from 1992 to 1994, a value of over $25 million of stone was quarried.

Source: Mining Recording Office, Manitoba Energy and Mines.

PRODUCTION AND UTILIZATION OF RESOURCES

Crushed Stone

In the Rockwood area, there are seven crushed stone producers (Table GS-19-3) quarrying at nine sites. From 1992 to 1994, they produced over $5 million worth of stone averaging $5 per tonne, and 1994 production was slightly under 2 million tonnes (Table GS-19-2). Based upon 1994 production values, the annual net contribution of crushed stone from the Stonewall East area to the Manitoba Gross Domestic Product is about $16 million (Table GS-19-4). However, the availability of stone that meets required specifications so close to Winnipeg, facilitates construction projects worth about $80 million.

Table GS-19-3
Crushed Stone Producers in the Rockwood Area, 1992-1994

Standard Limestone Quarries
B-A Materials Limited
Mulder Construction & Materials Ltd.
Riverside Gravel (1985) Inc. (Bison Rock and Asphalt Products)
Borland Construction (1989) Limited
Mariash Construction Ltd.
City of Winnipeg, Equipment and Materials Services Branch

Note:

Winkler Construction Ltd. worked for Borland Construction on the Borland South Quarry.

Source: Mining Recording Office, Manitoba Energy and Mines.

Table GS-19-4
Annual Contribution to the Provincial Gross Domestic Product by Crushed Stone from Stonewall East

Production of Crushed Stone	$10 000 000
Trucking of Crushed Stone to Job Sites	6 000 000
	$16 000 000
Construction Projects	$80 000 000

Note:

The value of Construction Projects is assumed to be five times the net cost of the delivered crushed stone, as determined in Table GS-19-6.

Manitoba Highways and Transportation is a major user of the crushed stone from Stonewall East. From January, 1993 to October, 1995, 33 tenders were awarded totalling almost $20 million (Table GS-19-5). A specific example of the importance of crushed stone from Stonewall East to the Province is shown in Table GS-19-6, where 60 000 tonnes of granular "A" base, worth $441 000 was used in construction of the P.T.H. No. 7 and No. 101 interchange. The total cost of this project was over $2 million.

Table GS-19-5
Province of Manitoba
Department of Highways and Transportation
Crushed Stone Tenders Awarded 93/01/01 to 95/10/26
Stonewall East

No. of Tenders	Class "A" Granular Base Course Quantity	Class "A" Granular Base Course Value	Class "C" Average Quantity	Class "C" Value	Weighted Price/t
25	1 603 550	$12 935 327			$8.07
8			1 046 200	$7053 374	$6.74

Table GS-19-6
Province of Manitoba
Department of Highways and Transportation Project:
Concrete Pavement, P.T.H. No. 7 Interchange at P.T.H. No. 101

Description of Work	Estimated Quantities	Unit Price	Total
Subgrade Modification	130 000 m^2	$1.50	$195 000
Granular "A" Base Course	60 000 t	7.35	441 000
Bituminous "A" Pavement	16 000 t	16.00	256 000
Concrete Pavement (Poured)	56 000 m^2	16.22	919 674
Concrete Pavement (Reinforced)	8 300 m^2	18.22	155 376
Other			349 600
Total Cost			$ 2 316 650

Note:

The total cost of the Project was five times the value of the Granular "A" Base Course.

Dimension Stone

In the Garson area, there is one active dimension stone producer, Gillis Quarries Limited. Over the past 100 years, Tyndall Stone has been used in over 50 major buildings across Canada, such as the interior of the Parliament Buildings in Ottawa; the Manitoba and Saskatchewan Legislative Buildings; and the Canadian Museum of Civilization in Hull. This is in addition to the thousands of Manitoba homes with Tyndall Stone exterior facings or interior treatments, such as fireplaces. In 1993, Gillis produced 37 174 tonnes of dimension stone averaging over $60 per tonne.

CURRENT WORK

Since November 1995, work on the Capital Region Study has included four components:

- compilation of water well data;
- geological description of quarries;
- drilling of industrial mineral coreholes; and
- updating industrial mineral inventory cards.

Water Wells

In 1995, water well data from most of the northern portion of the Capital Region was downloaded from GWdrill (Manitoba Natural Resources, Water Resources Branch digital water well database of about 80 000 wells). This data was used to locate the water wells, to estimate surface elevation, and to record depth to bedrock. The compiled water well data (1600 wells) was used to produce a bedrock elevation map of NTS 62I/2, I/3 and I/6. An oblique view is shown in Figure GS-19-2, which clearly outlines a north-trending bedrock escarpment from south of Stonewall to Gunton. According to Bannatyne (1988), the escarpment, locally breached or notched, is capped by the Gunton Member of the Stony Mountain Formation. Outliers of the Gunton Escarpment are present as a series of topographic highs from Winnipeg to Stony Mountain. Missing data along the Red River represents the river lot land tenure system, and water well data (about 9000 wells) are currently being selected for the Capital Region database. From this set of data, all water wells to bedrock will be plotted onto 1:20 000 and 1:50 000 scale topographic maps.

Quarry Descriptions

Four quarries in the rural municipality of St. Clements and in the Garson area were inventoried in 1996. Stratigraphic sections for each quarry were drafted in final form and their corresponding data entered into a computer database. A total of twenty-two quarries have been visited for the Capital Region study over the past two summers. For an overview of the stratigraphy of the Capital Region area, see Bamburak and Bezys (1995).

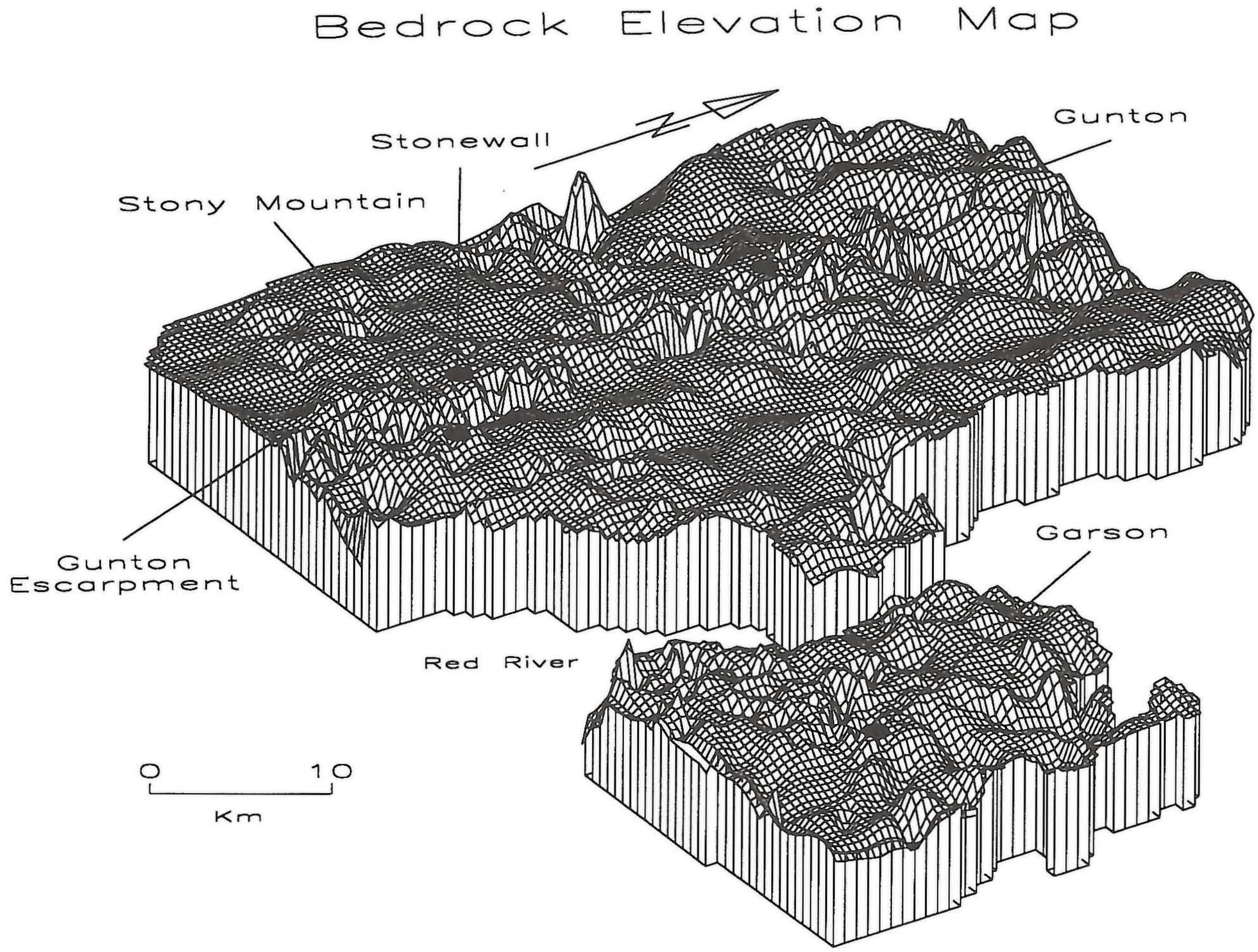

Figure GS-19-2: Bedrock elevation map for portions of NTS 62I/2, I/3 and I/6 (oblique view looking northwest, vertical scale exaggerated).

Coreholes

Six industrial mineral coreholes were drilled to provide information on potential crushed and dimension stone resources (see Table GS-18-1, Bezys, this volume for a corehole summary of each hole). Figure GS-19-3 shows the locations of three coreholes drilled north of Stonewall in the Rockwood area (M-4-96 to M-6-96) and three in the Garson area (M-7-96 to M-9-96).

The Stonewall holes (Fig. GS-19-3a) were drilled to determine the presence and thickness of the Gunton Member (Stony Mountain Formation), a major source of crushed stone for the Capital Region. Corehole M-4-96 encountered bedrock at 10.0 m (Penitentiary Member, Stony Mountain Formation). No Gunton Member lithologies were present in this hole. At this locality the Penitentiary is a green to red, fossiliferous dolomitic mudstone. At 4.5 m corehole M-5-96 encountered buff to brownish, dolomitic wackestone bedrock (Gunton Member) and at 5.9 m intersected purplish red and green dolomitic mudstone of the Penitentiary Member. Corehole M-6-96 was drilled on bedrock that comprises a light brown to yellow buff, dolomitic, slightly fossiliferous wackestone (Gunton Member) and at 17.4 m it intersected a mottled reddish green dolomitic mudstone of the Penitentiary Member. The drill program in the Stonewall area extended the aggregate resources of the Gunton Member 6 km to the northwest of corehole M-1-80 (McCabe, 1980).

In the Garson area, three holes (Fig. GS-19-3b) were drilled to confirm the presence of Tyndall Stone within the Selkirk Member of the Red River Formation. Drilling (corehole M-9-96) indicated that the best stone is situated 3 km to the southeast of the operating quarry.

The use of water well records in the selection of drill locations for the above coreholes demonstrated that information must be used with caution. Drilling of the holes showed that abrupt changes in bedrock elevation can occur over short distances or that a displaced boulder within the water well may have been recorded as bedrock.

Industrial Mineral Inventory Cards

Eleven industrial mineral inventory cards describing active and former quarries in the Rockwood area were updated to May 1996. This information was added to the documentation package that is being prepared for each quarry.

DISCUSSION

Preliminary Resource Estimation

Drilling in the Rockwood area in 1996 showed the down dip continuity of Gunton Member beds from corehole M-1-80 to M-6-96 (Fig. GS-19-3a) with an increase in overburden thickness from zero to 6.5 m (Table GS-18-1, Bezys, this volume). Coreholes M-4-96 and M-5-96 indicate that Gunton Member beds were completely eroded 3 km north of M-1-80. A 1980 resource estimate of 5 m of uncrushed Gunton Member thickness in the Stonewall East area by James F. MacLaren Limited (1980) indicated a resource of 230 million tonnes (Table GS-19-7). A preliminary estimate based upon our recent study, indicates that a 10 m thickness of Gunton Member is present and that a crushed stone estimate of 600 million tonnes is probably more accurate. At an average price of $5 per tonne (Table GS-19-6), this resource has a potential value of $3 billion.

Corehole M-9-96, drilled 3 km southeast of the active Tyndall

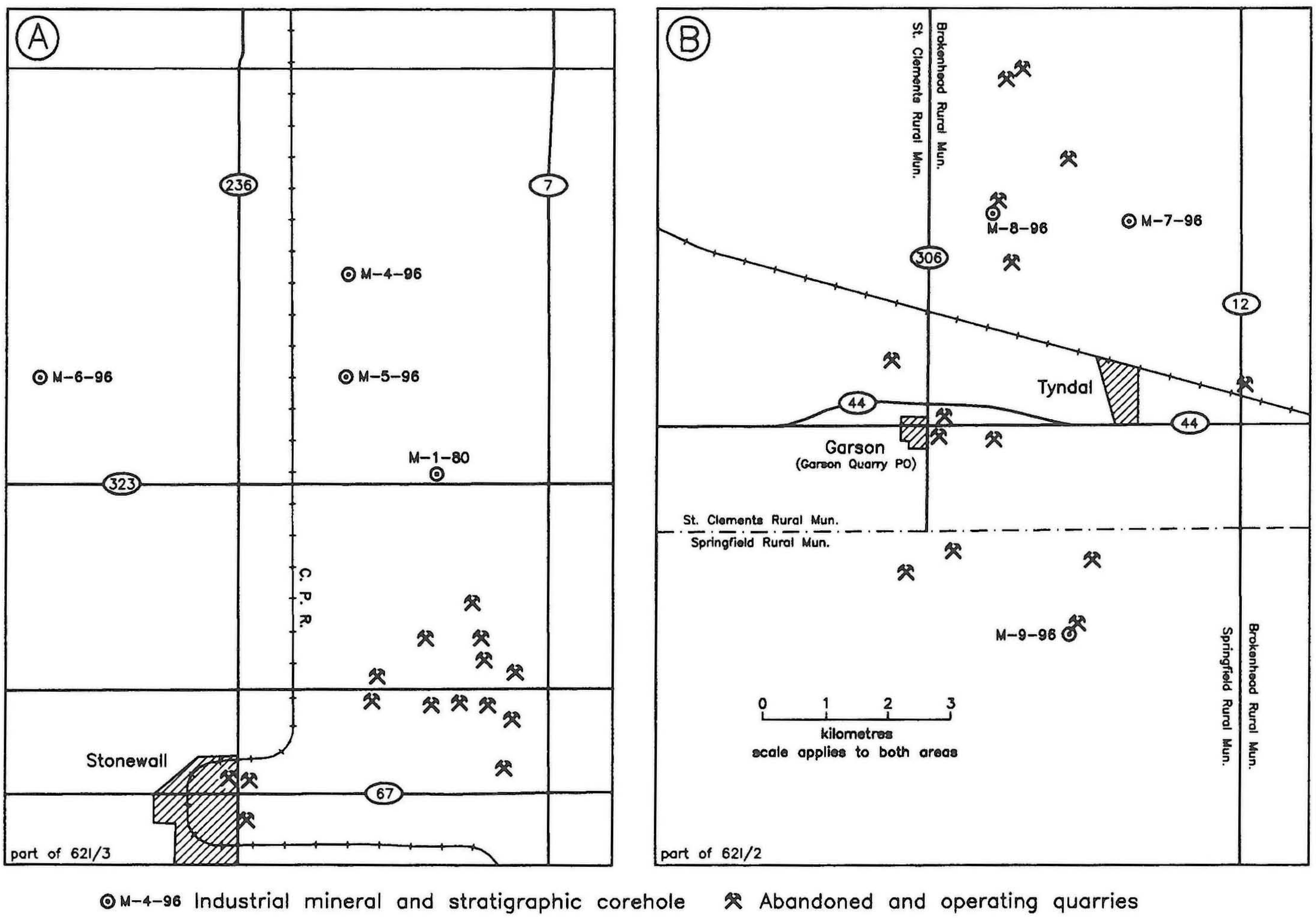

Figure GS-19-3: Location of industrial mineral coreholes in southern Manitoba, Rockwood and Garson areas.

Stone quarry at Garson, penetrated over 7 m of good stone close to surface. Future residential development southeast of the quarry should be discouraged. Drilling north of the quarry, (M-7-96 and M-8-96) indicated that the drift-covered bedrock has low dimension stone potential.

Table GS-19-7
Preliminary Estimate of Quantity and Value of Dolomite Stone Resources from the Gunton Member, Stonewall East

	1980* (Uncrushed) Estimate	1995 (Crushed Stone) Estimate	Potential Value
Thickness	5 m	10 m	
Density	2.30 t/m³	1.78 t/m³	
Area	20 km²	20 km²?	
Tonnage	230 000 000 t	600 000 000 t	$3 billion

Note:

The 1995 estimate of potential value of the crushed stone is based on a minimum cost of $5 per tonne.

Source: James F. MacLaren Limited (1980)

Recycling and Quarry Rehabilitation

The future demand for crushed stone from the Rockwood area will be affected by recycling of concrete, aggregate and asphalt materials recovered from the rebuilding of roads and bridges. This process is underway within the Capital Region, and at least three storage and crushing sites were operated by Maple Leaf Construction Ltd. during 1996 (Fig. GS-19-4). The recycling of these materials was flagged by the Manitoba Round Table (1996) as a sustainable development goal under Policy 4.3 of the Capital Region Strategy (Action Item 4.3g).

The rehabilitation of quarries is also covered under Policy 4.3. The City of Winnipeg quarries at Stony Mountain are currently being considered for rehabilitation. The preservation of access to the fossil sites of the quarries is under discussion (Winnipeg Free Press, September 16 and 21, 1996). Policy 1.6 of the Manitoba Round Table's Minerals Strategy (1994) states "Significant natural, cultural and heritage resources and areas shall be identified and protected." The natural aspects of the quarries is represented by their unique fossil content and by the only exposures in the Province of the Gunn Member of the Stony Mountain Formation. The contribution of the quarried stone to the development of the Capital Region is now part of history. However, substantial quantities of stone still remain at the margins of the quarries.

Further Work

Upon completion of the plotting, and subsequent generation of structure contour and isopach maps, the geological maps and mineral potential maps of the area will be produced. The latter will show potential areas of near surface mineral reserves and will be helpful to land use planners.

The next phase of the Capital Region area is to extend the study area south of 50°N. In this area there is no bedrock exposed due to thick overburden. There is also abundant Mesozoic (Jurassic) infill in the area

Figure GS-19-4: Maple Leaf Construction Ltd.'s Sturgeon Road recycling site.

(*i.e.*, the Dominion City Channel) that may cause construction problems due to the need for pile construction reinforcement. The Jurassic sediments will be mapped in this area using the water well data.

ACKNOWLEDGMENTS

We would like to thank Lynda Bennett of Mining Recording Section of the Mines Branch for compiling data on crushed stone production and to Manitoba Highways and Transportation for providing information on crushed stone tenders awarded in the Rockwood area. We gratefully acknowledge the assistance of Karla Horsman in the drafting of quarry outlines and sections, and the update of the corresponding industrial mineral inventory cards. Glenn Conley is thanked for graphic production.

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GS-20 PRAIRIE-TYPE MICRO-DISSEMINATED Au MINERALIZATION - A NEW DEPOSIT TYPE IN MANITOBA'S PHANEROZOIC ROCKS (NTS 63C/14)

by M.A.F. Fedikow, R.K. Bezys, J.D. Bamburak and H.J. Abercrombie[1]

Fedikow, M.A.F., Bezys, R.K., Bamburak, J.D. and Abercrombie, H.J., 1996: Prairie-type micro-disseminated Au mineralization - a new deposit type in Manitoba's Phanerozoic rocks (NTS 63C/14); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 108-121.

SUMMARY AND CONCLUSIONS

Regional and local tectonic and stratigraphic characteristics of Phanerozoic rocks of the Western Canadian Sedimentary Basin (WCSB) in western Manitoba are favorably compared to rocks comprising the WCSB in northeastern Alberta, the discovery site of Prairie-type, micro-disseminated Au mineralization. In Manitoba, the definition of the Churchill-Superior Boundary Zone (CSBZ) beneath Paleozoic cover provides a locus for Paleozoic tectonic features such as structural and stratigraphic anomalies associated with the dissolution front of the Prairie Evaporite, as well as a possible source of metals. Chloride-rich brines, bitumen laminites and red bed sequences all contribute to a depositional environment that satisfies the requirements for the formation of Prairie-type micro-disseminated mineralization. An example of Prairie-type Au mineralization in Manitoba is documented from the Mafeking area in Upper Devonian Souris River Formation limestone. A modern-day, currently forming example of this style of mineralization is described from a brine spring near Red Deer River, north of Mafeking, west-central Manitoba. Exploration for this deposit type should focus on the coincidence of the CSBZ with paleobrine discharge solution chimneys or other flow localization structures along the dissolution front of the Prairie Evaporite. In this area metal-enriched brines, microbial oxidation of organic material and reduction of sulphate may have localized precipitation of Au and base metals.

INTRODUCTION

Despite the recognition of the importance of formation waters or brines in sedimentary rocks for mobilizing and accumulating metals and hydrocarbons, Phanerozoic rocks in Manitoba have primarily been viewed as hosts for oil and gas and industrial minerals. Sporadic attempts have been initiated, and to some degree maintained, towards the exploration of Pb-Zn deposits and the documentation of the chemistry of potential host rocks (*cf.* Gale *et al.*, 1981, 1984; Nielsen and Gale, 1982) and formation waters and their precipitates (Stephenson, 1973; Wadien, 1984; McRitchie, 1989, 1994 and 1995). Formation waters and organic-rich precipitates from Manitoba's salt springs were sampled by Stephenson in 1973; Wadien (1984) sampled the same springs for a geochemical analysis. It is worth noting that Pb and Zn mineralization have been discovered in significant quantities at Pine Point within the WCSB. Olson *et al.* (1994) document similar mineral occurrences within the WCSB in Alberta. Recent studies of potential base and precious metal source rocks within the WCSB have identified Ordovician metal-rich black shales at Black Island (Fedikow *et al.*, 1995; Schmidtke and Fedikow, this volume). Accordingly, the recognition of a new Au and base metal mineral deposit type in the WCSB in Alberta with recently discovered Manitoba examples of similarly mineralized zones underscores the need for a review of the metallogenetic potential of the relatively underexplored Phanerozoic stratigraphy in Manitoba.

This report and field work, to date, attempts to build on the foundation laid by Abercrombie and Feng (1994, 1996), Feng and Abercrombie (1994) and Abercrombie (1996) who described this deposit type and the mechanisms of its formation. The widespread nature of this type of mineral deposit through WCSB section in northeastern Alberta, the relative ease of access for purposes of exploration in Manitoba and the discovery of the first Manitoba examples of Prairie-type mineralization in a location predicted by the depositional model brings exciting new potential to this area of the province.

PRAIRIE-TYPE MICRO-DISSEMINATED MINERALIZATION

The discovery of micro-disseminated Au-Ag-Cu mineralization in the Fort MacKay area of northeastern Alberta in sedimentary rocks of the WCSB and the underlying granitic basement represents a significant new type of low temperature polymetallic mineral deposit (Abercrombie and Feng, 1994, 1996; Feng and Abercrombie, 1994). The Fort MacKay mineralization has been called "Prairie-type" (Abercrombie, 1996) and consists of 0.5-5.0 μm assemblages of native and alloyed Au, Ag, Cu, Pb, Zn, Cd, Fe, Cr, Ni, Sb and Bi in argillaceous limestone (Upper Devonian Waterways Formation). Mineralization may be in the form of oxides, chlorides, carbonates and be accompanied by native sulphur and marcasite.

Prairie-type mineralization occurs through the stratigraphic sequence at or near the intersection of the Sewetakun and Muskeg River faults that appear to have provided ground preparation for the migration of mineralizing brines. Evidence to support this hypothesis is provided by altered and mineralized brittle-ductile shears within the basement granitic gneiss. Widespread Au, Pb, Ag, Cu, Zn, Sb, Sn, W, Bi and Cl and two alteration facies have been documented from the granitic rocks. The older phase of alteration is Precambrian in age and comprises potassium feldspar, chlorite, disseminated hematite $\pm$ Fe-epidote. The younger phase consists of Ce-bearing minerals, carbonate, quartz, hematite and pyrite or marcasite. Monazite and $CeCO_3$ microveinlets are widespread.

The formation of polymetallic Prairie-type mineralization and associated alteration is attributed to oxygenated brines derived from halite evaporites within the Prairie Evaporite (Elk Point Group). Brine movement was driven by downward density flow through metal-enriched red beds, evaporites and sheared granite gneiss basement rocks. Metal-bearing brines were subsequently discharged at the eastern margin of the WCSB subsequent to up-dip migration and cross strata migration due to fractures and faulting. The precipitation of Au and associated metals was constrained by oxidation-reduction reactions that involve oxidation of organic material (bitumen) and hydrocarbons and sulphate reduction to locally produce abundant native sulphur (Abercrombie, 1996; Abercrombie and Feng, 1996).

The presence of Au, Ag, Pb, Bi, Cr, Cu and Fe chlorides in the deposits indicates that Cl was important in the mineralizing fluids and these were probably Cl-rich brines or formation waters. The main alteration mineral assemblages of calcite, NaCl, KCl, clays and quartz indicate the mineralizing fluids were enriched in Cl, CO_3^{2-}, Si, Na and K. The widespread occurrence of Ce-bearing minerals in all rocks suggests oxidating conditions since Ce^{4+} can only be decoupled from other rare earth elements under oxidizing conditions. The small grain size and disseminated nature of Prairie-type mineralization, the alteration mineral assemblages, and the wide distribution of bitumen in the host sedimentary rocks indicates the temperature of deposition of the mineralization probably did not exceed 100°C (Abercrombie and Feng, 1996). This overall style of mineralization is similar in genesis to red bed Cu and unconformity-related Au-PGE-U mineralization (Sverjensky, 1987; Eugster, 1989; Bloom *et al.*, 1992).

TECTONIC AND DEPOSITIONAL FRAMEWORK OF THE PHANEROZOIC IN SOUTHWESTERN MANITOBA

The northeastern periphery of the WCSB in Manitoba is characterized by Paleozoic and Mesozoic outcrop belts (Fig. GS-20-1). The

[1] Geological Survey of Canada, 33-3-3rd St. NW, Calgary, AB, T2L 2A7

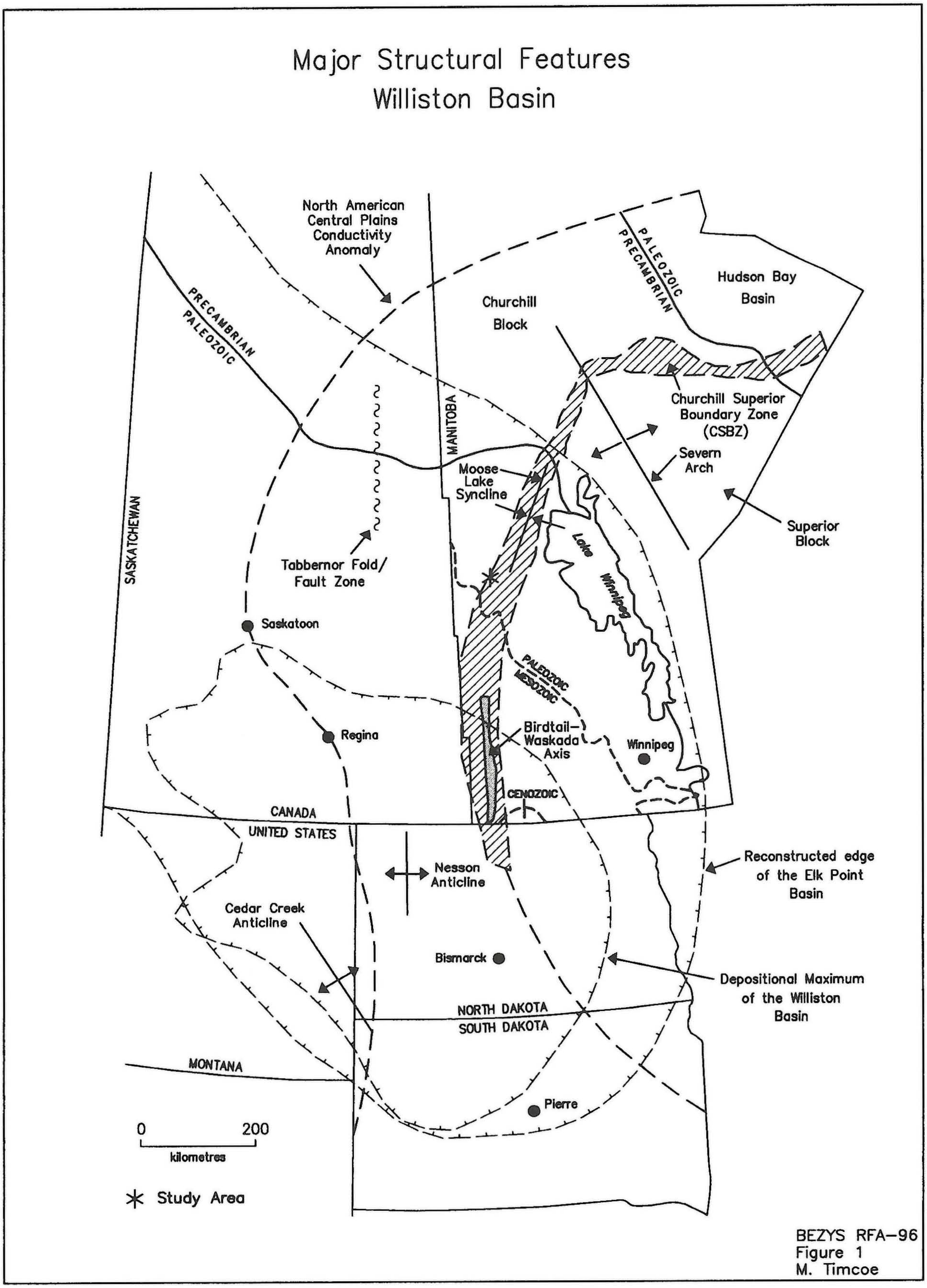

Figure GS-20-1: Major structural features and geology of the Williston and Elk Point basins, Manitoba and vicinity.

WCSB is a composite feature that includes both the Elk Point Basin, centred in south-central Saskatchewan (which controlled deposition during Devonian time), and the Williston Basin centred in northwestern North Dakota (which controlled the depositional patterns throughout the remainder of post-Cambrian time) (Fig. GS-20-1). Structural disruption of these basins has been affected by both Precambrian and Paleozoic tectonics.

The principal basement tectonic feature effecting the stratigraphy of both basins in Manitoba is the CSBZ (Fig. GS-20-1). The extension of the CSBZ, the contact or discontinuity developed between the Superior Craton to the east and the Churchill Craton to the west, beneath Phanerozoic strata, has been established on the basis of gravity and aeromagnetic geophysical surveys.

McCabe (1967) considered the CSBZ as having exerted a significant effect on sedimentation patterns in the Manitoba portion of the WCSB, as well as localizing Paleozoic structures (such as salt collapse features) that produced stratigraphic anomalies arising from compaction and salt dissolution of the Devonian Prairie Evaporite. Evidence of this is seen in the form of structure contour and isopach maps of individual stratigraphic horizons (Bezys and McCabe, 1996). McCabe (1967) also considered the east-trending orogenic zones of the Superior Craton to have contributed to the disruption of the depositional framework of the Paleozoic rocks, albeit to a lesser extent than the CSBZ.

The most prominent Paleozoic structural feature effecting WCSB stratigraphy is the dissolution edge of the Prairie Evaporite salt basin (Fig. GS-20-2). The salt basin edge is coincident with the CSBZ trend (or the Birdtail-Waskada Axis in southwestern Manitoba). This axis is also coincident with the trend of Winnipegosis Formation reef development in the Dawson Bay and Swan River areas that probably reflect basement involvement (Norris *et al.*, 1982). The axis has also had a significant effect on local permeability of the sedimentary rocks, which is reflected by the apparent control of oil accumulations in Mississippian strata in Manitoba (McCabe, 1967).

The Moose Lake Syncline, located north and west of the north end of Lake Winnipeg (Fig. GS-20-1), represents another prominent tectonic feature that coincides with the CSBZ. This syncline represents a flexure in the Ordovician and Silurian outcrop belt and has been used as evidence to support post-Precambrian structural movement along the CSBZ (McCabe, 1967).

The Devonian outcrop belt in north-central Manitoba comprises the northeastern truncated edge of the Middle and Upper Devonian Elk Point Basin. Devonian rocks rest with slight angular unconformity on Silurian (Interlake Group) dolomites (Fig. GS-20-3). In turn, Jurassic and Cretaceous clastic rocks overlie the Devonian with angular unconformity (Fig. GS-20-4).

The outcropping portion of the Devonian sequence comprises a series of complex carbonate-evaporite cycles, although the evaporites have subsequently been dissolved from the outcrop area (Fig. GS-20-5). The first cycle is the Elk Point Group: Ashern-Winnipegosis-Prairie Evaporite succession. The second cycle is represented by the Dawson Bay Formation, initiated by the Second Red Beds and culminating with the Hubbard Evaporite. The third cycle is the Point Wilkins Member of the Souris River Formation, initiated by the First Red Beds and culminating with the Davidson Evaporite. The Sagemace Member of the Souris River Formation may have been the start of a fourth cycle, the top of which has subsequently been eroded.

The Souris River Formation consists of the Point Wilkins Member overlain by the Sagemace Member (not present in the northern outcrop belt). The Point Wilkins Member was redefined by Norris *et al.* (1982) and consists of four rock types, in ascending stratigraphic sequence: a red and green calcareous shale (First Red Beds); fossiliferous, argillaceous limestone; dense, micritic and fragmental fossiliferous limestone; and a yellowish brown, finely crystalline dolomite and dolomite limestone. These four rock units are informally referred to as the First Red Beds, Argillaceous Limestone Beds (ALB), Micritic Limestone Beds (MLB), and Dolomitic Limestone Beds (DLB) of the Point Wilkins Member.

AN EXAMPLE OF PRAIRIE-TYPE MICRO-DISSEMINATED AU MINERALIZATION IN MANITOBA

History of the Solution Chimneys

The recognition of the Au and base metal-enriched nature of features that were to become known as "solution chimneys" was the result of the initial recognition of these structures by Ruth Bezys during a Geological Association of Canada (G.A.C.) field trip led by Ruth and Hugh McCabe in May, 1996. Subsequent identification of the features by Hugh Abercrombie during the G.A.C. field trip and scanning electron microscopic evaluation of samples of rind and siliceous sinter collected from one of the solution channels, established the presence of a diverse suite of native metals, including Au, base metal alloys and compounds (Fig. GS-20-6; Table GS-20-1). In addition to the metals, the presence of compounds such as KCl and NaCl indicated a probable brine origin for the metals and associated compounds and heralded the documentation of a new deposit type in Manitoba.

Geology of the CBR Cement Ltd. Quarries and Description of the Solution Chimneys (Mafeking Area)

The bedrock at the Mafeking Quarry consists of the Upper Devonian Point Wilkins Member of the Souris River Formation, a buff coloured, mottled micritic and fossiliferous limestone that has been quarried for high-calcium limestone (MLB) (Fig. GS-20-7). These beds are overlain by a strongly oxidized, rusty red to brown, altered fossiliferous dolomitic limestone (DLB). The units vary in thickness in the north quarry from 5-10 m and 1-5 m, respectively. These two lithologies are the host rocks for Prairie-type micro-disseminated Au mineralization.

The two quarries examined for this program are situated 16 km north of the town of Mafeking and were operated by CBR Cement Ltd. (Regina) for the extraction of high-calcium limestone (Fig. GS-20-8, 9). Within these quarries a total of 19 solution chimneys were located, mapped and sampled. Seventeen of these chimneys were located in the north quarry, whereas only two were identified from the essentially rehabilitated south quarry. The rehabilitation of the south quarry and extensive till infill may have concealed further examples of the solution chimneys.

The solution chimneys are primarily developed within the relatively unoxidized high-calcium limestone (MLB) of the Point Wilkins Member, although good examples of these features have been documented within the overlying oxidized member (DLB). The relative paucity of these features in the oxidized member may be a function of erosion and removal during quarry development. The oxidized nature of the DLB may be attributed to fluid flow from the solution chimneys laterally through the more permeable and oxidized unit. The MLB, although described as relatively unaltered, are locally characterized by disseminated marcasite nodules (<1 cm to 10 cm in diameter), greenish-grey discolouration (argillic alteration?), and mottling with apparent proximity to the solution chimneys.

Solution chimneys are recognized singly or in clusters as inverted, conical-shaped features with a 1-8 cm thick siderite-rich rind that mantles the carbonates of both units (Fig. GS-20-10). The solution chimneys have maximum observed dimensions of 10-25 m in width and 10 m in height although it should be noted that the lower 10 m of the quarry is flooded. In cross section, the solution chimneys exhibit a relatively consistent lithologic progression from an outer siderite-altered carbonate rind to greenish clay infill with inclusions of elongate, cobble-sized silica-rich sinters near the rind-clay interface (Fig. GS-20-11). The sinters can be cherty at their outer edges and spongy at their cores or have dense cores with concentric banding. They are commonly rusty weathered, contain finely disseminated marcasite and/or pyrite and are coated with green clay. The siliceous sinters are not observed within the MLB and DLB, except where the solution chimneys are developed.

Solution chimney cores are often filled with a grey-white sand (locally with minor clay) that may represent Cretaceous Swan River Formation infill. This material may be covered by till that has slumped over the quarry wall.

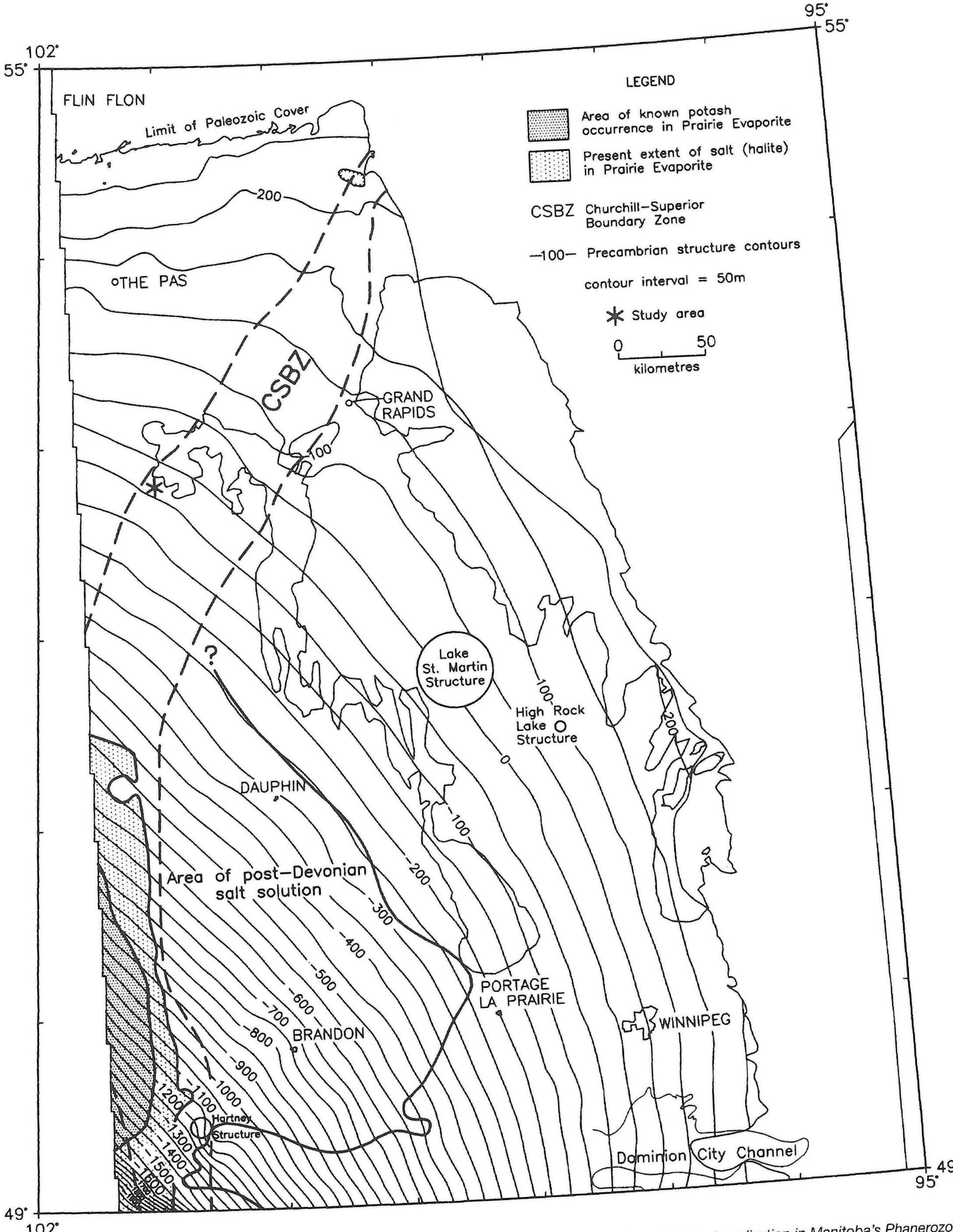

Figure GS-20-2: Regional controls and priority areas for the localization of Prairie-type micro-disseminated mineralization in Manitoba's Phanerozoic rocks.

Table GS-20-1
Summary of scanning electron microscope investigations on broken surfaces of samples from west-central Manitoba. Samples were broken and rock chips were mounted and carbon-coated prior to analysis.

Sample	Location[1]	Rock Type	Mineralogy		Microdisseminated Mineralogy[2]			Bitumen
	• Formation		Major	Minor	Base Metals	Precious Metals	Others	
AU96 MB8a-1	Red Deer River salt spring • Dawson Bay Formation (Lower Member)	• dolomite	• dolomite	• Fe-S: *marcastie* • FE-O: hermattie • halite	• Cu-S: *chalcocite* • Cu-Zn: *alloy* • Pb: *native* • ZN: *native* • SN: *native*	• AU-Cu-Ni-ZN: *alloy (1x3μm)* • Ag-Fe-Ni-Cu: *alloy (1x2μm)*	• Bas-So-: *barite* • La-Ce-carbonate	• C (Na, Al, P, S, Cl, K, Ca); *type I* • C-S (Cl): *type II*
AU96 MB8e-1	Highway 10 road cut • Dawson Bay Formation (Upper Member)	• dolomitic limestone	• calcite • dolomite	• FE-O: *hermatite* • Fe-O: *limonite* • FE-S: *pyrite*	• Pb-Zn-P-O: Pb-Zn phosphate • Cu-Cl: *CuCl$_2$* • CU-Zn: *alloy* • Sn-Pb: *alloy* • Pb: *native* • Ni: *native*	• none deserved	• Zr-Si-O: *zircon* • Ce-La-Nd-P-O: *monazite* • Ce-La-Nd carbonate	• C (Al, S, Cl); *type I* • C-S: *type II*
AU96 MB8e-2	Highway 10 road cut • Dawson Bay Formation (Upper Member)	• partly silicified limestone	• calcite	• FE-S: *marcasite* • Fe-O: *hermatite*	• Cu-Zn: *alloy* • Pb (Cr): *native* • Cd: *native*	• none deserved	• Ce-La-Nd carbonate • Ba-S-O: *barite* • Ca-S-O: *gypsum* • K-Al-Si-O: *K-feldspar* • Si-O: *quartz* • Zr-Si-O: *zircon*	• C (Na, Cl, K): *type I* • C-S: *type II*
AU96 MB9-1	Mafeking Quarry • Souris River Formation (Point Wilkins Member)	• sideritized limestone	• siderite	• calcite	• Fe-O: *hermatite* • Ni-P-O: nickel phosphate • Cd-C-O: *Cd carbonate* • Fe-S: *marcasite* • Zn-S: *sphalerite* • Cu-Fe-S: *chalcophyrite* • Cd-S: *hawleyite or greenockite* • Cu-Zn: *alloy* • Ni (±Al, P, O) *native Ni or Ni-Al phosphate (?)* • Cu: *native* • Sb: *native* • Pb: *native*	• Ag: *native (1x5μm)*	• Ba-S-O: *barite* • Ce-La-Nd-P-O: *monazite* • Zr-Si-O: *zircon* • Br: *HBr(?)* • Ca-Br: *CaBr$_2$*	• none observed

[1] Locations from Bezys and McCabe (1996).
[2] Major elements determined by energy dispersive x-ray spectrometry and are listed in order of decreasing peak height; phase identifications based solely on EDS results are indicated in italics

Table GS-20-1 (continued)
Summary of scanning electron microscope investigations on broken surfaces of samples from west-central Manitoba. Samples were broken and rock chips were mounted and carbon-coated prior to analysis.

Sample	Location[1]	Rock Type	Mineralogy		Microdisseminated Mineralogy[2]			Bitumen
	• Formation		Major	Minor	Base Metals	Precious Metals	Others	
AU96 MB9-2	Mafeking Quarry • Souris River Formation (Point Wilkins Member)	• siliceous sinter	• quartz	• none	• Fe-O: *hermatite* • Fe-S: *marcasite* • Fe-S-K-O: *jarosite* • Fe-Cr-Ni: *alloy* • Cr-Ni: *alloy* • Ni-Cu: *alloy* • Cu-Zn: *alloy* • Cu-Zn-Ni: *alloy* • Ni: *native* • Zn: *native* • Sn: *native* • Pb: *native* • Bi: *native*	• Au: *native (3x1-3µm)* • Au-Cu-Ag: *alloy (1x4µm)* • Ag: native *(1x1µm)*	• Ca-C-O: *calcite* • Ca-Mg-C-O: *dolomite* • Ce-La-Nd-P-O: *monazite* • Ba-S-O: *barite* • Sr-S-O: *celestite* • Ti-O: *rutile* • Zr-Si-O: *zircon* • K-Cl: *sylvite*	• C (Na, Ca, Cl, K): *type I* • C-S (Cl): *type II*
AU96 MB12-3	• Winnipegosis Quarry • Souris River Formation (Sagemace Member)	• partly dolomitized limestone	• calcite • dolomite		• Fe-S: *marcasite* • Zn-S: *sphalerite* • Fe-O: *hematite* • Fe-Ni-Cu: *alloy* • Cu-Zn: *alloy* • Ni: *native* • Cu: *native*	• none observed	• Ce-La-Nd carbonate • Ce-La-Nd-P-O: *monazite* • Ti-O: *rutile* • Na-Cl: *halite* • Zr-Si-O: *zircon*	• C (Al, Si, S, Cl, K) *type I* • C-S: *type II*

[1] Locations from Bezys and McCabe (1996).

[2] Major elements determined by energy dispersive x-ray spectrometry and are listed in order of decreasing peak height; phase identifications based solely on EDS results are indicated in italics

ERA	PERIOD	FORMATION	MEMBER	MAXIMUM THICKNESS (m)	BASIC LITHOLOGY
CENOZOIC	QUATERNARY	(Recent)			Top soil, dune sands, lake clays, peat
		Glacial Drift		140	Clay, sand, gravel, boulders, till
	TERTIARY				
		Turtle Mountain	Peace Garden Goodlands	160	Shale, clay, sand, lignite
MESOZOIC	CRETACEOUS	Boissevain		45	Sand, sandstone, greenish grey
		Pierre Shale (First White Specks)	Coulter Odanah Millwood Pembina Gammon Ferruginous	400	Grey shales, non-calcareous, local ironstone, bentonitic, carbonaceous
		Niobrara		75	Grey speckled shale, calcareous, bentonitic
		Morden Shale		55	Dark grey shale, non-calcareous, concretions, local sand and silt
		Favel (Second White Specks)	Assiniboine Keld	45	Grey shale with calcareous specks, bands of limestone and bentonite
		Ashville	Belle Fourche Shale Westgate Newcastle Skull Creek	80	Dark grey shale, non-calcareous, silty, Newcastle (sand zone)-quartz sandstone
		Swan River		150	Sandstone and sand, quartzose, pyritic shale, non-calcareous
	JURASSIC	Waskada		60	Banded green shale and calcareous sandstone, bands of limestone, varicoloured shale
		Melita		145	
		Reston		45	Limestone, buff, and grey shales
		Amaranth	Evaporite	55	White anhydrite and/or gypsum and banded dolomite and shale
	TRIASSIC		Red Beds	45	Red shale to siltstone, dolomitic
PALEOZOIC	PERMIAN PENNSYLVANIAN	St. Martin Complex		265(+)	Carbonate breccia, trachyandesite (crypto-explosion structure?)
	MISSISSIPPIAN	Madison Group: Charles		20	Massive anhydrite and dolomite
		Madison Group: Mission Canyon	MC-5 MC-4 MC-3 MC-2 MC-1	120	Light buff limestone, oolitic, fossiliferous, fragmental, cherty, bands of shale and anhydrite
		Madison Group: Lodgepole	Flossie Lake Whitewater Lake Virden Scallion Daly	185	Limestone and argillaceous limestone, light brown and reddish mottled, zones of shaley, oolitic, crinoidal and cherty limestone
		Bakken	Upper Middle Lower	20	Two black shale zones separated by siltstone
	DEVONIAN	Qu'Appelle Group: Three Forks		55	Red siltstone and shale, dolomitic
		SASK. GROUP: Birdbear		40	Limestone and dolomite, yellow-grey, fossiliferous, porous, some anhydrite
		SASK. GROUP: Duperow		120	Limestone and dolomite, argillaceous and anhydritic in places
		MAN. GROUP: Souris River (First Red)		90	Cyclical shale, limestone and dolomite, anhydritic *
		MAN. GROUP: Dawson Bay (Second Red)		50	Limestone and dolomite, porous, anhydritic, local red and green shale
		ELK PT. GROUP: Prairie Evap		120	Halite, potash and anhydrite, interbedded dolomite
		ELK PT. GROUP: Winnipegosis		75	Dolomite, yellow brown, reefy
		ELK PT. GROUP: Elm Point			Limestone, fossiliferous, high-calcium
		ELK PT. GROUP: Ashern		12	Dolomite and shale, brick red
	SILURIAN	Interlake Group		110	Dolomite, yellow buff, fossiliferous, several argillaceous marker beds
	ORDOVICIAN	Stonewall	t-marker zone	25	Dolomite, sparsely fossiliferous, t-marker defines Ordovician-Silurian boundary
		Stony Mountain	Williams Gunton Penitentiary Gunn	45	Dolomite, yellow buff Dolomite, dusky yellow, fossiliferous, red shale, green fossiliferous limestone bands (Gunn)
		Red River	Fort Garry Selkirk ?— Cat Head Dog Head	170	Dolomitic limestone and dolomite, mottled (Tyndall Stone within Selkirk)
		Winnipeg	Upper Unit	65	Green shale, waxy, interbedded sandstone
			Lower Unit		Sand, sandstone and quartzose
	CAMBRIAN	Deadwood		25	Black to green grey sand, waxy, glauconitic siltstone and shale
PRECAMBRIAN					Metamorphic and crystalline rock

* Host rock of Prairie-type Au mineralization

Figure GS-20-3: Geological formations in Manitoba including the host rocks for recognized Prairie-type micro-disseminated Au mineralization.

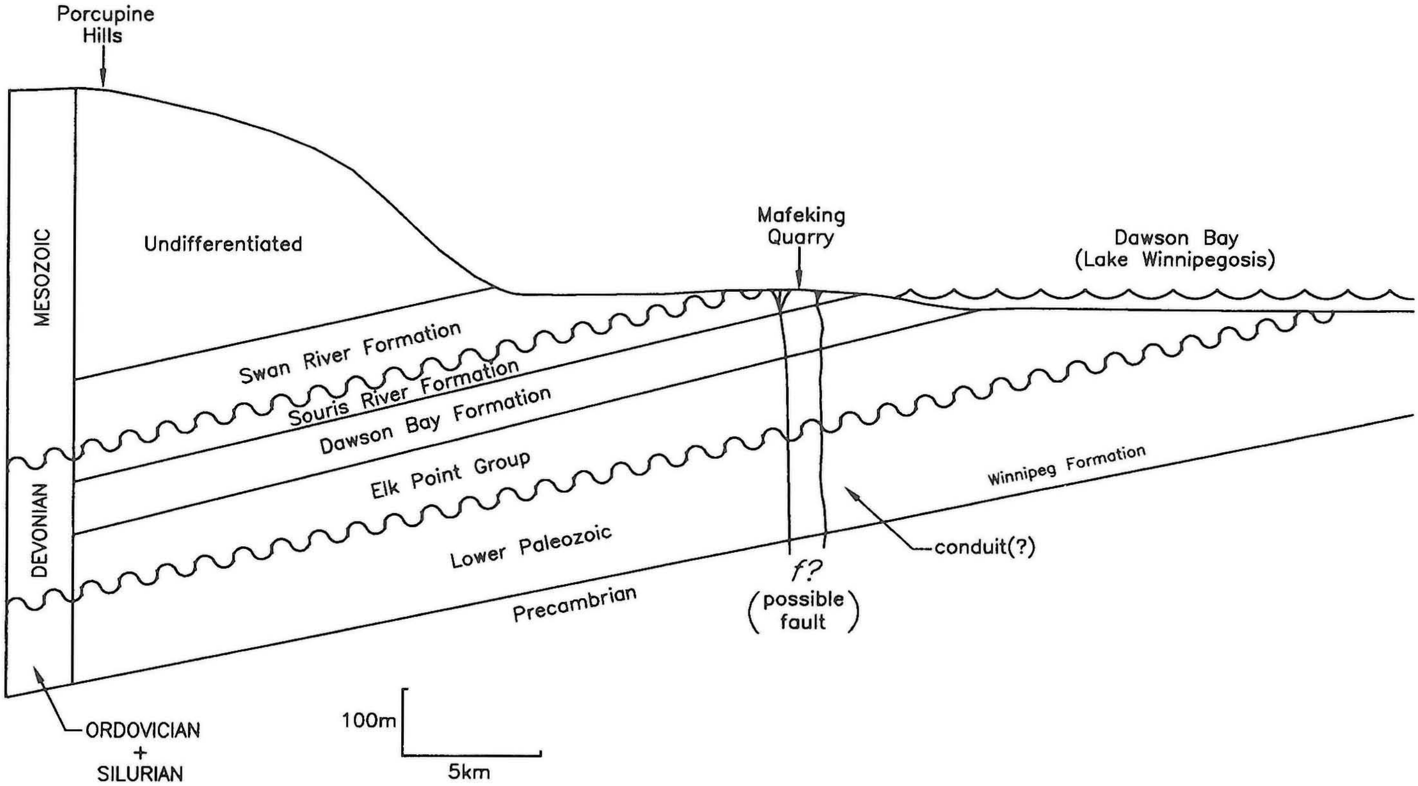

Figure GS-20-4: Structural cross section of west-central Manitoba including the Mafeking Quarry study area.

Ongoing Petrographic and Geochemical Studies

Samples from each of the 19 observed solution chimneys that were accessible in the north and south quarries are currently undergoing petrographic examination and geochemical analysis. Samples of the siderite-rich rind, siliceous sinter and marcasite-bearing wallrock from each accessible solution chimney were collected. A vertical and a southeast-trending lateral sampling transect was completed through the stratigraphy and along apparently altered beds of the Point Wilkins Member at solution chimney 2 (SC-2) (Fig. GS-20-8, 9). These samples will be used to assess the host rocks for the presence of Au ± base metal mineralization, and for evidence of fluid flow and concomitant alteration, including the dispersion of base and precious metals away from the solution chimneys.

EXPLORATION CONSIDERATIONS

Regionally, the zone of overlap between the CSBZ beneath Paleozoic formations and the dissolution edge of the Prairie Evaporite represent prospective areas for Prairie-type micro-disseminated mineralization (Fig. GS-20-2). The presence of high salinity brines or formation waters, bitumen-bearing laminites (Winnipegosis Formation inter-reef facies), biogenic, pyritic carbonates, metal-rich shales, native sulphur, zones of increased permeability (such as those associated with salt dissolution collapse breccia), and redox boundaries should be considered key elements for the localization of Prairie-type mineralization.

A demonstration of the importance of the recognition of these criteria is provided in the area of the Red Deer River salt spring (25 km north of the town of Mafeking on Highway 10; Fig. GS-20-7). This salt spring emanates from the Devonian outcrop belt with a total salinity of 52 800 mg/l and a flow rate of approximately 0.44 litres per minute (Stephenson, unpublished data). The stratigraphic section near the spring consists of a small section of Lower Dawson Bay Formation, an argillaceous, fossiliferous limestone and the basal Second Red Beds. It is probable that the red beds are underlain by a Winnipegosis Formation reef, the spring source.

The base of the Dawson Bay Formation in the Devonian stratigraphic column is marked by the Second Red Beds, whereas the base of the Souris River Formation is marked by the First Red Beds (Fig. GS-20-5). In the deeper portions of the Elk Point Basin, these beds were underlain by evaporites. In the Manitoba outcrop belt, these evaporites have undergone dissolution. Appreciable brecciation and therefore induced permeability is apparent in both red bed intervals. Interestingly, scanning electron microscopic analysis of a sample of a limonite-goethite coated cobble collected from the site of the Red Deer River salt spring this past summer revealed a 3 μm Au-Cu-Ni-Zn grain (Table GS-20-1). Abundant marcasite and/or pyrite and halite are observed as infillings of intracrystalline pore spaces and dissolution porosity in a microcrystalline dolomite. Ag in association with Fe, Cu and Zn is also present as are several grains of Cu-Zn or Cu-Zn-Ni alloys. Grains of Fe-Cr-Ni and native Sn were also observed. Two types of bitumen were also recognized in the sample. These are a C and S-bearing variety and a second more complex bitumen with C, O, Na, Si, Al, K and Cl (Fig. GS-20-6). Many of the carbonate and Precambrian boulders and cobbles present in the salt flat area are undergoing *in situ* leaching.

The Red Deer River salt spring and the associated rocks are an example of a modern day, on-going process of metal-bearing brines altering and precipitating precious and base metals within Dawson Bay Formation carbonate rocks. The over- and underlying red beds represent a potential metal source.

DISCUSSION

Micro-petrographic analysis of only a few samples from a select number of sites in the Mafeking area of west-central Manitoba demonstrate the presence of; (1) a diverse suite of native metals, including gold, (2) the presence of a brine or formation water "signature" consist-

CRET. / JUR.	GROUP/FORMATION/MEMBER	M	DEPOSITIONAL THICKNESS (METRES) AND SUMMARY LITHOLOGY	
DEVONIAN	SOURIS RIVER FORMATION: Sagemace Member	20+	Limestone, pale yellowish brown to reddish grey, microcrystalline, dense, minor argillaceous interbeds. Passes laterally to totally dolomitized sequence.	
DEVONIAN	SOURIS RIVER FORMATION: basal shale	2–14	Shale, dolomitic, massive, medium brownish red with some greenish mottling.	
DEVONIAN	SOURIS RIVER FORMATION: (evaporite dissolved)		(Davidson Evaporite)	
DEVONIAN	SOURIS RIVER FORMATION: Point Wilkins Member – Undifferentiated carbonate beds	26	(southern area only) Limestone, argillaceous limestone, calcareous dolomite and dolomite. In places the carbonate beds of the Point Wilkins Member are completely dolomitized. Equivalent to the Point Wilkins Member of the north, excluding the 'First Red Beds'.	
DEVONIAN	SOURIS RIVER FORMATION: Point Wilkins Member – Dolomitic limestone beds (DLB)	6+	(northern area only) Orange and cream–brown, thin– to medium–bedded, finely granular dolomitic limestone and limestone locally containing stromatoporoids; typically developed near junction of Steeprock River road and Highway 10. These are the uppermost beds of the Point Wilkins Member represented in the northern part of the outcrop belt, the upper boundary of which is an erosion surface.	*
DEVONIAN	SOURIS RIVER FORMATION: Point Wilkins Member – Micritic limestone beds (MLB)	18–21	Resistant, thick–bedded, yellowish–grey, micritic and pelletoid limestone; some minor dolomitic limestone; contains scattered *Athyris vittata*; typically developed in the Point Wilkins area and recognizable southward on islands in Swan Lake.	*
DEVONIAN	SOURIS RIVER FORMATION: Point Wilkins Member – Argillaceous limestone beds (ALB)	11–15	Thin–bedded argillaceous limestone with shaly partings, and some pelletoid limestone beds; typically developed in the Point Wilkins area.	
DEVONIAN	SOURIS RIVER FORMATION: Point Wilkins Member – 'First Red Beds'	2–14	Red and greenish–grey calcareous and non–calcareous shale, some silty shale and thin interbeds of argillaceous dolomite; in places some beds are brecciated; barren of fossils	
DEVONIAN	(evaporite dissolved)		(Hubbard Evaporite)	
DEVONIAN	DAWSON BAY FORMATION: Upper Dawson Bay	6–17	Limestone, white to pale yellowish brown, highly fossiliferous with corals and stromatoporoids, in places grading to stromatoporoid biolithite. In part extremely pure high–calcium limestone (99.8% $CaCO_3$), but in places variably dolomitized, especially lower part of unit.	
DEVONIAN	DAWSON BAY FORMATION: Middle Dawson Bay	11–18	Calcareous shale, fossiliferous, medium grey to dark greyish red, massive (recessive).	
DEVONIAN	DAWSON BAY FORMATION: Lower Dawson Bay	9–25	Gradational sequence passing upward from brown partly laminated and bituminous dolomite to grey and reddish grey dense slightly argillaceous micrite and fossiliferous micrite, which in turn grades upward to highly fossiliferous brachiopod biomicrite at top. Lower two zones thin markedly to the north.	
DEVONIAN	DAWSON BAY FORMATION: Second Red Beds	6–15	Red to greenish grey dolomitic shale, commonly brecciated as a result of salt collapse.	
DEVONIAN	ELK POINT GROUP: PRAIRIE EVAPORITE	0–129	Prairie Evaporite: dominantly salt with potash interbeds and minor anhydrite in basinal areas; entirely anhydrite in shelf areas (at present). Originally present throughout the entire Devonian outcrop belt, but subsequently removed by subsurface salt solution. Where preserved in subsurface, overlaps and completely buries Winnipegosis reefs with resultant thinning of evaporite section.	
DEVONIAN	ELK POINT GROUP: WINNIPEGOSIS FORMATION – Upper Winnipegosis (reef)	0–90	Reefal facies: dolomite, very fine to medium crystalline, ranges from compact dense to subsaccharoidal, massive to medium/thick bedded, variably fossiliferous but texture largely obscured by dolomitization. Reef thicknesses tend to be relatively uniform in a given area.	
DEVONIAN	ELK POINT GROUP: WINNIPEGOSIS FORMATION – Upper Winnipegosis (interreef)	35	Interreef facies: dolomite, brown to black, finely laminated with black bituminous partings, in places calcareous. Lamination best defined towards top of unit.	
DEVONIAN	ELK POINT GROUP: WINNIPEGOSIS FORMATION – Lower Winnipegosis	10–20	Lower Winnipegosis: dolomite, fine to medium crystalline, moderately granular to saccharoidal, medium to thin bedded. In part calcareous and grades laterally to Elm Point limestone facies.	
DEVONIAN	ELK POINT GROUP: ELM POINT FORM.	10–20	Elm Point: limestone, pale yellowish brown dense fine grained biomicrite. In part shows lighter yellowish dolomitic mottling. Pure high–calcium limestone to calcareous dolomite.	
DEVONIAN	ELK POINT GROUP: ASHERN FORMATION	3–18	Argillaceous dolomite and dolomitic shale, medium to dark greyish and brownish red, in places reduced to greenish grey. Local basal dolomite breccia.	
SIL.	INTERLAKE GROUP		Dolomite, white to pale yellowish buff, mostly microcrystalline dense, thin bedded, sublithographic, in part stromatolitic. Some porous biostromal interbeds towards top.	

* Units present in CBR Cement Ltd., North Quarry (Mafeking)

Figure GS-20-5: Detailed stratigraphic succession and lithologies, Devonian formations (modified after Norris et al., 1982).

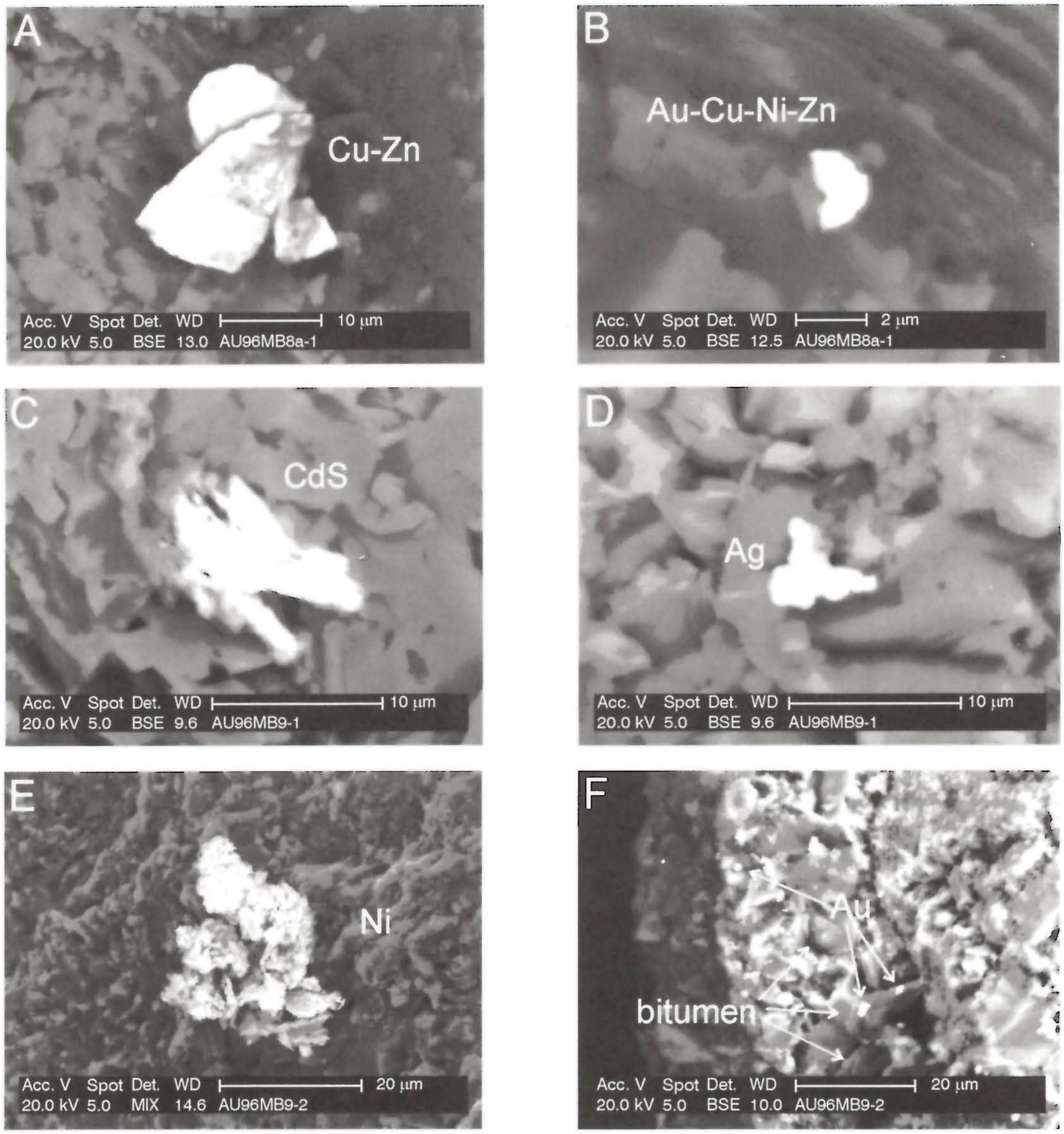

Figure GS-20-6: Scanning electron microscopy photomicrographs of Prairie-type mineralization:

A. A group of three Cu-Zn particles in a dolomite originating from the Dawson Bay Formation; sample AU96MB8a-1. This sample is an iron oxide coated cobble that was taken from float in the Red Deer River salt spring. The dolomite has been partly dissolved and locally contains up to 15 % marcasite, hematite or halite infilling dissolution pores.

B. A single 3 μm Au-Cu-Ni-Zn particle was observed in dolomite sample AU96MB8a-1 which also contains Ag-Fe-Ni-Cu. Energy dispersive x-ray spectrometry (EDS) shows that Au is alloyed with Cu, Ni and Zn. An alternative explanation is that Au and Cu-Ni-Zn may be physically intermixed at submicron scales. This sample is from a site of contemporary brine discharge indicating that Prairie-type mineralizing processes are active at present.

C. Abundant 3-10 μm CdS (greenockite or hawleyite) particles with marcasite, sphalerite, chalcopyrite, Cu-Zn alloy and native Ag, Ni, Cu, Sb and Pb were observed in sample AU96MB9-1 from the north Mafeking Quarry. This sample is a partly sideritized "rind" developed in limestone of the Souris River Formation at the immediate margin of solution cavity SC-1 at the south end of the quarry (see Fig. GS-20-8).

D. A 5 μm native Ag particle in sample AU96MB9-1, a sideritized limestone of the Souris River Formation.

E. A 25 μm composite particle of native Ni in a siliceous sinter boulder from the margin of solution cavity SC-1 at the south end of the north Mafeking quarry'; sample AU96MB9-2. The Ni particle consists of numerous small (<1-5 μm) Ni particles that have coalesced to form a larger, sintered Ni particle. EDS analysis of some sintered Ni particles show P, O and less commonly A1 peaks indicating the presence of a Ni (Al) phosphate mineral with native Ni in some cases.

F. Native Au particles associated with type I bitumen in sample AU96MB9-2. Type I bitumen is characterized by EDS analysis as being predominantly composed of C with minor peaks of some or all of Na, Al, P, S, Cl, K and Ca. A second bitumen, type II, is predominantly composed of C and S and may contain small amounts of Cl. The presence of two types of bitumens in many samples may indicate that two hydrocarbon systems have been active in this region and is consistent with microbial reduction of metal-bearing oxyhalide complexes in brines and concomitant oxidation of organic material as a mechanism for formation of Prairie-type mineralization.

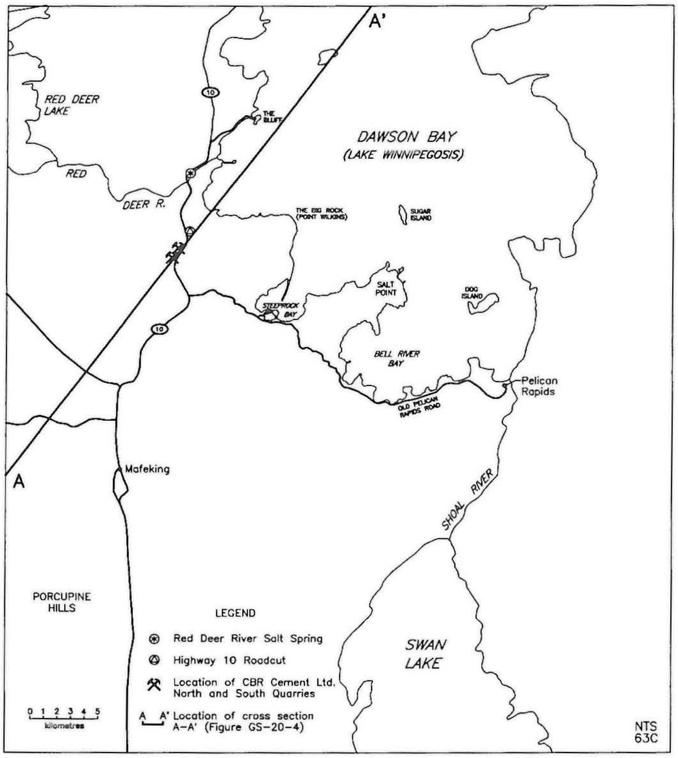

Figure GS-20-7: Location of the Mafeking (CBR Cement Ltd.) high-calcium limestone quarries, Mafeking area, Red Deer River salt spring and cross section A-A' (Fig. GS-20-4).

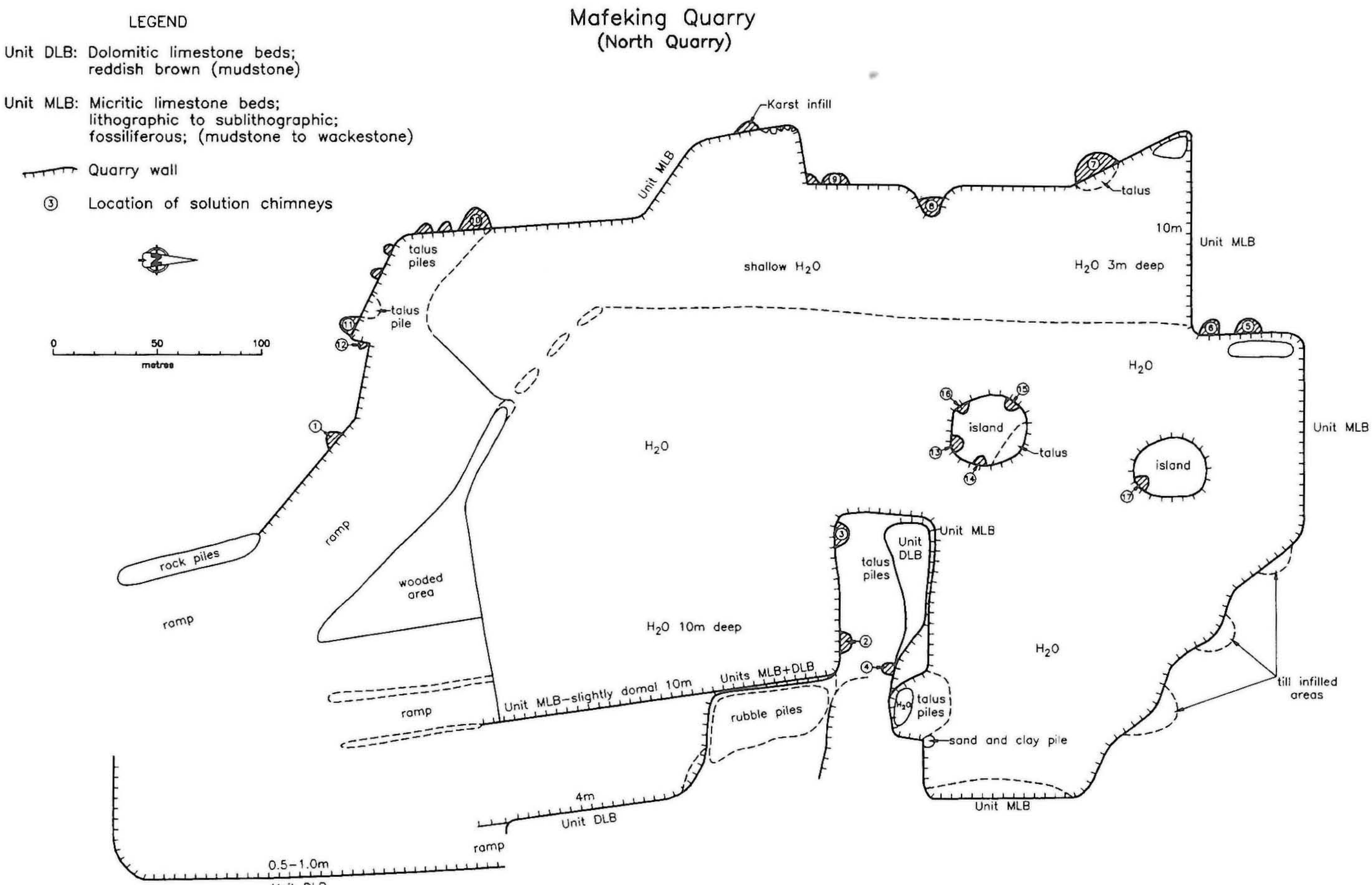

Figure GS-20-8: Geology and location map for the solution chimneys in the north quarry, CBR Cement Ltd., Mafeking area.

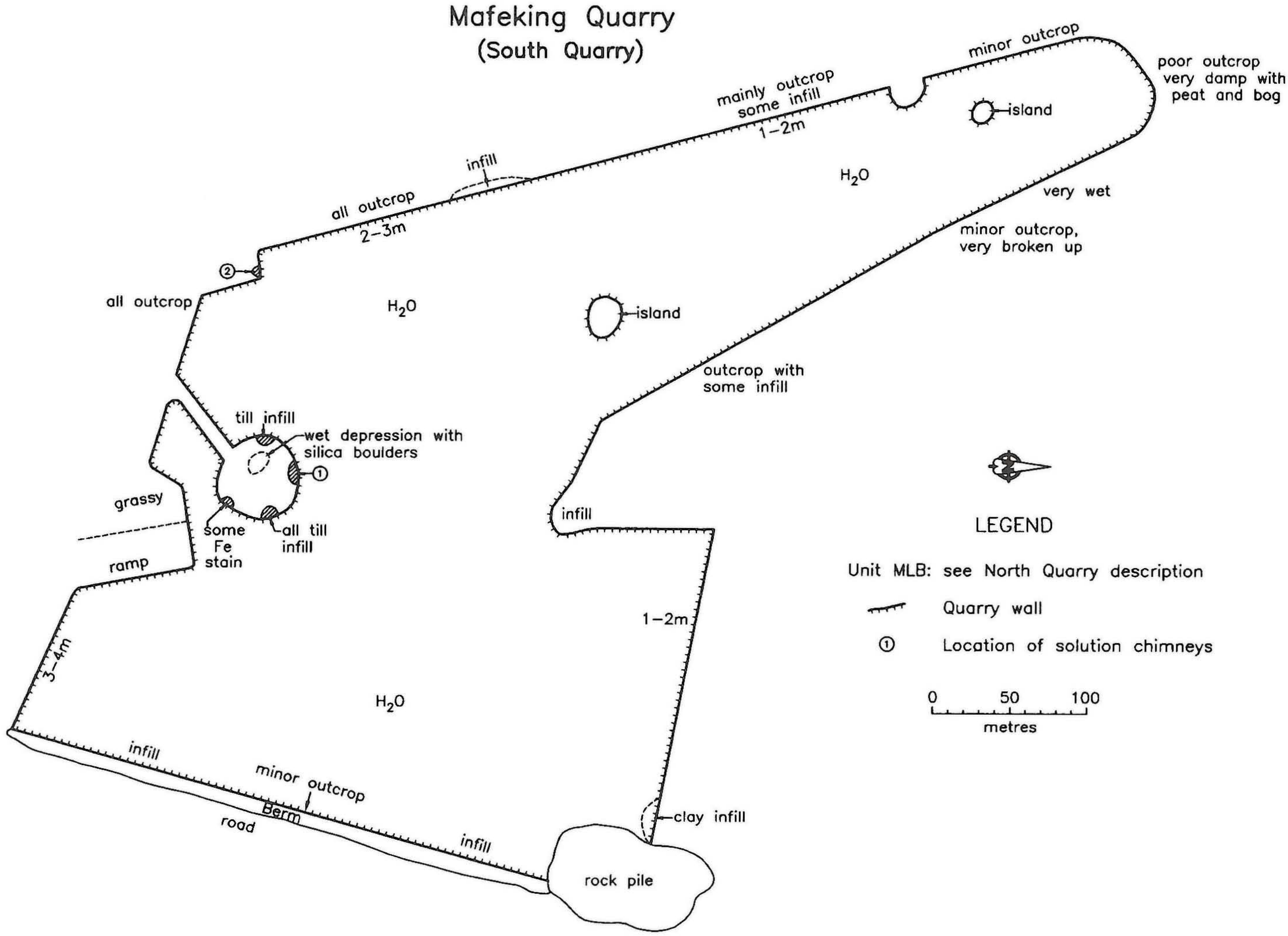

Figure GS-20-9: Geology and location map for the solution chimneys in the south quarry, CBR Cement Ltd., Mafeking area.

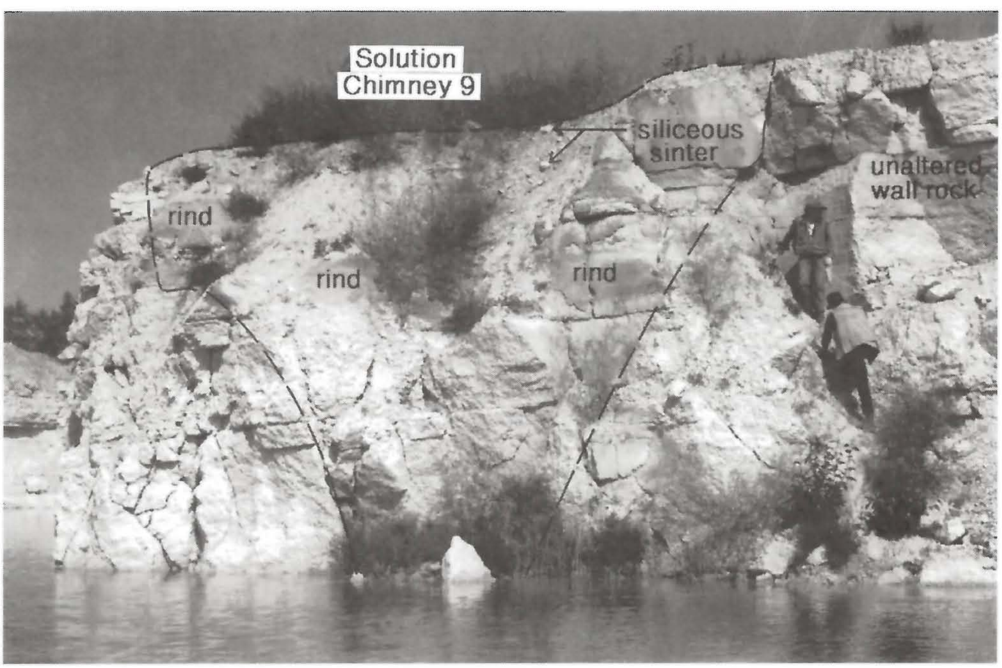

Figure GS-20-10: Photograph of a solution chimney.

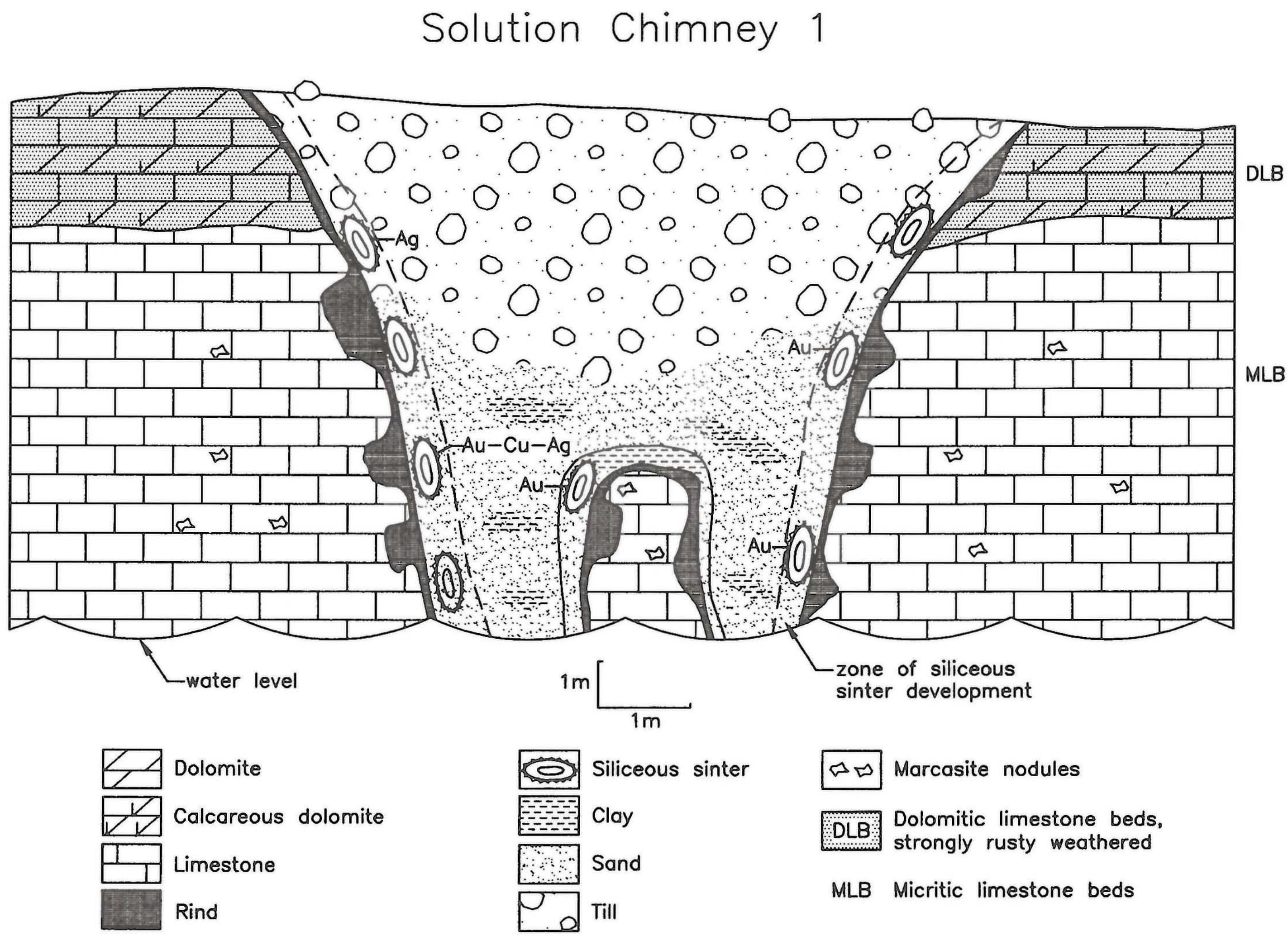

Figure GS-20-11: Schematic diagram illustrating the local setting of solution chimney (SC-1) at the Mafeking Quarry (CBR Cement Ltd.), and the relationship between chimney morphology and the location of micro-disseminated Au, Ag and base metals.

ing of KCl and NaCl and bitumen in the samples, (3) apparent low temperatures of formation, and (4) high induced permeabilities through ground preparation by structural disruption and dissolution phenomena. Together these phenomena are highly suggestive of a style of mineralization similar to that recognized in northeastern Alberta and termed "Prairie-type".

Although only small amounts of Au, Ag and base metals have been identified in samples examined to date, it appears reasonable that a mechanism invoking metal delivery by oxygenated chloride-rich brines and precipitation by redox reactions has been identified in a small segment of Phanerozoic rocks. As demonstrated in the Red Deer River area, this process is currently active and is precipitating base and precious metals in a saline spring environment.

The source of metal necessary for the development of a mineable precious metals deposit is unknown although it is plausible that metal-enriched black shales or perhaps mineralization leached from the rocks comprising the CSBZ represent possibilities. The role of the black shales in the formation of this mineral deposit type will possibly be elucidated by a regional geochemical evaluation of these units. The black shale sampling program is currently in progress and will utilize oil and gas well chips, as well as outcrop samples to assess the nature of the depositional environment and geochemical characteristics of the black shales.

The Prairie-type micro-disseminated base metal ± Au-Ag mineralization identified in Upper Devonian rocks from the Mafeking area represents a first step to a better understanding of this new mineral deposit type. The recognition of precious metal mineralization, potentially over large areas of the Phanerozoic in Manitoba, represents an exciting new target for exploration in a readily accessible area of the Province.

ACKNOWLEDGMENTS

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GS-21 EVIDENCE OF CRETACEOUS(?) VOLCANISM ALONG THE CHURCHILL-SUPERIOR BOUNDARY ZONE, MANITOBA (NTS 63G/4)

by R.K. Bezys and M.A.F. Fedikow, and B.A. Kjarsgaard[1]

Bezys, R.K., Fedikow, M.A.F. and Kjarsgaard, B.A., 1996: Evidence of Cretaceous(?) volcanism along the Churchill Superior boundary zone, Manitoba (NTS 63G/4); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 122-126.

SUMMARY

Sub-Phanerozoic mineral exploration drilling for Ni-Cu mineralization along the Churchill-Superior Boundary Zone (CSBZ) in north-central Manitoba has provided abundant Phanerozoic drill core for stratigraphic evaluation. One drillhole, Cominco RP-96-21, intersected 3.5 m of tuff that contains accretionary lapilli within infill material that may be Cretaceous in age. The infill material consists of unconsolidated sands, silts and clays that are similar to the Cretaceous Swan River Formation present in the outcrop belt. Traditionally, the infill material is thought to represent sediments infilling karst features such as sink holes or caverns within the consolidated and competent Paleozoic rocks. However, the presence of accretionary lapilli in tuff of intermediate composition that occurs as infill material in Cominco RP-96-21 suggests that the drillhole may have intersected a large channel-like structure (pre-Mesozoic in age) that was subsequently infilled with Mesozoic age strata (one of the beds representing a pyroclastic unit). The recognition of an explosive or pyroclastic rock is indicative of volcanism. The presence of accretionary lapilli suggests a relatively proximal volcanic source that geographically may be spatially associated with the CSBZ. Alteration and mineralization of this rock and associated zones in both Precambrian and Phanerozoic rocks is indicative of hydrothermal activity. This has important implications for future mineral exploration in the area.

INTRODUCTION

The bedrock geology of north-central Manitoba consists of Silurian dolomites of the Interlake Group (noncyclic carbonate deposition interspersed with argillaceous marker beds). In drill core, the carbonates are lithified and competent, except where fractured and rubble-like. The location of Cominco's RP-96-21 drillhole, 7.5 km south of Easterville, is in an area of very thick glacial overburden of the east-west trending The Pas Moraine (Fig. GS-21-1). North and south of the moraine the overburden thins to 1-3 m and bedrock is exposed in many places.

Drillhole RP-96-21 was drilled to target Ni-Cu mineralization along the CSBZ based on geophysical information. The CSBZ is the boundary between the Superior Craton to the southeast and the Churchill Craton to the northwest (see Fig. GS-20-1, Fedikow *et al.*, GS-20 this volume). This zone has been considered relatively stable since at least Ordovician time, although Bezys and Bamburak (1994) and Bezys (1996) have

[1] Geological Survey of Canada Ottawa, 601 Booth St., Ottawa, K1A 0E8

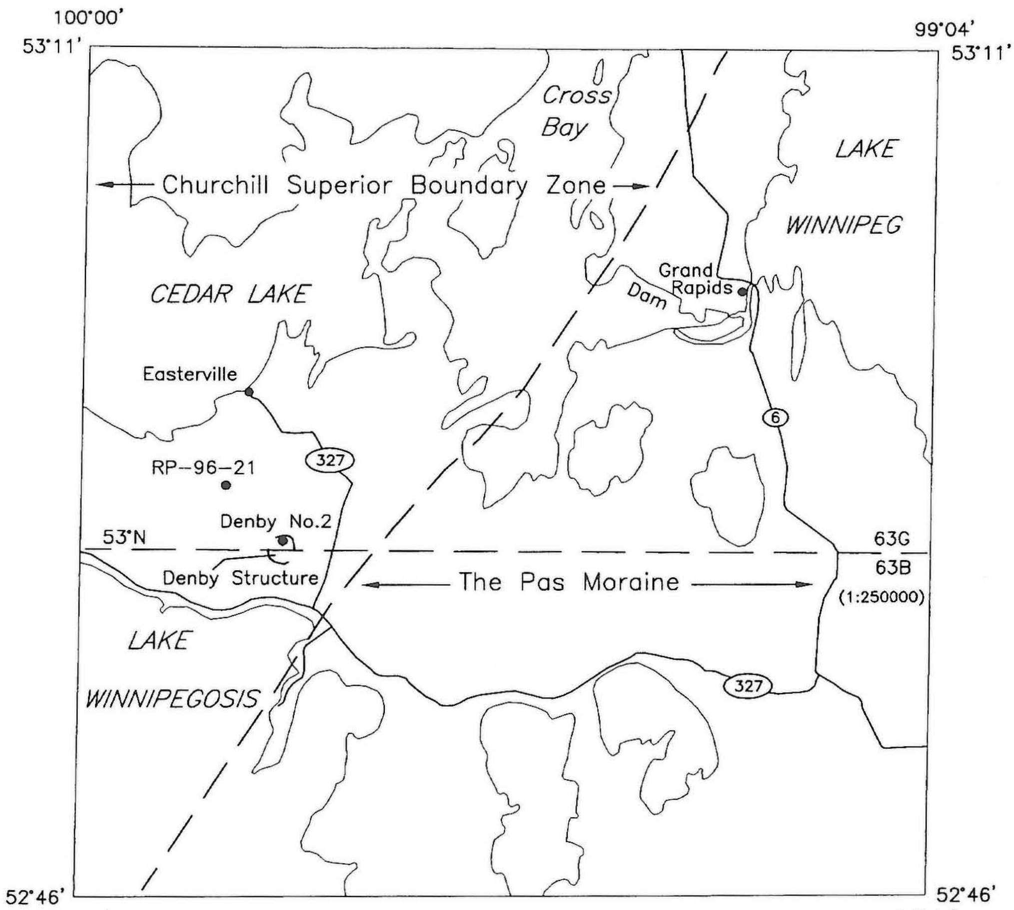

Figure GS-21-1: Location of Cominco drillhole RP-96-21, Denby Structure and the Churchill-Superior Boundary Zone.

documented structural abnormalities within the Paleozoic strata west and north of the Grand Rapids area. The abnormalities may represent post-Precambrian movement or uplift.

Mesozoic strata do not outcrop in the Easterville area, although drill core with Cretaceous sediments was documented by Bezys (1996) from a Falconbridge drillhole located in William Lake (85 km northwest of Easterville). Many of the Phanerozoic intervals logged from mineral exploration drillholes have zones of sand and clay "infill". The infill zones vary in thickness from 1-2 cm to approximately 30 m. These are thought to represent karst void fillings within the Paleozoic carbonate rocks and may be sink holes or caverns.

RESULTS

Drillhole RP-96-21 intersected 182 m (measured depths) of overburden, infill and Paleozoic material (Table GS-21-1; Fig. GS-21-2). The hole was abandoned due to sand. The Pas Moraine is represented by 28 m of glacial overburden at the top of the hole. Lithified and competent carbonates are present between 28.0-50.5 m, 66.4-109.8 m, and 138.2-182.0 m. Ordovician and Silurian stratigraphic picks were determined from these intervals. Between 50.5-66.4 m and 109.2-138.0 m were zones of infill material. The infill material consists of light brown, tan to white (some red), very fine grained sand, silt and clay. Interbedded with these lithologies are minor amounts of black shale and sand, that locally contain coal-like fragments. These sediments may represent transitional deltaic facies. The interval 133.1-136.6 m contains a light brownish tan lapilli tuff with small accretionary lapilli, 1 mm to 2 cm in size. Some of the lapilli have pyritic rims with kaolinized cores indicating one or possibly two phases of hydrothermal alteration and mineralization. The interval 133.1-136.6 m contains a light brownish tan, matrix-supported lapilli tuff. The lapilli tuff unit is located at the base of an infill zone, which may represent a pre-Mesozoic channel that eroded into the Paleozoic (Fig. GS-21-2) bedrock.

Analysis by thin section petrography revealed the lapilli beds to be a fresh intermediate volcanic rock. The beds contain abundant accretionary lapilli, indicating a pyroclastic origin. The lapilli and groundmass of the samples are dominated by sideromelane (glass), which is variably devitrified. The phenocrysts in the sample are 0.1-0.6 mm across and consist of clinopyroxene and plagioclase feldspar, plus rare zircon. The sample contains approximately 65 modal percent phenocrysts and thus is probably a crystal tuff. The fresh nature of the sample, and absence of non-volcanogenic components suggests the sample is not crystal rich due to epiclastic (reworking) processes. The samples are not kimberlitic.

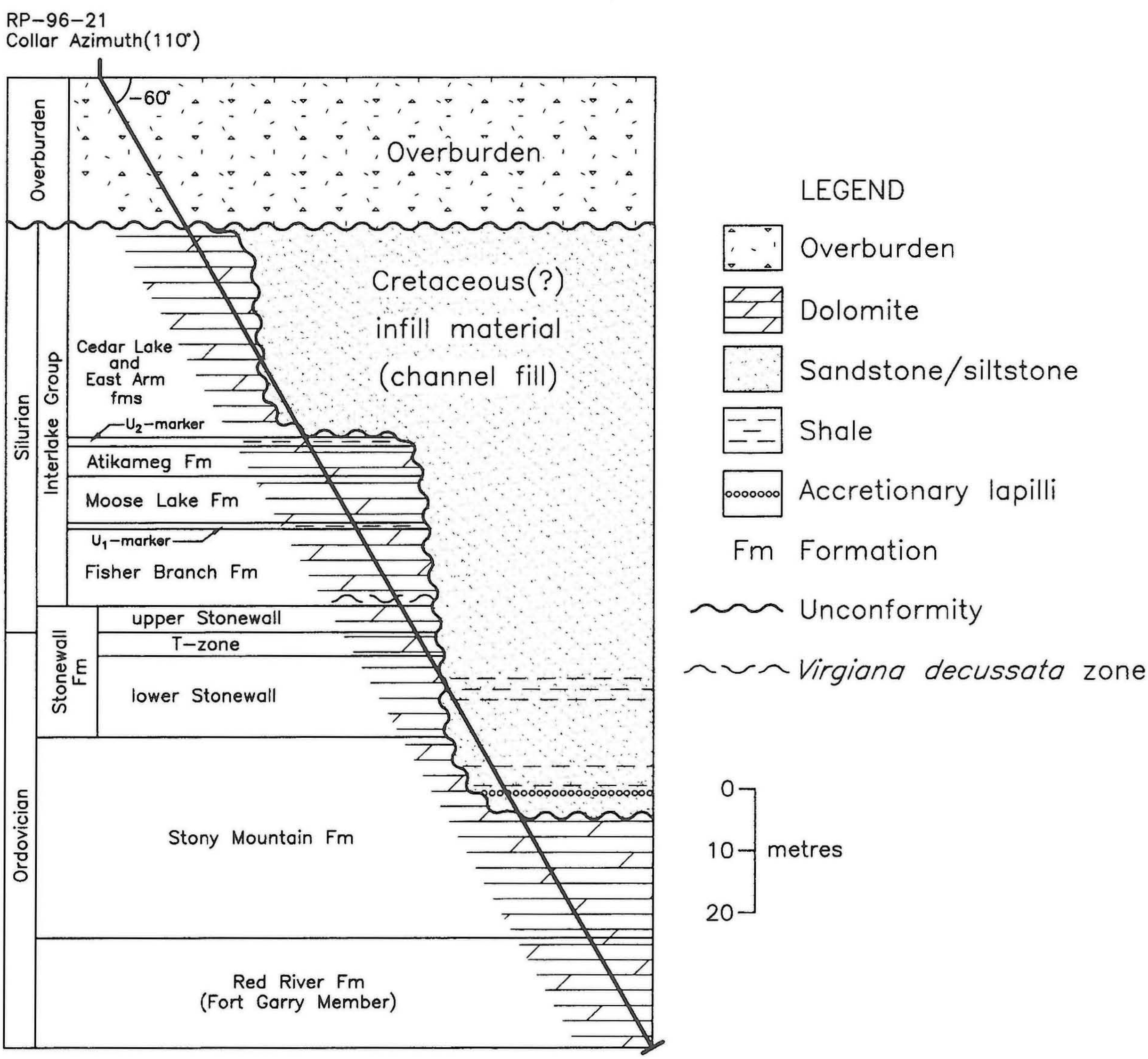

Figure GS-21-2: Geologic profile of Cominco drillhole RP-96-21.

DISCUSSION

Accretionary lapilli form as moist aggregates of ash in eruption clouds, by rain that falls through dry eruption clouds or other processes (Fisher and Schmincke, 1984). Accretionary lapilli usually fall within a few kilometres of the eruptive vent; they are rare at distances greater than 20 kilometres (Williams and McBirney, 1979). This would place the location of the vent within or adjacent to the CSBZ. The presence of accretionary lapilli, 133.1 m down hole from the drillhole collar elevation is perplexing, but not if the infill zones are envisioned as large channels eroded into the Paleozoic bedrock (Fig. GS-21-2). The channels could have formed in pre-Mesozoic time and were subsequently infilled with Mesozoic or younger age sediments, similar to the Dominion City Channel in southern Manitoba (Manitoba Energy and Mines, 1990).

Approximately 5 km southeast of drillhole RP-96-21 is the Denby Structure (McCabe, 1978). In 1971, the Cominco Denby No.2 drillhole intersected, below glacial till, a "deep layered soil section (91.4 m thick) consisting of red, blue, and grey clay that contains a thick layer of uniformly sorted fine sand. In the layered complex, sheets of limestone (which may or may not have been boulders) about 3-4 m thick were found" (McCabe, 1978; p. 64). Large marcasite concretions occur in the blue and grey clay and a large amount of marcasite occurs in the limestone boulders. McCabe interpreted this interval to be Mesozoic (Cretaceous?) in age and the feature probably represented a channel or karst deposit. A thin interval of Paleozoic carbonate was intersected between 114.0-130.1 m and passed directly into Precambrian serpentinite at 130.1 m. The elevation of the Precambrian surface is approximately 106.7 m above regional elevations.

The Ordovician sequence in the Cominco Denby No.2 drillhole is normal carbonates, although they are somewhat fractured and weathered. The basal Ordovician Winnipeg Formation is either not present or is very thin in this hole. McCabe (1978) suggested that Paleozoic correlations cannot explain the Precambrian high as a simple erosional high (monadknock) on the Precambrian erosion surface, and that 80-105 m of local, post-Ordovician, probably pre-Mesozoic(?), structural uplift has occurred in the vicinity of Cominco Denby No.2. Structural uplift as a result of volcanism is suggested as a potential solution. The infill material present in Cominco Denby No.2 may be very similar to the infill material found in RP-96-21, located only 5 km apart. It is probable that the infill zones in both holes have a similar history and may be related. Unfortunately, the Cominco Denby No.2 core is not available for relogging and resampling.

Currently, zircons are being extracted from the Cominco RP-96-21 sample for U-Pb age determination. Additionally, palynological dating of the organic-rich beds overlying the lapilli tuff will provide complimentary data to compare biostratigraphic and isotopic age determinations. A sample of the pyritic lapilli tuff will be sent for multi-element geochemical analysis.

ACKNOWLEDGMENTS

Special thanks go to John Pearson (Cominco Ltd.) for allowing us to view and sample the drill core and to publish this report. Doug Berk is thanked for assisting in the retrieval of the drill core from the field and to R. Carter who helped log the core.

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Table GS-21-1
COMINCO RP-96-21 Core Log
NTS Map 63G/4 UTM: 5876641N, 443349E
Ground Elevation: 269.7 m
Logged by R. Bezys, M. Fedikow and R. Carter
Collar azimuth: 110° @ 60° dip
80 m: 110° @ 61° dip
155 m: 108° @ 62° dip

Measured Depth (m) (True Depth (m))	Description
0.00-28.00 (0.00-24.45)	**Overburden**
28.00-50.50 (24.45-43.73)	**Silurian Interlake Group: East Arm/Cedar Lake formations:** light brown tan to dark brown dolomudstone, wackestone, and grainstone; very fine to medium grained; core is very broken and fractured; <2% porosity in mudstones, 3-5% in grainstones; stromatolitic at 40.5 m (35.07); at 41.4 (35.85) m is a dark brown, 30 cm day to silt infill.
50.50-66.40 (43.73-57.79)	**Infill zone:** light grey tan sandy/silty clay infill; only 4 m of core remains; white clay contains pyrite along black(?) veined layers, the pyrite is very finely disseminated; Sample 88-10-96 from 53.2 (46.30) m; it appears this interval is a primary depositional unit and not infill (?).
66.40-69.10 (57.79-60.14)	**U_2-marker:** blue grey to green grey laminated dolomudstone; very fine grained; <1% porosity, pinpoint; massive; between 67.8-68.2 (59.10-59.36) m shows evidence of floating sand quartz grains and green grey clay beds; minor clay infill.
69.10-74.85 (60.14-65.47)	**Atikameg Fm:** light brown to tan to cream dolowackestone; faint algal laminations present; no discernible fossil material; fine to medium grained, slightly sucrosic; 5-10% porosity, vuggy; no salt casts present; sharp upper contact.
74.85-75.00 (65.47-65.60)	**Moose Lake Marker:** light tan to brown laminated dolomudstone; slightly brecciated; very fine grained; <2% porosity, pinpoint; sharp upper contact.
75.00-83.60 (65.60-73.12)	**Moose Lake Fm:** change from HQ to NQ core occurs at 82.0 (71.72) m; light brown to tan dolomudstone, wackestone to grainstone; core is broken up and fractured; algal laminations present; ashtray stromatolites well developed in upper 1.0-1.5 m; very fine to medium grained; porosity ranges from <2% in mudstones to approximately 3-5% in grainstones, mainly pinpoint and vuggy; sharp upper contact.
83.60-84.20 (73.12-73.64)	**U_1-marker:** light brown to green grey laminated dolomudstone; slightly brecciated and containing quartz sand; very fine grained; <2% porosity, pinpoint; sharp upper contact.
84.20-99.50 (73.64-87.02)	**Fisher Branch Fm:** light brown tan to cream dolowackestone; very fine to medium grained; fossiliferous with scattered solitary coral debris; burrow mottled; two *Virgiana decussata* beds, one at 99.3 (86.85) m (10 cm thick), and another at 97.5 (85.28) m (30 cm thick); 3-5% porosity, vuggy, core is broken up and slighty rubbly; sharp upper contact.
99.50-109.18 (87.02-95.49)	**Stonewall Fm**
99.50-100.90 (87.02-88.25)	**Upper Stonewall Marker:** light grey to dark grey dolomudstone; very fine grained; laminated; <2% porosity, pinpoint; at the base is a 4 cm thick green clay bed; sharp upper contact.
100.90-103.60 (88.25-90.61)	**Upper Stonewall:** light brown to tan dolomudstone, some grainstone; some fossiliferous material, mainly solitary coral debris; very fine grained; <2% porosity, pinpoint; gradational upper contact.
103.60-109.00 (90.61-95.33)	**T-zone:** light brown tan to blue grey dolomudstone; this zone is marked by two distinct argillaceous marker beds, separated by a tan, mottled wackestone; very fine grained; porosity varies from <2% to 4-5%, vuggy; minor sand at the base; minor breccia beds; gradational upper contact.
109.00-109.18 (95.33-95.49)	**Ordovician Lower Stonewall (Williams Member):** (no contact to the Williams present, due to loss of core boxes); buff yellow to tan to brown dolomudstone; massive; very fine grained; <2% porosity, vuggy; gradational upper contact.
109.80-138.00 (96.03-121.28)	**Cretaceous(?) infill zone**
109.80-110.20 (96.03-96.38)	White clay with grey silt; massive; at 110.25 (96.43) m, are round spherical to oval clasts/spheroids (lapilli?), matrix supported, 2 mm-1.5 cm; kaolinitic; N8-N9.
110.20-110.27 (96.38-96.44)	Red brown silty clay.

Measured Depth (m) (True Depth (m))	Description
111.25-113.00 (97.30-98.83)	Red to purple clay with abundant white flecks(?); 5R6/2, 5R5/4.
113.00-116.00 (98.83-101.46)	White to light grey silt and clay; massive; waxy; N7-N8.
116.00-122.00 (101.46-106.70)	Lost core, sand.
122.0-123.00 (106.70-107.58)	White sand and white to light grey, waxy shale (similar to interval 113-116); looks like Swan River Fm; N7-N8.
123.00-123.60 (107.58-108.10)	Red to purple shale with a slight white discolouration; sandy at the base.
123.60-128.10 (108.10-112.04)	White to light grey silt and sand (similar to interval 122-123).
128.10-128.30 (112.04-112.21)	Black to dark grey clayey silt; N3-N4.
128.30-132.50 (112.31-116.44)	White to light grey silt and clay (tuff-like?); abundant quartz sand; no distinct lapilli; gradational lower contact; N7-N8.
132.50-132.60 (116.44-116.53)	Light brown to tan waxy shale.
132.60-133.10 (116.53-116.97)	Black, coaly shale; N3
133.10-136.60 (116.97-120.05)	Accretionary lapilli; light brown tan grading to a light tan to white tuff at the base; lapilli are 1 mm to 2 cm in diameter; some have dark rims and may be pyritic; lapilli are filled with white and black fragmental material - very kaolinized; the lapilli are matrix supported; the lower part of the unit is very kaolinitic; sharp lower contact; 5YR6/1 and 10YR6/2.
136.60-136.80 (120.05-120.22)	Black shale and sand; N3.
136.80-138.20 (120.22-121.45)	Light brown tan clay and silt; waxy; N8.
138.20-160.40 (121.45-140.96)	**Stony Mountain Fm:** light brown tan dolowackestone; massive; very fine grained; fossil material is mainly crinoidal hash; abundant hardground surfaces; burrow mottled towards the base, becoming nodular at the top; 3-5% porosity, small vugs; containing rare blebs of pyrite mineralization.
160.40-182.00 (140.96-160.70)	**Red River Fm**
160.40-181.10 (140.96-159.90)	**Upper Red River (Fort Garry Member) Unit 4** (160.4-164.9 (140.96-144.92) m): blue grey to brown dolomudstone; minor burrow mottling; very fine grained; <2% porosity, pinpoint; minor bituminous partings, up to 1 cm thick; core is very broken up and rubble-like; sharp upper contact. **Unit 3** (164.9-170.6 m): light brown to tan dolomudstone; massive; very fine to fine grained; core is slightly broken and fractured; 2-3% porosity, pinpoint and small vugs; rare bituminous partings; sharp upper contact. **Unit 2** (170.6-178.0 m): blue grey dolomudstone; distinctly mottled to burrow mottled; massive; upper 1.5-2.0 m is a wackestone, light brown to tan; rare chert nodules; very fine to medium grained; <2% porosity in blue grey mudstone, to 3-5% in wackestone; gradational upper contact. **Unit 1** (178.0-181-1 m): light brown to tan dolomudstone with some blue grey mottling; essentially massive; very fine grained; containing chert nodules, white and tripolized, up to 3-4 cm in size; minor burrowing; 2-3% porosity, pinpoint; gradational upper contact.
181.1-182.0 (159.90-160.70)	**Lower Red River:** blue grey to light brown tan dolomudstone; distinct burrow mottling with fine bituminous partings; very fine grained; 2-3% porosity, small vugs and pinpoint; gradational upper contact. End of Hole

GS-22 BENTONITE INVESTIGATIONS AND INDUSTRIAL MINERAL MAPPING OF THE BRANDON MAP AREA (NTS 62G)

by J.D. Bamburak

Bamburak, J.D., 1996: Bentonite investigations and industrial mineral mapping of the Brandon map area (NTS 62G); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 127-133.

SUMMARY

The mapping of Upper Cretaceous calcium bentonite seams, along the edge of the Manitoba Escarpment and within the Pembina Valley in the Brandon map area, has demonstrated the lateral continuity of the seams. At least 6 bentonite seams, each with a thickness greater than 7.6 cm and separated by black shales, have been identified.

Mining operations for bentonite began in 1936 and continued until 1990. Many of the economic seams along the Manitoba Escarpment, west of Miami and Morden, were extracted, but additional potential exists within the map area to the north and south, and within the Pembina Valley.

In the past, brick shale and natural cement rock were produced from quarries located near the Manitoba Escarpment. Bedrock shales, as well as Pleistocene sand and gravel, are currently used as fill and as road metal. Sandstone was also quarried for building construction in the late 1890s, just west of the southern part of the map area. Saline brines from deeper formations have been used to produce caustic soda and chlorine.

INTRODUCTION

The Brandon map area is situated within NTS 62G, bounded by latitudes 49° and 50° and longitudes 98° and 100° (Fig. GS-22-1). The map area covers the transition from the First to the Third Prairie level in southern Manitoba. The lowest elevation occurs in the northeast corner at less than 249 m and the highest elevation 716 m is located on the Turtles Back on Turtle Mountain in the southwest corner.

The early settlers found that the bentonite clay was useful in the construction and repair of wooden buildings. In 1914, A. MacLean of the Geological Survey of Canada noted nonswelling calcium bentonite clay in the Pembina Valley, in Deadhorse Creek and on the east side of the Manitoba Escarpment (Fig. GS-22-2). In the 1930s researchers found that the calcium bentonite was useful in bleaching lube oil. In May 1933, sample shipments of bentonite were made from the Spencer pit (Fig. GS-22-2). Mining operations for bentonite began in 1936.

Pembina Mountain Clays was incorporated in 1939, and for the next 50 years, it was the sole producer and processor of nonswelling natural and activated calcium montmorillonite clays in Canada. In 1990, the plants in Winnipeg and Morden were levelled, the staff were laid off, and the leases were dropped. Since that time, canola producers and waste lube oil recyclers have inquired about obtaining their bentonite requirements, locally, instead of paying haulage costs from Jackson, Mississippi. In addition, the Manitoba product is said to have been a superior adsorbent compared to the imported bentonite.

In 1993, the Marketing Branch of Manitoba Energy and Mines requested that bentonite be given a priority in future industrial mineral investigations. During the summer and fall of 1993, samples were collected during reconnaissance investigations and sent to a U.S.-based company, for evaluation. Samples were also sent to Dr. W. Dresler, of Laurentian University, to test their usefulness as a binder of chromite fines.

Field tours were made for industry representatives, and additional samples were collected in 1994. The following year, 4 bentonite occurrences were sampled to assess their grade by measurement of their cation exchange capacity.

In 1996, detailed field work began in the Brandon map area (Fig. GS-22-1). The objectives were: to map the extent of the bentonite occurrences; to relate them to their stratigraphic position; and to inventory past production sites. In addition, the potential of other industrial mineral commodities in the Brandon map area were investigated.

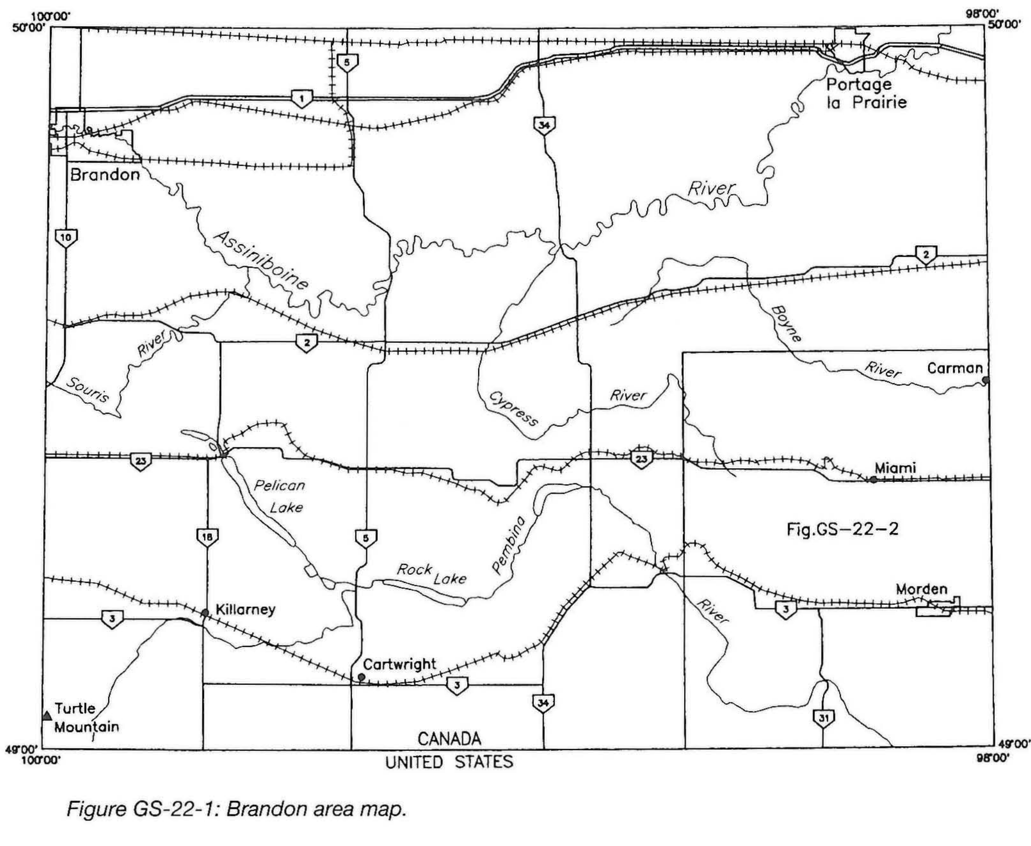
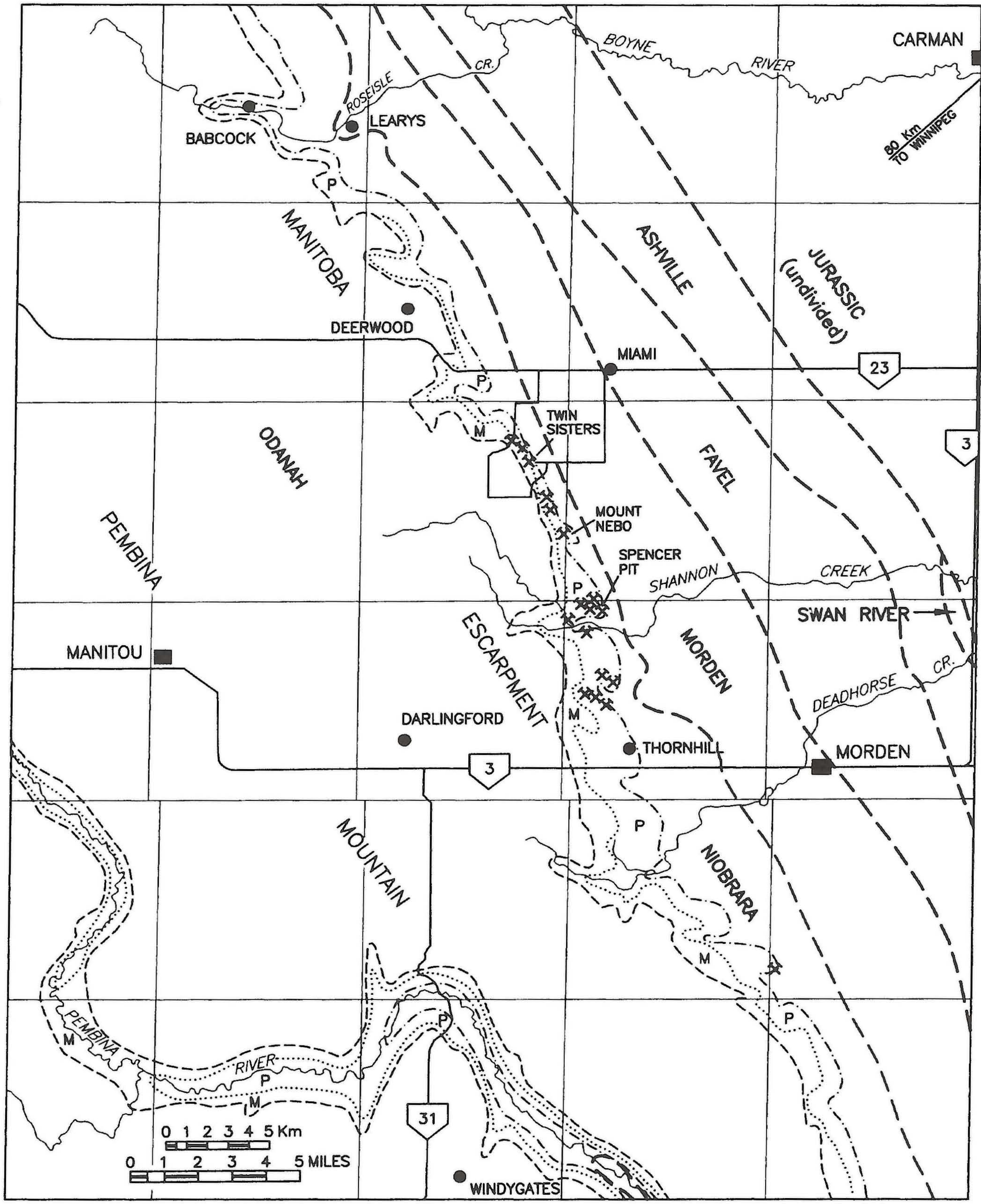


Figure GS-22-1: Brandon area map.



M = MILLWOOD
P = PEMBINA

⚒ = former bentonite quarry

Figure GS-22-2: Simplified bedrock geology of the Manitoba Escarpment and the Pembina River Valley

STRATIGRAPHY

The Upper Cretaceous stratigraphy of the Brandon map area is shown in Table GS-22-1. For the most part, the marine shales and thin limestone beds were removed by erosion north of the Assiniboine River and east of the Manitoba Escarpment (Fig. GS-22-1).

The oldest exposed bedrock, the Upper Cretaceous Favel Formation, is located east of the Manitoba Escarpment, and within the Assiniboine Valley (Fig. GS-22-1). The basal formation of the Manitoba Escarpment is the Morden Shale, followed upward in ascending order by the Niobrara Formation and the Gammon Ferruginous, Pembina, Millwood, Odanah and Coulter members of the Pierre Shale (Table GS-22-1).

In the far southwest corner of the map area, at the east end of Turtle Mountain, the Pierre is overlain by the sands of the Upper Cretaceous Boissevain Formation. Overlying the Boissevain, are the sands, silts and shales of the Paleocene Turtle Mountain Formation. Pleistocene glacial sediments blanket the north half of the Brandon map area and most of the southern portion.

Favel Formation

The Favel Formation, or the "Second White Speckled Shale", reaches its maximum thickness in the Province, within the Brandon map area. The Favel consists of the overlying Assiniboine Member and the underlying Keld Member (Table GS-22-1). Over 40 m of Favel beds are present along a north-south trend following Rge. 10W, south of the Assiniboine River. Its thickness decreases to less than 34 m to the East and West. The upper structural surface of the Favel rises from +91 m at Turtle Mountain to over +274 m east of the Manitoba Escarpment (Bannatyne, 1970, Fig. 24).

Very limited exposures of the Marco Calcarenite, with overlying and underlying speckled calcareous shales of the Favel Formation (Table GS-22-1), are located in the Assiniboine River valley, east of PTH 34. Another exposure, 8 km east of Mount Nebo in SW1-14-4-6W, was drilled (M-10-77, Table GS-22-2) by the department in 1977 (McCabe, 1977; Bannatyne, 1977).

The conformable contact of the Favel with the overlying Morden Shale, marked by a ferruginous zone at the top of the former, can be seen in the south bank of Assiniboine River in NW9-27-8-11W.

Table GS-22-1
Formations in the Brandon Map Area (NTS 62G)

Formation/Member	Maximum Thickness	Lithology
Paleocene		
Turtle Mountain Formation	48 m	
Peace Garden Member*		Grey silty clay with minor greenish sand and silt
Goodlands Member		Bentonitic carbonaceous sands, silts and clays
Upper Cretaceous		
Boissevain Formation	38 m	Greenish grey sand and sandstone, kaolinitic upwards
Pierre Shale		
Coulter Member	44 m	Bentonitic silty clay
Odanah Member	230 m	Hard grey siliceous shale
Millwood Member	60 m	Soft bentonitic clay
Pembina Member	7 m	Interbedded black shale and bentonite
Gammon Ferruginous Member	30 m	Black shale
Niobrara Formation	46 m	Chalky buff and grey speckled shale
Morden Shale	65 m	Black carbonaceous shale
Favel Formation	40 m	
Assiniboine Member		Olive-black shale with Marco Calcarenite beds near top
Keld Member*		Olive-black shale with Laurier Limestone Beds near top

* present in subsurface only.

Table GS-22-2
Summary Logs of Stratigraphic Drillholes in the Brandon Map Area

Hole No./ Location	Elev. (ft.*)	Formation/ Member	Depth (m)	Depth (ft.)
M-1-75/	1389	Boissevain	0.0	0.0
SE04-01-03-19W	1359	Coulter	9.2	30.3
	1357	E.O.H.	9.8	32.2
M-8-77/	1425	Odanah	0.0	0.0
SW05-24-04-7W	1380	Millwood	13.7	45.0
	1318	Pembina	32.6	107.0
	1299	Niobrara (Upper)	38.4	126.0
	1221	Niobrara (Lower)	62.2	204.0
	1181	E.O.H.	74.4	244.0
M-10-77/	1245	Surficial	0.0	0.0
NE14-32-03-6W	1228	Niobrara	5.2	17.0
	1145	Morden	30.5?	100.0?
	1063	E.O.H.	55.5	182.0
M-12-77/	975	Favel	0.0	0.0
SW01-14-04-6W		E.O.H.	45.1	

* Available topographic sheets for the southern 3/4 of the Brandon map area have elevations in feet above sea level.

(McCabe, 1975, 1977; Bannatyne, 1977)

Morden Shale

The Morden Shale (formerly a member of the Vermilion River Formation) is a thick sequence of noncalcareous dark grey to black shale that overlies the Favel Formation. The contact was found in oil exploration holes drilled west of the Manitoba Escarpment edge.

The Morden shows little vertical variation in lithology along the bottom edge of the Manitoba Escarpment. A strong sulphur odor, numerous gypsum prisms, jarosite-coated fracture surfaces and turtle-back concretions are characteristic of the Morden Shale. Thin bentonite seams may also be present. Excellent exposures of Morden Shale can be seen in road cuts where Shannon Creek crosses Townships 3 and 4, Range 6WPM (Fig. GS-22-2).

Isopachs of the Morden Shale, from northwest to southeast across the Brandon map area, show an increase in thickness from less than 50 m to more than 65 m (Bannatyne, 1970, Fig. 25). Its upper structural surface rises from +152 m at Turtle Mountain to at least +349 m in drillhole M-10-77 (Table GS-22-2) at the edge of the Manitoba Escarpment (McCabe, 1977; Bannatyne, 1977).

Niobrara Formation

The grey and buff chalky calcareous Niobrara Formation overlies the Morden Shale. The Niobrara (formerly, the Boyne Member of the Vermilion River Formation) is also known as the "First White Speckled Shale". The contact is exposed on the south bank of the Pembina Valley in C3-4-1-6W and was penetrated in drillhole M-10-77 (Table GS-22-2) (McCabe, 1977; Bannatyne, 1977). The position of the contact can be approximated between two outcrops along the south side of PTH 23, 5 km west of the town of Miami.

The Niobrara is 43 to 46 m thick in the Pembina Mountain area. The upper part consists of buff and grey speckled calcareous shale, and corresponds to the "chalky member" of McNeil and Caldwell (1981). The lower part consists of dark grey carbonaceous and calcareous shale, containing abundant small white specks that are small fossils, mainly foraminifera, rhabdoliths and coccoliths. This corresponds to the "calcareous shale" (*op. cit.*). Most of the Niobrara Formation is low grade oil shale (Bannatyne and Watson, 1982, p 9-11).

The structural top of the Niobrara rises from +385 m in the Pembina Valley in 18-1-6W to +391 m at Deadhorse Creek in 21-2-6W (Tovell, 1948), and to +396 m in drillhole M-8-77 (Table GS-22-2). Excellent exposures of the Niobrara can be seen in road cuts along Roseisle Creek (Snow Valley).

Gammon Ferruginous Member of the Pierre Shale

Bannatyne (1970, p. 52) interpreted the presence of the Gammon Ferruginous Member in Cretaceous intervals in southwestern Manitoba from a study of the mechanical logs of several hundred oil wells. The member is present between ~~the~~ calcareous speckled ~~shale~~ at the top of the Niobrara Formation and the bentonite beds at the base of the Pembina Member and it attains a maximum thickness of 55 m in the southwestern corner of Manitoba, but thins eastward.

Gill and Cobban (1965) indicate that the lower 50 cm or so of the Pembina Member exposed in the Pembina Valley, North Dakota (SW 1/4 sec. 30, tp. 163N., rge. 57W situated 10 km south of the International Boundary), may represent the thin eastern edge of the Gammon Ferruginuous Member. In western North Dakota, the Gammon Ferruginous Member reaches a thickness of 260 to 330 m. Ferruginous beds were recognized at the base of the Pembina Member along the Manitoba Escarpment during the 1996 field season and sampled. Further study is required to determine if they are the Gammon Ferruginous Member.

Pembina Member of the Pierre Shale

The distinctive interlayered buff and black noncalcareous marine shales of the Pembina Member of the Pierre Shale overlie the Gammon Ferruginous Member, or in its absence the Niobrara Formation. The Pembina Member was formerly a member of the Vermilion River Formation. The contact can be seen in gullies at the west ends of old quarries in SE11-6-2-5W and 15-31-3-6W; in a deep ravine in NW13-34-4-7W; and can be approximated in a road cut in 14-16-5-7W.

According to Bannatyne (1963, p. 7), the black shales at the top of the Pembina Member pass gradationally upward into chocolate brown, waxy, less organic shale and finally into the brownish green, waxy, non-carbonaceous shales of the Millwood Member. In the Miami area the upper part of the Pembina Member exhibits some swelling properties and is close to the Millwood in its composition.

The Pembina-type shales thin markedly to the north, from 24 m in the Pembina Valley to 8 m in Deadhorse Valley (Tovell, 1948; p. 5) to less than 6 m in drillhole M-8-77 (Table GS-22-2) (McCabe, 1977; Bannatyne, 1977). The structural upper surface of the Pembina Member rises northeastward across the map area from +213 at Turtle Mountain (Bannatyne, 1970; Figure 27) to +402 m in drillhole M-8-77.

The Pembina Member is exposed in road cuts and in ravines adjacent to former mining operations along the Manitoba Escarpment. At least 11 bentonite seams, ranging in thickness from 1 to 30 cm, have been documented (Table GS-22-3) in previous investigations (Bannatyne, 1963; Bannatyne and Watson, 1982). Of these seams, six have a thickness greater than 7.6 cm. The seams are separated by black carbonaceous, pyritic shale. The bentonite seams thicken to the west, but the overburden increases abruptly in thickness to 12 to 15 m.

According to Bannatyne (1978), the volcanic ash from which the bentonite beds were formed resulted from eruptions in the Elkhorn Mountains of Western Montana, and a K-Ar date from equivalent strata in Montana indicates an age of 87.4 ± 2.9 Ma (Russell, 1970).

Table GS-22-3
Typical Section of Interbedded Bentonite/Black Shale within the Upper Cretaceous Pembina Member of the Pierre Shale

Zone	Thickness of Bentonite Seams	Thickness of Black Shale Seams
A	13 cm	
B		5 cm
C	25 cm	
D		5 cm
E	9 cm	
F		5 cm
G	10 cm	
H,I,J,		8 cm
K	10 cm	
L		6 cm
M	9 cm	
TOTAL	76 cm	29 cm

(Source: Bannatyne and Watson, 1982)

Millwood of the Pierre Shale

The Millwood Member is a popcorn or cauliflower-weathering clay that overlies the Pembina Member. The Millwood (formerly a member of the Riding Mountain Formation) consists of bentonitic shale composed largely of partly swelling montmorillonite. In outcrop, the Millwood forms rounded buttes just below the top of the Manitoba Escarpment. Mount Nebo and the Twin Sisters (Fig. GS-22-2) are examples of this type of butte. Although the contact is not exposed because of the soft "flowing" nature of the Millwood, an estimate of its position can be made at the break in slope at the base of the buttes.

In the Brandon map area, the thickness of the Millwood Member increases from east to west. Drilling in 1977 (Table GS-22-2) in the Miami area indicated a thickness of 18.9 m for the Millwood (McCabe, 1977; Bannatyne, 1977). South of Brandon, the Millwood is over 60 m thick (Bannatyne, 1970, Fig. 30).

The structural upper surface of the Millwood Member rises from about +259 m at Turtle Mountain (Bannatyne, 1970, Fig. 30) to +421 m in drillhole M-8-77 (Table GS-22-2) near the edge of Manitoba Escarpment (McCabe, 1977; Bannatyne, 1977).

Southward from the Pembina River area, the lower part of the Millwood Member increases in calcareous content (Bannatyne and Watson, 1982, p. 13).

Odanah Member of the Pierre Shale

The hard, brittle, grey (when dry) iron and manganese stained siliceous shale of the Odanah Member overlies the Millwood. The Odanah (formerly a member of the Riding Mountain Formation) caps the Manitoba Escarpment and is exposed in numerous road and river cuts, ravines and quarries throughout the southern and western portion of the Brandon map area. The contact is not exposed because undercutting of the softer Millwood causes collapse of the "heavier" overlying blocks of Odanah. However, the Millwood-Odanah contact can be seen in NE13-30-1-5W.

In the extreme southwest portion of the map area at Turtle Mountain, the thickness of the Odanah, below the Boissevain Formation is approximately 230 m and its structural surface elevation is about +518 m (Bannatyne, 1970, Fig. 31).

Coulter Member of the Pierre Shale

A bentonitic, soft silty clay overlies the Odanah. These beds were informally named the Coulter Member of the Riding Mountain Formation by Bamburak (1978, p. 6). The contact with the overlying sands of the Boissevain Formation is gradational upwards with an increase in grain size. A former exposure of the Coulter in NW15-35-2-19W, at the base of a Boissevain section, is no longer visible due to slumping of surrounding sediments. In 1975, 0.6 m of the Coulter was penetrated in hole M-1-75 (Table GS-22-2) (McCabe, 1975), drilled north of the former Coulter exposure.

The thickness of the Coulter Member ranges from 37.2 m to 43.6 m and its upper surface ranges from +482 m to over +506 m in three holes in the Turtle Mountain area (Bamburak, 1978, Fig. 10).

Boissevain Formation

Greenish-grey sand with ovoid sandstone concretions overlies the Pierre Shale. The crossbedded sands were deposited in a fluvial environment (Bamburak, 1978, p. 23, 24). The sands become kaolinitic upwards indicating an erosional unconformity. An excellent exposure of the Boissevain can be seen in a gully south of PTH 3, about 16 km west of Killarney, in NW15-35-2-19W.

The Boissevain Formation maintains a thickness of about 30 m across Turtle Mountain. Its upper surface rises from west to east from less than +500 m to more than +530 m (Bamburak, 1978, Fig. 11).

Turtle Mountain Formation

The Turtle Mountain Formation is comprised of the Goodlands Member and the overlying Peace Garden Member. The Goodlands Member was defined by Bamburak (1978, p. 14) as the lignite-bearing shale that overlies the kaolinitic sands of the Boissevain Formation. An exposure of the Goodlands Member was documented in 2-25-1-24W in 1971 by Bamburak (1978, p. 14); unfortunately this outcrop is no longer exposed.

Marine grey silty clay with minor greenish sand and silt of the Peace Garden Member overlie the Goodlands Member (Bamburak, 1978, p. 16). No exposures of the Peace Garden in the Brandon map area are known.

CHEMICAL AND MINERALOGICAL STUDIES

Previous studies have concluded that the chemistry of bentonite is probably due to variable weathering (Bannatyne, 1963; Bannatyne and Watson, 1982). However, the nature and extent of these chemical changes were not determined in the studies.

A mineralogical study was completed on samples of the bentonite (Guillet, 1989) to determine if there were any value-added products, such as fillers or extenders, that could be produced from bentonite samples supplied by Pembina Mountain Clays Ltd. The study concluded that the presence of fine grained, disseminated, magnetite precluded the use of the bentonite as a source of filler material.

PEMBINA MOUNTAIN CLAYS LIMITED, 1939-1990

From 1939 to December 1990, Pembina Mountain Clays Limited produced the only nonswelling natural and activated calcium montmorillonite clays in Canada. The bentonite was quarried, on a seasonal basis from May to October, by a contractor from approximately 20 sites situated 30 km northwest of Morden (Fig. GS-22-2). The main processing plant (1979 m^2) was in Winnipeg; and the drying and crushing plant (929 m^2) was in Morden (128 km southwest of Winnipeg). In 1990, twenty-three employees, with an annual payroll of $800,000, worked at the two plant sites. Goods and services purchased in the area totalled nearly $2.3 million; and more than $43,000 was paid in local taxes (Englehard Corporation, Fact Sheet, 1989).

From 1949 to 1961, the volume of activated bentonite produced averaged about 8000 tonnes per year with a value of approximately $400,000. When Pembina Mountain Clays Limited was in full operation, between the years 1982-1986, an average annual production was 30 000 tonnes of bentonite at an approximate mining cost of Cdn. $15.00 per tonne (Personal Communication, R. Gunter, 1994).

In 1979, the locally owned Pembina Mountain Clays Limited was purchased by Filtrol Corporation. Two years later Filtrol was acquired by Kaiser Aluminum and Chemical Corporation and in 1983, by Gulf Oil's Harshaw Chemical Company. Englehard Canada Limited acquired most of the Harshaw/Filtrol Partnership in 1988 (Englehard Corporation, Fact Sheet, 1989).

In 1990, after considering the business, the market and removal under the Free Trade Agreement with the United States of America, Englehard decided the plants were not cost effective (Winnipeg Free Press, October 6, 1990). Early in 1992, the Winnipeg and Morden plants were levelled.

BENTONITE RESOURCES

Nonswelling Calcium Bentonite

The Pembina Member contains the only economical nonswelling calcium bentonite seams in the Brandon map area. In the former quarries, a cumulative thickness of about 75 cm of bentonite was recovered from 6 beds in a section totalling about 1 m thick. Characteristically, a section of bentonite will consist of a 40 cm layer of black soil followed by alternating layers of bentonite clay and a carbonaceous black shale. The bentonite to shale ratio can change laterally.

By the end of July 1994, Englehard Corporation dropped all of its leases in Manitoba and the land became available for exploration. It was estimated that the area of near-surface bentonite seams that have not been mined, cover a total area of over 5 km^2 (Personal Communication, R. Gunter, 1994). Early in 1996, Millwood Resources Ltd. applied for leases over a total area of only 64 hectares of the available ground. It should be noted that land with mineral rights not vested in the Crown also contains bentonite. Access will have to be negotiated with the mineral rights owners.

Partly Swelling Bentonite

Partly swelling bentonite occurs in the upper part of the Pembina Member and is the major constituent of the Millwood Member of the Pierre Shale. The best quality material is in the Pembina Mountain area where the Millwood averages 19.8 m in thickness (Bannatyne, 1963, p. 18-20.

No production has occurred. However, tests conducted over the years have indicated some success in pelletizing iron ores, as a fire retardant in fighting forest fires and as raw material for lightweight aggregate. The addition of sodium carbonate, 2% of the dry weight of the bentonite, was found to greatly increase its gel-forming properties. However, this product had much lower viscosity than a true swelling bentonite (Bannatyne, 1963, p. 34-42).

Swelling Bentonite

A 17.5 to 35 cm bed of green swelling bentonite occurs near the contact between the Millwood and Odanah members of the Pierre Shale. No production has occurred. Bannatyne (1963, p. 43) stated that this bed was uneconomic because of: 1) its thinness; 2) added cost of sodium carbonate to improve its swelling properties; and 3) availability of other swelling bentonites in western Canada and the northern United States.

OTHER INDUSTRIAL MINERALS

Brick Shale

A brick-making plant operated in Roseisle Creek at Learys (Fig. GS-22-2) in 1900, 1914-1917, 1947-1952 and in 1962. The raw material was quarried from a 10 m bank of Morden Shale (Bannatyne, 1970, p. 47).

In 1912, a brick plant was in production on the west bank of Mary Jane Creek at La Riviere (Fig. GS-22-2). The Odanah Member shale was quarried from the upper 10 m of a 25 m exposure on the east bank of the creek (Bannatyne, 1970, p. 63).

Sewer pipe and brick were produced in 1916 at Carman (Fig. GS-22-2). Raw materials were obtained by mixing the carbonaceous Morden Member Shale from Morden and the siliceous Odanah shale (Bannatyne, 1970, p.63).

Face brick was produced by Red River Brick and Tile using Odanah Member shale from the Rural Municipality of Thompson quarry in SW05-24-4-7W and from the Morden Shale beds in E14-33-3-6W.

Natural Cement Rock

Natural cement has also been produced from the highly calcareous (37% CaO, 1.5% MgO) Niobrara Formation shale beds at Arnold, 3 km east of Deerwood (Fig. GS-22-2) from 1898? to 1904 and at Babcock from 1907 to 1924 (Bannatyne, 1970, p. 52). The Babcock deposits were leased by Lafarge Canada Inc. in 1992.

Road Metal and Fill

Siliceous shale from the Odanah Member, extracted from over 50 pits and quarries located primarily in the south half of the Brandon map area, is currently used as fill and as road metal,. The shale occurs "in place", "glacially disturbed", as a shale-rich till, or as a combination of all three. Blasting of the shale is not required because it quickly exfoliates with exposure to the elements. Only a short period of time is necessary before a new talus pile develops at the base of an outcrop.

Calcareous shale from the Niobrara Formation, obtained from a quarry in NW15-19-7-8W, has also been used as a fill in road construction.

Pleistocene beach and outwash sand and gravel are used for road surfaces, if available, instead of the siliceous shale because of its durability in wet weather. Over 100 pits and quarries are distributed throughout the Brandon map area. These deposits have been investigated by Manitoba Highways and the Mines Branch of the Department (Manitoba Energy and Mines, 1988).

Sandstone

South of Boissevain, 3 km west of the southwestern part of the map area, sandstone was quarried for building construction in the late 1890s.

Placer Gold

Although not strictly an industrial mineral, placer gold was reported from Badger Creek, north of Cartwright (Fig. GS-22-1) in May 1931. During the staking rush that followed, numerous claims were staked northwards to Rock Lake. Although Hudson's Bay Mining and Smelting, Limited expressed some interest in sinking a few test holes, the land owners demanded too high a price for access. Subsequent investigations by J.S. DeLury of the Mines Branch of the Department failed to find significant gold to sustain the gold fever (Internal Government Report, DeLury, 1931).

Caustic Soda and Chlorine

In 1968, Dryden Chemical Limited began the production of caustic soda and chlorine from brines obtained from the Devonian Winnipegosis Formation at Brandon (Fig. GS-22-1). The brine was pumped from depths of 688.9 m and 731.5 m in two wells. The plant was leased by Hooker Chemical Canada Limited in 1972, and four years later production ended and both wells were cemented closed.

REHABILITATION

At many potential quarry sites, the bentonite clay underlies prime agricultural land. At these sites, the topsoil excavated from above the bentonite layers must be stockpiled and later returned to the exhausted pit to rehabilitate the land back to its original condition. The satisfactory reclamation of farm lands is critical to the continued mining of these lands. During their most recent years of operation, Pembina Mountain Clay Ltd. had a good record for rehabilitation.

Although mineral rights are controlled by the mining company, the permission to disturb the land surface is in the hands of the farmer and must be negotiated to receive permission to mine. Poor reclamation will either increase the cost per hectare or cause cessation of mining operations until the Mining Board arbitrates the disagreement. Not all mineral rights in the area are vested in the crown. Access to bentonite reserves in areas of private mineral rights will have to be negotiated with the rights holders.

FOSSILS

During the former quarrying operations of Pembina Mountain Clays Limited, numerous fossils, including vertebrate remains, fish scales and shark teeth, were exposed. Mososaur and plesiosaurs bones were collected and placed in the National Museum in Ottawa, the Museum of Man and Nature in Winnipeg, and in the Morden Museum. In 1972, a spectacular find of the plesiosaur *Dolichornychops* was made in a quarry 0.6 km west and 8.2 km north of Thornhill. The fossil was recovered and is on display at the Morden Museum.

FURTHER WORK

Limited stratigraphic drilling and auger backhoe sampling is planned to test areas of bentonite potential in the fail of 1996 or in spring 1997. Bentonite and black shale samples will be prepared for analyses. The bentonite will be analyzed to determine the nature and extent of the weathering-induced chemical changes to the clay. The black shales will be analyzed for trace elements as part of the on going black shale study by the department.

ACKNOWLEDGEMENTS

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GS-23 SCORIACEOUS CLINKER IN SWAN RIVER VALLEY GRAVEL PITS (NTS 63C/2 and C/3)

by J.D. Bamburak and E. Nielsen

Bamburak, J.D. and Nielsen, E., 1996: Scoriaceous clinker in Swan River Valley gravel pits (NTS 63C/2 and C/3); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 134-138.

SUMMARY

Numerous pieces of multicoloured noncalcareous breccia with intergrown fragments and glassy vesicular texture were discovered in two gravel pits in the Swan River valley. Although these clinkers have not been recognized *in situ* within the pits, their fragile nature and slightly rounded surfaces, suggest limited glacial or fluvial transport. The clasts consist of baked fragments of shale, siltstone and sandstone that probably originated from the Cretaceous bedrock on the slopes of Duck and Porcupine mountains in the Swan River valley. The presence of clinker suggests that sudden heating and cooling of sedimentary rock has occurred, but the method is speculative at this time.

INTRODUCTION

During a 1994 till sampling survey, numerous scoriaceous clasts were found in a gravel pit located, 0.4 km east of Hubbell Creek and 14 km northwest of Swan River (Fig. GS-23-1). The Hubbell Creek pit is situated within SW2-20-37-28W. The clasts range in size from 2 to 10 cm in diameter and are rounded to subrounded. They are light weight, highly vesicular and red, brown or black. The glass-walled vesicles are hollow and their fragile nature suggested limited transport from a local source, possibly on the south side of Porcupine Hills (Matile and Nielsen, 1994).

In 1995, Cliff Gussie, a retired school teacher, from Swan River recognized what he thought were "melted" rocks in a gravel pit situated within E10-11-36-24W (Fig. GS-23-1). The pit is situated on the northeastern slope of Duck Mountain. It is located 3 km southeast of Renwer, 39 km east of Swan River and 46 km southeast of the Hubbell Creek pit. The Renwer pit had been catalogued in 1991 as Deposit Number 14624 by Groom (1993) as part of an aggregate resource inventory of the R.M. of Minitonas. Groom reported that the pit had relatively abundant large pebbles and small cobbles compared to other pits in the area. The Renwer pit, owned by the rural municipality, recently supplied aggregate for construction of the new Louisiana-Pacific Canada Ltd. fiberboard plant near Minitonas.

The bedrock stratigraphy of the Swan River area, shown in Figure GS-23-2, was described by Nielsen (1988), who followed the nomenclature proposed by McNeil and Caldwell (1981).

RECENT INVESTIGATIONS

Hubbell Creek Pit

In 1994, a scoriaceous sample from the Hubbell Creek pit was submitted for $^{40}Ar/^{39}Ar$ dating. The Geological Survey of Canada age dated the sample at 470 ± 50 Ka (written correspondence, M. Villeneuve, 1996). Two additional samples were sent to Activation Laboratories for whole rock, rare earth and trace element geochemistry. Results are shown in Table GS-23-1.

Renwer Pit

Examination of the Renwer pit in June, 1996 confirmed the unusual nature of the brecciated rock that is scattered throughout the pit, but mainly occurs within four boulder piles. The fragile multicolored noncalcareous breccia was found with angular red and purple shale cobbles and well rounded boulders and cobbles of Precambrian granite and Paleozoic limestones and dolomites.

Some fragments of the breccia are extremely brittle and angular, but most are slightly rounded. The highly porous nature of some fragments gives them a light weight. Volcanic-like features range from pumice (with extremely tiny vesicles) to scoria (vesicles up to 1 cm), flow banding and ropy textures. Colours range from red to mauve, orange, yellow, beige, purple and black. The largest breccia fragment (Sample No. 96-SR-2-2-27) collected in the Renwer pit has a length of 29 cm, width of 21 cm and a thickness of 17 cm. The size, colour and texture of the 31 samples collected in the Renwer pit are listed in Table GS-23-2.

Several other gravel pits, 3 km to the west and one pit located

Table GS-23-1
Chemical Composition of Hubbell Creek Pit Samples

	Sample No.			
	94-1		**94-2**	
	%		%	
SiO_2	60.96		61.92	
Al_2O_3	18.19		18.20	
Fe_2O_3	6.84		6.39	
MnO	0.02		0.02	
MgO	1.65		1.56	
CaO	5.91		4.39	
Na_2O	1.21		1.05	
K_2O	3.10		3.19	
TiO_2	0.69		0.71	
P_2O_5	0.28		0.25	
LOI	0.90		1.90	
TOTAL	99.75		99.58	
	ppm		**ppm**	
Ba	600		611	
Sr	185		162	
Y	42		40	
Zr	172		174	
Au	10	ppb	7	ppb
As	4		<1	
Br	<0.5		<0.5	
Co	21.2		20.5	
Cr	122		113	
Cs	7.7		8.1	
Hf	4.0		4.2	
Hg	<1		<1	
Ir	<1		<1	
Mo	73	ppb	63	ppb
Rb	122		136	
Sb	0.7		0.3	
Sc	13.9		13.8	
Se	<0.5		<0.5	
Ta	1.4		0.8	
Th	13.3		12.8	
U	24.0		21.5	
W	5		2	
La	51.1		52.6	
Ce	96		99	
Nd	42		42	
Sm	6.89		7.12	
Eu	1.36		1.41	
Tb	1.2		1.1	
Yb	3.82		3.67	
Lu	0.57		0.53	
Mass	1.339 g		1.601 g	
	ppm		**ppm**	
Cu	112		122	
Pb	11		10	
Zn	328		264	
Ag	0.9		0.8	
Ni	136		113	
Cd	0.5		<0.5	
Bi	<5		<5	
V	416		376	
Be	2		2	

Note:
SiO_2 to Zr - fusion ICP
Au to Lu - INAA
Cu to Be - total digestion ICP

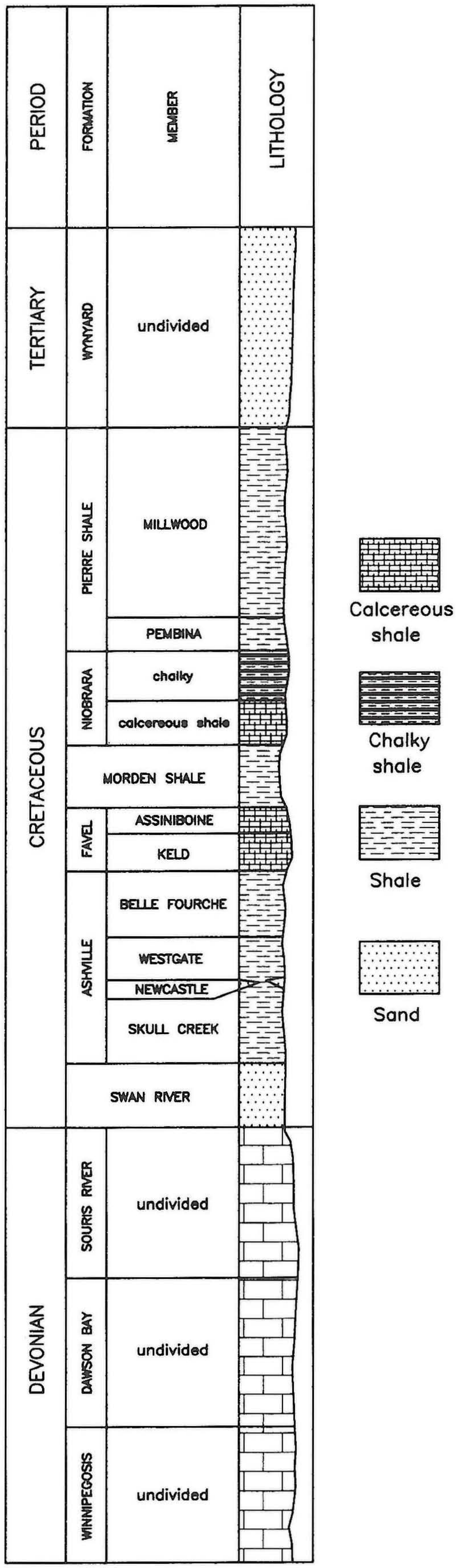

Figure GS-23-2: Bedrock stratigraphy of the Swan River area (from Nielsen, 1988, p.4).

6 km miles to the east were examined for similar material. Only one well rounded piece was found in the eastern pit situated at a lower elevation, interpreted as a glacial Lake Agassiz beach deposit.

DISCUSSION

Source Locations

According to Matile and Nielsen (1994), the vesicular nature of the clasts in the Hubbell Creek pit suggests a short distance of transport. The south side of the Porcupine Hills was indicated as a possible source. Transport of the clasts was by counterclockwise longshore drift in Lake Agassiz, although a fluvial source from Saskatchewan was not ruled out.

The relatively large size and angularity of the scoriaceous breccia in the Renwer pit indicates that the boulders are very near their source on the north slope of Duck Mountain. The direction and distance of the Renwer pit from the Hubbell Creek pit suggests two sources in the Swan River valley.

Mode of Origin

Several possible modes of origin for the clinker in the pits may be postulated:

1. Waste rock from a smelter, such as those at Flin Flon or Thompson, transported by truck and dumped;
2. Rock subjected to a lightning strike;
3. Volcanic activity;
4. Meteorite impact, or;
5. Clinker formed by autocombustion of oil shale.

The waste rock from a smelter has been ruled out as a mode of origin because it does not make rounded beach gravel as found in the Hubbell Creek pit and would not give an age of 470 ±50 Ka. The volume of scoriaceous material in the two pits, 46 km apart, rules out a lightning strike. Evidence for volcanic activity or a meteorite impact is absent. The most likely mode of origin is that the clinker was probably formed by the autocombustion of oil shale. Oil shale is present in the Favel Formation in the Porcupine Mountain area (Bannatyne, 1970). The Favel Formation forms the bedrock interior of the Swan River valley (Fig. GS-23-2) and it should underlie the sand and gravel in the Renwer pit.

Further Work

Follow-up work will consist of examination of the Renwer pit to see if scoriaceous clinker can be found *in situ* at the bottom of the pit by using a backhoe. Neighbouring gravel pits in the Swan River valley will also be visited to determine if similar material is present.

ACKNOWLEDGMENTS

Cliff Gussie is thanked for alerting the Department to the Renwer occurrence; for providing accommodation for field staff; and for his time in investigating the occurrence. The late Chris Roddick of the GSC provided the argon dating. Assistance in the field was conscientiously provided by Rob McGregor.

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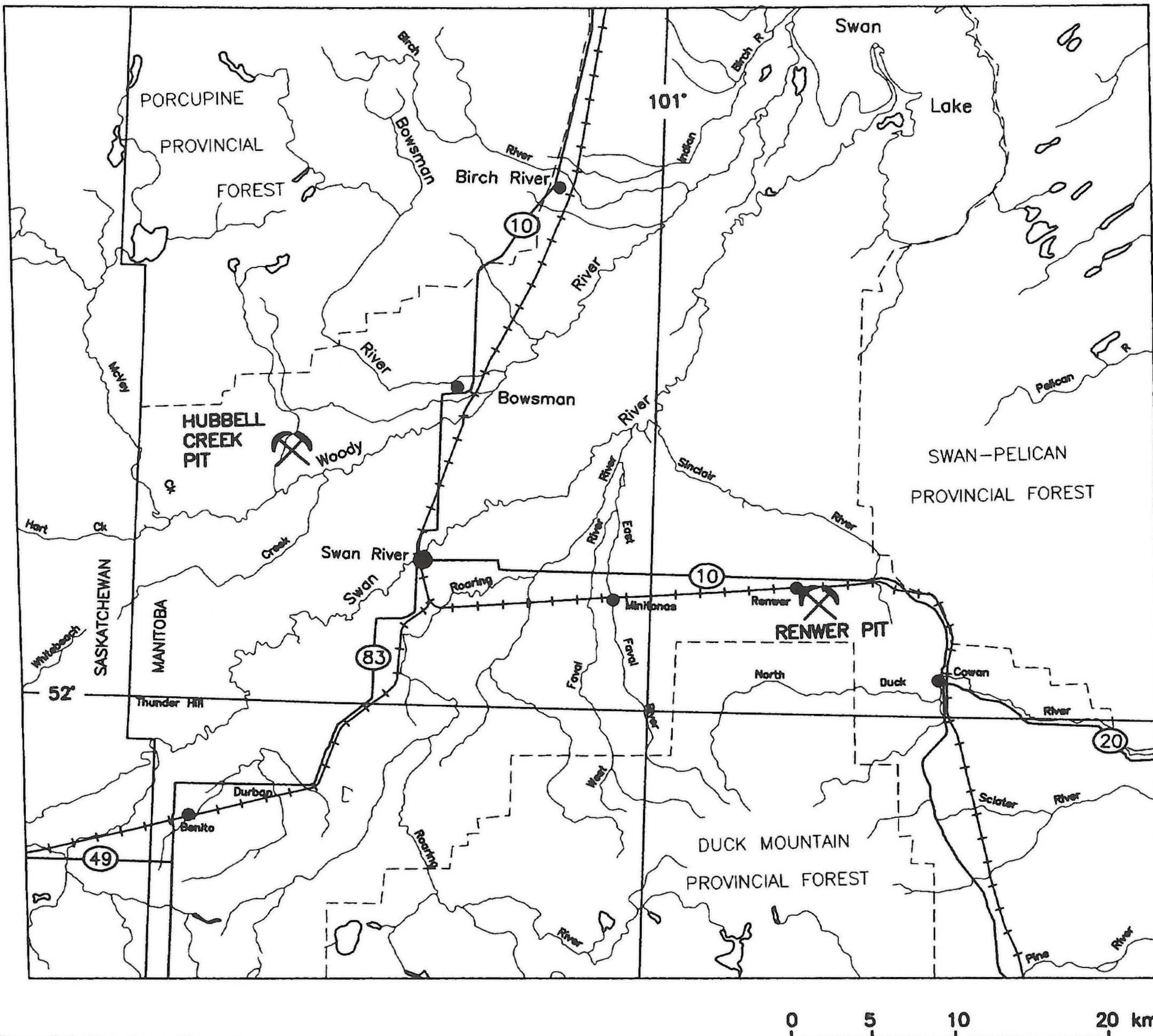


Figure GS-23-1: Swan River area.

Table GS-23-2
Lithologic Descriptions of Breccia Samples from the Renwer Pit

Sample No.	Size A axis cm	Size B axis cm	Size C axis cm	Lithology
96-SR-2-2-01	13	11	7	Colour: **red**, brown, orange, black, yellow Texture: banded, scoriaceous, blue iridescence, rounded with buff, muddy appearance
96-SR-2-2-02	9	8	5	Colour: **mauve and black**, yellow, purple, grey Texture: pink shell with black core, yellow sandstone inclusion with grey melted rim and black and grey stringers, ropy purple and yellow weathered surface, tiny black inclusions in purple portions
96-SR-2-2-03	12	8	7	Sample formerly one piece with 96-SR-2-2-02 and is similar but with more scoria
96-SR-2-2-04	16	11	8	Colour: yellow-brown, orange Texture: conglomerate with well-defined clasts (one 100 mm by 60 mm), ferruginous cement holding sand grains to clasts
96-SR-2-2-05	14	13	8	Colour: yellow, black, red Texture: weakly banded, black cores with red edges, vesicles filled with noncalcareous white material
96-SR-2-2-06	9	5	4	Colour: dark grey-brown Texture: very finely crystalline, no vesicles, or melting, calcareous fracture surfaces (sample does not seem to be representative of clinker)
96-SR-2-2-07	7	5	5	Colour: beige, black, black Texture: red rim around black core, latter has scoria with nearly spherical amygdule (2 mm in diameter)
96-SR-2-2-08	10	5	5	Colour: yellow and black Texture: Tiny vesicles throughout, vug with calcite crystals, blue iridescence, faintly banded, ropy yellow portion
96-SR-2-2-09	13	12	6	Colour: grey-black, mauve Texture: banded, red shells with black cores, 1 mm thick laminae, vesicles look flattened parallel to banding, fissile into 5 mm thick plates, hexagonal fracture planes, slightly ropy
96-SR-2-2-10	13	6	6	Colour: red and grey with yellow Texture: banded, vesicles aligned parallel to banding, pumice-like, square fracture pattern, contains irregular tapered blobs with rounded margins
96-SR-2-2-11	11	9	9	Colour: red with black and beige Texture: red shell around black core, many open fractures, no scoria or pumice, cooling joints?, weathered beige coating on top of red core
96-SR-2-2-12	13	9	8	Colour: **red** with beige and black Texture: distorted beige siltstone inclusions with black rims in red matrix, augen-like, beige coating
96-SR-2-2-13	11	10	8	Colour: greenish yellow and black Texture: banded, black laminae in greenish yellow portion, abundant vesicles in black portion
96-SR-2-2-14	11	11	9	Colour: **beige**, reddish brown, grey Texture: inclusion surrounded by scoria and very fine grained yellow and red bands or red and black bands, quartzite core surrounded by contact rim and scoria with 2 mm vesicles
96-SR-2-2-15	9	4	2	Colour: **black**, red and yellow Texture: very fine flattened vesicles, coarser near one end, hint of flow bands, iridescence, subconchoidal fracture
96-SR-2-2-16	6	5	3	Colour: reddish pink and black Texture: pink rim around black (shale) core, tiny vesicles in some bands, others aphanitic
96-SR-2-2-17	10	5	2	Sample formerly one piece with 96-SR-2-2-15
96-SR-2-2-18	18	12	10	Colour: yellow and beige Texture: banded with some bands having rare vesicles, thin (1 mm) laminae of "greenish" glass, numerous open fractures, mud cracks? in base
96-SR-2-2-19	17	13	12	Colour: red and purple Texture: extremely fragile, fractured throughout, tiny vesicles becoming microscopic in size, black cores surrounded by red rims, also purple surfaces appear to be surface coating on red
96-SR-2-2-20	26	16	15	Colour: beige, yellow, purple, orange Texture: scoriaceous, ropy, vuggy, wispy black shale inclusion, healed fracture
96-SR-2-2-21	13	12	9	Colour: mauve, purple, red, black, yellow Texture: laminated?, red rim around black core, open fractures with some yellow stained, few portions scoriaceous, fragile
96-SR-2-2-22	11	11	6	Colour: buff, grey, yellow, mauve, purple Texture: ropy, scoriaceous, flow banded, vuggy, lava-like
96-SR-2-2-23	24	18	14	Colour: mauve, purple, beige, black Texture: mauve rim around yellow-beige siltstone core, scoriaceous, flow banded?, open curved cooling? fractures,
96-SR-2-2-24	17	13	7	Colour: beige, grey, purple, mauve Texture: flow banded, curved gas? cavity, scoriaceous, beige inclusions, speckled mauve portions with cream-coloured specks

Table GS-23-2 Continued

Sample No.	Size A axis cm	B axis cm	C axis cm	Lithology
96-SR-2-2-25	24	19	8	Colour: greenish beige, mauve, purple Texture: partly scoriaceous, banded, beige and purple interlayers
96-SR-2-2-26	15	14	12	Colour: black, yellow, beige, pink Texture: laminated, finely recrystallized?, yellow weathering? rind, very fine vesicles in place, metasediment? with 1 mm thick white layers in black matrix
96-SR-2-2-27	29	21	17	Colour: red, black, golden brown Texture: open fractures, banded, red rims with black cores, very fine vesicles in portions, rusty yellow stained fractures
96-SR-2-2-28	19	17	8	Colour: mauve, brown, yellow Texture: ropy, open cooling? fractures, mauve rims around black cores, very fine vesicles with variable distribution
96-SR-2-2-29	29	22	15	Colour: **beige**, black, purple Texture: large vugs, platy, vesicular and scoriaceous in places, siltstone inclusions, open curved fractures, speckled
96-SR-2-2-30	22	17	14	Colour: **mauve**, red, black, beige Texture: interlayered mauve and beige, laminated, mauve rim around black core, tiny vesicles in place, open fractures, wispy, ropy
96-SR-2-2-31	16	11	11	Colour: **red**, yellow, black Texture: yellow stained open fractures, tiny vesicles, mauve rims around red cores and red rims around black cores

GS-24 MINERALOGY OF METAL-RICH ENCRUSTATIONS ON ORDOVICIAN WINNIPEG FORMATION BLACK SHALES AND SANDSTONES, BLACK ISLAND, LAKE WINNIPEG (NTS 62P/1)

by B.E. Schmidtke and M.A.F. Fedikow

Schmidtke, B.E. and Fedikow, M.A.F., 1996: Mineralogy of metal-rich encrustations on Ordovician Winnipeg Formation black shales and sandstones, Black Island, Lake Winnipeg (NTS 62P/1); **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p.139-152.

SUMMARY AND CONCLUSIONS

The canary yellow crust observed mantling the Ordovician Winnipeg Formation sandstone at the Black Island silica sand quarry is identified as magnesiocopiapite ($MgFe(SO_4)_6(OH)_2 \bullet H_2O$) and the aquamarine crust developed on the black metal-enriched shales is predominantly rozenite ($FeSO_4 \bullet 4H_2O$) with minor szomolnokite ($FeSO_4 \bullet H_2O$). Copiapite and szomolnokite are recognized in association with oxidation zones of sulphide deposits. Rozenite forms as a dehydration product of melanterite ($FeSO_4 \bullet 7H_2O$) produced by the efflorescence of pyrite. The close mineralogical association of these hydrated iron sulphates is attributed to the leaching of gold-enriched near solid pyrite from a sediment-hosted sulphide facies iron formation intersected during diamond drill testing of a hematite occurrence on Black Island (Fig. GS-24-1). Ultramafic rocks mapped on the island may also have contributed to the metal-enriched nature of the yellow and aquamarine encrustations and to the black shales.

INTRODUCTION

The development of a black shale geochemical database was initiated in 1995 (Fedikow *et al.*, 1995) with the collection of a suite of samples from a section through Ordovician Winnipeg Formation black shale beds exposed by quarrying activities in the former Selkirk Silica quarry on Black Island, Lake Winnipeg (Fig. GS-24-1). During the collection of these samples distinctive, gelatinous crusts were observed coating the black shales and the sandstones immediately beneath the shales. Crusts developed on the black shales were a bright aquamarine colour whereas bright canary yellow crusts were formed on the underlying sandstones. The crusts appeared to be especially well developed on their respective lithologies where groundwater trickled down the quarry wall from the contact between the overlying till and the black shale. Fedikow *et al.* (1995) attributed the formation of these crusts to the oxidation of sulphide minerals in the black shales by interaction with groundwater. It was noted that the aquamarine and canary yellow crusts

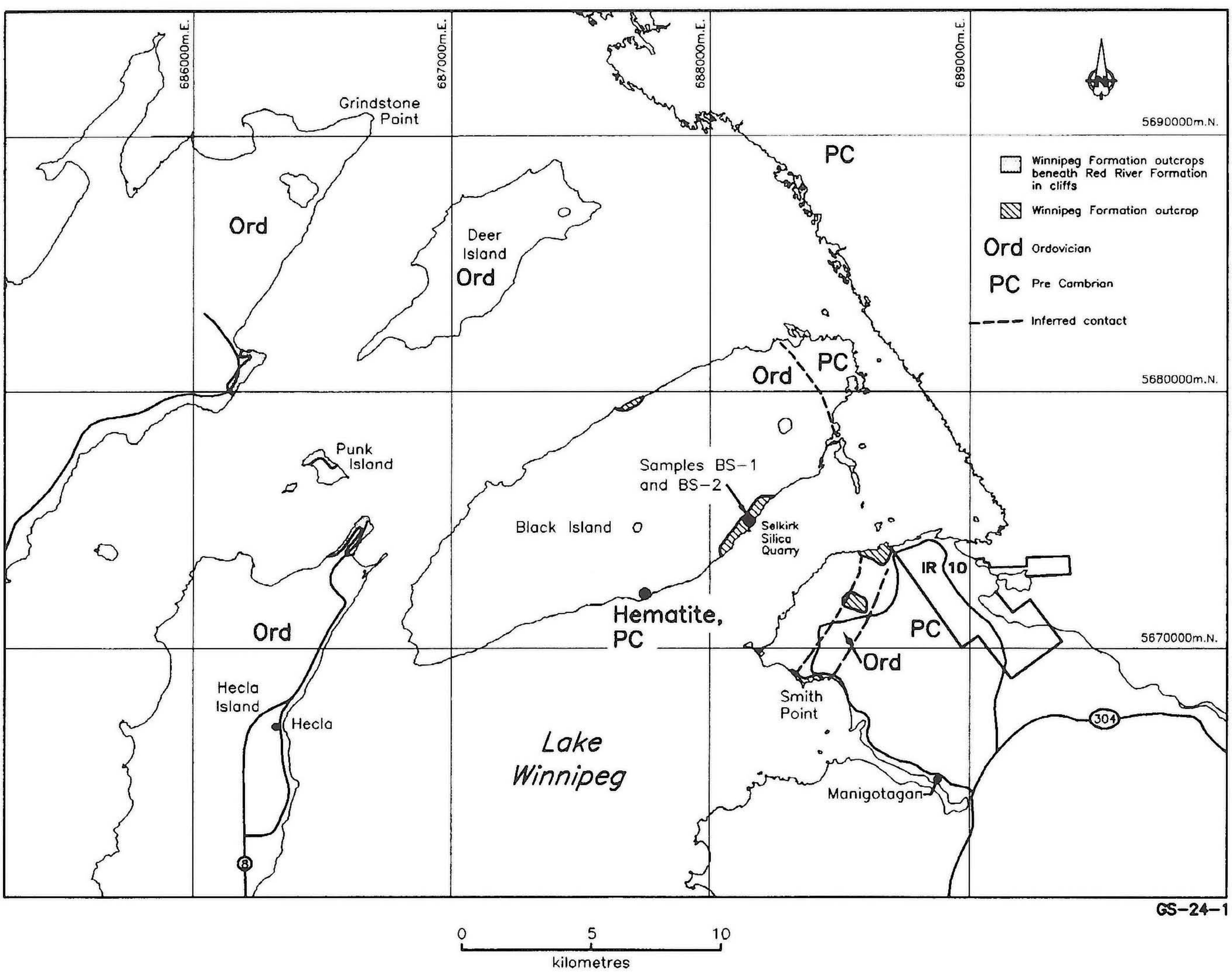


Figure GS-24-1: Location of silica sand quarry and hematite occurrence on Black Island in Lake Winnipeg.

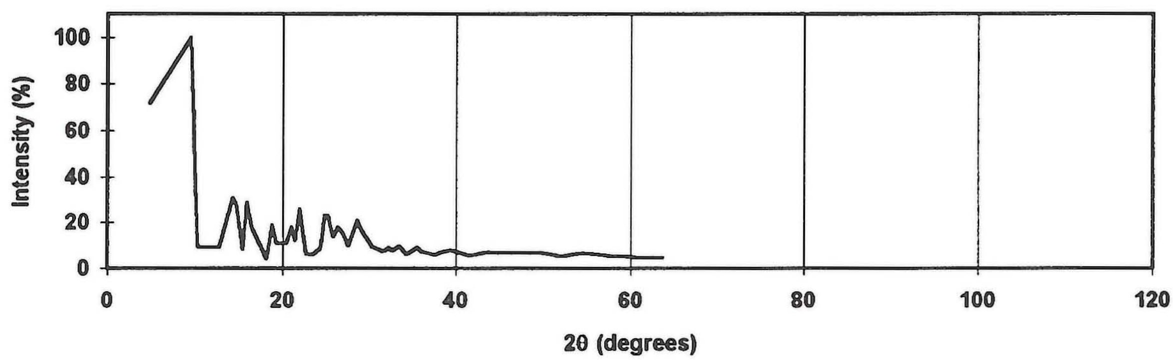
were poorly developed or absent where interaction with groundwater was negligible. In addition to the analysis of black shale and sandstone samples a geochemical assessment of the crusts was undertaken (Fedikow *et al.*, 1995). Crusts were analysed by inductively coupled plasma mass spectrometry (ICP-MS) subsequent to dissolution with hot nitric acid. Both crusts were determined to be distinctive on the basis of their major and trace element chemistry. Aquamarine and canary yellow crusts are iron enriched with 19.54 and 10.35%, respectively. The aquamarine crusts contained higher Li, B, Mg, Al, Sc, V, Ni, Ga, Rb, Y, Zr, Cd, Ag, In, Sb, Te, Cs, rare earth elements, Hf, Pt, Tl, Pb, Bi, U and Th whereas the canary yellow crusts contain higher Ca, Ti, Cu, As, Br, Sr, Nb, Mo, I and Ba. The distinctive metal-enriched character of the black shales and the aquamarine and canary yellow encrustations, as well as their possible relationship to mineralization (as source and/or host rocks), stimulated the mineralogical speciation of the crusts. Mineralogical observations are described below.

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

A particularly well developed sample of aquamarine crust, identical in colour, form and mode of occurrence to aquamarine crusts developed on shales on the quarry wall, was obtained from a piece of shale found at the base of a scree in the northeast part of the quarry. It is uncertain whether the encrustation formed on the shale in the quarry wall or on the quarry floor. The canary yellow sample was taken from the sandstone at the base of the black shale layer on a previous trip to Black Island. Its locale is described in Fedikow *et al.* (1995).The aquamarine encrustation quickly dried to form a fragile, granular, white encrustation on the shale. The white crust was carefully removed from the rock to avoid including shale in the sample. Individual samples of the aquamarine/white and the canary yellow encrustations were sent to the Department of Geological Sciences, University of Manitoba for X-Ray Diffraction (XRD). The sample of canary yellow crust was labelled BS-1; the aquamarine crust sample, BS-2. Both samples were air dried overnight and then ground. Rounded 1 mm diameter quartz grains were selectively removed from sample BS-2 before grinding. Step scan X-ray diffraction data were collected on a Philips automated diffractometer system PW1710, using a Bragg-Brentano goniometer equipped with incident and diffracted beam Soller slits, 1.0 divergence and anti-scatter slits, a 0.2mm receiving slit and a curved graphite diffracted-beam monochromator. The normal focus Cu X-ray tube was operated at 40 kV and 40 mA, using a take-off angle of 6°. The profiles were collected using a step interval of 0.05° 2θ, with a counting time of 2s/step. Diffraction data was collected for BS-1 from 3-120° 2θ and from 10-120° 2θ for BS-2. Peak search and diffractogram output were handled with Siemens DIFFRAC-AT software. Fein-Marquart's micro-Powder Diffraction Search Match software (μPDSM) was used for the identification of the phases present, based on a search of the Minerals subfile of the Powder Diffraction File (PDF) database leased form the International Centre for Diffraction Data (ICDD) (Ball, written communications, 1996).

The X-ray diffraction data for samples BS-1 and BS-2 are displayed graphically in Figures GS-24-2 and 3. The graphs were produced using the Microsoft Excel spreadsheet. 2θ values were recalculated

X-ray diffraction pattern for sample BS-1



X-ray diffraction pattern for magnesiocopiapite, $MgFe(SO_4)_6(OH)_2 \bullet H_2O$

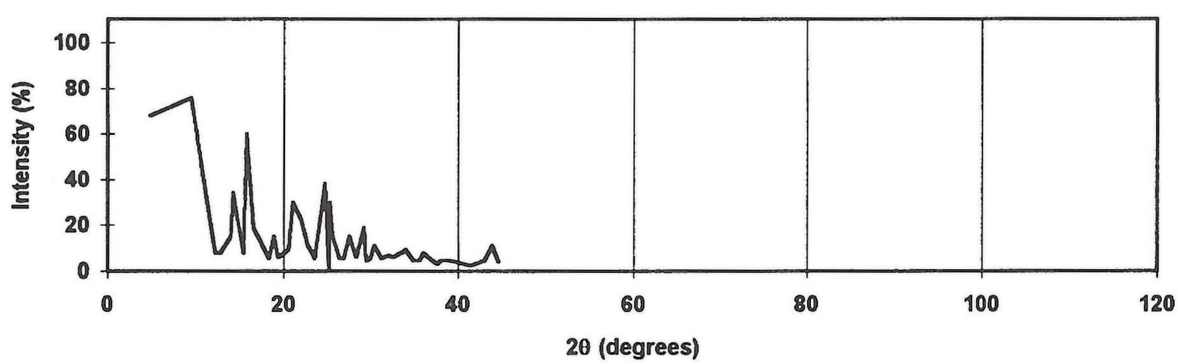
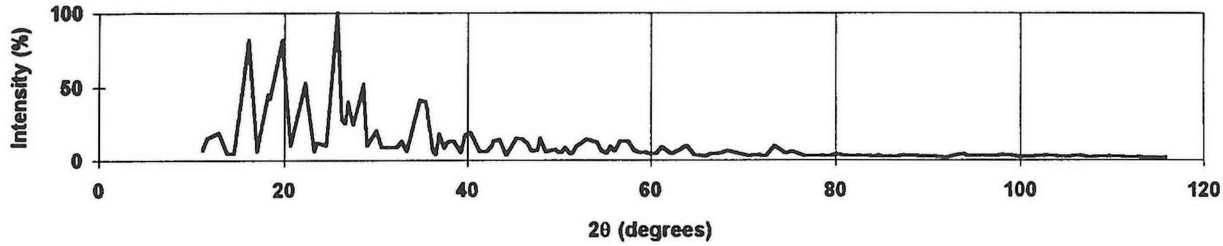
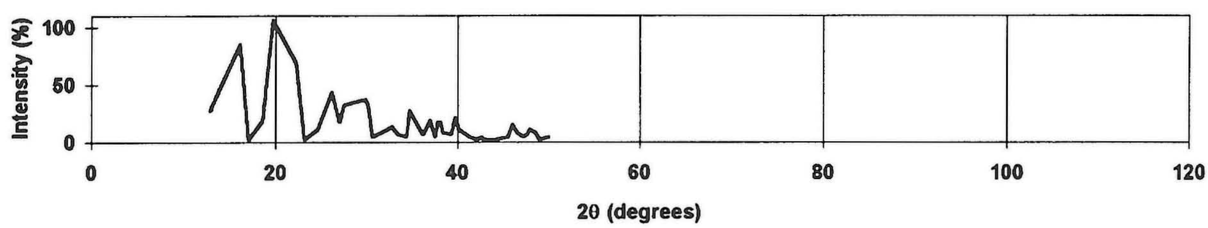


Figure GS-24-2: X-ray diffraction patterns for sample BS-1.

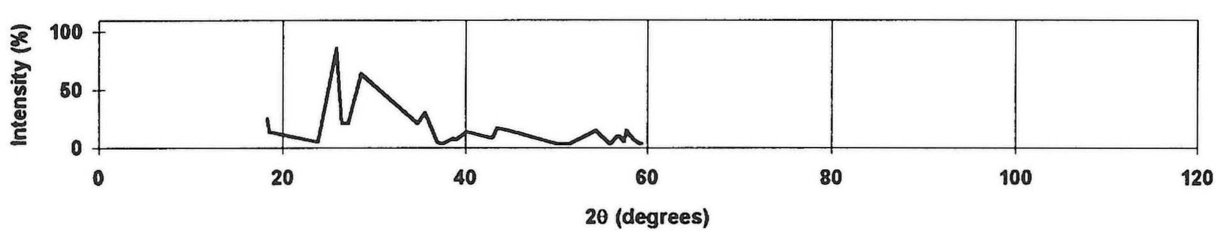
X-ray diffraction pattern for sample BS-2



X-ray diffraction pattern for rozenite, $FeSO_4 \bullet 4H_2O$ @ 106%



X-ray diffraction pattern for szomolnokite, $FeSO_4 \bullet H_2O$ @ 85%



X-ray diffraction pattern for quartz, SiO_2

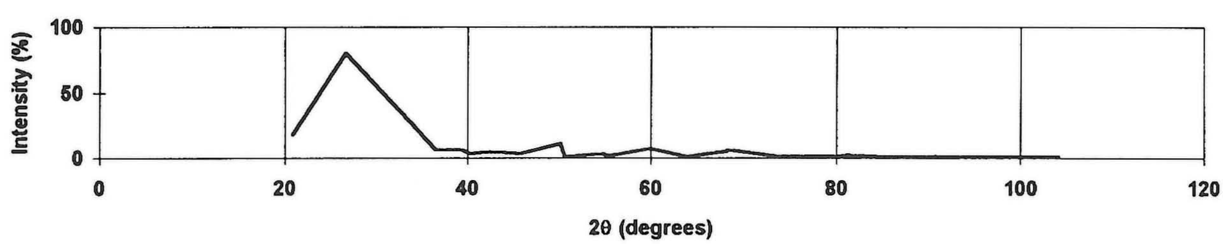


Figure GS-24-3: X-ray diffraction patterns for sample BS-2.

from d spacings using Bragg's equation in the form:

$$\theta(\text{degrees}) = \sin^{-1}(\lambda/2d))\times 180/\pi$$
where $\lambda = 1.54$ (wavelength in Å for Cu radiation)

This conversion was done to produce a linear scale on the x-axes of the graphs. The d spacings are a sin value,

$$d = \lambda/(2\sin\theta)$$

which produces a nonlinear x-axis.

RESULTS

The canary yellow crust, sample BS-1 (Fig. GS-24-2) is a relatively pure phase of magnesiocopiapite ($MgFe(SO_4)_6(OH)_2{\bullet}H_2O$), the magnesium end member of copiapite ($(Fe,Mg(SO_4)_6(OH)_2{\bullet}H_2O$). Copiapite, a secondary mineral formed by the oxidation of pyrite and other sulphides, occurs as scales or granular crusts and is often associated with other sulphates including melanterite. X-ray diffraction results from the aquamarine/white crust, sample BS-2 (Fig. GS-24-3) identifies rozenite ($FeSO_4{\bullet}4H_2O$) as the major phase, szomolnokite ($FeSO_4{\bullet}H_2O$) as the second major phase and quartz (SiO_2) as a minor third phase in the white crust. Rozenite is a dehydration product of melanterite, $FeSO_4{\bullet}7H_2O$, a sulphate that occurs as a result of efflorescence of pyrite. Rozenite typically occurs as a microcrystalline crust. Szomolnokite forms in oxide zones of sulphide deposits and is associated with copiapite.

DISCUSSION

Previous mineral exploration on Black Island consisted of outcrop examination and diamond drilling of the Black Island hematite occurrence (Brownell and Kliske, 1945). Interestingly, Dowling (1898) describes the hematite on Black Island but also states that the occurrence was noted on a map produced in 1762. Early descriptions of the deposit included the association of "grey quartz seams with $9.00 gold per ton" as well as "iron and copper pyrites and sulphurets of silver and gold in a coarse grained, greenish-grey, silver mica schist" with the hematite. Brownell and Kliske (1945) reproduce the drill log of DDH No. 8 drilled in 1943 that identifies intersections of 4.5m, 5.6m, and 5.8m of near solid pyrite associated with black, graphitic phyllite and quartz veins with pyrite. Enargite ($3Cu_2S{\bullet}As_2S_5$) and disseminated arsenopyrite were identified within the phyllite.

The identification of an apparently gold-enriched sulphide facies iron formation at Black Island and the proximity of metal-enriched crusts on the Black Island shales and sandstones are considered to be interrelated. The pyrite-rich sedimentary rock-hosted near solid sulphide zone is overlain by a hematite-calcite rich cap that represents an oxidation product of the parent sulphide mineralization. Rusty, weathered, waterfilled fractures within the pyrite zone indicate oxidation and the potential for transport of metals by formational waters. It is proposed that the waters draining the mineralized zone at Black Island are responsible for mobilizing a wide range of trace metals in solution to the site of precipitation and crust formation. Undoubtedly, metals have been scavenged from other sources, such as the black shales that are themselves metal-enriched.

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GS-25 GROUNDWATER GEOCHEMISTRY AND STRUCTURAL INVESTIGATIONS OF PALEOZOIC CARBONATES IN MANITOBA'S INTERLAKE REGION

by W. D. McRitchie

McRitchie, W.D., 1996: Groundwater geochemistry and structural investigations of Paleozoic carbonates in Manitoba's Interlake Region; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities, 1996, p. 143-152.

SUMMARY

Spring water sampling in the Grand Rapids region was concluded, and the evaluation of Mississippi Valley Type mineralization potential in Paleozoic carbonate rocks extended to include a regional study of fracture orientations throughout Manitoba's Interlake region.

GENERAL

The current search for indications of Mississippi Valley Type (MVT) lead-zinc mineralization in Manitoba's Paleozoic formations has focused largely on detecting geochemical anomalies in indicator elements in both spring waters and associated marly sediments from the northern Interlake, *i.e.* Grand Rapids region. This augmented earlier work by Gale *et al.* (1984) and Gale and Nielsen (1985) that, respectively, used systematic geochemical analyses of stratigraphic drill core and basal tills in southern Manitoba to search for regional geochemical and indicator mineral anomalies that might guide and focus subsequent exploration.

This year's spring water investigations in the Grand Rapids region entailed sampling of six springs west of Mechiso (Eating Point) Lake (Fig. GS-25-1), one spring north of Buffalo Lake and the Karst Spring at Iskwasum Lake (Table GS-25-1). This, largely infill sampling, concludes a multiyear orientation study evaluating the potential for MVT lead-zinc mineralization in the carbonate rocks of the region (McRitchie 1989, 1994 and 1995). No evidence was found to signal the existence of concealed MVT mineralization in the watershed. Analyses from the spring water and marl samples collected in this and previous years exhibit trace levels of lead, zinc and fluorides, and barium contents consistent with depositional levels in the carbonate bedrock.

Fluoride levels from site 04-94-30W (although low compared to other groundwater aquifers in Manitoba - see Betcher *et al.* 1995 p. 25-26) were relatively elevated (X4) compared to other spring waters in this region. However, repeat sampling at this and nearby locations in September 1996 was unable to duplicate these results.

Sodium (8-11 mg/L) and chloride (5-8 mg/L) contents of spring waters west of Mechiso Lake are elevated compared to other springs in the study area (*i.e.* sodium 1-3; chloride <2 mg/L). This may reflect proximity to and seepage from, the saline front of formational waters south and west of Cedar Lake. Sulphate contents (<10 mg/L) are low, with no evidence of contamination from surface waters in the Saskatchewan River (*i.e.* seepage under or through the nearby grout curtain of the Grand Rapids Hydro installation containment structure).

FRACTURE ORIENTATIONS

A second component of the study has been an investigation of fractures and permeability in the carbonates, channelways that could

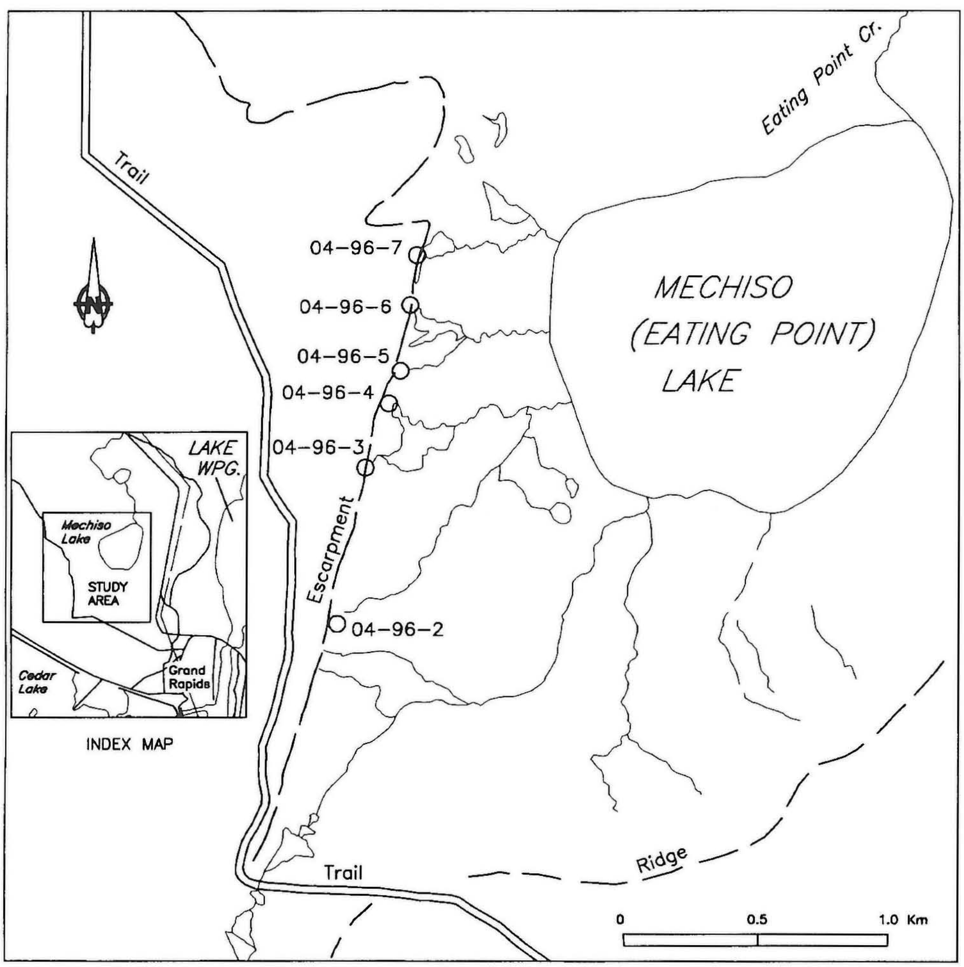


Figure GS-25-1: Location of springs sampled west of Mechiso (Eating Point) Lake, Grand Rapids region, 1996.

Table GS-25-1
Analyses of spring waters from the Mechiso Lake region, Buffalo Lake and Iskwasum Lake, 1996

Sample #	East	North	Estimated Elevation	1	2	3	4	5	6	7	8	9	10	11	12	13
04-96-1W	481242	5923755	823	255	312	<18.0	<10.2	7.81	7.81	250	<0.10	1.4	0.08	5.7	<10	<0.001
04-96-2W	477306	5894321	795	245	299	<18.0	<10.2	8.08	0.16	280	<0.05	7.0	0.01	6.9	<10	0.003
04-96-3W	477429	5895034	782	274	334	<18.0	<10.2	7.55	0.23	320	<0.05	8.3	0.01	8.6	<10	<0.001
04-96-4W	477315	5895275	797	292	356	<18.0	<10.2	7.72	0.23	310	<0.05	8.2	0.04	8.1	<10	0.001
04-96-5W	477494	5895306	791	276	337	<18.0	<10.2	7.72	0.21	300	<0.05	7.8	0.07	8.1	<10	<0.001
04-96-6W	477485	5895602	787	286	348	<18.0	<10.2	7.75	0.16	300	<0.05	5.4	0.02	7.1	<10	<0.001
04-96-7W	477509	5895858	775	300	365	<18.0	<10.2	7.77	0.15	310	<0.05	5.6	0.09	6.7	<10	<0.001
04-96-8W	382427	6050830		110	134	<18.0	<10.2	7.59	0.1	140	<0.05	1.4	0.05	5.7	<10	<0.001

1 Alkalinity - Total ($CaC0_3$) mg/l
2 Alkalinity - Bicarbonate mg/l
3 Alkalinity - Carbonate mg/l
4 Alkalinity-Hydroxide mg/l
5 pH
6 Fluoride mg/l
7 Solids/Residue
8 Boron-soluble mg/lB
9 Chloride - soluble mg/l
10 Nitrate-Nitrite-N Soluble mg/lN
11 Silica - soluble Reactive mg/l $Si0_2$
12 Sulphate - Soluble mg/l SO_4
13 Arsenic - total mg/l

Sample #	East	North	Estimated Elevation	14	15	16	17	18	19	20	21	22	23	24	25
04-96-1W	481242	5923755	823	0.043	55.2	<0.01	<0.01	<0.0020	31.7	<0.005		<1.00	<1.00	<0.01	0.104
04-96-2W	477306	5894321	795	0.029	56.8	<0.01	<0.01	<0.01	29.7	<0.005		1.14	9.97	<0.01	0.057
04-96-3W	477429	5895034	782	0.055	63.2	<0.01	<0.45	<0.0020	33.4	0.019		1.63	11.3	0.01	0.041
04-96-4W	477315	5895275	797	0.077	63.7	<0.01	<0.01	<0.0020	33.9	<0.005		1.78	10.3	0.01	<0.020
04-96-5W	477494	5895306	791	0.057	62	<0.01	<0.01	<0.0020	32.4	<0.005		1.92	11.2	<0.01	<0.030
04-96-6W	477485	5895602	787	0.066	64.3	<0.01	<0.01	<0.0020	32.4	<0.005		1.42	7.98	<0.01	<0.020
04-96-7W	477509	5895858	775	0.044	67.7	<0.01	<0.01	<0.0020	35.5	<0.005		1.28	8.67	<0.01	<0.020
04-96-8W	382427	6050830		0.013	27.4	0.01	0.07	0.001	11	0.005		1	1.06	0.01	0.02

14 Barium - Extractable mg/l
15 Calcium - Extractable mg/l
16 Copper = Extractable mg/l
17 Iron - Extractable mg/l
18 Lead - Extractable mg/
19 Magnesium - Extractable mg/l
20 Manganese - Extractable mg/l
21 Nickel - Extractable mg/l
22 Potassium - Extactable mg/l
23 Sodium - Extractable mg/l
24 Zinc - Extractable mg/l
25 Ammonia mg/l N

have controlled/influenced the direction and movement of subsurface brines in the past, as well as the geometry of any resultant MVT mineralization. The current investigation in the Interlake region involved collection of information at three levels,

- fracture orientations in the Precambrian basement as interpreted from aeromagnetic trends. These may have influenced the formation and orientation of fractures in the overlying Paleozoic carbonates,
- fracture orientations in the Paleozoic carbonate formations from the near-surface, as determined from maps of caves, and
- fracture (joints, faults *etc.*) orientations measured in carbonate bedrock exposures throughout the Interlake region.

Basement fractures

Fractures (faults, belts of concentrated planar structures and major lineaments) in the Precambrian basement were interpreted from parts of thirteen 1:250 000 scale aeromagnetic maps that cover areas underlain by Paleozoic rocks west of the Precambrian Shield (Figs. GS-25-2a, b and c). The along-strike continuity of the interpreted features was extrapolated eastwards to the exposed Shield, by linking up with and incorporating fracture systems (faults and major lineaments) identified by Brown (1981), Brown *et al.*, (1995), Corkery and Cameron (1987), Ermanovics (1970a,b, 1973a,b, and 1975), Lucas *et al.*, (1996) and McRitchie and Weber (1971).

Near-surface fractures

Previous work, based on commonly widely spaced water well records, suggested that paleokarstic cavities (channels, caves, multilevel galleries *etc.*) were developed in the Paleozoic carbonate formations prior to the beginning of the Jurassic period with subsequent infill by a wide range of Jurassic arenaceous redbeds, as well as high purity silica sands, kaolin, and lignite of Cretaceous age (Barker 1984; Simpson *et al.*, 1987). Studies by Grice (1964) and others have also demonstrated the existence of more recent (Quaternary) clays, silts and sands filling cavities in Ordovician to Devonian dolostones, indicating that some cavities were either still forming, or remained open, at the end of the Cretaceous. Since most of this evidence is based on drill hole records it generally is not possible to determine the orientations of the karst channels. However recent geophysical surveys over the Sylvan kaolin deposit near Arborg appear to confirm the existence (in the carbonate host rocks) of narrow buried channels filled with silica sands and kaolin that trend between 090° and 110° (Hosain *et al.,* 1995).

Reconnaissance traverses and detailed mapping by the Speleological Society of Manitoba (1991) demonstrated the existence of caves in several parts of the Interlake that exhibited both early phreatic and, with isostatic glacial rebound, later vadose stages of development. The maps clearly display the predominance of passageways with a 90-100° azimuth (Fig. GS-25-3), the orientation in the region north of Grand Rapids being parallel to the dip of the current potentiometric surface, and the predominant axis of sink hole chains (collapsed solution cavities) near the Grand Rapids Hydro Installation (Grice, 1964).

Indirect information on the orientation of subsurface fractures has also been obtained through recent studies of groundwater movement in the Paleozoic dolostones. A comprehensive discussion of groundwater flow systems in the Carbonate-Evaporite Unit in Manitoba has recently been published by Betcher *et al.* (1995).

On a regional scale, southwestern Manitoba lies along the eastern and northern edge of a continental scale, east and northeasterly flowing groundwater system developed in Paleozoic sediments of the Williston Basin (Downey, 1984; Hitchon *et al.,* 1969; and Van Everdingen, 1971). This long-lived system is driven by the hydraulic head of the catchment areas in Alberta, Saskatchewan and the Manitoba Uplands, with discharge occurring along a northwest- to southeast- trending belt that lies east of the Mesozoic shale cover where a series of salt water springs and seepages occur along the western shores of Lake Winnipegosis and Lake Manitoba (Stephenson, 1973; McKillop *et al.,* 1992; and Wadien, 1984).

The central portion of the Interlake forms a major area of fresh water recharge to the carbonate aquifer. In the southern Interlake, Betcher (1994), Render (1970), and Rutulis (1984) have demonstrated contemporary lateral movement of subsurface waters to the east and west away from a topographically high recharge mound along the drainage divide. The existence of an integrated fracture-controlled shallow groundwater system throughout the southern Interlake has been indicated by the Water Resources studies (Betcher, *et al.* 1995).

More recently, the current spring water sampling program has confirmed the existence of a regional east-dipping potentiometric surface in the Grand Rapids region (Fig. GS-25-4 and Table GS-25-2), together with the inference that the direction of groundwater movement has been strongly influenced by bedrock fractures with a predominant orientation of 090°, perpendicular to the contours on the potentiometric surface.

Surface fractures

Fracture orientation measurements (2454) were collected this summer throughout the Interlake, from locations where the Paleozoic carbonates are exposed at surface. This approach was deemed to be more selective than the air photo interpretation adopted by Mollard (1957), which inevitably included linears of superficial, glacial, origins *e.g.* striae, iceberg scours *etc.* In most instances 20-50 measurements were taken from each site/subarea to give a statistically valid sample together with a subjective assessment on which fractures represented the predominant and laterally extensive set (*i.e.* master joints). On-site inspection also allowed discrimination between joints and fault/shear zones on which movement could be inferred. Initial results from 40 subareas (Figs. GS-25-2a, b, and c) appear to show a moderate to high level of correlation between the inferred basement fracture trends and those measured in the Paleozoic carbonates at surface.

Almost without exception, all basement trends can be recognized in the overlying carbonates, however maxima do not necessarily correspond *i.e.* strong trends in the carbonates do not always reflect strong trends in the basement and strong trends in the basement do not necessarily get reflected as dominant fracture sets in the overlying carbonates.

In the Iskwasum area 040° trends are not represented in the carbonates and 090° trends are underrepresented. Between Ponton and Grand Rapids 000° trends are underrepresented in the carbonates and 200° linears do not show up as joints. At Morrison Lake and Baldys Bluffs, older 070° and 080° Archean trends show up in the carbonates, but 020° and 040° do not. In the central Interlake, trends in the carbonates generally reflect basement orientations, although carbonates appear more sensitive to 000° fractures and less responsive to 130° trends which dominate the east shore of Lake Winnipeg between Doghead Point and Manigotagan. In the southern Interlake, all basement trends are reflected in the overlying carbonates but not all with the same degree of prominence and locally the carbonates exhibit 000° trends not readily apparent in the basement.

Fractures in the Stony Mountain and Stonewall regions exhibit a high degree of preferred orientation, those at Stonewall (120°, 40° and 180°, in order of dominance) being prominently mineralized with thin, black, nodular (2-4 mm) films of pyrite.

Overall, the principal fracture sets trend E, NE, and NW with restricted zones of north-trending fractures. Accordingly observations thus far are compatible with the existence of a long-lived regional stress regime in the Western Canada Basin as proposed by Bell and Babcock (1986), together with an attendant and equally persistent regmatic fracture pattern (Greggs and Greggs, 1989).

IMPLICATIONS AND FUTURE WORK

A more detailed and thorough comparison of the three data sets is currently being undertaken to evaluate the degree to which the fracture orientations correlate from Precambrian basement to the overlying Paleozoic carbonates. If the orientations prove highly correlative, then it would be possible to infer that the fracture systems in the carbonate formations were inherited in large part from the basement and were probably long lived (Hobbs, 1911; McCabe, 1967; Bezys and McCabe, 1996). In this context, recent work by Brown *et al.* (1995) on the Lac du Bonnet Batholith has found evidence that in zones of fractures associ-

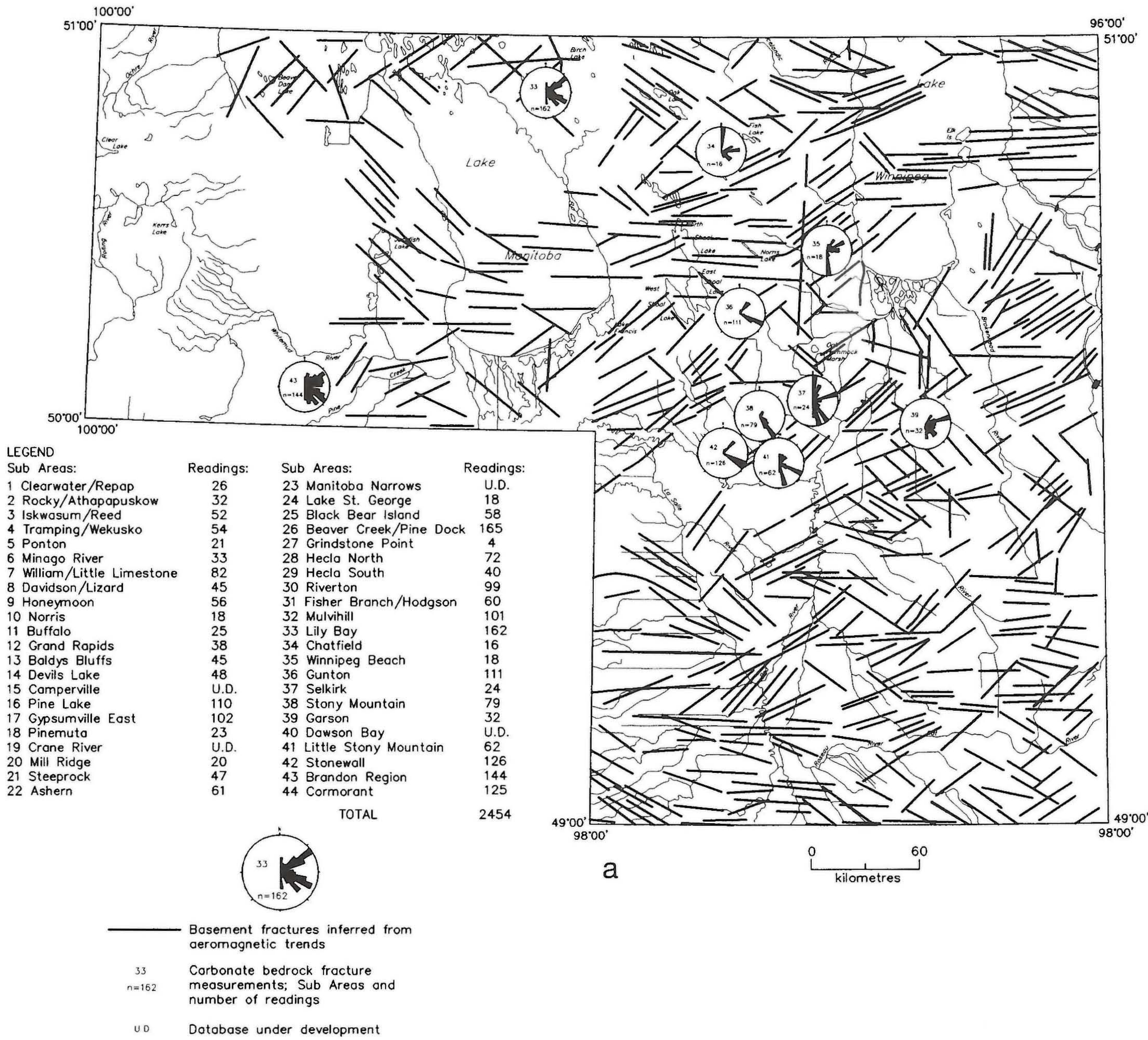
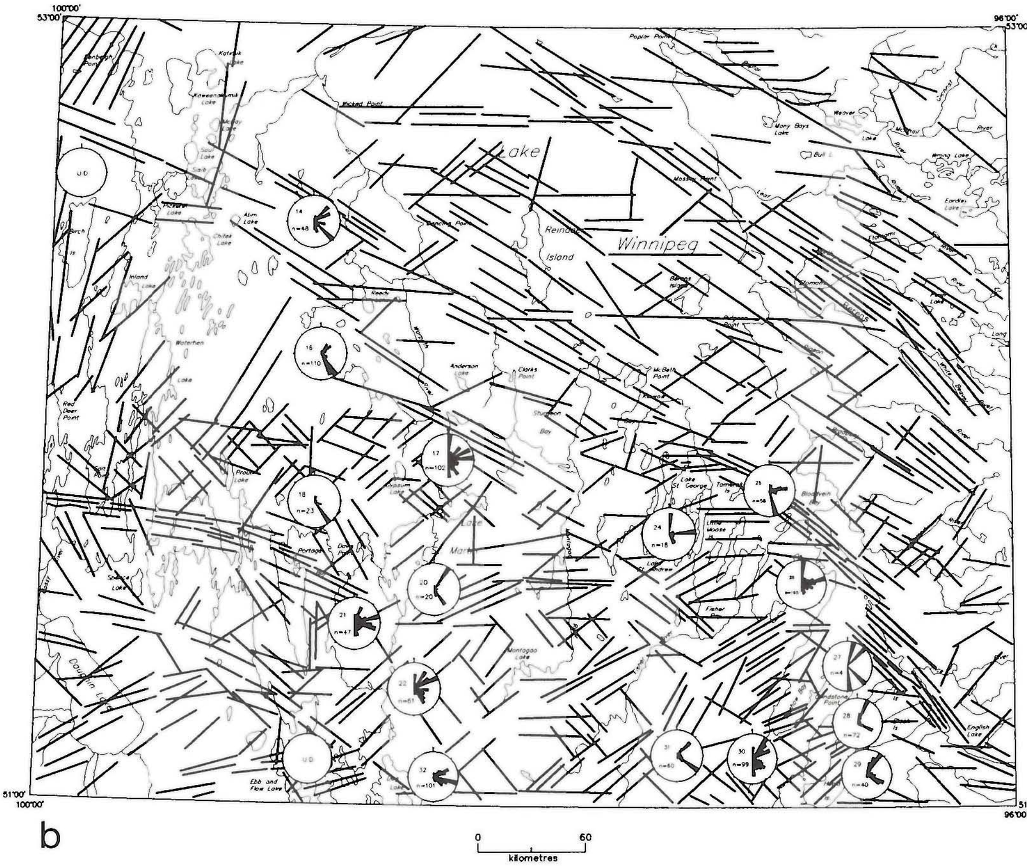


Figure GS-25-2: Basement fracture systems inferred from aeromagnetic trends, and rose diagrams illustrating orientation of surface and near surface fractures in bedrock carbonates; a) southern Interlake; b) central Interlake; c) northern Interlake.



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Winnipeg
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97°15'

c

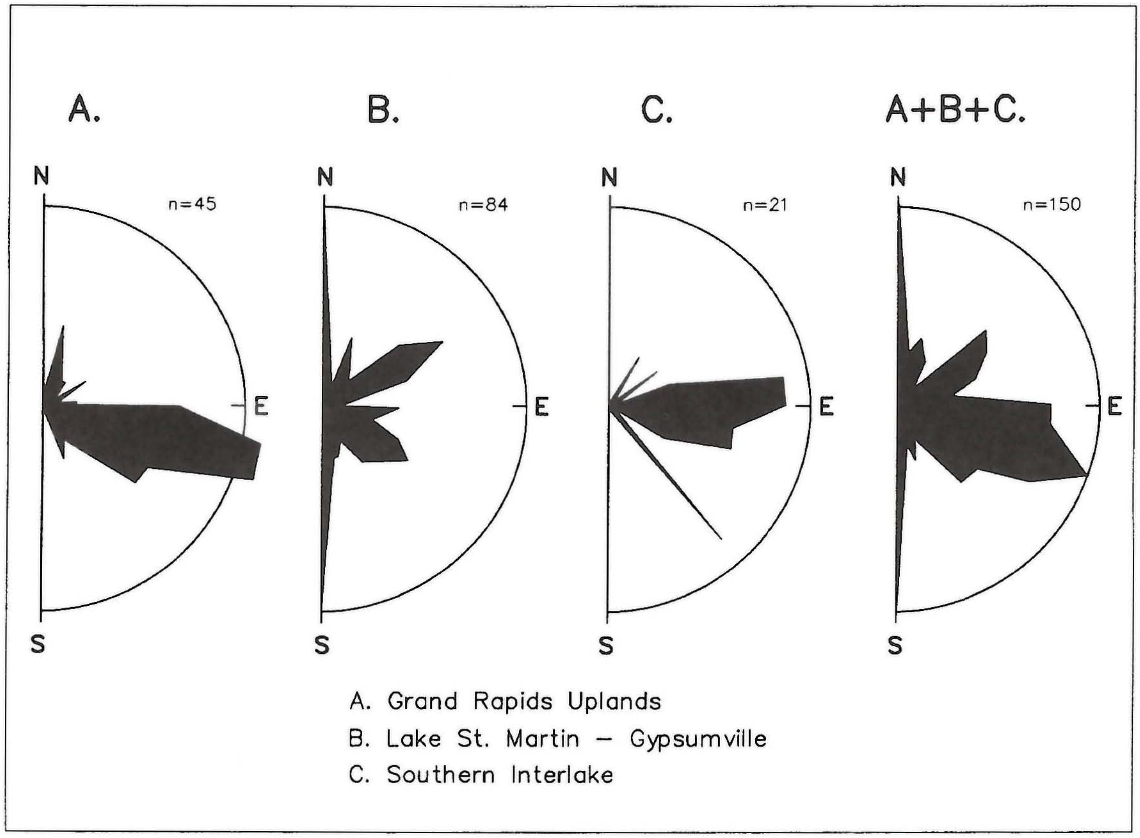


Figure GS-25-3: Orientation of near-surface cave passageways from Manitoba Interlake Region.

ated with significant faults (originally formed more than 2 000 Ma ago), fracture propagation or reactivation has possibly continued up to the last deglaciation at approximately 400 Ka. In the William Lake area, Bezys (1996) has provided convincing evidence that suggests that tectonic movements were active during Lower Paleozoic times along the boundary between the Churchill and Superior provinces. Recent interpretations of the 206° trending McNeill Lake lineament (Ruffman, *et al.*, 1996) suggest that movement along this axis may have occurred in post Lake Agassiz times.

Post-Paleozoic movement in the carbonates was recognized during the current investigation both from well developed sub-horizontal slickensides on E-W fractures in dolostone quarries near Tramping Lake and as 135° trending, closely spaced sets of microfractures in many quarries and roadside exposures throughout the northern and central Interlake. In the southern Interlake, a pronounced 15 m diameter, shallow basinal structure exposed on dolostone pavement on the eastern fringe of one of the quarries in the Lily Bay area, suggests that the folding in the quarry itself is of tectonic origin, rather than being related to the quarrying operations as was previously inferred.

It seems highly likely therefore, that basement fracture orientations are either directly continuous with or impose a strong and immediate degree of control on those formed in the overlying sandstone and carbonates, especially in the Interlake region where the veneer of carbonates is rarely greater than 250 metres thick.

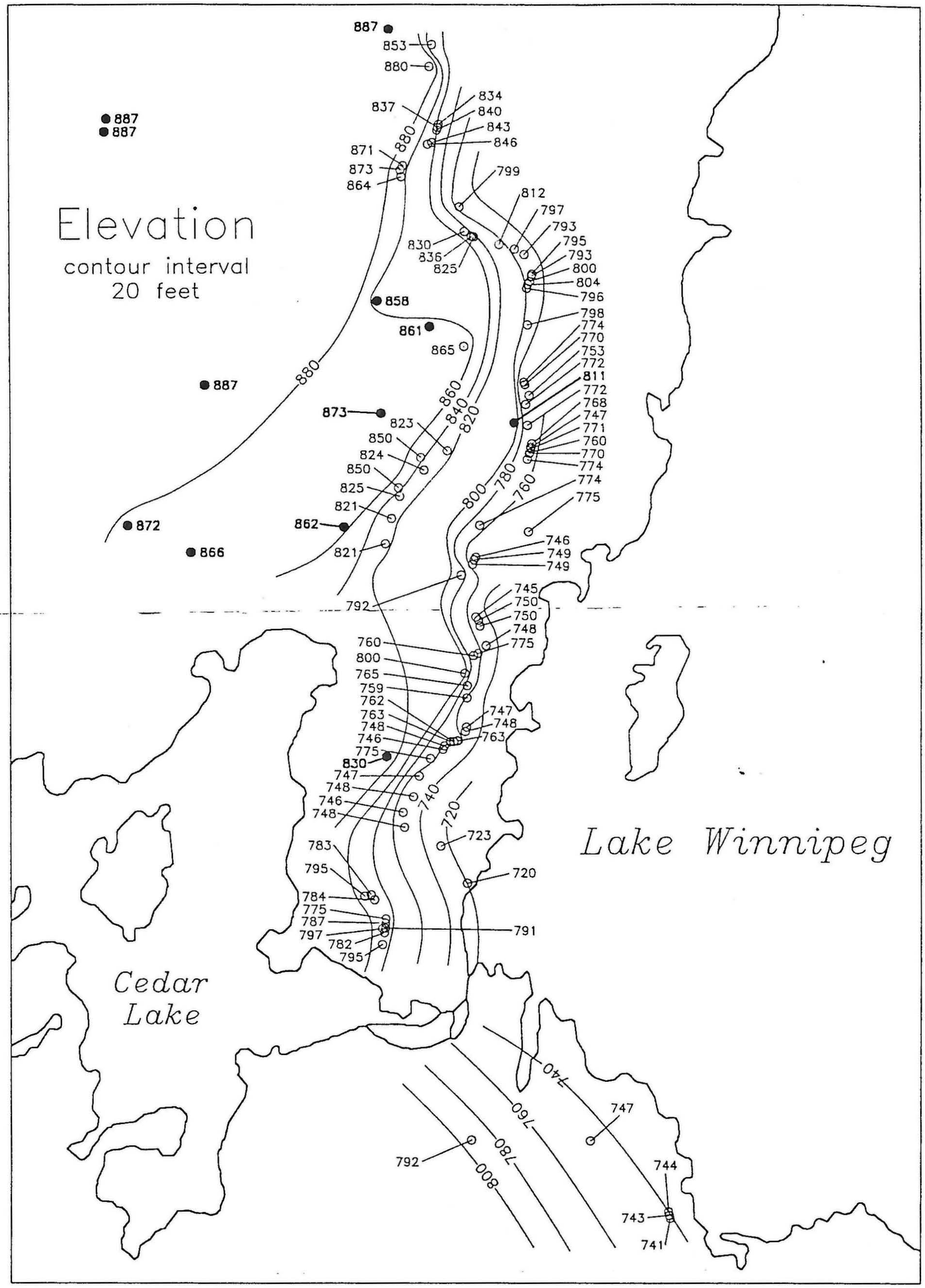
Consequently, fracture systems formed in the carbonates soon after their deposition and induration could have provided the permeability (channelways) for deep brines to move into or through this sector of the Williston Basin, as well as influencing the geometry of resultant MVT deposits. Furthermore the fracture sets would have influenced/determined the pattern of karstic erosion during the pre-Jurassic period and the orientation of channels/gorges subsequently filled with Cretaceous silica sand/kaolin. This is already suggested by the orientation of the Dominion City Channel (Manitoba Energy and Mines, 1990), and the buried silica/kaolin filled channels at Arborg, both having a pronounced easterly trend.

In the context of exploration for concealed silica/kaolin-filled channels in the Interlake or Shield margin regions, a high degree of correlation between basement fracture orientations and those observed in outcrops of dolostone would permit basement fracture trends (inferred from aeromagnetic maps) to be used as a guide to the orientation (and distribution) of subsurface fracture sets (and channels) in the Paleozoic carbonate formations, in areas where the dolostones are not exposed.

In a like manner, should geochemical anomalies be found (in the southern Interlake) flagging the existence of concealed MVT mineralization up-drainage, the observed or inferred fracture orientations in the dolostones could be used to guide follow-up geophysical (microgravity) surveys searching for the more dense, lead and zinc-bearing deposits.

As a final note, recent fluid inclusion and biomarker studies in the Upper Mississippi Valley District (Rowan and Goldhaber, 1996) present significant evidence supporting a Permian age for many of the lead-zinc deposits in the main MVT district. Given that the Manitoba segment of the Williston Basin was elevated and subjected to a high degree of karstic erosion during the Permo-Triassic interval, it is unlikely that mineralizing brines were active in this segment of the Williston Basin at this time. Nevertheless, if it can be demonstrated that local convection cells (Spirakis, 1995) were active in association with the basement features such as the Birdtail-Waskada axis during pre-Permian times, the potential for MVT deposits in southwestern Manitoba would still exist. In this context, Rowan and Goldhaber's (1995) working hypothesis is that movement of fluids in the Illinois Basin and Upper Mississippi Valley District took place in pre-Triassic times and that movement, in these regions was towards the north.

ERRATUM



Spring elevations and inferred contours on potentiometric surface, Grand Rapids region. Local anomalies may be caused by seasonal fluctuations in the "water table" i.e. samples were collected at different times each summer (1989, 94, 95, 96). Bold elevations correspond to water levels in diamond drill holes.

FIGURE GS-25-4

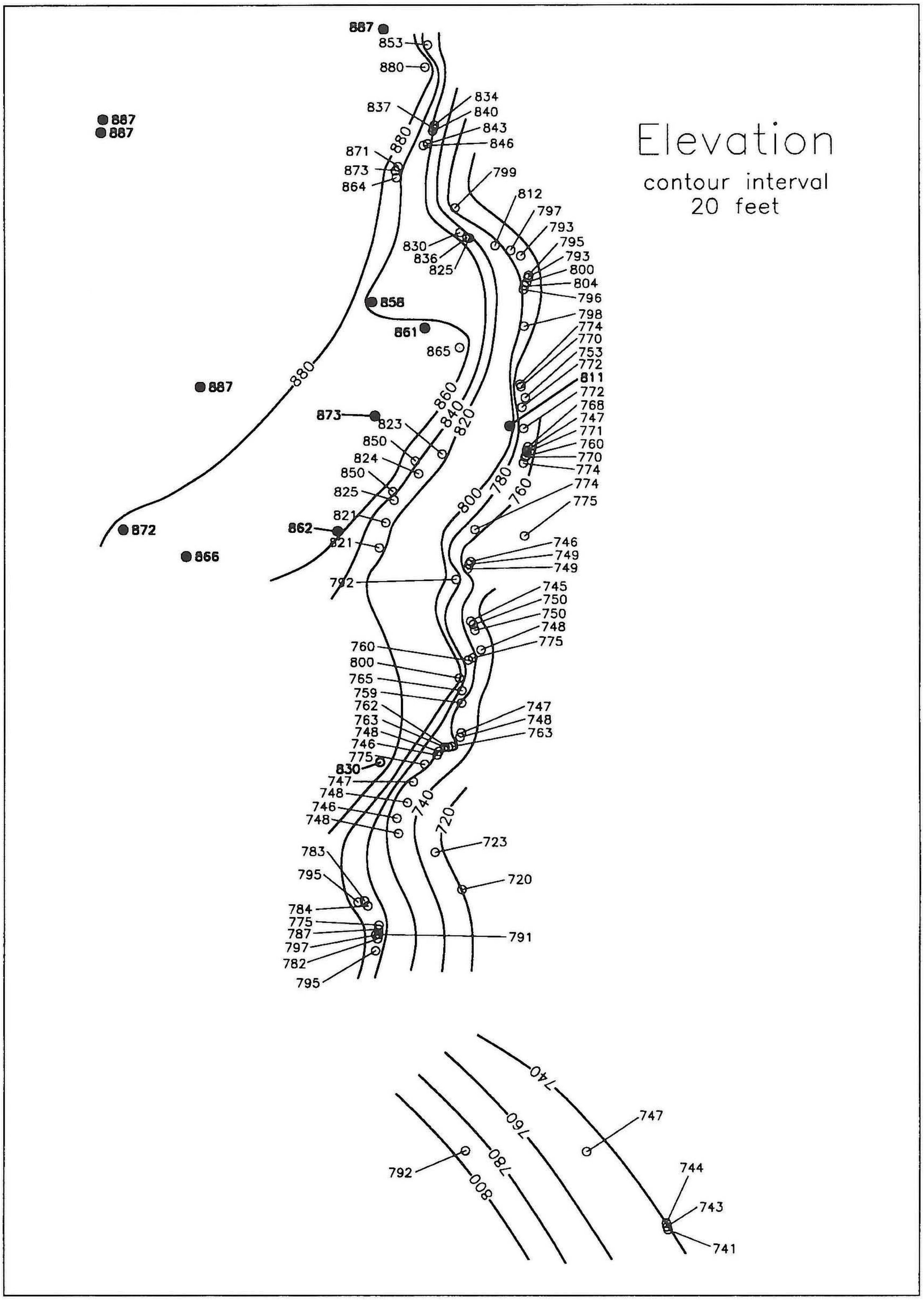


Figure GS-25-4: Regional, east-dipping potentiometric surface on groundwaters north of Grand Rapids. Numbers are estimated elevations (in feet) of springs sampled 1989, 1994, 1995 and 1996, 20 foot contour intervals.

Table GS-25-2
Spring sample locatons, UTM coordinates and estimated elevations, 1989, 1994, 1995 and 1996 sampling programs

Site	East	North	Estimated Elevation	Site	East	North	Estimated Elevation
04-95-01W	489612	5882505	747	04-94-14W	485900	5926500	772
04-95-07W	482707	5916967	749	04-94-15W	486000	5925250	772
04-95-08W	482808	5917244	749	04-94-16W	480250	5946650	880
04-95-09AW	482906	5917395	746	04-94-17W	480400	5947950	853
04-95-09BW	482906	5917395	746	04-94-18W	477525	5918225	822
04-95-10W	483148	5919312	774	04-94-19W	482250	5930000	865
04-95-11W	486050	5918927	775	04-94-20W	485275	5935775	797
04-95-14W	485988	5923224	774	04-94-21W	485850	5935450	793
04-95-15W	486090	5923577	770	04-94-22W	486300	5934300	795
04-95-16W	486155	5923638	760	04-94-23W	486275	5934175	793
04-95-17W	486193	5923862	771	04-94-24W	486175	5933850	800
04-95-18W	486173	5923959	747	04-94-25W	486050	5933685	804
04-95-20W	486252	5924177	768	04-94-26W	486000	5933450	796
04-95-30W	494400	5877875	741	04-94-27W	477909	5919724	821
04-95-31W	494350	5878050	743	04-94-29W	478399	5921044	825
04-95-32W	494300	5878275	744	04-94-30W	478332	5921554	850
04-95-33W	477525	5918225	821	04-94-31W	479650	5923357	850
04-95-34W	482900	5913850	745	04-94-32W	479850	5922600	824
04-95-35W	483050	5913654	750	88-94-01W	475350	5962625	
04-95-36W	482597	5882560	792	88-94-02W	469580	5961700	
04-95-39W	483145	5913309	750	04-89-10W	480950	5905950	746
04-95-40W	483507	5912145	748	04-89-11W	481050	5906150	748
04-95-41W	483033	5911681	775	04-89-12W	481400	5906400	763
04-95-42W	482245	5910481	800	04-89-13W	481600	5906400	762
04-95-43W	482391	5909742	765	04-89-14W	481800	5906450	763
04-95-44W	482367	5909015	759	04-89-15W	482275	5907000	748
04-95-45W	486031	5931263	798	04-89-16W	482350	5907275	747
04-95-47W	479185	5903133	748	04-89-17W	484350	5936050	812
04-95-48W	480210	5905406	775	04-89-18W	482850	5936500	825
04-95-49W	479534	5904367	747	04-89-19W	482725	5936525	836
04-95-50W	482381	5897960	720	04-89-20W	482300	5936825	830
04-95-51W	480815	5900177	723	04-89-22AW	482010	5938300	799
04-94-01W	480800	5943200	834	04-89-22BW	482010	5938300	799
04-94-02W	480750	5943000	837	04-89-23W	486200	5824775	
04-94-03W	480700	5942850	840	04-89-24W	477525	5818255	
04-94-04W	480400	5942100	843	WR-89-01	476850	5897000	784
04-94-05W	480150	5942000	846	WR-89-02	476650	5897300	783
04-94-07W	478650	5940750	871	WR-89-03	476280	5897220	795
04-94-08W	478500	5940500	873	WR-89-04	478650	5901300	748
04-94-09W	478550	5940100	864	WR-89-05	478560	5902200	746
04-94-11W	485800	5927850	774	WR-89-06	482760	5911550	760
04-94-12W	485850	5927700	770	WR-89-07	482050	5916340	792
04-94-13W	486100	5927050	753				

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GS-26 STATUS OF THE MANITOBA STRATIGRAPHIC DATABASE

by G.G. Conley

Conley, G.G., 1996: Status of the Manitoba Stratigraphic Database; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 153.

SUMMARY

All deep Lower Paleozoic wells within the Province have been verified for the interval between the top of the Silurian Interlake Group to the top of the Precambrian and have been entered into the Manitoba Stratigraphic Database. Over the past year, 194 new wells have been added (160 stratigraphic wells and 34 new mineral exploration wells).

The complete lower Paleozoic Stratigraphic Map series (Interlake, Stonewall, Stony Mountain, Red River, Winnipeg and Precambrian) are currently under production in digital format and are expected to be completed by November 1996.

UTM location and depth to bedrock have been determined for 1630 water wells in 62I/02, 62I/03 and 62I/06 for use in the Capital Regions Project (see GS-19, Bamburak and Bezys, this volume). Preliminary digital Overburden Thickness, Bedrock Surface Elevation and Ground Surface Elevation Maps have been generated for this area. Another 6000 to 7000 water wells are under review for inclusion in this study.

BACKGROUND AND OBJECTIVES

The Geological Services Branch's (GSB) Manitoba Stratigraphic Database (MSD) is a database of all subsurface Phanerozoic stratigraphic data and core storage data for all relevant Phanerozoic wells in Manitoba. These wells include petroleum, stratigraphic, mineral exploration, Manitoba Hydro, and some water wells. When completed, this database will be the most comprehensive collection of information on the Phanerozoic bedrock of Manitoba.

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 component of MSD is the ability to generate accurate isopach, structure contour, and depth to Precambrian maps for Phanerozoic data by extracting data directly from MSD into a mapping and contouring software package or into a Geographic Information System.

CURRENT STATUS OF THE PROJECT

All deep Lower Paleozoic wells within the Province have been verified for the interval between the top of the Silurian Interlake Group to the top of the Precambrian. The tops conform to stratigraphic nomenclature established by the Western Canada Sedimentary Basin Atlas Project. Several products that are readily reproducible and of interest to exploration geologists include Overburden Thickness and Depth to Precambrian Maps.

The database currently contains a total of 5667 wells. Of these, 1355 wells are Lower Paleozoic wells that have been verified. The verified wells include, 369 stratigraphic wells (29835 m), 688 mineral exploration wells (138266 m), 2 Manitoba Hydro wells (295 m), 2 water wells (207 m), and 185 petroleum wells (180947 m).

The stratigraphic data is stored in a well header table and a well tops table. The well header data includes 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, core log availability indicator, confidentiality indicator, faulted well indicator, source of the data, and date of last update. The well tops data for each well includes stratigraphic picks, isopach values, subseas 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 to the lower contact. An eroded or incomplete designation indicates that the formation should be excluded from isopach calculation. Data can be displayed in either feet or metres.

Stratigraphic maps for the Stonewall, Red River and Winnipeg formations were produced jointly with Saskatchewan for a display at the GAC conference in spring of 1996. To achieve this the GSB exchanged non-confidential data with Saskatchewan, extending about 5 townships east and west of the Provincial Border.

The complete lower Paleozoic Stratigraphic Map series (Interlake, Stonewall, Stony Mountain, Red River, Winnipeg and Precambrian) are currently under production in digital format and are expected to be completed by November 1996.

Core storage location data continues to be maintained 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.

FUTURE DEVELOPMENTS

The Capital Regions Project (1996-97) is concerned with identifying near surface economic carbonate bedrock in the area north and west of Winnipeg. New stratigraphic data obtained from water wells will be added to MSD during this project.

Programming of MSD is expected to be undertaken in late fall (1996) with completion in spring to summer of (1997). This will provide access for GSB internal users as well as on-line access to the core storage facility. As soon as the technology is available, GSB will make non-confidential data available to external clients via a Web Page on the Internet. For those users without digital capabilities, the data will continue to be made 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 from the 1996 field season are currently being gathered in a word processor by R. Bezys (Paleozoic Stratigrapher) and will be incorporated into MSD by early 1997.

As time permits, historical picks maintained by GSB will continue to be entered into the database. The historical data includes wells primarily picked by H.R. McCabe and other Manitoba geologists. The picks will cover the entire stratigraphic column in Manitoba and will serve as a valuable permanent reference.

Also as time permits, a comprehensive 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 (Subphanerozoic Precambrian Geologist).

GS-27 GEOSCIENCE INFORMATION SERVICES PROJECTS

by L. Chackowsky and P.G. Lenton

Chackowsky, L. and Lenton, P.G., 1996: Geoscience information services projects; **in** Manitoba Energy and Mines, Minerals Division, Report of Activities 1996, p. 154.

SUMMARY

GIS technology and data automation was used extensively in support of Survey mapping, in the production of preliminary and final geological maps, resource evaluation and land management studies (*e.g.*, Grass River Provincial Park land use study), and in the NATMAP 1:100 000 geological map compilation project.

ARC/INFO GIS SYSTEM

Geological Services Branch has greatly expanded its GIS capabilities with the incorporation of a new GIS system using ARC/INFO GIS software on a SPARC 20 workstation running on UNIX operating system. The advantages of this system over the old PC-based GIS system running PAMAP software are:
increased efficiency of day-to-day GIS support;

- more GIS features, such as triangulated irregular networks (TIN's) for modelling continuous data;
- increased compatibility with data types such as raster files, scanned images and digital elevation models;
- easier to exchange information with outside agencies (*e.g.*, GSC) that use ARC/INFO software (an industry standard);
- ability to produce colour maps in-house; and
- electronic colour map production by colour-separated plate negatives from GIS-generated encapsulated PostScript files.

NATMAP SHIELD MARGIN PROJECT

The 1:100 000 compilation is nearing completion with release scheduled for May, 1997. The Reed Lake, Snow Lake-File Lake, and Wekusko Lake areas have been incorporated into the Flin Flon Belt compilation, extending the boundaries east to 99°52'30" and north to 54°55'. Geological information has been edge-matched with the Kisseynew compilation to the north and to the sub-Phanerozoic interpretation (Leclair) to the south. A colour draft of the Flin Flon-Reed Lake area was presented as a poster display in May of 1996 at the GAC/MAC Joint Annual Meeting in Winnipeg.

The Reed Lake 1:50 000 Geology Map has been completed. Geological information was digitized and combined with digital topographic data. Final colour map production was done by the GSC and published as Manitoba Energy & Mines Open File OF96-3 and GSC Open File 3149.

In other GIS news, the 1:5 000 colour geological map "Geology of the Chisel Volcanic-Hosted Massive Sulphide Area, Snow Lake" was released jointly by Manitoba Energy and Mines and the GSC (MANITOBA ENERGY AND MINES Open File OF95-4; GSC Open File 3262).

GEOLOGICAL MAP OF MANITOBA

Manitoba Energy and Mines has been working with the GSC to convert the 1:1 000 000 scale Geological Map of Manitoba to GISbased digital form. The new digital map is released as a joint GSC and MANITOBA ENERGY AND MINES Open file on CD-ROM. During the digital conversion minor editorial changes were made to the contacts on the map to correct some of the most obvious errors, but this initial release is not meant as a major revision of the geological content. The GSC has encorporated a composite image of the geology draped over re-gridded total magnetic data for the entire province.

WETLANDS PROJECT

This joint project with the University of Alberta has continued with the scanning/vectorizing of 55 mylar maps classifying wetland areas into 15 units over the entire province. The 55 individual vector files have been geo-referenced, edge matched and rubber sheeted using ARC/INFO GIS. Unit identifiers were digitized using AutoCAD and data transferred to GIS for colour themeing and production of draft copies for editing. The map is currently in final edit stage. Final printing has been contracted to Linnet Geomatics Inc.

GOLD IN MANITOBA

Three colour geological maps that show the locations of gold occurrences in the Flin Flon-Snow Lake-Kisseynew belts, Northern Superior area, and the Rice Lake belt were produced for inclusion in the department's new edition of "Gold Deposits in Manitoba". Digital geological information from the Geology of Manitoba map, Bedrock Geology Compilation Map Series 63K, and digitized from paper maps (Rice Lake area, BGCM 63J, 63N and 63O) was combined with digital topographic information and hand-digitized gold occurrences. Colour map production was done in-house using ARC/INFO GIS. Final printing was done by converting GIS-generated encapsulated PostScript (EPS) files directly to colour-separated plate negatives. These maps were displayed at the MINExpo Conference, Las Vegas, Nevada, in September of 1996.

BEDROCK GEOLOGY COMPILATION MAP SERIES - NORTHERN SUPERIOR

A 1:500 000 colour geological map of NTS areas 53L, 53M and 63P was produced using ARC/INFO GIS. This compilation derives information from the 1:250 000 Bedrock Geology Compilation series and is designed as an initial geological base for use by Operation Superior projects. Geological information (D. Lindal) on paper and mylar copy was hand digitized using AutoCAD, then colour themed and combined with digital topographic coverages in GIS. Colour map production was done in-house with proofs plotted on our colour ink-jet plotter. The initial displayed map is an editorial tool. The compilation is not designed to be released as a separate product, but as a base for other information such as the Multimedia Geochemical Survey (see Fedikow *et al.*, GS-1 this volume).

MINERAL OCCURRENCE DATABASE

Development of the Mineral Occurrence database has continued. Data entry has concentrated predominantly on regions of the northern Superior in support of Operation Superior programs.

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PRELIMINARY MAPS

GEOLOGICAL SERVICES BRANCH		SCALE
1996S-1	North East Edmund Lake (NTS 53K/11 NE) by M.T. Corkery	1:20 000
1996F-1	Photo Lake (NTS 63K16) by A.H. Bailes[1], D. Simms[2], A.G. Galley[3] and J. Young[4]	1:10 000
1996F-2	Lac Aimée-Naosap Lake (parts of NTS 63K/13SW, 14SW) by H.P. Gilbert	1:20 000
1996F-3	North Arm-Athapapuskow Lake and Persian Lake (NTS 63K/12) by D.E. Prouse	1:10 000
1996K-1	Dow Lake-Martell Lake (parts of 63K/15, 63N/2) by H.V. Zwanzig	1:20 000

[1] Manitoba Energy and Mines
[2] Hudson Bay Exploration and Development Company Limited
[3] Geological Survey of Canada
[4] University of Manitoba

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	Vacant	
Precambrian Geologists	Dr. A.H. Bailes	Snow Lake, Wekusko Lake, Reed Lake
	M.T. Corkery	Cross Lake-Northern Superior Province, Nelson and Churchill Rivers, Partridge Breast Lake, SE Manitoba
	H.P. Gilbert	Tartan Lake, Wekusko Lake-South, Dion Lake
	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, Reed Lake
	Dr. H.V. Zwanzig	Churchill Province, Kisseynew belt
Compilation Geologist/Mineralogist	C.R. McGregor	Sub-Phanerozoic Precambrian compilations; mineralogy
Phanerozoic Geologist	R.K. Bezys	Southwest Manitoba, Hudson Bay Lowlands, and Interlake
Mineral Investigations:		
Senior Mineral Deposit Geologist	Dr. G.H. Gale	Flin Flon
Industrial Minerals Geologists	B.E. Schmidtke	Industrial mineral inventory, dimension stone, peat
	J.D. Bamburak	High-magnesium dolomite, dimension stone High-calcium limestone, silica, bentonite
Resident Geologist (Flin Flon)	T. Heine	Flin Flon - Snow Lake region; Iskwasum Lake
	D.E. Prouse	Bakers Narrows; exploration activity, drill core program
Resident Geologist NE (Thompson)	Dr. P. Theyer	Thompson Nickel Belt, Island Lake
Resident Geologist NW (Thompson)	Dr. D. Peck	Cross Lake anorthosites, Lynn Lake
Staff Geologist (Thompson)	H.D.M. Cameron	Cross Lake anorthosites, Lynn Lake
Geoscience Information Services:	P.G. Lenton	Geological Data Management and Analysis
	G.G. Conley	Stratigraphic data files
	L.E. Chackowsky	Geographic Information Systems
Geological Compiler (Atlas)	D. Lindal	1:250 000 bedrock compilation maps
Geophysics, Geochemistry and Terrain Sciences:		
Section Head/Geophysicist	I.T. Hosain	Superior Province
Geochemist/Mineral Deposit Geologist	Dr. M.A.F. Fedikow	Snow Lake
Quaternary Geologists	Dr. E. Nielsen	Elbow Lake, Naosap Lake, Lake Winnipeg, Superior Province
	G. Matile	Southern Manitoba, Westlake Plain

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