GEOLOGICAL SURVEY OF CANADA
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PROJECT SUMMARIES

CANADA-NORTHWEST TERRITORIES MINERAL DEVELOPMENT SUBSIDIARY AGREEMENT 1987-1991

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INTRODUCTION

This volume summarizes the results of projects carried out under the Canada-Northwest Territories Mineral Development Subsidiary Agreement (MDA), 1987-91. The first report contains a short description of the objectives, funding and organizational components of the MDA. Of the remaining 53 reports, 47 summarize projects of the *Geoscience Program* implemented by the Department of Energy, Mines and Petroleum Resources (EM & PR), Government of the Northwest Territories (GNWT) and the Department of Indian Affairs and Northern Development (DIAND), and by the Geological Survey of Canada (GSC). The final 6 reports present the results of mining technology and mineral processing projects that were implemented under the *Northern Technology Assistance Program (NTAP)* by EM & PR with scientific supervision by the Canada Centre for Mineral and Energy Technology (CANMET). The reports contained in this volume were submitted in January, 1991. The reports have been reviewed by GNWT-DIAND, GSC and CANMET staff, but have not undergone rigorous scientific review or editing.

Geoscience Program papers in this volume report on a wide range of activities related to mineral deposit geology, including regional geology, structural geology, mineral deposit modelling, geochemistry, isotope geology, and airborne geophysics. The locations of GNWT-DIAND and GSC *Geoscience Program* projects are shown in figures 1 and 2, respectively. Bibliographies of publications derived from the geoscience MDA project by GNWT-DIAND and by the GSC are presented in Appendices A and B, respectively.

This volume represents a co-operative product in that it contains summary reports authored or co-authored by university-based geologists, consultants and contractors, as well as by geologists from GNWT-DIAND and the GSC. Many project leaders cooperated closely with staff of exploration and mining companies, especially so with the NTAP.

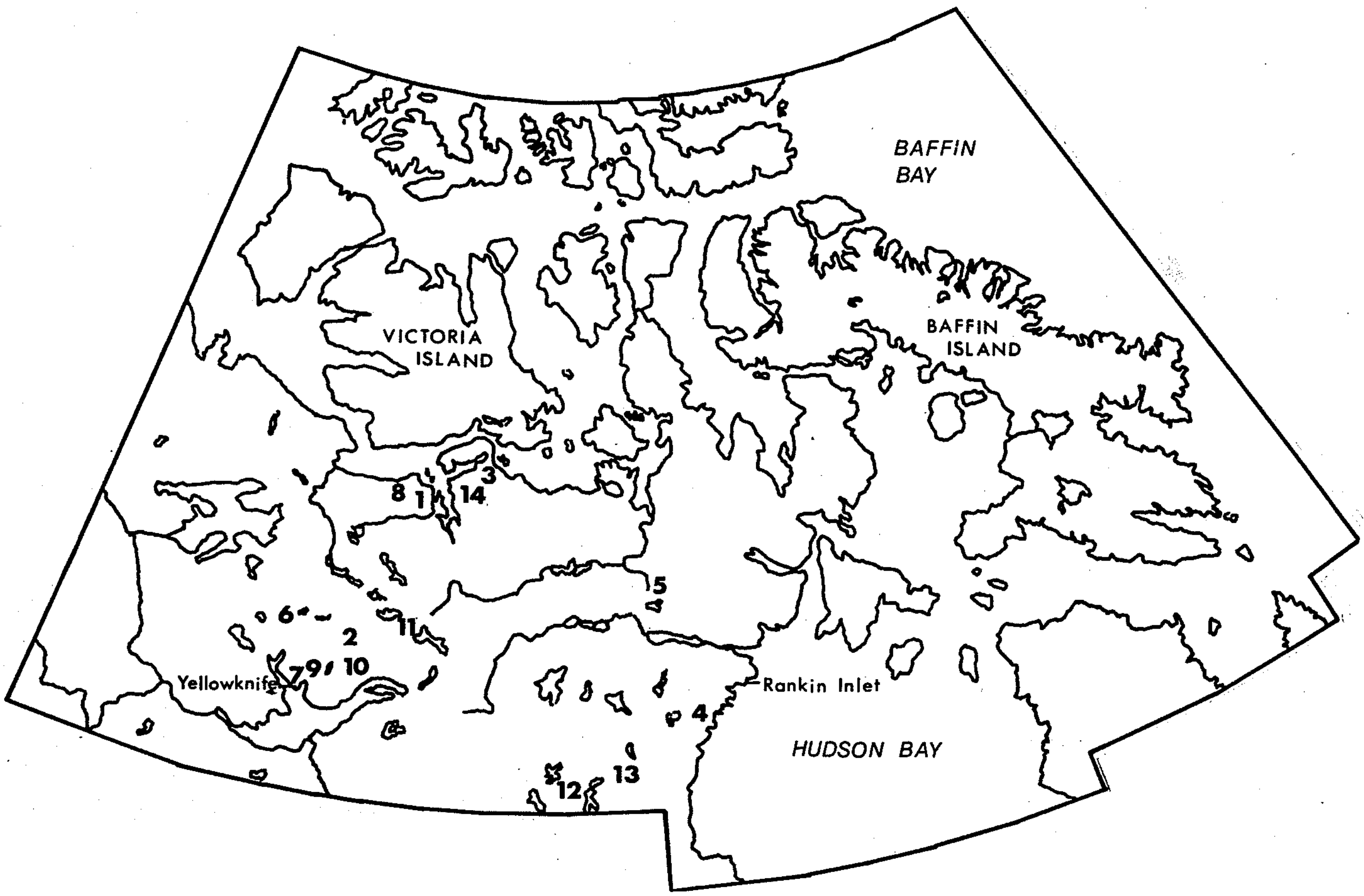
INTRODUCTION

Le présent document donne un aperçu des résultats des projets menés dans le cadre de l'Entente auxiliaire d'exploitation minérale (EAEM) Canada-Territoires du Nord-Ouest (1987-1991). Le premier rapport qui y est cité décrit sommairement les objectifs, le mode de financement et les composantes organisationelles de l'EAEM. Quant aux 53 autres rapports dont on fait mention, ils se répartissent ainsi : 47 résument des projets du *Programme géoscientifique* mis sur pied par le ministère de l'Énergie, des Mines et des Ressources pétrolières (MERP) du gouvernement des Territoires du Nord-Ouest, le Ministère des Affaires indiennes et du Nord (MAIN) et la Commission géologique du Canada (CGC); quant aux 6 derniers, ils présentent les résultats des projets dans les domaines des techniques d'exploitation minière et du traitement des minerais entrepris dans le cadre du *Programme d'aide technique pour le Nord* (*PATN*) du MERP. Il est à noter que la supervision scientifique de ces derniers projets était assurée par le personnel du Centre canadien de la technologie des minéraux et de l'énergie (CANMET). Les rapports cités dans ce document furent soumis en janvier, 1991. Les rapports ont été revus par des employés du gouvernement des T.N.-O., du MAIN, de la CGC et du CANMET; ils n'ont cependant pas été soumis à une révision scientifique rigoureuse.

Dans le document, les articles rattachés au *Programme géoscientifique* font état d'une grande variété de travaux en géologie des gîtes minéraux; parmi les sujets abordés, il y a la géologie régionale, la géologie structurale, la modélisation des gîtes minéraux, la géochimie, la géochimie isotopique et la géophysique aéroportée. Les figures 1 et 2 montrent où ont été effectués les travaux des projets du *Programme géoscientifique* relevant du gouvernement des T.N.-O. et du MAIN (fig. 1) et de la CGC (fig. 2). Quant aux annexes A et B, elles donnent la bibliographie des documents publiés en rapport avec le projet géoscientifique d'EEM, par le gouvernement des T.N.-O. et le MAIN d'une part et la CGC d'autre part.

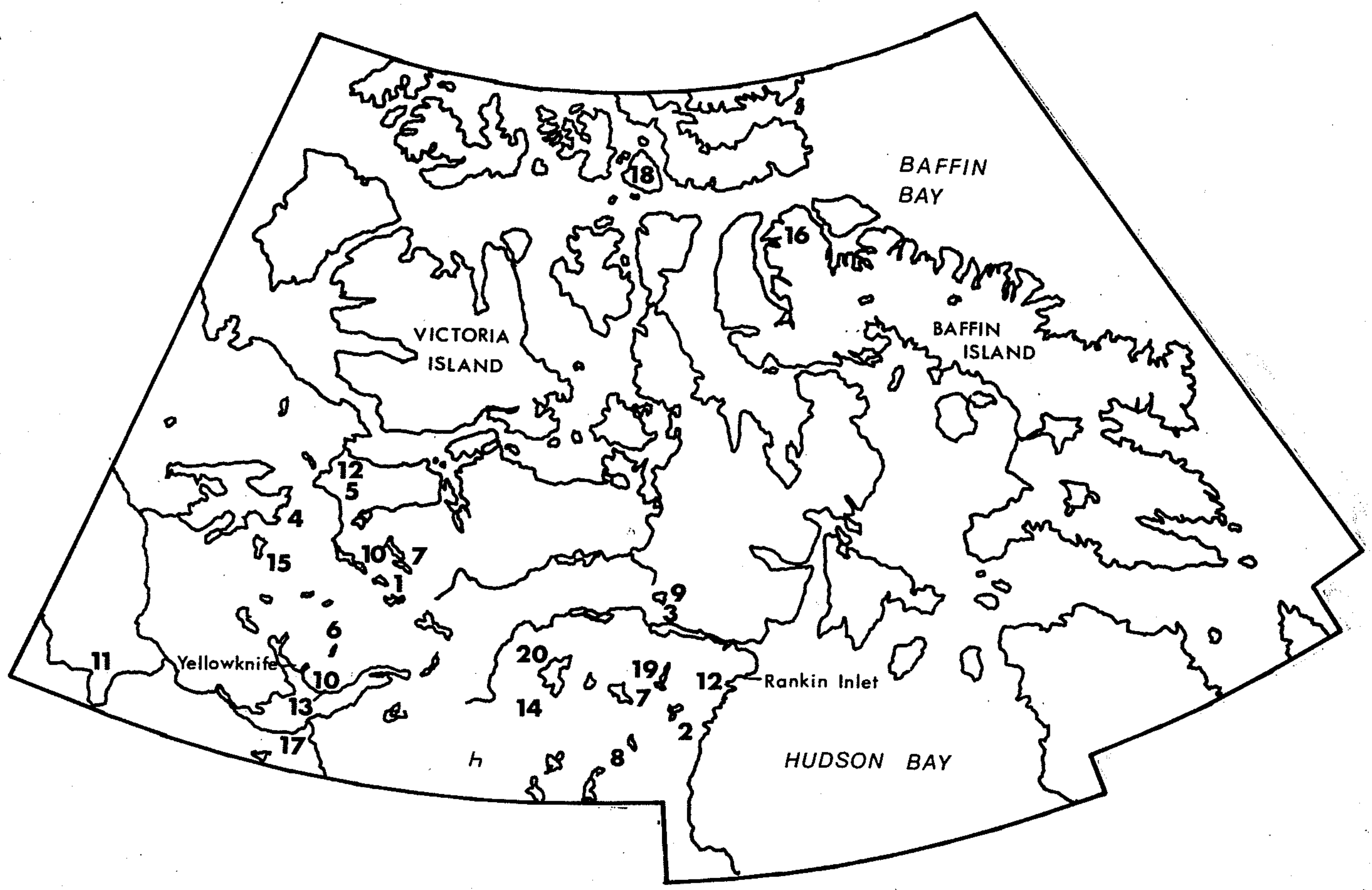
Le présent document a été produit conjointement; en effet, il contient des comptes rendus dont les auteurs ou les coauteurs sont des géologues, des consultants et des contractuels travaillant pour des universités, mais aussi des géoscientifiques du gouvernement des T.N.-O., du MAIN et de la CGC. Plusieurs directeurs de projet ont travaillé en étroite collaboration avec des employés de compagnies d'exploration et d'exploitation minière, particulièrement dans le cadre du *PATN*.

Figure 1. GEOSCIENCE PROJECTS OF THE GOVERNMENT OF THE NORTHWEST TERRITORIES AND THE DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT.



1	LOWER HOOD-JAMES RIVER	8	ANIALIK RIVER
2	BEAULIEU RIVER	9	GORDON LAKE
3	HOPE BAY	10	BENIAH LAKE
4	MISTAKE LAKE	11	SOUTH SLAVE PEGMATITES
5	TEHEK LAKE	12	WINDY-KIYAK LAKE
6	INDIN LAKE	13	HURWITZ
7	YELLOWKNIFE	14	HOPE BAY-IDA POINT

Figure 2. GEOSCIENCE PROJECTS OF THE GEOLOGICAL SURVEY OF CANADA.



1 CONTWOYTO-NOSE LAKE
2 TAVANI GREENSTONE BELT
3 BAKER LAKE
4 MYSTERY ISLAND
5 MUSKOX INTRUSION
6 CAMERON RIVER
7 GEOCHEMISTRY [FERGUSON/YATHKYED/CONTWOYTO]
8 DRIFT PROSPECTING [KAMINAK-TURQUETIL]
9 AEROMAGNETIC SURVEYS [WHITEHILLS-TEHEK LAKES]
10 AIRBORNE GEOPHYSICS [LUPIN & THOR LAKE]
11 SOUTH NAHANNI
12 PGE IN ULTRAMAFICS/MAFICS [MUSKOX-RANKIN INLET]
13 RARE METALS [BLATCHFORD LAKE/THOR LAKE]
14 RARE METALS [ENEKATCHA/CAREY LAKE]
15 POLYMETALLIC DEPOSITS [GREAT BEAR MAGMATIC ZONE]
16 MINOR METALS [NANISIVIK LEAD-ZINC DEPOSIT]
17 PINE POINT
18 POLARIS
19 REMOTE SENSING APPLICATIONS [FERGUSON-KAMINAK]
20 CLAY MINERALOGY

REGIONAL SURVEYS:
GOLD METALLOGENY, CHURCHILL PROVINCE
GOLD METALLOGENY, SLAVE PROVINCE

Appreciation is expressed to the many project leaders who contributed to this volume. W.H. Poole (GSC), in addition to reviewing the entire volume and offering many useful comments and suggestions regarding organization and layout, was primarily responsible for co-ordinating the production of this document.

Daniel G. Richardson Martin Irving

Nous remercions les nombreux directeurs de projet qui ont participé à l'élaboration de ce document. W.H. Poole de la CGC a été non seulement celui qui a revu tout le texte et y est allé d'un grand nombre de commentaires pertinents et de bonnes suggestions quant à l'organisation et à la mise en page, mais aussi le coordonnateur principal de la production de ce document.

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THE CANADA-NORTHWEST TERRITORIES MINERAL DEVELOPMENT SUBSIDIARY AGREEMENT 1987-1991

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The Canada-Northwest Territories Mineral Development Subsidiary Agreement (MDA) was one of the six sub-agreements of the second Canada-Northwest Territories Economic Development Agreement. Starting in 1987, the MDA ended on March 31, 1991. During this time 7 million dollars were contributed by the federal and territorial governments to further mineral resource development in the Northwest Territories (NWT), under three programs: *Geoscience, Technology Assistance and Mining Information.*

The MDA was administrated by a Management Group. The Management Group included representatives from the Department of Indian Affairs and Northern Development (DIAND), the Department of Energy, Mines and Petroleum Resources (EM & PR), of the Government of the Northwest Territories (GNWT), the Department of Economic Development and Tourism, of GNWT, and Energy, Mines and Resources Canada (EMR). Environment Canada was represented by an ex-officio member. The Management Group designed each of the three programs after consultation with the GNWT, the Geological Survey of Canada (GSC), the NWT Geology Division of DIAND and with the mineral industry through the NWT Chamber of Mines.

The Management Group reviewed and approved all projects conducted under each of the three programs. Each application for funding from a program was first reviewed by the Technical Sub-committee responsible for the program. The sub-committee ensured that the application was complete and that the proposed project's purpose, objectives, timetable and budget were reasonable and feasible.

EM & PR of the GNWT implemented all of the projects under the Northern Technology Assistance (NTAP) and the Northern Mining Information (NMIP) programs. The scientific supervision of the NTAP projects was supplied by the Canada Centre for Mineral and Energy Technology (CANMET) of EMR. Delivery of Geoscience Program projects was shared by GSC and EM & PR. The NWT Geology Division provided the scientific supervision of the Geoscience projects delivered by EM & PR.

During the last year of the MDA, an evaluation of the Agreement was undertaken by Don Ference & Associates Ltd. of Vancouver. Since many of the projects funded by the MDA were not yet complete, it was difficult to measure all of the impacts of the projects. Many of the impacts of the geoscience and NTAP projects are likely to be long term in nature. The evaluation strongly supported the work performed under the MDA and made a number of recommendations including:

1) Renewal of the MDA

2) Geoscience projects should continue to be accorded the highest priority.

3) The total funding under a future MDA should be increased.

4) A new MDA should be structured to allow 4 to 5 field seasons for the completion of geoscience projects.

5) Highest priority should be given to regional geological mapping projects.

6) NTAP should be re-structured to lower the maximum percentage of the MDA contribution, the primary criteria should be the potential benefits to the NWT mining industry as a whole, and a greater emphasis should be placed on projects dealing with environmental issues.

Geoscience Program

The objective of the Geoscience Program was to assist and encourage mineral exploration, by improving and increasing the geological data base of the NWT. Projects consisted of the mapping of selected areas with high mineral potential, detailed studies of significant mineral deposits and the compilation and publication of index maps, bibliography and data files.

The program supported over thirty multi-year projects across the NWT during the term of the Agreement. The budget for the four year term was $5.9 million. The GSC delivered $2.85 million, while EM & PR implemented the remaining $3.05 million.

To date, over 175 maps of various scales and more than 40 publications have been produced under the Program (see Appendices A and B of this volume). Industry activity has increased in almost all of the areas targeted by MDA projects. By 1991, the Geoscience Program had been credited with increasing investment, actual and planned, in exploration activities by approximately $1.7 million, with the potential for much more in future years.

In addition to regional and detailed mapping projects, the Geoscience Program supported compilation work in the DIAND Geology Archives. The Northern Geological Inventories (NGI) are a computer based (DBase lll Plus and AutoCAD) listing of all the geoscience work (Government and industry) undertaken in specific 1:50,000 NTS map sheets. The NGIs are the primary source of information for the exploration industry for the covered areas. Industry has expressed great interest in and support for the NGIs and work will continue on them in the future.

Under the GNWT/DIAND MDA, computers have been used to aid in production of geological maps. The use of Computer Assisted Drafting (CAD) programs has lead to the fast and efficient production of geological maps. The MDA Office has used AutoCAD to produce the geological maps as well as posters, slides and diagrams.

Northern Technology Assistance Program (NTAP)

The objective of this program was to assist the private sector in the development of innovative technologies which will improve mining and processing operations and adapt mining and processing operations to northern conditions.

This program consisted of seven projects. Three projects were oriented towards mining technology, while the other four dealt with mineral processing. These projects had a number of impacts including:

- The pillar recovery projects at Nanisivik Mine have extended the life of the mine by one or more years.
- The gold recovery project at Giant Yellowknife Mine was technically successful, and an enhanced recovery rate of 0.5% translates into an estimated $0.5 million of increased revenue per year.
- The toxic stabilization and pressure oxidation projects at the NERCO Con Mine have led to the planned construction of an autoclave which will allow the mill to recover gold from mine tailings and leave environmentally safe by-products.

Due to a lack of industry awareness regarding the NTAP, response to the program was initially poor; however, by the second year of the program, the number of projects proposed exceeded available funding.

Northern Mining Information Program (NMIP)

The objective of this program was to promote greater awareness of the economic importance of the mining industry in the residents of the NWT. Most of the projects funded under NMIP had a long term focus and were educational in nature.

Employment brochures, slide shows and career profile posters informed local residents and students that the mineral industry consists of more than just mining and mineral exploration companies; it also includes vital mining services and supply companies. The Mining Industry Newsletter, produced by the NWT Chamber of Mines, helped keep those with an interest in the NWT mining industry abreast of developments affecting the industry. Rock kits, maps and a Mining Activity book were produced for the schools in the NWT.

A. GEOSCIENCE PROGRAM

A1. PROJECTS OF THE GOVERNMENT OF THE NORTHWEST TERRITORIES AND THE DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

LOWER HOOD-JAMES RIVER PROJECT

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Objectives
The main objectives of the project were the regional mapping and economic evaluation of the Torp Lake and Hood River supracrustal belts in NTS map areas 76N/2,3,5,6,7,11,12 and 76K/11,14,15. Emphasis was to be placed on assessing gold potential and in particular, Lupin-style gold.

Methods
With concurrent graduate student and GSC-MDA 1:10,000 scale mapping projects conducted in the Hood River Belt, mapping was concentrated in the Torp Lake Metasedimentary Belt and the northern end of the Hood River Belt (parts of 76N/3,4,5,6,7,11,12). Mapping was conducted at a scale of 1:30,000 within the belt and of 1:50,000 in areas underlain by granitic rocks. The project was complemented in 1990 by a DIAND-supported study examining regional metamorphism in the Torp Lake Metasedimentary Belt. This M.Sc. thesis project was conducted by K. Venance of Carleton University.

Gossans, sulphide-enriched alteration zones, sulphide-bearing quartz and quartz-carbonate veins and iron formations were sampled for geochemical and petrological analysis in the course of mapping.

Results
The supracrustal rocks in the map areas are mainly medial to distal turbidites: fine-grained wacke, siltstone and mudstone (Fig. 1). In addition, the Torp Lake Belt has rare sulphide-facies and oxide-facies iron formations and minor arenite. The northern end of the Hood River Belt has a thick polymict conglomerate unit.

The belts are partly bordered by biotite-muscovite granite/granodiorite batholiths. The batholiths contain large xenoliths of a porphyritic melanogranite. Stocks and dykes of muscovite-biotite granite intrude the batholiths and the supracrustal rocks of the Torp Lake Belt.

Regional metamorphic grade increases southwestward from greenschist to amphibolite grade with cordierite-andalusite and muscovite-sillimanite isograds trending west to northwest.

The higher grade rocks in the southwestern end of the Torp Lake belt include small stocks and numerous dykes of recrystallized tonalite and a small stock of diorite. Samples of these rocks were collected for a geochronological study conducted by Dr. O. van Breeman of the Geological Survey of Canada. The U-Pb dates obtained were 2610 +3/-6 Ma for the tonalite and 2604 +/-4 Ma for the diorite. These dates, combined with a structural study as part of this project, have expanded the tectonic database in the northern Slave Province. The earliest structures and plutonic rocks can be correlated with similar structures in the Contwoyto Lake area of the northeastern Slave Province. Several sets of later tectonic fabrics, folds and faults have been identified which may be unique to the Proterozoic and Archean rocks of the western Bathurst Inlet region.

The most significant Proterozoic structures in the region are the Bathurst Fault and its splay faults. The north-northwest trending Bathurst Fault borders the two belts to the east. Strata of the Proterozoic Western River and Parry Bay formations underlie the area east of the fault. Splays of the fault isolate a block of Parry Bay Formation strata in the northern end of the Torp Lake Belt.

Mapping and sampling along these Proterozoic faults have identified small concentrations of base metals within the carbonate-flooded fault breccias and significant concentrations of gold in sulphide-enriched quartz-carbonate veins. The veins contain arsenopyrite, pyrite, chalcopyrite, bornite, galena and commonly sphalerite. The gold invades fractures in arsenopyrite. The discovery of gold with these faults has introduced a new exploration target for the northern Slave Province. Smaller, yet still significant concentrations of gold were also found in arsenopyrite-enriched quartz and quartz-carbonate veins of Archean age. The establishment of the gold exploration potential of certain areas led to the 'first-time' staking of nineteen claims in the Torp Lake Belt in 1990.

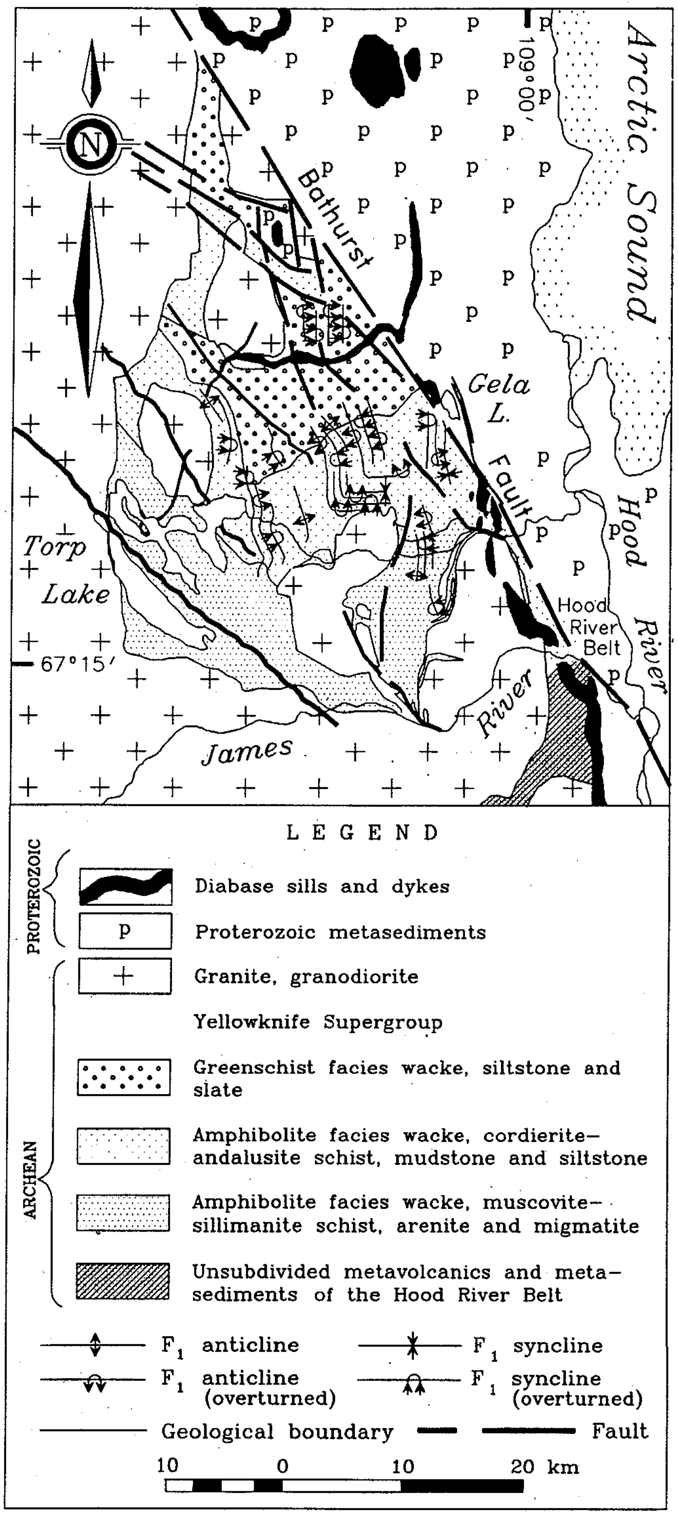

Figure 1. Geology of the Torp Lake Belt.

Table 1: Significant Assay Data

Sample No.	Au g/t	Ag ppm	As ppm	Cu ppm	Fe %	Pb ppm	Zn ppm
1	143.76	36.0	22500	151	2.4	10400	3200
1*	142.00	62	23000	n/a	3.0	n/a	3740
2	6.58	20.0	6190	93	1.96	10000	127
2*	9.46	16.0	6400	n/a	2.37	n/a	74
3	5.00	8.6	497	341	2.17	46	45
3*	10.30	<5	550	n/a	2.37	n/a	74
4	4.5	22.0	3650	11200	10.1	54	370
4*	7.03	42.0	3500	n/a	11.1	n/a	410
5	3.09	0.5	26600	41	2.63	56	3100
5*	1.09	<5	29000	n/a	3.37	n/a	3600
6	2.12	0.4	6390	43	2.26	46	130
6*	0.61	<5	6000	n/a	2079	n/a	154
7	0.63	0.7	965	68	8.75	26	112
8	0.71	0.6	38700	31	5.4	9	45

* indicates a repeated assay

THE NORTHERN BEAULIEU RIVER PROJECT

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Objectives
The purpose of this project was to map and describe the geology of the northern Beaulieu River volcanic belt and surrounding area (NTS 85P East); to evaluate the mineral potential of the area; and to compile and present the results to the mineral industry in order to stimulate further private-sector exploration.

Method
Field work spanned twenty-seven weeks over three seasons. Examination of outcrops entailed noting lithology, metamorphism, structural relationships, indicators of potential economic significance, and other points of interest. A total of 984 rock samples were collected for subsequent reference and analysis. From these, 281 thin sections and 47 polished sections were prepared; 123 whole rock analyses and 364 fire assays were performed. Compilation of field and laboratory data resulted in three 1:50,000 open-file geological maps. Reports, abstracts and a paper, in addition to oral and poster presentations, conveyed the results to the geological community.

Results:

Introduction
The Beaulieu River volcanic belt (BRVB) comprises an irregularly shaped northerly trending zone of Archean supracrustal rocks in the Slave Structural Province, NWT. The study area, between 63 N and 64 N latitude, is centred approximately 150 km northeast of Yellowknife (Fig. 1). Previous mapping of the area is limited to the 1:253,440 map of Miller et al. (1951) and recent studies in the Beniah Lake area (Padgham, 1987; Roach, 1989, 1990). Although numerous mineral showings are known within the study area, few have reached a preliminary diamond-drilling phase of development. The recent discovery of high-grade polymetallic deposits near Sunset Lake, south of the study area within the BRVB, has revitalized exploration along the belt.

General Geology
Supracrustal rocks of the BRVB are bounded by variably metamorphosed granitoids and gneissic complexes. Basement gneisses of the Sleepy Dragon Complex (Henderson, 1985) crop out in the southwesternmost area of mapping. Relative ages of other gneissic and foliated granitoid complexes to the supracrustal rocks can be inferred, in places, by stratigraphic or intrusive relationships. Extensive faulting and paucity of outcrop obscures the nature of many contacts.

An extensive heterogeneous suite of paragneiss, injection gneiss and various intrusive phases underlies much of the northwestern area of mapping. The high calcium and iron content of some of the paragneiss distinguishes it from typical turbiditic sediments of the Yellowknife Supergroup (Henderson, 1985). Despite amphibolite grade metamorphism, cordierite and alumino-silicates are rare or absent. Several small lenses (up to 1.5 km^2) containing banded magnetite iron formation and Fe-amphibole and garnet-rich beds have been identified southwest of Prang Lake.

Supracrustal rocks of the Yellowknife Supergroup are broadly divided into quartzose metasedimentary formations stratigraphically below and above metavolcanic rocks. Metagabbroic intrusions are ubiquitous throughout lower portions of the supracrustal package. The lowermost sequence, the Beniah Formation (Roscoe at al., 1989), comprises phyllite, arenite and subordinate orthoquartzite and quartz-pebble conglomerate and is interpreted to record shallow siliciclastic shelf deposition (Rice et al., 1990). Banded magnetite iron formation and ultramafic intrusions are present locally (Covello et al., 1988). The uppermost sequence, the Beaulieu Rapids Formation (Roscoe et al., 1989), comprises arenite, phyllite and polymictic conglomerate preserved in a fault-bounded syncline south of Spencer Lake. Pyritic paleoplacer mineralization is evident in the latter subaerial alluvial fan deposits.

Metavolcanic rocks are predominantly tholeiitic pillow lavas, pillow breccias and hyaloclastites. Various volcaniclastic and interflow sediments and rare anorthositic intrusions are preserved locally. Volumetrically minor intermediate and felsic volcanics are more common at higher stratigraphic levels.

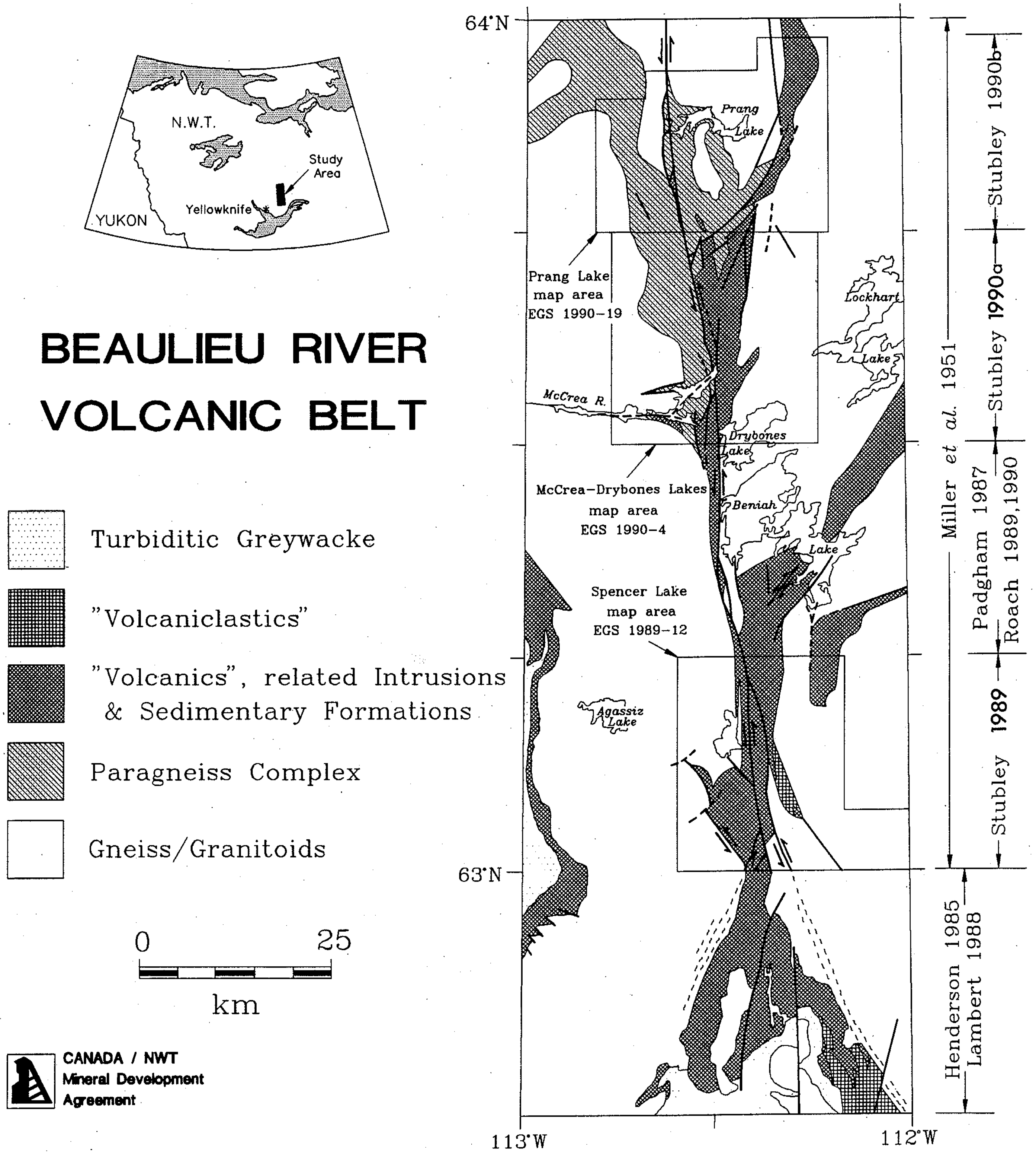

Figure 1. Geology of the Beaulieu River Volcanic Belt.

Massive medium-grained to porphyritic granite crops out along much of the western boundary of mapping. Variably oriented Proterozoic mafic dykes, commonly weakly magnetic, transect all lithologies.

Structure

Polyphase deformation has affected the Beaulieu River volcanic belt; a minimium of three, and probably four folding events are recorded. However, only a single regional foliation is apparent in most outcrops. In rare outcrops, the regional foliation transects small isoclinal folds of a pre-existing layering which suggests at least one pre-peak-metamorphism folding event. Locally developed crenulations overprint the regional foliation.

The complexity of folding is most evident in the Beaulieu Rapids Formation (BRF) which unconformably overlies pillowed basalt (Roscoe et al., 1989). The arenite-conglomerate sequence is preserved in a regional-scale syncline. The most prominent foliation is associated with subsequent tight meso-folding of the regional syncline. A third event is recorded in the BRF by locally developed crenulations and minor folds. The intense regional foliation in the subjacent volcanics predates meso-folding, and possibly deposition, of the BRF.

A complex system of late strike-slip faults postdates all, except possibly the youngest, folding events described above. The faults delineate "domains", particularly in the Spencer Lake area, with distinct differences in a combination of the following: a) lithology and stratigraphy, b) fold style and orientation, c) strain history, d) younging directions, and e) metamorphic grade. Confirmed displacements are everywhere subhorizontal: dextral on northeast-trending fault zones and sinistral on northwest- and north-trending zones. North-trending faults are the youngest; one is expressed as a zone (up to 2 km wide) of anastomosing brittle to ductile faults and shear zones, and can be traced continuously for approximately 180 km. Reactivation of some faults is probable; the latest movement on the major north-south zone was 15 km. Abundant quartz and, in places, reddish medium- to very coarse-grained hematitic granite is intruded along the fault zones. These faults postdate all lithologies except possibly some Proterozoic mafic dykes.

Economic Potential

Pyrite and pyrrhotite are the most common sulphides in the northern BRVB; arsenopyrite is present locally. Significantly anomalous concentrations of Ag, Ni, Cr, Co, PGE or REE were not detected. Indicators of polymetallic deposits similar to those near Sunset Lake (high lead, zinc and silver concentrations relative to copper) were not recognized. This may be due, in part, to the relative scarcity of felsic volcanic rocks in northern parts of the belt.

Eighteen sites of anomalous gold concentrations (≥ 100 ppb average) were identified. Two zones of previous industry exploration in the Spencer Lake map area yielded average gold concentrations exceeding 1000 ppb. Four generalized settings for anomalous concentrations are recognized:

(1) in or adjacent to siliceous shear zones in mafic volcanics,

(2) pyritic paleoplacer deposits in the Beaulieu Rapids Formation (Roscoe et al., 1989; Rice et al., 1990),

(3) with stratabound sulphides in Fe-amphibole, garnet and banded iron formation zones of the paragneiss complex, and

(4) sporadic sulphide-bearing quartz veins in mafic volcanics and in gneissic and mafic intrusive complexes.

Each of these, except possibly the last, offers potential for significant discoveries with further exploration and sampling.

Base metals (0.25 to 2.5%), primarily copper with lesser zinc and lead, are in settings (1) and (4) above. In addition, significant copper occurrences were discovered in quartz-breccia zones associated with late-faults: along the western contact of the paragneiss complex in the McCrea Lake area, and in sheared Beniah Formation. Further prospecting in the northern Beaulieu River volcanic belt may reveal larger and richer deposits.

Acknowledgements

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1990b: Preliminary geology of the Prang Lake area (parts of NTS 85 P/15 & 16); Department of Indian Affairs and Northern Development, DIAND EGS 1990-19.

GEOLOGY OF THE HOPE BAY AND ELU INLET METAVOLCANIC BELTS, NORTHEASTERN SLAVE PROVINCE, NWT

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Objectives

The purpose of this project was to complete 1:50,000 scale mapping in the Hope Bay (NTS 76 O/8-10, 15-16, and 77 A/3,6) and Elu Inlet (NTS 77 A/2,7,10) metavolcanic belts and to assess the mineral potential of these areas. Descriptions of mineral showings and metallogenic models will aid in future mineral exploration. Mapping in this little-studied area will also contribute to the overall understanding of the Slave Province.

Methods

A total of 18 weeks was spent in the map area during the summer field seasons of 1988, 1989 and 1990. During the summer of 1989 and 1990 geological trainees were hired from Cambridge Bay through the GNWT Department of Education. A computerized mapping system was employed to reduce the amount of time required to produce geological maps.

Known mineral showings were visited and described, and all large gossans encountered in the field were sampled for gold or base metals. In order to understand the genesis of gold mineralization S.G. Leclair was contracted to perform a metallogenic investigation of the Ida Point gold showing in the northern Hope Bay Belt (this volume). Geophysical surveys were also performed at the Ida Point gold showing to characterize the response of the gold showings of the region.

In order to constrain the timing of volcanism and plutonism in the map area samples were collected for U-Pb geochronology. The analyses were performed and interpreted by M.L. Bevier of the Geological Survey of Canada (Bevier and Gebert, 1991).

Results

Hope Bay Belt

The southern and central portions of the Hope Bay belt were mapped whereas the geology of the northern portion was compiled from previous mapping (Gibbins, 1987). The Hope Bay belt is dominated by mafic volcanic and intrusive rocks (Fig. 1). Other lithologies include felsic volcanic, volcaniclastic and intrusive rocks, metasedimentary rocks, and minor iron formation and ultramafic sills. The belt is bordered to the east and west by granite to granodiorite, and to the southeast by a heterogeneous gneiss terrane derived partly from supracrustal rocks. The metamorphic grade of the belt increases from greenschist- to amphibolite-facies towards the contact with the granitoid rocks. A conglomerate composed of clasts of granite and supracrustal rocks from the Hope Bay belt is exposed in Hope Bay at the northern end of the belt. This conglomerate unconformably overlies vertically dipping mafic rocks and is the youngest recognized supracrustal unit in the belt. Aphebian sedimentary rocks overlie the belt at its northern end. Mackenzie and Franklin diabases cut the rocks of the Hope Bay area.

The Hope Bay belt is structurally complex and bears the overprint of several subparallel, north-trending fabrics. These fabrics locally include two foliations and structures related to shearing and late faulting. The least deformed rocks of the northern Hope Bay belt indicate that the belt was isoclinally folded into a series of north-trending anticlines and synclines, and was cut later by north-trending shear zones and faults.

Base metal mineralization is along mafic/felsic contacts in the central and southwestern portions of the Hope Bay Belt. Two zones of gold potential were identified: a zone running along the medial axis of the belt and the contact aureole of the belt. Work on the Ida Point gold showing indicates that two periods of gold mineralization occurred but that most gold was deposited at the end of the first period of deformation. The observations at Ida Point correspond well to other areas of the Hope Bay Belt.

Elu Inlet belt

The Elu Inlet belt was mapped in less detail and efforts were made to outline the belt and major contacts within the belt (Fig. 1). The southern portion of the belt was mapped entirely by helicopter

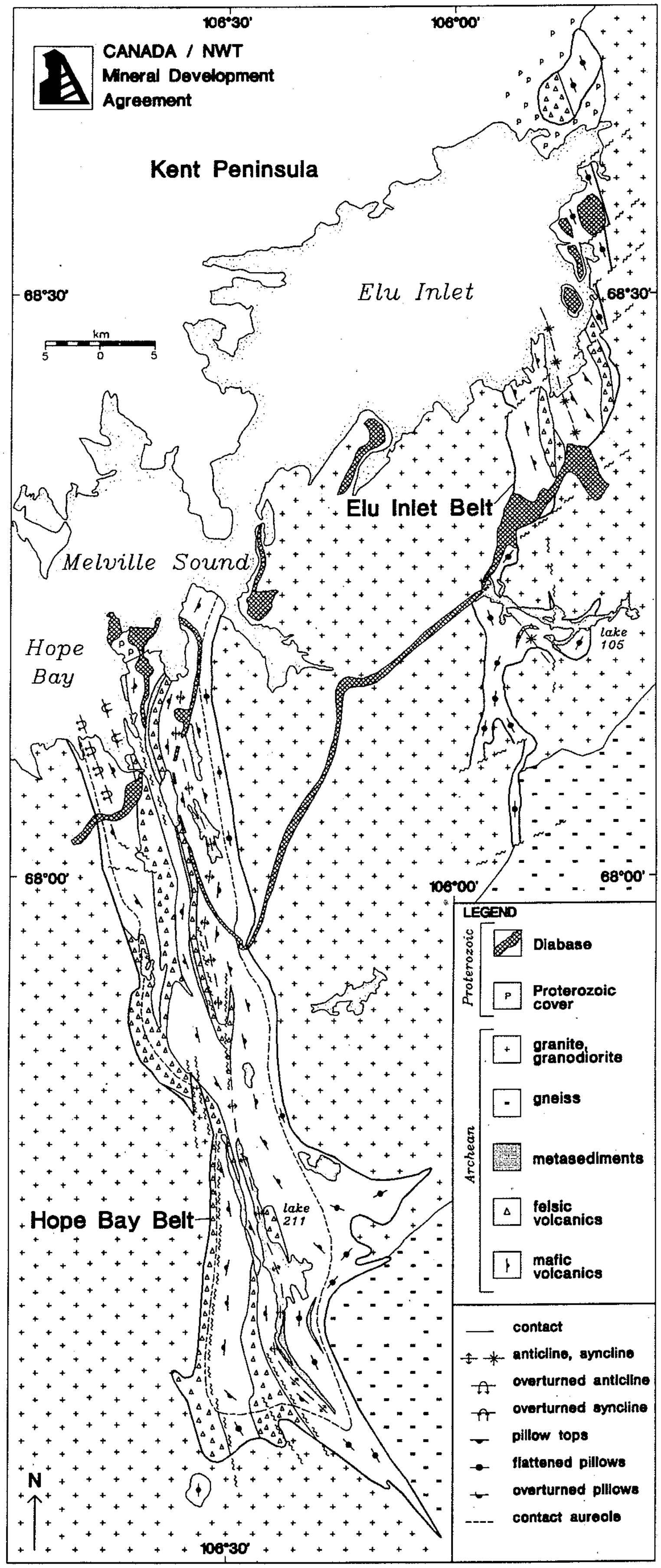

Figure 1. Geology of the Hope Bay and Elu Inlet metavolcanic belts.

reconnaissance. The Elu Inlet belt is composed of lithologies similar to the Hope Bay belt, consisting of mafic volcanic and intrusive rocks with subordinate felsic volcanic rocks, metasedimentary rocks and ultramafic sills. The belt is overlain by Helikian sedimentary rocks, and disappears under sedimentary cover on the Kent Peninsula to the north. The southern half of the belt is metamorphosed to amphibolite-facies and many primary structures of the rocks are destroyed.

Structural patterns of the northern Elu Inlet belt are similar to the Hope Bay belt with north-trending isoclinal folds overprinted by later shearing and faulting. Late northeast-trending dextral faults have offset the contacts of the Elu Inlet belt.

Gold mineralization was not noted in the Elu Inlet belt although many of the same structures that host gold mineralization in the Hope Bay belt were identified. Iron sulphides form linear gossans along mafic/felsic contacts in the Elu Inlet belt. These contact showings may be pathfinders to blind massive sulphide lenses. Care must be taken to distinguish syngenetic sulphide mineralization from late epigenetic iron sulphide mineralization introduced along late faults. A carvingstone showing consisting of a metamorphosed ultramafic sill was identified in the southern portion of the Elu Inlet belt.

Geochronology indicates that volcanism in the Hope Bay belt occurred between 2685 and 2677 Ma and that felsic plutonism occurred between 2672 and 2608 Ma. It is possible that the Hope Bay and Elu Inlet belts were once part of a larger volcanic belt that was disrupted by the intrusion of the regional granites.

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GEOLOGY OF THE PISTOL BAY-MISTAKE BAY AREA, KAMINAK GREENSTONE BELT

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Objectives
The object of the project was to update the lithological relationships, stratigraphy and structure of the 1:250,000 survey of Heywood (1973); to document and provide gold assays of mineral showings and gossans; and to provide a geological framework which would assist mineral exploration of the District of Keewatin.

Methods
The Kaminak belt is one of the largest volcanic-sedimentary terranes in Canada but has seen only limited exploration for copper, nickel and gold. It is in the Hearne Province, a subdivision of the Churchill Structural Province (Hoffman, 1988). A segment of this belt was mapped at a scale of 1:30,000 in 1988 (55 K/7 and 10, 2NE, 11E and parts of 6 and 9), and completed in 1989 (55 K/7 SW, 2, 8 and 9S). Detailed mapping of the southwest extension of the belt (Park and Ralser, 1990) and of the separate Rankin Inlet belt to the northeast (Tella et al., 1986) have been published.

Results

Geology
The generalized geology of a 60 km long section across the NE end of the Kaminak belt, from Whale Cove to the north of Pistol Bay is displayed in figure 1. This area is underlain by the Archean Kaminak Group which here comprises two mafic-metavolcanic and two metasedimentary units. These units are described in order from south to north:

1) A westerly younging metavolcanic unit at Whale Cove is composed predominantly of plagioclase porphyritic to variolitic pillow basalts, intravolcanic mafic sills, pillow breccia, minor felsic volcanics and stocks of intrusive gabbro and porphyritic diorite. Intravolcanic beds of chert, black slate, and chert-amphibole-magnetite, less than 5m thick, may contain minor pyrite. Farther west, in Mistake Bay, the upper part of this sequence is composed of pillow basalts with minor phyllite domes followed by thin bedded mafic to intermediate agglomerate to lapilli tuff.

   Morso Island, to the south, is a subvolcanic complex of massive basalts cut by thin intravolcanic aphyric to porphyritic mafic sills and grey biotite granite to quartz diorite veins.

   Pork Peninsula, to the northeast, is included in this unit. It comprises a northerly younging sequence of pillow basalt, mafic intravolcanic sills and minor porphyritic diorite sheets. Intravolcanic beds of quartz-chlorite and black shale are less than 5m thick and may contain pyrrhotite and chalcopyrite. Beds of chert-magnetite, chert-dolomite-quartz and pyrite-dolomite may occur in composite zones, one of which is over 20m thick. Below this sequence on the southeastern part of the peninsula is a south-dipping complex of massive to pillowed basalt and gabbro-diorite sills.

2) A southwesterly dipping homoclinal sequence of turbiditic metasediments northeast of Wilson Bay comprises two main lithologies: a repetitive sequence of graded feldspathic arenite, wacke, siltstone and slate with rip-up clasts, intraformational conglomerate and chert-magnetite bands, as well as a thickly-bedded massive feldspathic arenite member.
   Chert-magnetite bands, mafic volcanic flows and felsic agglomerates intruded by rhyodacite domes, occur in the middle part of the sequence which is intruded by gabbro plugs. To the west, across Wilson Bay, the upper part of the unit shows a similar turbidite sequence with minor basalts.

3) A belt of west to southwesterly younging, mafic metavolcanic flows occurs north of Pistol Bay. This is predominantly pillowed with subsidiary massive flows, minor variolitic massive flows and pyroxene cumulate flows or

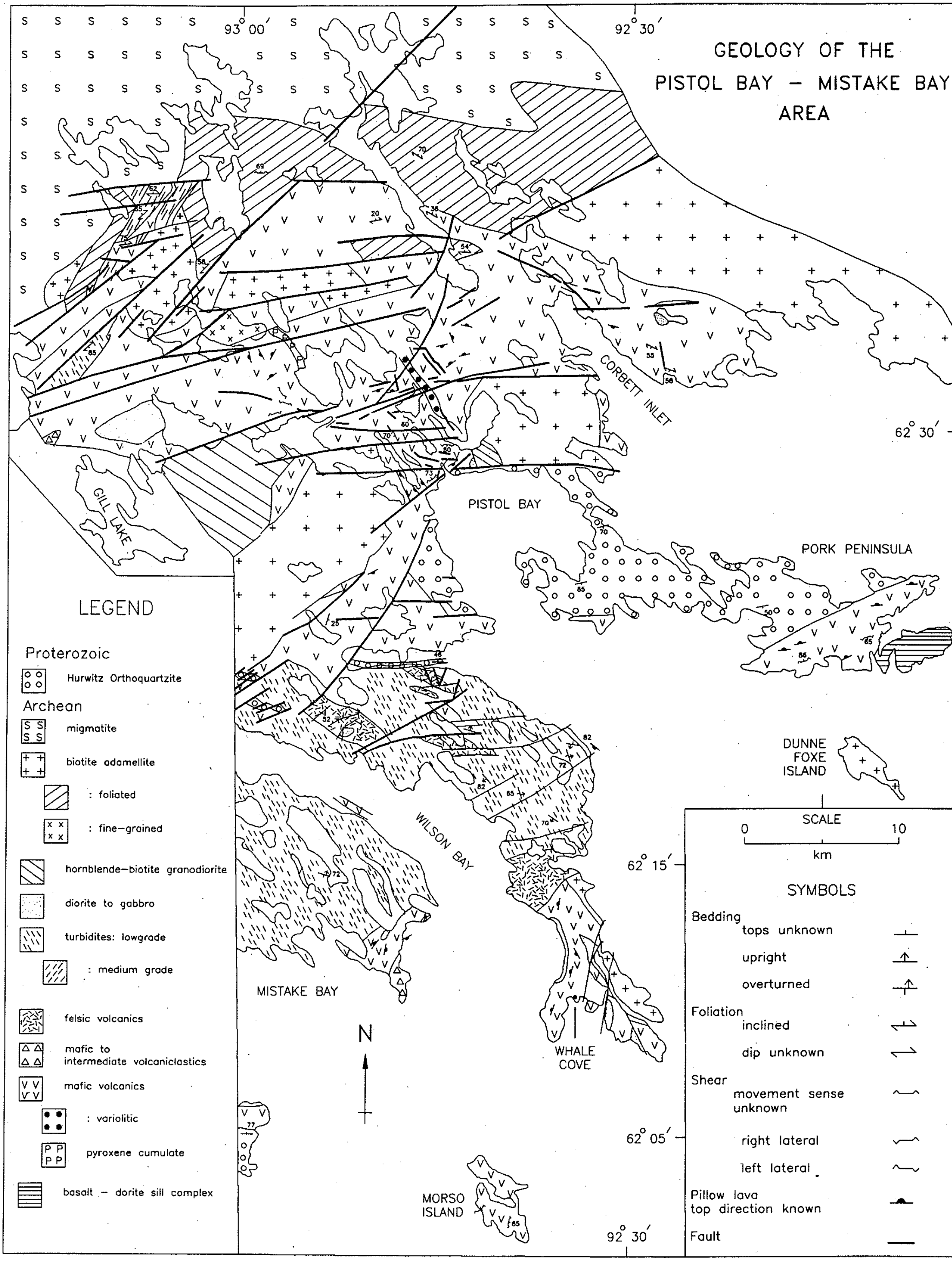

Figure 1. Geology of the Pistol Bay-Mistake Bay area, Kaminak Greenstone Belt.

sills. Subvolcanic lenticular domes of rhyodacite are common. Intravolcanic beds of quartz-magnetite and of chert may occur with sulphides, displaying pyrite and pyrite-pyrrhotite respectively. Gabbro to diorite plugs, up to 4 km in length, intrude this sequence.

4) A northeasterly trending belt of schists shows fine scale interlaying of quartzo-feldspathic and garnet-biotite schists ± staurolite, kyanite and sillimanite, suggesting high pressure, medium grade metamorphism of a turbidite sequence. This sequence contains numerous thin magnetite bands and therefore differs from that at Wilson Bay. Minor interlayered garnet-hornblende schists represent basalt flows.

Late tectonic, porphyritic biotite to biotite-hornblende adamellite and biotite-hornblende granodiorite plutons intrude the mafic units. These show stoped and veined contacts at Whale Cove but gradational contacts, in places, farther north at Pistol Bay. Regional metamorphism reached greenschist facies just west of Pistol Bay. Higher-temperature albite-epidote-amphibolite facies was reached in east Pistol Bay and farther south, at Whale Cove. North of Pistol Bay, amphibolite facies occur and the granitoid plutons become increasingly sheared and foliated, eventually forming a migmatite zone with banded biotite and hornblende gneiss with later veins of pink granite.

Ripple-marked, white to pink orthoquartzite of the Proterozoic Hurwitz Group unconformably overlies the Kaminak Group in the centre of the mapped region.

In the Whale Cove and Mistake Bay areas, north-striking shear zones are associated with dolomitization whereas an 050 striking fracture set is host to quartz-chalcopyrite veins. On Pork Peninsula, an 080 striking, vertically dipping ductile shear set strikes parallel to bedding, is associated with chlorite-quartz-dolomite and is cut by a later 150 striking, easterly dipping dextral ductile shear set. In the Pistol Bay area, at least two phases of brittle to ductile shear occur: S_1 - a 155 striking, westerly dipping, bedding parallel set shows both sinistral and dextral offsets and is accompanied by the injection of narrow biotite granite veins; S_{2a} - a less pervasive 060 striking, sinistral set cuts the granitoid intrusions and is accompanied by aplite injection; and S_{2b} - a major 085 striking, north dipping, post granitoid, sinistral set possibly conjugate with S_{2a}. All sets, notably S_{2b}, are associated with quartz-dolomite veining and dolomite replacement of host metabasalt. Pyrite and chalcopyrite can occur in these veins.

Economic Potential

Mineral showings associated with the four main lithological units are outlined below. Over 170 grab samples from mineral showings and gossans were assayed for gold and significant gold concentrations are shown in Table 1.

1) In the Whale Cove area, actinolite-magnetite-chert beds interlayered with the metabasalts are potential hosts for syngenetic gold, as are the rarer pyritized iron carbonate-quartz exhalite beds. Quartz veins, less than one metre wide, commonly associated with shear zones or the margins of granitoid intrusions, contain molybdenite or gold in association with chalcopyrite or pyrite. A grab sample from one such vein yielded 108 ppm gold. Pyrite-chalcopyrite and pyrrhotite-chalcopyrite assemblages are associated with numerous gossans. At Pork Peninsula, a prominent pyritized iron carbonate bed associated with magnetite-chert produced grab sample assays of 3.4 and 5.0 ppm gold.

2) Within the metasedimentary rocks of Wilson Bay, gold exploration should focus on closely-grouped magnetite-chert beds as well as pyrite, arsenopyrite and iron carbonate bearing shear zones in small gabbro stocks. A grab sample of the latter yielded 3.74 ppm gold. Pyrite-chalcopyrite-magnetite beds, associated with the minor mafic flows of Wilson Bay, yielded values of 1.24 and 1.4 ppm gold whereas a crosscutting 020 trending chloritized shear zone produced a grab sample assay of 0.93 ppm gold.

3) North of Pistol Bay, numerous gossans in mafic and felsic metavolcanic rocks mark pyrite-chalcopyrite and pyrrhotite-chalcopyrite mineralization. Quartz-calcite, quartz-dolomite and quartz-iron carbonate pods and veins display a variety of trends but are closely associated with S_2. These may contain pyrite and chalcopyrite, and have yielded assay values of over 1 ppm. Several phases of quartz veining occur but pyrite and chalcopyrite mineralization tends to be associated with quartz veins showing an 060 trend. Pods of magnetite-pyrite were observed in metasedimentary screens within the metabasalts but yielded no significant gold concentrations.

Table 1: Significant gold assays (>0.5 ppm) for mineral showings in the Pistol Bay - Mistake Bay area.

Grab Sample No.	Au ppm (g/t)*	Sample Description	Host Lithology	NTS Sheet	Grid Reference m E	Grid Reference m N
SG88-2454	108.0	py-cp-qtz in 7cm 005° vein	granitoid/basalt	55 K/2	523900	6897100
SG88-2089	1.16	py in 120° fracture	gabbro-diorite	55 K/6	493250	6929100
SG88-490	0.632	py-qtz in 20m 020° shear	dolomitized basalt	55 K/7	513450	6926700
SG88-494B	0.639	py-qtz-Fe carbonate;Z-fold	turbidite	55 K/7	519050	6903000
SG88-2393A	0.934	py in 3m 020° shear	basalt	55 K/7	523150	6908900
SG88-2393B	1.24	mgt-py-cp 10cm bed	basalt	55 K/7	523150	6908900
SG88-2394B	1.4	py-mgt-cp bed	basalt	55 K/7	523100	6909050
SG88-2418	1.3	py-po dissemination	turbidite/diabase	55 K/7	521900	6909850
SG88-2433	3.74	py-cp-qtz in shear	gabbro	55 K/7	507200	6910000
SG88-2449B	0.567	py-qtz in 15cm pod	felsic agglomerate	55 K/7	505850	6911850
SG88-4369C	3.4	Fe carbonate-py bed	basalt	55 K/8	538000	6914200
SG88-4369D	5.0	Fe carbonate-py bed	basalt	55 K/8	538000	6914200
SG88-5101	0.864	Fe carbonate-py bed	basalt	55 K/8	541400	6917350
SG88-5110	0.6	py-po in slate	basalt	55 K/8	537350	6914650
SG88-2314	1.68	py-qtz 1m 040° vein	basalt	55 K/11	496950	6945400

*NAA analysis

Acknowlegements
Mapping was carried out in 1988 and 1989 by the author with senior assistance from Doug Irwin and Jean Coupey, and junior assistance from Aline Mongrain, Grace Fortowsky and Andrew Alikashuak. Fern Heitcamp acted as cook in 1988. Much logistical and material assistance was provided by the Geology Section of DIAND, Yellowknife.

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GEOLOGY OF THE WOODBURN LAKE GROUP, TEHEK LAKE AREA

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Objectives

The object of this project was to refine the lithological relationships, stratigraphy and structure of the Woodburn Lake Group covered by the 1:250,000 survey of Fraser (1988) by mapping at 1:30,000, and to document and provide gold assays of mineral showings and gossans. The economic potential of this belt has been emphasized recently by a gold discovery in a sulphidized oxide - iron formation at Meadowbank River, just west of the area of study (Mudry, 1990).

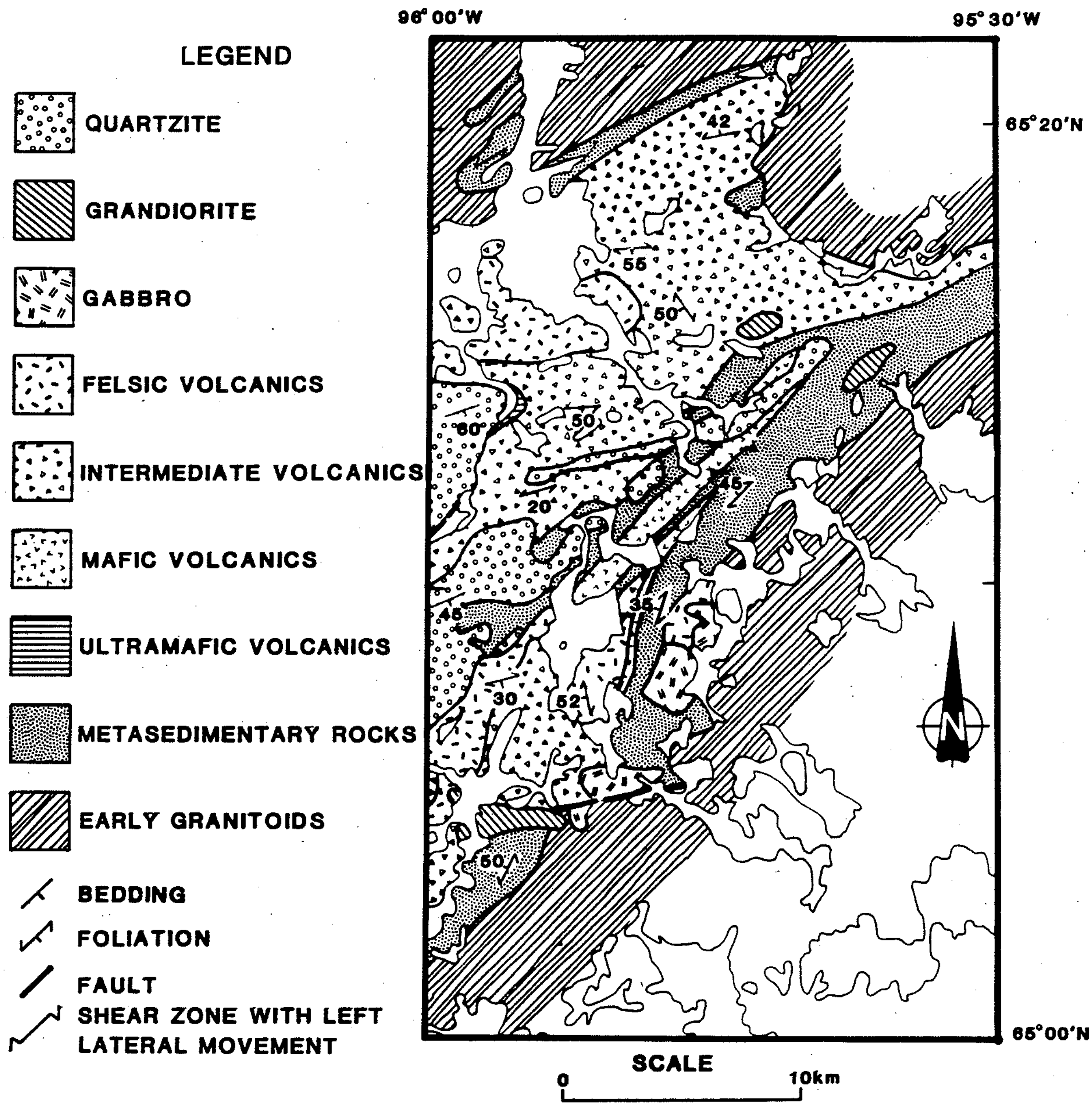

Figure 1. Geology of the Woodburn Lake Group, Tehek Lake area, NTS 56 E/4 and part of E/5.

Methods

In 1989, mapping of the supracrustal sequences within NTS areas 56 E/4 and 5 was completed and much of 56 E/3 was mapped in addition. A map summarizing the work in 56 E/4 and 5 is shown in Figure 1. To the west of 56 E/4, the adjacent map area (66 H/1) has been mapped at a scale of 1:50,000 (Ashton,1987), and the continuation of the Woodburn Lake Group southwest of the Meadowbank River gold discovery (66 A/16), has been mapped by Henderson et al., (1991).

Results

Introduction

The Woodburn Lake Group (Ashton, 1981) is an informal name used to describe an Archean volcanic-sedimentary package which occurs northwest of Tehek Lake approximately 100 km north of Baker Lake. This sequence is located in the Armit Lake Block (Heywood and Schau, 1978) of the Rae Structural Province (Hoffman, 1988).

Geology

In 56 E/4 and 5 the Woodburn Lake Group lies in a northeasterly-trending trough, separated in part on its southeast and northwest margins from granitic basement by high strain zones. A metasedimentary unit dominates the southeast margin of this trough and comprises a fine- to medium-grained greenish to pale pink biotite psammite, representing metamorphosed feldspathic wacke, plus minor siltstone and slate. To the north, a suite of metavolcanic rocks comprises: rhyodacitic volcanic centres, composed of white to pale green aphanitic flows, crudely-bedded agglomerate and bedded tuffs; intermediate volcanics, which are more chlorite rich; and metabasalts which are commomly foliated and contain epidote and hornblende. Minor metasedimentary members occur within the volcanic units. Farther northwest, a narrow belt of sheared komatiitic volcanics is represented by chlorite-talc-carbonate rocks with remnant pillow structures. Isolated komatiitic flows with spinifex textures occur in several places.

The northern flank of the belt comprises a sedimentary unit with minor basalts now metamorphosed to medium grade: feldspathic, biotite psammitic schists interlayered with rarer garnet-biotite-sillimanite schists and minor banded hornblende schists. Magnetite-chert iron formation, up to 10m thick, occurs throughout the belt. Stocks of gabbro and quartz monzonite to granite intrude the southern margin of the belt. A structurally overlying orthoquartzite unit in the centre of the trough was emplaced, as thrust sheets, from the southeast.

A dominant easterly striking foliation with a shallow southerly dip occurs throughout the belt in 56 E/4 and 5, and coincides with the orientation of axial planes of isoclinal folds in metasedimentary rocks in the north part of the trough. A second phase of folding occurs with southeasterly trending fold axes. A third phase of deformation was observed as a crenulation with easterly trending fold axes on micaceous bedding planes within orthoquartzites.

A separate supracrustal belt in 56 E/3 has undergone medium grade metamorphism and shows an east-west

Table 1: Gold assays (>0.1 ppm) for mineral showings in the Tehek Lake area.

Grab Sample No.	Au ppm (g/t)*	Sample Description	Host Lithology	NTS Sheet	Grid Reference mE mN
SG89-2032A	1.85	gossan	felsic volcanics	56 E/5	370800 7241250
SG89-2075	0.103	py in 200^0 fracture	quartzite	56 E/4	363500 7231800
SG89-2083A	0.15	hm-py in 056^0/57^0 shear	chl.sch/quartzite	56 E/4	360600 7231100
SG89-3087	5.38	mgt-py-cp chert bed	felsic volcanics	56 E/4	361000 7223000
SG89-3095	0.111	py-cp-quartz vein	chlorite schist	56 E/4	362500 7224750
SG89-3142A	0.293	py in 095^0/35^0 vein	quartzite	56 E/4	366000 7234700

*NAA analysis

foliation. It is composed of banded, hornblende-bearing metabasalts and feldspathized, biotite-poor psammites with interlayered magnetite-chert iron formation.

Over 110 grab samples from mineral showings and gossans were assayed for gold and the highest gold concentrations are shown in Table 1. Samples containing over 1ppm gold were obtained from a gossan in felsic volcanics and a pyrite-chalcopyrite-magnetite-chert iron formation.

Acknowledgments
The NWT Geology Division, Department of Indian Affairs and Northern Development, arranged a great deal of material support; able field assistance was provided by Rick Walker, Alan Armitage and Anne Sequin; and the staff of Comaplex Minerals Corp., notably Phil Mudry, are especially thanked for allowing the use of their excellent field camp on the Meadowbank River.

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INDIN LAKE PROJECT

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Objectives
Most of the gold occurrences in the Indin Lake supracrustal belt are in the central part of the belt between 64°07.5'N and 64°32.5'N (Fig. 1). This area has all of the belt's large mineral deposits including Colomac Zone 2. The purpose of the Indin Lake Project was to map the gold occurrences in this area, describe and classify them and explain their origin.

Methods
Data acquisition had two parts:

1) 4.5 months of field mapping around major showings and deposits at scales ranging from 1:200 to 1:10 000, with emphasis on structure and

2) compilation at scales ranging from 1:10 000 to 1:25 000, which served to integrate field data with previous workers' data, consisting mainly of company assessment reports.

Results
All significant occurrences are within 1 km of a volcanic-sedimentary contact and none is more than 1 km above (i.e. on high-metamorphic grade side of) the cordierite isograd. The richest part of belt is the widest part of the belt which has the widest area of greenschist-facies rock. The number and average size of gold showings in the area (compared to parts of the belt to the north or south) appears larger than that expected if the amount of gold were merely in linear proportion to the area of greenschist-facies rock.

All gold occurrences in the study area are associated with quartz ± Mg carbonate ± Fe oxide Fe± As sulphide vein systems and silicic- carbonate- Fe ± As sulphide ± Fe ± Mg alteration. For any one location, the character of host-rock alteration reflects the chemistry of vein minerals. Two phases of quartz, a white or milky phase and a grey or smoky phase, are commonly present in a single vein. Commonly the two types are observed to form a breccia, either of dark clasts in a light quartz matrix or the reverse. The order tends to vary from one location to another without any known pattern.

Vein systems tend to be developed where brittle extension of a competent rock unit has taken place within or next to relatively ductile (incompetent) surrounding rock. Mineralized veins are especially concentrated near intersections between the local structural trend and obliquely striking or cross-cutting fractures. Commonly the obvious cross-cutting feature is a late mafic dyke or Proterozoic fault. These features are interpreted to be the result of Proterozoic reactivation of a network of shear zones and early fractures which started developing during the Archean.

Steep to vertical faults predominate in the study area and have a variety of slip directions. Shallow-dipping faults also exist which may be coeval with the others–as is commonly the case in various other studies (field and model studies) in which vertical transcurrent faults have shallow ramps or branches. Both sets have been important in a negative way, having complicated exploration for possible extensions of, and/or grade control within, major deposits in the area.

At most locations, vein systems are composed of tension veins and coeval shear veins; one or the other kind may predominate at a particular location. Most gold deposition and associated vein emplacement and fracturing dates from a period of oscillating low to high fluid (CO_2 and H_2O) pressure during regional metamorphism.

The gold occurrences of the study area are divided into three categories based on the mechanical properties of their respective host rocks. Type 1 occurrences are in deformed competent units (e.g. massive subvolcanic sills) within the volcanic sequence (e.g. Colomac and Cass deposits). Type 2 occurrences are along contacts of volcanic units next to sediments (e.g. Lex Main deposit, Pop Grid). Type 3 occurrences are in metasediments or metatuffs next to volcanic rocks (e.g. Treasure Is. Main deposit, Diversified-North Inca deposits). Occurrences of all three types are related to a competence contrast

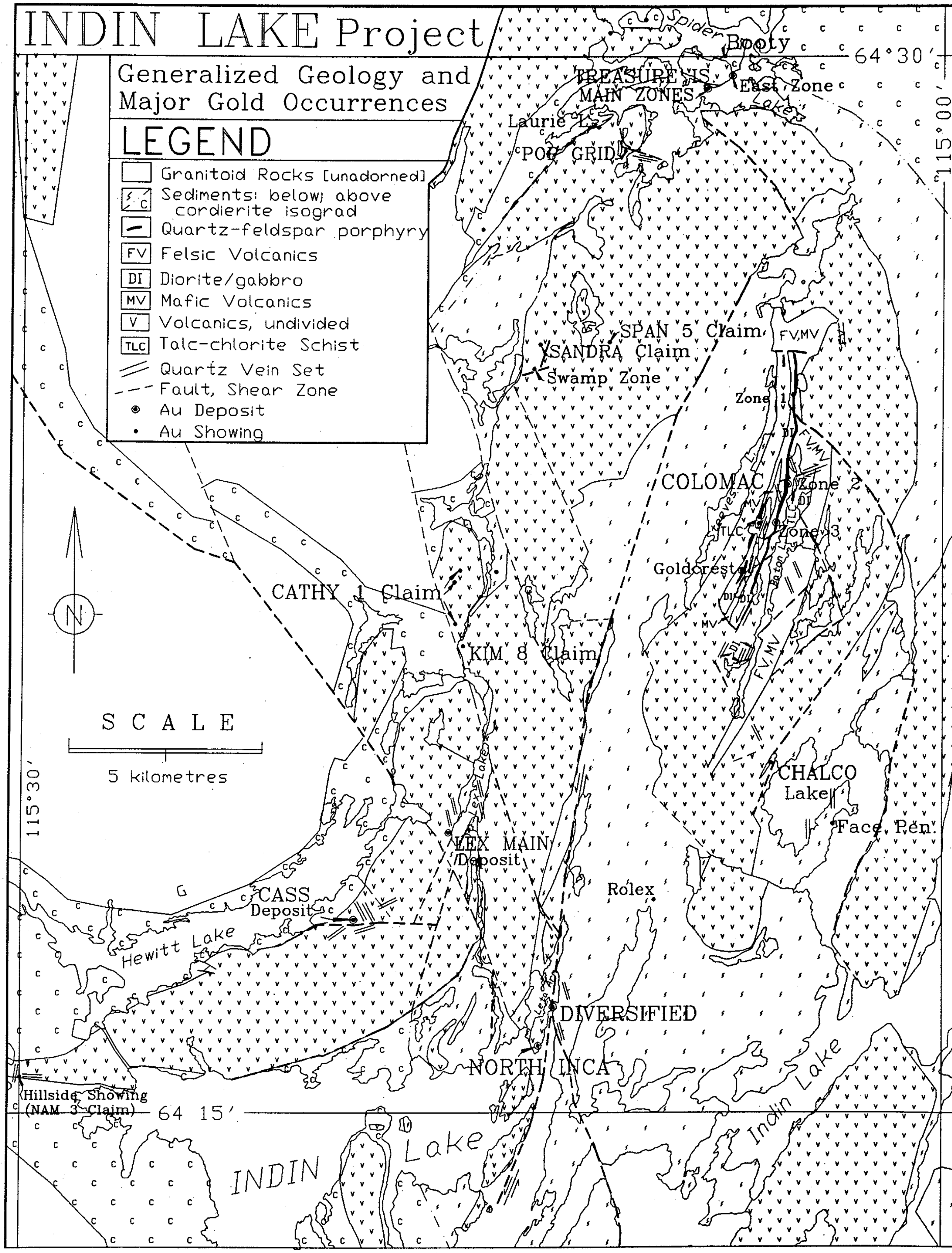

Figure 1. Geology and main gold occurrences within the central part of the Indin Lake supracrustal belt.

between relatively massive rocks (such as porphyry sills or massive flows) and relatively inhomogeneous rocks (such as pillowed volcanic sequences or turbidites).

Relative to a geographic reference frame, orientations of strain due to vein emplacement vary greatly from one part of the study area to another. This is also true of strain features (such as foliation, lineation) coeval with regional metamorphism. Nevertheless vein patterns at most locations have consistent orientations relative to orientations of syn-metamorphic strain features. To take a typical example of this type of relationship, at many locations the main set of tension veins is at right angles to the predominant schistosity.

The presently observed large-scale fold pattern post-dates the formation of most of the gold-bearing vein systems. The rearrangement took place by means of slip on faults and late shear zones after the extensive ductile deformation (i.e. deformation during concomitant regional metamorphism) and so involved translations and rotations in bulk of sizeable pieces or enclaves of rock not internally affected by the rearrangement. This event is proposed to explain the large variation in orientations of vein sets and syn-metamorphic strain features from one place to another.

Gold occurrences similar to those in the study area are not expected to exist far outside the area of greenschist-facies metamorphism. The maximum possible competence contrast between any given pair of rock types decreased with increasing metamorphic grade, and therefore deformation during regional metamorphism had an increasingly ductile character with increasing distance into the area of amphibolite-grade metamorphism.

GOLD MINERALIZATION IN THE YELLOWKNIFE MINING DISTRICT, NWT (NTS 85J/7,8,9,16)

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Objectives
The topic of gold mineralization in the Yellowknife region has been popular since discovery of the precious metal at Burwash Point in 1934. This discovery on the east side of Yellowknife Bay sparked concerted exploration in the Yellowknife region which continues today. Since the original discovery, over 400 tonnes (13,000,000 ounces) of gold have been mined from two major and numerous smaller mines, attesting to the mineral wealth of the region.

A large volume of information concerning the geology, structure and nature of gold mineralization, has been amassed. Some of this data is readily available to the public through assessment files, government maps and publications, and journal articles, but much more is stored in the files of mining companies and private individuals.

This study undertook to document the geology of gold deposits in the Yellowknife region with an emphasis on the examination of smaller and lesser known showings in the district (Fig. 1). The aim of this project was to stimulate and guide further exploration of the region.

Methods
Field work was initiated in 1989 and the bulk of it was completed in 1990. Gold showings, identified from a variety of sources including assessment files, government compilation maps and personal communications, were examined. Several unreported showings were discovered, compensating for the few that could not be found. The geological setting of each showing was mapped and the economically interesting minerals were identified. Additionally the mineral sequences, host rock, small scale structural features, wall rock alteration and metamorphic grade were recorded.

Two sampling biases were used. At each showing, a grab sample of the most mineralized rock was collected and assayed for Au, As, Co, Fe, Mo, Ni, Zn, Mn, Pb, and Cu. Where a variety of distinct vein mineral assemblages or a distinctive alteration of the host rock was apparent, a suite of samples for geochemical analysis and polished sections was gathered. Approximately 220 sites were visited and over 400 samples were collected.

Results
Based on the fieldwork and analysis of the data, several conclusions can be made:

A) Five distinct events affect gold deposition.

1) Syngenetic to early epigenetic deposition of pyrite and pyrrhotite formed stratabound accumulations in sediments. These gossanous pods are best developed at the contact between the felsic Banting Group and the metasedimentary Burwash Formation but are also at similar contacts around the Clan Lake Felsic Complex. The sulphides are concentrated in fine, highly-foliated pelitic layers in stratiform deposits. Pyrite-rich bands form up to 15% of the pelitic beds in the gossanous zones. In addition to the pyrite-rich bands are 5-10 cm wide nodules of massive pyrite. Locally, graphitic sediments wrap around nodules of pyrite.

   The pyrite-pyrrhotite event is also represented by sulphide-filled amygdules and fractures in mafic volcanic rocks of the Kam Group or as stratiform stringers in the interflow sediments. These deposits are best preserved in relatively undeformed rocks. This mineralization event was only weakly associated with gold deposition with an average of .063 g/t Au for 45 samples (Fig. 2).

2) An arsenic-rich event is most commonly represented by smoky to blue/grey quartz-arsenopyrite veins. Arsenopyrite is present in three distinct forms. The strongest gold association is with fine-grained amorphous masses 50-100 cm across commonly on the margins of quartz veins. An average grade of 10 g/t Au was returned for 11 samples of massive arsenopyrite.

   The second arsenopyrite habit is as euhedral crystals, irregular blebs and stringers in grey quartz

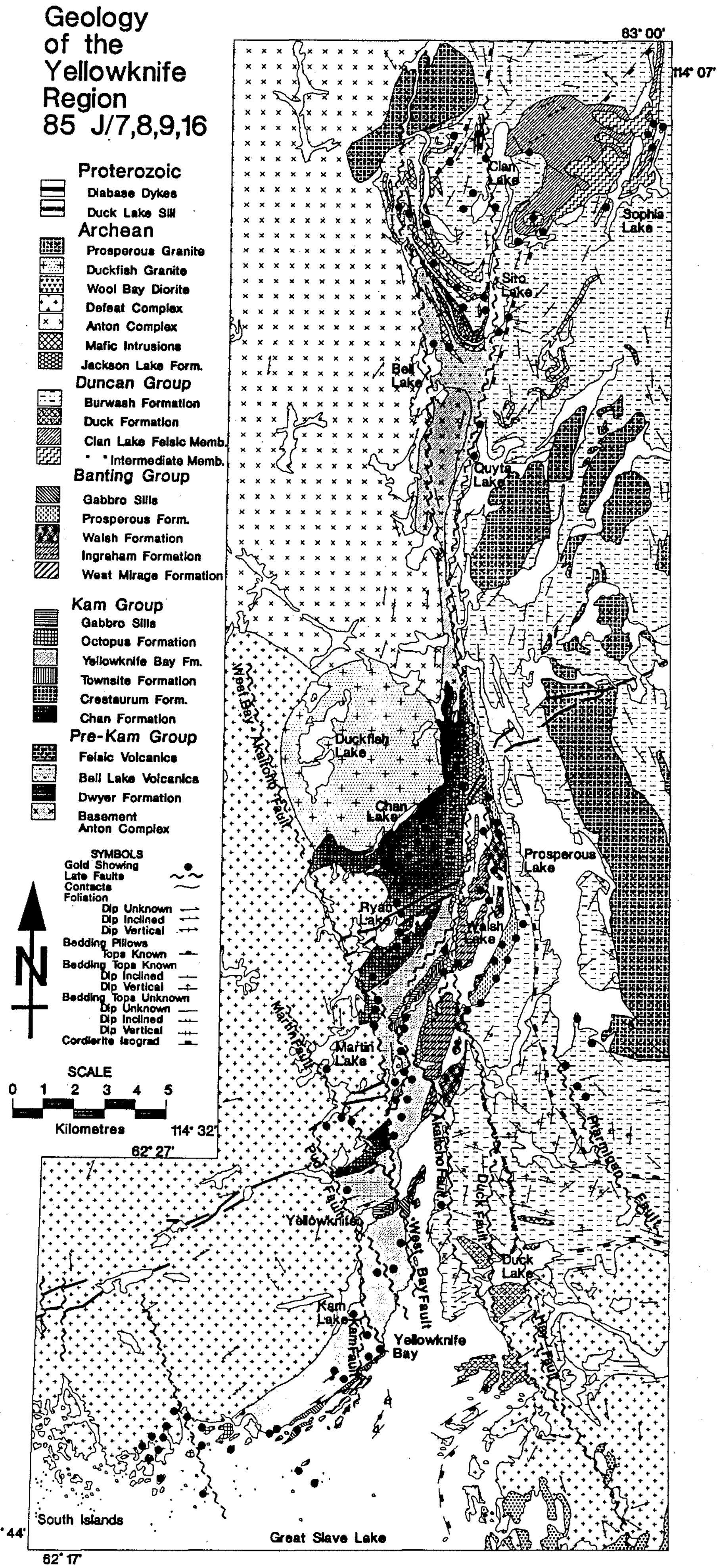

Figure 1. Geology of the Yellowknife region, NTS 85J/7, 8, 9, 16.

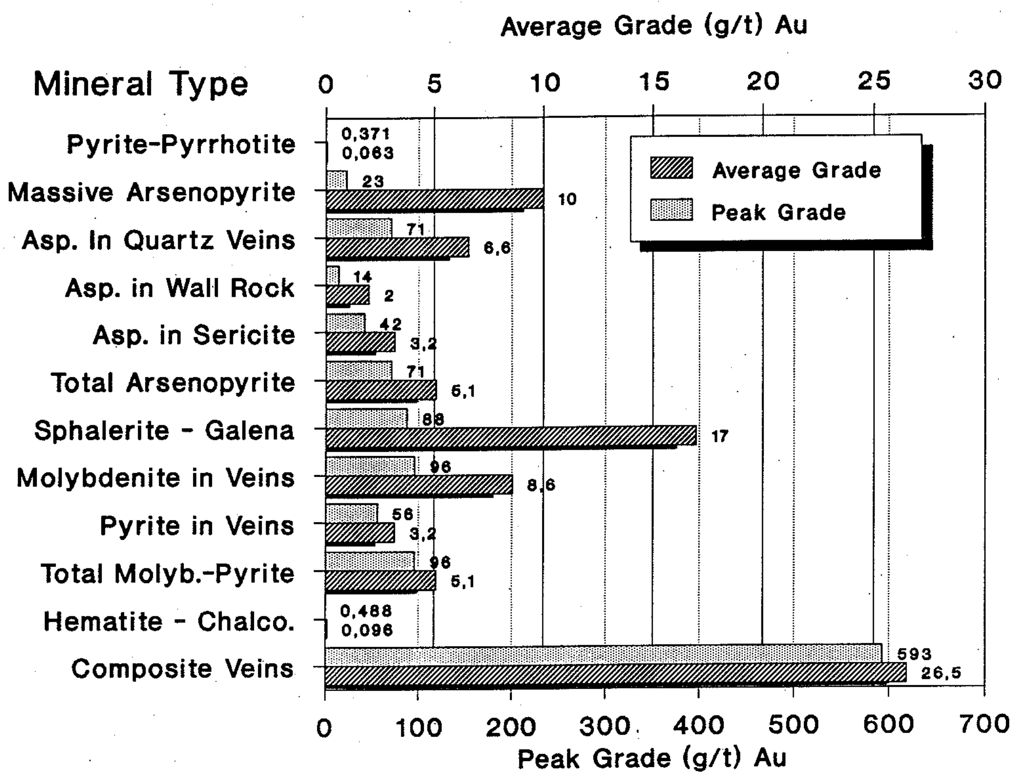

Figure 2. Gold values in mineralized rock.

veins. These have a halo of euhedral arsenopyrite crystals disseminated in the wall rock. Locally, the arsenopyrite porphyroblasts grew across the foliation in the wall rock and were fractured in the foliation direction indicating minor deformation after mineralization. Post-mineralization deformation is also supported by the foliated and recrystallized nature of many arsenopyrite-bearing quartz veins. Where the quartz veins cut sedimentary and felsic rocks, the wall rock is silicified with a purple-tinge related to biotite alteration. The veins and alteration are best developed in highly foliated rocks and most have been extensively deformed. The quartz veins have consistently higher gold concentrations than the wall rock alteration halos. The average grade for 30 quartz veins was 6.6 g/t Au compared to 2 g/t Au for 14 wall rock samples.

The third form of arsenopyrite is as fine needles in quartz-carbonate-sericite schist. Arsenopyrite and tourmaline commonly have similar habits as thin acicular crystals along the foliation planes in this schist. Fine needles of arsenopyrite are distributed throughout the schist without a direct association to any quartz vein sets. The shear margins are a chlorite-carbonate schist with a core of quartz-sericite schist. Ankerite and fine pyrite crystals fill veinlets and are disseminated along the foliation planes, contributing to the rusty appearance of the recessive weathering rock. Generally, sericite schist with only arsenopyrite mineralization is a poor gold target, but sericite schist with multiple mineralization assemblages is ore for the two major gold mines in Yellowknife. An average grade of 3.2 g/t Au was obtained from 31 arsenopyrite-bearing schist samples, but when one anomalous sample of 42 g/t is excluded, the average is 1.9 g/t Au.

3) A sphalerite-galena event is characterized by introduction of quartz and carbonate veins into brittle fractures with irregular pods or blebs of sphalerite and galena. Galena-sphalerite-chalcopyrite-bornite in quartz ± carbonate veins locally cross-cut and brecciate the quartz-arsenopyrite veins along brittle straight fractures. Locally, the fractures filled by bands of pyrite, galena and sphalerite are sharp and no alteration is apparent. These transect foliation and are slightly folded but are otherwise undeformed. At some showings, quartz-vein fracture-surfaces have both a brown and a black tourmaline.

Irregular pods 20-50 cm across are filled by pyrite and massive sphalerite and euhedral crystals of galena. These vug fills are not uniformly enriched in gold but can contain substantial concentrations of silver. In several different lithologies including the mafic pillows of the Crestaurum Formation at Crestaurum Mine, and the Western Granodiorite at the Rod Claims, the sphalerite-galena event resulted in fine stringers of sphalerite and galena in white recrystallized quartz veins. Locally vug-fills of sphalerite have been preserved but more commonly the vugs have been deformed and stretched into fine stringers.

In many showings, later deformation has blurred the temporal relationships of different mineralization events which now are indistinguishable as distinct assemblages. Where the relative timing can be determined, the sphalerite-galena event postdates the arsenopyrite event.

Gold is strongly associated with both sphalerite and galena. Twenty-three samples had an average grade of 17 g/t Au. Although sphalerite appears to be more common than galena, the relative abundance of zinc to lead has no apparent correlation with gold concentration (Fig. 3).

4) The fourth mineralization event is characterized by white-glassy quartz veins with vugs and fractures filled by molybdenite and pyrite. These cut most lithologies in the Yellowknife region but tend to be concentrated in granitoid plutons and adjacent mafic volcanic rocks. Molybdenite showings are common in the Western Plutonic Complex as small irregular blebs or plates in quartz-rich pegmatite phases of the granodiorite. These showings tend to be small and monometallic but in places are associated with pyrite-filled vugs.

At Chan Lake, several quartz veins cross the amphibolitic volcanic rocks of the Chan Formation. The 2-3 m wide veins are filled with white glassy quartz with gradational transitions to pink recrystallized quartz. Locally, the quartz is fractured and has 5-10 cm vugs with massive pyrite infills. Albite altered to kaolinite is an important component of the limonite-stained quartz veins. These veins have sharp margins with a slight bleaching of the surrounding wall rock. Concentrated in the vein margins are vugs filled by pyrite and molybdenite. These veins commonly follow older shears and may show evidence of post-emplacement deformation. Besides cutting the mafic volcanics, the large quartz veins cut dykes from the nearby Duckfish Granite, showing that the molybdenite-pyrite event is younger than this young granite.

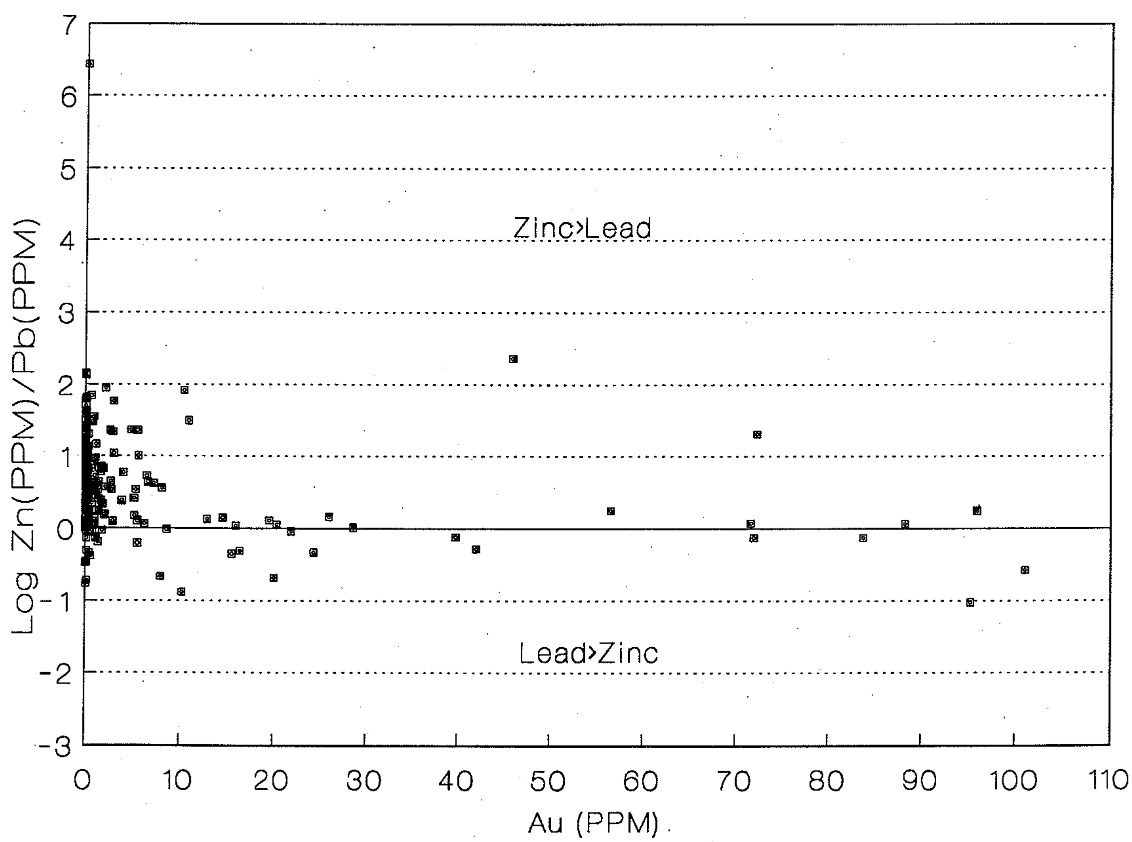

Figure 3. Gold values in samples with differing proportions of zinc and lead.

Showings on the South Islands have vug fills of pyrite and sphalerite with flakes of molybdenite in white quartz suggesting that the sphalerite-galena event may be co-genetic with the molybdenite-pyrite mineralization.

Quartz veins with just molybdenite do not contain substantial concentrations of gold. However, showings with multiple sulphides and molybdenum concentrations greater than 10 ppm were consistently associated with the richer gold showings. Twenty-five samples with at least 10 ppm of molybdenum had an average gold concentration of 8.6 g/t. Samples of 43 pyrite-rich veins yielded an average of 3.2 g/t Au.

5) Hematite-chalcopyrite mineralization is manifested as fracture fills of specularite or by hematized-jasperoid, quartz, carbonate and chalcopyrite in late faults. A spectacular quartz, jasperoid, and hematite breccia was formed where the West Bay Fault deviated by 3 to 4° at Ranney Hill. Multiple fault movements are recorded by a complex series of cross-cutting hematite veins, quartz veins and cemented and brecciated rocks. Smaller splay faults are filled by white vuggy quartz containing abundant chalcopyrite, malachite, hematite veinlets and drusy quartz. In the mafic volcanics of the Kam Group, small brittle fractures are filled with hematite and minor chalcopyrite accompanied by malachite-staining on fracture surfaces. Gold values in deposits related to the hematite-chalcopyrite event are generally low. Anomalous showings are commonly the result of gold remobilization. Based on 45 samples an average grade of .096 g/t Au was calculated.

B) Gold showings are present in almost every lithology in the Yellowknife region. Each showing was the consequence of one or more of the five mineralizing events with various permutations due to the local geology. Except for showings related to the pyrite-pyrrhotite event, no preferences for host lithology could be identified. Consequently, the term "Ore member" should not be used to describe the highly foliated portions of the upper Yellowknife Bay Formation. The concentration of gold in this "member" is a consequence of metamorphic and structural ground preparation and not due to any intrinsic property of the Yellowknife Bay Formation rocks. Deformation and metamorphism occurred before the mineralization.

Generally, the mineralizing processes for events 2, 3 and 4 took advantage of pre-existing pathways including shears, fractures and vein sets that followed zones of weakness such as interflow sediments, lithological contacts or fold hinges. Mineralized shear zones are commonly substantially retrograded in places, with chlorite and sericite cores in amphibolitic host-rocks. As the prograde metamorphism is commonly attributed to the thermal aureole of nearby plutons and these plutons are also mineralized, the gold deposition and the retrograde alteration of the shear zones was after peak metamorphism.

C) With the distinction of 5 events, the age of gold emplacement can be estimated. The first event, the pyrite-pyrrhotite event, is associated with the constructional phase of the volcanic belt and is most prominent in rocks marking the end of volcanism immediately after the Banting Group felsic volcanic rocks dated at 2.667 Ga (Helmstaedt and Padgham, 1986).

Events 2 - 5 are recognizable in the Western Plutonic Complex, granites of the Awry Plutonic Complex and in the Jackson Lake Formation (W.J. Humphries, personal communication, 1990), as well as all older lithologies. Boulders in the Jackson Lake Formation have been dated at 2.609 Ga and the Duckfish-Stagg Granite at 2.584 Ga, suggesting that mineralization events 2 - 5 could not be earlier than Late Archean (Isachsen and Bowring, 1989; Atkinson and van Breemen, 1990). Gold showings related to events 2,3,and 4 are present in all the major rock types of the Yellowknife region except the Prosperous Granites (2.521 Ga Rb-Sr (Green et al., 1968)) and the Proterozoic Dogrib diabase dykes (1.9 Ga Rb-Sr (Easton, 1984)), thus bracketing the youngest ages possible for mineralization. The hematite-chalcopyrite deposits are associated with large faults that cut all lithologies in the Yellowknife region. This event post-dates the early Proterozoic intrusion of the Dogrib diabase dykes.

This confinement of the age of gold mineralization strongly suggests that the source of the mineralizing fluids was granitic in origin and not metamorphic as has been previously proposed (Kerrich and Fyfe, 1987).

D) Gold deposition or remobilization was associated with all five of the mineralization events, but economically significant concentrations are present in showings most strongly affected by the arsenopyrite and galena-sphalerite events. Of the two, geochemical evidence suggests the latter was the more important event.

The findings also confirm the long established observation that the highest gold concentrations are associated with the greatest abundance and variety of sulphide minerals. Samples collected from showings affected by multiple mineralization events had gold concentrations averaging 26.5 g/t, substantially greater than samples attributable to a single mineralization event. Thus, it is not surprising that the extensive Giant-Campbell Shear System, which was active for a prolonged period, should be the main ore source for the two major mines in Yellowknife (Cunningham, 1984).

The discrimination of separate mineralizing events allows for the formation of different ore types in the same system. The arsenopyrite-rich refractory ore of the Giant and Con shear zones can be attributed to a major input by the arsenopyrite event. This contrasts with the free milling gold of the Campbell shear zone attributable to the greater influence of the sphalerite-galena event in that portion of the system. Detailed mineral distribution maps might further resolve the question of differences in ore-types for the Giant-Campbell Shear System.

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ANIALIK RIVER, ARCADIA BAY

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Objectives

The Arcadia Bay area (Fig. 1) is located about 600 km north of Yellowknife on the south shore of Coronation Gulf (part of NTS 76M/11). The Arcadia Bay area of the Anialik River Batholith (ARB) and the Anialik River Greenstone Belt (ARGB) was selected for several reasons:

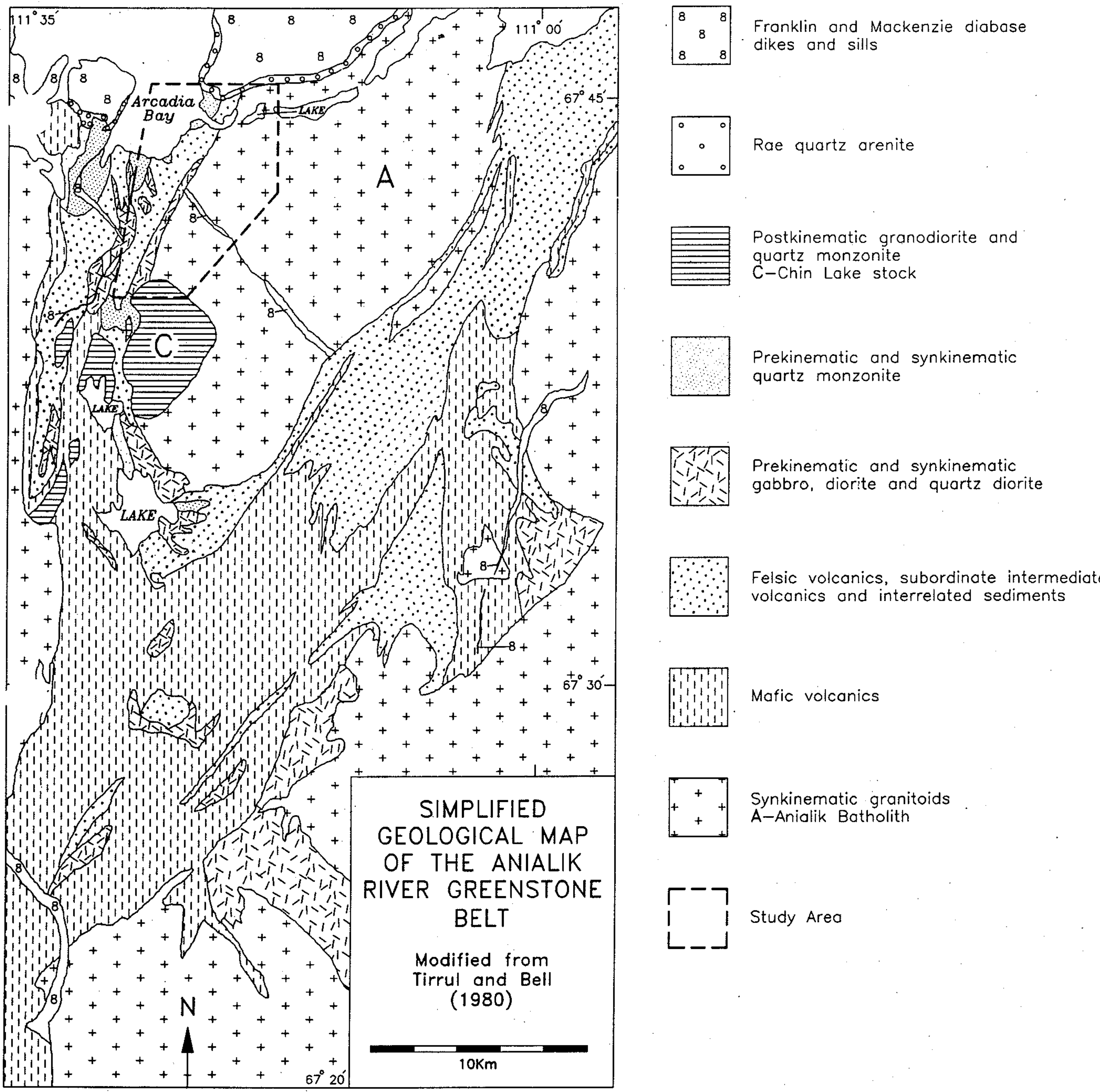

Figure 1. Geology of the Anialik River Greenstone Belt.

1) The Arcadia Bay area Au mineralization is distributed throughout approximately 32 km^2. Almost 65% of the area mapped is outcrop and many of the quartz vein/shear systems have been trenched. This area is probably the best exposed example of Archean shear zone-hosted gold-quartz vein mineralization in its geological context in Canada.

2) The shear zone gold mineralization is hosted in the ARB and shows a strong spatial association with felsic dikes intruding the ARB (Abraham and Spooner, 1988a, 1988b, 1989). These and other cross-cutting relationships provide excellent geological control for U-Pb geochronological studies and an exceptional example for testing of the magmatic and other hypotheses for Archean gold.

3) The lithostructural relationships observed in the area provide good opportunity to test whether the ARB and felsic metavolcanics of the ARGB are comagmatic and arc related.

The principal scientific objectives are:

1) To produce a high quality, detailed lithostructural map of the Arcadia Bay area encompassing the mineralized shear zones and the sheared western contact between the ARB and part of the ARGB.

2) To determine the petrogenesis of the ARB and associated "felsic dikes" as a basis for comparison with the ARGB metavolcanics and leading to critical analysis and testing of models for the evolution of the northwestern Slave Province.

3) To carry out a detailed U-Pb geochronological study of key lithologies in the Arcadia Bay area, and.

4) To determine the nature and origin of Archean gold mineralization in the ARB, and to test models for the origin of Archean lode gold deposits.

Research achievements and work in progress

Geological mapping and sampling of the Arcadia Bay area

This first objective has been achieved with the completion of three summers of detailed mapping and sampling in 1987, 1988 and 1989 (Abraham 1987; Abraham and Spooner 1988a, 1988b; Abraham, 1989). Over 800 samples from the ARB and ARGB were collected during the summers of 1987, 1988 and 1989 to provide a comprehensive suite of the major and minor lithologies, mineralized samples and those to be used for microstructural, geochemical and geochronological studies.

Petrogenesis of the ARB

The ARB diapirically intrudes the ARGB (Padgham et al., 1983). Together these form the northwestern extension of the recently named Hackett River Arc (Kusky, 1989). Abraham (1987, 1989) has described in detail the lithologies comprising the ARB and ARGB in the Arcadia Bay area. This study has identified a relatively undeformed leucotonalite phase of the intrusion and a mafic marginal phase comprising heterogeneously deformed diorite and gabbro along the western margin of the ARB. The western ARB/ARGB contact is defined by a 200-800 m wide zone consisting of an east to west transition from weakly deformed tonalite and mafic marginal phase rocks to mylonitized equivalents passing into highly strained metavolcanics. Felsic dikes (locally comprising approximately 80% of the width of this contact zone) intrude the host rocks subparallel to the foliation of this high strain zone, which is interpreted as a product of diapiric emplacement of the ARB. Jackson et al.(1985), recognized a similar zone of felsic dikes along the south and eastern margins of the ARB.

Supracrustals in the Arcadia Bay area are predominantly felsic metavolcanic, but approximately 50% of the supracrustal belt mapped comprises quartz-feldspar porphyry interpreted as sills and related flows.

Several problems have been identified from the field relations, as follows:

i) Mapped units in the ARB and ARGB require geochemical classification to ascertain their potential source(s) and petrogenetic histories and to determine if the metavolcanics of the ARGB are comagmatic with the ARB.

ii) The felsic dykes intruding the ARB are spatially associated with Au mineralization. A geochemical study of the dykes and the rocks comprising the ARB is necessary to establish what relationships, if any, exist between these host lithologies.

These problems are being addressed in a systematic major, trace and rare earth element, geochemical study which is in progress at the University of Toronto using standard X-ray fluorescence (XRF) and instrumental neutron activation analysis (INAA) methods; major element analyses will be performed by X-Ray Assay Labs (XRAL), Toronto. A total of 87 samples has been selected as being representative of the major rock units present in the study area, as deduced from field mapping and petrographic analyses. The samples chosen are the least altered so as to enable a lithogeochemical rather than alteration-mineralization geochemical study to be carried out. Thin sections of all 87 samples have been made and a thorough petrographic study of these is in progress.

Data obtained from this study will be critically compared with existing geochemical data for the Slave Province, specifically Hackett River-type belts in the eastern Slave Province (Cameron and Durham, 1974; Ewing, 1979; Frith and Fryer, 1985; Frith, 1987). It will also be compared with worldwide Archean TTG suites (O'Nions and Pankhurst, 1974; Arth et al., 1978; Barker, 1979; Jahn et al., 1981; Bickle et al., 1983; Martin et al., 1983; Campbell and Jarvis, 1984); with Archean granitoid-hosted Au deposits (e.g. Jemielita et al., 1988) and with subduction related Proterozoic and Phanerozoic suites. This study will help to establish a model for the evolution of the ARB and assess its petrogenetic and tectonic relationship with the northwestern Slave Province, and the Slave Province as a whole.

U-Pb geochronology

The relative ages of the intrusive and supracrustal rock types in the Arcadia Bay area have been established from detailed field mapping (Abraham, 1987; Abraham and Spooner, 1988a, 1988b; Abraham, 1989). The ARB has previously provided U-Pb zircon dates of 2.694 Ma and 2.692 Ma (Padgham et al., 1983) and the felsic metavolcanics of the ARGB have apparently provided a similar but less precise age (Padgham, personal communication,1987). Precise geochronology can provide absolute age constraints on rock units comprising the ARB and ARGB and can give upper and lower limits on the timing of Au mineralization.

A geochronological study is in progress at the Royal Ontario Museum using the methods of Dr. T.E. Krogh, under the supervision of Dr. D.W. Davis and S. Kamo.

The following geological points are relevant to the choice of samples for this study. A date from the ARB tonalite will provide the maximum constraining age for mineralization in the Arcadia Bay area, while the sample from the Chin Lake Stock will provide the minimum constraining age. A felsic dyke will be dated to provide evidence of their age relationship to gold mineralization. Similar studies have been carried out in the Abitibi Belt of the Superior Province (Corfu et al., 1989), and this type of study has been successfully carried out by Jemielita et al. (1990) on the Camflo gold mine.

Quartz monzonitic plutonic rocks associated with the 2.5-2.6 Ga cratonization event, recently interpreted as being post-collisional anatectites produced during crustal thickening (Kusky, 1989), cross-cut all rocks of the Slave Province. It is possible that the Chin Lake Stock may belong to this suite of intrusion and a U-Pb date on this intrusion is therefore crucial to understanding the overall extent of late post-tectonic plutonism in the Slave Province.

The Hackett River-type belts have an overall northwesterly trend along the eastern margin of the Slave Province from Walmsley Lake to the Anialik River Greenstone Belt on the Arctic coast (the present study area). Volcanism in the Slave Province took place ca. 2.7-2.66 Ga (Henderson, 1981; van Breemen et al., 1987; Mortensen, 1988; Kusky, 1989). It is thought that the Hackett River-type metavolcanics were fed by subvolcanic tonalitic to trondhjemitic plutons (Padgham et al., 1983; Padgham, 1985; Frith and Fryer, 1985; van Breemen et al., 1987; Kusky, 1989) of which the ARB is characteristic. One of the objectives of the proposed research is to test this suggestion using U-Pb geochronology and igneous geochemistry. The age relationship between the ARB and the ARGB is important with respect to the overall petrogenetic and tectonic history of the study area, in particular the test to determine whether they are cogenetic.

A sample of the quartz-feldspar porphyry unit was collected along with a sample from the synvolcanic Salt Lake Stock; both will be used to date the metavolcanics. This research will be the first integrated geochronological, petrological and geochemical study of gold mineralization in the Slave Province.

Nature and origin of Archean Au mineralization in the Arcadia Bay area

The Arcadia Bay deposit is hosted in tonalitic, trondhjemitic and mafic marginal rocks of the ARB along its western contact with the ARGB. Mineralization (860,000 tons grading 0.22 oz Au/t, Northern Miner, October 31st 1988) occurs in an approximately 32 km^2 area in the strongly to intensely foliated tonalite and marginal mafic rocks of the western Anialik Batholith. It is predominantly hosted by longitudinally extensive (up to 5 km strike length), narrow (typically less than 4 m wide), brittle/ductile shear zones containing mylonitized tonalite, associated mafic phases, and "felsic" dikes and quartz veins. This type of mineralization is characteristic of the Northwestern Zone of gold mineralization in the Slave Province (Padgham, 1990a, 1990b).

Two principal sets of shears are recognized: a north to northeasterly trending set (predominantly 030° trending, e.g. North Central, Sidewalk and C-vein systems) and a north-northwesterly trending set (about 345° trending, e.g. H-vein and Boundary Vein systems). Although quartz veins appear to have significant along-strike extension, it is important to note that they are in many cases closely spaced en echelon shear-type veins.

Mineralization occurs up to 5 km into the batholith and recent assay results suggest that gold mineralization may extend even farther. There is a strong spatial association of mineralization with the marginal rocks of the batholith and "felsic" dikes within the mineralized shears.

Detailed reflected (and transmitted) light microscopy to determine the paragenesis of the Arcadia Bay mineralization will enable comparison with the TTG-hosted Renabie deposit (Callan and Spooner, 1987; Studemeister and Killias, 1987) and other Archean lode gold deposits.

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STRUCTURAL, GEOCHEMICAL AND $^{40}Ar/^{39}Ar$ DATING CONSTRAINTS ON THE FORMATION OF GOLD-BEARING, METATURBIDITE HOSTED QUARTZ BRECCIA/ VEIN SYSTEMS OF THE SOUTH GORDON LAKE REGION, NWT

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Introduction
A structural and lithologic model is proposed for the localization of stratabound auriferous, quartz breccia zones, hosted in lower greenschist grade Burwash metaturbidites of the Archean Yellowknife Supergroup (Stokes et al., 1989). The mineralized breccia zones occur in the hinge of a N-S trending, vertically plunging regional (km scale) refold at the southern end of Gordon Lake (lat. 62°54'N; long. 113°15'W). Of these breccias the most economically important is the Kidney Pond Zone 1 which has a strike length of 260 m, a width of 5-20 m and depth extent of at least 180 m. Total reserves for this zone are 173,000 tons at 0.5 oz/ton Au, for assays cut to 3.0 oz/ton (Caelles and Burston, 1986).

The brecciation, probably the result of refold hinge tightening, started in and continued after peak metamorphism. The late tightening produced (predominantly dextral) bedding parallel slip that: 1) developed a distinctive crenulation cleavage and 2) focused mineralizing fluids into the refold centre. A lithological transition, of alternating graywacke and black (carbonaceous) siltstone beds, situated within the centre of the refold (on the western shore of Gordon Lake) possibly enhanced this late deformation.

Geochemical constraints
Eighty vein, breccia and lithological samples (including appropriate duplicates and standards) were analyzed for gold, trace and major elements. The purpose of this pilot study was to investigate:

1) evidence for an alteration halo around the main stratabound breccia at Kidney Pond;

2) the relationship between gold mineralization, sulphides (particularly arsenopyrite) and carbon;

3) the geochemical differences between the black siltstones, grey siltstones and greywackes; and

4) the possible tectonic provenance of the metasediments.

Preliminary results from siltstone samples taken <5 m to >200 m from the Kidney Pond Zone 1 breccia zone indicate:

1) a major element enrichment of K_2O, TiO_2, and Al_2O_3, and a depletion of SiO_2 towards the breccia;

2) no distinct trends in CaO, Na_2O, MgO, MnO, P_2O_5 and Fe_2O_3;

3) distinct gold and trace element (including As, Ni, Cu, Cr, Ba, Sr, and Rb) enrichment towards the breccia zone; and

4) no distinct trends in Pb or Zn. From this data a distinct geochemical halo of at least 20 m wide, is apparent surrounding the breccia zone.

Gold and arsenic appear spatially related with breccia systems. A log plot of arsenic versus gold concentration produced a linear correlation for both breccias and host lithologies; once a threshold value of approximately 50-100 ppm arsenic is reached. This agrees with comparable data taken from Brophy (1987) that covers other areas within the Yellowknife Basin.

Siltstones within the Kidney Pond breccia zone display higher percentages of total carbon compared to the other surrounding siltstones and wackes. There also appears a close correlation between gold and total carbon within the breccia zone itself. The carbon, probably primary (organic) in origin, possibly played a role in: 1) reducing or scavenging gold from the mineralizing fluids and 2) assisting hydrofracturing mechanisms by the rapid evolution of volatiles.

Greywacke major element plots of Fe_2O_3+MgO versus TiO_2, Al_2O_3/SiO_2, K_2O/Na_2O and $Al_2O_3/(CaO+Na_2O)$, after Bhatia (1983), were used to discriminate the tectonic setting of the provenance. The plots indicate that the greywackes lie within fields of continental island arcs or possibly active continental margins. Graywackes derived from these volcanic dominated settings probably provided a good source region for the gold.

Temperature, pressure and fluid composition constraints

All the stratabound quartz-breccia zones occur within biotite grade metasediments, below the mapped cordierite isograd of Henderson (1985). However, close to the brecciation, metamorphic porphyrblasts of cordierite (retrograded to quartz, biotite and chlorite) occur and possibly indicate a zone of increased thermal activity. Geothermometry from fine grained arsenopyrite veinlets within the breccia indicate temperatures of approximately 475°C.

Fluid inclusions occur in all quartz vein and breccia types. However most of the quartz has undergone partial sub-grain development and recrystallization, and the inclusions are all concentrated in linear arrays and are probably secondary in origin. Secondary, liquid dominated inclusions from the Kidney Pond breccia zone have the following characteristics: 1) homogenization temperatures of 145°-240°C, 2) cubic daughter mineral (probably NaCl) melting temperatures of 160°-180°C, 3) ice eutectic temperatures of -60° to -75°C, 4) final ice melting temperatures of -20° to -26°C, and 5) commonly no freezing at all. This thermometric data indicates high salinity fluids of approximately 25 wt% NaCl ($\pm$ CaCl) with both CO_2 and CH_4. A minimum entrapment pressure of approximately 2-3kb is obtained for this fluid, assuming a 25 wt% NaCl solution and a trapping temperature of 475°C.

Geochronological constraints

Five mineral separates were analysed by the Ar^{40}/Ar^{39} dating technique in order to: 1) provide temporal and thermal constraints on the breccia formation and 2) test the applicability of this technique to Slave thermal/uplift problems.

The hornblende spectra displayed a steep age gradient, but the age obtained from the last heating step is in reasonable agreement with U-Pb dates of Henderson et al. (1987) for the formation of the Yellowknife Volcanic Belt. All the micas exhibited well defined and relatively undisturbed spectras. The calculated plateau ages from the micas (with the exception of the crenulated biotite) indicate that the peak metamorphism, brecciation and granite intrusive events are within 50Ma (i.e. 2%) of each other. This data is at present inconclusive and open to several interpretations. A favoured interpretation is that the Gordon Lake region probably reached peak metamorphic (biotite grade) conditions around 2600 Ma (Thompson, 1989). While cooling but still above the closure temperature of biotite, some areas were overprinted by thermal highs caused by the intrusion of late granites (such as Spud Lake) and structurally focussed hydrothermal systems (such as the Kidney Pond quartz-breccia zones).

The whole region then cooled below the closure temperature of the micas (ca. 300°-350°C) around 2500-2550 Ma. Whether or not the crenulated biotite age represents a real event is unclear.

Towards a structural, geochemical and thermal model

The above analytical data provides further constraints on the process and mechanisms for the formation of the gold-bearing breccia zones at Gordon Lake. Stratabound brecciation was initiated by bedding parallel slip mechanisms within siltstone beds during tightening of the refold hinge. Oxidized metamorphic fluids (Kubilius and Ferry, 1989), probably derived from hydrothermal circulation within the metaturbidite pile, were focused into the refold centre and zones of hydrofracturing. These over-pressured fluids were probably at temperatures of at least 475°C and infiltrated the cooler (300°-400°C?) host lithologies.

The fluid focussing and micro-fracturing around the breccia zone probably accounts for the wider geochemical halo, as compared to those found by Boyle (1979) at the Ptarmigan Mine. Rapid de-pressurization during hydrofracturing and abundant carbon rich volatiles (possibly derived from the black siltstones) probably assisted in reducing the infiltrating fluids and precipitating the grey-black quartz, gold and sulphides.

Exploration criteria for additional mineralized breccia zones

1. *Regional scale* - Find areas with:

a) evidence of multi- and post-peak metamorphic deformation, and

b) siltstone dominated lithologies.

2. *Mine scale* - Find areas with:

   a) vein systems that are characteristically syn- to post-metamorphic in relative age,

   b) evidence of metamorphic overprinting (such as cordierite blasts),

   c) veins systems associated with arsenopyrite, and

   d) grey quartz veins hosted in carbonaceous siltstone sequences.

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THE GEOLOGY OF THE BENIAH LAKE AREA, SLAVE STRUCTURAL PROVINCE, NWT

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Objective
Several Archean supracrustal belts were known to converge amidst granite and gneiss at Beniah Lake. Stratigraphic and structural details of this configuration were unknown. The objective of the Beniah Lake project was to determine the detailed stratigraphic and structural relationship of the supracrustal belts and the surrounding gneissic/granitoid terrain (Fig. 1).

Method
The project involved three field seasons (approximately seven months) of detailed geological mapping (1:32,000) by a 2-person mapping crew. Mapping was aided by petrography and chemical analyses of samples.

Results
The main result of the project is a detailed geological map at 1:32 000 scale of the Beniah Lake area (NTS 85 P/8, Roach, 1990).

Stratigraphy
Three metamorphosed supracrustal belts, trending north, northeast and east, converge amidst granitic plutons at Beniah Lake. The stratigraphically similar belts appear to unconformably overlie the adjacent tonalite gneiss. In all belts, the lowermost supracrustal rocks are metasediments, < 1 km thick, of the Beniah Formation. These are overlain by a one to three kilometre thick sequence of mafic metavolcanics. Minor intermediate to felsic volcanic and volcaniclastic rocks are uppermost in the supracrustal belts.

Description of units
The tonalite gneiss consists of centimetre-scale layers of tonalite and amphibolite. This gneissossity is cut by metamorphosed mafic dykes. In the southeastern corner of the map area the gneiss is less layered and granodioritic.

The metamorphosed rocks of the overlying Beniah Formation include, in approximate stratigraphic order, calc-silicate rock, quartz-pebble conglomerate, orthoquartzite, quartz arenite, and siltstone. There are local accumulations, typically <1 km thick and 1-3 km in strike length, of felsic volcanics and volcaniclastic sediments. A discontinuous sulphide-poor quartz-magnetite iron formation outcrops near the top of the Beniah Formation.

The Beniah Formation contains metamorphosed ultramafic sills, most commonly medium grained, chromite-bearing serpentinized metadunite. Chromite rims are metamorphosed to ferritchromite (Templeton, 1988). Detrital chromite grains in the massive metaquartzite do not have metamorphic ferritchromite rims, suggesting pre-metamorphic erosion of the ultramafic rocks.

The Beniah Formation and its ultramafic rocks are intruded by voluminous mafic dykes and sills. On outcrops at the scale of 10 metres, the metasediments can contain up to 50% (by volume) mafic intrusions. The metagabbro dykes are one to ten metres wide, fine to medium grained and have chilled margins. A few dykes contain rounded glomeroporphyritic plagioclase (up to 0.3 m in diameter).

The mafic dykes may have been feeders to the overlying massive and pillowed mafic volcanics, but no dykes can be traced across the poorly exposed sedimentary-volcanic contact. Mafic volcanic clasts in a polymictic conglomerate from the upper Beniah Formation indicate some mafic volcanism during the latter stages of sedimentation. The mafic volcanics are overlain by 100 to 300 m of intermediate metavolcanics, typically lapilli or block tuff, in places cemented by carbonate. The uppermost 20-200 m of metavolcanics are felsic crystal tuffs with minor rhyolite. Black, possibly graphitic metasediment and metasiltstone outcrop at the top of the sequence in the core of a syncline of the central supracrustal belt. The uppermost felsic metavolcanic and volcaniclastic rocks are distinguished from similar rocks in the Beniah Formation by their lack of intrusive mafic dykes. This further supports a feeder role for the metagabbro dykes.

Three diatreme dykes are mapped in the central supracrustal belt. A spectacular dyke and accompanying breccia outcrops within the Beniah Formation on the northern limb of the central syncline. The magnetite-rich metamorphosed dyke contains

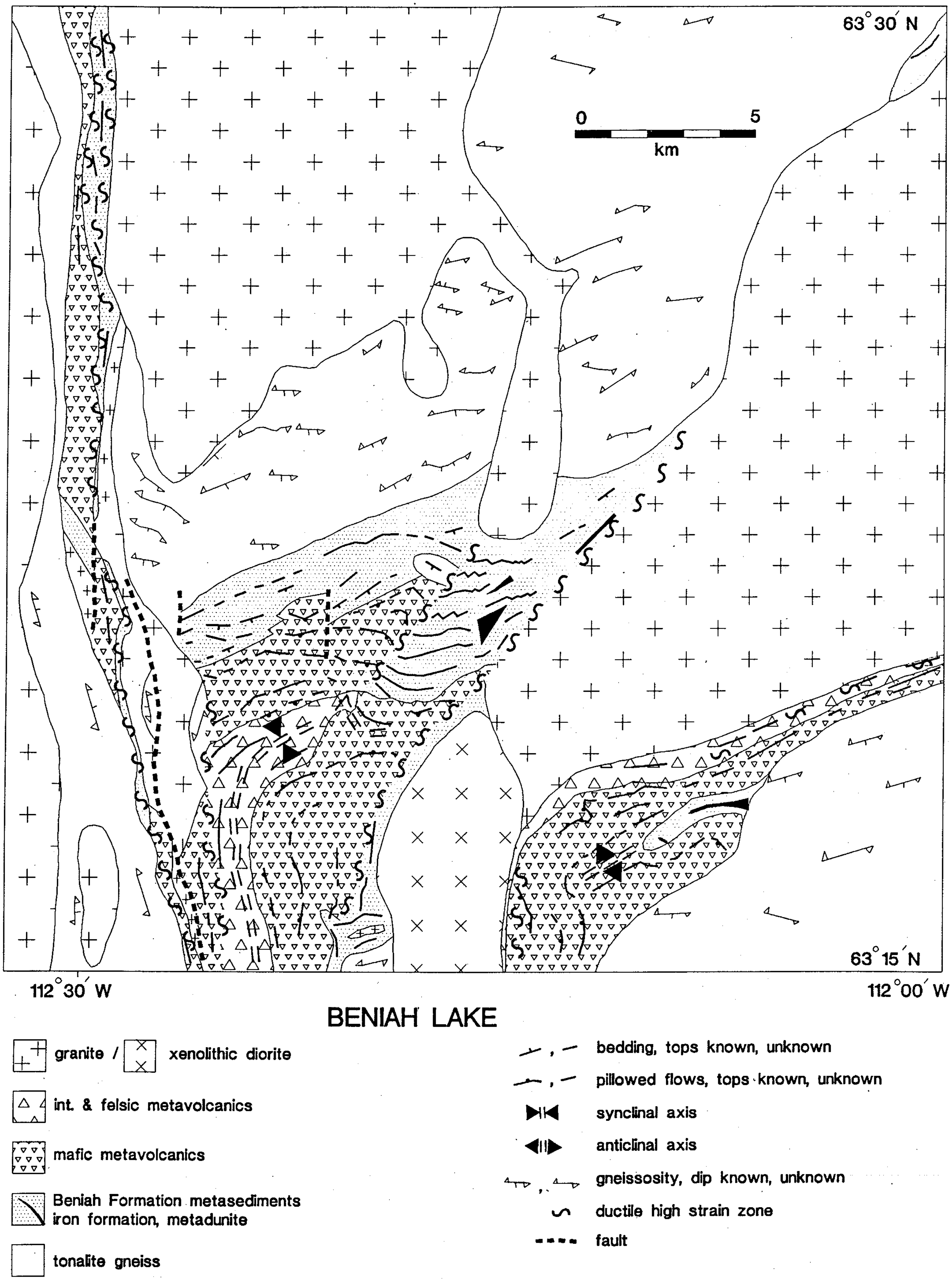

Figure 1. Geology of the Beniah Lake area.

rounded xenoliths of tonalite gneiss, granite, and quartzite. Two diatremes are found in the overlying mafic metavolcanics. One contains rounded granite xenoliths and the other quartzite xenoliths. These dykes consistently strike north-northeast, and may be genetically related to megacrystic, magnetite-rich, hornblendite dykes having a similar orientation. The hornblendite-magnetite dykes are the only dykes observed to be intrusive into the uppermost felsic metavolcanics. This field relationship and the granite xenoliths in the diatremes suggest a post-volcanic age for the diatreme and hornblendite dykes.

The gneisses and supracrustal rocks are intruded by granitic plutons of varying composition, some containing volumetrically significant xenoliths of amphibolite and tonalite. Vertically dipping unmetamorphosed diabase and gabbro dykes are intrusive into all units. The orientation of the individual dykes is generally parallel to the dominant foliation.

Metamorphism

The supracrustal rocks are metamorphosed to greenschist facies. Porphyroblastic hornblende and cordierite are restricted to supracrustal rocks adjacent to pluton margins.

Structural geology

The three supracrustal belts are structurally distinct. The north-trending belt along the western edge of the map area is the most deformed. Within it the stratigraphic top indicators are unrecognizable, but stratigraphic similarities with the other belts suggest that the north-trending belt is a west-facing homoclinal sequence, locally fault repeated. Ductile strain in the metavolcanics increases progressively towards its eastern contact with the high strain zone in the Beniah metasediments. Contacts in the high strain zone strike north, whereas the dominant foliation and minor ultramylonite zones both strike north-northeast, dipping steeply eastward. The high strain zone contains elongate red granitoid bodies and north-striking brittle fault breccia zones. Pillowed volcanics are flattened parallel to the foliation in the adjacent Beniah metasediments. A strong elongation and mineral aggregate lineation plunges shallowly to moderately north-northeast and south-southwest. Within a single outcrop, shallow to moderately plunging fold axes in quartzite can trend both north-northeast and south-southwest. No steep lineations have been observed in the north-trending supracrustal belt. Shear bands in the metasediment and mylonitic granite indicate late north-south sinistral ductile shear.

Towards the west the supracrustal belt is in contact with a thin (<1 km) sliver of tonalite gneiss which borders a large granitic pluton. The eastern margin is a sheared mixture of metasediment, metagabbro, granite and epidotized tonalite gneiss.

The central supracrustal belt is the least deformed. It forms a southwest-plunging syncline, the axis of which is faulted along a northeast-trending dextral ductile-brittle fault. The southern limb of the syncline is rotated southward along its western contact with the north-trending supracrustal belt. A bedding parallel foliation dips gently away from the northern contact with the tonalite gneiss. Elongation, mineral and crenulation lineations in the metasediments and metagabbros plunge down-dip on the northern limb of the synclinal structure. The plunge of these lineations increases southward following the dip of the bedding/foliation. A similar relationship exists within the southern limb where the lineations plunge and the bedding/foliation dip northward. Foliation and bedding in the northeastern section of the central belt is crenulated by a northeast-striking foliation, which parallels a major ductile shear zone within the Beniah metasediments along the southeastern margin of the syncline. Within the northern limb the bedding parallel foliation is crenulated by a weak north-northeast-trending foliation.

The southeastern belt forms an anticlinal structure younging away from the tonalite gneiss which outcrops farther south. Steeply dipping high strain zones exist along the north-striking western margin at Bridge Lake and along the northern contact with the granite pluton. Elongation lineations along the slightly overturned northern limb plunge steeply southeast. In the southeastern belt the Beniah Formation is very thin and it's eastern contact with the tonalite gneiss is unclear. This belt lacks the late north-northeast crenulation characteristic of the central belt.

Tectono-stratigraphic interpretation

Mature quartzite with minor oligomictic quartz-pebble conglomerate were deposited on a shallow siliciclastic shelf (Rice et al., 1990). Isolated crustal fractures facilitated emplacement of high level ultramafic sills. This was followed by crustal extension and the deposition of mafic volcanics and later intermediate and felsic volcanics. This was followed by a period of synmetamorphic, synplutonic crustal shortening which steepened bedding and produced a bedding parallel foliation and a steep down-dip elongation lineation.

The last ductile deformation was largely strike-slip, possibly in response to a late east-west shortening event. Late brittle faulting occurred predominantly along pre-existing ductile shear zones.

Economic potential
Several units in the supracrustal rocks may prove to be prospective. Some metadunite bodies contain 0.3 m thick cumulate chromite layers containing up to 70% (by volume) chromite. Grab samples from sheared metadunites in the central belt show very minor platinum and paladium enrichment (60 and 230 ppb respectively) associated with nickel sulphides (Covello et al., 1988). Pyritic quartz pebble conglomerates in the Beniah Formation show very low grade concentrations of uranium and gold (Roscoe, 1990; Roscoe et al., 1989; Covello et al., 1988).

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GRANITIC PEGMATITES IN THE AYLMER LAKE BASIN

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Objective
The exploration of the pegmatite population of the Aylmer Lake basin (Fig. 1), a 10,900 km^2 expanse lying approximately 300 km northeast of Yellowknife, began in 1988. The purpose of the study was to explore the prospect for mineralized granitic pegmatites in the area, as mid 20th century reports indicated the presence of pegmatites containing Be, Nb-Ta and Li. Due to the escalating demand of these elements (and others, such as Rb, Cs, and Sn, in which pegmatites are commonly enriched) by technologically advanced industries, detailed accounts of all pegmatite occurrences are desirable. Such a body of information will aid researchers in achieving a more complete understanding of the entire pegmatite-generating process and hence benefit pegmatite prospectors in the future. In specific, this work sets exploration guidelines for rare-element pegmatites in this area.

Introduction
The twelve areas where pegmatites had been noted in preliminary geological mapping of the basin were investigated, along with other selected areas. The areas selected were based largely on findings from the Yellowknife pegmatite field and elsewhere, where pegmatite aureoles surround late tectonic to post-tectonic leucocratic granitic stocks; the pegmatites mainly intrude amphibolite facies metasediments. The area is noteworthy for the proclivity of granitoids to be largely pegmatitic; these are far more volumetrically significant in outcrop in this area than more primitive facies. Geochemical analysis of major elements from whole rock granite samples and the individual K-feldspar and muscovite from potassic pegmatite facies and pegmatite dykes yields means by which granite-pegmatite relations may be clarified and regional zonation of pegmatite swarms may be interpreted.

Results
A total of 203 pegmatites have been discovered in the Aylmer Lake Basin during 1988 and 1989. Many pegmatites contain the rare-element mineralization and internal features characteristic of the beryl-columbite, beryl-columbite-phosphate, and spodumene subtypes. Beryl was found in 44 dykes, columbite-tantalite in 13, and spodumene in 19 separate pegmatites. The pegmatite field has been divided into five geographically distinct areas: Reid Lake, Kirk Lake, Aylmer Lake, "Nebbish" Lake and Thonokied Lake.

The Reid Lake area contains five pegmatite swarms (FISHHEAD, YES, FINE, OIG and SWEET) in which pegmatites range from barren to spodumene-bearing. Geochemical analyses of granites and pegmatites from the area suggest a genetic link between granite on the south side of the lake (between Reid Lake and Munn Lake) and pegmatites whose degree of fractionation increases northward.

The progression from biotite granite (with K/Rb near 300) through pegmatitic leucogranite (where potassic pegmatite blocky K-feldspars have average K/Rb values of 200) into pegmatites proper (K/Rb from K-feldspar ranges from 131 in barren dykes to 31 in spodumene-bearing dykes) is clearly documented in this area. The evidence for regional zonation of pegmatites about a parental pluton is not as pronounced in other parts of the Aylmer Lake pegmatite field, except at Nebbish Lake.

The isolated spodumene-bearing pegmatite, SWEET, approximately 12 km northeast of Reid Lake, is too distant to be related to the previously-mentioned granite-pegmatite system. It is possible that this single outcrop is related to a well-fractionated pegmatitic granite which borders Zyena Lake, 3 km north of the pegmatite.

The Kirk Lake area contains two isolated pegmatite swarms (BORIS and BUGGER) which lack highly-fractionated mineralogies. The BORIS swarm lies immediately west of the pegmatitic granite in the centre of Kirk Lake. These pegmatites lack conspicuous internal zoning as well as rare-element mineralization, and their geochemical signatures relate them to the central granitic body. The BUGGER swarm may in fact consist of the two spatially overlapping but genetically unrelated swarms. Both subsets are geochemically rather primitive, but one subset is highly enriched in phosphate minerals, some of which are replacement products of primary Li-bearing phosphates. The phosphate mineral sarcopside collected in these dykes is the first report of this mineral in the NWT. The elevated phosphorous content of the pegmatitic granite lying just northeast of

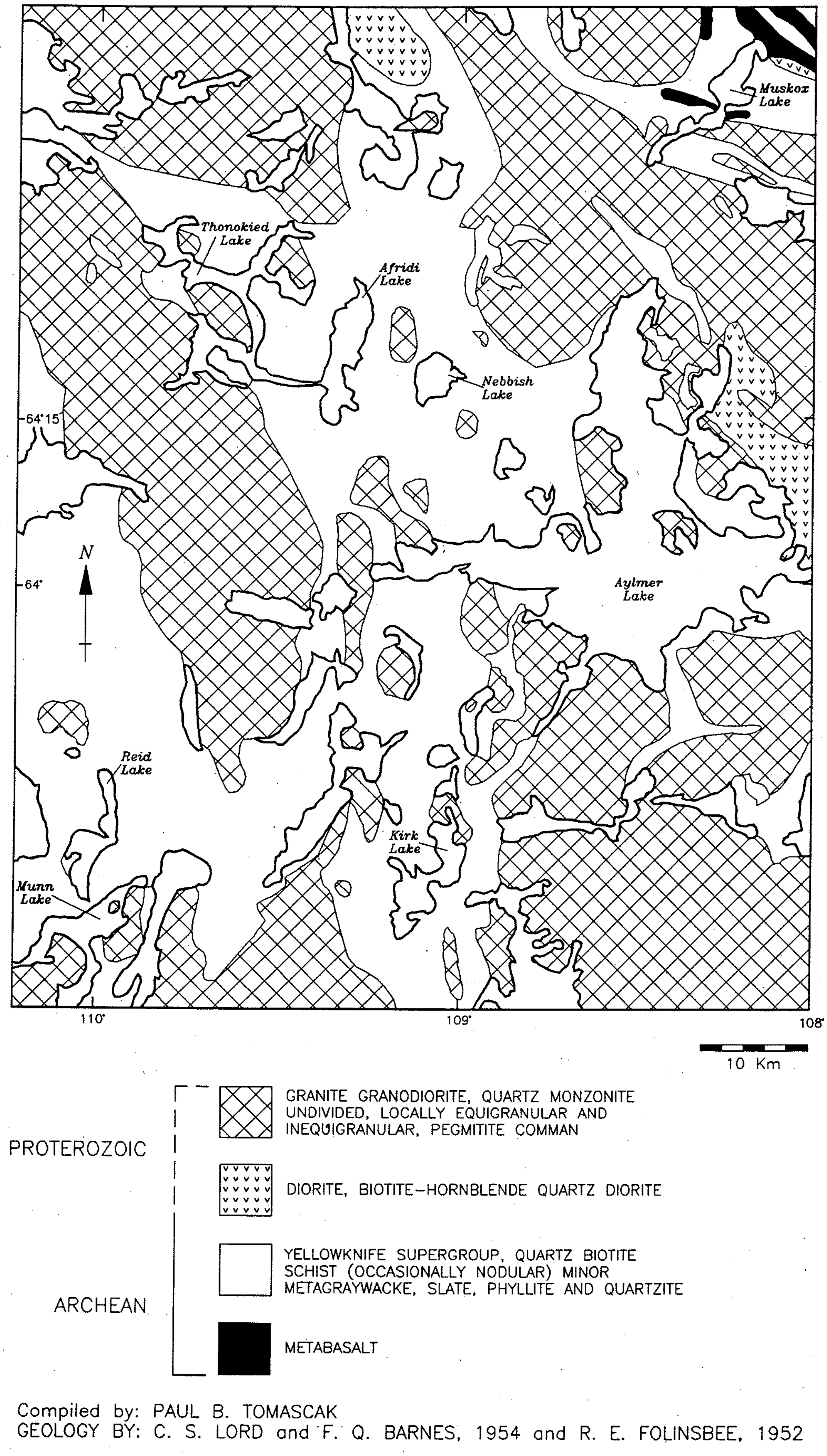

Figure 1. General geology of the Aylmer Lake pegmatite field.

Kirk Lake (average P_2O_5 of 0.52 wt% compared to 0.13 wt% in the central granite body) suggests that it is the parent of the phosphate-rich pegmatites.

The Aylmer Lake area contains six pegmatite swarms which all contain beryl (AL, MACRO, SLOG, BOO, GHIT, and NANNE). In two instances totally altered spodumene occurs. The AL swarm is isolated significantly from the outcropping granitic plugs which surround the area, arguing in favour of a parent pluton at depth. The majority of the Aylmer Lake pegmatite swarms are clustered around a central island of pegmatitic leucogranite, and geochemical interpretation favours that granite as a parental pluton over spatially related plutons.

The NANNE swarm lies along the far south of Aylmer Lake. The swarm is made up of beryl-and columbite-tantalite-bearing pegmatites. The swarm may or may not be related to pegmatitic granites south of Aylmer Lake, near Laverty Lake; the geochemical connection is not definite.

A previously unnamed lake, called Nebbish Lake in this study, lies between Aylmer Lake and Thonokied Lake and is surrounded by six pegmatite swarms (SK, BURBUR, WILLI, BIRD, REDS and NEBBISH) (Fig. 2). Four of these swarms contain pegmatites rich in spodumene, five contain beryl, and three contain columbite - tantalite. Aside from one strictly beryl-bearing swarm, these are the most fractionated

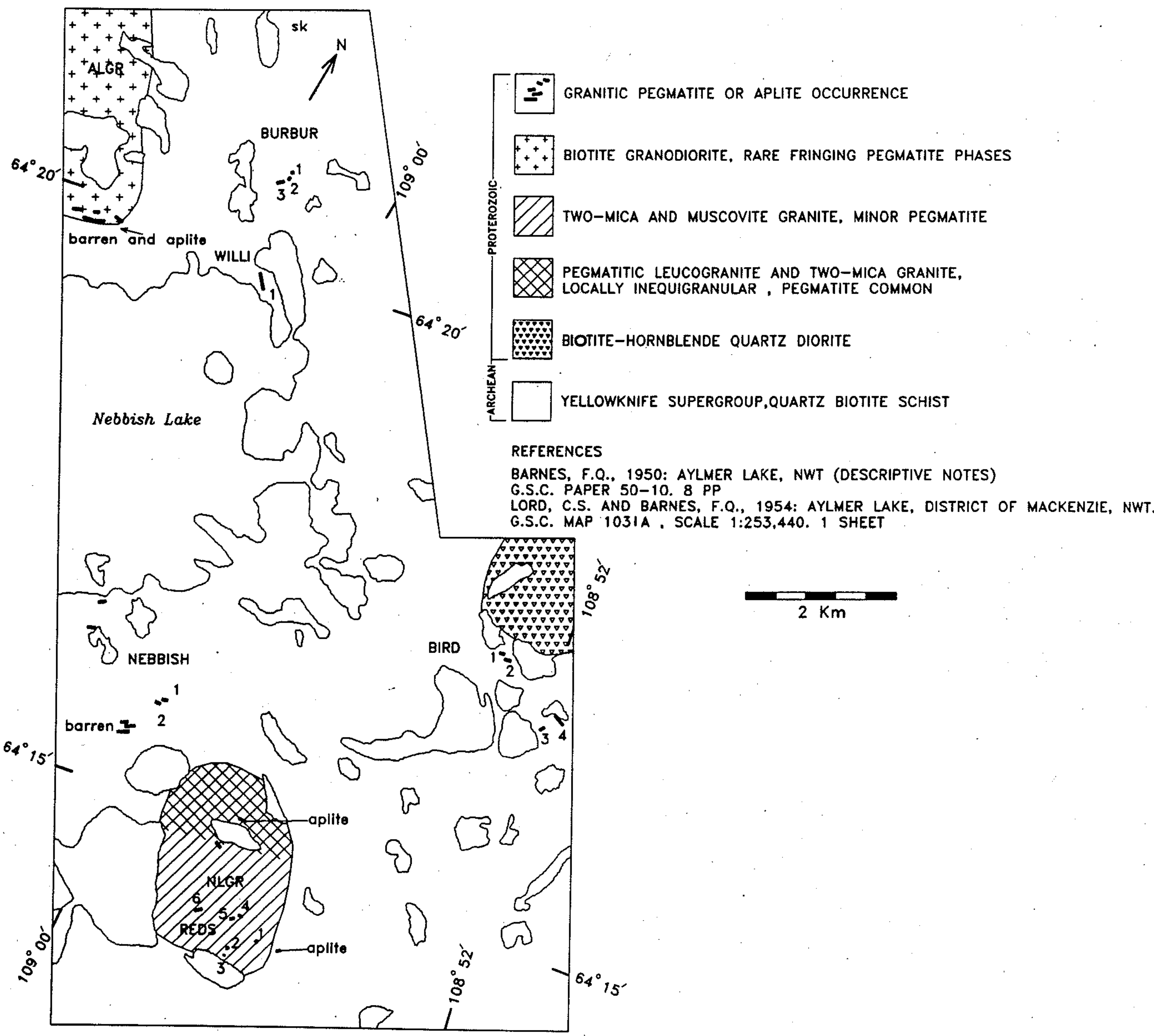

Figure 2. Granitic pegmatites of the Nebbish Lake area, geology by Paul Tomascak and Micheal A. Wise.

pegmatites in the Aylmer Lake field. The matter of parental plutons for the pegmatites in this area is not clearly resolved in all cases. The SK, BURBUR and WILLI swarms which lie north of the lake do not appear to be essentially related to one another--a pluton or plutons in the subsurface could be responsible for their generation. The BIRD swarm lies southeast of Nebbish Lake and is equidistant from outcropping fertile granites to neither of which can a firm geochemical connection be made.

The most highly-fractionated dyke swarm, REDS, rich in spodumene and Li-phosphates, outcrops within a zoned stock of fine-grained leucogranite and pegmatitic leucogranite, approximately 4 km southeast of Nebbish Lake. The highly advanced level of fractionation achieved by this pluton (K/Rb whole rock average of 137) as well as its enrichment in phosphorus (average P_2O_5 of 0.67 wt%) suggest that it is parental to the REDS swarm.

As at Reid Lake, there is excellent mineralogical, textural and geochemical evidence supporting regional zonation of the remaining dyke swarm, NEBBISH, at Nebbish Lake. Dykes outcrop in a progression from south (beryl-bearing; rimming the pegmatitic leucogranite) to north (spodumene-bearing; near the shore of Nebbish Lake).

The pegmatite group at Thonokied Lake was discovered in 1988. Investigation in 1989 revealed over 118 dikes which are largely barren, containing only schorl and/or apatite, although several also contain beryl and lazulite. The pegmatite group is surrounded on all sides by granitoids which in all cases carry pegmatitic leucogranite facies. The granite outcropping immediately east of the pegmatite group has the most fractionated geochemical signature (high Rb and Rb/Sr, and low Sr, Ba and K/Rb), and as such is the best available choice for a possible parent pluton for the pegmatites.

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SEDIMENTOLOGY, STRUCTURE AND ECONOMIC GEOLOGY OF THE EARLY PROTEROZOIC HURWITZ/KIYUK BASIN, DISTRICT OF KEEWATIN

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Objectives

Most of the Hurwitz belt was mapped at a reconnaissance level 20-40 years ago by R.T. Bell, F.W. Chandler, A. Davidson, K.E. Eade, W.W. Heywood and C.S. Lord, all of the Geological Survey of Canada. The present study was designed to begin updating this pioneering work. Two areas were mapped at a 1:50,000-scale: the Poorfish-Kiyuk-Windy belt in 1988; and the Hawk Hill-Griffin-Mountain lakes area in 1989. Principal objectives were to undertake:

1)fundamental basin analysis (to determine depositional systems, stratigraphic, and facies relationships, and establish basin configuration, subsidence mechanisms and tectonic significance);

2)structural analysis (to determine the relative importance of thrusting versus basement-cover infolding and resolve the significance of a vergence pattern that is regionally inconsistent); and

3)mineral resource assessment (to actively prospect during the course of mapping and, as a corollary of understanding the basic geological framework, to establish a context for known deposits and to define future exploration targets).

Results

The Hurwitz Group is exposed as a discontinuous chain of outliers that extends from Hudson Bay to Ennadai Lake. The outliers represent the erosional remnants of synclinoria infolded with basement and relics of thrust-fold belts. Some may reflect an original sub-basin geometry. The Hurwitz strata record aborted rift and cratonic basin sedimentation unrelated to known collisional events in Trans-Hudson Orogen. Changes in Hurwitz Group facies and thickness are considered to reflect the growth and decay of marginal and intrabasinal arches formed due to intraplate stresses superimposed on cratonic basin subsidence. The origin of the intraplate stresses remains enigmatic: they may have been caused by cryptic pre-Trans--Hudson collisional processes, variation in spreading rates in the Manikewan Ocean, or both. The only effects of Trans-Hudson collision may have been deposition of conglomerate, arkose and arkose-clast breccia of the Kiyuk Group (inferred to be alluvial fan, stream and talus deposits formed ahead of a thrust front that carried Hurwitz Group and basement to erosional levels) and deformation of the entire Hurwitz/Kiyuk package.

The principal structural elements in the Poorfish-Kiyuk-Windy belt are: northwest-propagating piggyback thrusts (including a northwest-vergent duplex cut by in-sequence, breaching thrusts); northwest-vergent large folds; and north-northwest-and north-northeast-trending normal faults. The thrusts are responsible for a minimum horizontal shortening of 75 km.

In marked contrast, shallow-level Proterozoic shortening in the Hawk Hill-Griffin-Mountain lakes area was by thick-skinned basement-cover infolding; thrusting is limited to minor out-of-syncline structures. northwest-trending, upright, concentric D1 folds are refolded by east and northeast-trending upright (and locally inclined), concentric, D2 folds, generating dome and basin (and locally mushroom) interference patterns. Interference is inferred to be a consequence of superposed folding, with active north-south shortening overprinting northwest structures. It is uncertain if the interference represents episodic or polyphase deformation. Folding was primarily by flexural slip accompanied by tangential longitudinal strain; space was accommodated by minor thrusts, cross faults, joints, disharmonic folds, and fold and cleavage fans. Changes in basement rock type and structural grain provided anisotropies that influenced Hurwitz thickness and facies and guided Proterozoic deformation. Basement anticlinoria, with wavelengths of about 35 km, separate the Hawk Hill area from synclinoria east at Ducker Lake and west at Watterson Lake. Regional shortening at shallow crustal levels by basement-cover infolding may be balanced at depth by regional intrabasement detachment. The link between the Hawk Hill (and Watterson) areas and the Poorfish-Windy Thrust/Fold Belt may be a detachment that cut to surface to emplace hot basement over cold cover immediately east of the Poorfish-Windy Belt.

In the past, the primary exploration targets in the area have been the Archean supracrustal sequence (especially BIF) and Proterozoic Kinga Formation quartz arenites. Sedimentologic analysis, structural analysis and prospecting during the course of this study have established additional predictive models for future exploration and have suggested a new interpretation for the previously-mined "Shear Lake" and "B zone" gold deposits at Cullaton Lake. Three new first-order exploration targets have been specified:

1) hot spring gold in units subjacent to the Hawk Hill Member;

2) fold hinge zones, cross-faults and thrusts in any unit of the Hurwitz and Kiyuk groups; and

3) Proterozoic detachment surfaces and folds within Archean rocks.

Recognition of Hawk Hill Member cherts as sinter deposits opens the possibility of hot spring mineralization. Although apparently barren of precious metals (as indicated by limited sampling to date) the cherts mark sites of syndepositionally active hydrothermal processes that may have enriched precious metals in subjacent basement and Hurwitz Group. Slightly elevated gold values are in Whiterock Member crackle breccias (subsurface feeders?, 11-460 ppb) and in lowermost Ameto Formation mudrocks (8-25 ppb). In addition, related subsurface hydrothermal processes may have contributed to early diagenetic mineralization in stratigraphically higher units, that was subsequently enhanced by structural processes.

Structural analysis suggests that both the "Shear Lake" and "B-Zone" deposits formed as a consequence of Proterozoic strain possibly remobilizing low-level Archean gold. Systematic measurement of fractures in Kinga Formation quartz arenites has documented trends that are not regionally consistent but reflect heterogeneous strain of both D1 and D2 folds: fractures and cross faults formed due to outer arc extension and inner arc shortening during tangential longitudinal strain. The fractures are sites of pyrite-gold, similar to the "Shear Lake" deposit where joint patterns indicate hinge-zone extension in the outer arc of a D2 fold (A.R. Miller, unpublished data). A genetic relationship between folding, cross faulting, jointing and "Shear Lake"- type mineralization is suggested. The discovery of structurally controlled gold in stratigraphy above the Kinga Formation suggests that any unit in the sequence may host gold-rich shear zones, fractures and quartz veins. Indeed, the highest gold value determined from the present mapping (0.966 oz./ton, 33,100 ppb) is in a grab sample from a quartz-pyrite veined, sheared calcareous arkose of the Watterson Formation.

At the Cullaton B Zone, analysis of subsurface data suggests that chlorite alteration, quartz stockworks, and gold zones in Archean iron formation are spatially restricted to shallowly dipping faults and axial surfaces of folds (A.R. Miller, personal communication, 1989) that are probably Proterozoic in age. Similarly, gold in Archean rocks at Hawk Hill Lake is concentrated in the hinge zone of a Proterozoic fold. Geometric constraints of concentric folding imply intrabasement detachment both as local space-accommodating structures (in fold cores) and as regional-scale structures that balance shortening at depth. Either type of detachment may have localized Proterozoic gold in Archean rocks.

Acknowledgments

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FINAL REPORT ON THE TECTONIC EVOLUTION OF THE HURWITZ GROUP

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Objectives
The purpose of the project was to determine the geological evolution and economic potential of the Early Proterozoic Hurwitz Group. Lateral and vertical variability in the stratigraphic sequence, excellent preservation of primary sedimentary structures, and variation in deformation throughout the preserved basins of the Hurwitz Group rocks made this sequence suitable for a number of focussed studies.

The objectives were:
1)to evaluate the mineral potential of the Hurwitz Group;

2)to enhance all mineral exploration through an improved understanding of the geology of the region;

3)to determine the depositional environments of the Hurwitz supracrustal succession;

4)to determine the age of volcanic rocks underlying the Hurwitz Group and gabbros in the upper parts of the Hurwitz sequence through U/Pb geochronology;

5)to determine the geochemical signature of the Hurwitz Group mafic magmatic rocks and other groups of igneous rocks in the area;

6)to determine the structural style of deformation of the Hurwitz Group and involvement, if any, of underlying basement rocks;

7)to determine the relationship between the Hurwitz Group and the Early Proterozoic Amer Group to the north; and

8)to determine the linkage of Hurwitz Group evolution and the Trans-Hudson Orogen to the south.

The central and southern District of Keewatin was the site of extensive mineral exploration in the late 1980s. The bulk of this activity was focussed on evaluating the potential of the gold-bearing Archean Kaminak Group metavolcanic rocks. These rocks were affected by a pre-Hurwitz Archean deformation and by late Early Proterozoic (Hudsonian) orogenesis which deformed the Hurwitz Group. Knowing the structural style of Hudsonian deformation enables mineral exploration geologists to "peel off" the effects of Proterozoic diastrophism and directly see the Archean structures. This is of greatest significance in interpreting gold deposits which are structurally controlled.

The conglomerates at the base of the Hurwitz Group and underlying Montgomery Group were also assessed with regards to their potential as paleo- placer gold deposits by some mining companies in the late 1980s. The results of this research described herein may directly benefit mineral exploration efforts. Determination of the depositional environments for portions of the Hurwitz Group and other supracrustal successions delineates areas which may contain paleoplacer uraniferous or auriferous deposits.

Methodology
Field work was conducted in the summer of 1988, in four areas shown in figure 1. These areas were selected as most likely to provide study sites suitable to attaining the objectives of the study: relatively undeformed sections for sedimentological measuring, gabbro outcrops to sample for geochronological and geochemical studies, and key areas for resolution of stratigraphic problems. Standard mapping, sampling, and measuring techniques were used in the field. U-Pb geochronological analyses on zircon/baddeleyite were performed in the Deptartment of Geology at the Royal Ontario Museum with Dr. Larry Heaman. Geochemistry of the mafic rocks was done using XRF at a commercial laboratory and Neutron Activation Analysis at the Deptartment of Geology, University of Toronto. Thin sections were cut and examined at the Deptartment of Geological Sciences, Erindale College, University of Toronto.

Results
The most significant results from the research are the interpretations developing from the determination of a U-Pb age on zircon/baddeleyite of 2094 +26/-17 Ma for the gabbro which intrudes the Ameto Formation, Hurwitz Group, in the Padlei Belt (location 4, Fig. 1). Because of the uncertainty associated with the

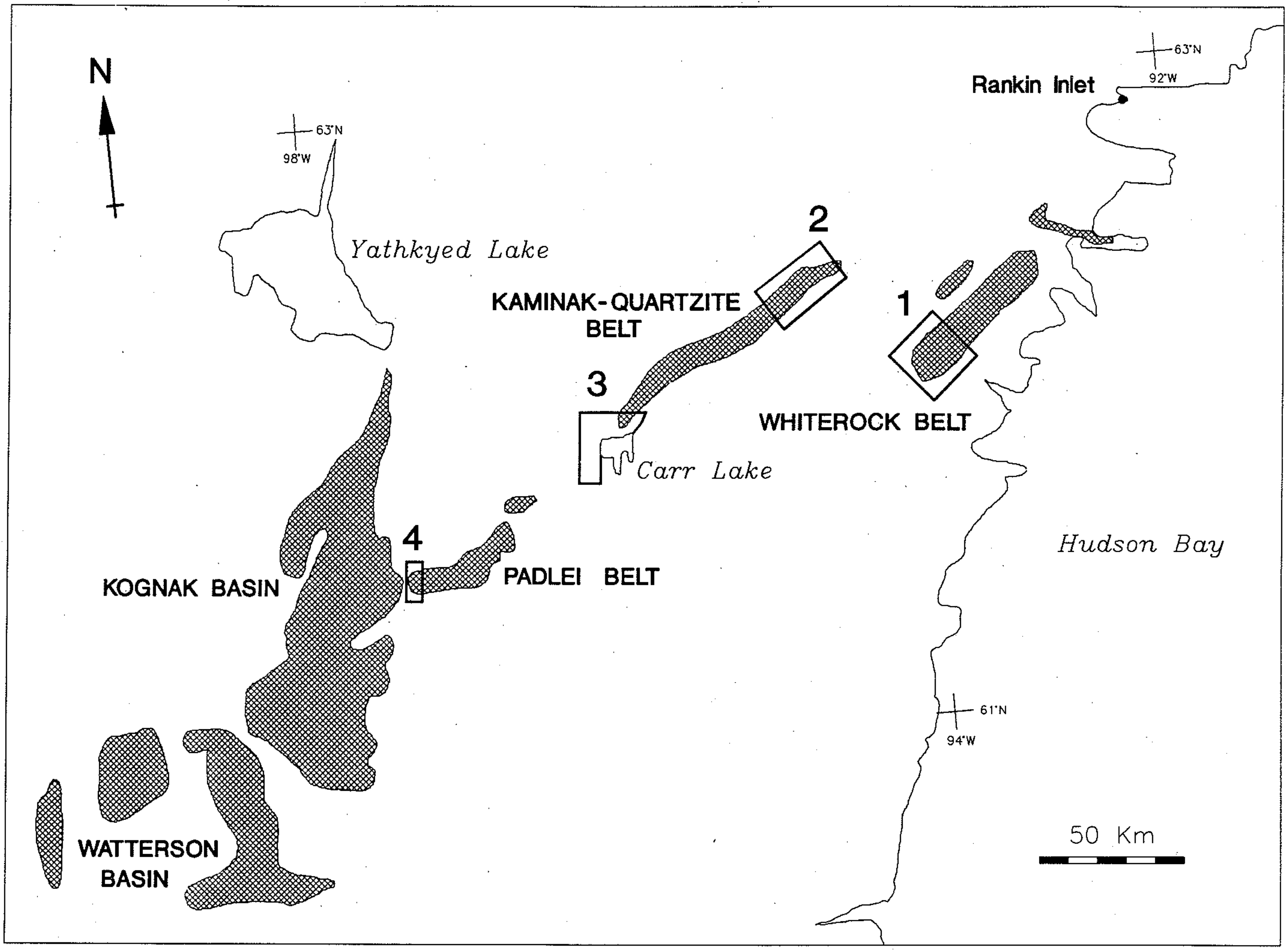

Figure 1. Distribution of Hurwitz Group and the four areas of work in 1988.

complex lead loss history in this sample, this age is considered to be a minimum value. The maximum age could be as old as ca. 2400 Ma, depending on the time of metamorphism. Attainment of this age provides important constraints on the depositional and tectonic evolution of the region in terms of the objectives of the research. As part of the geochronological study, a U-Pb age on zircon from a rhyolite in the Kaminak Group in location 2 (Fig. 1) of 2681 $\pm$ 2 Ma was obtained. This value is slightly younger but similar to U-Pb ages obtained from rhyolites along strike by other workers, and confirms the Archean ancestry of the rocks underlying the Hurwitz Group.

Near Spi Lake (location 3, Fig. 1), a rift sequence was deposited unconformably on the Archean basement either prior to, or contemporaneously with, the basal conglomerate (Padlei Formation) of the Hurwitz Group. This sequence at Spi Lake of basalts and overlying conglomerates is therefore older than 2.1 Ga.

The establishment of the age of the lower portion of the Hurwitz Group and, through correlation, the Spi Lake sequence, as older than 2.1 Ga is of great economic significance. The change in the earth's atmosphere from anoxic to oxidizing occurred between 2.5 and 2.0 Ga. This newly obtained age of 2.1 Ga for the lower Hurwitz and Spi Lake sucessions opens the possibility of the existence of paleoplacer uraniferous deposits in these clastic rocks.

Rift-related Spi Lake conglomerates have their provenance in a gold-bearing granite-greenstone basement, similar to the Witswatersrand type paleoplacer gold deposits, and therefore have the potential to be gold bearing. Quartz pebble conglomerates and polymictic conglomerates of the Padlei Formation show minor concentrations of gold, but are similar in many respects to stratiform gold-bearing deposits in the Huronian Supergroup. Further investigation of the Spi Lake conglomerates, and Padlei and Kinga formations of the Hurwitz Group may lead to the discovery of Witswatersrand or

Transvaal type stratiform gold deposits.

Geochemical analysis of four groups of rocks was done in the course of this study. Mafic rocks of the Kaminak Group show flat rare earth element (REE) patterns, typical of Archean tholeiites. The Spi Lake basalts are very fractionated continental tholeiites. The Kaminak (pre-Hurwitz) dykes are basaltic in composition and chemically have a continental tholeiite signature, based on REE analyses. Gabbros and basalts from the Hurwitz Group appear to be typical continental tholeiites.

Intensity of structural deformation increases from southeast to northwest across the area of study. In the Whiterock belt (location 1, Fig. 1), the Hurwitz Group is preserved in an open syncline. The Hurwitz rocks are highly fractured along the southeast margin, suggesting faulting occurred along the basement/cover contact. Along the northwest margin, some Kaminak basalts are schistose in texture, as are pelitic rocks at the base of the Hurwitz sequence, indicating slippage along this contact. It is not known whether there has been a great deal of transport along this contact, or simply slip along the bedding planes to accommodate folding. In the Kaminak-Quartzite belt (location 2, Fig. 1), basement overthrusts the Hurwitz rocks, verging southeast, and the intensity of deformation is much higher in this belt.

The intrusion of the gabbro sill into the Hurwitz Group at ca. 2.1 Ga occurred nearly 200 million years prior to the earliest magmatism related to onset of Trans-Hudson orogenesis through closure of the Manikewan Sea at 1.91 Ga. Therefore, intrusion of the gabbro is not genetically related to the Trans-Hudson Orogen, but rather, may represent rifting related to the opening of the Manikewan Sea. Determination of the age of the gabbro, and interpretation of the magmatic events as rift-related suggests that the thick, shallow marine quartz arenites of the underlying Kinga Formation are not passive margin deposits, but rather, may have been deposited in a broad intracratonic basin.

Based upon this work, it is possible to make some preliminary comparisons of the Hurwitz Group with the Early Proterozoic Amer Group. Both sequences unconformably overlie an Archean basement. Thick, areally extensive orthoquartzite dominates the lower portions of both sequences, but intense deformation in the Amer Group precludes comparative sedimentology of the two quartzites. In the Amer Belt, carbonate overlies the basal quartzites and is a thick (100-150 m) and widespread unit. Carbonate occurs only sporadically, and at variegated stratigraphic levels, in the observed portions of the Hurwitz Group. In the Amer Group, mafic volcanic rocks are restricted to the core of a narrow syncline along the southeast margin of the Amer Belt, and there is a small mafic intrusion at the southwest end of the Amer Belt. Conversely, the Hurwitz Group is intruded by gabbro sills both along and across strike (locations 1, 2, 3, and 4, Fig. 1) and at location 2, mafic volcanic rocks comprise volumetrically approximately half of the Hurwitz supracrustal rocks. While there are some similarities between the Amer Group and Hurwitz Group, there are obviously significant variations in tectonic evolution of these two groups.

THE IDA POINT GOLD SHOWING, HOPE BAY GREENSTONE BELT, NORTHWEST TERRITORIES

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Introduction
The Hope Bay Greenstone belt is located in the Bathurst Block, in the northeastern part of the Slave Province. Gold mineralization has been recognized in two major zones along the length of the belt:

1) the axial zone consists of a large carbonate-altered shear zone locally cut by auriferous quartz carbonate veins, and

2) the eastern contact zone hosts a series of auriferous quartz-carbonate veins that cut the amphibolite margin of the belt. The belt is regionally metamorphosed to greenschist facies (Gebert, 1990 and in this volume). The Ida Point gold showing belongs to the northernmost tip of the eastern zone; it consists of gold-bearing quartz veins in shear zones at the contact between volcanics and a tonalitic intrusion.

General geology
The main rock units of Ida Point are sequences of pillow lavas and massive flows. They are probably part of a flood-basalt lava sequence as the flows are characterized by their extensive strike length and the vent area is difficult to establish (Gibson, 1990). Top directions are generally towards the east. A 500m wide sedimentary unit, of possible volcanic origin, was found on the west side of the Ida Point Penisula. It corresponds with similar units mapped by Gibbins (1987) in Roberts Bay south of Ida Point. A garnet-rich more-aluminous sediment outcrop of a few metres in apparent thickness is present along with volcaniclastic rocks on the western side of Ida Point. These volcanics are cut by granitoids to the east and by large masses of Proterozoic diabase sills to the west. The area is also cut by several generations of dykes including porphyry, lamprophyre and minor felsic dykes.

Two types of granitoid rocks have be recognized at Ida Point: 1) A large tonalitic intrusion covers the northern tip of the belt. It extends from Ida Point across the inlet to Kuururjuak Point for a distance of 3km. On the mainland, it is present as a 100m by 200m isolated plug. Chemical analyses reveal that the tonalite follows a calc-alkaline trend with high aluminum, sodium and calcium. Contact metamorphism at amphibolite facies has developed for 50m to 100m around its edge on the mainland. 2) The eastern margin of the Hope Bay belt in the vicinity of Ida Point is bordered by a trondhjemitic intrusion. This rock is coarser grained and more siliceous than the tonalite.

Structure
The rocks are structurally controlled by three vertically oriented schistosities:

1) The pillows are symmetrically flattened on a ratio of 5:1 in a north-northwestern pattern. Vertical extension is of similar or greater magnitude.

2) Early north to northwest, steeply dipping, sinistral structures, subparallel to the pillows, cut the volcanic rocks. They show milky white and microsaccharoidal quartz infill and late ductile deformation. This shear zone is assumed to be pre-intrusion because it does not cross-cut the tonalite. Subhorizontal quartz veins, considered to be tension gashes are possibly associated with this first generation shear.

3) Late, northeast, steeply dipping, dextral, brittle structures cut the northwest-sheared volcanics and the tonalite. They contain little quartz and are characterized by intense carbonate alteration overprinting the contact metamorphic assemblages. Therefore this type of shear zone is assumed to be post-intrusion. A relatively low magnetic anomaly determined with a portable magnetometer is associated with the carbonate alteration indicating destruction of primary magnetite.

The tonalite intrusion is weakly foliated at 140 /60 . Blue quartz, sometimes indicative of deformation (Zolensky et al., 1988), is present throughout the intrusion.

Mineralization
Gold mineralization is located in the contact aureole where the tonalitic intrusion is in ductile fault contact with the pillow lavas. Quartz veins in the northwest

structures contain most of the mineralization. Gold is usually present associated with arsenopyrite-rich bands on the margins of the microsaccharoidal quartz or as free gold disseminated in the veins. The veins are discontinuous and show very little vertical extension.

Northwest shear zones are usually chlorite +/- sericite schists with quartz veins and lenses. Sulphide minerals include arsenopyrite, pyrite and minor chalcopyrite. Gold grades range from 0.04 to 3.40 oz/ton. Scanning electron microscope analyses of arsenopyrite reveal an unusually high As content. This may be attributable to Fe depletion and replacement by Au in the crystal structure (Bonnemaison and Marcoux, 1990). A lack of zoning in the arsenopyrite crystal may also indicate its primary nature. Gold grains are usually present with the arsenopyrite either on the edges or inside the grain.

Northeast shear zones and fractures are usually carbonate-rich pencil schist. Where quartz is present, it is bull white with minor chalcopyrite, pyrite and rare arsenopyrite. Gold grades can range from 0.13 to 2.06 oz/ton.

Discussion

Four major events can be established at Ida Point. These points are summarized in the following table.

1. Dominant lateral compression flattened pillow lavas in a northwesterly horizontal direction with strong vertical extension. Fracturing and shearing probably occured at this point. Quartz veining and mineralization in those fractures followed. A metamorphic dehydration model could explain the source of the mineralizing fluids (Kerrich, 1989).

2. Mineralized quartz veins are generally boudined and folded in a sinistral fashion. This indicates recurrent movement on the initial structures. Milky white quartz veins changed by cataclasis to microsaccharoidal quartz is other evidence of this movement. An episode of infilling may have taken place as not all the northwest shears quartz veins are recrystallized. Subhorizontal tension gashes containing chalcopyrite mineralization are also present. Spatial relationships indicate that they formed with the northwest-southeast shearing.

3. The tonalite probably intruded the volcanics at this point. It evidently metamorphosed the surrounding volcanics from greenschist to amphibolite facies as pillow selvages around the intrusion for a distance of 50 to 100m are amphibolitized. Beyond that distance the selvages reflect a carbonate alteration. Small quartz pods with chalcopyrite mineralization are distributed in the intrusion.

4. The latest event was northeast dextral shearing and faulting. These structures cut the volcanics, the mineralized zone and the tonalite. Intense carbonate alteration, minor quartz veining and gold mineralization are present in the structures. These events may be a remobilization effect where movement of hydrothermal fluids was influenced by the tonalite (Peacock, 1989).

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A. GEOSCIENCE PROGRAM

A2. PROJECTS OF THE GEOLOGICAL SURVEY OF CANADA

CONTWOYTO-NOSE LAKES PROJECT, CENTRAL SLAVE PROVINCE

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Objectives
This study was designed in part to contribute to the understanding of the regional structural and metamorphic setting of gold mineralization, and to address the problem of predicting the shape of multiply-deformed iron formations, thereby reducing the costs of drilling them.

Method
Geological mapping at a scale of 1:50,000 was carried out in the area underlain by metaturbidites of the Contwoyto Formation (Fig. 1). Local 1:2,000 mapping was conducted on grids set up by exploration companies. Cleaned outcrops and better location control on these detailed maps have provided essential data on which a large part of the fold interference interpretations are based.

Drill hole data from exploration companies were combined with information from surficial mapping to determine fold plunges and the dips of isograd surfaces in different parts of the study area. Structural data were plotted on equal area stereonets in order to distinguish between structure sets of different generations and determine fold plunges.

Thin sections were examined for metamorphic mineral assemblages and microstructures, to establish the P-T conditions of metamorphism and the relative timing of different structures with respect to porphyroblast growth.

Results
Results of this study which have implications for the exploration of gold-bearing iron formation in the Contwoyto Lake area include the following:

1) Bostock (1980) originally distinguished the Contwoyto Formation from the Itchen Formation by the presence of iron formation in the former. In addition, Bostock (ibid.) pointed out that the metaturbidites of the Itchen Formation are generally more thickly bedded (20-30 cm) than those of the Contwoyto Formation (5-15 cm). Calcium-rich concretions, originally thought to be exclusive to the Itchen Formation (Bostock, 1980), were found during the present study in semipelitic beds adjacent to iron formation in several localities (King et al., in press). The presence of these concretions therefore no longer constitutes a criterion for distinguishing the Contwoyto and Itchen formations, and concretion-bearing metaturbidites should not be overlooked as exploration targets.

   King et al. (1988) noted the presence of 0.5-25 m thick layers of volcanogenic rocks in the Contwoyto Formation, including possible tuffs and pillowed flows in the informally-named Shallow Bay volcanic belt (Lhotka, 1988; Relf, 1989). This volcanic package within the Contwoyto Formation supports the concept of a genetic link between volcanism and the deposition of iron formation.

2) The contact between the Contwoyto and Itchen formations southwest of Contwoyto Lake, originally defined by Tremblay (1976) and Bostock (1980), was relocated on the basis of the discovery of iron formation adjacent to the Central Volcanic Belt east of the Wishbone pluton. All metaturbidites north and east of the Wishbone granodiorite are now included in the Contwoyto Formation. The Contwoyto/Itchen contact west of the pluton has been moved south by as much as 2 km. The area considered to be underlain by the Contwoyto Formation is thus significantly expanded, increasing the potential target area for Lupin-type gold mineralization.

3) Structural studies in the metaturbidites have determined the following Archean deformation sequence: D_1 - pre-thermal-peak isoclinal folds, associated axial planar cleavage, and contraction faults; D_2 - syn-thermal-peak isoclinal folds, associated

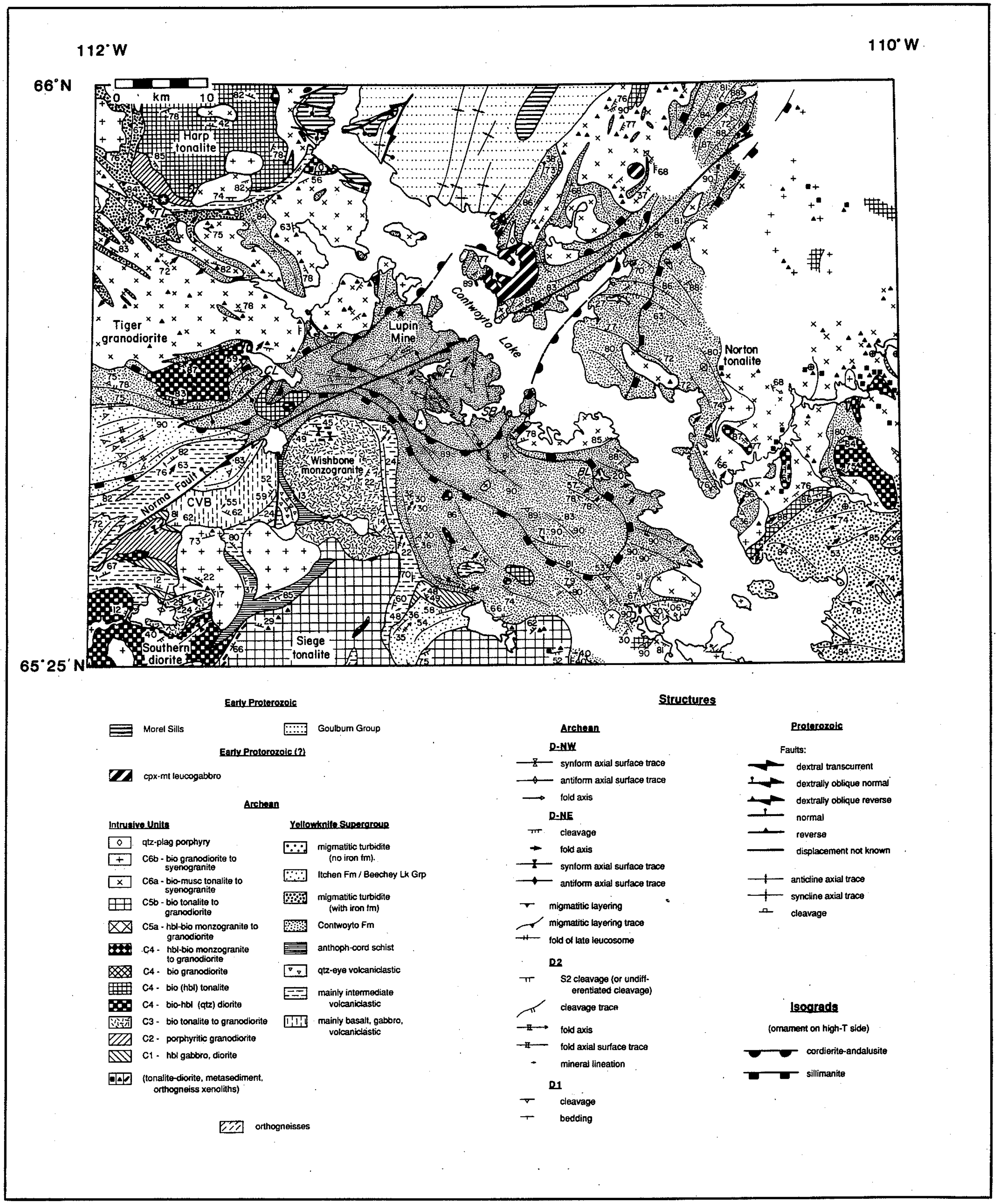

Figure 1. Simplified geology map of the area underlain by the Contwoyto Formation, from King et al. (in press). Abbreviations: CVB-Central Volcanic Belt; bodies of water: BL-Butterfly Lake, CL-Concession Lake; FL-Fingers Lake; SB-Shallow Bay; TL -Tuk Lake. Areas covered by Quaternary deposits are unpatterned.

axial planar cleavage, and contraction faults; D_3 - post-thermal-peak open cross folds and domains of crenulation cleavage. F_3 folds have conjugate northeast- and northwest-striking axial planes. The distinction between structural elements can be made by establishing their relationship to the thermal-peak mineral assemblage. Recognizing folds of different generations is necessary in order to predict fold plunges in a given area, and thus plan drilling strategies.

4) The interference of F_1 and F_2 produced fold patterns between Types 2 and 3 of Ramsay (1967); F_2-F_3 interference produced Types 2 and 3 patterns; and F_{3NE}-F_{3NW} interference produced Type 1 patterns. Through systematic structural mapping, it is possible to predict the three dimensional shape of a multiply-folded iron formation, which may help to reduce drilling expenses.

5) Although there is ongoing debate regarding the relationship between gold and quartz veins at Lupin Mine, the spatial association of gold with "late" quartz veins is undisputed. Five sets of quartz veins have been distinguished in the course of this study, based on the timing of emplacement of the veins with respect to different structures. Those associated with gold at Lupin Mine define en echelon arrays confined to the iron formation. They are oriented between 30° and 50° from the F_2 axial plane, and are locally weakly folded by F_2, suggesting emplacement late syn- to post-D_2. Quartz veins of similar generation elsewhere in the Contwoyto Lake area may be favourable exploration targets.

6) Examination of the distribution of quartz veins in the meta-sedimentary rocks has revealed that they are not spatially related to any single pluton, and that the most volumetrically significant set of quartz veins was emplaced during the thermal peak of regional metamorphism. Foliated tonalite to diorite plutons of the C4 suite (nomenclature of King et al., 1988) are interpreted to have intruded during the thermal peak (Relf and King, 1989), and thus during the emplacement of the bulk of the quartz veins. However, these plutons define thin sheets, and thus do not represent large volumes of magma. The potassic plutons (C6; King et al., 1988) which comprise the largest proportion of exposed plutonic rocks in the area - including the Contwoyto Batholith north of Lupin Mine - were not emplaced until about 25 to 30 million years after the thermal peak. It is therefore inferred that the fluids from which the veins precipitated were primarily metamorphic in origin.

7) A set of 1:50,000 geology maps covering the north part of the Contwoyto Lake sheet (76E) between latitudes 65° 25' and 66° 00' will be released as a GSC Open File during 1992. They will accompany a final report which will summarize the structural history of the Contwoyto Lake area (Relf, in prep.).

Acknowledgements

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BEDROCK MAPPING AND STRUCTURAL STUDIES IN THE TAVANI AREA, RANKIN-ENNADAI GREENSTONE BELT, NWT

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Introduction

The Tavani area is located at the northeastern end of the Rankin-Ennadai greenstone belt, a Late Archean greenstone belt which extends from northern Saskatchewan to Rankin Inlet, NWT, Canada (Fig. 1).

Detailed stratigraphic and structural mapping in the Tavani area (80 km southwest of Rankin Inlet) show a complex depositional and structural history occurring within a relatively short time frame. The

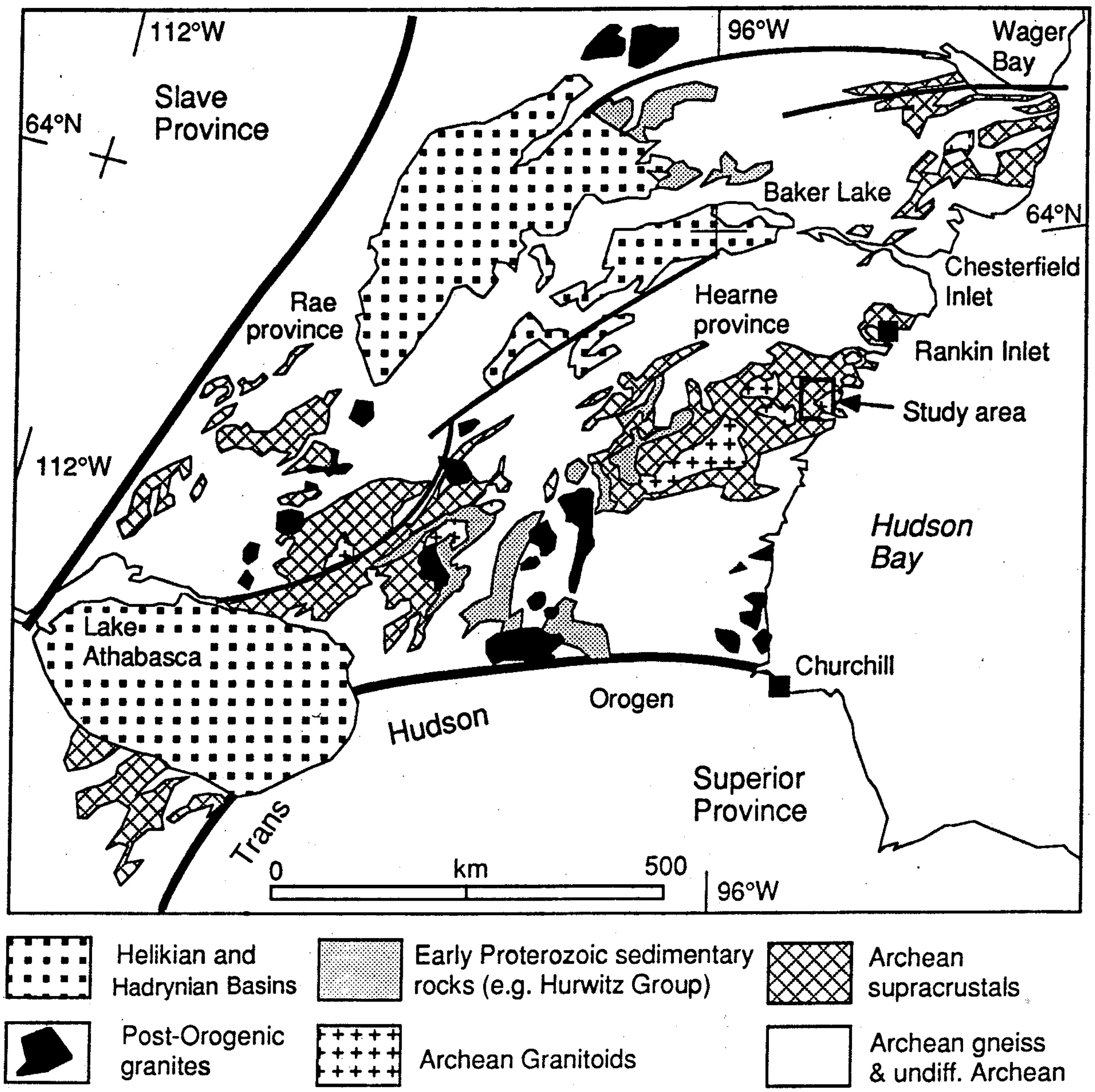

Figure 1. Map showing the extent of the Rankin-Ennadai greenstone belt.

early Proterozoic Hurwitz Group, represented by a quartz arenite succession in the Tavani area, unconformably overlies the Archean greenstone belt.

Objectives and Methods
The objectives of this project were to map parts of 55K/3, 4, 5, and 6 at 1:50,000 scale with emphasis on geochemistry, geochronology, structure, and stratigraphy to provide a better tectonostratigraphic framework for mineral exploration in southern Keewatin. Bedrock mapping was completed over two field seasons (1988 and 1989). Mapping was followed by detailed stratigraphic and structural analysis of specimens collected in the field. Many syn- and post-tectonic granites and some mafic volcanic rocks from the supracrustal sequence were analyzed for both major and minor elements. Geochronological studies were undertaken on subvolcanic and syn- and post-tectonic intrusions from the Gill Lake area in collaboration with Dr. J.C. Roddick (GSC).

Results

Stratigraphy (figures 2 and 3):
The Rankin-Ennadai greenstone belt in the Tavani area is divided into four informal formations, on the basis of either individual facies or associations of facies: Atungag, Akliqnaktuk, Evitaruktuk, and Tagiulik formations. The lowermost Atungag formation is dominated by pillow basalts and massive lavas. The Akliqnaktuk formation consists of a number of facies, with mafic volcanic and volcaniclastic rocks dominating the lower part and felsic volcanic and volcaniclastic rocks dominating the upper part of the formation. Conglomerates (including a granite-boulder conglomerate with mafic clasts) and arenites occur throughout the formation. Individual facies within the Akliqnaktuk formation cannot be traced for any great distances and often recur at different stratigraphic levels. The overlying Evitaruktuk formation consists largely of quartz-bearing turbidites and arkose. The Atungag, Akliqnaktuk, and Evitaruktuk formations form a coherent, mappable stratigraphic package, comprising the Kasigialik group. The Tagiulik formation consists of psammitic and semipelitic, feldspathic and quartz-poor, volcaniclastic turbidites, with magnetite-chert ironstone. The relationship of the Tagiulik formation to the Kasigialik group is allochthonous, and therefore the stratigraphic relation between the two is unknown.

Two suites of Archean gabbros intrude the Atungag formation and the lower mafic portion of the Akliqnaktuk formation. The Kiksautituk suite, the more wide spread of the two suites, consists of diabase, gabbro, and associated diorite, tonalite, and trondhjemite.

The Fat Lake suite consists of porphyritic quartz gabbro and diorite, containing megacrysts of plagioclase (up to 40 cm in size). At 'Fat Lake' the Fat Lake diorite contains gold-bearing quartz veins. Quartz-feldspar porphyries in the Akliqnaktuk formation may be sub-volcanic intrusive rocks related to either the felsic volcanic rocks or the granitoids. Granitoids (granite-granodiorite) throughout the Tavani area are both syn- and post-tectonic. Mafic dykes of both the Kaminak dyke swarm and the Mackenzie Dyke swarm occur in the area.

The early Proterozoic Hurwitz Group overlies the Archean rocks. The Hurwitz Group is represented by two formations: the Kinga Formation, consisting dominantly of a pure orthoquartzite, and the Tavani Formation, consisting of lithic arenites and arkoses.

Structure:
Two major phases of Archean deformation are observed in the Tavani area.

D_1 - D_1 is a progessive event; the early structures are small scale sheath folds in the basal parts of the allochthonous Tagiulik formation which overlies the Kasigialik group. As the D_1 deformation progresses, structures related to the D_1 deformation are best developed in the well bedded Evitaruktuk and Tagiulik formations, where F_1 folds are tight, recumbent, and appear to face west or southwest. These D_1 structures overprint the earlier sheath folds on the decollement between the Kasigialik group and the Tagiulik formation. F_1 folds are recognized on the basis of facing changes in S_2. In the volcanic/ volcaniclastic portions of the sequence (Atungag and Akliqnaktuk formation) D_1 is characterized by bedding-parallel high strain zones. Local D_1 folds are indicated by downward facing (on S_2) pillow sequences.

D_2 - D_2 structures in the well bedded Evitaruktuk and Tagiulik formations are characterized by northeast trending open to tight folds. In the volcanic/ volcaniclastic sequences D_2 is characterized by steeply dipping northeast trending shear zones, and a more regional northeast trending foliation.

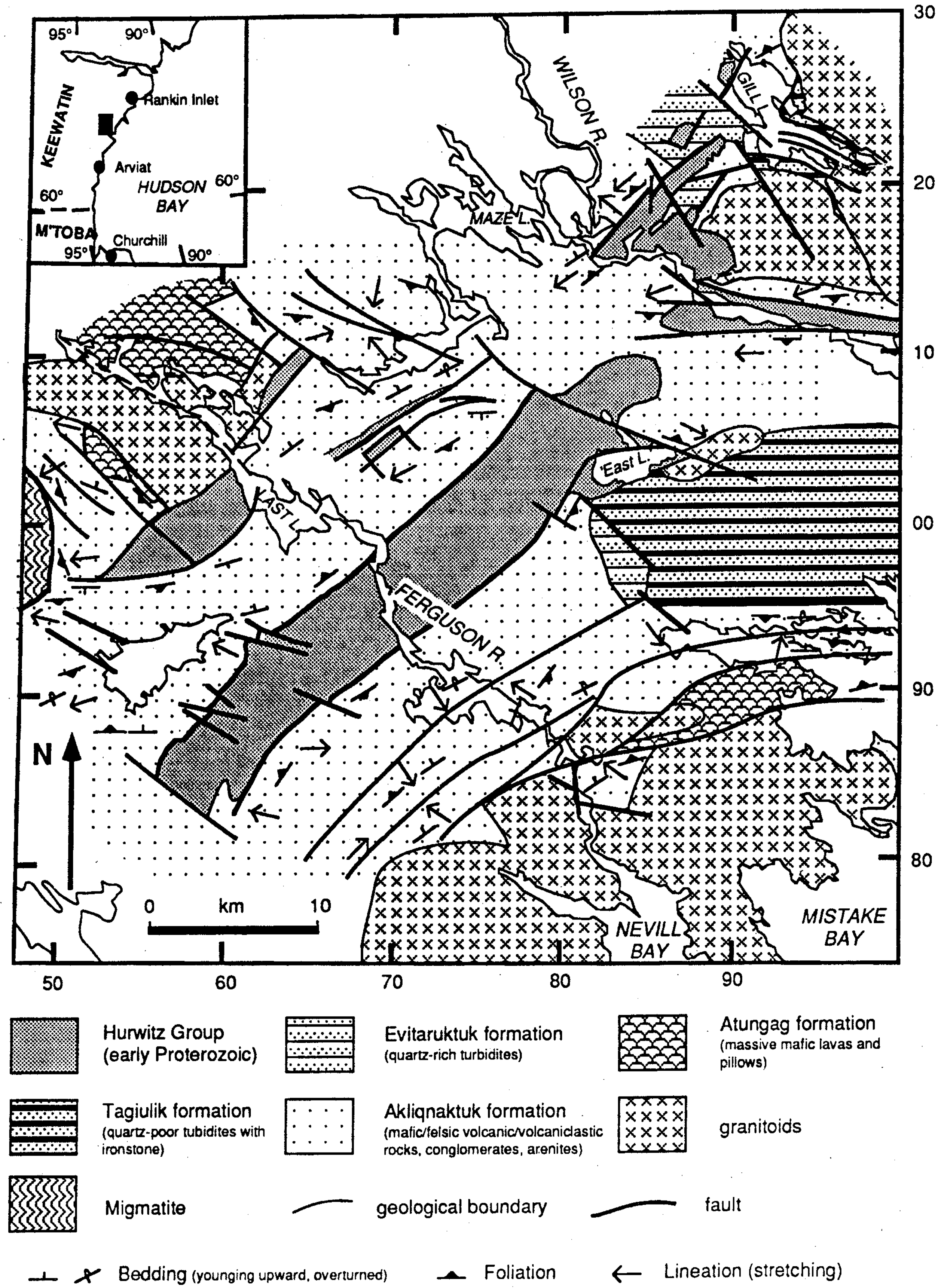

Figure 1. Simplified geological map of the Tavani area, District of Keewatin.

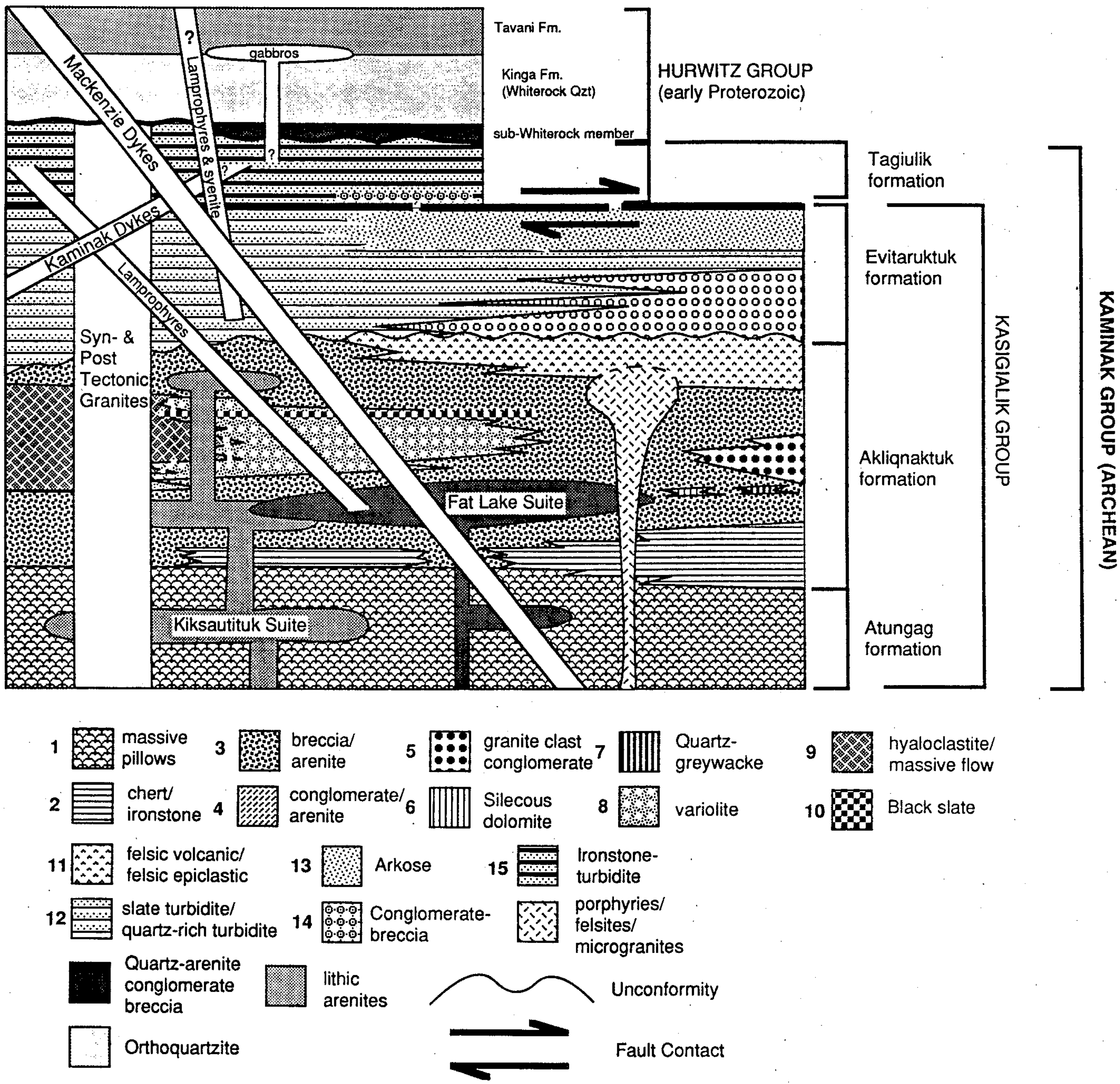

Figure 3. Interactive stratigraphic column showing relations between associations of facies for the Archean Kaminak Group and the Proterozoic Hurwitz Group.

D_3 - D_3 structures primarily affect the Hurwitz Group, and are characterized by predominantly northeast trending folds and faults. Shear zones within the area show a complex movement history (dip-slip and strike-slip, brittle and ductile), with reactivation from the Archean into the Proterozoic.

The metamorphic grade is generally up to greenschist facies with local lower grade assemblages. In the western part of the mapped area a migmatite, which may represent a high grade equivalent of the mafic Archean rocks, was emplaced from the west.

Geochronology:
The age of the supracrustal sequence in the Tavani area is unknown. However in the Rankin Inlet area felsic volcanism is dated at 2629 Ma (Tella et al.,

1990), and approximately 40 km west of the Tavani area a rhyolite is dated at 2681 $\pm$ 3 Ma (U-Pb zircon, Patterson and Heaman, 1990). Granites in the Gill Lake area are used to constrain the age of the deformation. The North Gill Lake granite is dated at 2677 $\pm$ 2 Ma (U-Pb zircon). The margins of this granite contain the S_1 foliation. The East Gill Lake granite is dated at 2666 $\pm$ 2 Ma (U-Pb zircon; 2666 $\pm$ 3 U-Pb sphene). This granite was intruded during a syn-to post-D_2 event. A deformed quartz-feldspar porphyry is dated at 2666 $\pm$ 9 (U-Pb zircon). The South Gill Lake granite, the youngest of the three granites, is post-tectonic, and its age is poorly constrained in the range 2645-2690 Ma (U-Pb zircon).

Conclusions

The geological history of the Archean rocks in the Tavani area can be summarized as follow:

a) *Depositional history:*
The Atungag formation, represented by gabbros, marks the local depositional basement. The Akliqnaktuk formation represents detritus from growing submarine mafic volcanic edifices, with both proximal and distal facies present. A granite boulder conglomerate within the mafic volcaniclastic portion of the Akliqnaktuk formation represents detritus from a presently unknown source. These edifices are capped by felsic volcanic and epiclastic rocks. The source for the felsic volcanic rocks is unknown. The Evitaruktuk formation represents reworking of the felsic cap and burial of the volcanic complex. The Tagiulik formation represents reworking of mafic to intermediate volcanic meterial, but its depositional basement and its relationship to the rocks of the Kasigialik group are unknown.

b) *Tectonic history:*
The first stage of deformation begins with the emplacement of a nappe, from the north or northeast, containing the Tagiulik formation, on to the rocks of the Kasigialik group. Deformation was initially localized close to the decollement surface, but became more widespread, affecting both the nappe and the basement. This deformation, in the Tavani area, cannot be older than 2677 Ma (the age of the North Gill Lake granite, which contains the S_1 foliation). The second phase of deformation involved widespread development of northeast-southwest trending shear zones and open, upright folds. The quartz porphyry dated at 2666 $\pm$ 9 Ma contains the S_2 foliation and therefore gives a maximum age for D_2. A number of granitoid complexes and the migmatite were emplaced during this time. The post-tectonic south Gill Lake granite (with a 2645-2690 Ma range) records a minimum age for the Archean deformation.

The U-Pb geochronology shows that deposition of the sedimentary sequence and subsequent deformation may have occurred within a timespan of less than 20 million years, and that deformation occurred at different times in different parts of the greenstone belt. Such time scales for deposition and deformation are comparable with those of modern island arcs.

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MAPPING AND GEOCHRONOLOGY IN THE BAKER LAKE REGION

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Objectives
The purpose of the project was to map and sample selected units in the Baker Lake region for U/Pb and Nd/Sm isotopic studies. Emphasis was placed on establishing the age of supracrustal rocks with high potential for base metal and precious metal mineralization. An integral part of the project after 1988 was follow-up mapping to assist in interpretation of the Whitehills-Tehek lakes area aeromagnetic gradiometer survey (report by D.J. Teskey, this volume). In addition to defining new exploration targets, the study was designed to assist regional geological interpretation and to improve metallogenic and tectonic models.

Methods
Samples for isotopic studies were collected during 1987 and 1988 mapping of supracrustal belts in the Schultz Lake map area. Also, in 1988, work was focussed along the margins of epicontinental basins west of Baker Lake. Mapping in 1989 and 1990 provided structural and stratigraphic information for the Whitehills-Tehek lakes area. The 1989 field work was MDA-funded and mapping was continued in 1990 using regular Geological Survey of Canada (GSC) funds. Special attention was paid to establishing the structure and continuity of Archean banded iron formation associated with metagreywacke and a bimodal suite of metavolcanic rocks. Geochronology samples were prepared and analysed at the Royal Ontario Museum (ROM) and GSC geochronology laboratories.

Results

Mapping:
1987 work in the Schultz Lake area was primarily within an Archean supracrustal belt (Ketyet Group) made up of polydeformed metagreywacke, mafic and felsic metavolcanic rocks and orthoquartzite. Anomalous Au occurs in structurally controlled quartz veins, in pyritic rhyolite tuff and in thin bands of sulfide-rich iron formation. In areas of poor outcrop, composite potential field maps are useful for tracing shear zones and helping to interpret structure in complexly folded supracrustal rocks. Regional aeromagnetic, gravity and gamma-ray spectrometry data from the Baker Lake and Wager Bay areas were displayed as individual and composite maps at the 1988 GSC Forum; images were correlated with existing geological knowledge.

In 1988, mapping concentrated on the northern margin of the Baker Lake Basin and the southeastern margin of the Thelon basin. Exploration interest was peaked by analogy to Coronation Hill Au-PGE mineralization in Australia, which is associated with uranium (U) showings in continental volcanic and sedimentary rocks. No significant Au-PGE showings were discovered. In the Schultz Lake area, steeply-dipping successions of 1.85 Ga alkaline volcanics and volcaniclastic sedimentary rocks overlie a strongly deformed granitoid basement. The 1.85 Ga rocks and the basement were extensively weathered prior to felsic volcanism at 1.76 Ga. Weathering continued after extrusion of the rhyolitic flows. Silcrete caps were superimposed on earlier regoliths prior to deposition of Thelon Formation sandstone.

In the Dubawnt Lake area, Archean basement rocks underlie continental sedimentary and volcanic rocks of the Dubawnt Group. Thick, syndepositionally- faulted conglomerate sequences are exposed in an extensional basin centred on Dubawnt Lake. Flat-lying rhyolites, conglomerates and sandstones unconformably overlie the faulted conglomerates and underlying basement. Saprolitic regoliths are preserved beneath the flat-lying successions.

1989 and 1990 mapping in the Whitehills-Tehek area, aided by aeromagnetic vertical-gradient maps, helped to place iron formation-hosted gold mineralization into a regional tectonic setting. Several horizons of iron formation with associated mafic-ultramafic flows can be traced discontinuously from Whitehills to Tehek lakes. Structural development of the area probably began with early low-angle faulting, that obscures the original stratigraphy. The structural geometry and stratigraphy is complicated by three or four superimposed fold sets. Deformation is almost entirely late Archean in age. The supracrustal belt is intruded by post-kinematic 2.6 Ga granites. Gold mineralization occurs in iron sulphide-magnetite-quartz bearing iron formation in contact with chemically altered and foliated ultramafic rocks. Exploration drilling showed that high gold values occur in nearly vertical beds of iron formation which form the hinge of a recumbant fold.

U-Pb isotopic studies:
Emplacement ages for monzogranites from Dubawnt Lake and Schultz Lake provide additional evidence for extensive 2.58-2.61 Ga Archean felsic magmatism in central Keewatin. Megacrystic granites, intruded at 2610, 2605 and 2595 Ma, and high-level porphyries, emplaced at 2610 and 2581 Ma, are coeval with plutonic events in the eastern Slave Province. Metamorphosed basic dykes and gabbro stocks that intruded greywackes of the Ketyet Group and the Archean metaplutonic rocks contain trace amounts of zircon-rimmed baddeleyite. Gabbro sills, emplaced into metasedimentary rocks southwest of Whitehills Lake at 2151 Ma, may be coeval with gabbro sills in the Amer and Hurwitz groups.

Mantle-derived mafic magmas are thought to be important in generating voluminous 1.75-1.76 Ga rhyolites and rapakivi granites emplaced during late-stage development of Dubawnt Group extensional basins. U-Pb zircon systematics and Nd isotopic evidence indicate the source region was dominated by 2.6 Ga or older continental crust. A U-Pb baddeleyite age for the McRae Lake gabbro dyke, which intruded the rhyolites, is almost concordant at 1750 Ma. The age confirms that mafic magmatism was closely linked to the felsic magmatism and supports the interpretation that the high-silica magmas originated by crustal melting when mantle-derived mafic magmas rose into the crust during extension.

Many Mackenzie dykes transect the Thelon and Athabasca basins and some are spatially linked to uranium mineralization. In the Schultz Lake area, a large Mackenzie dyke cuts the mineralized zone of the Kiggavik uranium deposit. U-Pb ages for Mackenzie dykes were obtained to establish the temporal relationship between uranium mineralization and dyke emplacement and to confirm that the dyke swarm is linked to the Cr-, Ni-, Cu- and PGE-rich Muskox intrusion. U-Pb baddeleyite fractions from four widely-spaced Mackenzie diabases plot on a single discordia line with an upper intercept age of 1267 ± 2 Ma. The age of the Muskox intrusion was determined to be 1270 ± 4 Ma. The results confirm the Muskox -Mackenzie linkage and provide the first precise age for the Mackenzie igneous events. Uranium mineralization events in both the Thelon and Athabasca basins occurred close to the time of dyke emplacement. Mineralization patterns probably reflect both short-term thermal effects and long-term changes in fluid circulation patterns.

Nd/Sm isotopic study:
Analyses of rocks from the Baker Lake region (previously dated by U-Pb zircon) were undertaken to determine the extent of Archean crust in central Keewatin. Thirteen widely-spaced Archean and Early Proterozoic granitoid rocks have Archean crust formation ages (T_{DM}) of 2.5-2.9 Ga. Rocks from the Rae and Hearne provinces have similar isotopic signatures, suggesting that their proposed boundary, the Snowbird tectonic zone, separates terranes with similar crustal histories. Proterozoic rocks from Baker Lake are distinct from rocks of the Trans-Hudson orogen and Taltson magmatic zone in having no Proterozoic mantle component, and suggest that formation of the Snowbird tectonic zone did not involve closure of a major Proterozoic ocean basin.

MYSTERY ISLAND INTRUSIVE SUITE AND ASSOCIATED ALTERED AND MINERALIZED ROCKS, ECHO BAY, DISTRICT OF MACKENZIE, NWT

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Introduction
The Mystery Island intrusive suite comprises several sheet-like plutons of intermediate composition which intrude andesitic stratovolcanoes within the 1.87 Ga Great Bear Magmatic Zone of Wopmay orogen. The plutons have haloes of altered wallrock comprising three zones: albite, magnetite-actinolite-apatite, and pyrite. Interest in magnetite-actinolite-apatite deposits has increased significantly in recent years due to the discovery and development of the Olympic Dam and related deposits, South Australia. Magnetite-actinolite-apatite mineralization in the Echo Bay area and elsewhere in the Great Bear Magmatic Zone is a current exploration target for silver and uranium.

Pitchblende and native silver (Ag)-bearing veins in the Echo Bay area are spatially associated with plutons of the Mystery Island intrusive suite and their altered wallrocks. Although more than two million ounces of silver and over 14 million pounds of U_3O_8 have been mined from the Echo Bay area, the origin of the mineralization remains obscure. Spatial and temporal relationships between the Mystery Island intrusive suite, altered and mineralized wallrocks, and pitchblende-native Ag-nickel (Ni)-cobalt (Co) arsenide-bearing veins, as outlined during this project, are essential in understanding the geological history of mineralization in the Echo Bay area. These relationships provide an empirical guide for further mineral exploration.

Objectives
The principal objectives of this study were: 1) to map and sample the plutons of the Mystery Island intrusive suite and associated alteration haloes in the Echo Bay area, 2) to understand the formation of the alteration haloes, and 3) to determine the relationship between the plutons, alteration haloes and pitchblende - native Ag-Ni-Co arsenide-bearing veins. This was accomplished by:

- compilation and assessment of available geological information for the Echo Bay area.

- 1:15 000 scale mapping of the Mystery Island intrusive suite, associated alteration haloes, and quartz veins in the Echo Bay area.

- determination of mineral textures, paragenesis and composition in altered and mineralized (magnetite-actinolite-apatite) zones of the alteration haloes.

- characterization of the nature and origin of hydrothermal fluids, and estimation of the extent of water-rock interaction during alteration using oxygen and hydrogen stable isotope data for both whole-rock samples and mineral separates.

- determination of spatial and temporal relationships among the plutons, associated alteration haloes, and pitchblende - native Ag - Ni-Co arsenide-bearing veins.

Methods
Fourteen weeks of field mapping at 1:15 000 scale and sampling of the plutons of the Mystery Island intrusive suite, altered and mineralized wallrocks, and quartz-carbonate veins in the Echo Bay area was completed during 1988 and 1989 (Reardon, 1989; 1990). In appropriate areas, outcrop scale mapping of actinolite-magnetite-apatite vein/altered wallrock relationships was completed. A map of the area at 1:25 000 scale, showing the distribution of alteration in the Echo Bay area, and an accompanying report will be released as a GSC Open File during 1992 (Reardon, 1992).

Forty whole-rock hydrogen and 150 whole-rock oxygen isotope analyses of the plutons of the Mystery Island intrusive suite and their altered wallrocks were completed. In addition, mineral separates were prepared for representative magnetite-actinolite-apatite zone veins and breccias. Nineteen hydrogen isotope analyses of amphibole, talc, epidote, and biotite; 35

oxygen isotope analyses of quartz, feldspar, magnetite, amphibole, apatite, epidote, talc, and biotite. Thin sections were prepared for all samples for which isotopic analyses were completed.

Results

Excellent exposure of the plutons and their altered wallrocks in oblique cross-section allowed a unique assessment of geologic, geothermal and geochemical variations with depth. The results of this study are the first of their kind for intermediate magmatic - hydrothermal systems.

All of the plutons of the Mystery Island intrusive suite are characterized by alteration haloes, primarily above their roofs, but also within and below the plutons locally. Three zones of altered rock were mapped:

1) an albite zone within and adjacent to the plutons characterized by pervasive replacement of the rocks by albite;

2) a magnetite-actinolite-apatite zone generally present at some distance above the pluton roofs and characterized by actinolite-magnetite-apatite veins, pods, hydrothermal breccias and replacement; and

3) an outer pyrite zone of disseminated pyrite, and pyrite veins and pods.

A chalcopyrite subzone, beyond the pyrite zone, was mapped in the Port Radium area. The zones are somewhat irregular, and overlap of two or all of the zones is common. Alteration is generally more pronounced within sedimentary units, which may be due to differences in composition and permeability. The greatest concentration of pitchblende - native Ag - Ni-Co arsenide-bearing veins is found where the magnetite-actinolite-apatite and pyrite zone overlap, within sedimentary units. However, although pitchblende - native Ag - Ni-Co arsenide-bearing veins are *spatially* associated with the plutons of the Mystery Island intrusive suite and their altered wallrocks, they are not related temporally. Both the plutons and their alteration haloes are displaced by the faults in which both unmineralized and mineralized veins occur. Cross-cutting relationships indicate two periods of activity in these fault systems, the later veins being mineralized (Jory, 1964; Robinson, 1971). This younger period of veining postdates the 1.67 Ga (Bowring and Ross, 1985) Hornby Bay Group (Furnival, 1939), and thus is much younger than the plutons and alteration haloes (Hildebrand, 1988; Reardon, 1990).

Mapping also revealed new outcrops of the Cameron Bay Formation at Contact Lake. Above a local unconformity, a pebbly conglomerate contains fragments of altered and mineralized andesite and as much as 5% 1 to 2 mm rounded quartz grains.

This indicates that the altered and mineralized rocks, and possibly a pluton of the Mystery Island intrusive suite (a source for the quartz), were exposed before deposition of part of the Cameron Bay Formation, a relationship found elsewhere in the area by Hoffman et al. (1976) and Hildebrand (1981).

Paragenesis of the minerals in veins and breccias indicates that magnetite was deposited first, but possibly in two generations: before and during actinolite deposition. Apatite, where present, is typically a late mineral. Textures observed in altered and mineralized zones indicate that alteration occurred by replacement, veining, and brecciation. Magnetite is invariably altered either partly or entirely to hematite. Actinolite is chloritized and, in at least two veins, altered to talc. Minor amounts of sphene and carbonate were present in all vein and breccia samples studied in thin section.

Petrographic studies indicate that pervasive propylitic alteration of wallrocks; feldspar is altered to sericite, secondary albite and epidote; ferromagnesian minerals are altered to chlorite with lesser calcite and magnetite. Saussuritization of feldspars within the plutons occurs locally. Within the albite zone, the rocks are replaced by granular albite. Regional metamorphism is subgreenschist.

Whole-rock $\delta^{18}O$ range from +5.3 to +11.7 for altered andesitic lavas, volcaniclastic rocks and intrusive porphyries, and from +5.7 to +12.3 for the plutons. δD range from -56 to -92 for andesitic lavas, volcaniclastic rocks and intrusive porphyries, and from -57 to -83 for the plutons. These data indicate that the rocks are hydrothermally altered, and rule out a *dominantly* meteoric geothermal system and high water/rock ratios, since most $\delta^{18}O$ and δD are higher than +6.0 and -70, respectively. The data are comparable to those from geothermal systems in which the fluids are magmatic water and evolved seawater or highly-evolved meteoric water (see Taylor, 1987), although lower δ-values indicate a higher meteoric input locally. Stable isotope data for mineral separates of actinolite -80.3 to -53.4; biotite -112.2; epidote -98.1; and talc -55.05 support these conclusions. Sulphur isotope data, yet to be completed, will indicate the significance of magmatic input to the system.

The determination of pressure, temperature and fluid composition during alteration and mineralization, and of the effects of late quartz-carbonate veins on pluton-related alteration is in progress.

Conclusions

Field and laboratory studies carried out in this project indicate that:

1) all of the plutons of the Mystery Island intrusive suite have alteration haloes.

2) three zones of altered rock are present: 1) an inner albite zone; 2) a intermediate magnetite-actinolite-apatite zone; and 3) an outer pyrite zone (and chalcopyrite subzone in the Port Radium area).

3) the presence of hydrothermal breccias, zoned alteration haloes, wallrock replacement and the stable isotope data indicate formation of actinolite-magnetite-apatite mineralization by hydrothermal processes. Isotope data also indicate that the fluids involved were magmatic and evolved seawater or evolved meteoric water.

4) pitchblende - native Ag - Ni-Co arsenide-bearing veins are spatially, but not temporally, associated with the plutons and their altered wallrocks.

5) the greatest concentration of pitchblende, native Ag, Ni-Co arsenide veins is present where the magnetite-actinolite-apatite and pyrite zones overlap, particularly within sedimentary units.

Acknowledgements

Isotope analyses and sample preparation were supported by an NSERC research grant to Bruce Taylor. Thanks is extended to DIAND and many of the staff at the GSC in Ottawa, especially Richard Lancaster, Guy D'Arcy and Gerry Gagnon for their invaluable assistance; to John Sekerka for mass spectrometer analyses of isotope samples; to CEGB for, well, lots of things; and to my assistant, Stéphane Lagacé.

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THE MARGINAL ROCKS OF THE MUSKOX INTRUSION

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Objectives
The Muskox intrusion is a large layered intrusion in the late Proterozoic **Coppermine River - Mackenzie - Muskox** magmatic system, located south of the Coronation Gulf in the Northwest Territories of northern Canada (Fig. 1). The strong demand for platinum group metals (PGE) and the presence of anomalous PGE values makes the Muskox intrusion a potentially important host for PGE reserves. The objective of this MDA project was to study the interaction between the magmas of the Muskox intrusion and its host paragneiss with an aim towards understanding its implications for the localization of sulfide mineralization along the margin of the Muskox intrusion.

Methods
The north-plunging structural attitude of the Muskox intrusion presents a continuous stratigraphic section of the contact between paragneiss country rocks and magmas of the intrusion from a narrow keel dyke in the South to a large layered intrusion in the north. south of the Coppermine river, the Muskox intrusion consists of a zoned dyke approximately 200 metres in width which has vertical contacts with its host paragneiss. North of the Coppermine River the intrusion opens into a funnel-shaped magma chamber consisting of layered cumulates which reaches more than 5 km in width at its northernmost extremity.

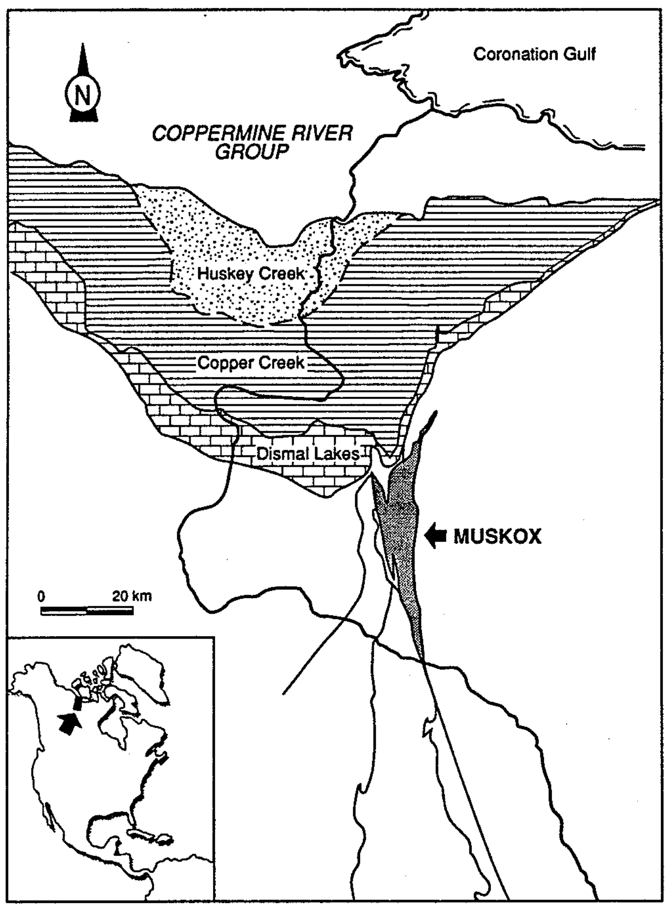

Figure 1. Location of the Muskox intrusion.

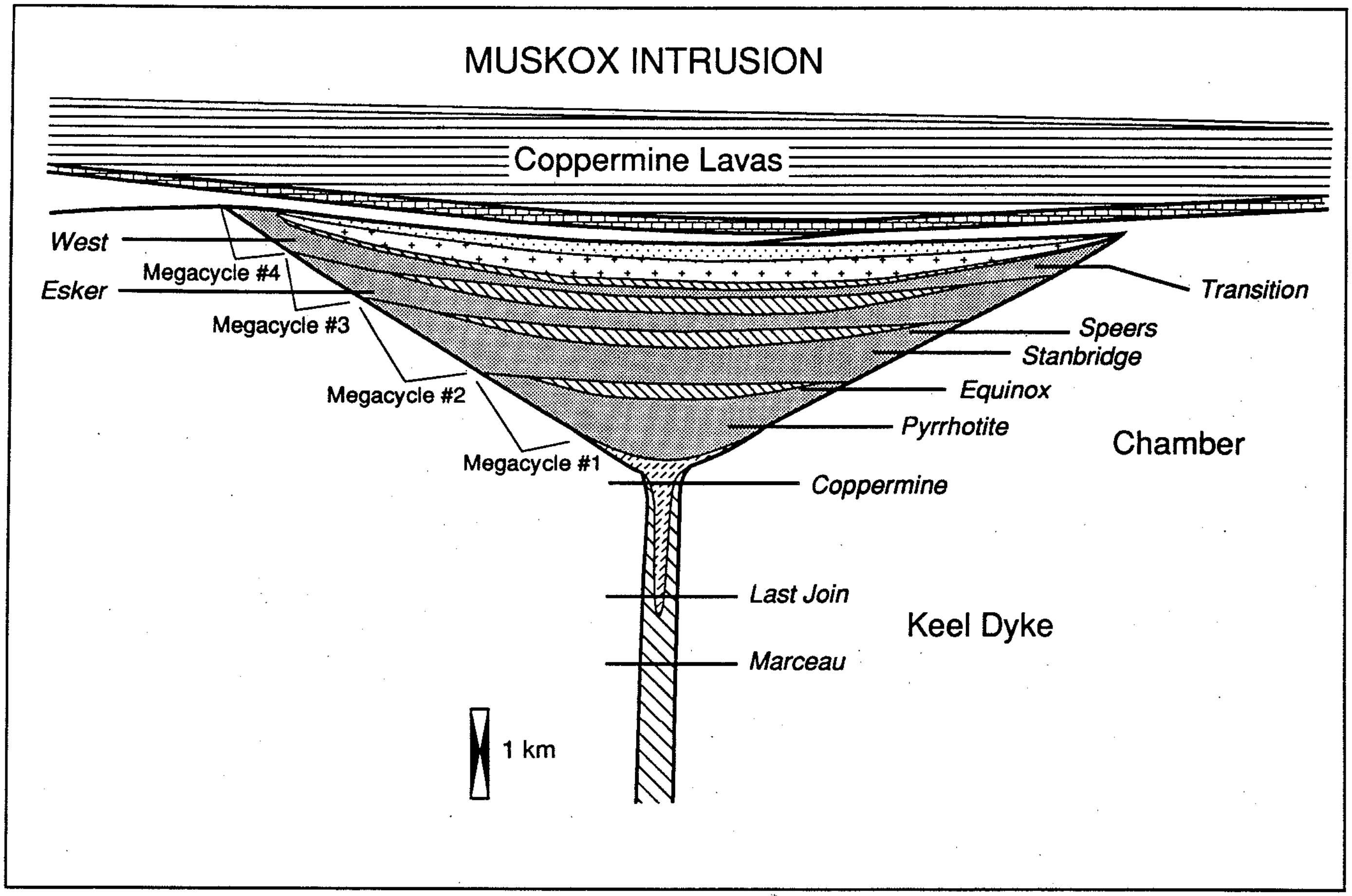

Figure 2. Composite cross section of the Muskox intrusion showing four megacycles and localities where sections through the intrusion were studied.

The approach used in this study was to undertake a systematic lithochemical sampling of the marginal rocks across 10 sections of the contact distributed over the entire exposed stratigraphy of the Muskox intrusion (Fig. 2). Individual sections extended at least 50 metres into the intrusion and 25 metres into the adjacent paragneiss, with sample spacing varying from less than 1 metre near the contact to 5 metres at the most distant points. All the collected samples were analyzed for 11 major elements and 11 trace elements by X-ray fluorescence and selected samples were analyzed for rare earth elements (REE), Sc, Th, U, Hf, and Ta by neutron activation and PGE by a combination of fire assay and neutron activation (Francis, 1990). In addition electron microprobe analyses were performed on olivines and pyroxenes of selected samples.

Results

As much of the case for the nature of the interaction between the magmas and the host rock of the Muskox intrusion is drawn from the differences between the marginal rocks of the keel dyke and those of the main magma chamber, the following is so divided.

Keel Dyke

The dyke extending south of the Coppermine River from the Muskox intrusion (Fig. 1) represents the lateral extension of the keel dyke (Fig. 2) of the intrusion (Smith et al. 1966).

The dyke is bordered on both sides by a homogeneous outer zone (about 20 m) of fine grained norite which locally exhibits plumose quench-textured pyroxenes at its outermost contact. Going into the intrusion, this zone gives way to a 50 m wide heterogeneous gabbro-norite zone of magmatic breccia with the first appearance of equant olivine grains and rounded gabbro-norite fragments ranging from a few centimetres to a metre in size.

Within 1 metre of the keel dyke, the adjacent paragneiss are converted to hornfels which at the contact became remobilized, and is continuous with narrow felsite veins which cut the norite of the keel dyke. In the outermost veins, quartz and feldspar retain the granular shape which characterises the hornfels, but farther into the keel dyke they take on an igneous texture characterized by the presence of granophyric intergrowths of quartz and potassium feldspar, disseminated sulfides, and bladed opaques. Sulfides within the keel dyke are relatively rare and tend to occur as disseminated grains in infrequent gabbro-norite fragments which occur preferentially along both contacts of the gabbro-norite magmatic breccia zone and in the veins of melted country rock which cut the fine grained norite margin of the intrusion. The dominant sulfide in the gabbro-norite fragments is pyrrhotite, but chalcopyrite is noticeably more abundant in the veins of melted country rock.

Chamber

The layered series of the magma chamber of the Muskox Intrusion can be divided into four megacycles on the basis of the mapping of Smith et al. (1966) (Fig. 2). Each megacycle begins with a thick olivine cumulate which becomes interbedded with cyclic pyroxenite layers up section and finishes with gabbro cumulates. Megacycles 1 through 3 are dominated by olivine cumulate dunites while Megacycle 4 is dominated by gabbro cumulates. In megacycles 1 and 2, the pyroxenite layers grade from olivine clinopyroxenite at their bases to clinopyroxenite and the final gabbro is troctolitic. The crystallization sequence is olivine followed by clinopyroxene, plagioclase and finally orthopyroxene. In megacycle 3, however, initial clinopyroxenite layers are replaced up section by websterite layers as orthopyroxene becomes the third phase to crystallise. In megacycle 4, the first pyroxenite layers are websterites in which orthopyroxene crystallizes before clinopyroxene. Irvine (1970) has interpreted this up section change in crystallization sequence to contamination from the granophyric melt rocks developed along the roof the magma chamber.

The marginal rocks of the chamber also exhibit a systematic evolution up section in the Muskox intrusion. In megacycle #1 (Pyrrhotite Lake and Equinox sections, Fig. 2), the outermost zone consists of norite characterized by euhedral orthopyroxene and an abundance of interstitial granophyric patches of quartz and potassium feldspar. Unlike the norite zone of the keel dyke, however, that of the magma chamber is heterogeneous and not significantly finer grained than the interior of the intrusion. It is typically strongly zoned with the modal proportion of clinopyroxene increasing rapidly towards the interior of the intrusion. The norite zone changes abruptly to gabbro-norite with the appearance and rapid increase in abundance of olivine at the expense of clinopyroxene. This marginal zonation is progressively telescoped towards the contact as one rises stratigraphically. The width of the olivine-free norite zone decreases from 3^{+}m in the Pyrrhotite section to less than 0.5 metres at the level of the Equinox section. This telescoping continues in succeeding megacycles such that the norite zone in Megacycle #2 is less than 0.2 metres at the level of the Speers Lake section and is absent through most of megacycles #3 and 4 where picrite and feldspathic peridotite are found directly in contact with country rock migmatites.

Local exceptions exist, however, such as the 7 m thick lens of norite along the western margin of Megacycle #3 in the Esker section (Fig. 2).

The paragneiss directly in contact with the norite of the magma chamber appears to have melted to produce a thin zone of plagioclase porphyritic diorite which is characterized by the dominance of phlogopite as the mafic mineral and the presence of abundant granophyric intergrowths of quartz and potassium feldspar. In places, plumose arborescent orthopyroxene has nucleated on the contact with the norite of the intrusion, while in others the contact is lined with pegmatitic plagioclase. Within a meter, the plagioclase porphyry grades outwards to a feldspar porphyroblastic migmatite with disseminated spinel inclusions in feldspar and then (4-5m) to paragneiss which retains the original metamorphic foliation of the country rock.

Many of the norite marginal rocks of the magma chamber, the plagioclase porphyry, and migmatized rocks of the enclosing paragneiss contain abundant sulfides which occur as blebs and pockets of massive sulfide consisting dominantly of pyrrhotite. The sulfide content of the picritic and feldspathic peridotite farther into the intrusion is, however, very low.

Evidence for contamination

The compositions of the fine grained norite margins of the keel dyke are very similar to those of the more primitive Mackenzie dykes and the reported compositions of Coppermine River lavas (Dostal et al., 1983). The noritic rocks in the chamber margins, however, are enriched in normative orthopyroxene, large ion lithophile (LIL) incompatible elements such as K and Rb, and in Th, U, Pb, and S compared to the norite margins of the keel dyke, despite their generally higher Mg, Cr, and Ni contents

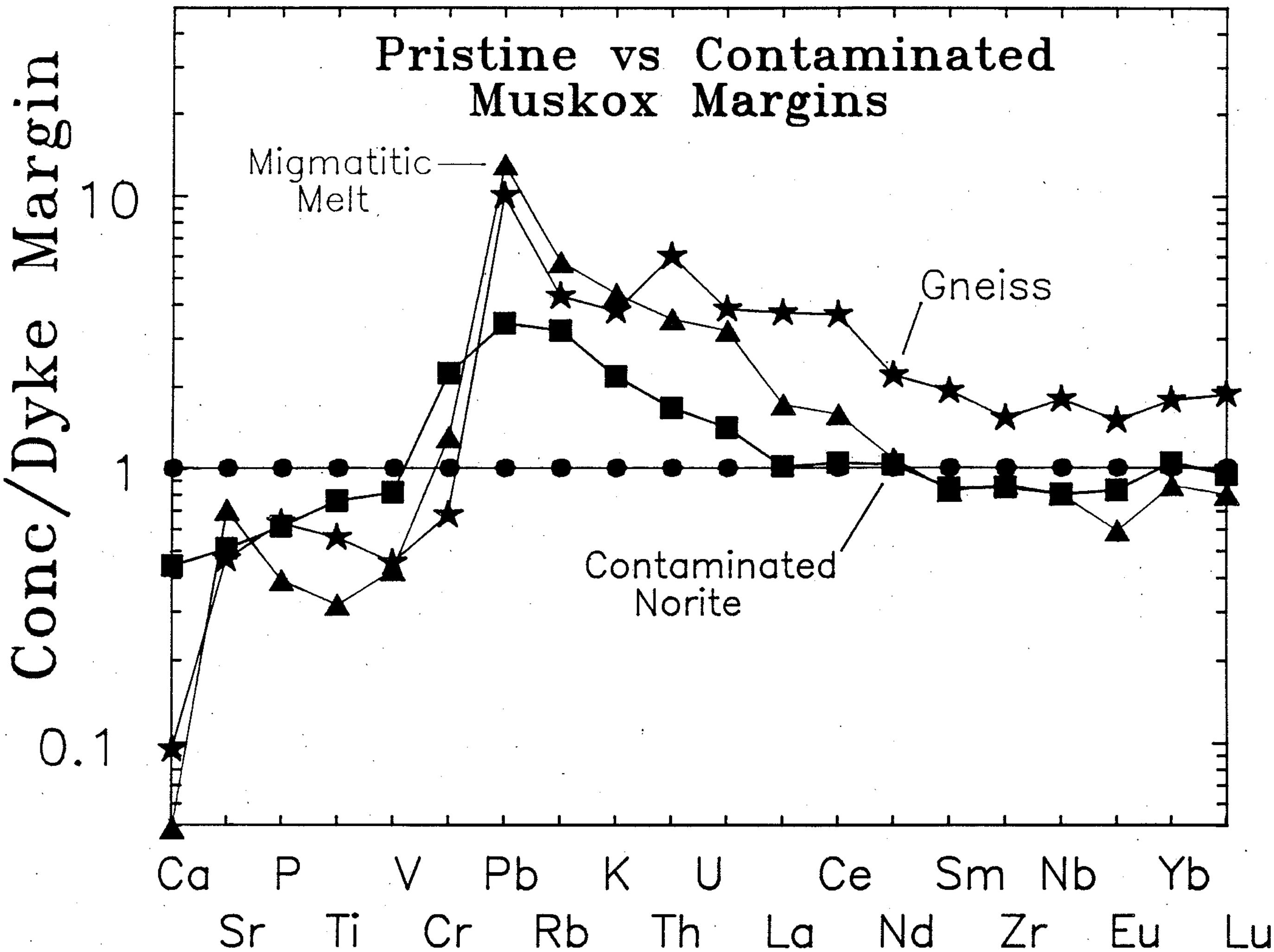

Figure 3. Spider diagram comparing the compositions of average paragneiss country rock (star), melt of paragneiss country rock (triangle), contaminated norite in the margin of the chamber (square) to the composition of uncontaminated norite in the margin of the keel dyke (circle).

(Fig. 3). The marginal norites of the chamber, however, have similar rare element (REE) profiles to those of the marginal norites of the keel dyke. The melted country rocks adjacent to the intrusion have similar high LIL element and U and Th concentrations to the paragneiss itself, but are significantly depleted in rare earth elements suggesting that during partial melting they were preferentially retained by a phase in the restite.

The simplest measure of the extent of wall rock contamination in the Muskox marginal rocks is the ratio of K/Ti. This ratio is particularly sensitive to contamination because the paragneiss has ten times the K content of the majority of the Muskox rocks while both have similar Ti contents. Ti and K behaved as incompatible elements in the mafic magmas of the Coppermine - Mackenzie - Muskox system, as they both rise with decreasing MgO in the Coppermine lavas and the Mackenzie dykes. This ratio will thus remain relatively constant during closed-system fractionation until an oxide phase becomes saturated. Across the margins of the keel dyke, the ratio of K/Ti remains low (about 1) and essentially constant right up to its contact with the paragneiss (Fig. 4a). The felsic veins cross cutting the norite margin have the elevated K/Ti ratios of the surrounding paragneiss, but the rocks of the intrusion itself show no signs of assimilation. Across the margins of the magma chamber of the intrusion, however, there is a distinct increase in the K/Ti ratio from those of gabbro-norite (which have K/Ti ratios similar to those of the keel dyke) to those of norite within 3 metres of the contact (Fig. 4b). These chemical features indicate that the magmas of the chamber of the Muskox intrusion were actively assimilating melts of their host paragneiss while those of the keel dyke were essentially uncontaminated.

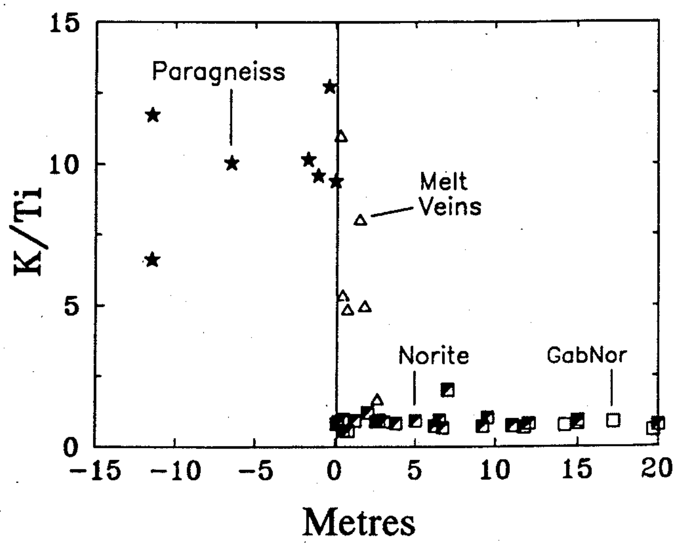

Figure 4a. Composite plot of potassium/titanium (K/Ti) ratios across the paragneiss-keel dyke margin.

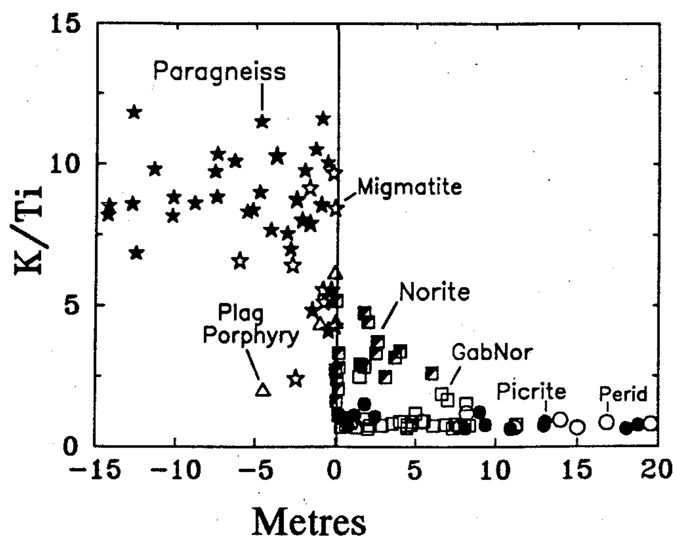

Figure 4b. Composite plot of potassium/titanium (K/Ti) ratios across the paragneiss-chamber margin.

Implications for mineral exploration

A preferential concentration sulphur (S) in the contaminated norites of the chamber of the Muskox intrusion and melted paragneiss along its contact clearly suggests the formation of an immiscible sulfide melt due to the interaction between the magma of the intrusion and its enclosing paragneiss (Fig. 5). Despite the apparent link between sulfide mineralization and crustal contamination, however, the highest observed concentrations of sulfides in the Muskox intrusion are restricted to the margins of Megacycle #1 which appears to be anomalously Fe-rich compared to the margins of succeeding megacycles. The anomalous character of Megacycle #1 is also supported by the fact that the background levels for PGE is significantly higher in the layered series of Megacycle #1 (Irvine, 1988). These observations suggest that the down plunge extension of Megacycle #1 holds the most potential for future exploration efforts to find economic concentrations of PGE.

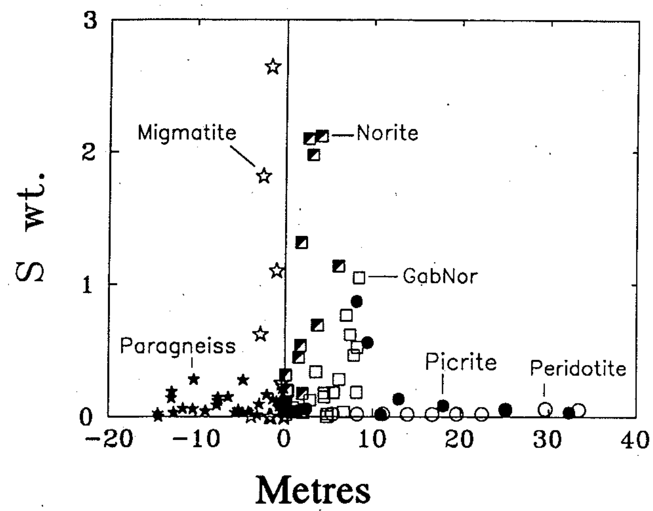

Figure 5. Composite plot of sulphur (S in wt%) across the paragneiss-chamber margin.

The ratio of K/Ti provides an excellent means for the recognition of contamination in both the layer series of the intrusion and the overlying Coppermine River basalts. There is a dramatic jump in the K/Ti ratio at the change from clinopyroxenite to websterite cumulate layers at the first 'early' crystallization of orthopyroxene in the middle of the layered series of Megacycle #3 and in the first pyroxenites just prior the development of the PGE-bearing 'Reef' in Megacycle #4 (DesRoches and Francis, 1990). Within the Coppermine River basalts, elevated K/Ti ratios (2 - 6) occur preferentially in the lower two members in which Baragar (1969) has previously identified evidence of crustal contamination in the form of granophyric clots. The concentration of native copper mineralization in the upper members of the Coppermine River lavas may reflect the fact that the magmas of the lower lavas were depleted in Cu by a contamination-induced immiscible-sulfide fractionation.

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GEOLOGICAL MAPPING OF THE SLEEPY DRAGON COMPLEX AND THE CAMERON RIVER METAVOLCANIC BELT, SLAVE PROVINCE: BASEMENT - COVER STRATIGRAPHIC AND STRUCTURAL RELATIONS

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Objectives
The objectives of this study was to map, at 1:50 000 scale, the geology of part of the Cameron River metavolcanic belt between Fenton Lake and Brown Lake, District of Mackenzie, Northwest Territories (NTS 85P, parts of P/2, P/3, P/6 and P/7) and to complete stratigraphic, structural and metamorphic analyses of the metavolcanic belt and adjacent metasedimentary and granitoid terranes. The subsequent map and report focus mainly on the metavolcanic belt and the tectonic boundary between metavolcanic rocks and the gneisses of the Sleepy Dragon Complex (proposed basement to the supracrustal rocks). The purpose of this study was to enhance understanding of the stratigraphic and tectonic evolution of Archean supracrustal sequences and granitoid gneiss complexes in this part of the Slave Structural Province.

This project represents a continuation of the 1:50,000-scale mapping of the Cameron River metavolcanic belt by M.B. Lambert of the Geological Survey of Canada south of 63° N (Lambert, 1988).

Methods
Mapping was conducted by a two-person ground traversing crew during three-month field seasons in 1988 and 1989. Mapping concentrated mainly on the metavolcanic belt, the gneissic and metaplutonic rocks of the Sleepy Dragon Complex, and the contact zone between the metavolcanics and the Sleepy Dragon Complex. The contact zone was examined in detail to determine what, if any, basement-cover stratigraphic relationships were preserved, and to determine the kinematic sense, timing and significance of ductile high-strain zones within the contact zone. Only cursory examinations were made of the metasedimentary rocks of the Burwash Formation and unmetamorphosed granitic rocks that intrude all rock types in the map area.

The field work is complemented by petrographic and geochemical studies, examination of petrofabrics in oriented specimens and U-Pb geochronological work (with J.K. Mortensen, Geological Survey of Canada, Ottawa). The geochemical study will chemically define the metavolcanic rocks and compare mafic and ultramafic rocks in the metavolcanic belt with those of metamorphosed mafic and ultramafic dykes that occur in the basement contiguous to the metavolcanics. The U-Pb geochronological study will focus on dating gneisses and metaplutonic rocks of the Sleepy Dragon Complex, meta-felsite from the metavolcanic belt and unmetamorphosed porphyritic granite. This work will determine the age of volcanism in the Cameron River belt, confirm the hypothesis that the gneisses and meta-plutonic rocks are basement to the supracrustal rocks and constrain tectonic models for this part of the Slave Province.

Results
Archean rocks are subdivided into four lithologic domains between Fenton Lake and Brown Lake (Fig. 1): (1) and (2) granitoid gneisses and meta-plutonic rocks of the Sleepy Dragon Complex, (3) metavolcanic rocks of the Cameron River metavolcanic belt, (5) metamorphosed greywacke - mudstone turbidites of the Burwash Formation, and (6) unmetamorphosed granite. West of Van Lake the Burwash Formation includes a thin belt of metavolcanic rocks informally named the Nicholson River metavolcanics (5). All metavolcanic and metasedimentary rocks in this area belong to the Yellowknife Supergroup.

Rocks of the Sleepy Dragon Complex form part of a 25 km x 110 km block of granitoid gneisses and meta-plutonic rocks that are intruded by unmetamorphosed granitic plutons and mantled by supracrustal rocks of the Yellowknife Supergroup. In the map area gneisses of the Sleepy Dragon Complex are dominantly biotite-hornblende tonalite gneiss and granitoid migmatite. They are intruded by at least two phases of metamorphosed and deformed tonalite veins. The Sleepy Dragon Complex includes a body of deformed and metamorphosed, K-feldspar

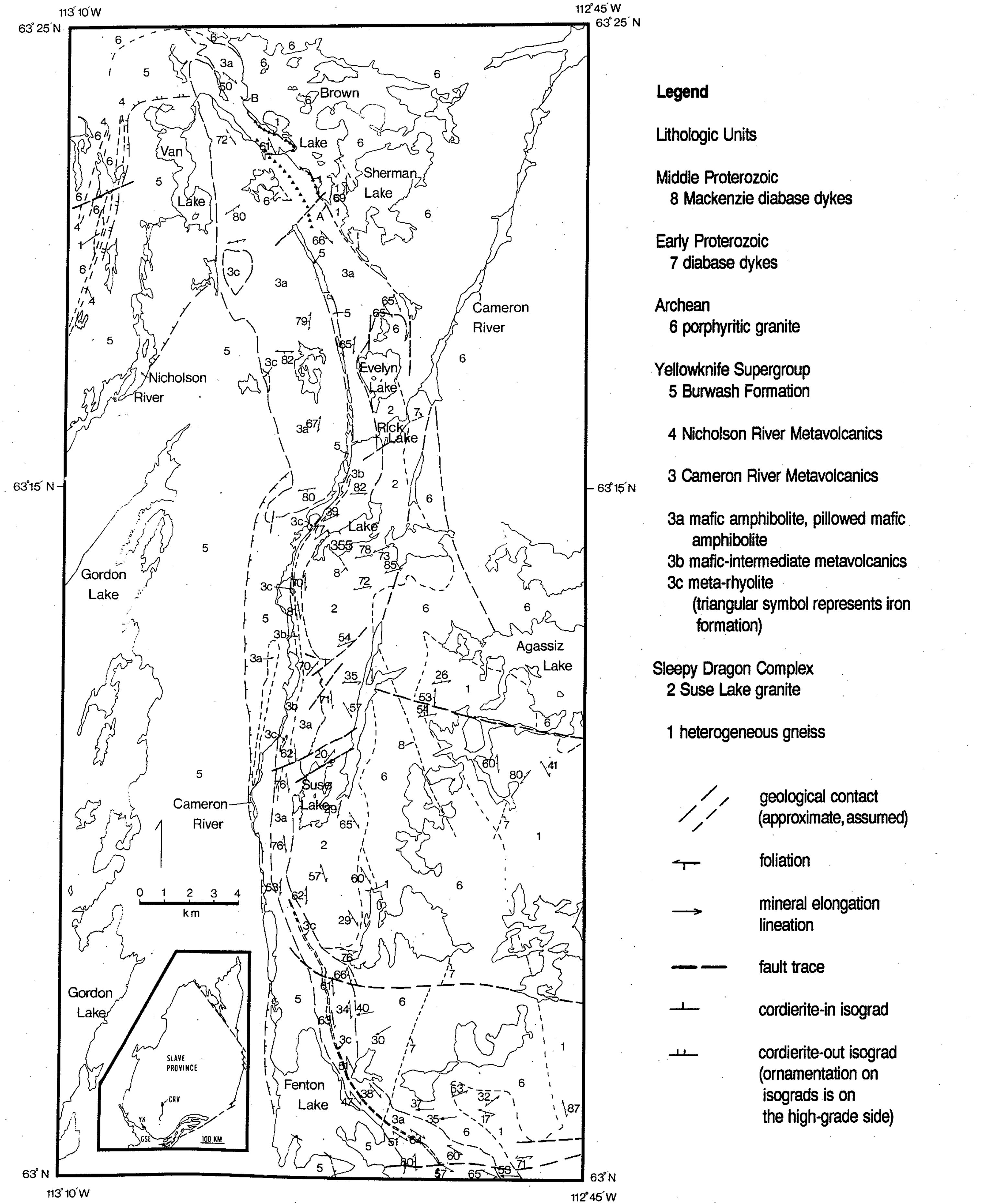

Figure 1. General geology of the Cameron River Metavolcanic Belt between Fenton Lake and Brown Lake, Slave province. Location map (inset) Yellowknife (YK) and great Slave Lake (GSL).

porphyritic granite, named the Suse Lake granite, also presumed to be older than the supracrustal rocks.

The Sleepy Dragon Complex contains deformed and metamorphosed mafic dykes that increase in abundance towards the contact with the metavolcanic rocks. Adjacent to the metavolcanic belt at Brown Lake, the gneisses also contain deformed and metamorphosed ultramafic dykes. Two ultramafic dykes from Brown Lake contain anomalous chromium (4372 ppm and 1319 ppm). The mafic and ultramafic dykes cannot be traced from the Sleepy Dragon Complex into the metavolcanic belt.

The Cameron River metavolcanic belt comprises dominantly metamorphosed and variably deformed, mafic volcanic rocks with relic pillows and pillow breccia and fine- to medium-grained, massive (i.e. without relic volcanic structures) mafic rocks with lesser amounts of intermediate metavolcanics and meta-gabbro dykes and sills. The dykes and sills make up less than 15% of the belt. Rare ultramafic rocks occur at the base of the belt at the south end of Brown Lake. Meta-felsite units occur as a 2 km^2 rhyolite dome 1 km southeast of Van Lake, and thin layers both in the middle of the volcanic succession at Fenton Lake and sporadically along the contact between the Cameron River belt and the Burwash Formation. Iron formation occurs at two main horizons. At Brown Lake chert-magnetite iron formation outcrops discontinuously for 4 km along the contact between the Cameron River belt and the Sleepy Dragon Complex. Another unit of chert-magnetite iron formation, garnet-amphibolite rocks, meta-felsite (?) and, sulphide-stained zones occurs within the metavolcanic belt about 400 m west of Brown Lake.

The Nicholson River metavolcanics (4) are mainly well-layered amphibolites with alternating mafic and felsic layers. Locally, the amphibolites are interlayered with iron formation and sulphide-stained zones. Granite intrudes these interlayered amphibolites and metasedimentary rocks west of Van Lake. Along the Nicholson River, however, these rocks make tectonic contact with tonalite gneisses that are presumed to be relics of Sleepy Dragon Complex gneisses. Metasedimentary rocks of the Burwash Formation conformably overlie the Nicholson River metavolcanics.

The Burwash Formation (5) consists mainly of metamorphosed, interbedded greywacke and mudstone. Greywacke is the dominant lithology in

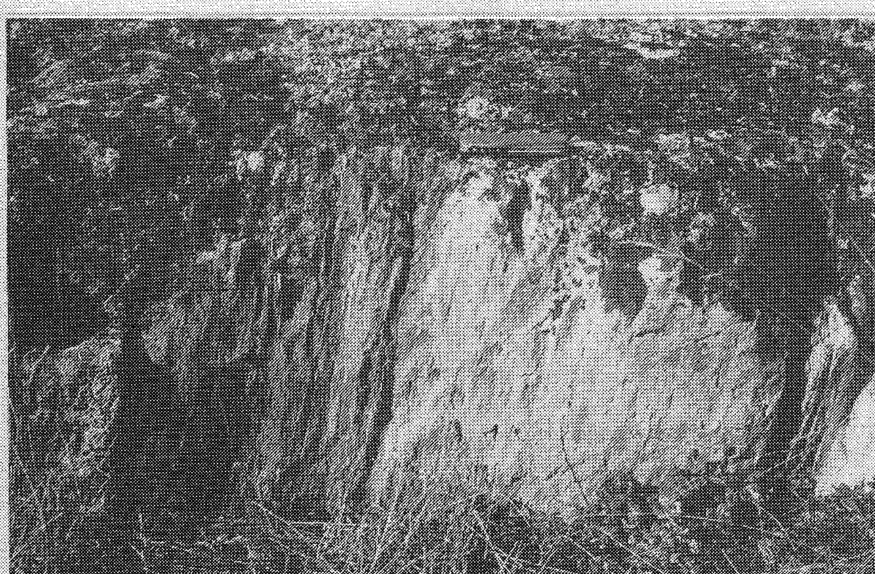

Figure 2. Contact between Cameron River belt and Sleepy Dragon Complex. Steeply west-dipping mylonite meta-plutonic rocks of the Sleepy Dragon Complex (right side of photo) are juxtaposed against highly strained, schistose, amphibolites of the Cameron River belt (left side of photo). Along the contact, ductile, high-stain fabrics in metavolcanic rocks are overprinted by brittle structures.

most outcrops. In the Van Lake area, the Burwash Formation commonly contains undeformed and unmetamorphosed dykes of granite that may be several tens of metres wide and dykes of pegmatite that are commonly tourmaline-bearing.

From the north end of Gordon Lake, metamorphic grade in the Burwash Formation increases to the north, towards a granite body which intrudes supracrustal rocks. Two mineral isograds mark the appearance and disappearance of cordierite. Above the 'cordierite-in' isograd rocks contain cordierite with biotite and muscovite, and local andalusite. Rarely, the rocks contain garnet and biotite as the metamorphic assemblage. Above the 'cordierite-out' isograd, rocks contain local sillimanite-quartz nodules and up to 20% deformed granitic veins (in situ derivation?). Concentric zonation of isograds about the granite body suggests that the metamorphism of the supracrustal rocks is related to plutonism.

Rocks of the Sleepy Dragon Complex and the Yellowknife Supergroup are intruded by unmetamorphosed, porphyritic and equal-grained granite. The rocks contain biotite and local muscovite. The granitic rocks are variably foliated although strain generally increases towards the contact between the granite and the Cameron River belt.

The contact zone between the Cameron River belt and the Sleepy Dragon Complex and granite domains is variably strained (Fig. 2). Commonly the contact zone is marked by protomylonitic and mylonitic rocks with westerly dips and steeply-oblique to down-dip mineral elongation lineations. Conflicting kinematic indicators from the high-strain zone demonstrate both a thrust displacement and a normal displacement and indicate that the contact zone has a history of syn-metamorphic and late syn- to post-metamorphic high-strain.

Kinematic indicators with a thrust sense from the Suse Lake granite at the contact at Rick Lake, and from Cameron River metavolcanics at Brown Lake attest that the contact zone had an early history of east-vergent thrusting of the metavolcanic rocks over the Sleepy Dragon Complex. Thrusting may have been synchronous with early syn- to syn-metamorphic east-west shortening and the main deformation of the supracrustal rocks. Kinematic indicators with a normal sense in Sleepy Dragon gneisses that occur several hundred metres from the contact at Brown Lake and from the Suse Lake granite and porphyritic granite, demonstrate that the contact zone had a late history of west-side-down (i.e. normal) displacement. Normal displacement was late-syn- or post-porphyritic granite and may be related to post-metamorphic extension that followed the major episode of east-west shortening in this part of the Slave Province.

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GEOCHEMISTRY (TILL, GOSSAN AND LAKE SEDIMENT - AU AND PGE) AND SURFICIAL GEOLOGY OF THE FERGUSON, YATHKYED AND CONTWOYTO LAKES AREAS, NWT

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Introduction

In glaciated regions, most primary surficial sediment has been formed by glacial erosion and transport of fresh bedrock, with secondary processes restricted to the development of immature post-glacial soil. Till, the preferred sample medium in drift prospecting programs, is considered to most closely reflect the composition of the underlying bedrock, because it has undergone a relatively simple cycle of erosion and transport solely by glacier ice (Shilts, 1976). Glaciofluvial sediment, on the other hand, has undergone an additional cycle of erosion and transport by meltwater, whereas glaciolacustrine sediment reflects the combined influence of glacial and glaciofluvial processes as well as redistribution within proglacial lakes. All modern surficial materials (e.g. modern lake sediment) derived from, or developed on, glacial sediment produce a geochemical signature that reflects, at least in part, the mineralogical composition of glacial sediments as well as underlying bedrock (Coker et al., 1979). For this reason the success of surficial geochemical exploration in glaciated terrain depends upon a basic understanding of the glacial history of any given region, of the distribution, and physical and geochemical characteristics of various types of surficial materials, and of near-surface weathering processes (Coker and DiLabio, 1989; Coker and Shilts, 1991).

Objectives

A primary objective in most till sampling programs is to identify the lithologic and/or chemical components that reflect various bedrock sources, and to map out the patterns of glacial dispersal developed through erosion and transport of distinctive bedrock lithologies. These data, combined with detailed surficial geologic mapping can be used to aid in the design and implementation of prospecting programs aimed at locating sources of mineralized erratics and drift. The primary objectives of this study were to:

1) identify how Au and platinum group element (PGE) mineralization are reflected in the associated till, and to demonstrate the value of till geochemistry as an exploration method;

2) define the mobilization and redistribution of Au and PGE in the zone of weathering;

3) define patterns of glacial dispersal in areas of Au and PGE mineralization in the central Keewatin and Contwoyto Lake areas;

4) develop analytical methods to determine low levels of Au and PGE in gossans, overburden, vegetation and waters (Hall et al., 1990); and

5) test the effectiveness of lake centre sediment geochemistry as a method of exploring for Au in the tundra.

Methods

Sampling of till, within this zone of continuous permafrost, was facilitated by the presence of mud boils, sites of periglacial churning that extrude till to the surface (Shilts, 1973). Shallow surface till samples (8 to 10 kg) from approximately 1 m depth were collected from hand-dug pits in mud boils. Till is generally present as a thin veneer (1 to 10 m) draping topographic highs and filling topographic lows. In some areas, particularly near eskers, glaciofluvial deposits dominate the landscape and were sampled instead of till (e.g. Dune grid).

Helicopter-supported reconnaissance level till sampling was carried out at a density of 1 sample per 9 sq. km in both the Yathkyed Lake and Contwoyto Lake areas. Ground traversing was conducted for detailed sampling of both till and gossan in the Ferguson Lake area, and to sample till on the SY-4 and SY-13 grids in the Yathkyed Lake area and on the Amwood, CTL, Dune, P-1, OP and SB-1 grids in the Contwoyto Lake area.

Helicopter-supported reconnaissance centre-lake sediment sampling was carried out at a density of 1 sample per 9 sq. km. in the Contwoyto Lake area.

In the Yathkyed Lake area, the sequence of ice flow directions related to the Keewatin ice divide was determined, as was the extent of the late glacial marine limit (MacInnis, 1989a).

In the Contwoyto Lake area, field checking of an interpretation of the surficial geology and ice flow history of the area was carried out (Hart et al., 1989). The area flooded by a proglacial lake was estimated by measurement of the elevations of raised beaches (MacInnis, 1989b)

The till samples, after drying and preparation, were routinely subjected to a number of analytical techniques. The silt plus clay (<63 um or -250 mesh) fraction of most tills was analyzed at Bondar-Clegg and Co. Ltd., Ottawa, for Au + 34 elements by direct irradiation neutron activation and for V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Ag, Cd and Pb by atomic absorption spectrophotometric techniques after a hot acid (HCl-HNO_3) digestion.

The gossan samples from Ferguson Lake were dried and separated into the <2 um, <63 um (-250 mesh), <180 um (-80 mesh), and 2-6 mm fractions. Heavy mineral concentrates (HMC) were prepared by Overburden Drilling Management Ltd., Ottawa. All fractions were analyzed for Au, Pt and Pd by either fire assay/ICP mass spectrometer at Acme Analytical Laboratories, Vancouver; or by fire assay/DCP at Bondar-Clegg and Co. Ltd., Ottawa; and, for V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Ag, Cd and Pb by atomic absorption spectrophotometric techniques, after a hot acid (HCl-HNO_3) digestion, at Bondar-Clegg and Co. Ltd., Ottawa.

Lake sediments, after drying and preparation to <63 um (-250 mesh), were analyzed at Bondar-Clegg and Co. Ltd., Ottawa for Au + 34 elements by direct irradiation neutron activation; for Zn, Cu, Pb, Ni, Co, Ag, Mn, Mo, Fe, Cd, Sb, and V by atomic absorption spectrophotometric techniques after a hot acid (HCl-HNO_3) digestion; and, for As, Hg, F, and LOI by various other analytical techniques (Friske et al., in preparation).

Analytical quality (i.e. accuracy and precision) was controlled by insertion of standards and duplicates.

Results

Ferguson Lake area:

Surficial geology
The surficial geology of the Ferguson Lake area is dominated by constructional glacial landforms, except on the uplands where thin drift and bare bedrock are common (Aylsworth et al., 1981). The only indicated ice flow direction seen in the field is to the southeast.

Till and gossan geochemistry
Six trenches were hand dug within the gossanous till/bedrock zone over the PGE-bearing nickel-copper mineralization (See Wright, 1967, and Legget et al., 1976 for a description of the geology and mineralization). Grab samples of the gossanous bedrock contained up to 70 ppb Au, 590 ppb Pt, 2500 ppb Pd, 9000 ppm Ni, >2 % Cu, 45.0% Fe, 500 ppm Mn, and 250 ppm Cr.

Based on the distribution patterns of Au, Pt, Pd, Ni, Cu, Fe, Mn, and Cr (Coker et al., 1990; Coker et al., in preparation) there appears to be a combination of both clastic dispersal (i.e. Pt, Ni, Cu, Fe, Mn and Cr as evidenced by their preferential accumulation in the coarse fractions) and hydromorphic dispersal (i.e. Au, Pd, Ni and Cu as evidenced by their preferential accumulation in the fine fractions). As well, coprecipitation of Ni and Cu (and perhaps Au and Pd) may be occurring with Fe and Mn hydroxides/oxides in the gossanous till zone.

Although no one fraction of the gossanous till stands out as the optimum sample medium, analysis of the HMC and <63 um fractions would seem to provide the best approach to exploring for PGE in this environment. However, it proved difficult and costly to recover sufficient heavy minerals from the non-gossanous tills in order to obtain reliable analytical data. Therefore, the <63 um fraction was used to examine the distribution patterns of the PGE and associated elements within the gossan and tills.

Gold, Pt, Pd, and Cu concentrations in the <63 um fraction of gossan and till were statistically analyzed as separate populations. Their spatial distribution patterns (see Coker et al. 1990; Coker et al., in preparation) show the element levels and their degree of variation within the gossan, as well as the limited down-ice (southeastward) glacial dispersal in the tills. The exposed gossan zones are evident and a possible extension of the mineralization beneath a peat- and till-covered area to the northeast of the known gossanous mineralization is also suspected. Only limited (one to two hundred metre) down-ice dispersal of Au, Pt, Pd, Ni and Cu occurs in the <63 um component of the till samples collected from frost boils.

Biogeochemistry
A differential response in PGE metal concentrations occurs between plant species, Labrador tea *(Ledum palustre ssp decumbens)* and dwarf birch *(Betula*

glandulosa) and between tissue types - twigs vs. leaves. Highest PGE concentrations were found in twigs, which may reflect the retention of the PGE in the woody tissue (Dunn, 1986; Dunn et al., 1989). Although the highest concentrations of Pt, Pd, Rh and Au in plant tissue are found over the gossan, these metals are also detectable in plant samples within the zone of glacial dispersal of gossanous debris which extends a few hundred metres in the direction of presumed ice movement. The zone of dispersal detected by the plant samples is very similar to the zone detected by till sampling. The biogeochemical studies carried out in the Ferguson Lake area are described by Rencz, Wright and Hall (this volume).

Yathkyed Lake area:

Surficial geology

The greenstone belt (see Eade, 1985, for a description of the geology and mineralization) hosting the gold mineralization south of Yathkyed Lake is blanketed by a silty-sand till which contains a significant component of Dubawnt Group debris transported southward from extensive outcrops just north of the belt. Only the hard, fine-grained mafic volcanics on the south side of the belt stand up as a streamlined ridge. On the ridge and in exploration trenches, three distinct sets of glacial striae are preserved. The oldest set indicates a possible northerly ice flow direction. The two younger sets truncate the first and indicate ice flow towards the southeast and east, with very little erosion of the second set by the third. The early northward flow is a potential complication in the interpretative stage of a geochemical program. Field observations only revealed evidence of southeastward debris transport and therefore the up-ice tracing of anomalies should probably be done towards the northwest.

Till geochemistry

The Au, As, Cu, Pb, Zn, Ni, Fe, Na, and Br contents of the reconnaissance till samples in the Yathkyed Lake area depict the gross geological features (Eade, 1985) of the area outlining the extent of the greenstone belt that contains the auriferous iron formation. Most of the elemental patterns in the till show some degree of displacement to the southeast. The iron formation hosted gold mineralization is best reflected by Au, As and Cu in the <63 um component of the tills. There is also enhancement of some of the elements north of the greenstone belt, possibly reflecting the paragneisses in the area or perhaps indicative of the early northward ice flow.

Geochemical data for Au, As and Cu in the <63 um fraction of till for the SY-4 and SY-13 grids depict the trend of the known gold mineralization on these grids with some modification of the patterns due to the southeastern glacial dispersal and due to local topographic effects.

Contwoyto Lake area:

Surficial geology

The most striking surficial feature of the area is the large amount of debris that was produced during glaciation of Yellowknife Supergroup rocks. These rocks are covered by a till plain locally over 10 m thick. In areas where the drift cover is thick, flutes and drumlins are common surface features. Where the drift cover is relatively thin, the surface morphology mimics that of the underlying bedrock. Several broad esker complexes run roughly parallel to the drumlinoid ridges. The constructional landforms in the complexes are peaked or flat-topped ridges composed of pebbly sand. Commonly flanking the eskers is a zone of thin bouldery till. Details of the surficial geology of the Contwoyto Lake study area are published in Hart et al. (1989).

The only ice flow direction observed as significant was towards the northwest (330°).

During deglaciation, the Contwoyto basin was flooded by a multi-outlet proglacial lake, dammed by the retreating ice front (MacInnis, 1989b). Only at very low elevations did this lake deposit much sediment of its own, seen as silt patches near the present Contwoyto Lake. Extensive reworking of till and eskers took place as the water plane fell, and a complex sequence of raised beaches, deltas, baymouth bars, and spits was built at elevations below about 160 m. This reworking by waves has covered a few of the gold occurrences with several metres of well sorted beach and littoral sand, a factor that limits the use of geochemistry here. Only where fresh till is at the surface can till sampling be carried out by simply using a shovel.

Till geochemistry

The Au, As, Cu, Pb, Zn, Ni, F and Br contents of the reconnaissance till samples primarily outline the Contwoyto Formation of the Yellowknife Supergroup (King et al., 1991; Relf this volume) and associated iron formation, showing some dispersal to the northwest and geochemical variation related to known occurrences of Au mineralization. Gold, As and Cu, in the <63 um fraction of till from the Amwood, CTL, Dune, P-1, OP and SB-1 grids depict the trend of the known gold mineralization on the grids with some modification of the patterns due to glacial dispersal and local topographic effects.

Till geochemical surveys, using frost boils, can be very useful, when properly applied, for gold exploration in this geological and physiographic environment.

Lake sediment geochemistry
Assessment of the centre-lake sediment geochemical data indicates that the Lupin Mine and many of the other known gold occurrences in the Contwoyto Lake area are reflected by anomalous patterns of Au, As, Cu, Br and W in the lake sediments. There is a strong correspondence between the patterns of Au, As, and Cu in lake sediment and till. The northwesterly trend of the lake sediment geochemical patterns, as with the trend of the till patterns, reflects the nature of glacial transport in the area. It appears that lake sediment surveys can be useful for gold exploration throughout rocks of the Yellowknife Supergroup.

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DRIFT PROSPECTING FOR GOLD IN THE KAMINAK LAKE-TURQUETIL LAKE AREA, DISTRICT OF KEEWATIN

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Introduction
In 1988, closely spaced samples of glacial sediments were collected around known gold mineralization in the Turquetil-Maguse Lake region of southern District of Keewatin. As part of this project, several thousand archived samples, from both detailed and regional drift sampling programs carried out between 1970 and 1975 in the same region, were reanalyzed for a wide range of elements, including gold and platinum group elements using ICP methods. The results of the 1988 sampling were evaluated in light of the geochemical patterns derived from the analysis of archived samples Shilts and Wyatt, 1989).

Geology
The bedrock of the area comprises belts of Archean metasedimentary and metavolcanic rocks interspersed with granitic intrusions of slightly younger age (Davidson, 1970a,b; Bell, 1970; Ridler and Shilts, 1974a). Superimposed across these older igneous and relatively low grade metamorphic rocks are thin belts or remnants of Aphebian age sedimentary and volcanic terranes, consisting of orthoquartzites, minor carbonate facies, basic volcanic rocks, and slates. The whole complex forms the central part of the east-west to northeast-southwest striking Rankin Inlet-Ennadai Greenstone Belt.

The glacial history of the region is fairly simple. Glaciers moved southeastward to east-southeastward across the region from the Keewatin Ice Divide, located in its last stages about 100 km nothwest of the study area. Large quantities of red-coloured, kaolinitic and hematitic debris, eroded from the slightly to unmetamorphosed, late Proterozoic bedrock of the Thelon Basin, west and northwest of the area, were glacially transported to the Kaminak-Turquetil lakes area, where they form a major component of the drift and tend to mask the compositional contribution of local bedrock. In the field, the extent to which the masking is likely to present a sampling problem can be inferred from the color and texture of the drift; the redder and more clay-rich the sediment, the more its chemical composition is likely to be distorted by far-travelled debris. As the glacial front retreated across the isostatically depressed terrain of the sampling area toward the Keewatin Ice Divide, all deglaciated terrain, except for a few small hills, was submerged in the Tyrrell Sea. Nevertheless, with the exception of areas adjacent to eskers or along major modern river courses, only minor thickness of marine muds were deposited. As the shoreline regressed toward the present coast of Hudson Bay because of isostatic uplift, beaches were developed preferentially on prominent hills and on ice-contact gravels,and some fine sediment was washed into hollows. Apart from this minor redistribution of fine sediment the effects of the marine episode were remarkably restricted above 100 m a.s.l. Below 100 m a.s.l. the glacial surface was greatly modified by waves or buried under a general blanket of offshore, fine-grained sediments in areas adjacent to the present coast.

Patterned ground
Because of the cold climate, the sampling area is underlain by thick permafrost, the surficial sediments thawing to maximum depths ranging from 10-15 cm in poorly drained organic terrains such as grass-sedge meadows, to 1.5 to 2.0 metres beneath bare till or gravel surfaces. Surfaces underlain by well-sorted sand and gravel (beaches and eskers) are marked by individual, orthogonal, or polygonal frost cracks, as are poorly drained organic deposits. Poorly sorted or fine grained mineral sediments, on the other hand, are covered by circular mudboils, rings of stone or turf surrounding bare soil patches, with diameters ranging from 80 or 90 cm in marine silty clay to over 2 m in till. In cross-section mudboils are diapiric structures resulting from soft-sediment deformation processes acting on saturated muds during the thaw season (Shilts, 1978). The fidelity of the different types of surface patterns to different underlying sediment types is a considerable aid in choosing sites for sampling

specific sediments, whether in the field or in planning traverses from air photographs (Ridler and Shilts, 1974b).

Sampling
Samples were collected from hand-dug pits in mudboils and on esker ridges. Although some of the mudboil samples may be admixed with or consist wholly of marine mud, by far the majority of them (probably over 95%) are of till. As pointed out by Shilts (1973) the geochemistry of fine fractions of samples collected from glaciofluvial or shoreline sediments cannot be compared directly to those of adjacent till samples because of the tendency of the former to be composed primarily of secondary oxides/hydroxides of Fe and Mn and degraded or secondary silicates with high exchange capacities. The fine fractions of till, in contrast, are formed by the crushing of unweathered bedrock and clasts, yielding a material with low exchange capacity and correspondingly low concentrations of metals adsorbed from circulating groundwater. Thus, background concentrations of cations in fine fractions separated from sands and gravels are commonly several times higher than those of adjacent tills. Sample populations based on different sediment facies in this terrain should be controlled and defined rigorously, and results should not be plotted together without awareness of these factors.

Preparation and analytic techniques

Sample preparation
The silt and clay fraction was separated by sieving dry sediment through a stainless-steel 250 mesh (0.063 mm) screen.

A clay-sized fraction, < 0.002 mm diameter, was obtained by centrifuging. Each sample was centrifuged twice in a standardized, very weak solution of sodium hexametaphosphate in distilled water. The supernatant (decantate) from each sample was then centrifuged for a time sufficient to produce a sediment containing primarily phyllosilicate particles of from 0.0003 to 0.002 mm in diameter.

Analytical techniques
The < 0.063 mm fraction of regional and detailed grid samples (collected and sieved during the 1970s) was reanalyzed in 1988 by Chemex Labs Ltd., Vancouver. Trace metal concentrations were determined by taking 0.5 grams of sediment digested for 2 hours in a nitric-aqua regia ($3HCl:1HNO_3$) solution, diluting it to volume (about 50 mls) and analyzing by ICP atomic emission spectrophotometry.

Gold analyses were carried out by a dry fusion fire-assay of 10 grams of sample with a fluxing agent, yielding a silver bead containing the gold. The bead was mounted on tape and irradiated for a neutron activation finish. The detection limit is 1 ppb assuming a sample weight of 10 grams. The detection limit for 5 grams is 5 ppb, and smaller samples can be analyzed with commensurate increase in detection limit and loss of reproducibility.

PGE analyses were done on a 20 gram sample and involved the same fusion process as for gold. The resulting silver bead was dissolved in $HN0_3$, and platinum, palladium, and gold concentrations were determined by ICP atomic florescence spectrophotometry.

Gold

Discussion
Sample size was a limiting factor in reanalysis of regional samples collected and prepared during the early seventies. The < 0.063 mm fraction was first analyzed for several trace elements, and the remainder, commonly < 10 g, was analyzed for gold. Utilizing a 10 gram or less sample size significantly lowers reproducibility of the gold analysis. One can appreciate the significance of the nugget effect by calculating that a single cube of gold 40 by 40 by 40 um (0.04 mm cubed) (s.g. 19.32) in 10 grams of sediment (s.g. 2.6) would yield an assay around 120 ppb.

A reproducibility test was run on samples that yielded the 56 highest gold analyses from the regional grid. The remainders of the original < 0.063 mm fractions, many of which were under 10 grams, were reanalyzed by the method described above, but only 30 percent of the high gold values were reproduced satisfactorily. Reanalysis of four gold-rich gossanous sediment samples yielded reproducible results, possibly indicating that the gold was very fine and/or evenly redistributed (chemically) throughout the sample as exchanged or absorbed ions or complexes.

It is likely that the nugget effect, causing poor reproducibility, would be significantly reduced with larger sample size. Though not always reproduced, the high values nevertheless are probably significant. If, for example, one 0.030-0.040 mm cube of gold occurs per 30-40 grams of sediment, then 1 in 3 analyses of 10 gram portions will have approximately a 100 ppb assay. Thus, the high values are probably significant, but it is also possible that a number of samples with nugget-style gold will go undetected. Samples (10 gram analysis) collected around known gold occurrences in the Turquetil Lake area did produce distinct although short dispersal trains accurately delimiting mineralized outcrop areas.

Turquetil Lake area

Giant Yellowknife Mines first explored the Turquetil Lake area in the early 1960s, identifying a gold showing, since referred to as the "Joyce" showing, near the east bank of the Turquetil River, just north of its entrance into the lake. GSC geologists who mapped the area in the early 1970s considered the lithologic setting to be similar to Larder Lake carbonate-hosted gold deposits. Minor drilling was carried out by Essex Minerals Co. in 1976. Dejour Mines Ltd., in joint venture with Noble Peak Resources Ltd., recently conducted diamond drilling, EM surveys, and geochemical sampling programs over several claims in the Turquetil Lake area. Supracrustal rocks in this area consist of Kaminak Group volcanics and sediments intruded by Archean mafic to felsic plutonic rocks. Late Archean and Hudsonian tectonic events produced lower to middle greenschist facies metamorphism. Gold-bearing iron carbonate alteration horizons hosted within mafic to intermediate flows and tuffs, which strike perpendicular to regional ice-flow, have been traced southwestward about 13 km from the Joyce showing. In the vicinity of the Joyce showing the zone of altered volcanics turns 90° to the north-northwest, roughly paralleling ice flow in the area of Turquetil River. Outcrop sampling has produced anomalous gold results at several localities along this unit.

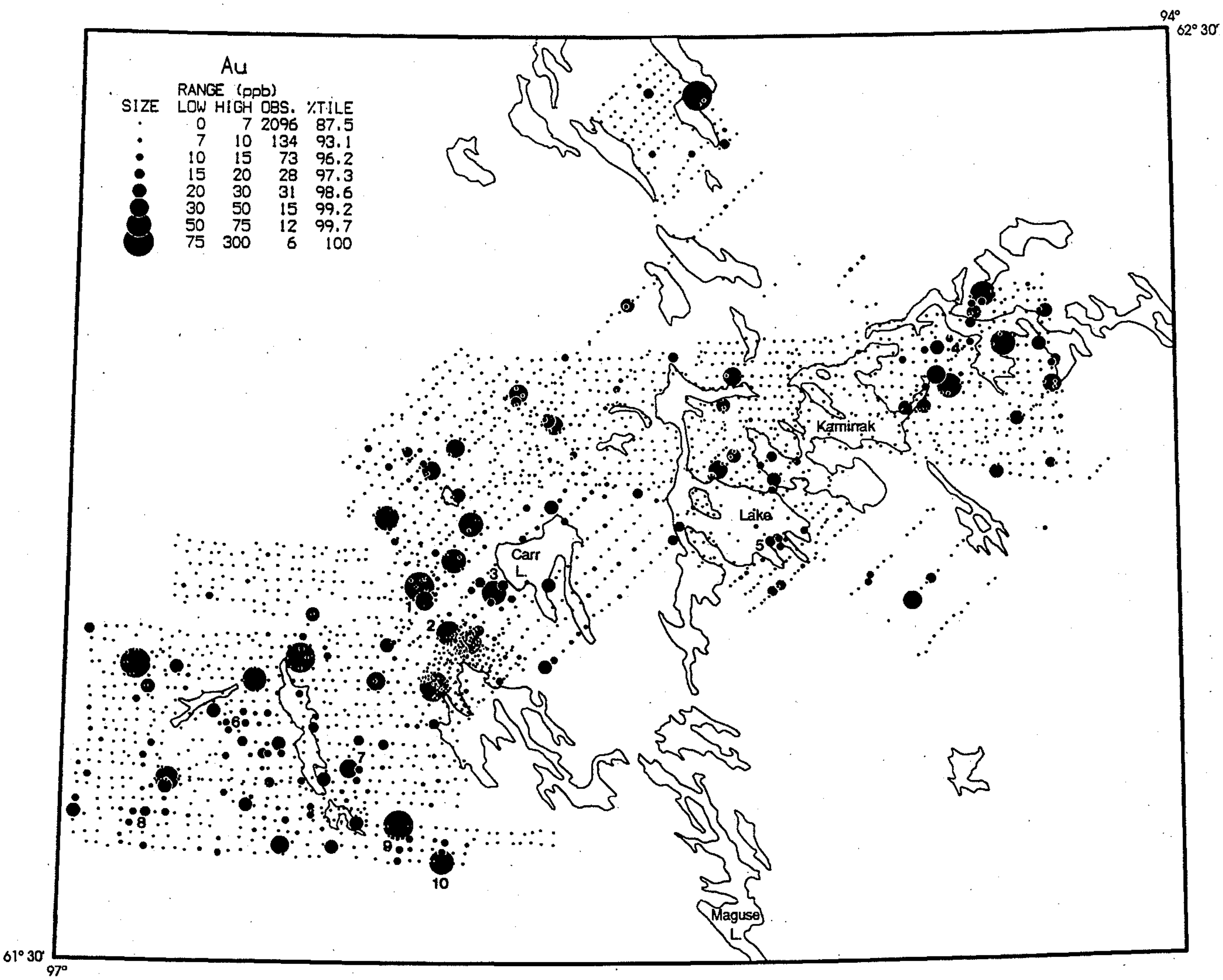

Figure 1. Distribution of gold in till (< 0.063 mm fraction). Sample sites may occur on islands not shown on the base map.

High gold values occur in till immediately surrounding the Joyce showing and other auriferous altered volcanics identified by Dejour Mines Ltd. Dispersal trains are short. Till samples collected 8 m down-ice from a mineralized outcrop contained 75 ppb gold, and till sampled 30 m down-ice from the outcrop contained 43 ppb gold. A sample taken about 1000 m down-ice was below detection limit for gold.

Two different esker systems cross mineralized outcrops in the vicinity of the Joyce showing. Samples with anomalous gold values were collected in one esker at 4 km down-ice and in the other at 7 km down-ice from auriferous outcrops. Although the eskers were not systematically sampled long distances up-ice and down-ice, it appears as though these enriched samples represent detached anomalies. This supports Shilts' (1973) contention that eskers were built in short segments by subglacial streams extending only tens of meters to several kilometres back from the ice margin. The abundant potholes visible on outcrops in the area are probably the result of supraglacial runoff draining through the glacier to its base via an ice tunnel. Sediment eroded from mineralized outcrops and adjacent glacier debris could have been carried to the esker tunnel mouth and deposited several kilometers down-ice.

The distribution of gold in the < 0.063 mm fraction of till from the regional grid is shown in figure 1. There are 10 areas where clusters of high gold values may indicate gold mineralization. One of these, number 2, is the site of the detailed sampling carried out around the Joyce showing at Turquetil Lake in 1988. The significance of the other areas of anomalous gold can be appreciated by seeing the effect of a major showing in a regional context. Although the Joyce showing is indicated by some high values, there are many samples with background gold concentrations interspersed with the anomalous samples.

Except for anomaly 3, which falls on a felsic volcanic unit adjacent to and associated with the massive sulphide mineralization at Spi Lake (Ridler and Shilts, 1974 a,b; Ridler, 1974; Shilts, 1974a,b), the other Au anomalies are in terrain with unknown potential.

The groups of anomalous samples flagged as region 4 near Quartzite Lake are several kilometres south-southwest along strike from the "Happy Lake" showings, currently held by Noble Peak Resources Ltd., and are in the area of the Southwin claims acquired by Noble Peak.

Areas 5 through 10 are located at sites with little or no prospecting history. Area 5 is located over two small adjacent peninsulas extending into Kaminak Lake. The bedrock is mapped by Davidson (1970a) as massive grey hornblende tonalite, minor leucodiorite, and biotite-hornblende granodiorite cut by a diabase dyke.

Area 6 is located in a region of mafic to felsic volcanics between Yandle and Heninga Lakes. This area is anomalous for many trace metals and has been discussed in some detail by DiLabio and Shilts (1977).

Areas 7 and 8 occur in regions of undifferentiated volcanics, and Areas 9 and 10 straddle the contact between undifferentiated volcanics and intruded hornblende diorite and leucogabbro.

Numerous Au-bearing quartz and quartz-carbonate veins with associated Cu, Pb, and Zn are present throughout the region. Occurrences of this type may in part be responsible for the many scattered or isolated anomalous gold concentrations observed in till.

Conclusions

Till sampling carried out by excavating mudboils is a viable technique for identifying regional targets for gold exploration. Using detailed follow-up sampling in target areas, information about the location of gold-bearing outcrops hidden beneath drift may be obtained. Weight of the fine fraction (<0.063 mm) separate should be greater than 10 g to avoid the worst aspects of the nugget effect, and samples exceeding 20 g are preferable. Care must be taken not to mix sample populations, e.g. glaciofluvial sediment and till samples, because of the differing mineralogical and geochemical characteristics of the fine fractions, a result of the varying responses of different types of sediment to weathering. Likewise, the amount of far-travelled components in a sample can affect apparent metal concentrations in this region because of the diluting effects of metal-poor, kaolin-rich debris, glacially transported from the Thelon Basin. The amount of dilution to be expected can be estimated from a number of observable characteristics, including kaolin concentrations, red colour of fine fraction, concentration of specular hematite in sand, Dubawnt Group erratics among coarse clasts, and concentrations of phosphorous and barium in sieved silt and clay fractions, both of the latter being enriched in some Dubawnt Group lithologies.

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AEROMAGNETIC TOTAL FIELD/GRADIOMETER/VLF-EM SURVEY
WHITEHILLS-TEHEK LAKES AREA, NWT.

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Objectives
The objective of this program was to carry out a high resolution gradiometry survey as an aid to detailed mapping of iron formation and associated volcanics in the Whitehills-Tehek lakes area. Detailed geological mapping was also carried out by Henderson et al. (1991) under a separate project.

Methods
The survey parameters were set at 300 m flight line spacing in an east-southeast direction at 150 m mean terrain clearance. The contract to conduct the survey was awarded to Kenting Earth Sciences who flew the area in July, 1988. Flight path recovery was from video and air photographs assisted by limited Global Positioning System (GPS) coverage, particularly over large bodies of water. Processing was completed in 1989.

Results
The survey was very effective in mapping iron formation, shown as the white areas in figure 1 which is a grey tone map of the vertical gradient. The scale from white to black corresponds to gradient values less than -1.0 to greater than 1.0 nt/m. Dykes can be traced as more subdued anomalies such as those trending roughly east-west near 64 45' North. Two granitic bodies can be recognized in the upper region of the map on either side of the north-northeast trending iron formation and in the southeast portion, although they are more evident on the 1:50,000 colour interval maps.

Products produced included (Geological Survey of Canada , 1990a, b, c, d, e):

i) digital data in both profile and gridded form available from the Geophysical Data centre,

ii) printed colour interval maps of both total field and vertical gradient at 1:50,000,

iii) open file contour maps of the total field and vertical gradient at 1:20,000, and

iv) open file profile maps of the VLF total field and quadrature at 1:20,000. The areas covered included 66A/9, 66A/16 and parts of 56D/12, 56D/13, 56E/4 and 66H/13.

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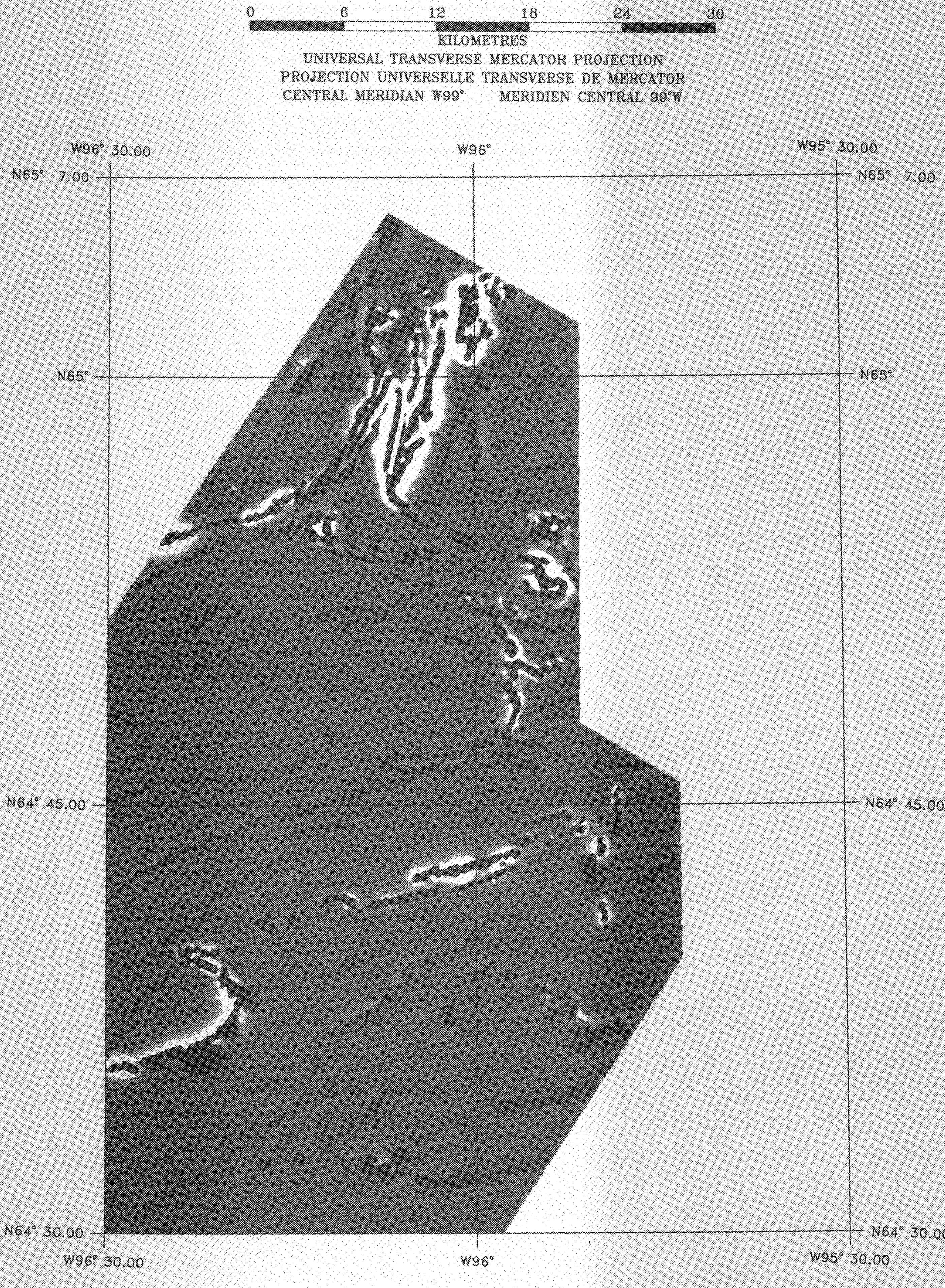

Figure 1. Grey tone map of vertical gradient, Whitehills area, Northwest Territories. The grey scale is from < -1.0 nt/m (white) to > 1.0nt/m (black).

INTERPRETATION OF AIRBORNE GEOPHYSICAL DATA FOR THE LUPIN AND THOR LAKE AREAS, NWT

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Introduction

Project C.1.4.2 of the Geophysics subprogram of the Canada-NWT Mineral Development Subsidiary Agreement, 1987-91, comprised detailed airborne geophysical surveys flown with 250 metre line spacing over areas covering the Lupin Gold Mine and the Thor Lake rare metal deposit. These areas, shown on figure 1, are both within the Slave Structural Province of the Canadian Shield.

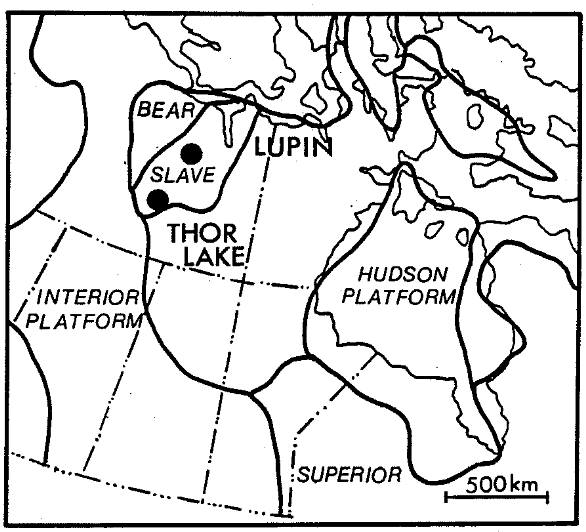

Figure 1. Location of the Lupin and Thor Lake deposits, Slave Structural Province.

The airborne geophysical surveys combined gamma ray spectrometric, magnetic and VLF-EM sensors. The two surveys were flown in the summer of 1988; results were released for viewing in November 1988, and published in July 1989. Field work involving geological observations, sampling and ground geophysical measurements in the two areas was carried out in the summer of 1989.

The objective of the project was to use the integrated geophysical survey data to improve the understanding of the genesis of the two mineralized areas and to demonstrate the application of the method to exploration for these two types of mineralization.

Methods

Airborne geophysical surveys

The geophysical surveys were flown with the GSC airborne gamma ray spectrometer system which has been described by Bristow (1979). In addition to the spectrometer, with 50L of NaI detectors, the system included a Geometrics G-803 proton precession magnetometer, and a Herz Totem 1A VLF-EM sensor.

Data are presented (Geological Survey of Canada, 1989a, 1989b) as a set of eleven colour maps for each survey and as stacked multiparameter profiles for each flight line. The gamma ray data are presented as a set of eight colour maps (ternary radioelement, exposure rate, potassium, equivalent uranium and equivalent thorium concentrations and eU/eTh, eU/K and eTh/K ratios). The aeromagnetic data are presented as colour maps of total field and calculated vertical magnetic gradient. The VLF-EM data are presented as a total field colour map and a quadrature profile map. A geological compilation accompanies the geophysical maps. The stacked profiles show seven radiometric parameters, magnetic total field, and VLF total field and quadrature components for each flight line.

Lupin area

The major geologic feature of the Lupin study area is a two-mica granite body (Unit C-6), approximately 700 km^2 in area, dated at about 2581 Ma (King et al., 1990) which intrudes Contwoyto Formation sediments. The Contwoyto Formation comprises thinly bedded turbidites and contains iron formation. The Lupin gold mine and numerous other gold occurrences in the area are hosted by the iron formation.

Two main hypotheses have been outlined for the origin of the gold:

1) An origin in which the gold is derived syngenetically during sea-floor deposition of sulphide iron formation.

2) An epigenetic origin in which the mineralization originates from fertile quartz veins that cut the iron formation resulting in sulphidization, alteration of grunerite to hornblende and introduction of scheelite, arsenic, gold, etc.

Although many gold occurrences in the Contwoyto Lake area are clearly epigenetic (Lhotka and Nesbitt, 1989; Kerswill, 1986, 1992), the genesis of stratiform deposits such as Lupin is controversial (see Kerswill, this volume). It is possible that the fertile quartz veins which controlled gold distribution in the non-stratiform occurrences (epigenetic) also controlled gold distribution at Lupin (Bullis, 1990).

It is conceivable that the fertile quartz veins could be related genetically to the granite as it is known from structural geology that they are in fact very close in age (King et al., 1990; Relf, 1989). The major purpose of this study is to provide a more extensive data base to evaluate the possibility of the granite having played a part in the mineralizing process.

The spatial association of felsic intrusions with gold mineralization is well known (Cherry, 1983). However, the relationship between such intrusions and gold mineralization is complex as discussed by Marmont (1983), who outlined four possible ways that a felsic intrusion could play a part in a gold mineralizing event:

1) Magmatic effect whereby the intrusions may be the source of metalliferous fluids.

2) Metamorphic/hydrothermal association whereby the pluton in metamorphosing adjacent country rocks can dehydrate its contact zone thereby releasing fluids which may leach, transport, and re-deposit metals in favourable sites.

3) Assimilation whereby the passive emplacement of a magma can be accompanied by digestion and enclosure of metalliferous strata.

4) "Ground preparation" whereby the felsic intrusion in fracturing caused by cooling, hydraulic pressure, brittle response to stress, propagating structural grains in the country rocks, and post-emplacement cataclastic deformation, will generate conduits for the circulation and deposition of ore forming fluids.

Interpretation and ground study

In order to assess the significance of the geophysical patterns a ground study was undertaken involving gamma spectrometry, scintillometry and measurement of magnetic susceptibility. Polished thin sections and geochemical analyses were obtained for many rock samples collected.

The major observations from the airborne geophysical survey are:

1) The granitic rocks of unit C-6 in the Lupin area are clearly separated from the metasedimentary rocks of the Contwoyto Formation by increased average levels of radioactivity and of eU/eTh ratio. Typical total radioactivity levels over the C6 granites are 6-10 R/hr compared to levels of less than 6 R/hr over metasedimentary rocks and other igneous rocks in the area. The total count radioactivity levels of the C-6 granites are not much above average crustal levels of radioactivity in Canada (Grasty et al., 1984) and are somewhat lower than typical granites.

2) Average levels of eU/eTh ratio are however quite high and variable over the granite ranging from the average crustal value of 0.2 up to well over 1.0.

3) The eU/eTh ratio highs trend radially to the northwest away from the Lupin gold mine which lies immediately adjacent to the body of granite. The zones of anomalous eU/eTh ratio appear to occupy structural highs in the granite.

4) The magnetic pattern is influenced by the sharp linear anomalies relating to the numerous diabase dykes in the area. These anomalies are however set in a broad pattern of magnetic variation. The broader magnetic pattern indicates much lower values over the granitic rocks near the Lupin Mine than over portions of the same granite farther to the northwest. There are no obvious anomalies which relate to iron formation which hosts the gold at Lupin. This is because of the relatively small size of the iron formations and their minimal ferromagnetic contrast with country rocks.

Based on ground and laboratory study, the batholith is a non-magnetic (non-magnetite-bearing) peraluminous subalkaline granite (calcic peraluminous after the classification of Keith et al., 1990). The granite is reduced, with an Fe_2O_3/FeO ratio of <0.9, at ~73% SiO_2. The rock is characterized by high total alkalis (nearly 9% combined K_2O+Na_2O) with low values of CaO (<1%). The only anomalous trace elements are tin (10 ppm) and boron (200 ppm). Gold is typically very low (<1 ppb).

Radiometrically the batholith is slightly enriched in uranium at about 5 ppm and has a high and variable eU/eTh ratio. The eU/eTh ratio can be related to muscovite/biotite ratio and to increased differentiation index. The eU/eTh ratio is mainly controlled by thorium concentration. The low ratio (low differentiation index) rocks have more thorium which is tied up early in monazite and zircon located at sites either within or near biotite. The monazite and zircon have low solubilities in peraluminous magma. This is a common scenario in peraluminous granites (Charbonneau, 1991). The high eU/eTh ratio rocks are more muscovite-rich and typically have increased boron levels. The differentiation index increases slightly with the ratio as does the albite content of plagioclase (An_{16} to An_8).

There is nothing specific in the geophysics and geochemistry of the Contwoyto batholith that could clearly point to it as having played a role in the gold mineralizing process although its proximity to the gold occurrences, age (timing), calcic peraluminous nature, and non-magnetite-bearing character are all favourable features.

Thor Lake area

The Blatchford Alkaline Intrusive suite (Davidson, 1982) is composed of several distinct, successively intruded, plutonic phases. The suite hosts at its centre the Thor Lake beryllium (Be) - rare metal deposit (Trueman et al., 1988) which was originally discovered through follow-up of a Geological Survey of Canada reconnaissance airborne gamma ray survey (Trueman et al., 1988).

The principal geological units are from oldest to youngest:

1) Caribou Lake Gabbro, a marginal unit that grades inward to a plagioclase-rich leucoferrodiorite phase. These rocks contain abundant inclusions of anorthosite.

2) Whiteman Lake Quartz Syenite.

3) Hearne Channel Granite and Mad Lake Granite both of which are moderately aluminous and contain hornblende and biotite.

4) Grace Lake Granite and Thor Lake Syenite in abrupt gradational contact. These units are both peralkaline and contain alkali amphibole. They occupy some 200 km^2, north of Hearne Channel.

Phases of the complex itself have been dated at between 2175 Ma (Hearne Channel granite) and 2094 Ma (Thor Lake syenite) based on U-Pb (zircon), (Bowring et al., 1984).

Interpretation and ground study

Ground investigations were carried out at this area, similar to the Lupin area. The object of the integrated airborne survey and the follow-up was to obtain information on the alkaline complex at Thor Lake to see if the geophysical patterns could provide additional information on the mineralizing processes. The major observations from the airborne geophysical survey are:

1) The total count radioactivity map of the Blatchford complex and surrounding area shows anomalies relating to the Archean granite to the west of the complex, a well defined anomaly which outlines the Hearne Channel granite, an elongate anomaly which parallels the north shore of Hearne Channel which is in part related to increased bedrock exposure, and an isolated but extremely strong anomaly at the Thor Lake rare metal deposit. The radiometric pattern is essentially flat over the Grace Lake Granite and Thor Lake Syenite with no obvious large scale variations.

2) The only prominent eU/eTh ratio anomaly relates to an Archean two-mica granite west of the Blatchford complex. eU/eTh ratios over the Blatchford complex are generally constant with the exception of one slight increase near the Thor Lake deposit and another near the shoreline of Great Slave Lake. The eU/K, eTh/K values are elevated at the Thor Lake deposit and also in an area corresponding to a magnetic anomaly described below.

3) The magnetic anomaly map shows a prominent anomaly in the western part of the survey related to the Caribou Lake Gabbro and a portion of the Whiteman Lake Quartz Syenite. Within the Grace

Lake Granite, which is elsewhere uniformly non-magnetic, an arcuate magnetic anomaly occurs west of Thor Lake and extends down to the shoreline of Great Slave Lake. The southern part of this anomaly and a corresponding radiometric increase in total count, eU/K, eTh/K coincide with increases in other metals, i.e. tin, rare earth elements, niobium and tantalum. Another significant magnetic anomaly divides the Thor Lake syenite into a magnetic western and a non-magnetic eastern half. A number of northwest-trending and northeast-trending linear magnetic anomalies relate to diabase dykes of the Mackenzie and Hearne "sets".

The petrochemistry of the entire Blatchford complex from mafic to felsic end members has been described by Davidson (1982). The elemental abundances reported by Davidson vary predictably with SiO_2. The uranium and thorium abundances observed in this study are in accord with those reported by Davidson. Highest values were found in the Hearne Channel Granite, with concentrations in the Grace Lake Granite and Thor Lake Syenite concentrations being somewhat lower. Thorium averages, for example, were 29 ppm in the Hearne Channel Granite, and about 18 ppm in the Grace Lake Granite and the Thor Lake Syenite. Uranium-thorium ratios were quite constant at about 0.2 for all rocks.

Aside from the extremely strong uranium and thorium anomaly in the immediate vicinity of the Thor Lake deposit, the radiometric data do not focus on the deposit in any way. This suggests the origin of the deposit may be of a late stage episodic nature since the principal radioactive minerals i.e. zircon, allanite-bastnaesite crystallize late in alkaline rocks.

Several processes within the Blatchford suite may help explain the magnetic patterns noted above:

1) Primary magmatic concentrations of iron-titanium oxides and their oxidation state.

2) An alteration process wherein alkalies are removed from amphiboles, principally riebeckite and hornblende, resulting in a pseudomorph of quartz and iron oxides (magnetite - hematite). Sodium and potassium removed in this process could show up in the late stage feldspathization - albitization associated with much of the mineralization.

3) Hydrothermal-metasomatic enrichment in iron towards the late stage and mineralized phases of the intrusion.

Mineralogical work to date indicates that a combination of all three processes is the most likely explanation for the magnetic patterns. Primary iron enrichment (#1) towards the latest stages of the Blatchford complex is accompanied by an alteration process (#2) and hydrothermal-metasomatic enrichment in iron (#3).

Summary

This project has involved study of two "granites" which represent end points in the spectrum of U and Th behavior. In a peraluminous granitic magma such as Lupin, Th is tied up early because it is found in zircon and monazite which have low solubilities. The more evolved phases of the granite thus have low thorium and quite high U/Th ratios. In an alkaline "complex" like Thor Lake the radioactive minerals such as zircon and allanite-bastnaesite that host the Th and U crystallize with the last stages of the intrusion along with many granophile elements (Maurice and Charbonneau, 1987).

Acknowledgements

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NEW PLACER GOLD ANOMALIES ALONG THE LIARD RANGE - RAM PLATEAU SEGMENT, SOUTH NAHANNI RIVER METALLOGENIC TRANSECT, DISTRICT OF MACKENZIE, NWT

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Objective

The original objective of this project was to document the content of tungsten, gold, silver, gallium and germanium in the South Nahanni River area by:

1) analyzing Ga and Ge contents of selected samples from Ag-Pb-Zn occurrences in the area; and

2) analyzing heavy mineral concentrates (HMCs) from stream sediments.

Selected lead-zinc and tungsten showings were to be documented in the field and sampled. Preparation of HMCs was to be contracted out. This project was designed to enhance the mineral resource assessment of proposed extensions to the Nahanni National Park Reserve (Spirito et al., 1988) and contribute to a metallogenic transect across the southern Mackenzie Mountains.

Method

1) Eight Ag-Pb-Zn prospects in the Mackenzie Mountains were sampled and analyzed for Ga, Ge, Au, Ag, and a suite of other trace elements (analyses via contract to XRAL Assay Laboratories).

2) During previous field work for the mineral resource assessment of South Nahanni region (Spirito et al., 1988), very large samples of stream silt (1.5-3 kg) were collected in addition to sieved (<1 cm) sandy gravels (1.5-3 kg) for preparation of heavy mineral concentrates (HMCs). For the resource assessment, small splits of the silt samples were routinely analyzed for a large suite of elements by ICP and neutron activation, and the <850 um portions of the gravels were passed on a Deister concentrating table (Stewart, 1986) to prepare HMCs. This MDA project was proposed to experiment with the remaining splits of the large silt samples. Two techniques were being tested: a) the efficiency and effectiveness of the Deister concentrating table in preparing HMCs from large silt samples; and b) the comparability of geochemical results from silt HMCs, standard 30 g silt samples and sieved-gravel HMCs. If the results were favourable, a new exploration technology would have been developed, making it possible to sample stream sediments for heavy minerals and standard silt samples in one, less expensive step.

The scope of the HMC project was increased due to two factors:

1) On-going preparations of HMCs from stream gravels for the resource assessment showed great success at separating free gold grains (up to 33 per sample and as small as 10 um) on a Deister concentrating table with black deck.

   Most of the gold grains were captured in a petri dish at the table and were not included in the HMCs which were sent for neutron activation. These grains were measured (most were flakes in the order of 100-300 microns in diameter) and weighed (Table 1). A South American conical gold pan was used to immediately confirm the presence of very fine gold grains (>10 um) in the table HMC.

   Highly anomalous gold (calculated 30,000 ppb Au in HMC from gravel) was thus documented before neutron activation analysis, in one stream of Ram Plateau, informally named Wretched creek for its rugged topography. Subsequent neutron activation analyses of a series of samples from which free gold had been removed yielded very low gold abundances, indicating that initial

Table 1: Comparison of gold from silt heavy mineral concentrates with gold from standard silt samples and from sieved-gravel HMCs, eastern Nahanni Karst (Ram Plateau) and northeastern Tlogotsho Plateau (northern Liard Range). The ppb Au in silt HMCs and sieved-gravel HMCs was determined by combining weights of separated gold flakes (determined by J.C. Bisson on a Perkins-Elmer ultramicrobalance with AD-6 autobalance, giving precisions of +/- .0005 mg on <2 mg samples and +/- .001 mg on samples up to 20 mg.) with the ppbs of gold determined by neutron activation on the remaining HMC. Gold in standard silt samples was determined by neutron activation alone.

Location	Sample Number	Silt (g)	Silt HMC (g)	Au flakes #	Au flakes (mg)	Silt HMC Au (ppb)	Net ppb Au in 3 media silt-HMC	silt	gravel-HMC
Wretched1	6237	2575	27.00	1	0.0409	360	1,875	<5	77,000
Wretched2	6239	2100	20.75	2	0.0411	<5	1,981	<5	<5
Tetcela1	6242	2000	14.25	7	0.4741	180	33,450	<5	22
Tetcela2	6243	1800	24.05	6	0.0528*	<5	2,195*	<5	<11
Windy Ck.	6244	2775	20.80	17	0.1641*	330	8,219*	<5	<5
Jackfish	6249	2100	27.95	11	0.1785	705	7,091	<5	7
N. Yohin	6273	2275	16.90	0	0.0	<5	<5	<5	31,000*
Ram Ck.	6276	3300	13.35	3	0.3328	<5	24,929	<5	<5
Wretched	7065	2550	11.80	0	0.0	<16	<16	<5	4,750*
Wretched	7066	3025	11.25	0	0.0	N/A	N/A	<5	41,400*

* = minimum value, because one or more grains of gold were lost before weighing.
silt HMC = heavy mineral concentrate made on Deister concentrating table from silt.
silt = 30 g split of whole standard silt from stream.
gravel HMC = heavy mineral concentrate made on table from <850 um split of gravel.

preparation of HMCs on the Deister table gave immediate results which were as useful for gold as the final neutron activation analyses (Table 1). Final analyses of standard silt samples and gravel HMCs were still useful for base metals and for accessory elements which helped to interpret the gold values.

2) Consorminex Inc., which had been preparing the gravel HMC concentrates, offered a proposal to the Department of Supply and Services Canada (DSS) to develop and test technology to extract HMCs from fine-grained stream sediment samples in the same region. DSS supported the proposal, as did GSC through this project, with a resultant tripling of the MDA funding previously obtained to process samples on the Deister table. A total of 211 HMCs were then prepared from the silt samples. With 26 standards and duplicates, the silt HMCs were analyzed by neutron activation for gold and 33 other elements. A total of 53 silt HMCs and 53 previous gravel HMCs were further concentrated using methylene iodide (3.3 s.g.), mounted and analyzed using a 30-class mineral point-counting program. Rigorous statistical comparisons among the geochemical and mineralogical data sets from the three different sample media are in progress.

Results

1) Ga-Ge-Ag prospects: no anomalous values were returned. However, the style of each prospect was documented and will be published together with analytical results in the resource assessment.

2) Heavy Mineral Concentrates from streams: The HMCs from silt samples confirmed gold anomalies which had been identified using gravel HMCs, and indicated 6 new highly anomalous placer gold localities: Jackfish River, Windy Creek in Liard Range, a small tributary to Nahanni River at the south end of Nahanni Karst, and 3 tributaries in Ram Plateau (Fig. 1, Table 1). All but one of these new localities are aligned north-south on a trend that appears to be independent of the distribution of glacial deposits.

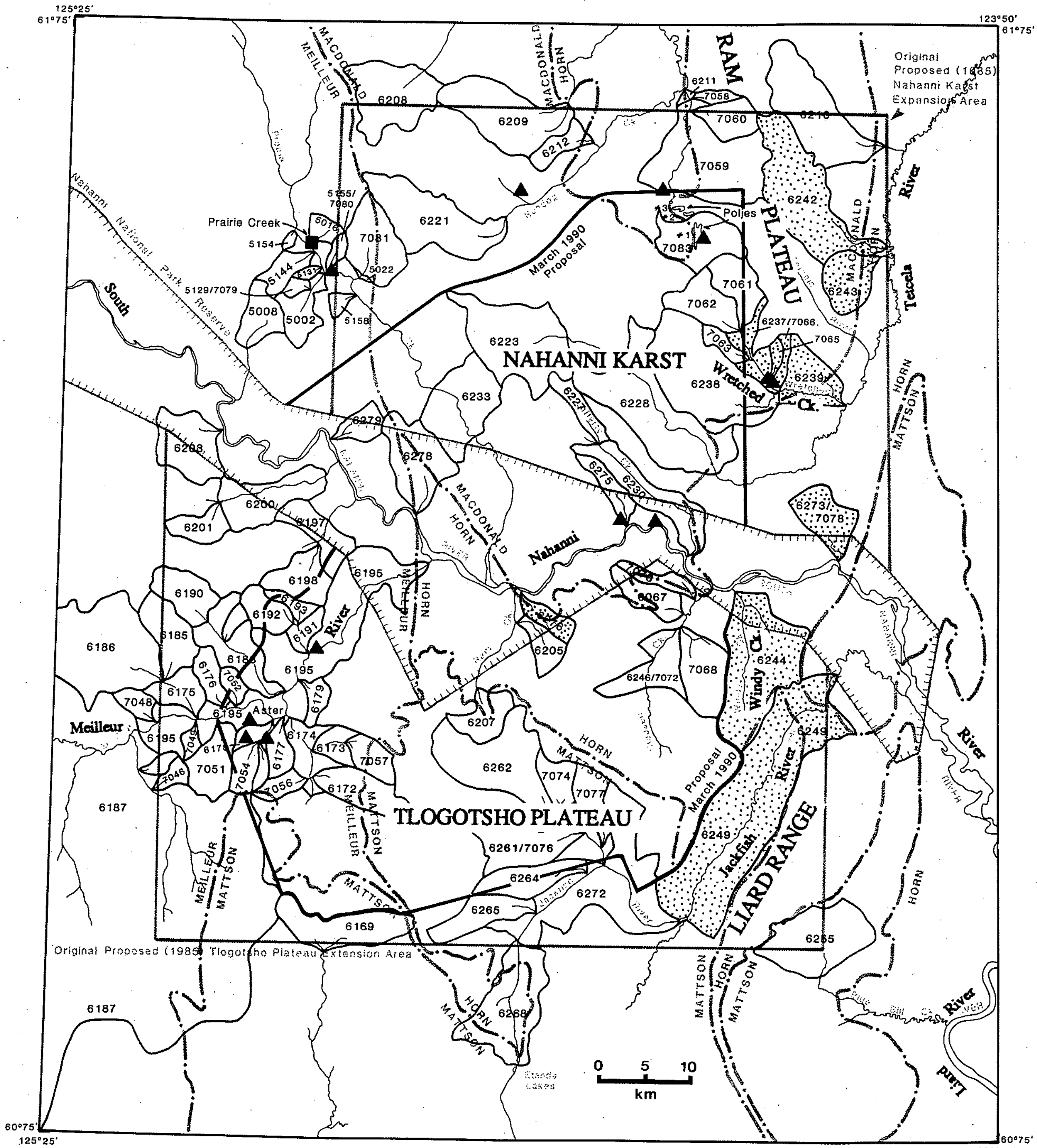

Figure 1. Locations of catchment basins (numbered polygons outlined by solid lines) in the eastern part of the South Nahanni River resource assessment area. Dotted polygons are those which yielded anomalous amounts of placer gold (Table 1) in heavy mineral concentrates made from stream sediment samples. faint background lines and text outline the Nahanni national Park Reserve, earlier proposed park extensions, and various geological domains: HORN = Devonian and younger shales, MACDONALD = platformal carbonates, MATTSON = Mesozoic sandstones; MEILLEUR = Ordovician to Devonian shales of Selwyn Basin. Heavy line indicates the current working proposal for the Nahanni karst and Tlogotsho Plateau park extensions.

Each locality coincides with an intersection of northerly and northwesterly trending faults. The provenance of this placer gold is being investigated in the resource appraisal. Inspection also shows that zinc values from silt HMCs parallel those from sieved-gravel HMCs. Discussions with Parks Canada officials have resulted in revision of proposed park boundaries to exclude the gold-bearing stream catchment basins.

Acknowledgements

The above sample collection and processing could not have been accomplished without the assistance of W.A. Spirito who is preparing an M.Sc. thesis on spatial analysis and stream sediment geochemistry in the South Nahanni River area. Polar Continental Shelf Project provided helicopter support for field work. B. Cooke and other staff of Consorminex Inc. provided invaluable assistance in the laboratory. S.B. Ballantyne and Y.T. Maurice provided advice on sampling techniques and on the design of the proposal. P.W.B. Friske and R.N.W. DiLabio co-supported the unsolicited proposal at GSC, making it possible for DSS to add its support. R.N.W. DiLabio critically reviewed this report.

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PLATINUM GROUP ELEMENT MINERALIZATION ASSOCIATED WITH THE MUSKOX, RANKIN INLET AND FERGUSON LAKE INTRUSIONS, NWT.

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Muskox intrusion
The marginal zone of the Muskox intrusion contains anomalous concentrations of Cu-Ni sulphide and platinum group element (PGE) mineralization. However, the sulphide-bearing layered sequence does not contain anomalous PGE.

The main focus of the Muskox project was the marginal zone mineralization. Detailed mineralogical, geochemical and isotopic investigations of this zone revealed some diagnostic geochemical signatures that significantly enhance our understanding of the genesis of this mineralization and how to explore for additional reserves.

Analytical data for PGE+ gold (Au) levels from the eastern and western marginal zone are illustrated in figure 1.

This data comprises only values > 100 ppb, and represents 35 samples from the western marginal zone and 140 from the eastern marginal zone out of approximately 2000 collected, by the GSC and

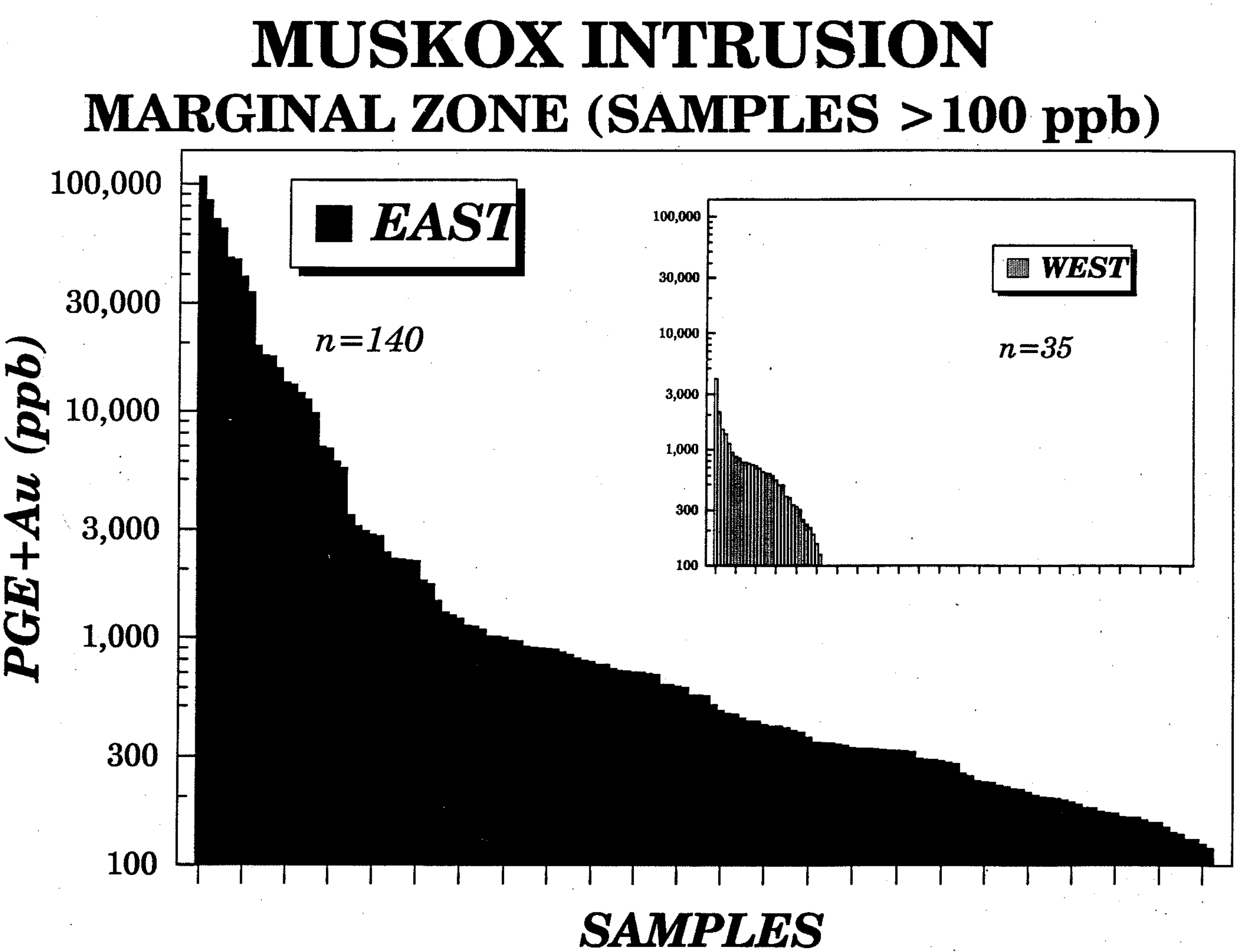

Figure 1. PGE + gold (Au) values in the eastern and western marginal zones of the Muskox Intrusion.

Equinox Resources, from the marginal zones. The highest concentration of PGE+Au occurs in the eastern portion where samples containing about 100,000 ppb have been discovered. The highest grade sample from the western portion contains about 4000 ppb. The quantity of PGE+Au is not a function of the abundance of sulphides in either zone. Numerous magmatic iron(Fe)-copper (Cu)-nickel (Ni) occurrences are present in both the eastern and western marginal zones. The massive, semi-massive and disseminated sulphides from the western marginal zone are characteristically deficient in Ni and Cu as well as PGE+Au (Fig. 1). In the eastern marginal zone nickel and copper assays as high as 8.0% and 16.0% respectively have been recorded from massive sulphides. Also, higher background levels of PGE+Au are present in the eastern zone. The proportions of platinum (Pt), palladium (Pd), Au, ruthenium (Ru), rhodium (Rh), osmium (Os) and iridium (Ir) present in the mineralization from the eastern and western marginal zone are approximately the same. The proportions and concentrations of these elements in massive sulphides from the eastern marginal zone are shown in figure 2. The contribution of Os, Ir, Ru and Rh to the total noble metal concentration is insignificant and thus does not appear on the bar plot in figure 2. The Muskox mineralization is characterized by high Pd/Pt ratios and relatively high Au contents.

Sulphides of the eastern marginal zone are characteristically enriched in selenium (Se), arsenic (As), tellurium (Te), bismuth (Bi) and antimony (Sb) relative to comparably mineralized (sulphide) lithologies in the western zone. A log-log plot of sulphur (S in wt. %) vs selenium (Se in ppm) (Fig. 3) discloses two discrete geochemical trends. Samples from the eastern area, for the same amount of sulphide, are considerably enriched in selenium relative to their western

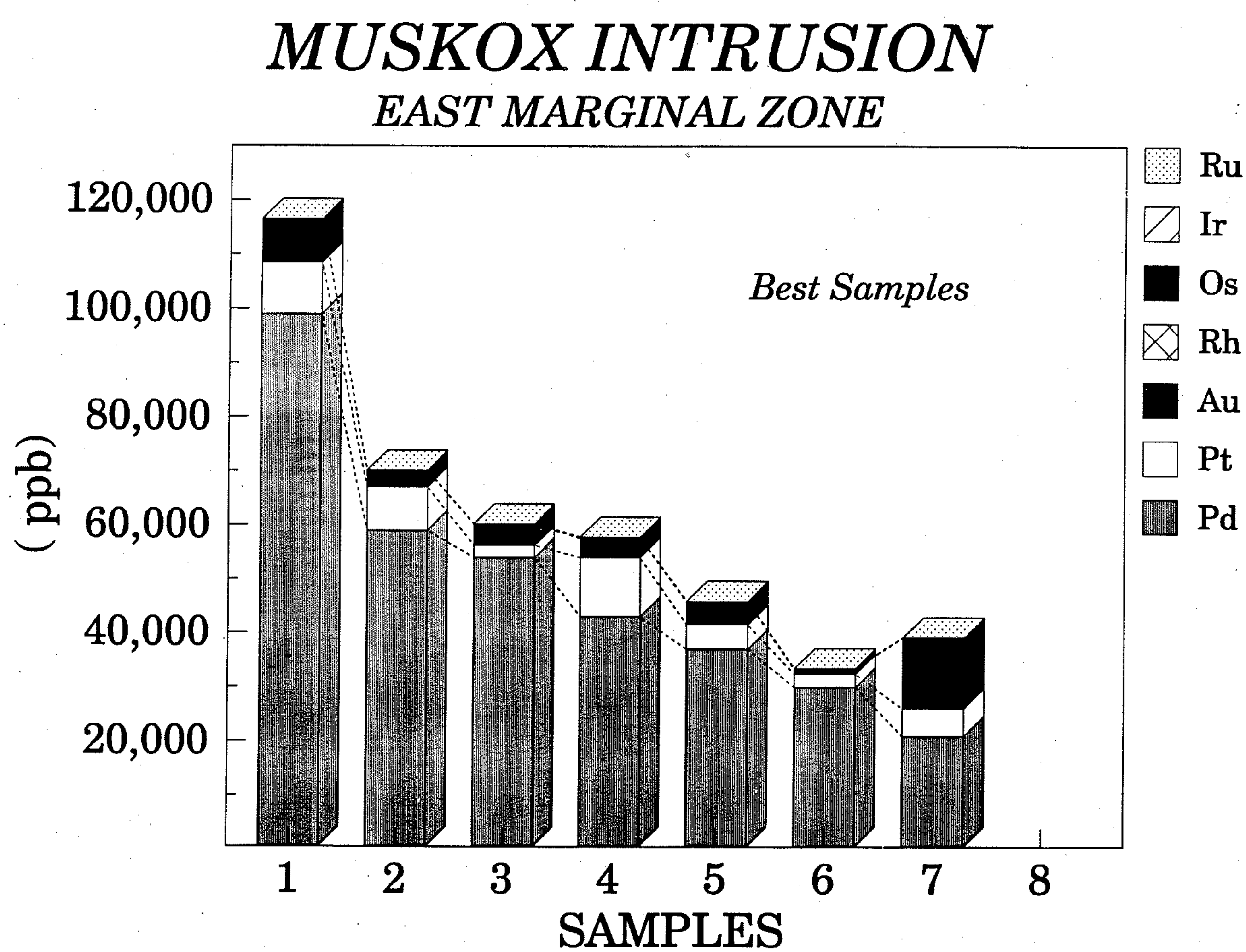

Figure 2. Platinum (Pt), palladium (Pd), gold (Au), rhodium (Rh), osmium (Os), iridium (Ir), and ruthenium (Ru) concentrations in the eastern marginal zone, Muskox intrusion.

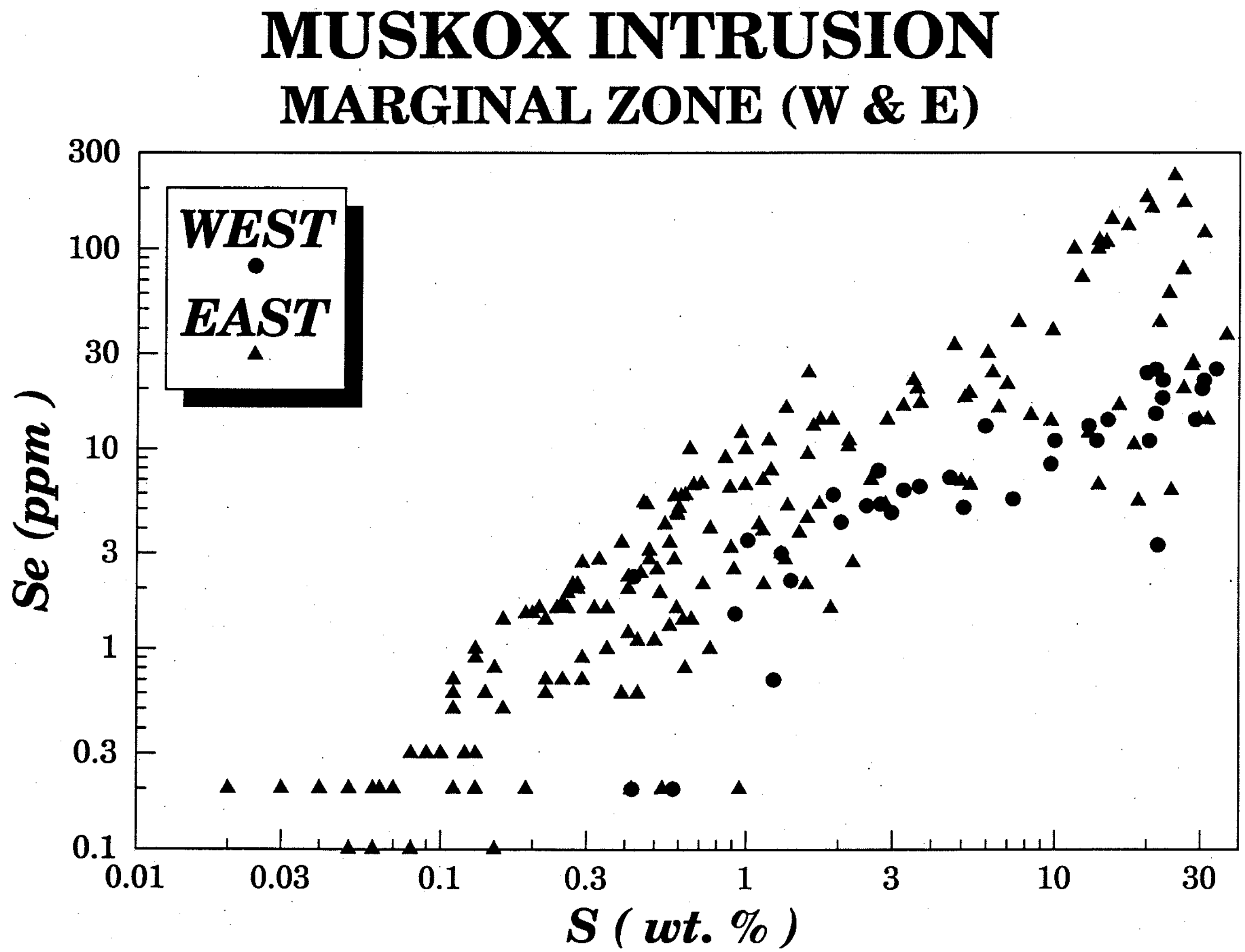

Figure 3. Log-log plot of selenium (Se in ppm) vs sulphur (S in wt. %) concentrations in the marginal zones of the Muskox intrusion.

counterparts. A plot of the S/Se ratio for mineralized and unmineralized samples from the different portions of the marginal zone indicate (Fig. 4) that about 70% of the samples from the eastern portion have S/Se ratios less than 5000 which appears to be a characteristic ratio for sulphides enriched in PGE in the Muskox Intrusion.

The eastern and western marginal zones also differ in their sulphur isotope signature (Fig. 5). Samples from the eastern zone generally contain values > 9.0 whereas those from the western zone are < 9.0 . The data represents that of material collected by the author and Sasaki (1969).

The difference in geochemical and isotopic character of samples from the eastern and western marginal zones is attributed to crustal contamination. In the field, the eastern and western marginal zones appear to be very similar in terms of lithological distribution, crystallization order, mineral compositions and major element geochemistry. However, the contrast in terms of Ni, Cu, PGE, Se, As, Sb, Te, and Bi is believed to be the result of contamination from two distinctly different sedimentary formations, each with its own particular geochemical characteristics. Eastern marginal zone rocks are in contact with psammitic and semi-pelitic members of the Odjick Formation. The Odjick Formation outcrops from just north of Speers Lake to 5.5 km south of McGregor Lake (a distance of 24 km) where it is truncated by a northwest-trending fault. Country rock exposures south of this fault and along the western marginal zone consist of Fontano Formation pelitic rocks (and migmatized equivalents) as far north as the north arm of McGregor Lake. As a general rule high PGE+Au concentrations have only been found in eastern marginal zone rocks that contain heavy sulphur

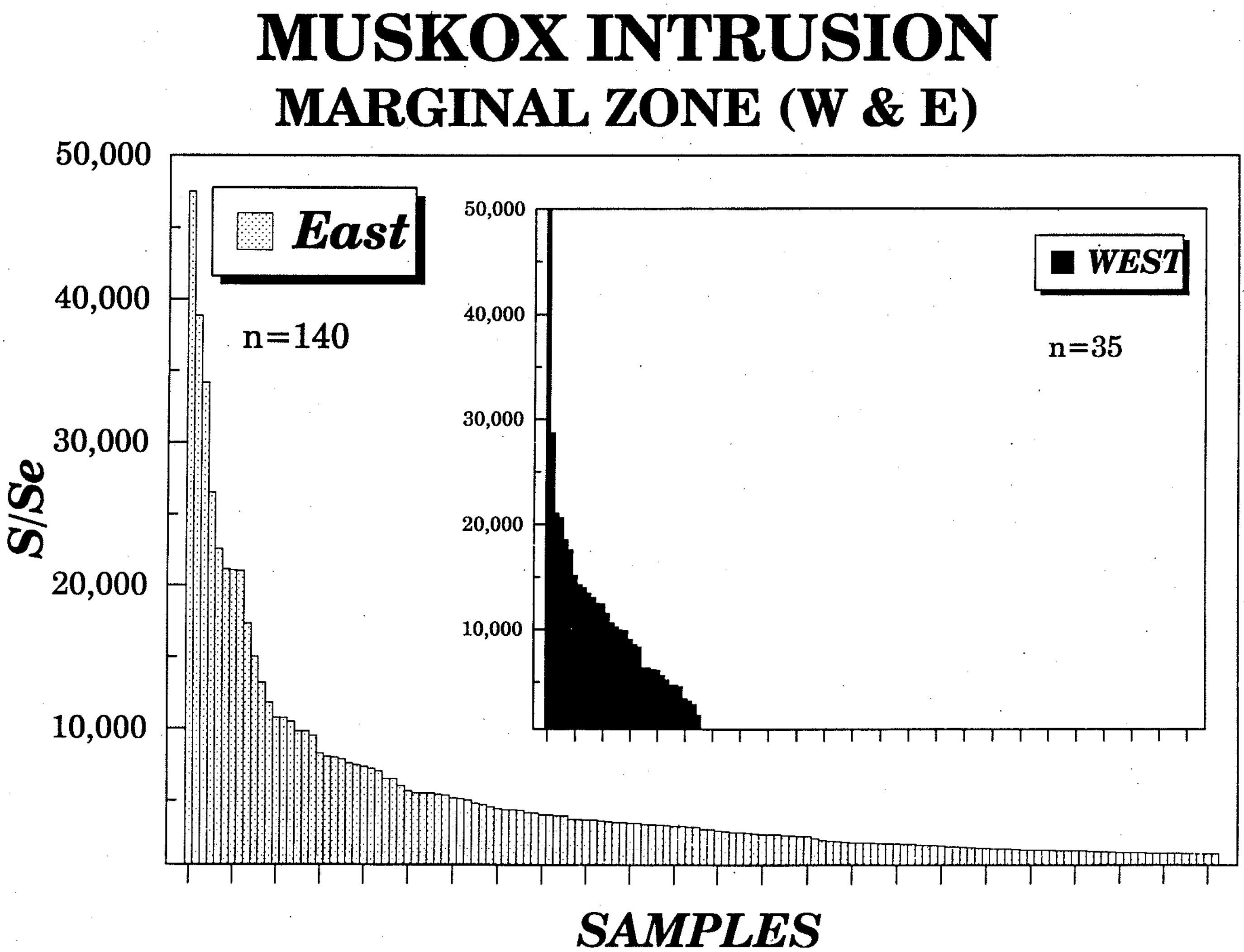

Figure 4. Sulphur/selenium (S/Se) ratios in the marginal zones of the Muskox intrusion.

(> 14), very low S/Se ratios (< 2500) and high concentrations of As, Sb, Bi, and lead (Pb). It is inferred that the As, Se, Sb, Bi, Cu, Pb and isotopically heavy sulphur were incorporated from the Odjick country rocks and the addition of the first four elements increased the noble metal scavenging capacity of the immiscible magmatic sulphides that were formed in the melt as a result of sulphur saturation. Assimilation of sulphur-rich pelites from the Fontano Formation did not have the same effect due to the dearth of Se, As, Sb and Bi associated with these sulphides, thus explaining the abundance of barren sulphides associated with these marginal rocks. The higher Cu-content of samples from the eastern margin may also be related to the higher relative copper content in the Odjick samples. The Fontano Formation contains more sulphide than the Odjick Formation but the latter is enriched in As, Se, Bi, and Sb. Had the mineralization been classified on the basis of: *(i)* marginal zone rocks in contact with Odjick Formation and *(ii)* marginal zone rocks in contact with Fontano Formation, the relationships discussed above and illustrated with the aid of figures 1 to 5 would be significantly enhanced. Such a reclassification is in progress. The identical character of the marginal zone lithologies, crystallization order and major element chemistry clearly suggest that the eastern and western marginal zones crystallized from the same initial magma and had similar PGE concentrations. Platinum-group element enrichment by selective contamination, as discussed above, appears to be an important factor and raises some important questions regarding the significance of initial PGE concentrations and the role of the R-Factor (ratio of silicate melt/sulphide melt) in controlling the noble metal content of immiscible magmatic sulphides.

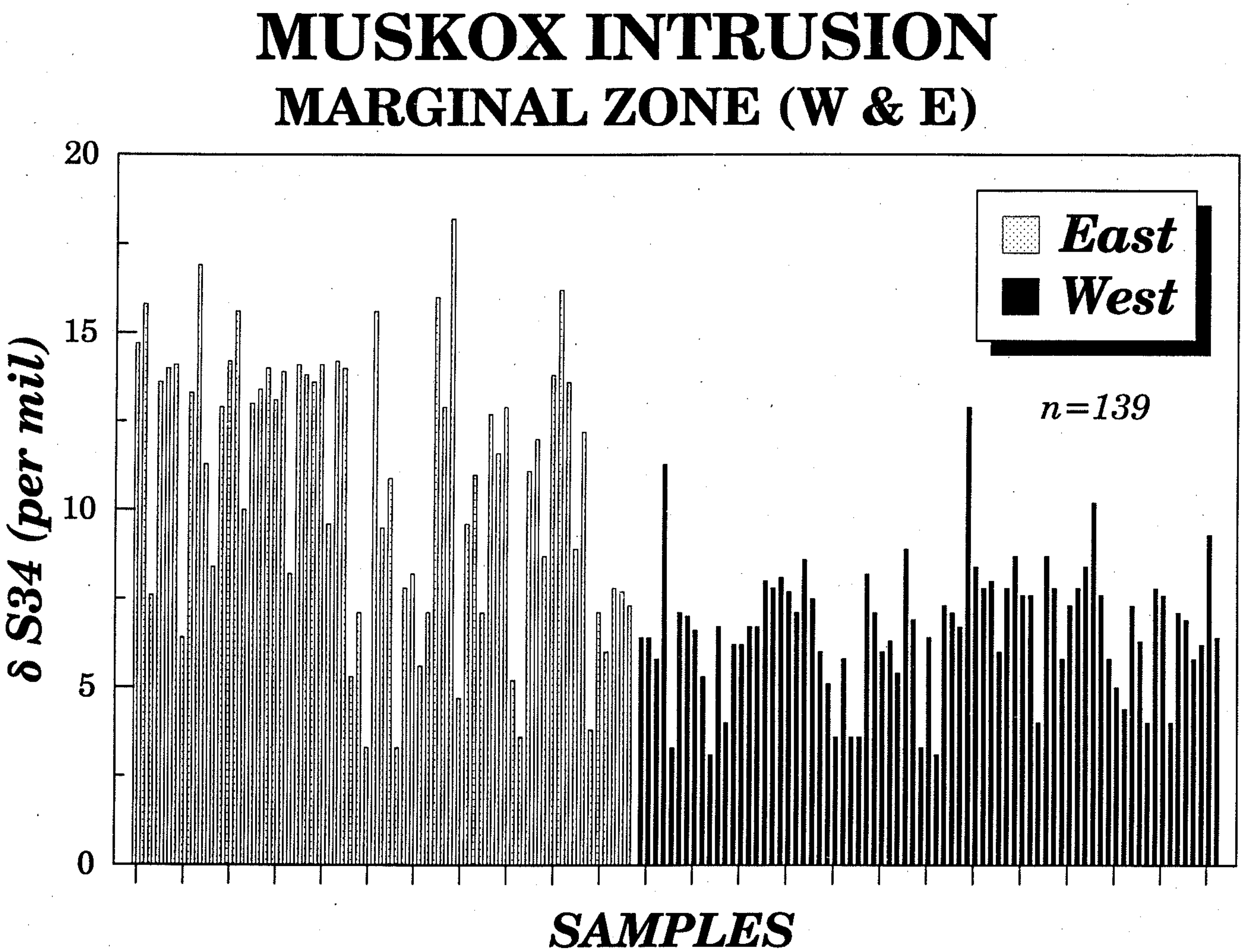

Figure 5. Sulphur isotopes in the marginal zones of the Muskox intrusion.

Rankin Inlet intrusion

Investigation of the Rankin Inlet intrusion and asociated Ni-Cu-PGE mineralization revealed some rather unexpected results.

The Ni content of the massive sulphide mineralization ranges from 7.9 to 11.6 per cent. Total platinum-group element assays as high as 10,340 ppb were recorded; with Ru, Rh, Pd, Pt, Os, Ir and Au values as high as 2300, 1000, 5800, 2300, 1100, 580, and 300 ppb respectively. In general the massive sulphides contain $PGE_{(t)}$ in the 4197 to 10,004 ppb range, about 6324 ppb. Unusually high concentrations of As are associated with this ore (up to 5.6%), the As being present in magmatic gersdorffite (exsolved from the monosulphide phase upon cooling). All the ultramafic rocks and mineralized equivalents are relatively enriched in As compared to the Clarke for equivalent lithologies in other intrusions. The hanging wall of the massive sulphide zone consists of a horizon of lower grade net-textured to disseminated mineralization that was regarded as waste during the period of high-grade nickel mining activity. An overall grade for this zone would be 0.65% Ni, 0.25% Cu, 420 ppb Pt and 930 ppb Pd. There is a disproportionate amount of PGE in this horizon relative to that of the massive sulphides. Net textured and disseminated samples rich in sulphides can contain from 3525 to 8030 ppb PGE. Relatively high As and PGE contents for basaltic rocks were also observed in the co-magmatic Rankin tholeiites up to 5 km away from the intrusion. Unmineralized gabbroic bodies in the vicinity of the Rankin Intrusion were found to contain anomalous PGE levels in the 53 to 335 ppb range. A significant quantity of ultramafic rocks enriched in Ni, Cu and PGE mineralization may be concealed beneath the gabbros.

A sulphur-isotope investigation of sulphides in the Rankin Intrusion also disclosed unusual values in the range 0.3 to 11.1. If the one unusually low value is excluded, a value of 7.7 is suggested. Uncontaminated mantle derived sulphur typically has a signature of about 0.0. Due to the dearth of sulphate reducing bacteria in Precambrian, sulphur-isotope fractionation seldom occurs. However, the heavy isotopic character of the sulphur implies that the incorporated sulphur was originally derived from an Archean sea containing sulphate reducing bacteria.

The presence of sulphides enriched in ^{34}S and the abnormal concentration of As in both the intrusions and the volcanics suggests that a parent magma chamber existed at depth and this chamber was extensively contaminated with sedimentary-derived sulphur and arsenic prior to emplacement of the Rankin Inlet intrusion and coeval volcanics.

The high concentrations of Os and rhenium (Re) in the Rankin mineralization make this material particularily well suited for Os-Re geochronological studies. An eleven point $^{187}Os/^{186}Os$ vs. $^{187}Re/^{186}Os$ isochron suggest an age of 2893$\pm$105 Ma (Fig. 6; Hulbert and Grégoire, in preparation).

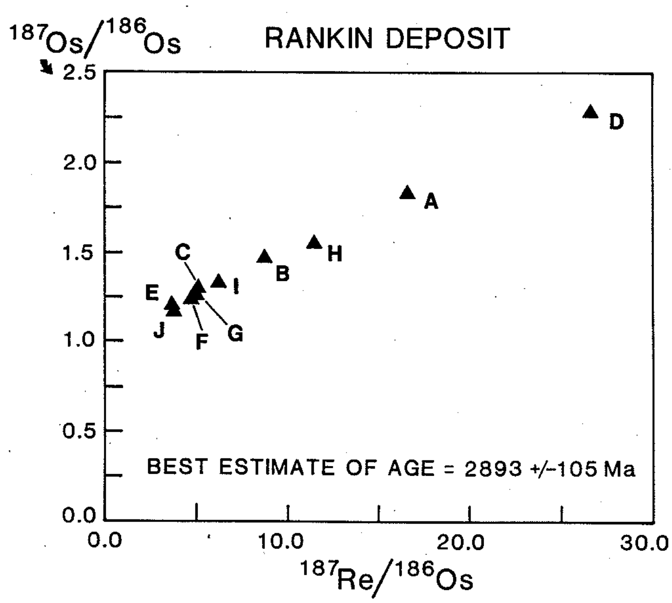

Figure 6. Osmium/rhenium (Os/Re) isochron for the Rankin Inlet intrusion and associated mineralization.

Ferguson Lake

A reconnaissance investigation of the PGE concentrations present in this highly deformed amphibolitic, anorthosite terrane was conducted. The distribution of all elements, including the PGE, was found to be very erratic. The maximum concentration of Cu and Ni was 35000 and 8200 ppm respectively and that of Pt, Pd and Rh was 3000, 1900 and 110 ppb respectively. The massive sulphide generally contains 800-1200 ppb Pd and 240-520 ppb Pt. All samples are depleted in As, Se, Te, Bi and Sb. The gossan material contains very erratic values with a preferential enrichment in Pt relative to that of the fresh underlying sulphide samples.

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STUDY OF THE PERALKALINE GRANITE-SYENITE CONTACT IN THE THOR LAKE AREA, NWT AND ITS RELATIONSHIP TO THE T-ZONE MINERALIZATION AND ALTERATION

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Introduction
The Thor Lake deposits represent a large resource of beryllium, yttrium and other rare metals. The North T-Zone deposit, for example, contains 1.6 million tonnes grading 0.85% BeO, including 435,000 tonnes grading 1.4% BeO and 0.26% Y_2O_3. Various aspects of the deposits and their host rocks have been documented by Davidson (1972, 1978, 1981, 1982), de St. Jorre and Smith (1984, 1988), Cerny and Trueman (1985), Trueman et al. (1984, 1988) and Pinckston and Smith (1988).

The North T-Zone deposit is a north-trending, irregular body that is hosted by Thor Lake Syenite and Grace Lake Granite. It is about 1 km long, up to 250 m wide, and extends to depths of at least 150 m. Contacts between the deposit and host intrusive rocks are sharp. Rock types and alteration within the deposit were divided by Trueman et al. (1984, 1988) into four major lithologies. The outermost part of the deposit, designated the Wall Zone, is an albitite that consists largely of albite replacements of earlier K-feldspar; fluorite and columbite are present in small amounts. The Lower Intermediate Zone, which has a gradational contact with the Wall Zone, consists of quartz, albite, riebeckite and micas, with lesser magnetite and fluorite. This zone is distinguished by variably preserved xenoliths of the granite and syenite wall rocks. Phenacite (Be_2SiO_4), REE minerals, columbite, thorite and zircon are present in small amounts. The Upper Intermediate Zone, which is transitional from the Lower Intermediate Zone, is marked by increased quartz content and a predominance of quartz-polylithionite-albite assemblages. Fluorite is abundant, and phenacite, columbite and REE minerals (mainly bastnaesite) are common. A sub-zone rich in quartz and bastnaesite-type minerals contains about 60,000 tonnes grading approximately 8% rare earth oxides. The Quartz Zone is characterized by a predominance of massive, coarse crystalline quartz in which mica, fluorite and carbonates (siderite and dolomite) are minor constituents. Patches and veinlets rich in REE-bearing minerals, predominantly bastnasite, are locally conspicuous, but for the most part this zone is monomineralic quartz.

Objectives
This study is a detailed investigation of the North T-Zone deposit with emphasis primarily on two objectives:

1) to determine the mineral parageneses of the important alteration types (e.g., albitization, greisenization, silicification), and

2) to determine the origin of the ore-forming fluids and the conditions of ore deposition.

Methods of Investigation
To determine mineral parageneses, an investigation of ore, gangue and alteration minerals was undertaken, including detailed macroscopic and petrographic examination of hand specimens and drill core. To determine the nature and origin of the ore-forming fluids, geochemical and fluid inclusion studies were carried out. The geochemical studies included analysis of carbon and oxygen isotopes in carbonate minerals, sulphur isotopes in sulphide minerals, and oxygen and hydrogen isotopes in fluid inclusions in quartz and fluorite.

Results

1) Studies of ore, gangue and alteration minerals:

Macroscopic and petrographic studies indicated that many of the original mineral assemblages in the Lower Intermediate Zone and the Upper Intermediate Zone have been partly to completely replaced. The bulk of these zones, however (together with the Wall Zone and the Quartz Zone), appear to have formed mainly by mineral precipitation into open space, with some replacement or alteration of the earliest minerals (e.g., aegerine and/or albite in the Lower Intermediate Zone) during deposition of the later mineral phases. At the deposit scale, the timing relationships indicate that the Wall Zone formed at an early stage and was followed successively by the development of the Lower Intermediate Zone, the Upper Intermediate Zone, and the Quartz Zone. At the macroscopic and microscopic scales the timing is similar, with, for example, Wall Zone albite- and aegerine-bearing assemblages being overprinted and/or infilled with a quartz+magnetite+biotite+carbonate assemblage characteristic of the Lower Intermediate Zone.

2) Geochemical studies:

Analysis of carbon and oxygen isotopes was conducted on twelve carbonate concentrates (all ankerites except for one siderite sample coexisting with ankerite) separated from samples of Upper Intermediate Zone and Quartz Zone rocks. Values of $\delta^{13}C$ ranged from -2.07 to -5.94 per mil and are similar to those in carbonate minerals from carbonatites (δ^{13} = -2 to -8 per mil; Deines, 1989). Oxygen isotopes ranged from $\delta^{18}O$ = +11.71 to +15.24 per mil and are comparable to oxygen isotope values from kimberlites, which have a strong maximum at about +12 per mil (Deines, 1989). Both the carbon and oxygen isotope values reflect a strong magmatic component, with little or no meteoric contribution.

Sulphur isotopes were analyzed on 21 samples of sulphides from the Upper Intermediate Zone and the Quartz Zone, including four sets of sulphide pairs. Values of $\delta^{34}S$ ranged from 0.0 to +1.9 per mil, with no clear distinction between the Quartz Zone rocks and the Upper Intermediate Zone rocks. These values show little deviation from the Canyon Diablo troilite (FeS) standard, and reflect a dominantly magmatic component, similar to the carbon and oxygen isotopes.

The hydrogen isotopic composition of water released from fluid inclusions is consistent with a magmatic derivation for the hydrothermal fluid; the oxygen isotopic composition results are ambiguous but do not rule out a magmatic origin.

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GEOCHEMICAL, ISOTOPIC AND GRAVITY STUDIES OF THE THOR LAKE DEPOSITS AND ASSOCIATED HOST ROCKS OF THE BLATCHFORD LAKE INTRUSIVE COMPLEX

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Introduction

Geoscientific studies of the Blatchford Lake Intrusive Suite and the Thor Lake rare-metals deposits carried out under the Canada-NWT MDA have advanced understanding of the area in three ways:

1) timing of the formation of the deposits from geological observations,

2) the third dimension of the complex from gravity measurements, and

3) the evolution and alteration of the rocks from isotopic studies of Nd and Sm.

Methods and Results

1) Timing of formation of the deposits:

At the beginning of the project, the relative chronology of the deposits and surrounding rocks was poorly constrained, and the principal working hypothesis of exploration geologists and most researchers was that the deposits were late magmatic, related to the emplacement and cooling of the Grace Lake Granite and the Thor Lake Syenite. Consideration of the form and distribution of the deposits indicated that the principal deposits, the Lake and T zones, were located along a north-south fracture system, and the R and S zones in secondary fractures related to the main system.

Field investigations showed that diabase dykes which cut the Grace Lake and Thor Lake intrusive rocks are themselves dismembered and chemically altered by the mineralizing process. Feldspar-phyric diabase is transformed to an unusual rock notable for radiating splays of K-feldspar in a dark, fine-grained matrix. It can thus be concluded that the Grace Lake and Thor Lake intrusions were sufficiently cool to allow brittle failure and dyke emplacement of diabase before the mineralizing event. It now seems most likely that the deposits were formed with or after the emplacement of the nepheline syenite which underlies the Lake zone. The local development of balls of diabase in the Thor syenite suggests that the span of time involved in all these events was relatively short.

Previously determined age dates based on the K-Ar method have indicated an age for the Blatchford Lake complex of about 2150 Ma (Wanless et al., 1979). Hearne Channel Granite from the western portion of the Blatchford Suite has yielded a more precise U-Pb zircon date of 2175 +/- 7 Ma, whereas a date of 2094 +/- 10 Ma was obtained from a mineralized part of the Thor Lake Syenite (Bowring et al., 1984); the history of intrusion and mineralization related to the Blatchford complex thus appears to span at least 80 to 100 Ma. Age dating of the diabase to constrain the age of the mineralization more closely is currently underway.

2) Gravity studies of the Blatchford complex:

The Thor Lake deposits are located at the centre of the Blatchford Lake Intrusive Suite. Of interest is why the deposits are in the centre rather than distributed around the margins or randomly within the complex. To allow a better understanding of the geometry of the complex, a gravity survey was carried out on two lines crossing the Blatchford Lake Intrusive Suite (Birkett et al., in preparation). The interpretation of the gravity data was constrained by the geology as mapped by Davidson (1972, 1978) and rock densities measured as part of this study. Gravity modeling was carried out in 2 1/2 dimensional space using the MAGRAV2 program of Wells (1979) as modified by Broome (1986).

The results of the gravity modeling indicate that the Caribou Lake mafic intrusive rocks in the western part of the complex have a deep, subvertical root. The granites which make up the major part of the complex are of limited vertical extent, and can be modeled as flat bodies about one kilometre thick. There is no evident root zone in the centre of the complex which could be ascribed to the granites or to the underlying nepheline syenite. If root zones exist for these bodies, they are too small to be resolved by gravity measurements (i.e. much smaller than the bodies themselves).

3) *Isotopic studies of neodymium (Nd) and samarium (Sm)*:

One other approach to understanding the development of the intrusive suite and its mineral deposits is through isotopic tracer studies. Although K-Ar and Rb-Sr studies had been applied to the area as parts of age dating programs, the Nd-Sm isotopic system had not been used in the area. A series of samples were prepared for analysis through chemical separation of the Sm and Nd, and isotopic analyses obtained by mass spectrometric methods supported by isotope dilution analyses of the Sm and Nd in each sample.

The results (Birkett and Jenner, in preparation) show a complicated pattern both around the deposits and in the intrusive suite as a whole. The rocks of the intrusive complex near Great Slave Lake have disturbed isotopic patterns in the same areas which are anomalous in K, Th and U from the airborne radiometric survey (Charbonneau and Legault, this volume). Scatter in the isochron diagram of samples of mineralized rocks suggests either initial isotopic heterogeneity or local resetting of isotopic systems later in the history of the deposit.

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PETROLOGY OF ALKALINE RARE EARTH ELEMENT-BEARING PLUTONIC ROCKS, ENEKATCHA LAKE (65E/15) AND CAREY LAKE (65L/7) MAP-AREAS, DISTRICT OF MACKENZIE

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Objectives

The principal objectives of this subproject were to investigate radiometric anomalies in the Enekatcha Lake and Carey Lake areas, District of Mackenzie and to examine the plutonic rocks in these areas with regard to their potential to host rare metal deposits similar to the Be-Ce-Y deposits at Thor Lake, about 540 km west of the study area.

Introduction

Small-scale anomalies at Enekatcha and Carey lakes are part of an oblong northeastern-trending regional radiometric anomaly that extends from Boyd Lake in the southwest to Wharton Lake in the northeast. This regional anomaly has a northeast-southwest dimension of approximately 375 km and an average northwest-southeast dimension of 125 km (Darnley et al., 1986). Within the larger area of anomalous radiometrics, two high amplitude discrete source anomalies are identified near its southwestern edge, coincident with the Enekatcha and Carey lakes study areas.

Enekatcha Lake

At Enekatcha Lake, semicircular airborne gamma-ray spectrometric anomalies (Geological Survey of Canada, 1978b) up to 5 km in diameter are coincident with an irregular bulbous aeromagnetic anomaly (Geological Survey of Canada, 1955a; 1984). The Enekatcha Lake area is centrally located within an areally extensive southeast-trending ribbed or rogen moraine field (Aylsworth, 1989) and consequently outcrop is extremely poor. However, boulder fields and irregular to sinuous ridges strewn with radioactive, magnetic megacrystic feldspar-bearing plutonic rocks are present east and northeast of Enekatcha Lake. This distribution roughly coincident with geophysical anomalies suggests little if any glacial transport to the west-southwest.

Plutonic rocks at Enekatcha Lake intrude foliated, layered in part, cataclastic granitic to granodioritic gneisses of presumed Archean age. In contrast, the Enekatcha Lake plutonic suite is unstrained to very weakly strained and exhibits only minor retrogression of essential phases. The principal alteration is saussuritization of plagioclase, chlorite after phlogopite, actinolite after hornblende and clinopyroxene and serpentine-iddingsite after olivine.

Leucocratic syenite, red-pink to cherry-red due to disseminated ultra fine grained hematite, is characterized by zoned megacrysts of microcline perthite, up to 5cm long. The cumulate perthite is randomly oriented to weakly aligned and is accompanied by intercumulus feldspar and mafic minerals (Fig. 1). Mesocratic syenodiorite and syenogabbro, pink grey to black, again with pinkish hues, are characteristically fine to medium grained and can contain trachytically aligned megacrysts of microcline perthite.

In megacrystic syenite cumulates, zoned and unzoned phlogopite and augite are the principal mafic intercumulate phases; they are also present along with altered olivine as finer grained inclusions in megacrystic perthite. Intercumulus magnetite and apatite characterize the assessory intercumulus assemblage. In contrast, fine to medium grained mesocratic rocks contain variable proportions of augite, hornblende, perthite, minor altered olivine and accessory euhedral magnetite and apatite.

Following the classification of Cox et al. (1979) and LeMaitre (1984), the Enekatcha Lake plutonic suite is alkaline (Fig. 2). The most abundant rock unit, coarse grained megacrystic feldspar-bearing syenite, contains on average 59-64% SiO_2, 13-16% Al_2O_3 and K_2O>Na_2O, up to 3.5:1. More mafic finer grained and equigranular varieties lie within the syenodiorite

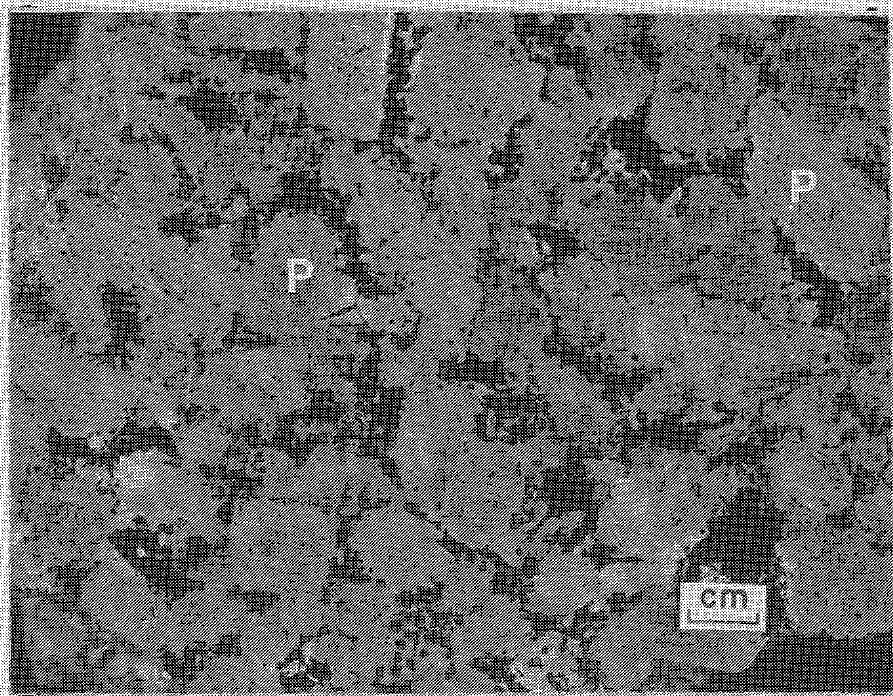

Figure 1. Photograph of megacrystic syenite, Enekatcha Lake. Cumulus microcline perthite (P) with intercumulus mafic minerals (black) and feldspar (white).

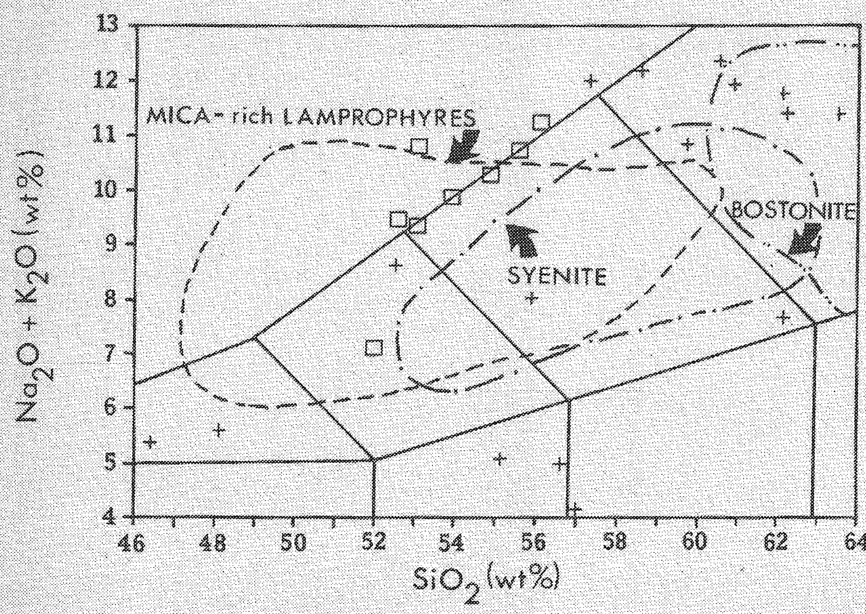

Figure 2. Silica vs total alkali for the Enekatcha Lake (cross) plutonic complex and Carey Lake (square) lamprophyres. Classification boundaries are those of LeMaitre (1984) for alkaline volcanic rocks and the dashed/dotted areas are for alkaline rocks from the 1.8 Ga intracratonic basins of central Keewatin (from LeCheminant et al, 1987)

and syenogabbro compositional fields and contain proportionally less SiO_2 and Al_2O_3, and variable ratios of K_2O/Na_2O (Table 1).

Highly anomalous U+Th-bearing and rare earth-bearing syenodiorite and quartz-bearing syenodiorite are related to the above alkaline suite but possess distinct differences in mineralogy and major element chemistry: SiO_2 contents are variable but lower, 46-57%; Al_2O_3 is markedly lower at 5.5-6.6%; K_2O is equal to or greater than Na_2O; iron is higher as Fe_2O_3 total ranges from 9.3 to 22%; and the LOI is higher

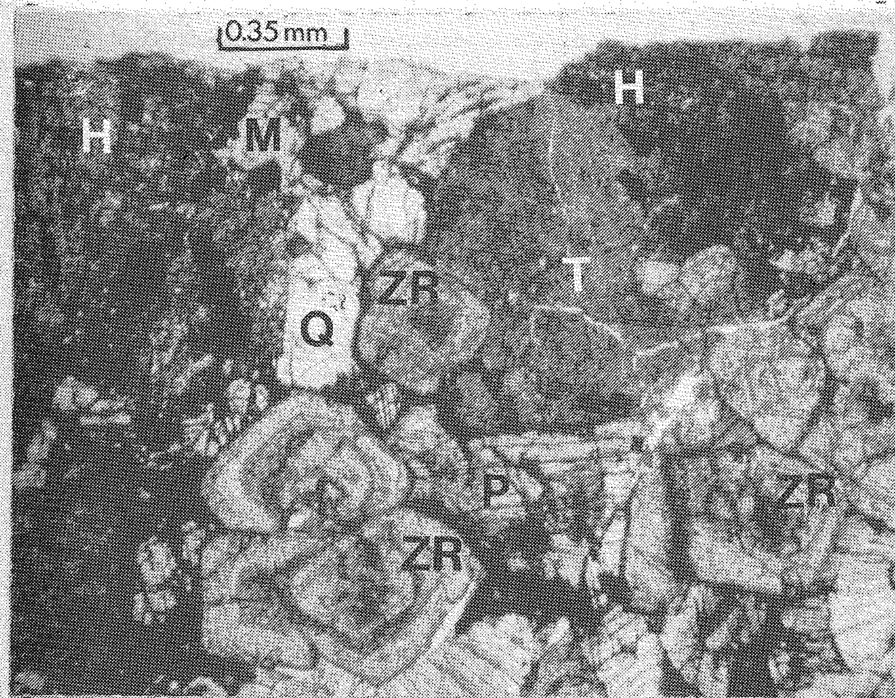

Figure 3. Photomicrograph of zircon-rich syenodiorite, analysis MYAA475-1, Table 1 and 2. Zoned euhedral zircon (ZR) and metamict Th + Si phase, thorite (T) are associated with hornblende (H) and magnetite (M) inclusions, interstitial perthite (P) and quartz (Q) fractured due to radiation damage.

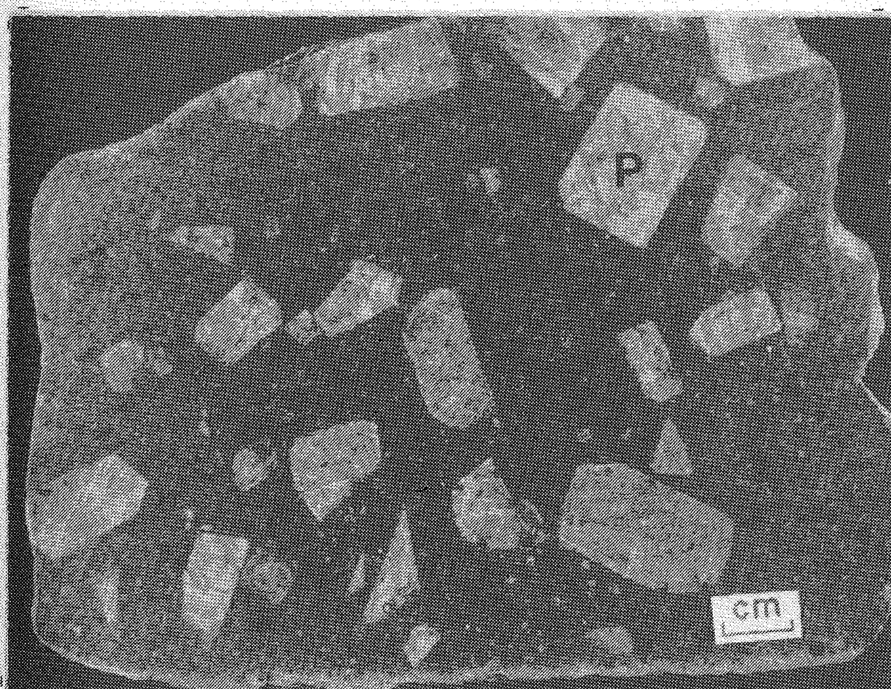

Figure 4. Photograph of megacrystic microcline perthite (P) - bearing lamprophyre, Carey Lake.

Table 1. Selected major element chemistry, Enekatcha Lake alkaline rocks

Rock type	Megacrystic syenite		Syenodiorite, syenogabbro			U+Th+REE hornblende syenite			
Sample	MYAA 471-1	MYAA 473-1	MYAA 474-1	MYAA 474-2	MYAA 474-6	MYAA 475-1	MYAA 475-2	MYAA 475-3	MYAA 477-2
SiO2	62.1	55.9	48.1	57.3	52.5	55.1	57	56.6	46.4
TiO2	0.9	0.91	1.21	0.82	0.92	1.17	3	0.82	2.7
Al2O3	15.5	13.5	6.88	15.2	10.8	6.6	5.19	5.64	5.56
Fe2O3T	5.66	7.7	12	4.52	7.48	9.38	20.6	11.4	22
FeO	0.6	3.7	1.3	2.7	3.3	1.9	3.2	3.4	7.7
MnO	0.14	0.12	0.19	0.08	0.14	0.48	0.23	0.46	0.42
MgO	1.55	6.01	12.4	3.97	9.15	2.16	1.62	1.94	2.04
CaO	1.1	5.37	9.23	2.79	6.77	2.87	2.93	3.19	3.22
Na2O	4.53	2.53	1.45	2.61	2.52	2.75	1.84	3.08	3.22
K2O	7.2	5.49	4.13	9.37	6.08	2.35	2.31	1.9	2.16
P2O5	0.33	0.88	1.56	0.54	0.76	0.29	0.28	0.42	0.26
S	0.014	0.015	0.003	0.007	0.027	0.003	0.001	0.004	0.012
H2O	0.3	0.9	1.2	0.2	0.4	2.9	0.9	2.9	1.5
LOI	0.85	1.16	1.23	0.7	0.54	4.08	1.47	3.08	1.85
Total	100.3	100.2	98.8	98.8	98.5	100.2	99.9	100.6	95.4

Table 2. Selected trace element chemistry, Enekatcha Lake alkaline rocks

Rock type	Megacrystic syenite		Syenodiorite, syenogabbro			U+Th+REE hornblende syenite			
Sample (ppm)	MYAA 471-1	MYAA 473-1	MYAA 474-1	MYAA 474-2	MYAA 474-6	MYAA 475-1	MYAA 475-2	MYAA 475-3	MYAA 477-2
B	50	30	20	20	30	270	110	220	110
Be	44	8	11	8	10	86	72	77	130
Li	47	8	11	8	10	86	72	77	130
V	120	170	200	100	130	96	96	100	140
Cr	82	240	660	170	560	26	32	24	16
Co	10	29	52	19	35	110	42	120	72
Ni	9	39	330	79	180	62	27	62	40
Cu	45	37	12	52	28	160	11	93	18
Zn	84	120	160	73	150	450	240	430	490
Ge	<10	10	10	10	10	60	10	60	40
Mo	9	5	9	7	6	54	25	35	53
Ag	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cd	<1	2	1	2	2	4	2	3	3
Sn	9	2	5	3	5	13	35	12	30
Rb	462	204	322	514	396	116	67	107	143
Sr	892	1610	981	1880	1410	313	123	195	454
Y	43	24	39	15	30	803	349	736	289
Zr	974	190	248	106	330	94200	24100	88200	39800
Nb	70	<10	20	16	42	<10	186	<10	<10
Ba	1470	3440	1260	5040	4530	477	697	314	376
Bi	0.7	0.7	<0.1	<0.1	<0.1	1	<0.1	1.5	0.2
Th	167	20.1	58.6	46.3	56.8	967	3270	1280	891
U	37	5.9	16.2	14.6	21	1530	518	1400	1100
Pb	84	20	4	24	28	1300	200	490	3400
Ta	5	<1	1	<1	2	20	22	13	25
Cs	31	4	29	16	49	9	2	3	13
La	134	57.3	187	85.8	99	4240	1060	1790	2750
Ce	248	113	397	180	187	6820	2330	3040	4850
Nd	78.5	52.1	203	90.3	80.4	1580	520	360	1360
Eu	2.46	2.75	6.73	3.41	4.29	24.4	15.6	13.9	21
Tb	1	0.9	3	1.1	1.5	16.7	13.9	11	11.6
Yb	2	1.6	3	1.2	2.4	49.1	34.2	47.5	28.6
Lu	0.28	0.26	0.42	0.23	0.4	6.8	4.75	6.75	4.04

at 1.85-4.08% (Table 1). Based on modal mineralogy, the LOI is interpreted as H_2O^+. The silicate assemblage in syenitic rocks containing anomalous concentrations of Zr, Ce, La, U, Th, Y, Nd, and Nb is hornblende+perthite+albite $\pm$ minor interstitial quartz and blue to green-blue Na-amphibole (Table 2). Modal proportions of assessory radioactive and rare earth-bearing phases and Fe-Ti oxides are highly variable. Metamict to partially metamict zircon (var. cyrtolite) is the most abundant phase, almost 1 wt%. It is unique in that individual grains are very coarse grained, to 0.7 mm, compared to the normal grain size distribution in igneous rocks, and have a complexly-zoned euhedral habit (Fig. 3). Additional assessory phases include amber to orange subhedral sphene, euhedral to anhedral metamict radioactive phases, non titanium-bearing magnetite and minor to trace ilmenite.

Electron-microprobe energy dispersive spectral investigations on metamict and crystalline phases have shown that the following phases are present: Nb-bearing sphene; a metamict phase consisting principally of Th+Si with trace Zr+U+Ce, interpreted as thorite; zircon containing variable trace proportions of U+Pb+Th; a very fine grained yellow to red-brown crystalline La- and Ce-bearing phase containing the principal elements Si+Al+Ca+Fe $\pm$ Ti; a red-brown metamict phosphate containing La+Ce+Th interpreted to be monazite; and euhedral apatite containing trace Ce. The distribution of metamict and crystalline, radioactive and non-radioactive phases in syenodiorite and syenogabbro is reflected in the elevated to highly anomalous concentrations of the incompatible elements Zr, Y, and REE (Table 2) compared to megacrystic syenite and mafic equivalents.

Carey Lake

Immediately north of Carey Lake and east of the Dubawnt River, a broad semicircular airborne gamma-ray spectrometric anomaly (Geological Survey of Canada, 1978a) approximately 15 km in diameter is coincident with an oblong aeromagnetic anomaly (Geological Survey of Canada, 1955b). The Carey Lake anomaly is broader and of lower intensity compared to the Enekatcha Lake anomalies.

North and northeast of Carey Lake, the improved outcrop permitted direct observations between the basement complex, relative ages of deformation and intrusion of alkaline rocks. The basement consists of biotite and/or hornblende-bearing metagranite with megacrystic perthitic microcline. The metagranite has intruded foliated granitic gneisses and layered granodioritic gneisses. Garnet-bearing phases of the megacrystic granite indicate the basement complex attained at least amphibolite facies metamorphism. The metagranite is identical to 2.605 Ga intrusive units (LeCheminant and Roddick, 1991) in the Dubawnt Lake map-area, NTS 65N/5, which have been described by Peterson et al. (1989).

Brittle to ductile faults transect the basement in several directions. Near-vertical undeformed mica-rich lamprophyres are restricted to west-trending mylonites in the basement. Dyke rocks contain phenocrysts of fluorine-bearing, zoned phlogopite; normally and reversely zoned diopside-salite; altered olivine; and zoned megacrystic perthitic microcline (Fig. 4), all texturally and chemically similar to respective phases in rocks from the Enekatcha Lake alkaline complex. Carey Lake intrusive rocks are markedly more mafic in terms of bulk composition (Fig. 2). The possibility exists that these rocks represent a much less fractionated suite, thus accounting for relatively low contents of incompatible elements when compared to the syenitic rocks located at Enekatcha Lake.

Based upon the reconnaissance evaluation of the Enekatcha and Carey lakes and subsequent mineralogical and chemical studies, this plutonic suite is remarkedly similar to aerially extensive volcanic and plutonic rocks mapped to the northeast in the Dubawnt and Baker lakes regions. Lamprophyres and plutonic stocks and dykes in the study areas are considered to be associated with the extensive 1.8 Ga potassic alkaline magmatic event that was coeval with the early stages of intracratonic basin formation in the central District of Keewatin (LeCheminant et al., 1987). The presence of this plutonic event in the Carey and Enekatcha lakes region may represent the southwestern limit of this event.

Summary

Preliminary evaluation of the study area indicates that the Enekatcha plutonic rocks in particular are significantly enriched in heavy rare earth elements. An evaluation of their economic potential is hindered by poor exposure and their ultimate value as a source of those metals is as yet not known.

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POLYMETALLIC DEPOSITS OF THE SOUTHERN GREAT BEAR MAGMATIC ZONE

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Introduction

The southern Great Bear magmatic zone is noted for several promising prospects of uranium, copper, gold, bismuth and cobalt, and one past producer of uranium, namely the Rayrock Mine (Fig. 1). The discoveries have resulted from exploration carried out intermittently since the 1930s. The region is logistically favourable for exploration and development, because of its proximity to Yellowknife and the presence of a winter road through it.

Geological and metallogenic studies of the region have lagged behind the exploration activities. The regional mapping was done 50 years ago (Kidd, 1936; Lord, 1942). Since then regional and more detailed mapping has been restricted to parts of the area (Fraser, 1967; McGlynn, 1968, 1977, 1979), including the property level mapping by various exploration companies. A metallogenic study was begun by the writer in 1987, as part of the 'Rare Metals Project' of the Canada-Northwest Territories Mineral Development Subsidiary Agreement, and it represents the first attempt towards understanding the regional metallogeny of this large and geologically complex area.

This summary highlights the results of this 3-year study. Details of the work are reported in papers on the Fab, Sue-Dianne and Gar prospects at Lou Lake (Gandhi, 1988, 1989; Gandhi and Lentz, 1990), and were presented orally at several meetings.

Objectives and Methods

The project started with 3 objectives:

1) To define the geological setting of some of the more promising prospects,

2) To interpret their significance in terms of regional metallogeny, and

3) To provide guides for further exploration.

The fieldwork was conducted by a two-man team for less than 5 weeks in each of the 3 years (1987 through 1989). Results of this fieldwork were integrated with exploration data from the assessment files, complemented by some unreleased data obtained from company personnel upon request, and by chemical and mineralogical studies at the Geological Survey of Canada in Ottawa.

Metallogenic interpretations presented here are based on these studies, literature search, and a broader perspective the writer has developed through continuing uranium resource assessment work in the District of Mackenzie since 1977.

Results

General geology

The Great Bear magmatic zone is a continental, dominantly felsic volcano-plutonic zone formed 1880-1840 Ma ago, on the west side of the Wopmay orogen which culminated ca 1900 Ma ago (Hildebrand et al., 1987). Its eastern boundary is marked by the Wopmay fault zone, and on other sides its boundaries are concealed by younger nearly flat-lying Proterozoic and Paleozoic strata. Continuity of the north-trending magmatic zone beneath these strata is reflected in regional magnetic patterns. In the southern part of the zone (south of latitude 65° N), regional mapping by Lord (1942) resulted in recognition of Archean rocks east of the fault zone, which are overlain unconformably by the Aphebian Snare Group. This group comprises conglomerate, sandstone, siltstone, shale, dolomite, and mafic to intermediate volcanics. These supracrustal rocks have been affected by deformation and metamorphism, and have also been intruded by the Hepburn suite of granitic plutons, which are late Aphebian in age (Frith et al., 1977; Frith, 1986). Plutons of this suite are not well represented west of the Wopmay fault, due in part at least to the difficulty of distinguishing them from the plutons of the Great Bear magmatic zone. Metasedimentary rocks of the Snare Group are unconformably overlain by the volcanic sequence of the Great Bear magmatic zone. The unconformity is exposed near the Gar prospects at Lou Lake (Fig. 1). The volcanic sequence is at least 3 km thick. It has been intruded by related plutons and dykes of quartz monzonite, dacite, quartz-feldspar and feldspar porphyries and granite, and by younger diorite, and diabase dykes.

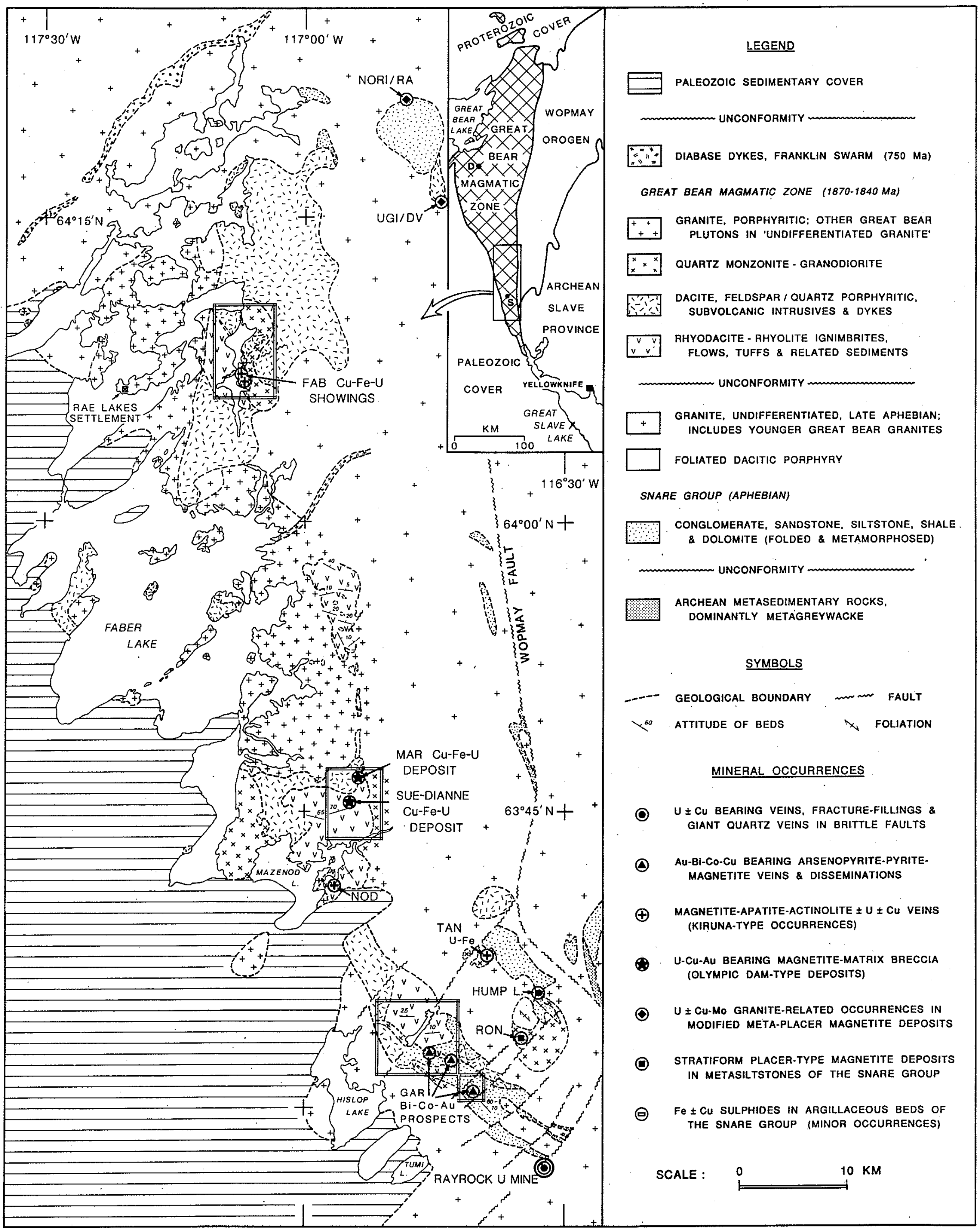

Figure 1. Map of the southern Great Bear magmatic zone showing general geology, selected mineral occurrences, and location of areas studied during 1987-89.

Metallogeny

Deposit Types:
Mineral occurrences in the southern Great Bear magmatic zone can be broadly grouped into the following types:

i) Synsedimentary/diagenetic sulphide concentrations in the Snare Group (minor occurrences in argillaceous beds).

ii) Meta-placer magnetite concentrations in the Snare Group (Hump Lake North and Ron prospects; Gandhi, 1992a).

iii) Meta-placers modified by granite-related U and Cu-Mo mineralization (Ham, Jones, Nori/Ra, JLD and UGI/DV prospects; Miller, 1982a, 1982b; Gandhi, 1992a).

iv) Polymetallic and monometallic magnetite-rich veins and breccia-fillings, related to the Great Bear magmatic activity, comprised of two subgroups:

  a) Magnetite-apatite-actinolite veins U Cu of Kiruna-type (Fab, Tan, and Honk prospects; Gandhi, 1988, 1992a).

  b) Breccia zones with magnetite matrix containing Cu, U and Au, of Olympic Dam-type (Sue-Dianne and Mar deposits; Gandhi, 1989, 1992b).

v) Polymetallic arsenopyrite-dominated veins and disseminations (Au, Bi, Co, Cu) related to the Great Bear magmatic activity (Gar and Burke Lake prospects; Gandhi and Lentz, 1990).

vi) Vein-type uranium ± copper occurrences in brittle fractures post-dating the Great Bear magmatic activity, including the giant quartz vein of the Rayrock Mine (numerous small occurrences; Gandhi, 1978; Gandhi and Lentz, 1990).

The present study concentrated mainly on the occurrences of groups (iv) and (v), namely the Fab prospect, and the Sue-Dianne and Lou Lake deposits.

Fab Prospect
Magnetite-rich veins and associated small breccia-fillings occur in an intermediate to felsic volcanic sequence and intrusive dacitic porphyry, and contain variable amounts of pitchblende, chalcopyrite, pyrite, fluorite, apatite and actinolite (Gandhi, 1988). The showings are as much as 100 m long and 5 m wide. The veins are widely distributed in a north-trending zone 7 km long and 2 km wide.

Sue-Dianne Deposit
This deposit is an irregular, pipe-like breccia zone in a thick pile of rhyodacite ignimbrite (Gandhi, 1989). Exploratory drilling has indicated 8 million tonnes averaging 0.8% Cu to a depth of 300 m. Magnetite forms fine to medium grained aggregates, and is associated with, and in part replaced by, hematite. Copper sulphides are distributed as veinlets, stringers and disseminations within the breccia matrix, and to a lesser extent in the fragments. Chalcopyrite is the dominant phase, but bornite and chalcocite are widely distributed, and predominate over chalcopyrite in some drill sections. Some copper-rich drill intersections contain as much as 60 g/t Ag and 0.34 g/t Au. Pitchblende occurs in two modes, as finely disseminated grains in magnetite aggregates that commonly assay 75 to 150 ppm U, and as massive aggregates in veins cutting the magnetite-cemented breccia. The pitchblende veins contain variable amounts of copper sulphides, quartz, calcite, hematite, and traces of mineral phases containing Bi, Se and Te, including kawazulite (Miller, 1982a, 1982b).

Mar Deposit
The Mar deposit located 2.5 km to the northeast of the Sue-Diane deposit is similar but smaller, nearly half in terms of surface area in comparison with the Sue-Dianne deposit, and lacks the secondary pitchblende veins (Gandhi, 1991b).

Main Gar Prospect at Lou Lake
Arsenopyrite veins and disseminations occur near Lou Lake within a zone extending 4 km along strike, in sandy and argillaceous metasedimentary rocks of the Snare Group, and in unconformably overlying felsic volcanic and volcaniclastic units of the Great Bear magmatic zone (Gandhi and Lentz, 1990). Similar occurrences are found in the metasedimentary rocks near Burke Lake. The main zone is located on the original Cab claims near Lou Lake, and has drill indicated reserves of 195 000 tonnes averaging 0.16% Bi; some values in Co, Cu and Au are also present. A high grade bulk sample contained 4.80 g/t Au, 2.36% Co, 0.63% Bi, 40.8% As, 22.5% Fe and 16.0% S. Microscopic and microprobe studies of arsenopyrite from this prospect and other occurrences have revealed that it contains variable amounts of Co, as

much as 14.7%, and minute inclusions of gold, bismuth, bismuthinite and pyrrhotite.

Associated phases are pyrite and magnetite-hematite, both major and minor to trace amounts of chalcopyrite, bismuthinite, native bismuth, emplectite, pyrrhotite, cobaltite, loellingite, wittichenite, tennantite, molybdenite, scheelite and wolframite. Pyrite has been commonly replaced or partly replaced by magnetite, with magnetite in places replaced by hematite. Magnetite closely associated with arsenopyrite is generally coarser than the magnetite inherent in thin layers and lenses associated with the chloritic argillaceous beds. Magnetite also occurs separately as veins, commonly containing chlorite and/or quartz, in the host beds. Arsenopyrite in some outcrops has partially weathered to green scorodite.

Genesis

The magnetite-dominated occurrences are interpreted to be genetically related to the Great Bear magmatic activity. The Sue-Dianne and Mar deposits are similar in many respects to the giant Olympic Dam deposit in South Australia, which contains 2 billion tonnes of ore averaging 1.6% Cu, 0.05% U, O.06 g/t Au and notable amounts of rare earth elements (Gandhi and Bell, 1990). It is also in a hematite-magnetite-rich breccia zone related to a continental, ca 1.60 Ga old, felsic volcano-plutonic complex. These type of deposits are regarded as products of differentiation in magma chambers that generated iron-rich magmatic fractions charged with volatiles. Escape of the volatiles created openings in which magnetite and associated minerals were deposited. The vein-type occurrences of the Fab prospect are morphologically similar to the large tabular magnetite deposits of the Kiruna district in Sweden, which has resources of greater than 3 billion tonnes of iron ore. These deposits are also associated with continental felsic volcanic rocks about 1.9 Ga in age, and represent the monometallic end of the deposit spectrum (Gandhi and Bell, 1990).

The arsenopyrite mineralization is regarded as hydrothermal, related to the Great Bear magmatic activity, and its genesis possibly involved meteoric waters. It is localized at the unconformity between chemically reactive metasedimentary units and the overlying volcanic sequence (Gandhi and Lentz, 1990). The mineralizing solution may have scavenged some of the elements from the argillaceous strata.

From the standpoint of regional metallogeny, the two styles of polymetallic mineralization may be manifestations of a single metallogenic episode.

Conclusion

The Great Bear magmatic zone hosts deposits similar in character to, and comparable in volcano-plutonic setting to the giant Olympic Dam deposit in South Australia. It has, therefore, a potential for large polymetallic deposits of the Olympic Dam-type. The Great Bear magmatic activity also formed arsenopyrite-dominated polymetallic hydrothermal veins and disseminations at the unconformity between the Snare Group and the overlying volcanic sequence. Larger and economically attractive deposits of this type may occur at and in the vicinity of this unconformity.

Guides to Exploration

In search for the Olympic Dam-type deposits, coincident magnetic and gravity anomalies provide very useful guides. Geologically favourable factors are the presence of magnetite-hematite-rich occurrences and proximity to centres of volcanic activity. Multi-element geochemical anomalies and radiometric anomalies are additional favourable indications. In exploration for the arsenopyrite-dominated deposits, detailed mapping, prospecting, and magnetic and geochemical surveys, are recommended in the vicinity of the unconformity between the Snare Group metasedimentary rocks and overlying volcanic sequence.

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MINOR ELEMENT CONTENT OF SPHALERITE, NANISIVIK LEAD-ZINC DEPOSIT, NWT

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Objective

Sphalerite from six ore types in the Main Zone at Nanisivik and from four peripheral localities were analyzed for a suite of minor elements by electron and proton microprobe techniques. Detection limits by proton microprobe for Ge, Ga, Ag, Cd, In, and Se were 100, 110, 10, 15, and 15 ppm, respectively.

Results

Se and In were found to be consistently below the detection limits and Ga was found in only two samples. Ge content averaged about 400 ppm but showed no major differences among the ten ore types and localities sampled. Ag averaged about 200 ppm and is strongly correlated with Ge (Fig. 1). Average Cd content is 2000 ppm; Cd and Fe, analyzed by electron microprobe, are directly correlated.

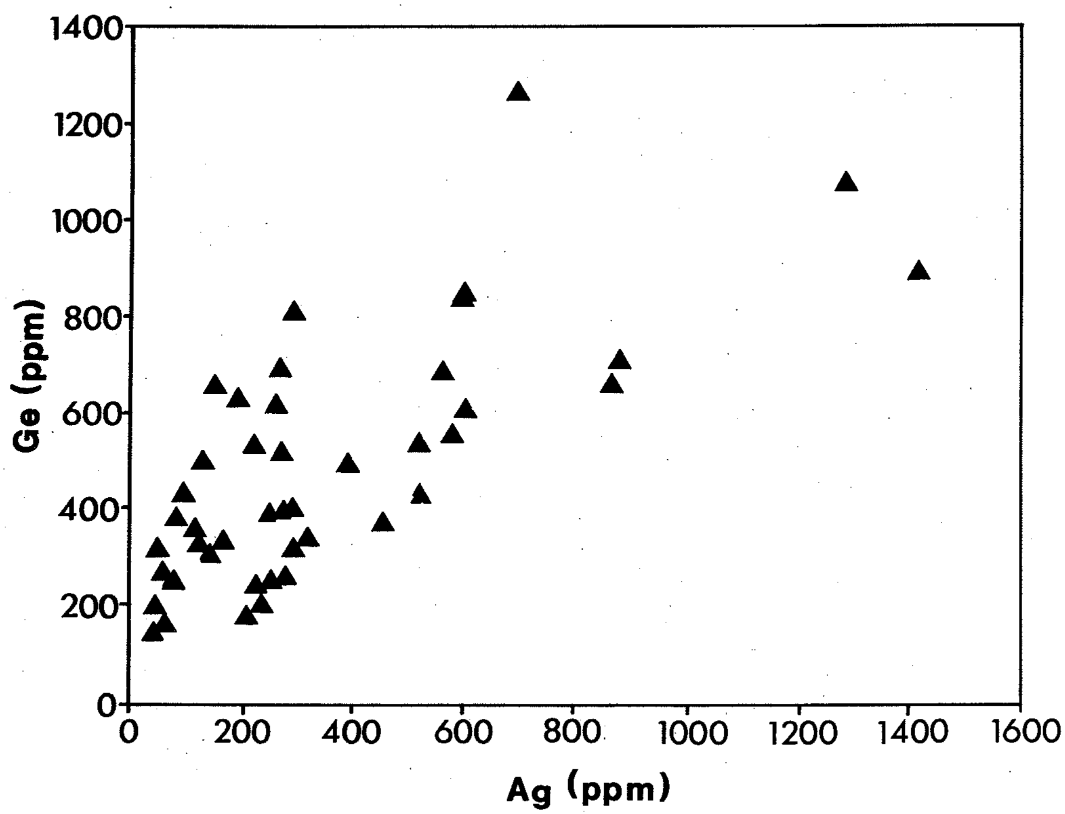

Figure 1. Relationship between germanium (Ge) and silver (Ag) in sphalerite, Nanisivik Main Zone and peripheral occurrences. Corelation coefficient = 0.72.

ORIGIN OF PRESQU'ILE DOLOMITE AND DISSOLUTION FEATURES AT PINE POINT AND ADJACENT SUBSURFACE

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Objectives

Mississippi Valley-type (MVT) deposits at Pine Point are hosted by Presqu'ile dolomites and are closely associated with dissolution vugs and breccias. The origin of these dolomites and dissolution features have previously been interpreted to be related to a Devonian meteoric system that formed during the sub-Watt Mountain exposure (e.g. Kyle, 1981, 1983; Rhodes et al., 1984). Others have suggested the hydrothermal fluids have played a role in the dolomitization and dissolution associated with mineralization at Pine Point (e.g. Skall, 1975; Krebs and Macqueen, 1984). The objectives of this project are to investigate:

1) the origin of the Presqu'ile dolomites and associated dissolution features both at Pine Point and in the subsurface to the west; and
2) their relationships with mineralization at Pine Point.

Methods

Within the Pine Point ore-field, a number of open pits and drill holes were systematically studied and the spatial distribution of dissolution features and the various dolomites mapped. In addition, core samples from 32 wells in the downdip subsurface portion of the Presqu'ile barrier west of Pine Point were sampled and studied to compare the effects of diagenesis in the subsurface and at Pine Point itself. Selected samples were analyzed for carbon, oxygen, and strontium isotopes, fluid inclusions, and trace elements.

Results

Four textural varieties of dolomite are recognized in the Middle Devonian Presqu'ile barrier:

1) fine crystalline dolomite (FCD);
2) medium crystalline dolomite (MCD);
3) coarse crystalline dolomite (CCD); and
4) saddle dolomite (SD).

The distinct petrographic features and geochemical signatures of these dolomites suggest three stages of dolomitization, with FCD and MCD forming prior to stylolitization. Presqu'ile dolomites (CCD and SD):

1) replace blocky sparry calcite cement;

2) postdate stylolites;

3) overlap with Pine Point mineralization; and

4) locally cross the Watt Mountain unconformity into overlying Slave Point Formation.

Fluid inclusion studies indicate saddle dolomite was precipitated from fluids with temperatures ranging from 90° to 180°C and salinities between 10 and 25 equivalent weight percent NaCl. Homogenization temperatures (Th) of the Middle Devonian Presqu'ile saddle dolomite (SD) cement increases from 100°C at Pine Point, to 110-145°C in other localities in the NWT, and is 150-170°C in northeastern British Columbia. Present burial depths of these three areas are 50 m, 500-1900 m, and 2200 m, respectively. As Th of Presqu'ile dolomite increases, the $\delta^{18}O$ decreases. Homogenization temperatures of SD suggest that Presqu'ile dolomitization took place after the host rocks were tilted and at minimum burial depths of about 2000 m at Pine Point and progressively deeper to the southwest. This could happen only at or near maximum burial conditions during Late Cretaceous or Early Tertiary time. This interpretation is in accord with that of Arne (1989) who estimated time of mineralization to be Late Cretaceous based on apatite fission track analysis.

Core samples from the subsurface Presqu'ile barrier show that meteoric dissolution related to the sub-Watt Mountain exposure is minor and differs from the dissolution associated with the Pine Point MVT deposits in at least three aspects: scale of dissolution (i.e. size of openings), materials that fill solution features, and spatial distribution of solution features. Vugs related to the sub-Watt Mountain exposure are small, usually 1 to 2 cm, whereas those that host the orebodies are much larger, ranging from centimetres to metres. Dissolution vugs and breccias related to the unconformity are commonly filled with green shale and, locally, pendant calcite cement; those at Pine Point are filled with saddle dolomite, sulphide minerals, coarse calcite, and other products of late diagenesis. Dissolution features resulting from the sub-Watt Mountain exposure are restricted to a narrow zone immediately beneath the unconformity. In contrast, locally at Pine Point and also in the subsurface, large-scale dissolution and breccias cross the unconformity and continue for several metres above it. Petrographic evidence also indicates that dissolution and brecciation postdate stylolites, suggesting that dissolution must have occurred at minimum burial depths of about 500 metres. Therefore, the authors conclude that the role of sub-Watt Mountain exposure relative to the extensive dissolution and karsting as an ore control in the Pine Point ore-field has been over-emphasized by previous workers. Large scale dissolution vugs and breccias that host the MVT deposits must have formed after the unconformity, both before and during precipitation of saddle dolomites, as suggested by some solution features postdating early stages of mineralization. Hence much of the dissolution in these MVT deposits was caused by subsurface hydrothermal fluids which almost completely obliterated the earlier, unconformity-related meteoric dissolution features. These later hydrothermal fluids were responsible for mineralization and dolomitization at Pine Point.

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THE GEOLOGY OF THE POLARIS ZINC-LEAD DEPOSIT, NWT

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Objectives
A geological and geochemical study of the Polaris deposit, located on Little Cornwallis Island, N.W.T., was undertaken with the aim of documenting the basic geological features of the deposit (mineralogy, structure, stratigraphy), comparing it with other deposits of the same type (Mississippi Valley-type), determining some of the factors which resulted in deposition of the ore, and hence of increasing our understanding of Mississippi Valley-type ores in general and of Polaris in particular.

Methods
The research is being carried out through several topics: mapping, stable isotopes, organics, trace elements, insoluble residues and clay mineralogy, fluid inclusions, and radiometric dating. Of these, only the first three have been completed, or nearly completed, to date.

Results

Mapping
Several field seasons have been devoted to mapping and core-logging, both in the mine and regionally. The Polaris orebody is confined to the Thumb Mountain Formation, a Middle Ordovician platform carbonate which is part of a widespread thick sequence of shales, evaporites, and carbonates ranging in age from Cambrian to Devonian. These rocks were folded into broad, open folds in late Silurian to early Devonian time (Kerr, 1977; Okulitch et al., 1986; Miall, 1986). The Pb-Zn district which surrounds Polaris coincides generally with part of the Cornwallis Fold Belt, and the underlying Boothia Arch in the basement rocks. This belt escaped the south-directed Ellesmerian Orogeny of late Devonian to early Mississippian age (Trettin and Balkwill, 1979), although a series of clastic lobes occurring in the Devonian succession are thought to be due to this orogeny (Embry, 1988). Mineralization was formerly thought to postdate both these folding events, but detailed mine mapping has demonstrated that at least some, and perhaps all, mineralization and associated dissolution and alteration occurred prior to folding. This conclusion resulted from a study of a number of occurrences of "internal sediments" distributed throughout the deposit. These sediments occur in host rock cavities up to several metres in length and occasionally contain considerable amounts of sulphide minerals, both clastic and perhaps locally precipitated. The laminations in these sediments are everywhere concordant to bedding in the Thumb Mountain Formation, except in areas of faulting and soft-sediment deformation. It is therefore deduced that mineralization existed prior to formation of the internal sediments and to folding of the Thumb Mountain Formation.

This study has also shown that a basal Devonian unconformity (formerly thought to be instrumental in controlling the disposition of ore through unconformity-related karsting) is not located near the deposit as previously believed by earlier workers. Dissolution features in the mine area are not demonstrably related to the unconformity.

Other structural features with possible genetic implications are under investigation.

Stable isotopes
Over forty analyses of $\delta^{34}S$ values have been obtained from sulphides (mostly sphalerite and galena) from locations throughout the mine. These are essentially random samples, as we have been unable to determine a detailed paragenetic sequence in the chaotically banded and brecciated ore, but both sphalerite and galena show fairly narrow distributions of $\delta^{34}S$ between about +1 and +10 per mil, relative to

the Cañon Diablo standard.

Organics
A petrographic study of organic matter separated from drill hole samples of the host Thumb Mountain carbonates has been completed. More than 80 polished slides of kerogen were examined and the reflectance of three varieties of microfossils (graptolites, scolecodonts, chitinozoa) were measured as well as that of algae and bitumen. The microfossil reflectances have been converted to the vitrinite standard and exhibit a rather unusual decrease stratigraphically downward. In addition there is a marked decrease in reflectance at the stratigraphic level of mineralization. The reflectance versus depth profiles of the three microfossil species are perfectly parallel with each other. These results are regarded as being due to a combination of thermal and chemical effects.

Other Methods
As indicated above, several other lines of investigation have been planned. Some progress has been made in examining the insoluble clay minerals of the host rock carbonates. This is being undertaken in collaboration with André Chagnon (Centre Géoscientifique de Québec) and discussions are underway as to the possibilties for radiometric dating of this material.

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DISCRIMINATION OF FE-OXIDE ALTERATION ZONES USING REMOTELY SENSED AND BIOGEOCHEMICAL DATA

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Objective

To determine whether there is a unique biogeochemical and spectral reflectance signature associated with gossans in an arctic environment. The study area was Ferguson Lake and Kaminak Lake, District of Keewatin, NWT (Fig 1).

Results

Biogeochemistry

1) Vegetation on gossans is limited. However plants growing on gossans accumulate elements to anomalous levels. Concentration factors (i.e. maximum concentration/minimum concentration) exceeding 1000 were found, Table 1 (Coker et al., 1990; Rencz et al., in preparation). Concentrations of elements varied significantly within relatively short distances; for example arsenic in leaf tissue of Labrador tea varied from 0.2 ppm to 836 ppm within a distance of 20 m (Rencz et al., 1989).

2) There was only limited uptake of metals in vegetation growing immediately 'down-ice' of the gossan. The zone of dispersal at Ferguson Lake was several hundred metres; however dispersal zones at the other sites measured tens of metres (Rencz et al., in preparation). Coker et al. (1990) showed similar results for till from the Ferguson Lake site.

3) The technique developed for analyzing PGEs in plant tissue was essential to characterizing the biogeochemical signature for these elements as it permitted low level detection with a relatively small sample size (Hall et al., 1990; Rencz et al., in preparation).

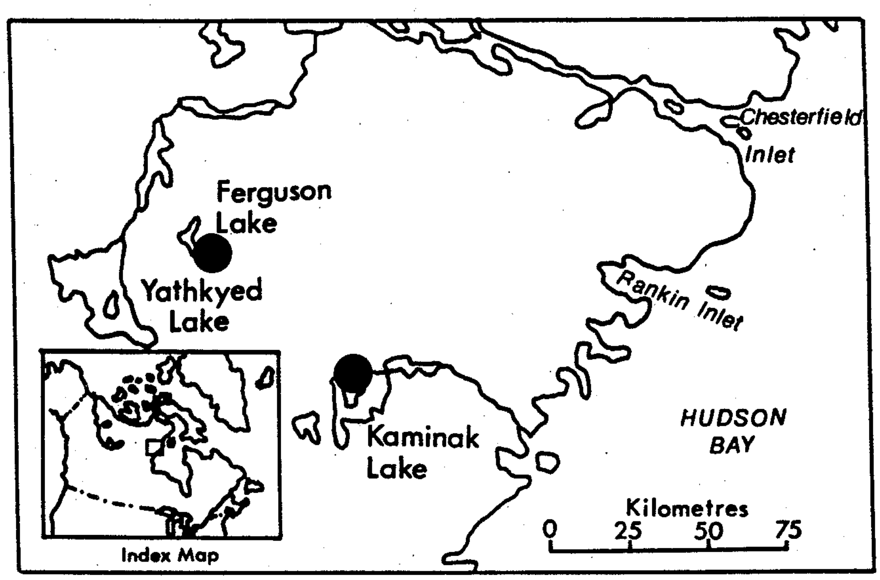

Figure 1. Location of study area, Ferguson-Kaminak lakes area, District of Keewatin, Northwest Territories.

TABLE 1: Minimum (min) and maximum (max) concentrations in twigs of dwarf birch from gossans, District of Keewatin, NWT.

SITE	Au ppb min	Au ppb max	Pd ppb min	Pd ppb max	As ppm min	As ppm max	Cu ppm min	Cu ppm max
Ferguson L.	.5	121.	.5	3860	n.a.		220.	8700.
Townend L.[1]	.5	330.	.5	14.	.2	836.	300.	350.
Spy L.	.5	93.	.5	55.	n.a.		500.	3657.

[1] Values are for Labrador tea leaf tissue.

NOTE: This table represents a small sample of the data set.

Ground Spectrometry

1) Reflectance of the altered material (gossan) measured at 10 wavelengths is higher than the unaltered material (mudboil) (Rencz et al., in preparation).

2) Reduced reflectance in altered material at 0.85 um is due to iron oxides whereas the absorption feature at 2.2 um is due to hydroxyl bonding in clay-bearing minerals. These features are not apparent in the unaltered sample (Rencz et al., in preparation).

Satellite Imagery

1) There was no detectable spectral response in vegetation growing adjacent to the gossan on LANDSAT TM imagery (Rencz et al., in preparation).

2) The 'reflectance levels' from the gossan were higher than other rock outcrop and were unique, Table 2 (Rencz et al., in preparation).

3) Attempts to find other gossans with spectral signatures similar to gossans at Ferguson and Townsend Lakes were unsuccessful. The inability to do this extrapolation was due to the limited area of continuous gossan.

Conclusions

1) Biogeochemical sampling would be as effective as till sampling in detection of gossans; however the dispersal zone around the gossans is short.

2) Analytical techniques for vegetation must be able to provide low level detection using limited plant material (< 50 g of dry material) in order to characterize the variation in the biogeochemical signature.

3) Ground based studies illustrated that the gossans have a specific spectral response. The unique spectral response was also captured by TM data; however the limited spatial resolution of TM imagery compared to the target (gossan) will preclude any practical application.

4) Airborne imaging spectrometres could be tested as effective means for detecting alteration zones.

TABLE 2: Comparison of 'reflectance levels' on LANDSAT TM imagery of a gossan with other cover types for the Ferguson Lake area.

'MEAN REFLECTANCE'

UNIT	LANDSAT TM BAND 1	2	3	4	5	6	7
Gossan	105	51	73	71	122	124	58
Sedge Meadow	74	30	30	77	93	124	30
Snow	117	54	74	88	84	120	31
Gneiss	91	37	43	45	119	129	62
Esker	119	57	70	87	103	128	40

NOTE: These are uncorrected digital levels from the Computer Compatible Tapes (CCT).

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LITHOLOGIC DISCRIMINATION USING SATELLITE IMAGERY

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Objective

To determine whether LANDSAT Thematic Mapper data discriminates lithologic groups in an arctic environment. The study area was the Kaminak Lake area of the District of Keewatin, NWT (Fig. 1).

Results

1) Accuracy in classifying rock groups was good in the ungrouped test except for the confusion between gabbro/diorite (unit 4), Kaminak Group pillowed basalts (unit 5), and the undifferentiated volcanics.

2) Classification accuracy was above 60% for the 7 units in the grouped assessment. Most classification errors were due to the confusion between geologically similar units. For example, the error in identifying adamellite was most often due to confusion with tonalite. TM band 1 was the best discriminator between lithologies. This was a function of the sensitivity of this band to iron content.

3) TM band 6 was useful in discriminating aggregate.

Conclusions

1) The rocks have different spectral signatures that are related to lithology.

2) The next step is to determine if rock outcrop in the area can be identified and then classified into different lithologies (Rencz and Wright, in preparation).

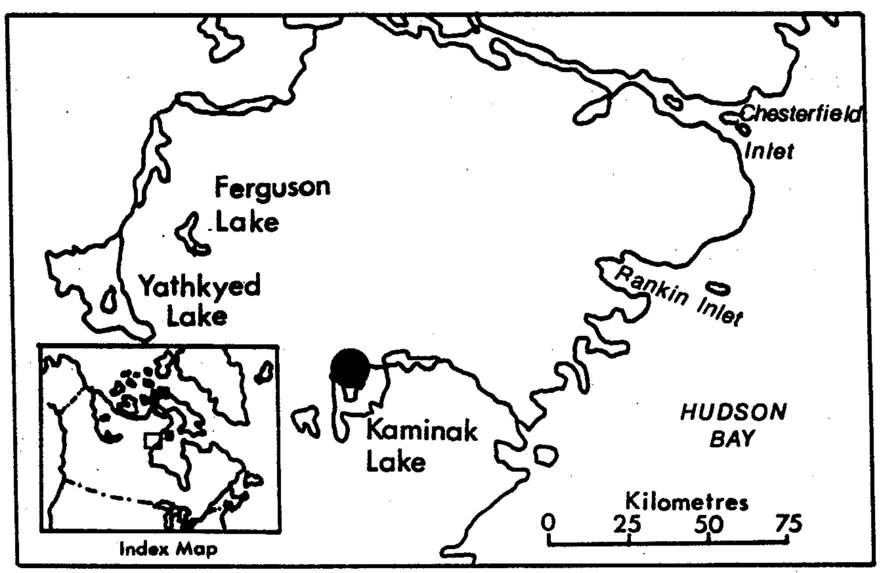

Figure 1. Location of study area, Kaminak Lake, District of Keewatin, Northwest Territories.

Table 1. Table of frequencies for ungrouped lithologic units (see below for legend defining units)

UNIT	1	2	3	4	5	6	7	8	9	TOT	%COR
1	<u>154</u>	21	8	0	0	0	0	3	11	197	79
2	0	<u>166</u>	17	0	0	0	1	6	1	191	87
3	0	23	<u>142</u>	0	0	0	5	19	1	190	75
4	0	16	8	<u>98</u>	48	23	3	0	8	204	48
5	0	5	14	46	<u>86</u>	18	23	11	10	213	40
6	0	0	2	9	3	<u>61</u>	0	0	6	81	76
7	0	0	27	0	0	12	<u>73</u>	2	13	127	72
8	1	3	8	1	0	1	3	<u>54</u>	4	75	72
9	0	0	5	1	0	7	8	1	<u>50</u>	72	69

LEGEND FOR LITHOLOGIC UNITS

1. Hurwitz Group Quartzites
2. Adamellite
3. Tonalite
4. Granodiorite
5. Kaminak Group - pillow basalts
6. Kaminak Group - greywacke and slates
7. Undifferentiated mafic volcanics
8. Aggregate
9. Kaminak Group - felsic tuff

Table 2. Table of frequencies for grouped lithologic units (see below for legend defining units).

UNIT	1	2	3	4	5	6	7	TOT	%COR
1	<u>154</u>	21	8	0	0	3	11	197	78
2	0	<u>161</u>	17	1	0	6	1	191	86
3	0	23	<u>145</u>	2	0	19	1	190	76
4	0	23	63	<u>321</u>	84	12	41	544	59
5	0	1	3	7	<u>63</u>	0	7	81	77
6	1	3	10	1	1	<u>54</u>	5	75	72
7	0	0	5	3	8	1	<u>55</u>	72	76

LEGEND FOR LITHOLOGIC UNITS

1. Hurwitz Group Quartzites
2. Adamellite
3. Tonalite
4. Combined Granodiorite, basalts, mafic volcanics (units 4,5,7 in Table 1)
5. Kaminak Group - greywacke and slate
6. Aggregate
7. Kaminak Group - felsic tuff

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APPLICATION OF LANDSAT TM DATA TO MAPPING SURFICIAL GEOLOGY

A. N. Rencz, J. Aylsworth and W.W. Shilts

Objective

To determine whether LANDSAT TM data can be applied to the mapping of surficial geology in Arctic Canada. The study area was the Ferguson Lake area, District of Keewatin, NWT (Fig. 1).

Results

1) A portion of an existing surficial geology map was digitized and compared to the classification results obtained using LANDSAT TM data. There was a high degree of correlation between the results on the two maps (Rencz et al., 1989).

2) The map units included rock, rock and till, striped till, alluvium, esker and beach, and water. Discrepancies between the two maps were generally due to confusions of geologically similar units such as the confusion between rock, and rock and till.

3) The map created from TM imagery had more detail as it was based on a 30 X 30 m pixel classsification.

4) Maps created by airphoto interpretation facilitate the incorporation of textural information and the mappers' experience.

5) The TM derived map had the further advantage of easier update capabilities because of its digital nature.

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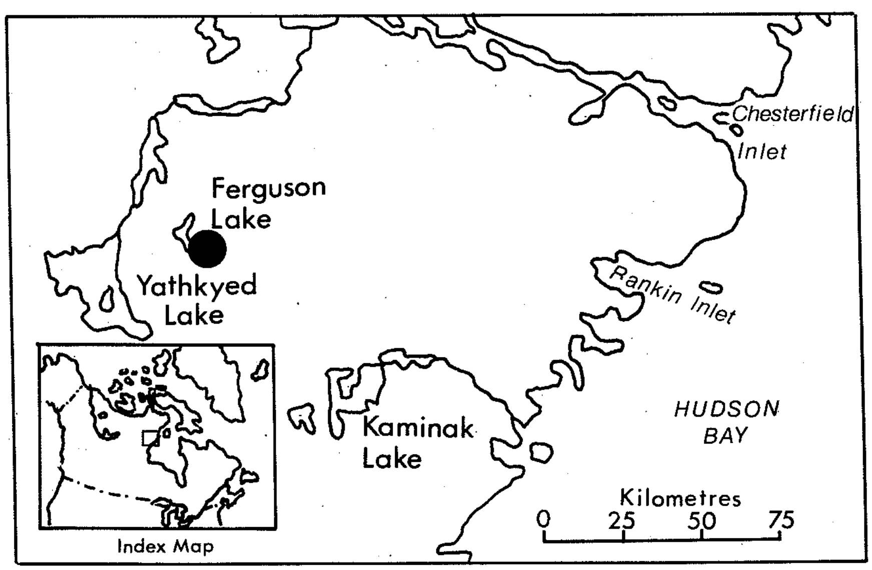

Figure 1. Location of study area, Ferguson Lake, District of Keewatin, Northwest Territories.

DIAGENESIS OF MIDDLE PROTEROZOIC BASINS, CHURCHILL AND BEAR PROVINCES WITH EMPHASIS ON CLAY MINERALOGY AND ITS RELATION TO URANIUM MINERALIZATION

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The ca. 1.74 Ga sub-Thelon Formation paleosol, whether developed on metasedimentary or igneous protolith, characteristically displays ascending protolith destruction, feldspar and ferromagnesium mineral dissolution, phyllosilicate growth and hematization within eroded profiles where only the C (R) horizon is now preserved. Geochemically the profiles are characterized by:

1) an ascending depletion of most elements in the order Al, Cu, Nb, Zr, Sc < Zn < Fe_T < Ti, Mn, Ca < Mg, Na < V, Rb < Ba < K;

2) residual accumulation of Sr, As < P, Cr < Si;

3) redox transformation of Fe^{3+} to Fe^{2+}; and

4) ascending increase in Chemical index of alteration (CIA) values. Pedogenic development of phyllosilicate growth and hematization can be distinguished from subsequent silica cementation, phyllosilicate growth and phosphate, carbonate and hematite cementation during diagenesis in the overlying Thelon Formation. The paleosol has been locally overprinted by mineral phases which suggest that Si, P, K, Fe, Ca- and Mg-bearing fluids penetrated the paleosol via veinlets during Thelon Formation diagenesis. The pedogenic and diagenetic paragenesis associated with the sub-Thelon Formation unconformity is essentially identical to mineral parageneses in the paleosol and overlying sediment at the base of the Hornby Bay, Elu, and Athabasca Basins. This lends further evidence that the paleosols and overlying sedimentary sequences are coeval and correlatable and that together they reflect an episode of Early to Middle Proterozoic continental weathering during the development of a very large (1000 km^2) sedimentary basin.

GOLD METALLOGENY, CHURCHILL STRUCTURAL PROVINCE

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Objectives
This project documents the geology of gold occurrences, developed prospects and previously mined deposits in the Hearne and Rae structural provinces, i.e the former Churchill Structural Province. The principal objectives were:

1) To undertake regional and detailed mapping to identify the lithological, metamorphic and structural setting for gold mineralization;

2) To establish salient features by petrography, whole rock and mineral chemistry that characterize alteration envelopes and associated opaque assemblages; and

3) To evaluate the gold metallogeny in light of Archean and Proterozoic tectonism.

Methods
Selected areas within three greenstone belts were studied:

1) Rankin-Ennadai greenstone belt

a) 'Lothrop Lake' area (NTS 65H/4)

b) B-zone deposit: Cullaton Lake gold mine (NTS 65G/7)

c) Shear Lake gold deposit (NTS 65G/7)

d) 'Fat Lake' gold deposit (NTS 55K/4)

e) north of Griffin Lake (NTS 65G/7)

f) Quartzite Lake area (NTS 55L/7)

g) Turquetil Lake area (NTS 55E/13)

2) Angikuni-Yathkyed greenstone belt - 'SY-area' (NTS 65I/4)

3) Ketyet Group in the Judge Sissons Lake area (NTS 66A/6)

Results

Rankin-Ennadai
The 2.69-2.68 Ga Rankin-Ennadai greenstone belt represents the largest Archean structural entity in the Hearne Province and has long been recognized for its gold and volcanogenic massive sulphide potential.

In the 'Lothrop Lake' area, located near the southwestern end of the Rankin-Ennadai greenstone belt, pillowed and massive metabasalt overlain by graded fine-grained metaturbidites are folded isoclinally about northeast-trending upright and overturned anticline-syncline pairs that plunge consistently to the southwest. Proterozoic Kinga Formation metaquartzarenite overlies the Archean sequence and was folded about a northeast axis plunging east-northeast. Steeply dipping northeast-trending gold-bearing shears in the Archean sequence are parallel to the northeast-trending structural grain. Shear zones are cored by discontinuous, deformed quartz veins. Alteration envelopes are commonly symmetrical, have gradational contacts with host metavolcanic rocks and vary in thickness depending on the intensity of quartz veining. These envelopes are characterized by the granoblastic assemblage: quartz+plagioclase+carbonate with biotite+hornblende and the opaque assemblage: pyrite, arsenopyrite, chalcopyrite and gold. Gold is also present in deformed tourmaline+biotite-bearing quartz veins. The granoblastic alteration assemblage associated with quartz-bearing shear zones is overprinted by unoriented hornblende and biotite. This lower amphibolite facies metamorphic overprint may be Aphebian.

The study of the Cullaton Lake B-Zone gold deposit was entirely dependent on limited core stored at the mine site. Two east-west sections were reconstructed with the purpose of examining the stratigaphy and alteration patterns in the iron formation and surrounding rocks. Banded oxide iron formation (BIF) is the principal type of iron formation observed in drill core. The iron formation is interbedded with Archean Henik Group fine-grained metaturbidites that have been metamorphosed to lower greenschist grade, biotite zone. Two types of iron formation were identified in drill core:

1) banded oxide-BIF: quartz+magnetite ± grunerite ± stilpnomelane, and

2) minor silicate-BIF: stilpnomelane+quartz+chlorite.

Banded or laminated sulphide-rich iron formation similar to the Lupin iron formation (see Kerswill, this volume) or portions of the 'SY-area' iron formation (see below) were not observed. The F_1 structure, defined by oxide-BIF and a grunerite isograd, is a shallowly north plunging isocline of presumed Archean age. Open F_2 folds with subhorizontal axes refold the F_1 isocline, are presumed to be Proterozoic and developed during folding of the Hurwitz Group. Massive to semi-massive sulphide zones, containing pyrrhotite+gold with minor chalcopyrite+magnetite, are distributed in and near the F_2 fold closure. A broad zone of chloritization overlaps the fold closure which contains numerous sulphide pods. Chlorite and carbonate prevasively replace the chert+magnetite iron formation and the adjacent Henik Group metagreywackes and meta-argillites. Chloritization is coincident with flooding of the altered iron formation by several generations of quartz and quartz+iron-carbonate veins. Arsenopyrite is present in and peripheral to vein networks and is erratically distributed through the pyrrhotite-rich sulphide pods. Gold mineralization is interpreted as epigenetic. The timing may be Archean or Proterozoic. Alteration assemblages, vein flooding and an oxide-BIF host rock are features common to Archean lode gold deposits. However, the distribution of gold-bearing pyrrhotitic pods around the interpreted Proterozoic F_2 closure and the accompanying veining suggest that mineralization is Proterozoic and that the Archean iron formation represents a lithology chemically reactive. Hydrothermal fluids would have been introduced due to dilation during folding and thrusting of the Hurwitz Group. Previously Page (1981) and Raman et al. (1986) interpreted the Cullaton Lake B-Zone deposit as a remobilized syngenetic sulphide facies iron formation.

The Shear Lake gold deposit, approximately 3 km north of the B-zone, is hosted primarily in Proterozoic Kinga Formation metaquartzarenite. Mineralization is confined to near-vertical, east-trending brittle faults and breccia zones that are localized along the outer arc of a Proterozoic D_2 fold. In the Hawk Hill-Griffin lakes area to the west, Aspler and Bursey (1990) interpreted the fracturing and faulting in the Hurwitz orthoquartzite to be contemporaneous with outer arc extension developed during Proterozoic D_2 folding of the Hurwitz Group. Sulphide-bearing structures are primarily confined to the metaquartzarenite but penetrate the Archean Henik Group metagreywackes. Gold-bearing pyritic fractures, faults and breccia zones are vertically zoned: an upper kaolinite zone grades into a chlorite zone then into a lower biotite zone. Alteration haloes are not present in the non-reactive orthoquartzite but are well developed in the more reactive metagreywacke. Gangue phases associated with pyrite-bearing fractures include: albite An_0, iron-bearing dolomite, barite and a Ca-sulfate phase. The latter two are most common in the chlorite and kaolinite zones. Gold is present as inclusions in pyrite and intergranular to gangue minerals. Based on mineralogy and the structural setting of the deposit within the Hurwitz fold and thrust belt, the Shear Lake gold deposit is interpreted to have been deposited in an environment similar to that of epithermal gold deposits.

In the 'Fat Lake' area, the Archean Kaminak Group is at lower greenschist grade and is preserved as an upright northwest-facing homocline. This volcano-sedimentary sequence was subdivided into three metavolcanic units with intervening metasedimentary units. Quartz+magnetite-bearing gabbros intruded the metavolcanic units and volcanic-sediment contacts. Steeply-dipping Archean ductile shear zones are localized within and along the boundaries of metasedimentary units. Variably deformed gold-bearing quartz veins are restricted to the 'Fat Lake' quartz gabbro intrusion and record increments of progressive deformation. Vein-filling assemblages are quartz + Mg-Ca-carbonate ± chlorite accompanied by gold, and variable but minor pyrite, chalcopyrite, sphalerite and galena. During deformation, the host intrusion was extensively epidotized whereas intense chlorite and carbonate replacement is restricted to alteration envelopes adjacent to quartz veins. One Pb/Pb model date of 2694.5 Ma (Western Superior model, Thorpe et al., in press) on galena from a gold-bearing vein indicates that veining and mineralization are Archean. The deposit is interpreted to be a typical mesothermal lode gold type. In summary, veining, alteration and gold distribution illustrate the interplay between contrasting rock ductility between country and host rock and an iron-rich host rock which was susceptible to hydrothermal alteration.

North of Griffin Lake, Archean rocks have been folded initially about a north-south axis then were refolded into a north-northeast- to northeast-trending, south southwest-plunging synform. All rocks have been metamorphosed to lower amphibolite facies. Retrogression to greenshist facies assemblages was identified locally. The lowest stratigraphic unit in the mapped area contains spinifex-textured flows displaying excellent preservation of primary flow textures. Massive and semi-massive copper-nickel sulphides were identified within the cumulate portion of one flow. The ultramafic unit is overlain by a grunerite ± hornblende+magnetite+quartz banded iron formation. The iron formation is overlain by pillowed basalt with concordant gabbroic intrusions, and possible minor carbonatized ultramafic rocks. The iron formation displays mineralogical variation along strike. Quartz+magnetite facies passes into sulphide-bearing silicate facies (pyrrhotite +hornblende ± garnet + grunerite). Gold in the iron formation is low, < 50 ppb. Arsenopyrite and significant quartz veining are lacking.

The Quartzite Lake area is one of several felsic volcanic centres in the central portion of the Rankin-Ennadai greenstone belt. In the study area, the Archean lower greenschist volcano-sedimentary sequence is upright and dips steeply north. From south to north, it consists of an intrusive quartz+feldspar porphyry, a felsic volcanic unit comprising massive and brecciated flows of rhyolitic to dacitic composition, pyroclastic rocks of similar composition overlain by a sedimentary carapace of siltstone, tuffaceous siltstone, debris flows and basaltic pillowed flows. Northeast-trending shear zones parallel the strike and are focused along zones of contrasting ductility at lithologic boundaries. Gold-bearing quartz veins, primarily confined to sheared felsic volcanic rocks, contain pyrite and Fe-carbonate with trace amounts of chalcopyrite and galena. Alteration envelopes adjacent to quartz veins are characterized by carbonatization and sulphidization. Pyrite in the wall rock overgrows the ductile fabric suggesting that gold mineralization is late in the history of shear zone development.

Studies on the Turquetil gold deposit were restricted to detailing the alteration assemblages in three drill holes within one vertical fence. The stratigraphy intersected by these holes consists of two units dominated by high-iron tholeiitic metabasalt and gabbro. Based on assemblages in metabasalt, the regional metamorphic grade is lower greenschist. These units are separated by a thin unit containing multiple rock types: felsic tuff and flows, fine grained metasiltstone, laminated cherty metasediment. The lack of stratigraphic continuity within the thin felsic volcanic-sediment unit and an increasing penetrative foliation toward that unit suggest it has been the locus of regional shearing. Alteration assemblages, from least to most altered, in the metabasaltic rock are:

LEAST	**plagioclase+chlorite+dolomite+titanomagnetite /magnetite+titanite;**
WEAK	**plagioclase+chlorite+dolomite+Fe-dolomite+trace paragonite+titanite+titanomagnetite/magnetite;**
MODERATE	**chlorite+Fe-dolomite+ankerite+paragonite+ titanite+rutile+quartz ± Na plagioclase;**
INTENSE	**ankerite+Fe-dolomite+paragonite+quartz. Carbonate is the most important alteration product in the mafic volcanic rocks and is accompanied by quartz, pyrite, chalcopyrite, arsenopyrite and gold.**

Angikuni-Yathkyed

The 'SY-area', located near the southeastern edge of the Angikuni-Yathkyed greenstone belt has been metamorphosed to the lower amphibolite facies. In the study area, the lithological assemblage, from southeast to northwest, includes: metabasalt, biotite-bearing arenacous metasediment (fine grained distal turbidite) and iron formation. Feldspar ± quartz-phyric porphyries cut the metaturbidite and iron formation. Transposition of porphyries into regional northeast-trending layering and megaboudinage of iron formation indicate high strain. The iron formation (BIF) is subdivided into a three subunits based on mineral assemblages:

1) sulphide-deficient oxide- BIF:
   banded quartz+magnetite+/-grunerite;

2) sulphide-bearing silicate-BIF:
   pyrrhotite>>chalcopyrite (2-3% sulphide content)+magnetite+hornblende+grunerite+ quartz ± carbonate; and

3) minor laminated sulphide-BIF:
   pyrrhotite>>> chalcopyrite (10-15% sulphide content)+grunerite+hornblende ± garnet.

The silicate metamorphic assemblage is consistent with the interpretation that portions of the iron formation may have been carbonate-bearing. Discordant quartz veins are present but they are not a prevalent structural feature in the iron formation. Gold is present in sulphide-bearing silicate-BIF, in discordant arsenopyrite ± pyrite-bearing quartz veins and discordant chlorite+hornblende veinlets. Arsenopyrite is disseminated throughout deformed well-laminated pyrrhotitic iron formation. Variation in silicate mineral assemblages particularly within the silicate-BIF, the abundance of pyrrhotite, the presence of minor chalcopyrite and the laminated character of the sulphide-BIF suggests a similarity to Lupin-type sulphide-BIF (see Kerswill, this volume).

Ketyet Group

In the Rae province, an Archean greenstone belt, part of the Ketyet Group, extends from Judge Sissons Lake, 66A/5, northeastward to the Meadowbank River area, 66H/1. Studies were restricted to the southwestern end of the belt where fine-grained metaturbiditic sedimentary rocks dominate the sequence. Basalt, ultramafic rocks, felsic volcanic rocks and tuffs, quartzite, black pyritic slate, banded chert+magnetite and minor laminated pyrrhotitic iron formation are recognized. The central portion of this belt in the study area was regionally metamorphosed to middle greenschist grade. However, near the southwestern end of the belt, large areas were thermally metamorphosed to hornblende amphibolite facies by Proterozoic fluorite-bearing granite. Gold distribution is structurally-controlled within:

1) D_2 fold noses in which interlayered fine grained mudstone, greywacke, felsic tuff and quartzite are intensely cleaved and pyritized;

2) sphalerite+galena+pyrite-bearing discontinuous shear zones marginal to Proterozoic syenodioritic-granitic intrusions;

3) fractured and pyritized banded oxide-BIF; and

4) fractured greywacke that hosts discontinuous pyrite +arsenopyrite-bearing quartz veinlets aligned in the D_2 foliation.

Both Archean and Proterozoic rocks in the District of Keewatin represent valid exploration targets for a variety of gold deposit types. Throughout the Hearne and Rae provinces, Archean structurally-controlled gold mineralization is associated with regional zones of transpression. Gold-bearing veins and shear zones occur in a variety of host rocks, each with distinctive alteration and opaque mineral assemblages. Laminated pyrrhotitic iron formation hosted in Archean fine-grained turbiditic metasedimentary rocks resembles Lupin-type iron formation. Crustal shortening during the Proterozoic resulted in folding and thrusting of the Hurwitz sedimentary cover rocks and detachment zones within the Archean basement. Proterozoic gold deposits and prospects may represent remobilized gold from Archean greenschist-grade auriferous turbiditic basin or a gold event unrelated to basement mineralization. Consequently Proterozoic gold may be hosted in either the Hurwitz Group or Archean strata.

Acknowledgments

The report is a summary of gold studies in the Hearne and Rae provinces, some of which involved collaborative research with Abermin Ltd., Corona Corporation, Dejour Mines Ltd., Noble Peak Resources Ltd. and Suncor Inc. This article was critically reviewed by J.A. Kerswill and S.M. Roscoe.

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GOLD METALLOGENY OF THE CONTWOYTO LAKE, RUSSELL LAKE AND COURAGEOUS LAKE AREAS, SLAVE PROVINCE, NWT

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Objectives

The principal goal of this project was to document critical features of a variety of gold deposits in Slave Province in an effort to establish useful exploration guidelines. A related objective was to provide additional constraints in constructing predictive genetic models for gold deposits in Archean volcano–sedimentary terranes.

Method

Field work included:

1) examination of iron formation (BIF)-hosted gold prospects on the Bugow and SP properties, Russell Lake area,

2) detailed lithological logging of two channel sampling traverses across the surface exposure of the Centre Zone at the Lupin mine,

3) underground work at Lupin to further evaluate spatial relationships among gold–rich sulphide–BIF, several varieties of gold–poor silicate–BIF, clastic sedimentary rocks, late quartz veins, and vein-controlled alteration zones, and

4) systematic sampling of drill core from the Red 24, Salmita North, Olsen, Marsh Pond and Boundary properties in the Matthews Lake area of the Courageous Lake gold belt to augment previous work at the Salmita mine and the Noranda/Total Energold Tundra property (Main and Carbonate Zones).

Laboratory studies to date have included:

1) systematic description of core samples from the above–mentioned properties in the Matthews Lake area,

2) major, minor and trace element analyses of gold-rich and gold-poor rock samples, mostly from the Matthews Lake area,

3) microscopic examination of representative gold-rich samples from the Main and Carbonate Zones, Tundra property,

4) microprobe analyses of gold grains from the Main and Carbonate Zones, and

5) management, display and manipulation of data. The latter stage is in progress.

Results

Contwoyto and Russell Lake areas

Investigations concerning BIF-hosted gold deposits in Slave Province and elsewhere (Kerswill, 1986, 1990; Kerswill and Caddey, 1987) indicate that although these deposits possess several important common features, significant differences among deposits can be used to constrain genetic models and develop effective exploration strategies. Based on the style of gold distribution, two principal types of BIF-hosted deposits are recognized:

1) non-stratiform, and

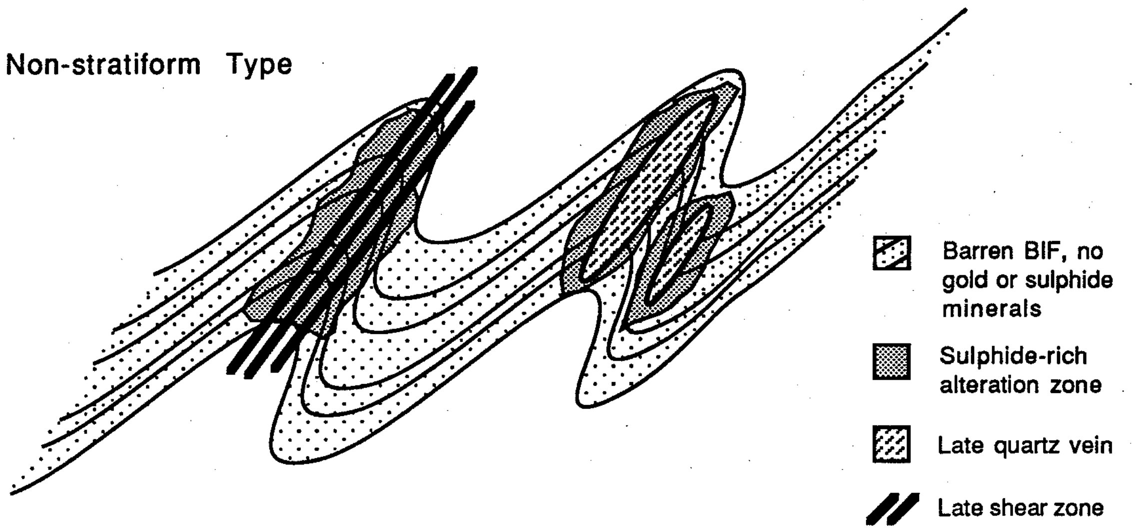
2) stratiform.

Critical features of both types and examples are provided in figure 1. Note that the stratiform deposits have been subdivided into those occurring within sediment–dominated settings (Lupin-like) and those within mixed sedimentary-volcanic terranes. The common features of BIF-hosted gold deposits as well as diagnostic features of both Lupin-like and non-stratiform deposits are listed in Table 1. Both stratiform and non-stratiform types of mineralization occur in the Lupin area. Evaluation of recently published information on the BIF-hosted gold deposits in the George Lake area, Slave Province (Olson, 1989; Chandler and Holmberg, 1990: Padgham, 1990; Jefferson et al., this volume) suggests that these deposits are of the non-stratiform rather than stratiform type.

Visits to the Bugow and SP properties led the writer to conclude that the geological setting and character of the deposits are remarkably similar to Lupin. This assessment is similar to that of Bunner and Taylor (1987) and Bunner (1988). As at Lupin,

The Two Principal Types of BIF-Hosted Gold Deposits

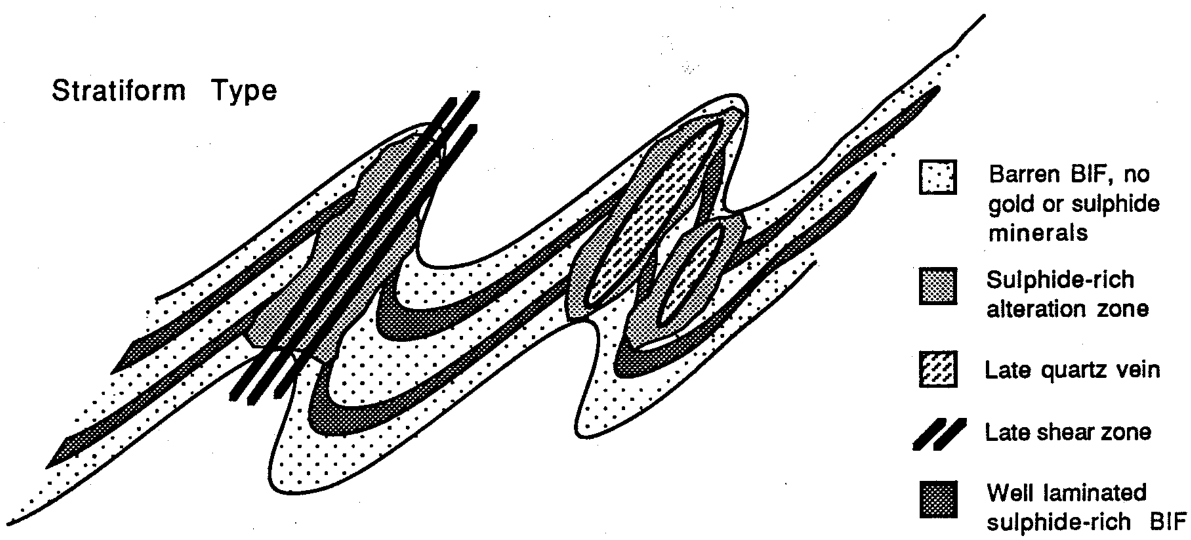
Non-stratiform Type



Gold restricted to late structures or to sulphide-rich BIF immediately adjacent to such structures

Examples are many and include: North Ore Zone, Geraldton, Ontario; Central Patricia mine and portions of the Pickle Crow mine, Pickle Lake, Ontario; Cullaton B Zone mine, NWT; Nevoria and Water Tank Hill mines, Western Australia; Lennox mine, Zimbabwe; and probably the Sao Bento mine in Brazil

Stratiform Type



Gold occurs in thin but laterally continuous units of sulphide-rich BIF as well as in sulphide-rich alteration zones adjacent to late structures

Examples are few but include: Lupin, NWT; Jardine, Montana; Homestake, South Dakota, all within sediment-dominated settings, as well as Morro Velho, Brazil; Cuiaba, Brazil; and, possibly Agnico-Eagle, Quebec, all within mixed sedimentary-volcanic terranes

Figure 1. Description of two principal types of BIF-hosted gold deposits.

Table 1. Characteristics of BIF-Hosted Gold Deposits

Features Common to all Deposits

Very strong spatial association between native gold and iron sulphide minerals
Gold-bearing shear zones and/or quartz-rich veins are present and locally abundant
Deposits occur in structurally complex settings
Ores contain only background contents of lead and zinc

Features Diagnostic of Non-stratiform Deposits

1 Deposits are non-stratiform
2 Gold commonly not restricted to sulphide-BIF or veins that crosscut BIF
3 Sulphide-BIF does not occur in laterally continuous units
4 Sulphide-BIF is not well-laminated; iron sulphides are commonly massive
5 Distributions of iron sulphide minerals and gold are clearly controlled by veins and/or late structures
6 Orebodies are typically less deformed than associated rocks
7 Iron sulphide minerals tend to be relatively undeformed and unmetamorphosed
8 Deposits not restricted to, but most abundant in greenschist facies
9 Sulphidation textures are common
10 Orebody scale alteration exists
11 Alteration products similar to those in mesothermal vein gold deposits
12 Oxide-BIF is typically the principal BIF lithology in the deposit
13 Pyrite is commonly the dominant iron sulphide
14 Arsenic, if present, is characteristically directly correlated with gold
15 Silver contents of gold grains are typically low(Au/Ag greater than 8.0)
16 Deposits are relatively common, generally small, difficult to evaluate and mine

Features Diagnostic of Sediment-hosted Stratiform Deposits

1 Deposits are stratiform
2 Gold mostly restricted to sulphide-BIF or to veins that crosscut sulphide-BIF
3 Sulphide-BIF occurs in several thin but laterally continuous units that are conformably interlayered with barren silicate-BIF and/or carbonate-BIF and clastic sedimentary rocks
4 Sulphide-BIF is well-laminated and chert-rich; iron sulphide minerals are typically finely banded
5 Distributions of iron sulphide minerals and gold are not clearly controlled by veins and/or late structures
6 Orebodies are as deformed or more deformed than associated rocks
7 Iron sulphide minerals show effects of deformation and metamorphism
8 Deposits occur in both greenschist and amphibolite facies terranes
9 Sulphidation textures are absent
10 Lack of orebody scale alteration; localized vein-related alteration occurs
11 Vein-related alteration atypical of mesothermal vein gold deposits
12 Oxide-BIF is lacking in the deposits, irrespective of metamorphic grade
13 Pyrrhotite is the dominant, if not only iron sulphide
14 Arsenic is abundant adjacent to late quartz veins but not well-correlated with gold
15 Silver contents of gold grains are moderately high(Au/Ag = 4.0 - 6.0)
16 Deposits are rare, tend to be large, relatively easy to evaluate and mine

1) much of the gold is disseminated in thin, but laterally continuous units of cherty, well-laminated sulphide-BIF that are conformably interlayered with gold-poor silicate-BIF and pelitic sedimentary rocks,

2) auriferous BIF occurs within a turbidite-dominated setting,

3) oxide-BIF is lacking,

4) there is no consistent spatial association between the distribution of gold-bearing sulphide-BIF and the distributions of fold hinges, late quartz veins or shear zones, and

5) much of the auriferous BIF has been metamorphosed to amphibolite facies.

Although the principal iron sulphide at Bugow is pyrite, petrographic work by Bunner (1988) indicates that much of the pyrite replaces pyrrhotite, the principal iron-sulphide at Lupin. Arsenopyrite, though abundant adjacent to late quartz veins at Lupin, is rarely associated with gold on the Bugow and SP properties. This is consistent with the lack of correlation between gold and arsenic at Lupin.

Although non-stratiform deposits are clearly epigenetic products of late sulphidation reactions in structurally and chemically favourable host rocks, the genesis of stratiform deposits is still controversial. Lhotka (1988) and Bullis (1990) favour an epigenetic model for Lupin in which gold, silver, copper, sulphur, arsenic, tungsten, iron and calcium were introduced into barren (gold- and sulphur-poor) silicate-BIF during formation of the late quartz veins. Recent work at the Homestake mine has led Bachman and Caddey (1990) to abandon the syngenetic model of Nelson (1986) in favour of epigenetic introduction of gold during reverse movement on high-angle shears synchronous with late quartz vein emplacement. However, this writer considers that syngenetic concentration of gold, silver and copper during seafloor deposition of sulphide-BIF best accounts for most of the critical features of Lupin-like deposits that are listed in Table 1. Arsenic, tungsten, much silica and possibly some gold were introduced during formation of the late quartz veins. Mobilization of synsedimentary gold during metamorphism and deformation, followed by its deposition in structurally favourable sites, though required in the model of Ford (1988), are not considered essential by this writer for the genesis of the stratiform ores.

Detailed comparison between gold-rich skarn deposits (Meinert, 1989; Hammarstrom et al., 1990) and Lupin-like deposits indicates many differences that are incompatible with a late metasomatic origin for gold and sulphur in the latter. In particular, there is typically a direct correlation between the distributions of at least some calc-silicate minerals (ugranditic garnet, hornblende, diopsidic clinopyroxene) and the distributions of gold and sulphur in gold skarns, but no such correlation exists at Lupin, Homestake or Jardine. Indeed, most of the mineralogical and chemical features of the stratiform ore away from the late quartz veins at Lupin are adequately explained by essentially isochemical metamorphism of variably mixed clastic and chemical sediments that contained different amounts of aluminous clays, Fe-rich carbonates, Fe-rich silicates, quartz, iron monosulphides (greigite, mackinawite, pyrrhotite) and gold.

The most useful empirical exploration guide for any BIF-hosted gold deposit is the presence of abundant iron-sulphide minerals. Units of well-laminated, cherty, pyrrhotite-rich BIF are particularly favourable for the occurrence of stratiform ores in sediment-dominated target areas. Oxide-BIF is a negative indicator for stratiform gold mineralization, but it is the typical host of non-stratiform deposits. Arsenic can be a useful guide to non-stratiform ores, but is considerably less reliable than sulphur in the search for stratiform ores.

Because much of the available data on stratiform BIF-hosted gold deposits favours a synsedimentary model for gold and sulphur concentration, exploration programs designed to discover such deposits should focus on evaluating features of the primary depositional environment. Exploration targeted at non-stratiform deposits should emphasize structural and metamorphic features. Although stratiform deposits typically contain more gold and are more easily mined than non-stratiform deposits, the favourable tonnage and grade characteristics of some non-stratiform deposits makes this deposit type an attractive target as well. Early recognition of the most probable deposit type should permit more effective evaluation of any prospect.

Courageous Lake area

Megascopic examination of core slabs and microscopic examination of polished sections from drill core on the Tundra property indicate the following (Kerswill, 1988):

1) Gold is structurally controlled and occurs in, or adjacent to, fractures and/or veins in variably deformed and altered host rock. Only a small amount of gold occurs within well-developed quartz veins, a feature in marked contrast to the nearby Salmita deposit in which virtually all the mined gold was confined to a large discordant quartz vein (the B vein).

2) Some of the gold-bearing fractures and veins are complexly deformed.

3) Although metallurgical studies indicate that much of the gold is refractory and tied up within arsenopyrite, a significant amount of the gold in the upper levels of the deposit is free or "visible". The average grain size is less than 10 microns with a maximum (to date) of 30 microns.

4) Free gold is very closely associated with arsenopyrite but not with pyrite or chalcopyrite (some arsenopyrite replaces early pyrrhotite, but much of the pyrite and chalcopyrite appear to post-date gold and arsenopyrite).

5) Despite the close spatial association between free gold and arsenopyrite, only some of the free gold is located within arsenopyrite (as inclusions or along fractures) or immediately adjacent to arsenopyrite. Much of the free gold is interstitial to silicate minerals.

Statistical analysis of a set of major, minor and trace element data from 92 core samples of both gold-rich and gold-poor rock from the Tundra property indicates the following (Kerswill, 1988):

1) Gold is very strongly positively correlated with arsenic, less strongly correlated with sulphur, and apparently not correlated with base metals.

2) Many auriferous samples have relatively great K_2O/Na_2O ratios probably generated during gold-related hydrothermal alteration.

3) Au/Ag ratios in core samples are widely variable and may be useful in defining different stages or styles of gold mineralization.

4) Relatively unaltered felsic volcaniclastic samples which lack fractures and veins but contain a few percent finely disseminated pyrrhotite consistently contain less than 200 ppb gold.

Differences among gold deposits in the Courageous Lake "gold belt" suggest a complex history of gold concentration. Although late shear zones typical of those associated with many Archean lode gold deposits appear to have controlled gold distribution at Salmita and other occurrences, synvolcanic structures and processes may have contributed to gold mineralization on the Tundra property. This indicates that the Slave Province may be favourable for the occurrence of large volcanic-hosted "epithermal-like" deposits.

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ARCHEAN PALEOPLACERS, SLAVE STRUCTURAL PROVINCE, NWT

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Introduction
Chemically mature clastic sedimentary rocks more than 2.6 billion years old form important parts of many supracrustal successions, such as the Witwatersrand Supergroup in South Africa and the Prince Albert Group in the northeastern part of the Northwest Territories, but occurrences of quartzarenites in narrow belts in the Slave Province have only recently been recognized. These belts warrant special attention, not only because they provide important new information on the tectonic evolution of the Slave Province, but also because most Archean and very early Proterozoic quartz-rich arenite formations contain concentrations of pyrite and other heavy minerals including, in the case of the Witwatersrand, gold and uraninite of immense economic importance. Accordingly, possibilities of discovering paleoplacer deposits and finding new potential host formations for these in the Slave Province were studied in the period 1987-1990 under the Canada-Northwest Territories Mineral Development Subsidiary Agreement. This paper summarizes findings reported in Geological Survey of Canada Current Research volumes by Covello et al (1988), Roscoe et al. (1989), Roscoe (1990a), and Rice et al. (1990), and in talks by J.A. Donaldson in 1987 and by the writer in 1988, at Yellowknife Geoscience Forums, and by the writer (Roscoe, 1990b) at the Vancouver meeting of the Geological Association of Canada-Mineralogical Association of Canada.

Paleoplacer hosts
Quartzose arenite beds occur at two positions in supracrustal belts in the Slave Province:

1) between granitoid gneisses and dominantly mafic metavolcanic successions that face away from the gneisses; and

2) atop thick metavolcanic successions.

Those at the bases of supracrustal belts comprise distinctive units of fuchsite-bearing supermature quartzarenite, whereas those capping volcanic sequences occur as lenses within dominantly submature to immature arenites and rudites. Concentrations of heavy minerals, including abundant, slightly auriferous pyrite and radioactive minerals, but no magnetite, are found in quartz pebble conglomerate beds in both the 'basal' and the 'cap' associations. These beds are weak manifestations of the placer-forming processes that were essential factors in the formation of the supergiant Elliot Lake and Witwatersrand uranium, gold and gold-uranium ore deposits.

Beniah Formation and other 'basal' metaquartzite units
The most extensive quartzarenites are in the Beaulieu River belt near Beniah Lake 145 km northeast of Yellowknife (Fig. 1) where they make up the Beniah Formation (Roscoe et al., 1989). The formation is exposed at scattered localities aligned throughout a north-south distance of 80 km. Its continuity and stratigraphic relationships are uncertain in many places, however, not only because of drift cover and structural disruptions, but also due to myriads of fine-grained gabbro dykes that outcrop preferentially and are difficult to distinguish from massive mafic flows.

Rice et al. (1990) studied lithostratigraphic and sedimentological variations through a 230 m thickness of the formation where it is best exposed and least deformed at a site 3 km west of the south end of Beniah Lake. They concluded that the strata were deposited subaqueously in a middle to outer shelf environment.

The section studied in detail is dominantly metaquartzite but phyllite and interlayered phyllite and metaquartzite are present in the upper and lower parts, and conglomeratic beds are present in the upper part. Cross-stratification and ripple lamination can be recognized in many beds. Argillaceous beds are faintly radioactive compared to quartzarenite beds. A slightly pyritic specimen from a distinctly radioactive paraconglomerate bed was found to contain 8 ppm U and 30 ppb Au. Quartz pebble conglomerate beds, however, are not pyritic and not significantly radioactive. Rusty matrices in one pebble bed suggest that pyrite was originally present, but that this pyrite, together perhaps with radioactive minerals, was

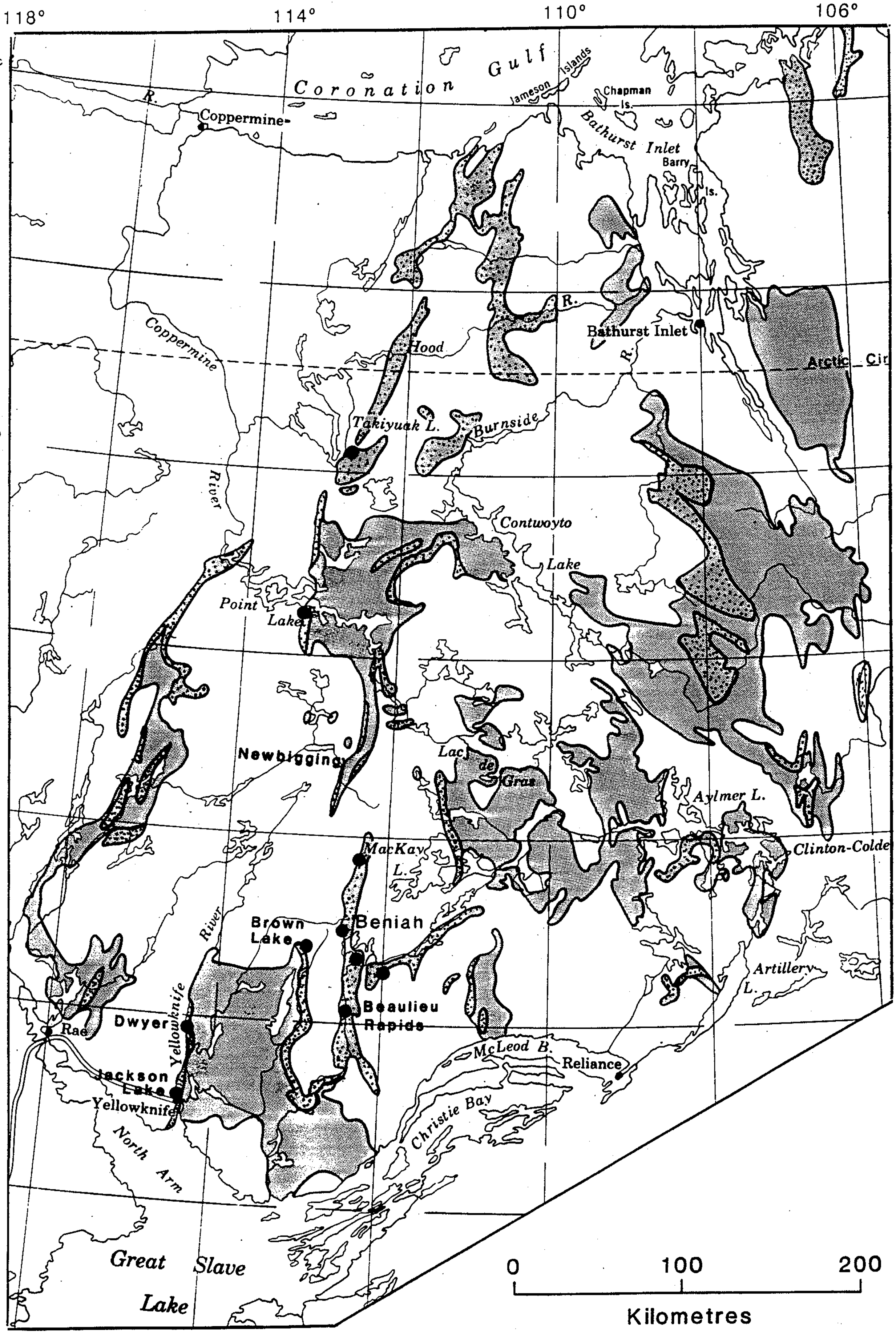

Figure 1. Archean supracrustal belts in the Slave Structural Province and locations of quartzose arenites, quartz pebble conglomerate and pyrite paleoplacers. Finely stippled (grey) areas are underlain mainly by metasedimentary rocks; coarsely stippled areas, by metavolcanic rocks (from Roscoe,1990a).

leached to considerable depths. Another section a few kilometres to the north contains several radioactive pyritic quartz pebble beds that were sampled (Table 1). Similar beds are present along the west side of Beniah Lake, but there the Beniah Formation is within a major shear zone and is greatly attenuated.

Quartzarenite units with lithostratigraphic and structural associations similar to those of quartz-arenite in the Beniah Formation are present at Brown Lake, 24 km west of Beniah Lake, in the north part of the Cameron River belt (James, 1990; Roscoe, 1990a) and 110 km west in the north part of the Yellowknife belt. Helmstaedt and Padgham (1986) described the rocks at the latter locality as "a narrow band of felsic volcanic rocks including fuchsite-bearing quartzofeldspathic rocks and thin beds of banded chert-magnetite iron-formation". Padgham (1987, Fig. 10) termed the unit the"Likely Fm" in an illustration that shows its stratigraphic position beneath the Kam Group. This name was used by Roscoe (1990a) who noted that a 70 m section of quartzarenite and feldspathic quartzite overlain by 20 m of banded chert-magnetite-amphibole iron formation contains crossbeds, silty beds, coarse grained beds and heavy mineral-bearing, pyritic, slightly radioactive beds. More recently, the unit has been called "Dwyer Formation" (Padgham, in preparation).

In common with other mature clastic formations found at bases of some Archean supracrustal successions, for example: Sakami Lake, Quebec (Roscoe and Donaldson,1988) and Eyapamikama Lake, Ontario (deKemp, 1987)), the Beniah Formation and metaquartzite at Brown Lake, as well as the Dwyer Formation, are capped by banded iron formation. In many places, the quartzarenites are associated with coeval felsic volcanic rocks or have been intruded by ultramafic rocks. Komatiites, as well as pillow basalt, are in some cases present at the base of overlying successions.

An assemblage of quartz-rich clastic rocks, polymict and oligomict conglomerate, felsic volcanic rocks, and pyritic, graphitic cherty rocks is present along the west side of a volcanic belt at Takiyuak (Takijuq) Lake (Padgham, 1985). It appears to be comparable to the Beniah Formation and contains abundant layers of radioactive pyritic pebbly arenites and conglomerates. A specimen (89RFTJ1, Table 1) was found to contain 250 ppb Au.

Beaulieu Rapids Formation

The recently discovered Beaulieu Rapids formation (Stubley, 1989), 30 km south of Beniah Lake in the Beaulieu River belt, is comprised dominantly of polymict orthoconglomerate and arkosic arenite members deposited in a subaerial alluvial fan (Rice et al., 1990). Many beds, enriched in quartz clasts, are distinctly more radioactive than more typical, immature clastic sediments, volcanic rocks and quartzarenites in Archean belts.

Pyritic pebbly layers and quartz pebble conglomerate lenses are particularly radioactive. Some samples (Table 1) contain more gold than any of those collected from Beniah conglomerates and also have higher Au/U and U/Th ratios.

The Beaulieu Rapids formation unconformably overlies the same thick volcanic pile that overlies the Beniah Formation. It is restricted to a complexly deformed synclinal structure 8 km long.

Jackson Lake Formation

Radioactive layers a few cm thick were discovered in the basal 2 m of the Jackson Lake Formation where it unconformably overlies the Kam Group of volcanic rocks at Giant Mine, Yellowknife. Like the Beaulieu Rapids formation, the Jackson Lake Formation is fluvial (Padgham, 1985). Evidence for paleoweathering beneath the unconformity is consistent with the occurrence of concentrations of quartz clasts and detrital heavy minerals in the radioactive layers, which are pyritic although they are not gossanous. Samples from separate localities and lenses along a 70 m length of the contact contain as much as 230 ppb Au and 280 ppm U and, like Beaulieu Rapids samples, have higher Au/U ratios than do Beniah samples. Correlation matrices show that Au, U, and S (along with Th, Ti, Zr, and REE) are placergenic, not epigenetic. Thus, the weak Au concentrations (probably in pyrite) predate the nearby structurally controlled gold deposits in the Giant Mine.

Formations found to be unfavourable as paleoplacer hosts

A belt of supracrustal rocks extending from a point (64°07' N, 112°45' W), 35 km northwest of the north end of the Beaulieu River belt, north 125 km through the Winter Lake sheet (85A) into the Point Lake area was reconnoitered and detailed sedimentological studies were carried out near Newbigging Lake (64°19-26' N), Beauparlant Lake (64°35' N) and Providence Lake (64°49' N). The belt is dominated

Table 1 Partial analyses of selected specimens of Archean radioactive, pyritic quartz pebble conglomerates and quartzose meta-arenites

	SiO2	Al2O3	K2 O	Na2O	CaO	MgO	FeO	TiO2	Pyrite	Au	Hg	U	Th	Ce	Y	P	Zr	Cr	As	Co	Ni	Cu	Zn	Pb
SAMPLE	%	%	%	%	%	%	%	%	%	ppb	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
88RF40	76.5	6.5	1.6	0.5	0.1	1.4	1.5	0.7	8.1	76	43	324	435	219	58	340	1160	470	13	134	190	460	61	250
88RF40A	86.9	5.7	1.5	0.2	0.1	0.6	0.7	0.3	1.8	2	7	10	17	64	<10	100	149	90	5	48	77	81	60	52
88RF41	65.1	12.2	1.3	2.5	1.6	2.1	6.8	0.5	3.6	12	9	64	82	165	41	290	507	2450	14	160	1600	640	260	36
88RF42	81.1	6.8	1.9	0.2	.0.0	0.7	1.5	0.4	4.9	17	14	37	53	87	46	130	402	200	53	73	71	80	38	40
88RF43	84.1	6.8	1.1	0.8	0.5	1.2	1.2	0.3	1.4	4	11	21	38	100	14	170	203	120	4	36	69	150	31	24
88RF43B	85.3	6.4	0.7	1.3	0.8	1.1	0.9	0.3	1.6	1	11	14	26	82	14	120	186	110	5	33	77	190	35	36
88RF44	61.2	16.2	1.9	3.1	1.9	2.8	4.9	0.7	4.4	3	5	109	126	294	58	530	537	270	5	194	340	420	53	48
88RF45A	77.3	8.6	1.6	0.5	0.2	2.3	2.8	0.5	2.1	<1	7	28	85	128	44	180	484	260	7	52	78	270	50	40
88RF47	70.2	13.5	2.3	0.2	0.4	1.9	5.5	0.6	0.9	630	19	287	155	116	23	240	618	130	4	22	44	79	86	32
88RF48	73.9	9.2	1.5	0.1	0.2	1.4	5.3	0.6	3.4	44	8	254	162	113	33	480	1280	130	36	55	88	140	66	36
88RF48B	69.5	12.4	2.1	0.2	0.4	1.7	6.2	0.7	2.4	410	11	218	195	113	53	250	977	150	10	41	70	100	77	36
88RF49	73.7	10.8	2.3	0.2	0.1	1.3	4.5	0.6	2.1	180	11	57	87	128	21	340	608	110	69	37	30	29	53	28
88RF50	56.7	9.6	1.5	0.2	0.1	1.8	9.6	0.7	14.1	250	34	83	47	89	13	580	262	100	180	100	120	130	85	32
88RF52	62.5	14.1	2.8	0.2	0.1	1.9	9.7	1.2	0.7	48	19	13	19	105	13	655	312	190	69	11	19	51	87	32
88RF53A	64.7	10.3	1.1	0.2	0.8	2.1	8.8	1.1	5.8	80	20	190	287	238	38	830	2620	170	75	104	140	120	89	48
88RF53B	66.4	7.6	1.1	0.1	0.3	1.3	8.7	0.7	8.2	200	30	104	101	94	21	568	1220	350	110	114	1400	240	310	28
88RF53C	61.8	9.5	1.7	0.2	0.2	1.5	8.2	0.7	11.2	58	18	99	105	79	18	420	604	100	120	128	140	230	68	16
88RF54	72.1	10.1	1.1	0.3	0.7	1.4	4.1	0.5	6.1	6	26	137	285	226	33	524	1400	96	34	106	90	150	40	72
89RFTJ1	82.0	3.7	0.3	2.1	0.5	0.6	6.5	0.3	1.9	250		80	117	66	24	830	189	41	140	23	54	125	36	73
89RFTJ3	77.7	7.4	1.9	0.1	0.0	0.5	5.4	0.6	0.5	58		18	47	133	32	306	268	100	460	2	18	25	33	136
89RFCJL6	61.5	16.4	2.0	0.5	0.4	1.0	8.1	1.1	2.7	230		103	280	176	107	913	3420	617	330	107	153	32	77	3
89RF301	66.2	16.9	1.9	0.6	1.0	2.0	5.2	1.0	0.5	49		35	43	114	28	786	973	240	110	29	74	13	95	22
89RF302	74.0	8.4	0.2	0.1	1.3	3.8	6.6	0.5	0.0	7		4	9	43	34	350	183	63	27	16	55	62	147	18
89RF303	77.7	12.3	0.9	0.2	0.3	0.7	7.7	0.5	0.1	<1		3	6	43	<10	437	106	120	210	22	64	7	58	>2
89RF304	75.4	10.4	0.6	0.2	0.3	2.2	5.7	0.4	0.1	43		13	10	53	18	961	250	98	110	23	67	230	128	7
89RF305	75.8	13.1	1.1	0.2	0.2	0.8	7.7	0.5	0.3	110		62	40	103	42	524	742	120	140	16	49	34	79	16
89RF306	78.4	11.6	1.2	0.4	0.2	0.6	4.8	0.6	0.3	200		56	40	146	44	481	932	180	190	33	54	36	58	15
89RF307	78.8	10.0	0.3	0.1	0.3	0.9	6.9	0.5	0.4	63		16	14	67	22	1005	374	120	380	17	45	44	81	8
89RF308	73.6	14.7	1.4	0.3	0.3	0.5	5.6	0.7	0.4	120		42	30	97	25	1005	642	180	85	16	32	6	62	13
89RF309	75.1	13.5	0.8	0.2	0.1	0.6	6.9	0.6	0.0	18		15	18	85	47	350	372	160	50	10	28	5	76	15
89RF200	74.5	14.0	2.4	0.6	0.1	0.5	2.6	1.1	0.8	16		14	54	161	57	306	383	140	460	127	202	175	33	<2
89RF201	61.0	11.3	2.0	0.5	0.2	1.4	8.9	4.0	2.0	60		306	2000	782	188	1920	10000	240	240	132	183	1190	72	197
89RFC1A	92.7	2.9	0.4	0.2	0.5	0.5	1.2	0.2	0.1	1		2	16	29	<10	440	39	16	160	14	50	50	48	16
89RFC1B	94.1	2.5	0.5	0.0	0.0	0.2	0.1	0.0	0.0	5		2	6	23	<10	90	53	16	76	<1	12	7	23	<2
87RF125	88.8	2.3	0.6	0.1	0.1	0.2	1.4	0.2	4.4	17		754	1270	174	112	1600	773	88	230	58	110	250	12	280
89RF21	75.4	12.4	4.9	2.1	0.5	0.6	1.4	0.2	0.0	<1		299	7	15	<10	130	73	21	5	11	49	9	26	32

Analyses by X-Ray Assay Laboratories Limited, multi-method, multi-element package; sulphur (S) reported as FeS_2; iron (Fe) as FeS_2 and FeO; not all elements analyzed are presented.

Sample	Description
88RF40-45A	Conglomerate lenses, Beniah formation near Beniah Lake at 63°21.1 'N, 112°21.2'W (from Roscoe et al, 1989), Table 1, Fig.4)
88RF40	drillcore hole 1
88RF40A	41 cuttings from hole 1
88RF42	drillcore hole 2 ca 10 cm beneath hole 1
88RF43	drillcore and 45A broken rock, site 4, 50 cm NE of hole 1
88RF44	drillcore site 5, on a separate conglomerate lens 50 m E of hole 1
88RF47-54	conglomratic lenses, Beaulieu Rapids Formation (from Roscoes et al.,1989, Table 1, Fig. 5)
88RF47, 48, 48B and 49	Site 1 - 63°04.55'N, 112°24.65'W
88RF47	drillcore vertical hole
88RF48, 48B	adjacent to 88RF47, inclined hole
88RF49	outcrop sample 7 m NE of drillholes
88RF50, 52, 53A, 53B, 53C	Site 2 - 63°04.45'N, 112°24.6'W
88RF50, 52	cores from vertical hole
88RF53A, 53B, 53C	from vertical hole at same locality
88RF54	Site 3 - 63°03.7'N, 112°24.3'W, drillcore
89RFTJ1, 89RFTJ3	quartz pebble conglomerate, Takiyyak Lake
89RFCJL6, 89RF301-309	pebbly layers near base of Jackson Lake Formation, Giant Yellowknife Mines
89RF200, 201	grit layer in quartz arenite, Eyapamikama Lake, northwestern Ontario
89RFC1A, 1B	basal 4 cm of quartz arenite formation at Eyapamikama Lake, northwestern Ontario
87RF125	pyritic quartz pebble conglomerate, Sakami Lake, Québec
89RF21	arkose, San Antonio Formation. Manitoba, containing epigenetic uranium concentration

by arenaceous and phyllitic beds, but includes important lenses of polymict conglomerate and basalt. Metasediments in the northern extension of the belt at Point Lake have been mapped as the turbiditic Itchen Formation and the conglomeratic Keskarrah Formation (Bostock, 1990), which unconformably overlies basement granitoid rock. Conglomerate and associated arenite to the south in the Winter Lake area are not unlike rocks in the Keskarrah Formation although correlations are not justified at present. The sedimentary rocks at 64°19-26' N have been interpreted to have been deposited in a submarine fan system (Rice et al., 1990), an environment unfavourable for the formation of placers. The immature character of the sediments is another unfavourable factor and, indeed, no significant concentrations of heavy minerals were found in the belt.

Conclusions and recommendations for further work

The area containing quartz-rich clastic sediments near Takiyuak Lake, and possible extensions thereof, should be geologically and radiometrically mapped in detail. Possibilities of finding economically interesting paleoplacers, however, in other areas examined to date are remote. The distal depositional environment of the Beniah Formation is unfavourable. The Beaulieu Rapids formation was deposited in a proximal environment, but limited weathering of its source rocks would have restricted supplies of heavy detrital minerals. Ratios of gold and uranium to pyrite and of gold to uranium in the known Slave paleoplacers are much lower than they are in submarginal Witwatersrand ores. This means that no amount of concentration of the heavy mineral assemblages relative to quartz would produce a gold ore, although sub-ore grade paleoplacers could have provided sources for gold in epigenetic deposits.

It is very likely that many more occurrences of mature, 'platformal' sediments will be found in the Slave Province, particularly in the western part that contains known pre-2.71 basement rocks and mineral occurrences with distinctive high 207/204 Pb signatures (Thorpe et al., 1992). If so, some of these may be found to have been deposited in more proximal environments than the Beniah Formation. More favourable sources of heavy minerals may have been available in some areas. The cost of seeking 'platformal' successions, potential paleoplacer hosts, are trivial and some target areas are obvious, eg.: quartz pebble conglomerate reported at Point Lake (Easton et al., 1982); bases of supracrustal successions that overlie known basement rocks; contact zones between metavolcanic rocks and gneiss belts that may include pre-volcanic rocks.

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RARE EARTH AND TRACE ELEMENT GEOCHEMISTRY OF SCHEELITES, SLAVE PROVINCE GOLD DEPOSITS

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Objectives

1) To determine the rare earth, Sr and Au contents of scheelites from Slave Province gold deposits, and compare them with those of scheelites from other Archean gold deposits; and

2) To analyze scheelites from Slave Province gold deposits for their Sm-Nd isotopic compositions to test the feasibility of using the Sm-Nd system to date the time of formation of these deposits.

Methodology

This study forms part of a PhD thesis at Carleton University by the author. The rare earth, Sr and Au analyses were done by neutron activation analysis by Nuclear Activation Services of Hamilton, Ontario under contract to the Geological Survey of Canada. The isotopic analyses were done by the author in the Isotope Geochemistry Laboratory at Carleton University. The feasibility of using the Sm-Nd isotope system to date scheelites from hydrothermal gold-deposits has been demonstrated by Anglin (1990) and Bell et al. (1989).

Samples of scheelite from the NERCO Con Mine were provided by D. Webb and B. Hauser. Samples from the Lupin and Salmita mines were provided by J.A. Kerswill. Their contributions are kindly acknowledged by the author.

Results

The results of the neutron activation analyses are presented in Table 1, and the results of the isotopic analyses are presented in Table 2.

The rare earth element (REE) data are presented in chondrite-normalized plots in figures 1 (Salmita), 2 (Con), and 3 (Lupin). REE data was normalized using the values of Taylor and Gorton (1977). Note that the neutron activation concentration data for some of the REE were reported as "less than" values in the case of both Con samples, two of those from Lupin, and one from Salmita. These data are presented here as one half their reported "less than" value, and are marked in Table 1 with an asterisk. Note also that La and Nd are not included in the Table or plotted. The presence of significant quantities of tungsten in the samples causes the background energy levels to be elevated during neutron activation analysis, and this interferes with determination of the REE and other trace elements that are present at low concentration levels.

Table 1. Neutron activation analyses of Slave Province scheelites.

LOCATION	SAMPLE	Ce	Sm	Eu	Tb	Yb	Lu	Au	Sr
NERCO CON	DRW-4783L	5*	0.8	11.3	0.5*	0.6*	0.05*	300	500*
NERCO CON	DRW-6	5*	0.9	3.3	0.5*	0.6	0.10	200	500*
LUPIN	LU250E-45	10	2.9	3.9	2.0	2.4	0.30	I	6000
LUPIN	LU330E	5*	1.0	0.3*	0.5*	1.4	0.05*	I	4000
LUPIN	LU110C-1	5*	0.2*	0.3*	0.5*	1.4	0.10	I	3000
SALMITA	SUS1-1	10	9.7	16.6	4.0	5.7	0.7	290000	500*
SALMITA	SUS1-2	10	11.2	22.9	4.0	8.3	0.60	340000	500*
SALMITA	SUS1-3	5*	12.5	20.8	5.0	5.9	0.70	330000	500*
SALMITA	SUS1-4	10	13.3	23.1	5.0	7.0	0.80	1000000	500*

Footnotes:

1. All data are reported as ppm , except for Au which is reported as ppb.
2. I = analysis incomplete due to interferences.
3. * = the analysis was reported as a 'less than' value, and is included in this table as 0.5 times the reported 'less than' value.
4. All La analyses were reported either as I, or as 'less than' 20 ppm.
5. All Nd analyses were reported as 'less than' 30 ppm.

All of the patterns (with the exception of two of the Lupin samples for which most of the REE were reported as "less than" values) show positive Eu anomalies and slight to moderate HREE depletion. This is typical of scheelites from Superior Province Archean gold deposits (Anglin et al., 1987; and unpublished PhD data).

The patterns of the Salmita scheelites (Fig. 1) are similar to those observed in scheelites from the Val d'Or area (Anglin et al., 1987; Ludden et al., 1984) in that they have a convex upward pattern, with significant LREE depletion. However, the REE content of the Val d'Or scheelites is approximately an order of magnitude greater than that of the Salmita scheelites. The Salmita scheelites also have a slightly more pronounced Eu anomaly than the samples from the Val d'Or area.

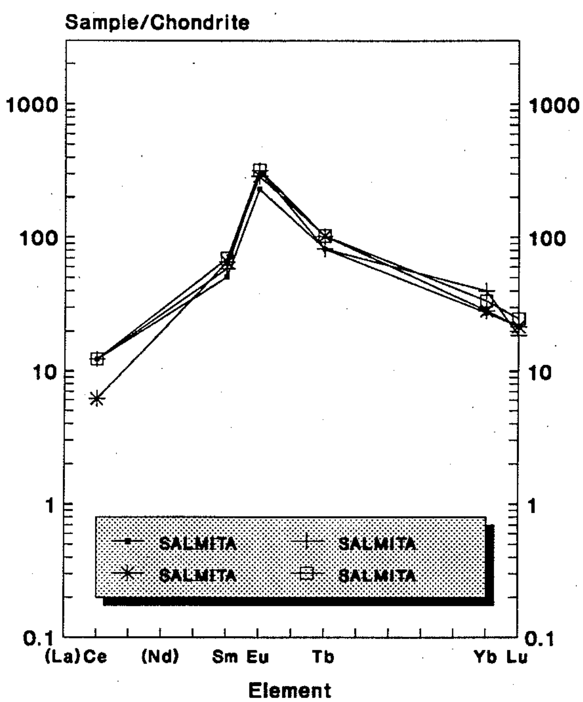

Figure 1. Chondrite-normalized REE patterns, Salmita Mine scheelite.

The NERCO Con scheelite samples (Fig. 2) are relatively low in REEs except for Eu. From the approximated chondrite-normalized REE patterns (note that most of the REE are below the elevated detection limits) they appear to have very significant positive Eu anomalies.

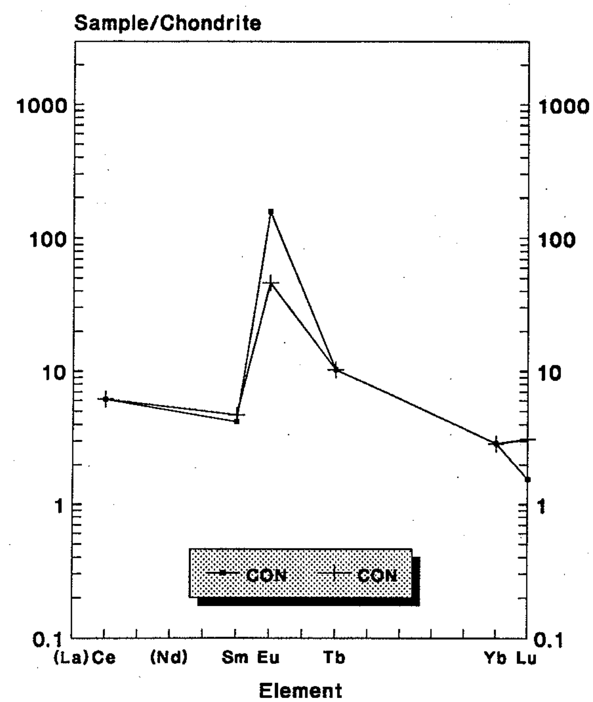

Figure 2. Chondrite-normalized REE patterns, NERCO Con Mine scheelite.

The Lupin scheelite (Fig. 3) exhibits a relatively flat pattern with only a slight positive enrichment in Eu, and REE concentrations below those of the Salmita samples.

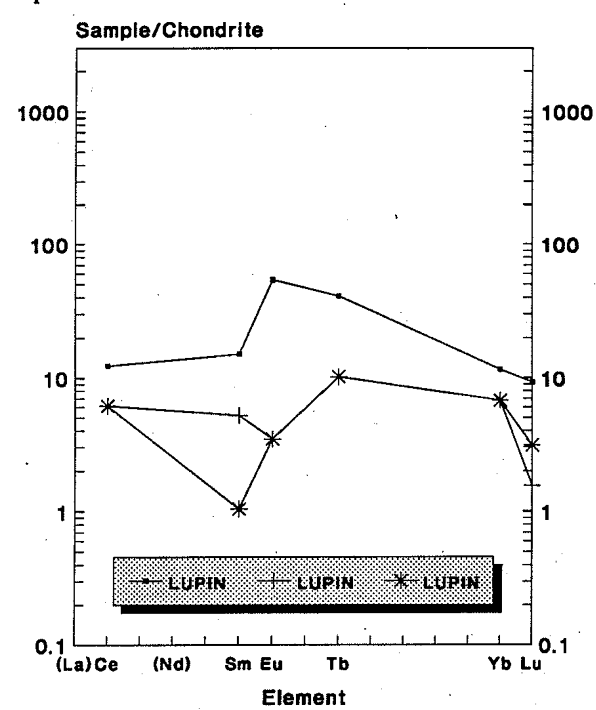

Figure 3. Chondrite-normalized REE patterns, Lupin Mine scheelite.

Three samples of scheelite from the NERCO Con mine were analyzed for their Sm-Nd isotopic compositions and the results are presented in Table 2.

Unfortunately, due to a combination of the low abundance and fine-grained nature of scheelite in the samples studied, and the relatively low Sm-Nd contents of these scheelites, the Nd isotopic determinations were relatively unsuccessful (i.e. the analytical errors are larger than acceptable for geochronological work). Therefore these analytical data are reported here only as very preliminary results.

Table 2. Isotope dilution analyses of NERCO Con Mine scheelites.

Sample	$^{143}Nd/^{144}Nd$	$^{147}Sm/^{144}Nd$	Nd (ppm)	Sm (ppm)	Sr (ppm)
CON-1	.51238 ± 3	.177	10.0	2.93	1275
CON-3	.51270 ± 5	.203	15.8	5.30	615
DRW-6	.51333 ± 1	.240	1.5	0.61	NA

The three samples taken together do not form a line within analytical uncertainty, however the unspiked CON-1 sample had a higher $^{145}Nd/^{144}Nd$ ratio than normal, suggesting that it was cross-contaminated at some point in the dissolution and separation procedure. For the sake of interest (although it must be stressed again that the analytical errors are much larger than normal) a two-point isochron age was calculated for samples CON-3 and DRW-6. The slope between these two points (0.01703) corresponds to a Sm-Nd isochron age of approximately 2580 Ma, and an initial $^{143}Nd/^{144}Nd$ ratio of approximately 0.50924. Although this work seems to indicate that the Sm-Nd method may be feasible for dating hydrothermal scheelite from gold-bearing veins at the NERCO Con Mine, this particular age may or may not have any geochronological significance, and needs to be tested by analyzing more samples.

Discussion and Conclusions

Differences in REE patterns and abundances for scheelite specimens from different gold mining camps have been noted by Anglin et al. (1987). The scheelites from the Salmita Mine have higher REE contents than the other Slave Province scheelites, and have patterns that show a slight LREE depletion. The Lupin and NERCO Con samples have lower REE abundances and patterns with flat to slightly LREE-enriched slopes. All the patterns show HREE depletion and positive Eu, except for the Lupin scheelites, for which two of the three analyses indicated the contents of most REE were below the elevated detection limits.

The differences in the REE patterns of scheelites, both within individual deposits and from district to district, suggest that more than simply crystallochemical effects are exerting controls on these patterns. Factors that may be controlling the patterns include: 1) co-precipitating phases, and/or 2) source of the fluid and original fluid REE patterns.

All scheelites from Archean gold deposits that have been analyzed to date in this study exhibit a positive Eu anomaly. This enrichment in Eu over the other REE may be related to the fact that Eu^{2+} would substitute preferentially over Eu^{3+} (and the rest of the trivalent REE) into the Ca^{2+} site in the scheelite. However, the varying degrees of Eu anomaly, and the fact that scheelites from other types of mineral deposits (unpublished data) do not all have positive Eu anomalies, suggests that the fluids from which scheelites in gold-bearing vein systems were precipitated, contained elevated abundances of Eu. This hypothesis also requires further study.

The fine-grained and relatively uncommon occurrence of scheelite at the NERCO Con Mine, coupled with the low REE contents of these scheelites, has resulted in the first attempts to obtain moderately good Sm-Nd geochronological data being unsuccessful. Larger quantities of scheelite than were used initially, will be needed for further study. Some preliminary data were obtained for three of the NERCO Con Mine scheelites. Unfortunately, one sample shows evidence of some contamination in the laboratory. The other two samples define a (poorly constrained) line with a slope corresponding to a Sm-Nd age of approximately 2580 Ma. Much more work is required to determine whether the slope of this line, and therefore this apparent age, reflects the true age of scheelite mineralization in the NERCO Con Mine.

In addition to continued study of the REE and trace element contents, and Sm-Nd isotopic compositions, of scheelites from Slave Province gold deposits, a study of the Rb-Sr systematics of the Giant shear zone has commenced. Preliminary analyses have been done by the author, and further work is continuing by Dr. J. Blenkinsop at the Carleton University Isotope Geochemistry Laboratory, under contract to the Geological Survey of Canada and partly funded by this project.

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A SIGNIFICANT Pb ISOTOPE BOUNDARY IN THE SLAVE PROVINCE AND ITS PROBABLE RELATION TO ANCIENT BASEMENT IN THE WESTERN SLAVE PROVINCE

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Introduction

It has been known for many years that some of the base metal deposits and occurrences within the Slave Province, NWT, have lead isotopic compositions with very high $^{207}Pb/^{204}Pb$ ratios relative to their $^{206}Pb/^{204}Pb$ values, whereas others do not (Robertson and Cumming, 1968; Franklin and Thorpe, 1982; Thorpe, 1982). The steep linear trend defined by these data, in combination with analyses of galenas from gold deposits, on a standard plot of $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$, was interpreted by Robertson and Cumming (1968) to indicate that different sources, possibly both enriched and depleted relative to unmodified mantle, were formed at about 4000 Ma. Robertson (1970) considered that this approximate 4000 Ma event included the formation of a protocrust in the Slave Province. Additional analyses acquired in recent years have greatly improved the geographic coverage of the lead isotopic data, and it has become evident that the leads enriched in $^{207}Pb/^{204}Pb$ are restricted to the western-southwestern part of the Slave Province.

Definition of the Boundary

A total of 63 lead isotope analyses for galena specimens from deposits and occurrences of volcanogenic massive sulphide (VMS) type, and related syn-volcanic veins (Homer Lake) and breccia fillings (PALE group), in the Slave Province define a distinct isotopic boundary trending a little west of north. The data defining this boundary are plotted on figure 1 and the distribution of the deposits throughout the Slave craton is shown in figure 2. The isotopic data are from 14 distinct localities to the east of the boundary and 8 to the west.

The low $^{207}Pb/^{204}Pb$ compositions for VMS deposits in the eastern and northern Slave craton are generally very uniform, with 28 analyses plotting in a narrow elongated field. Analyses for the Cavalier and Wolf (CAPE) properties form an appendage at the lower end of this field, likely because very impure galena concentrates were analyzed. Lead from the Indian Mountain Lake deposit is a little more enriched in the ^{207}Pb isotope, but contrasts with lead from deposits

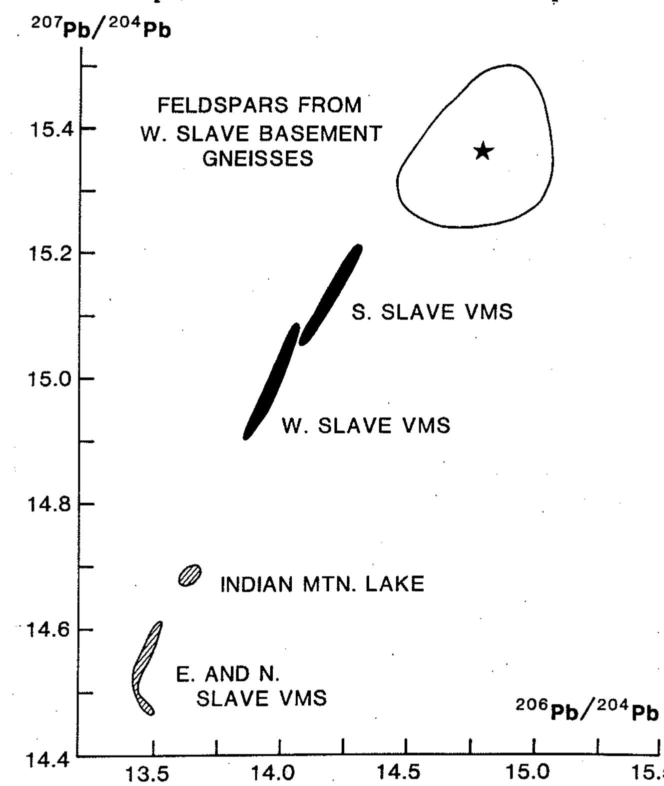

Figure 1. Lead isotope data for volcanogeneic massive sulphide deposits in the Slave Province in relation to those by Bowring et al. (1989a) for feldspars from basement gneisses.

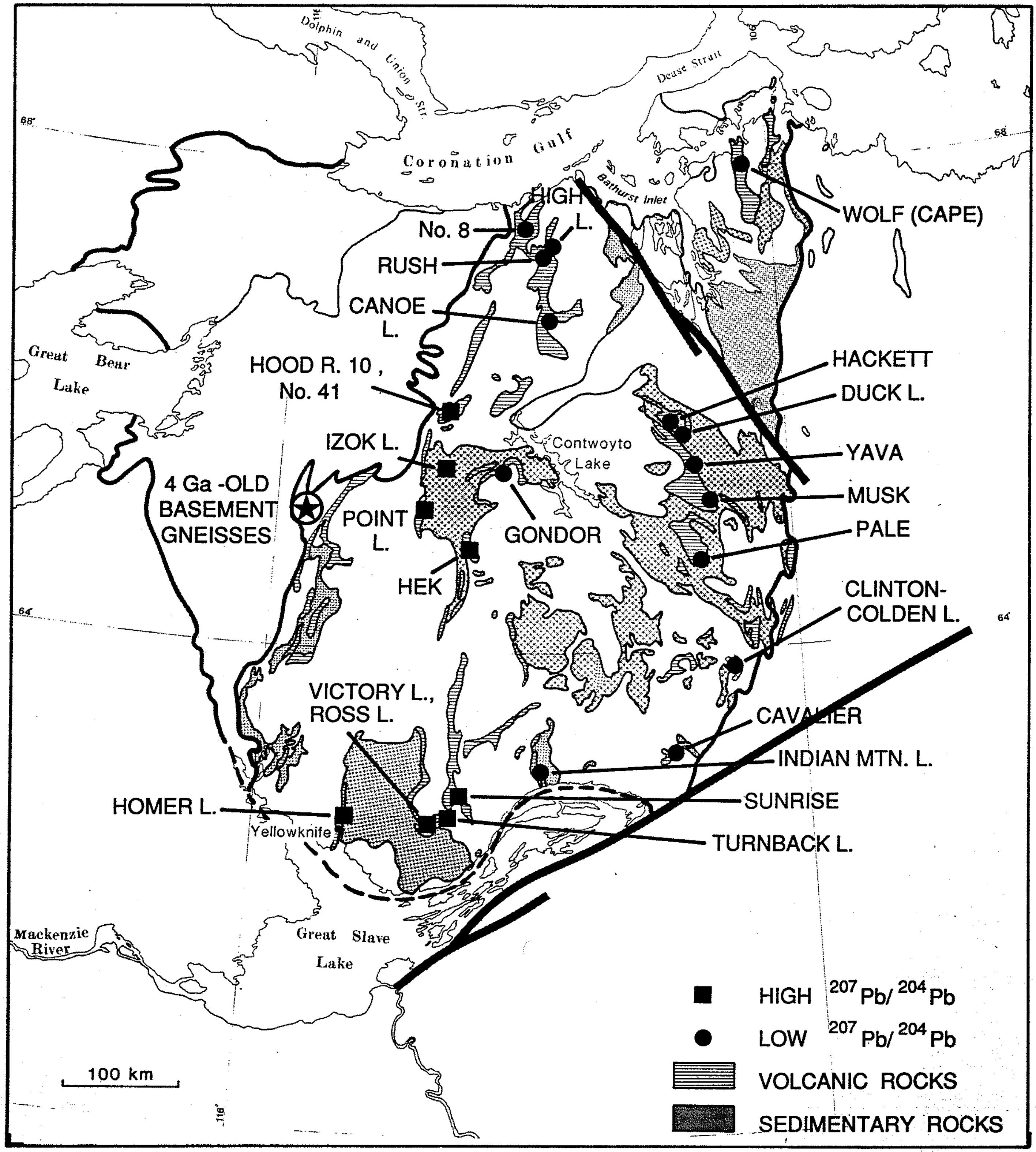

Figure 2. The distribution of volcanogenic massive sulphide deposits for which isotopic data are presented in figure 1.

west of the isotopic boundary and clearly belongs to the low $^{207}Pb/^{204}Pb$ class. VMS deposits in the Point Lake - Takijuq Lake region of the western Slave Province yield high $^{207}Pb/^{204}Pb$ compositions (12 analyses) which plot in a distinct elongated field. In this region the isotopic boundary is constrained to a position between the Izok and Gondor deposits.

The deposits in the southwestern Slave Province define a second elongate high $^{207}Pb/^{204}Pb$ field (19 analyses) that diverges slightly in trend from that for deposits in the Point Lake-Takijuq Lake region. The mineralized zones (O.K., IXL etc.) in the Turnback Lake area, although they have been highly metamorphosed and deformed, and in part complicated by the intrusion of granitic and pegmatitic bodies, yield Pb isotopic analyses equivalent to those for the Sunrise and Victory Lake VMS deposits in the area. This clearly suggests they had a comparable syngenetic origin.

The resulting lead isotope boundary between high $^{207}Pb/^{204}Pb$ leads in VMS deposits in the western Slave and low $^{207}Pb/^{204}Pb$ leads in VMS deposits in the eastern Slave is not precisely defined in terms of geographic position, but generally lies near 112° W longitude. Figure 2 shows that it is restricted to a position < 75 km east of the Beaulieu River greenstone belt in the southern Slave, < 50 km east of the Izok Lake VMS deposit in the Itchen Lake - Contwoyto Lake area of the central Slave, and probably < 80 km west of the High Lake greenstone belt in the northern Slave.

Interpretation and Implications of the Isotope Boundary

The simplest interpretation of the high $^{207}Pb/^{204}Pb$ compositions of the VMS deposits west of the boundary is that they reflect derivation of a significant component of their lead from an ancient upper crustal source. This explanation is unchanged from that offered by Robertson and Cumming (1968) and Robertson (1970) for such Slave Province leads. It is also the interpretation that has been adopted for leads elsewhere in the world with high $^{207}Pb/^{204}Pb$ ratios that must have been derived from long-lived high $^{238}U/^{204}Pb$ sources (Robertson, 1973; Thorpe et al., 1987; Sage et al., 1987; Browning et al., 1987; Vaasjoki, 1989). The conventional and most reasonable interpretation for the low ^{207}Pb leads east of the boundary is that they reflect a mantle source, and that their immediate source was juvenile crust.

Granitic and gneissic rocks that are established by zircon U-Pb dating to be basement to the Yellowknife Supergroup sequences are known only from the western part of the Slave Province (Kusky, 1989; Bowring et al., 1989a). The ancient age of some of this basement terrane in the western Slave has been dramatically established in the Acasta Lake area by the geochronological studies of Bowring et al. (1989a; 1989b), which show that the precursor to some of the gneiss must have formed at about 3962 $\pm$ 3 Ma. This appears to confirm the interpretation by Robertson (1970) that the Pb isotope data indicate an approximate 4000 Ma event which included the formation of a protocrust in the Slave Province. Also, the feldspar Pb isotope data by Bowring et al. (1989a) for the old gneisses appear to adequately confirm that such basement was the source of the ^{207}Pb - enriched component in the VMS deposits of the western Slave (Fig. 1).

It is of interest to consider the lead isotope boundary in relation to the distribution of quartzose arenite sequences, and associated lithologies, within the Slave Province. Roscoe et al. (1989) and Roscoe (1990, 1992) have given summaries of the nature of sites at which such platformal sequences of arenites and orthoconglomerates, and lesser associated carbonate and ultramafic rocks, have been discovered in recent years. These sequences lie unconformably beneath, or at the base of, the main supracrustal belts of the Yellowknife Supergroup, and provide important evidence for an early stable, or relatively stable, crustal terrane or craton from which they were derived by subaerial weathering (Roscoe, 1990). There is a remarkable parallel (Roscoe, personal communication, 1991 and see Fig. 2 in Roscoe, 1990) between the distributions of these quartzose sediments and the ^{207}Pb - enriched VMS deposits in the western Slave (Fig. 2 of this report). The fact that they occur in general proximity to each other may be coincidental, although as yet neither have been discovered in the greenstone belts along the western margin of the Slave Province south of the ancient basement gneiss site at Acasta Lake. In any case, the lead isotope boundary appears to correspond to the eastern limit of the known localities of quartzose arenites. If it is correct to assume that all of the Slave craton west of the Pb isotopic boundary contains a high ^{207}Pb (ie high $^{238}U/^{204}Pb$) source, then this high $^{238}U/^{204}Pb$ domain is about 500 km long and as much as 200 km wide.

A Sm-Nd study of granitoid rocks, along an east-west belt at the latitude of Point Lake, has indicated that late to post-deformation (about 2610 - 2585 Ma) granodiorite and granite plutons have negative ϵ_{Nd} values west of longitude 110° and positive ϵ_{Nd} values east of this (Davis and Hegner, 1990; Davis et al., 1990). This has been interpreted by these authors to mean that granites in the west may have been derived from mixed crustal sources dominated by a pre - 3.3 Ga component, whereas those in the east may be entirely derived from juvenile crustal sources similar to the exposed ~ 2.67 - 2.70 Ga supracrustal rocks. The isotopic difference also suggests that distinct crustal blocks have been juxtaposed within the central Slave Province (Davis and Hegner, 1990). This interpretation is the one that also best explains the lead isotope data, but the boundary based on the ϵ_{Nd} values for granitic plutons lies about 100 km east of the Pb isotope boundary as defined by the data for the Izok and Gondor massive sulphide deposits in this region.

Many geological similarities across the isotopic boundary zone favour establishment of different isotopic sources prior to the major phase of deposition of supracrustal rocks starting at about 2695 Ma. Most Yellowknife Supergroup sequences have similar ages (2695 to 2660 Ma) and are otherwise generally comparable (Mortensen et al., 1988; Padgham, 1985) across the zone, and no significant regional differences have been defined in volcanism and sedimentation. For example, the stratigraphic section at Wijinnedi Lake in the southern Indin Lake belt (Lord, 1942), and specifically the presence of limestone at the transition from volcanic to sedimentary sequences, is very similar to those in central and eastern Slave Province (and in which many VMS deposits and carbonate units show a close stratigraphic relation). Also, arsenide-gold mineralization in amphibolitic sulphide-silicate-facies iron-formation near Russell Lake, 100 km northwest of Yellowknife, resembles that at the Lupin Mine, Contwoyto Lake, and may have equivalents farther east. Many of the massive sulphide deposits on both sides of the boundary share a Pb- and Ag-rich "Slave signature" that is in general contrast to Superior Province deposits. These similarities across the zone help focus attention on the presence of older basement to the west as a likely explanation of isotopic patterns.

In contrast to these comments, Kusky (1989) suggested that volcanic belts in the western Slave are predominantly mafic, except at Indin Lake, whereas those to the east contain a much greater proportion of intermediate and felsic volcanic rocks. The presence of a calc-alkaline caldera complex in the Back River area, and evidence of related subaerial volcanism, can be considered as one manifestation of this difference. Kusky (1989) interpreted volcanic belts in his "Contwoyto terrane" (central Slave, including the host rocks to VMS deposits on both sides of the Pb isotope boundary) to be ophiolite-like slivers. This does not adequately account for felsic components within these belts, and one can only infer that felsic centres farther west at Russell and Indin lakes, within the basement-gneiss-bearing Anton terrane, are considered by Kusky to be parts of allochthonous slices. The geological similarities noted above do not mesh well with these views on subdivision of the volcanic rocks, and the Pb data for most VMS deposits within the western "Contwoyto terrane" provide evidence against deriving them from a source far to the east.

Establishment of the Pb isotope boundary reported here reinforces the evidence from zircon U-Pb geochronology of basement rocks and the distribution of platformal sequences that a line at or near its position separates two fundamentally different crustal blocks within Slave Province, or one older cratonic block in the west from younger accreted assemblages to the east. Kusky (1989) also suggested such a central boundary within the Slave craton.

King et al. (1989, 1990) generally concurred with the basic elements of the Kusky (1989) model, but questioned the validity of his proposed terrane boundaries, and suggested assembly of the central and eastern Slave by the accretion of the remnants of island arcs, syn-volcanic to syn-deformational turbidites and plutons derived from mantle and crustal sources, against (and onto) an east-facing continental margin. However, as noted above, a crustal boundary based on Sm-Nd data for late granitic plutons lies significantly to the east of the lead isotope boundary. The reason for this discrepancy is not yet known, although one possibility is to interpret the Gondor VMS deposit, and associated supracrustal assemblages, as parts of an allochthon. This would be in accord with the Kusky (1989) model. For Slave VMS deposits west of the lead isotope boundary, however, the concept of allochthonous transport from far to the east appears to be negated by their distinctly different high - ^{207}Pb compositions. An alternative, which obviates the need for allochthonous emplacement of Gondor assemblages, is to attribute the negative ϵ_{Nd} values of late plutons east of the lead boundary to their incorporation of large amounts of sediments derived from western basement terranes.

Most types of ore deposits in the Slave Province, as discussed previously, occur on both sides of the boundary without major differences being evident. The most obvious metallogenic significance of the boundary is that one would expect the potential for Au- and U-bearing paleoplacer deposits in quartzose arenite sequences (Roscoe, 1990) to be restricted to west of this line.

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STRATIGRAPHY, FACIES CHANGES AND STRUCTURE IN AURIFEROUS, IRON-RICH, ARCHEAN SEDIMENTARY SEQUENCES AROUND THE BACK RIVER VOLCANIC COMPLEX, NORTHEASTERN SLAVE PROVINCE, NWT

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Objectives
The Back River complex is centred about 100 km south-southwest of the George Lake gold prospect and 200 km southeast of the Lupin mine. This calcalkaline stratovolcano forms a southern extension to the Hackett River volcanic belt. This project was designed to elucidate the stratigraphic and structural settings of barren and auriferous iron formations and quartz veins which are spatially associated with the complex. Determining such settings would provide a framework to interpret previous results and to assist future mineral exploration. These strata have been extensively explored for precious and base metals, partly because of the extensive gossans developed in the units within the volcanic complex and the strong aeromagnetic signature of iron formations in the surrounding turbidites.

Methods
The project has involved detailed mapping, continuous physical tracing, logging and sampling of drill core provided by previous exploration, and measurement of surface sections through the iron-rich sequences, in 1988 and 1989. The sequences are continuous stratigraphic and structural markers which aid in the physical and geophysical tracing of complex fold geometries. Geochemical and petrographic studies are reported by Lustwerk (1992-this volume). Geochronological studies being conducted by J.Mortensen have been designed to determine the time span and regional correlations of the iron-rich strata and associated volcanic rocks.

Helicopter support by Polar Continental Shelf Project was shared with W.A. Padgham (Northern Affairs Program). Fixed wing support was shared with R. Johnstone (Government of the NWT). Geological discussions and access to core and geophysical data were provided by Silver Hart Mines Ltd.; Cominco Ltd. (D. W. Moore); K. Hudson and K. Waddell of the Esker Lake Joint Venture (Sirius Energy Corp. Ltd., Argus Resources Ltd. and Equity Silver Mines Ltd.); Cody Hawk Resources Ltd. (G. Grant); and Pamorex Minerals Inc. (G.G. Goucher, M. Cunningham and M. Glatiotis).

C.J. Beaumont-Smith contributed ideas and structural geology skills over two field seasons, as part of a PhD program at the University of New Brunswick, supervised by P. Williams. G. Burbidge contributed stratigraphic, sedimentologic and map data in 1989. Discussions with R.A. Baragar, B. Bluck, F.O. Dudas, G. Gross, J.R. Henderson, M.N. Henderson, J. King, K. Mann, F. Robert, and C.R. van Staal provided insight into various aspects of the studies. Technical assistance was provided by N. Kim, R.D. Lancaster and W.A. Spirito. This MDA project was linked to an on-going GSC project on the structure and volcanology of the area, led by M.B. Lambert. Constructive review by W.A. Padgham and J. King improved this summary.

Results
The first result, described below, has been to outline three separate, mappable, iron-rich stratigraphic sequences which punctuate turbiditic and volcanic strata in the area of the Back River volcanic complex (Fig. 1). Mapping of these sequences has shown that the complex includes two large structural domes and some smaller volcanic bodies which are

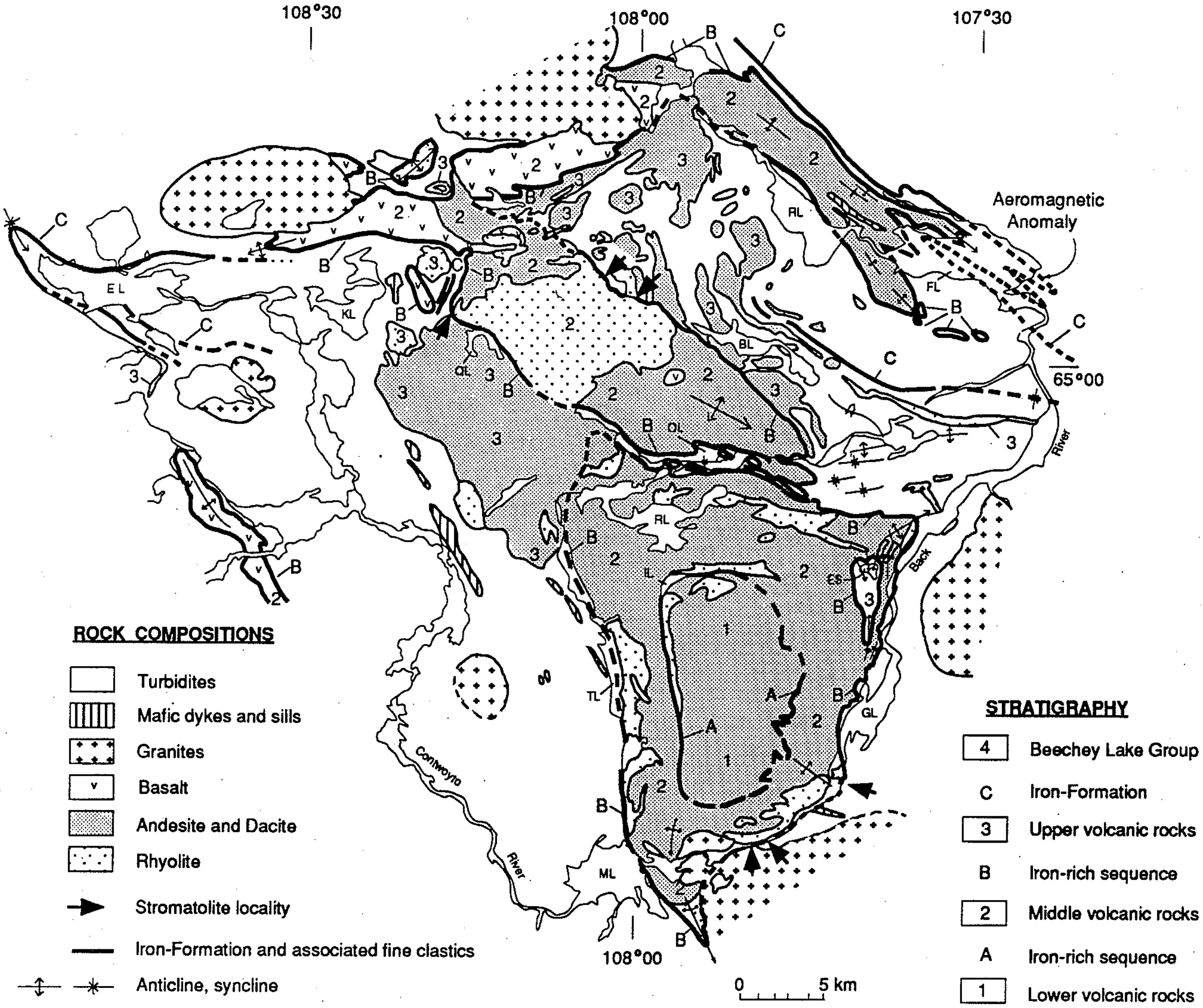

Figure 1. Simplified geology of the Back River volcanic belt, after Jefferson et al. (1989) and Lambert et al (1990). Volcanic rocks 1, 2, 3 are compositionally undivided, number 1 being stratigraphically lowest, 3 being highest. Patterns indicate composition as on legend. Letters A, B, C indicate iron-rich sedimentary sequences described in text, from oldest to youngest. BL = Boucher Lake; ES = Eastring Lake; EL = Esker Lake; FL = Fidler Lake; GL = Gold Lake; IL = Innerring Lake; KL = Keish Lake; ML = Magrum Lake; OL = Outerring Lake; QL = Quartermoon Lake; RL = Regan Lake; TL = Thlewycho Lake.

stratigraphically overlain by turbidites of the Beechey Lake Group. A spectrum of small, felsic-dominated volcanic bodies are stratigraphically enclosed by the turbidites.

Volcanic and sedimentary facies within the volcanic complex include subaerial to shallow subaqueous flows and sills of mafic to intermediate composition, voluminous tuffs and breccias of intermediate to felsic composition, felsic sills and domes with related clastic aprons, carbonate impregnated polymict volcanic breccia and arenite, and subaerial to deep-water volcanic conglomerates and amalgamated sandy turbidites (Jefferson et al., 1989 and Lambert et al., 1990).

The A-B-C Series of Iron-Rich Chemical Sedimentary Sequences has been mapped throughout most of the Back River Complex. The following is a brief summary of the sequences; Lustwerk (this volume) provides more details on Sequences A and B.

Sequence A is mapped only within the largest, southern structural dome of the Back River volcanic complex. Sequence A is the thickest (2 to >100 m in the vicinity of Innerring Lake) of several carbonate-rich sedimentary units which mark temporary cessation of volcanism and reworking of volcanic protoliths in a subaqueous environment. Sequence A is lithologically diverse and has marked lateral facies changes, including nearly complete pinch-outs. Subunits of Sequence A tend to occur in the following stratigraphic order, from bottom to top: calcite-cemented volcanic breccia with numerous pyritic fragments, gritty limestone, calcareous to magnetitic chert including banded iron formation, graded cherty volcaniclastic rocks, slate, and graded greywacke. All of the chemical sediments are variably sulphidic and iron-rich. Although Sequence A contains numerous gossans and is extensively staked, no significant gold or massive sulphide prospects have been discovered.

Sequence B, which is characterized by ferruginous carbonates and cherts (including banded iron formation), ranges in thickness from 2m (near Boucher Lake) to more than 100 m (Outerring Lake) and is generally 50-80 m thick. It continuously separates the thick pile of dominantly volcanic rocks from overlying turbidite-dominated strata. Sequence B includes, from top to bottom, various combinations of the following sub-units:

- carbonaceous sulphidic slate;

- sulphidic chert (banded iron formation);

- local sulphidic volcaniclastic/greywacke/slate units;

- magnetite-, sulphide- and siderite-chert beds (banded iron formation);

- arenaceous to relatively pure ferruginous dolomite with local oolites, stromatolites, ripple marks, laminations, cross beds;

- dolomite- to siderite-impregnated breccia and granule breccia.

Sequence B is overlain by upward-thickening turbidite beds of the Beechey Lake Group. Previously documented (Moore, 1977) stratabound, peneconcordant, grey, sulphidic quartz veins are the most auriferous rocks in Sequence B and are best developed in the lower part of the carbonaceous slate unit. Mineralogical facies of iron formation in sequence B typically change across distances of 10-300 metres laterally, and 1-10 metres vertically. The lateral mineralogical, as well as clastic facies changes, suggest variations in both paleoenvironment and volcanic paleotopography.

Sequence C is hosted by turbidites and is present in many parts of the study area. It consists of:

1) basal and/or capping graphitic slate,

2) extensive argillaceous to cherty magnetite iron formation with intense magnetic signature,

3) locally developed sulphide or silicate iron formation with subdued magnetic expression and moderate to weak conductivity,

4) chert nodules, and

5) cross-cutting, white quartz veins.

A complete spectrum from magnetite-silicate through mixed magnetite+sulphide-silicate to sulphide-silicate iron formation has been observed. Iron formations in the Sequence C facies association are spatially associated with thin to thick volcaniclastic units within the turbidites. Sequence C has been mapped very close to, but separated from, felsic domes and related conglomerates that are interbedded with turbidites.

Carbonate-cemented breccias in the Back River complex include patches, cross-cutting zones and laterally continuous units. Those at the base of sequence B overlie felsic, intermediate and mafic volcanic rocks around the perimeters of the structural volcanic domes. Similar carbonate-rich breccias, stratigraphically above sequence B, are associated with tuffs and rhyolite domes within the turbidites. A variety of hydrothermal, sedimentary, organic (stromatolites) and weathering processes are thought to have been involved in the formation of these carbonate rocks. The ferruginous chert to carbonaceous slate part of sequence B records a starved sedimentary basin. Together with the underlying carbonate units, they suggest that considerable time may have elapsed between volcanism below sequence B and volcanism associated with the overlying turbidites and the iron formation of Sequence C. On-going geochronologic studies by J. Mortensen and O. van Breemen will test:

1) the above suggestion,

2) whether iron formations in Sequence C are the same age throughout the Back River area, and

3) possible correlations with iron formations at George Lake, Lupin, and Pistol Lake.

Four generations of structures (three penetrative events followed by a fourth weakly developed local event) are described by Beaumont-Smith in Lambert et al. (1990). Very large folds of the volcanic rocks and tight, cylindrical, parasitic folds on their limbs (all F2) record the main deformation. Steeply plunging parasitic folds offset the volcanic-sedimentary contact. Variably curving easterly to northerly trends of distinct axial planar crenulation cleavages (S2) border the volcanic complex. Steeply and shallowly plunging open kink folds (F3, F4?) trend northerly and northwesterly.

Gold prospects in the study area are associated with iron formations and quartz veins. Stratiform (e.g. Lupin) and stratabound (e.g. George Lake) gold deposits and large prospects in the northeastern Slave Province are within turbidite-hosted iron formations. Similar prospects in the Back River study area are hosted by Sequence C, in the vicinity of Esker Lake and Fidler Lake.

Quartz veins in supracrustal rocks of northeastern Slave Province are abundant in high strain zones. Cross-cutting quartz veins are also well developed in competent units such as thick turbidite and arenite beds, hypabyssal intrusions and iron formations. Quartz veins cutting iron formations are associated with various combinations of sulphide, garnet, amphibole, chlorite, tourmaline, arsenopyrite and gold, particularly within Sequence C. In addition, large, peneconcordant, grey quartz veins are hosted by carbonaceous, sulphidic slates of Sequence B.

Moore (1977) noted three key aspects of gold distribution in rocks now termed Sequence B:

1) Significant gold in iron formation and associated rocks has been found mainly in and near the Eastring Lake Syncline (Fig. 1).

2) Sulphide and oxide facies of iron formation average about 60 ppb Au; grey quartz veins about 700 ppb Au; chert and chert-sulphide breccia about 1300 ppb Au.

3) The grey crack-seal quartz veins contain up to 85,000 ppb Au.

Moore (1977) concluded that the gold was concentrated first in the iron formation by exhalative processes, then remobilized during metamorphism into the quartz veins along with arsenic and bismuth. Our geochemical data are not adequate to test this conclusion. However we do show some variations related to lithology (Lustwerk, 1992, this volume).

The grey quartz veins have irregular crack-seal textures. The veins and their associated pyrite and pyrrhotite are inferred to have formed during the early stages of D2 or earlier, because they outline some F2 folds and the pyrite and pyrrhotite are deformed. Disseminated coarse-grained arsenopyrite, which is on the margins of many veins, is relatively undeformed, suggesting that arsenic was mobilized after D2. The inconsistent relationship between arsenopyrite and quartz veins is poorly understood and needs more documentation.

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GEOCHEMISTRY AND PETROGRAPHY OF IRON FORMATION AND OTHER SEDIMENTARY ROCKS ASSOCIATED WITH THE BACK RIVER VOLCANIC AND SEDIMENTARY COMPLEX, NWT

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Objectives

The original goal of this study was to determine the geochemical factors which contributed to the concentration of gold in iron formation of the Back River volcanic and sedimentary complex. This goal was modified considerably when analyses of available samples from the Back River complex failed to yield any gold concentration greater than 220 ppb. The secondary goals of the study, which then came to the fore, were the geochemical and mineralogical characterization of the sedimentary units of the Back River complex. Three sedimentary sequences containing iron formation are present in the vicinity of the Back River complex (Jefferson et al., 1989). The major emphasis of this study is iron formation closely associated with the volcanic rocks of the complex (Sequences A and B); only perfunctory observations were made of the iron formation in Sequence C which is contained in turbidites overlying the volcanic pile. Geological background and setting are provided in Lambert et al. (1990) and Jefferson et al. (1989). Place names given below are shown in figure 1 of Jefferson, Lustwerk and Lambert (this volume).

Method

This project utilized field observation and mapping, examination of hand samples and thin and polished thin sections, electron microprobe analysis at the Geological Survey of Canada in Ottawa, and chemical analysis performed by X-ray Assay Labs. Data for 12 major elements, 28 trace elements and 14 rare earth elements were collected on 150 core and hand samples comprising various volcanic rocks, carbonate-cemented volcaniclastics, shales, sandstones, slates, banded iron formation, massive sulphide and grey quartz veins. Elemental distribution and abundance patterns have been graphically evaluated for all units. The preparation of mineral separates for isotopic determination in the laboratory of B. Taylor at the Geological Survey of Canada is still in progress. The study would benefit from additional microprobe analysis.

Results

Sequence A is lithologically varied, discontinuous and bounded on both sides by volcanic rocks. It has been traced along a circular belt within the complex, informally termed the inner ring. The individual units are very heterogeneous.

The most common lithology of Sequence A is calcite-cemented volcaniclastic rock. Clast size of the volcaniclastic debris ranges from boulders to fine sand; the percentage of debris ranges from nearly 100% to less than 30%, the latter in a unit of impure limestone. Locally, some of the clasts have a very high pyrite content with accompanying elevated As, Bi, Co, Sb and Se. These trace-element concentrations are, however, depleted with respect to their concentrations in average pyrites. Cu and Zn concentrations are also notably low. Gold assays are all less than 50 ppb. With the exception of the pyrite clasts, no unusual elemental concentrations were noted in this unit.

The thickest exposure of Sequence A is in the vicinity of Innerring Lake. Here, siltstone, sandstone, black slate and iron formation are the principle rock types. Both the siltstones and the sandstones display considerable mineralogical and chemical variation due to the varying compositions of the locally contributed volcaniclastic debris. Carbonate cement is an important component in 10% of the clastic rocks analyzed from the Innerring Lake area.

Variably iron-enriched chert to banded magnetite-chert iron formation with uncommon accessory carbonate were noted at only two localities in Sequence A, both in the Innerring Lake area. Most of the samples are chert-rich with a range of iron content from 0.96% Fe_2O_3 to 62.3% Fe_2O_3; SiO_2 ranges from 32.0% to 94.5%. There is no volcaniclastic contamination evident in the samples analyzed from this iron formation.

Sequence B, in contrast to A, is:

1) underlain by volcanic rocks and overlain by greywackes;

2) continuous, with a generally predictable order of units from bottom to top (Jefferson et al., 1989); and

3) contains more homogeneous clastic units.

The units, from bottom to top, are: volcaniclastic units associated with the volcanic pile, carbonate-cemented volcaniclastic regolith and debris, banded magnetite-chert iron formation, an intermittent sulphidic volcaniclastic unit, and pyritic slate. Sequence B is overlain by greywacke of the Beechey Lake Group.

There is considerable local variation in mineralogy and chemical composition of the carbonate-cemented debris, due to the differing clast compositions and the varying proportion of detritus. The carbonate mineralogy also varies: dolomite and more rarely, siderite, complement the dominant calcite. Petrography of this unit indicates that some carbonate minerals (proportions of carbonate mineralogy not yet determined) replace earlier silicate minerals. Local high concentrations of Cr and Ni in this unit suggest the presence of an unusual carbonated mafic rock, possibly a lamprophyre; some basalts within Sequence B also share this characteristic.

Iron formation in Sequence B is dominantly banded magnetite-chert, with subordinate quantities of hematite-jasper and carbonate-chert varieties. Sulphide- and silicate-bearing cherty iron formation are also present, but the original mineralogy appears to have been magnetite and quartz for the siliceous iron formation; and quartz and either magnetite or siderite for the sulphidic iron formation. The carbonate is an impure siderite with up to 27% magnesite component and 10% rhodochrosite component. Pyrrhotite is a minor, but relatively early phase whose exact paragenesis is still uncertain. Pyrite has not been observed as a primary phase in iron formation in the Back River complex; rather it replaces carbonate, amphibole, pyrrhotite and rarely, magnetite. Grunerite with interlocking texture (metamorphic) clearly replaces both magnetite and quartz in samples from several localities.

The major element chemistry of the iron formation in Sequence B appears to be well within the norm of both Archean and Proterozoic iron formation from around the world (Dymek and Klein, 1988; Gole and Klein, 1981; Gross and Mcleod, 1980). Some samples of iron formation contain unusual levels of Mn (near the reported maximum in Gole and Klein, 1981) not related to the present carbonate concentration. In addition, this iron formation displays elevated levels of Be, Bi and Nb. Most other trace and rare earth elements are present in concentrations similar to those of the surrounding host rocks or below the detection limits of the methods utilized.

The banded magnetite-chert iron formation shows very little contamination by clastic material with only 3 out of 21 samples containing >0.06 % TiO_2 and >1.5 % Al_2O_3. This is at least partly due to the fact that iron formation is generally defined so as to exclude contaminated rocks. There is considerable evidence however, that chemical sedimentation similar, if not identical, to that which produced the banded oxide-rich iron formation was active during the deposition of the volcaniclastic unit underlying the carbonate-cemented debris, as well as during the deposition of the overlying pyritic slates. Magnetite-rich layers are present in the volcaniclastic unit, and magnetite-chert iron formation is intimately interbedded with black pyritic slate in at least one location.

Black, variably pyritic and variably siliceous slates gradationally overlie the magnetite iron formation. A thin unit of coarser clastic rock commonly intervenes between the two but no analyses of this unit are available. The pyritic slate is one of the most internally consistent units in the complex and represents a mixture of volcanically-derived material (clay component), chert and/or quartz, pyrite, and organic carbon. The proportions of these components vary considerably between samples, but these appear to be essentially the only four components. The pyrite from sites around and northeast of Eastring Lake forms centimetre-thick nodules and disseminated laminae of clearly diagenetic origin. The highest gold values recorded in this study (230 ppb) were from the pyritic black slates. Other trace elements correlated with the pyrite are Ag, Be, Co and Sb. Trace elements related to the clay (altered volcanic?) component are Si, Al, K and Rb.

Chemical analyses of the greywacke which overlies Sequence B and subsequent graphical analysis indicate considerable dilution of a complex matrix with quartz. The unit is less heterogeneous than the sandstones of Sequence A, but still cannot be characterized as a congruent statistical population. Trace element concentrations are unremarkable.

Grey quartz veins are rare in Sequence A but cross-cut Sequence B at all levels, and are most abundant in its iron formation and pyritic slate. Grey quartz veins are more prevalent on the east and south side of the complex, with very few observed elsewhere. The highest Au values reported by Moore (1977) are in such quartz veins, particularly those in the vicinity of Eastring Lake, where variably abundant pyrite and/or arsenopyrite sulphides are in the veins and/or immediate host rocks to the veins. This study was unable to obtain sufficient sample material to test Moore's findings. Quartz vein remnants in available drill core were too few and too small for adequate Au analysis. Gold is correlated with elevated Fe, Ag, Ba, Cd, Co, Cu, Mo and Ni in the 12 samples of veins which were analyzed.

Metamorphism in the complex ranges from lower greenschist in the areas around Innerring, Rusty, Outerring and Eastring lakes, to amphibolite grade to the west and south. Staurolite and cordierite are present in metagreywacke turbidites at the southern end of Jim Magrum Lake. Spessartine occurs with hornblende, biotite and an as yet uncharacterized radiating amphibole, in a local metamorphic aureole on the southeastern side of the complex in the volcaniclastic unit underlying carbonate-sedimented debris. Grunerite has been identified in thin sections of iron formation taken from the northeastern portion of the complex where the metamorphic grade is considerably lower. Carbonate grit immediately underlying the iron formation and turbidites in the immediate vicinity, however, do not show amphibolite grade metamorphism. The implication of these observations is that grunerite may be stable at lower temperatures than previously thought. Despite temperature ranges given for grunerite in the literature, the experimental work in this system has concentrated on the high temperature transition to quartz-magnetite and little work has been done on the location of the low temperature stability boundary (Gilbert et al., 1982)

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GEOLOGY OF THE ARCHEAN HOOD RIVER BELT, NORTHEASTERN SLAVE STRUCTURAL PROVINCE, DISTRICT OF MACKENZIE (NTS 76K, N), NWT

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Objectives

The purpose of this study has been to map the Hood River supracrustal belt (HRB) south of James River (Fig. 1), and to improve our understanding of the various known gold occurrences therein. This work included mapping on 1:10,000 to 20,000 colour aerial photographs and more detailed mapping, core logging and sampling of gold occurrences in this belt.

Methods

Field studies began in 1987 (Roscoe et al., 1988), continued through 1988 and 1989 (Jefferson et al., 1989a, b, 1990a, b, c; Penny, 1990) and were completed in 1990 (Henderson, 1990; Henderson et al., 1991a, b; Schaan, 1990; Schaan et al., 1991). Through the course of this work responsibilities evolved as follows: mapping, structural synthesis and compilation of the entire belt by Henderson, Henderson and Wright; mapping of the Turner Lake gold showing and surroundings by Schaan (MSc student, University of Ottawa) and Jefferson; and mapping of the Pistol Lake gold showing and surroundings by Wyllie (MSc student University of New Brunswick). This mapping has been conducted in parallel and integrated with studies in the Torp Lake domain, the extension of HRB north of James River (Johnstone, this volume). Sampling for geochronological work by O. van Breemen covered the two map regions.

At the request of GSC, detailed aeromagnetic data on tape were released to Dighem by Silver Hart Mines Limited, purchased by the project and reprocessed by J. Broome (GSC) at 1:50 000 scale. Silver Hart also released colour air photographs to Northwest Geomatics Ltd. for purchase by this project. In 1989 Chevron Minerals (G. Walton and S. Fumerton) shared logistical support, geological observations, and provided access to both drill core and company reports of gold showings. Canada Centre for Remote Sensing (A. Fabbri and C. Kushigbor) provided undistorted 1:10,000 and 1:20,000-scale SPOT and SAR images for base maps. R. Stone and L. Parney provided expediting services.

Helicopter support was obtained from Polar Continental Shelf Project and coordinated with W.A. Padgham. Northern studies grants were provided to S. Schaan and R. Wyllie from the universities of Ottawa and New Brunswick respectively, and NSERC grants to their respective supervisors, W.K. Fyson and P.F. Williams. Northern Affairs Program supported S. Schaan and assistants as COSEP students in 1989 and 1990. Chevron Minerals provided summer employment to R.W. Wyllie in 1989. T.O. Wright's travel and research costs were provided by the U.S. National Science Foundation. J.R. Henderson was seconded to the project by Continental Geoscience Division. This report was critically reviewed by W.A. Padgham.

Results

The Archean Hood River belt (HRB) is overlain unconformably to the east and south by the early Proterozoic Goulburn Group, intruded on the west by Archean monzogranite, and truncated on the northeast by the Proterozoic Bathurst Fault (Fig. 1). The HRB extends across the James River, and is continuous with the Torp Lake Belt to the northwest (Johnstone, this volume)

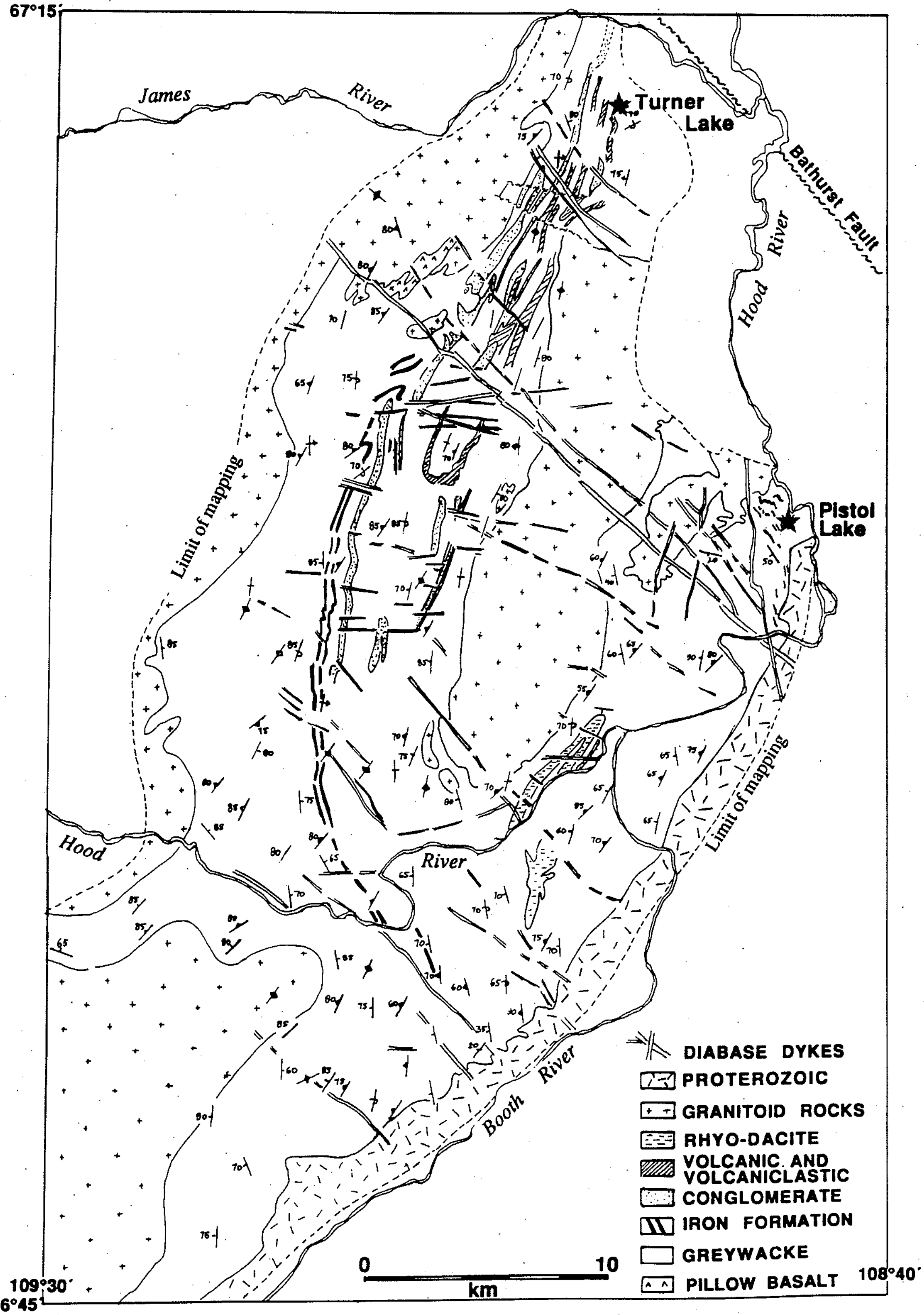

Figure 1. Geological sketch of the area mapped in the Hood River Belt. The Pistol Lake and Turner Lake gold prospects are indicated by stars.

The HRB is not to be confused with the supracrustal belt located at the headwaters of the Hood River, beside Takijuq Lake, that has long been called the Hood River volcanic belt by industry geologists and geologists of Indian and Northern Affairs Canada (e.g. Seaton, 1989, p. 12 and 14, No 16; Atkinson et al., 1989, p. 12). That volcanic belt, which contains the Hood claims, may now be referred to as the Takijuq Belt (V. Jackson, personal communication, 1991).

The HRB comprises an overall easterly younging, vertical to steeply overturned homoclinal supracrustal sequence. From bottom to top the preserved sequence is as follows:

1) A remnant of pillowed mafic volcanic rocks is separated on the east and southeast by thin, gossanous, sulphidic and magnetitic iron formation from overlying turbidites.

2) A lower sequence of turbidites includes both massive silty metagreywackes (beds 10-300 cm thick, separated by minor pelites) and alternating graded metagreywackes and laminated pelites each 2-10 cm thick.

3) Two continuous bands of mixed oxide-silicate-sulphide iron formation are traceable on aeromagnetic maps. Also present in this stratigraphic interval are discontinuous sulphidic iron formation, local mafic sills, and local felsic to mafic tuffs.

4) The polymict James Falls Conglomerate (Roscoe et al., 1988) unconformably overlies units 2 and 3. Clast size ranges from granule to boulder (> 1 m). Rock types include variably abundant felsic volcanic rocks, diorite, greywacke and locally abundant iron formation. These appear to be of local derivation and it is unlikely that any of the clasts represent basement to HRB. The James Falls Conglomerate is 170 m thick at the falls on James River (Jefferson et al., 1990c, Fig. 9); it extends more than 4 km north of James River and is mapped with some discontinuities for about 36 km south along the western margin of the central arenite-volcanic sequence (unit 5).

5) Metavolcanic, volcaniclastic, hypabyssal, and intercalated metasedimentary rocks are most abundant in the area near Turner Lake and pinch out to the south and north.

   5a) Nearly all conglomerates are volcanic-clast dominated. In places the conglomerates are relatively thin monomict volcanic breccias of felsic to mafic composition, overlain directly by turbidites. Rusty weathering arenites are mainly planar laminated. Cross beds are common in the central part of the intercalated belt. An emergent to relatively shallow water depositional environment, transitional to a turbidite basin, is inferred for this assemblage of sedimentary rocks.

   5b) Igneous rocks within unit 5 range in composition from rare ultramafic through magnesium-rich basalt to rhyolite. Volcanic features include tabular flows and monomict breccias. Volcaniclastic rocks commonly are monomict, laminated and locally cross bedded. Gabbro, medium- to fine-grained diorite and some felsic rocks form tabular to anastamosing peneconcordant sheets and lenses. The volcanic rocks are interpreted to have formed emergent edifices which provided sources for the conglomerates. Most of the intrusive rocks contain the same fabric elements as the arenites and tuffs, hence are interpreted as contemporaneous.

6) Argillaceous greywackes directly overlie the eastern margin of the central volcanic belt. Thin silicate-sulphide iron formation beds are present near Turner Lake. Several cherty iron formations of mixed oxide-silicate-sulphide facies are interbedded with greywacke at Pistol Lake. G. Walton (personal communication, 1989) has recognized tuffs near these iron formations.

7) Rhyodacite sills in thick-bedded turbidites outline a southwest-plunging isoclinal syncline north of Hood River; a more irregular body of the same composition lies south of Hood River (Fig. 1).

8) A variety of granitoid and mafic rocks intrude the above strata. The Pistol Lake Batholith is a central cluster of large to small, northerly elongate, plutons, stocks and sills with associated pegmatite. These bodies are variably deformed, foliated and probably late syn- to post-kinematic. Compositions range from monzogranite to granodiorite. A biotite-muscovite monzogranite marks the western margin of HRB from near Bathurst

Fault south to Hood River. Satellite bodies and related east-west aplitic to pegmatitic dykes intrude the western side of HRB. Various other pegmatite sheets in the Turner Lake area are irregular, gently to steeply dipping, variably deformed bodies with both tourmaline-defined layering and massive textures as exposed at James River Falls and near the Turner Lake gold prospect.

9) The Archean rocks were intruded by the 2023 Ma mafic-ultramafic-felsic Booth River Igneous Complex (Roscoe et al., 1987) before deposition of the Goulburn Group. The base of the latter is intruded by a laterally extensive gabbro sill.

10) At least three and possibly four diabase dyke swarms intrude the Archean rocks. The oldest are east-west diabase dykes with plagioclase megacrysts. They are tentatively assigned a Late Archean age of 2692 Ma (Rb-Sr mineral and whole-rock isochrons, Gates and Hurley, 1973). The MacKenzie dyke swarm is Proterozoic, with a baddeleyite U-Pb age of 1270 Ma (LeCheminant and Heaman, 1989). The youngest dyke is a northerly trending Franklin diabase which intrudes the east side of HRB and transects the basal Goulburn Group sill south of Pistol Lake.

The oldest structures are macroscopic slump folds observed below the James Falls Conglomerate. The supracrustal succession generally faces east, beds dipping vertically to steeply west. The main cleavage is vertical and strikes on average 250 clockwise relative to bedding throughout the entire belt. S1 is axial planar to local S-folds. Most later folds are locally developed and low in amplitude with shallow plunges.

Andalusite-cordierite grade metamorphism is uniform across the belt, both across section/strike and along structural plunge, implying that eastward homoclinal tilting took place before porphyroblastesis. Through most of the southern part of the belt S1 cleavage fabrics are absent within cordierite and andalusite porphyroblasts. Toward Turner Lake in the north, aligned micas are included in cordierites and the cordierites are elongate along the S1 cleavage. The uniform clockwise attitude of cleavage relative to bedding is interpreted to indicate sinistral transpression near the end of peak metamorphism.

The Turner Lake main gold prospect is on the north limb of a macroscopic, vertically plunging, eastward-closing, late fold in unit 5. The fold dies out gradually in unit 6 turbidites to the east, but is terminated abruptly to the west by an intensely foliated and quartz-veined zone trending approximately 020°. Trenches and drill holes have explored an amphibole-rich clastic rock of probable volcanic parentage. Gold is visible in transecting quartz veins and is disseminated in the host rock.

At Pistol Lake gold concentrations are hosted by iron formations that are stratigraphically separate from those near Fish-hook Lake, about 15 km to the west. The main showing is in the east limb of a faulted S-fold that is truncated to the north by the Pistol Lake pluton. The gold mineralization is structurally and compositionally controlled.

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STRATIGRAPHY AND SEDIMENTOLOGY OF AURIFEROUS ARCHEAN IRON FORMATIONS IN THE VICINITY OF GEORGE LAKE, EASTERN SLAVE PROVINCE

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Background and Objectives

George Lake is north of Back River, about 515 km northeast of Yellowknife and 175 km east of the Lupin gold mine (Fig. 1). Archean iron formations in this area are the focus of gold exploration by the George Lake and Back River joint ventures as described by Johnston and Olson (1984), Olson (1989, 1990) and Chandler and Holmberg (1990). The goal of the project reported here was to study the sedimentology, stratigraphy and structural geology of the iron formations at George Lake to establish local controls on gold distribution, to provide a framework for geochronological sampling (van Breemen et al., 1992, this volume; Jefferson et al., 1991) and for comparison with gold prospects in the Back River volcanic complex (Jefferson et al., 1992a, this volume) and Hood River Belt (Jefferson et al., 1992b, this volume).

Method

R.K. Johnston did the initial mapping and definition of basic lithologic units in 1983, at Locale 1 (Johnston and Olson, 1984). Continued field work by R.K. Johnston and numerous other TWOCL3 employees produced the 1:10,000-scale structural and stratigraphic maps from which this study proceeded. These maps were used as a guide to measuring reconnaissance and detailed stratigraphic sections through the iron formations. Iron formations were also investigated along strike, and specific structural-stratigraphic problems were investigated at the request of the joint venture. Primary iron formation features were documented in case they might have some relationship to the structurally controlled gold distribution. R. Rice was employed by the joint venture for two weeks in 1990 to sedimentologically document specific parts of the iron formations near potential ore zones, both in the field and petrographically.

This study was supported by both on-going GSC funding and the NWT MDA. J. Seaton (Department of Indian Affairs and Northern Development) shared logistics and observations in 1989. Polar Continental Shelf Project provided helicopter support in 1988. Expediting to GSC was provided by Rod Stone and Lynn Parney. This report benefitted from critical review by L.B. Aspler.

Results

The iron formations at George Lake are within the Beechey Lake Group which here comprises turbidites, mudrocks, granulestones and rare lapilli tuffs (Fig. 2). The turbidites and iron formation are obliquely intruded by lenticular bodies of aphanitic to quartz-feldspar-porphyritic rhyolite/dacite which are fractured and pyritic. The age of the iron formations has been constrained to 2683 $\pm$ 2 Ma by van Breemen et al. (this volume).

The rocks are at greenschist to lower amphibolite metamorphic grade. The deformed iron formations outline a belt that is about 3 km wide and extends tens of kilometres from northwest to southeast, covered in part on the northeast by the Proterozoic Goulburn Group. Isoclinal folds defined by iron formation trend northwest and have shallowly plunging (both northwest and southeast) hinges. The transecting main cleavage strikes on average, 25° clockwise relative to bedding and is crenulated by a second cleavage, 25° counterclockwise to bedding. High strain zones are sub-parallel and oblique to fold trends. Prominent quartz veins transect iron formations, Archean dykes and thick coarse-grained turbidite beds both vertically (east-west) and sub-horizontally.

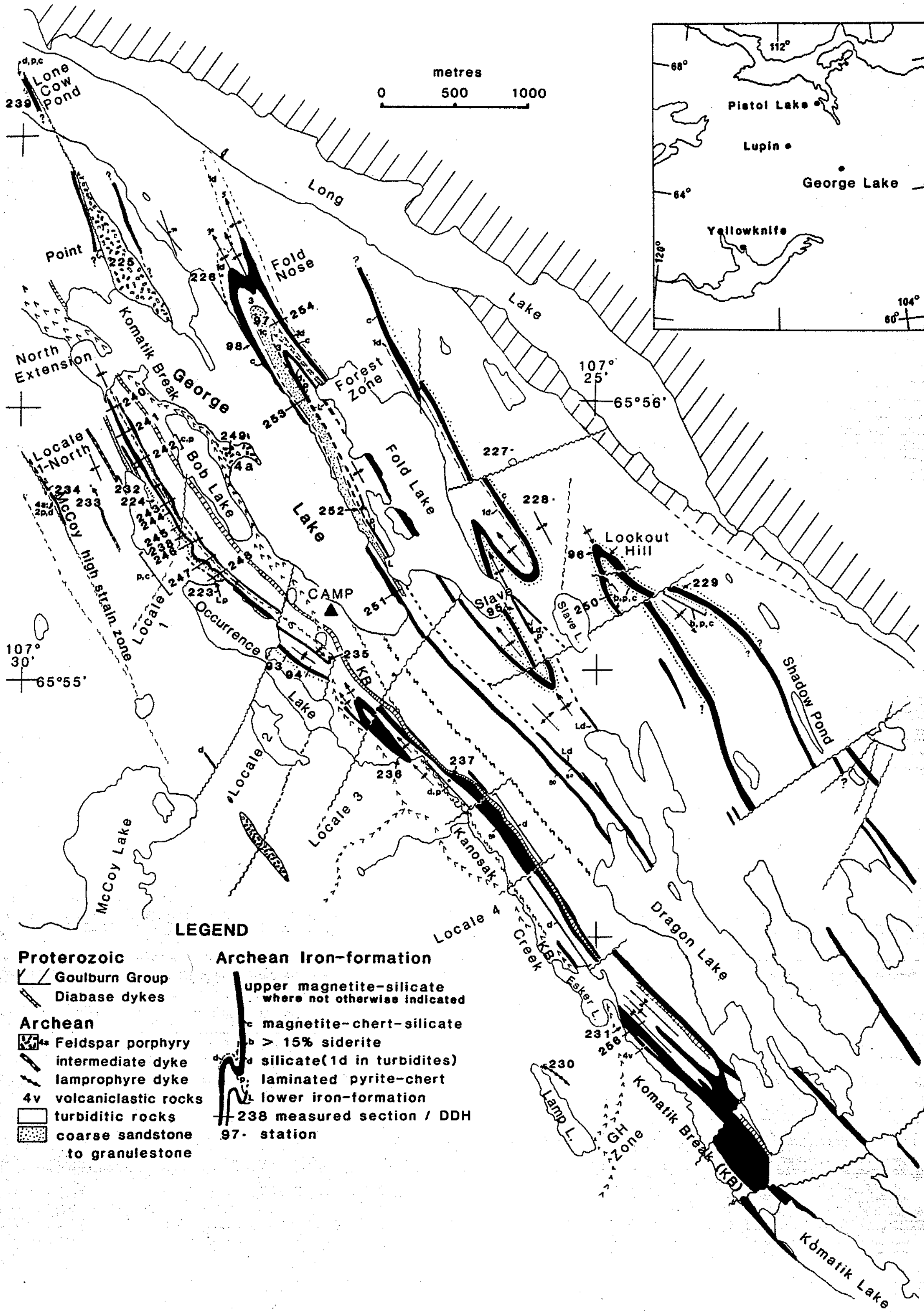

Figure 1. Sketch map of the iron formation and adjacent rocks around George Lake, showing distribution of selected sedimentary facies, and sections and stations examined by C.W. Jefferson and others in 1988 and 1989. Iron formation extends beyond the map area to the northwest and southeast. Geology is after internal reports by Trigg, Wollett, Olson Consulting Limited; base is form uncorrected Territorial Resource Photomosaic (NTS 76 G/14) from Indian and Northern Affairs Canada.

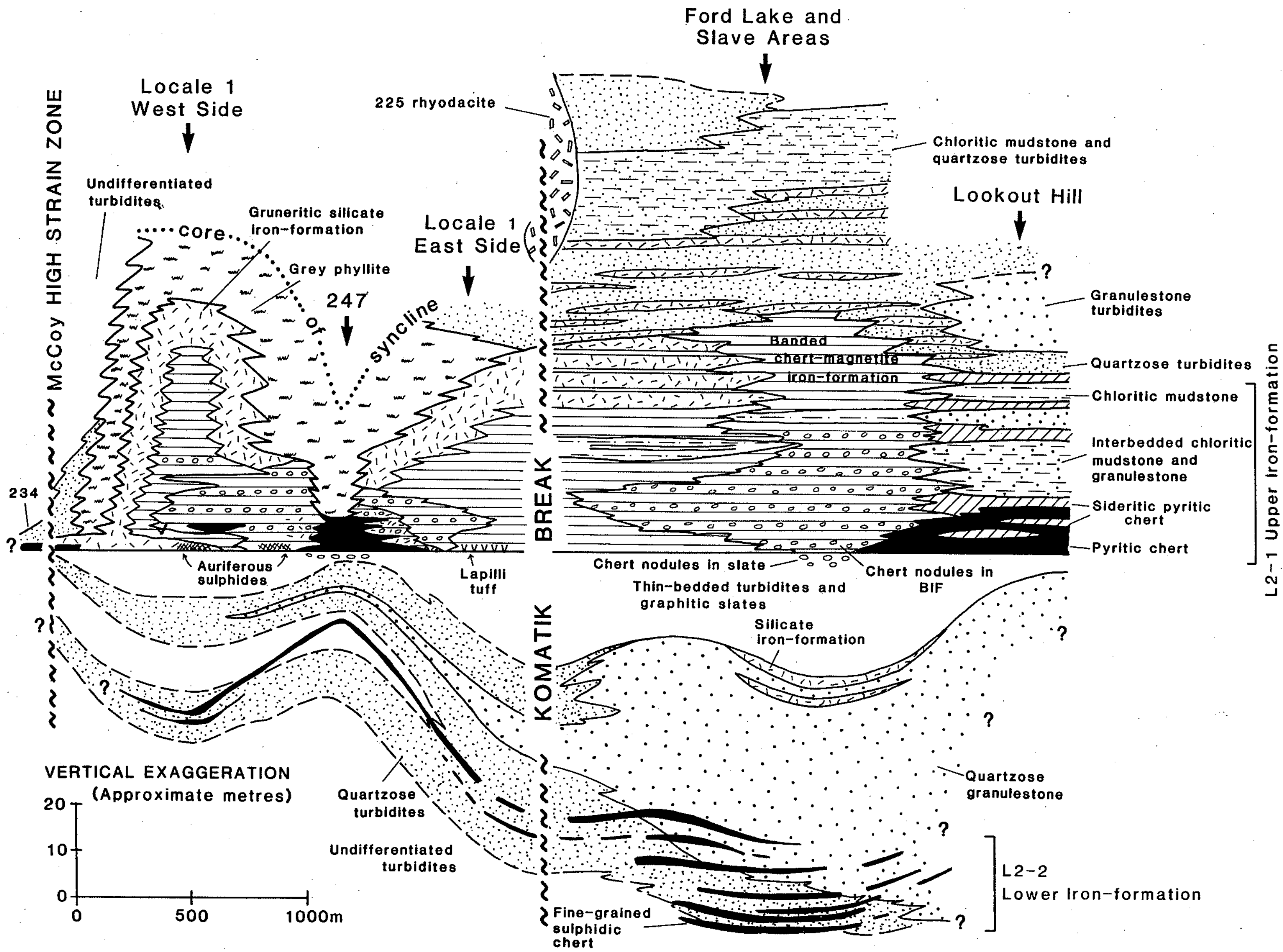

Figure 2. Generalized and inferred east-west facies relationships in the George Lake area, based on selectively arranged measured sections. This is a diagrammatic pre-deformation cross-section from Lookout Hill to Locale 1 North (Fig. 1), with some NW-SE facies changes from Locale 1 included for illustrative purposes. Most symbols are explained on Figure 1; combined symbols indicate mixed facies. Note vertical exaggeration in the order of 250:1

Two stratigraphically distinct iron formations have been defined. The lower iron formation unit (L2-2) comprises a number of thin (centimetres to 1 metre in thickness), discontinuous and lean pyrite-chert and silicate iron formation beds intercalated with variably bedded (2 cm to 2 m) quartzose arenite and granulestone turbidites (grits), and graphitic slates. The grits containing L2-2 are stratigraphically underlain by relatively uniform greywacke turbidites (10-50 cm), and overlain by graphitic-chloritic slates, phyllites, and thin-bedded (<10 cm) turbidites.

The upper, relatively thick (maximum 50-80 m) iron formation (L2-1) relatively abruptly overlies the graphitic, thin-bedded unit and has few, local clastic interbeds in its lower part. At the GH zone (Fig. 1) the base of the L2-1 iron formation contains thin intercalations of intermediate lapilli tuff. L2-1 is characterized by laminated chert-magnetite and thin-bedded silicate facies of iron formation. L2-1 includes local zones of fine-grained, finely laminated pyritic chert and sideritic chert. The upper part of L2-1 has a greater proportion of silicate facies and its upper boundary is gradationally intercalated with turbidites in the eastern part of the belt.

The George Lake iron formation belt is located at an overall east-west clastic facies change paralleled by overall changes in iron formation thickness and facies. Coarse quartzose clastic rocks dominate to the east where they enclose and are intercalated with siderite-pyrite-chert facies of L2-1 and silicate-sulphide facies of L2-2. Iron formations on the east are relatively thick, L2-2 occurring over a stratigraphic interval of 20 metres or more and L2-1 70 metres or more. Toward the west, the coarse clastic rocks are thinner and restricted to the interval between L2-2 and L2-1. A phyllitic slate caps L2-1 in the western syncline. In the west, L2-2 is correspondingly very thin and L2-1 is a maximum of 50 metres.

Relatively detailed lateral facies changes in both L2-1 and L2-2 are also partly coincident with those in enclosing clastic strata. For example, both L2-1 and L2-2 change thickness from east to west and from north to south in concert with the immediately underlying thin-bedded turbidite unit. The fine-grained pyrite-chert facies tends to occur in relatively thin parts of L2-1.

A syn-sedimentary exhalative to diagenetic origin is favoured for those facies characterized by:

1) relatively fine grain size and thinness of laminations in less deformed parts of the belt;

2) thin interbedding of the different facies;

3) changes in chemical facies of iron formation concomitant with clastic facies changes as described above;

4) concomitant variations in abundance and types of chert nodules (commonly septarian) related to chemical facies of iron formation; and

5) independence of the above features with respect to obvious cross-cutting structures such as quartz veins with arsenopyrite-chlorite-pyrite alteration halos.

The above facies associations and lateral changes have been overprinted and perhaps mimicked in places by deformation and metamorphic processes. Present data show no obvious correlation between sedimentary-diagenetic facies and gold content of the iron formation, however detailed documentation of the various sedimentary and diagenetic facies, and comparison of these with patterns of structure, alteration and the distribution of known structurally controlled gold, may aid in further exploration.

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PRECISE 2683 Ma AGE OF TURBIDITE-HOSTED AURIFEROUS IRON FORMATIONS IN THE VICINITY OF GEORGE LAKE, EASTERN SLAVE STRUCTURAL PROVINCE, NWT

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Objective

Turbiditic rocks in the George Lake area contain two stratigraphically distinct auriferous iron formations, and are cut by lenticular bodies of quartz-feldspar phyric rhyolite-dacite (Jefferson et al., 1992). The purpose of this study was to establish the minimum age of the turbidites by dating zircons from the intrusions, and the maximum age of the turbidites (and of source rocks) by dating single detrital zircons from a granulestone interbed.

Method

Seven individual detrital zircons from the grit, and three groups of zircons from the rhyolite, were dated by the U-Pb method. U-Pb analyses are all on single abraded grains of zircon and follow the techniques as detailed in Parrish et al. (1987).

Results

Detrital zircons from the granulestone are stubby, light brown and clear. Zoning, where evident, is

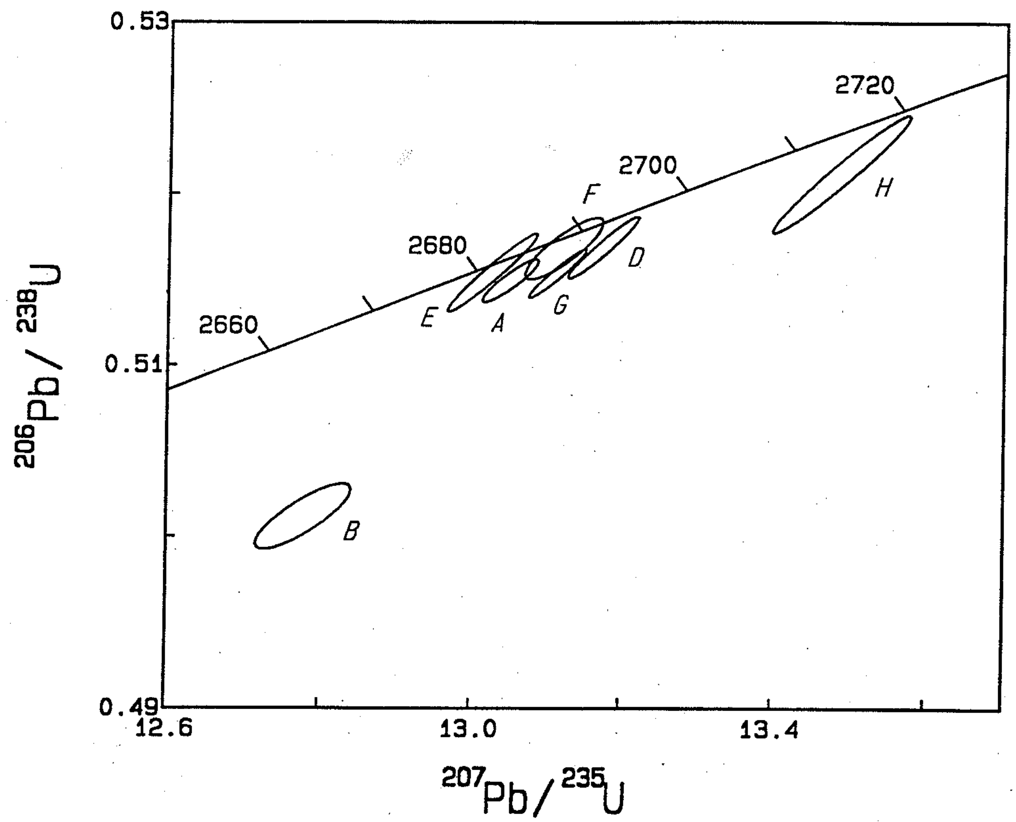

Figure 1. Isotopic ratio plot for granulestone which underlies iron-formation in the vicinity of George Lake.

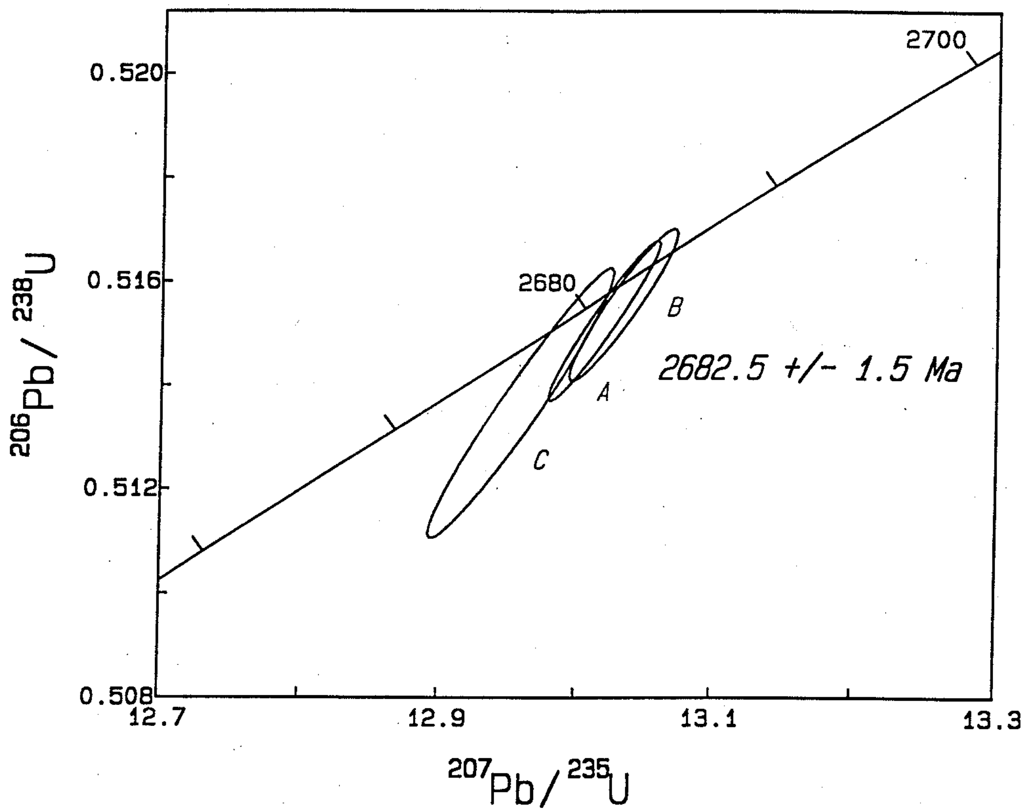

Figure 2. Isotopic ratio plot for rhyolite which intrudes turbidites and iron-formation in the vicinity of George Lake.

regular and indicates an igneous origin. The seven crystals analyzed have U concentrations ranging from 34 to 137 ppm. Five data points are concordant to slightly discordant with a range of $^{207}Pb/^{206}Pb$ ages from 2683 Ma to 2697 Ma. A somewhat more discordant (3.8 per cent) point yields a Pb/Pb age of 2698 Ma. The only outlier, an almost concordant data point, yields a Pb/Pb age of 2722 Ma (Fig. 1).

Zircons from the rhyolite/dacite are generally prismatic and clear. Fractures are common. U concentrations for the three zircon crystals analyzed are low; 25-46 ppm. Data points are concordant, have overlapping uncertainties and provide a precise age of 2682.5 $\pm$ 1.5 Ma (Fig. 2).

Rare tuffs and breccias intercalated with the iron formation indicate minor volcanism coeval with the exhalative activity that formed the iron formation. This inference is strengthened by the closeness in age of the rhyolite bodies that intrude the turbidites, and detrital zircons from the granulestone.

A proximal volcanic source area for the granulestone is suggested by coarse grit-sized fragments of quartz and feldspar, resorption embayments in quartz grains, and the closeness in age of the detrital zircon fractions (i.e minimal admixture from diverse source terranes). Eastward thickening of the granulestone suggests that volcanic edifices were to the east.

The George Lake iron formations are similar in mineralogy and stratigraphic setting to the Sequence C iron formations which are distal to but fringing the Back River volcanic complex (Jefferson, Lustwerk and Lambert, this volume). The 2683 Ma date reported here is compatible with an age difference of about 10 Ma between Sequence C and the main Back River Volcanic Complex (2692 $\pm$ 2 Ma, van Breemen et al. 1987) and Hackett River Volcanic Belt (2687-2696 Ma on Yava, 2689.3 +2.4 /-1.8 Ma on Musk, Mortensen et al., 1988).

Acknowledgments
This report is keyed to stratigraphic work reported by Jefferson et al., (1992), in this volume, and shares their acknowledgments. Critical review was by L.B. Aspler.

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1987: U-Pb, zircon and monazite ages from the eastern Slave Province, Healy Lake area, N.W.T.; in Radiogenic Age and Isotopic Studies: Report 1, Geological Survey of Canada, Paper 87-2, p. 101-110.

B. NORTHERN TECHNOLOGY ASSISTANCE PROGRAM

PROJECTS SUPERVISED BY THE CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY (CANMET)

POST PILLAR EXTRACTION, NANISIVIK MINE

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Objectives

The first objective of the project was to review and identify relevant information for the economic and safe recovery of post pillars in permafrost terrain and then to produce guidelines for mine planning. The second and most important objective was to assess ground behaviours and overall ground stability with various pillar extraction options, and to provide related guidelines for strategic mine planning. Project results are documented in Clarke (1990).

The basis of the review of relevant information is listed below:

1) Define a mining method to achieve a maximum recovery of high post pillars with safety and efficiency, addressing:
   - access
   - services (compressed air, ventilation)
   - drill patterns
   - explosive types, detonators, and sequencing
   - mucking procedures
   - sequencing
   - ground support
   - securing mined out areas from inadvertent access.

2) Define the equipment and manpower necessary to safely drill, blast, and muck the pillars, by reviewing:

   - equipment alternatives
   - remote control equipment required.

3) Define conditions and procedures under which pillars should or should not be mined.

4) Define the rock mechanics monitoring equipment required during the removal of the pillars.

An extensive literature survey was carried out. Five technical databases were consulted. These included: Mining Technology (MINTEC), Engineering Index (EI), Georef, National Technical Information Services (NTIS) and Soviet Science and Technology databases. The results of the study are summarized as follows:

1) Very little information exists on mining practices in frozen rock and hardly any deal with methods of pillar recovery under permafrost conditions.

2) Heat balance in frozen rock should be maintained. Ice content of the rock should be known if warming effects are to be evaluated. It takes very little latent heat to thaw a rock with 3% (by weight) pore ice. The nature of the infilling will determine the ground problems associated with warming effects, e.g. weak carbonates will disintegrate and crumble with thawing. Temperature sensors, thermistors/thermocouples are used to monitor soil or rock temperature.

3) The literature surveyed lacks information on pillar recovery effects on roof control, and lacks cases in which very wide room spans have been encountered.

4) Subjects of potential interest to the objectives of the Nanisivik pillar recovery project are lacking in published information. These are listed as follows:

   - drilling patterns
   - application of explosive technology
   - mucking procedures
   - mining equipment alternative
   - rock mass characterization
   - numerical modelling
   - pillar sequencing
   - geomechanical monitoring instrumentation.

5) References were obtained for controlled blasting practices.

The second part of the project, designed to develop strategies for the safe productive extension of the mine's life, was divided into two phases:

Phase 1: Ground control instrumentation and stress determination.

To assess the present and future ground

behaviours during pillar recovery. This involves the following elements:

- TV borehole inspections
- dilatometer tests
- ground stress determinations
- ground movement monitoring
- determination of the mechanical properties of mine rocks

Phase 2: Ground stability evaluation.

To evaluate overall ground stability, using an appropriate state-of-the-art computer simulation technique. This involves the following investigations:

- crown pillar stability
- sill pillar stability
- pillar mining sequences
- stope stability

Results

Phase 1: Ground control instrumentation and stress determination

1) The host rock is strong and massive. Inspection of roof strata up to 6.6 m above the roof line indicated sound roof conditions except for minor blast damage close to the roof line and some minor fracturing near the portal.

2) Ground stress determinations in the dolomite of the south abutment showed the maximum stress is oriented northeast-southwest in the horizontal plane with an average magnitude of 4.5 MPa. The maximum ratio of horizontal to vertical stress is 3.2:1. The magnitude of the vertical stress is equivalent to overburden stress.

3) Dolomite and sulphide behaved elastically. The mechanical properties of mine rocks are presented in the final report.

4) Ground movement monitors and strain rings were installed in the proposed test site. These rock mechanics equipment will be monitored throughout the pillar extraction processes.

Phase 2: Ground stability evaluation.

1) The study of strategic post-pillar extraction indicates that ground failure should not be a significant factor. On the basis of rock mechanics and ground control considerations, the complete removal of post-pillars without backfill should be feasible.

2) The crown pillar is considered stable. Engineering equations are provided as a guide to achieve ground control and provide necessary ground support in its design.

3) The sill pillar between the main ore zone and the lower lens is considered to be stable. However, ground conditions and major discontinuities should be carefully observed and evaluated for stability problems.

4) When the thickness of the north abutment is less than twice the stope width, the best pillar mining sequence is the following: mine the south side pillar first, then the north side pillar and the central pillar last.

5) When the thickness of an abutment is greater than twice the stope width, the best pillar mining sequence is the following: mine the central pillar first followed by the north or south pillar. Due to symmetry of mine structures the study does not indicate an order of preference.

6) From the point of view of access and ground control, post pillar extraction should be started from the extreme east end of the main ore zone and retreat towards the west.

7) Careful blasting procedures should be used near the tops of pillars to minimize roof damage and to maintain ground stability. Pre-splitting techniques are suggested. Pre-splitting near the roof line may be difficult especially in the case of high pillars (about 20 m), and some consideration should be given to the use of the Alimak drilling technique.

8) In the eastern portion of the main ore zone stopes near the north abutment are more prone to failure than stopes near the south abutment.

Reference

Clarke, R.W.D.
1990: Post pillar extraction, Nanisivik Mine; Canada Centre for Mineral and Energy Technology (CANMET), Open File Report, 90p.

NARROW VEIN MINING AND BLASTING TECHNIQUES, LUPIN MINE

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Objectives

The first part of the project was a literature review of blasthole stoping applied to narrow vein mining. The second part was to review and monitor current blasting techniques to determine if more efficient results were possible.

A computer search was made of the Mining Technology (MINTEC), the National Technical Information Services (NTIS) and the Engineering Index (EI) databanks. Very little pertinent information was obtained through this exercise. To complement the scarce information achieved at this point, a survey was made of Canadian mining operations with similar stoping methods.

Results

The detailed report (Clarke, 1990) summarizes the operating practices and design parameters in current use. A surprising variety of alternative designs were applied to, what initially appeared as, similar orebody geometries. The analysis focused on drilling and blasting practices. This revealed that numerous adjustments could be made to the relatively simple patterns to account for rock strengths and reducing blast vibration damage to the stope walls. The discussion highlights specific elements to achieve acceptable dilution: ground conditions, stoping widths, hole deviation, detonator cap scatter and general drilling and blasting procedures. Suggestions are made for future improvements by applying new scientific procedures for estimating fragmentation, use of advanced design software and modified explosive strength control.

As part of the blast monitoring and design project at the Lupin Mine, Golder Associates examined the current drill pattern and blasting techniques. The report (Clarke, 1990) describes the mining operation, the mining zone studied and the mining method. The study consisted of blast monitoring using a multichannel blast vibration monitor linked to geophones capable of assessing energy levels of blast vibrations, both in the near and far field. This demonstrated that the present patterns induced too much energy into the rock, causing excess energy transfer to the walls, induced sloughing and contributing to higher dilution. Another pattern was tested and shown to adequately break the ore with reduced wall damage. It is concluded that, for the established mining geometry, blasthole drilling inaccuracies will have to be addressed before significant beneficial results can be achieved from the proposed pattern changes.

Reference

Clarke, R.W.D.
1990: Narrow vein mining and blasting techniques, Lupin Mine; Canada Centre for Mineral and Energy Technology (CANMET), Open File Report, 30p.

GOLD RECOVERY IMPROVEMENT INVESTIGATIONS AT GIANT YELLOWKNIFE MINE

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Objective
The objective of this project was to increase recovery utilizing either improvements in the current process or available new technology. This work should eventually lead to increasing mining activity and employment, improving competitiveness of Giant Yellowknife Mine, and helping other NWT mines to overcome problems in the milling of refractory ores.

Methods and Results
The project was subdivided into four phases. The results of particular phases are documented in Stefanski and Halverson (1990) and are summarized below:

Phase 1 *Sample collection, preparation and distribution to the various laboratories (Giant Yellowknife Mine)*

This phase consisted not only of gathering, preparing and distributing samples but also of setting up details of the program with Surface Science Western and Lakefield Research.

Phase 2 *Mineralogical investigations to determine the mineralogical distribution of gold in the Giant Yellowknife ore and in the mill products (Surface Science Western)*

This phase became the most important and the most successful part of the project, thanks to novel mineralogical techniques, and in particular the Ion Probe Microanalysis developed by S. Chryssoulis, Surface Science Western and L. Cabri, CANMET. It was possible to establish a full mineralogical gold balance in Giant Yellowknife Mine's refractory gold ore, including the distribution of the sub-microscopic gold.

Results of Phase 2 can be summarized as follows:

1. *Feed and concentrate*

- Gold is concentrated in two minerals: native gold and arsenopyrite.
- The average silver content of the native gold is 6.9 wt%.
- The average sub-microscopic gold concentration in arsenopyrite is 299 ppm.
- Native gold contributes 38.7% of the assayed gold, arsenopyrite 59.7%, and pyrite only 1.6%.
- The majority of the native gold is liberated and coarse grained; 67.7 wt% of it floats in the Maxwell cell and reports to the rougher concentrate. Over 97% of the native gold is recovered. 10.7% of the native gold is associated with quartz, 9.8% with pyrite and 12.4% with arsenopyrite.
- Of the associated native gold, two forms are lost to the tailings: relatively coarse grained gold combined with quartz (high tails), and gold combined with fine grained arsenopyrite (low tails).
- The fine grained arsenopyrite (average 325 mesh) is more enriched in sub-microscopic gold (495 ppm) compared to the coarser grained arsenopyrite (153 ppm) (average 150 mesh).
- The fine grained arsenopyrite floats slower and accounts for 75.5% of the contained gold in the scavenger concentrate.

- The fine grained arsenopyrite accounts for 80% of the gold lost to tailings.

These results lead to the following recommendation concerning the potential recovery improvements: recover the coarse grained gold associated with quartz either by direct cyanidation or finer grinding and recover more of the fine grained arsenopyrite also by finer grinding.

2. *Feed and products of roasting, tailings material*

For these materials similar analyses were carried out as for the feed and concentrates. Results enabled us to obtain an exact distribution of gold and to identify its mineralogical associations and ranges of grain size. Of particular significance is the identification of colloidal gold in relation to less or more permeable parts of the calcine particles.

Gold is lost to the calcine residue:

- within the most impermeable maghemite particles (regrind will not help)
- in the permeable core of goethite/scorodite particles and sintered coating (regrind will improve recovery)
- in the sintered coating (regrind will have some effect).

3. *Gold distribution*

In a sample of mill feed the gold was distributed as follows:

Gold associated with arsenopyrite	64.5%
Gold associated with pyrite	5.4%
Gold in a liberated form	26.1%
Gold associated with quartz	4.0%
	100.0%

In a normal sample of flotation tailings the gold distribution was the following:

Sub-microscopic gold in arsenopyrite	60.9%
Sub-microscopic gold in pyrite	1.7%
Cyanidable gold	37.4%
	100.0%

Phase 3 *Bench scale testing to optimize recovery and check new technology (Lakefield Research, Giant Yellowknife Mines Limited)*

Full diagnostic testing was done on eight samples and included chemical analyses of sized fractions and gold association testing. This work verified the mineralogical results and identified minerals with which the gold is associated with the purpose of finding methods of increased recoveries.

Based on this work and on mineralogical tests the bench testing concentrated on grinding-flotation and grinding-cyanidation.

The following subjects were studied particularly carefully: grinding, gold distribution, flotation-grind/float, and selection of reagents. These studies enabled us to draw the following conclusions regarding flowsheet development:

- To get the best results flotation "pulling rates" should be low. Scavenger concentrate cleaning and combining cleaner concentrate with rougher concentrate for a final product are needed. Finer rougher grinding did not improve recoveries. The second best results give stage grinds. Ultra fine grinding did not improve recoveries.
- This result suggested that the best way to improve recovery might be the introduction of column cell flotation for scavenger cleaning. The feed is fully appropriate to this technology since it contains silica gangue and arsenopyrite-sulphide concentrate.
- Neither cyanidation testing of mill feed and tailing nor attempts to recover gold from calcine residues gave any encouraging results.

Phase 4 *Pilot scale testing (Lakefield Research)*

The pilot scale testing was carried out by Lakefield Research using the most promising technology, namely, the column flotation cleaning of the scavenger concentrate. It showed that column cleaning can work well on the scavenger concentrate, but the results would not economically justify introducing major changes into the Giant Yellowknife mill. Investigations of the grind-recovery relationship followed by additional mineralogical tests showed that the anticipated increase in recovery, and possibly grade, with finer product size, is largely offset by the increased proportion of ultra fine liberated arsenopyrite reporting to the tailings.

Conclusion

The results of the project has led Giant Yellowknife Mines Limited into several areas of further research. One is upgrading the scavenger concentrate utilizing column flotation which could improve overall recoveries by 1%. Potential increases in carbon plant recovery are possible by use of lime to remove arsenates, which lock up cyanidable gold. Cyanidation of mill tailings indicated higher recoveries (by 2% overall) but proved to be uneconomical in the mill and detrimental to conventional recoveries at the Tailings Reclaim Plant.

The testwork has shown that a substantial increase in recovery is not an economic reality. The milling operation is performing efficiently with only minor increases in recovery being possible. This leads to the conclusion that the recoveries being obtained by Giant Yellowknife Mines Limited are close to the best obtainable with present technology and economics.

The project has shown, however, the importance of mineralogical research to understand the application of unit processes for recovery. The identification of gold association down to 100 angstroms provides a basis for the rationale of the current process and verifies the previous thinking that gold in arsenopyrite is in the form of solid interstitial replacement on a molecular level, where an arsenic atom is replaced by a gold atom.

The project has been a success in the area of refractory ore knowledge. It has completely defined the association of gold in the Giant Yellowknife refractory ore. The gold analysis was followed through the process to identify gold association in flotation, roasting, and cyanidation unit processes.

The work done by Surface Science Western was confirmed by both Giant Yellowknife Mines Limited and Lakefield Research Limited metallurgical testing and showed clearly the importance of understanding the nature of the gold in the ore to identify potential problems and solutions to milling. Optical Microscopy/Scanning Electron Microscopy and Ion Probe Microanalysis can help future potential mines in the Northwest Territories to be successful operations. The final report of the study identifies the basic understanding and handling of refractory gold ore and has application for reference for current and future operations in the Northwest Territories.

Reference

Stefanski, M.J. and Halverson, G.B.

1990: Gold recovery improvement investigations, Giant Yellowknife Mine; Canada Centre for Mineral and Energy Technology (CANMET), Open File Report, consists of four volumes containing contract reports: Volume 1 - Giant Yellowknife Mines Limited Summary Report, 150p.; Volume 2 - Surface Science Western Report, 100p.; Volume 3 - Lakefield Research Limited Report, 180p.; and Volume 4 - Lakefield Research Limited report, 95p.

HIGH TEMPERATURE GAS FILTRATION, GIANT YELLOWKNIFE MINE

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Objective

The objective of this project was to produce a saleable arsenic trioxide product containing <0.05% Fe and <0.5% Sb by a high temperature filtration process from crude arsenic trioxide stock-piled as a by-product of Giant Yellowknife Mine's gold extraction process. The benefits of a successful outcome of the project would include:

1) the recovery of gold values and antimony oxide values from the high temperature filtration residue;

2) the removal of arsenic from underground storage chambers to make surrounding gold ore available for mining;

3) the elimination of the need for arsenic oxide-bearing baghouse dust storage; and

4) the elimination of the need for long-term arsenic-bearing baghouse dust storage.

Method

The project was focused on developing data to enable the design of a full-scale plant for the treatment of arsenic oxide. Design data were needed for pressure drop across the filter, collection efficiency, face velocity, etc. To determine the required engineering data for the construction of a full scale plant, a pilot plant was built and operated at the Giant Yellowknife Mine.

High levels of collection efficiency for high product purity require a balance between the factors of large filter area and high pressure-drop across the filter. The testing was aimed at achieving this balance.

Results

The necessary data for the design of phase one of a full-scale plant were obtained to enable a flowsheet to be designed, to prepare equipment size and to produce detailed cost estimates.

Test work of Giant Yellowknife Mines Limited showed that the choice of filter element is not critical and that a wide range of filter media are suitable for the application. Acceptable product purity was achieved with all filters tested, provided they operated at pressure drops in the range of 15 inches to 25 inches of water and at face velocities in the range of 8 to 15 acfm/sq ft of filter area.

Solids loading, pressure drops, face velocity and condenser temperatures are all independent of scale and these data can be directly transferred from pilot to plant scale.

A primary concern was arsenious oxide purity and, since the oxides of iron and antimony are the major contaminants in the crude As_20_3, both were consistently filtered out, with the correct filter design resulting in a final product consistently analyzing >99.5% As_20_3, < 0.05% Fe and <0.5% Sb.

In the pilot plant, Giant Yellowknife tested four filters from different manufacturers and found:

1) the four filters were similar in antimony collection efficiency;

2) the four filters were similar in iron collection efficiency;

3) three of the four filters had similar pressure drops for a given flow rate;

4) all filters were capable of producing As_2O_3 at the required Fe specification at pressure drops of 24 inches with the exception of the Fluid Dynamics filter which achieved this at 15 inches;

5) none of the filters achieved collection efficiencies greater than 75% and this yielded Sb concentrations in the product of 0.5-1.0%;

6) gold capture in the filters reduced gold in the baghouse dust from 0.123 oz/t to <0.01 oz/t which would mean an additional annual recovery of 660 ounces of gold;

7) arsenious trioxide upgrading in the filters was much more effective than in the ESPs.

Temperature control was the most difficult problem in operation of the pilot plant and even after the installation of 11 kW of heating elements the temperature gradient in the filter assembly was 304°C at the bottom and 621°C at the top.

Conclusions

Since none of the antimony removal efficiencies were better than adequate, it was concluded that the choice of filter should depend on iron removal efficiency at the lowest pressure drop. For instance, the Pall filters, with a pore size of 10 microns and a pressure drop of about 8 inches of water, achieved an antimony removal efficiency almost the same as the Fluid Dynamics (FD) filter with a pore size of 0.4 microns and a pressure drop of > 16 inches of water, although iron collection efficiency in the Pall filter was only about one-half that in the FD filter. Collection efficiency can be controlled by varying the blow-back frequency and the filter cake thickness. Project results are summarized in Skeaff and Morton (1990).

Recommendations

It is recommended that a full-scale plant be designed and built to provide adequate antimony removal and help treat underground feedstocks of impure arsenious trioxide. Filters with pore sizes in the range 0.4-0.8 microns, a pressure drop as low as 10 inches of water and a face velocity of 10 acfm/sq ft should be utilized.

Additional pilot testing could be used to determine whether antimony oxide is recoverable using two stage filtration and to determine whether antimony was volatilized in the heated filter during the pilot testwork. Given that the vapour pressure of antimony oxide is approximately 10 torr at its melting point of 656°C, some volatilization is likely, but with the wide difference in vapour pressures between arsenious trioxide and antimony trioxide, a good separation should be possible.

Reference

Skeaff, J.M. and Morton, K.

1990: High temperature gas filtration, Giant Yellowknife Mine; Canada Centre for Mineral and Energy Technology (CANMET), Open File Report, 110p.

TOXIC STABILIZATION AND PRECIOUS METALS RECOVERY FROM BY-PRODUCTS, NERCO CON MINE

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and

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NERCO Con Mine, Yellowknife

Objective

The objective of the project was: "To check the toxicity of the various materials and to develop the technology to treat them, recover the gold and produce an environmentally acceptable residue (as necessary)".

The Toxic Stabilization Tests were performed according to the Regulations of the Environmental Protection Act (EPA). They were carried out at the mine in Yellowknife, by the NERCO Con Mine environmental staff (on Arsenic Plant Residue) and at Lakefield Research (on the batch neutralization products from the autoclave liquor).

Methods and Results

A) Arsenic Plant Residue

1) EPA toxicity tests of the arsenic plant residue

"Leach Test" experiments were conducted as a means for predicting the environmental impact that Arsenic Plant Residue would have on tailings water chemistry (in the Pud Lake tailings area). The amount of arsenic solubilized from the residue as a percentage of the initial weight of residue varied in particular tests between 0.03 and 0.43%. The solubilizing was independent of pH, within the range pH = 9 to pH = 3.

The probable impact can be summarized as follows:

a) pH dropped dramatically, from a neutral pH in the tailings water prior to sludge addition, to a very acidic pH after sludge addition.

b) Arsenic levels, in general, remained unchanged during the Leach Tests.

c) Metal levels increased (Cu, Ni, Fe, Pb, Zn) as a result of sludge addition. Iron levels increased most dramatically, although copper levels rose as well. The soluble Fe levels may be a factor in the surprising arsenic results, which as noted in (b), remained unchanged during the leach tests.

d) Most favourable results were obtained when solids-to-liquids ratios were low, in other words:

i) when Pud Lake volumes were higher, and

ii) sludge quantities were lower

e) Contaminant levels did not change after 72 hours of continuous stirring.

f) The very low pH levels would result in the formation and emission of HCN proportional to the cyanide levels in the tailings water at the time of deposition.

There may be other items of importance, in terms of environmental impact, that were not evident as a result of this limited experimentation. The leach testing experiments were conducted, however, to duplicate as closely as possible, the conditions expected during deposition of Arsenic Plant Residue into the Pud Lake tailings area. To know whether or not the final residue can be safely disposed into the Pud Lake, more test work would be needed.

2) Mineralogical studies

Studies performed at Surface Science Western did not confirm the presence of arsenic trioxides in the Arsenic Plant Residue. However, the iron X-rays confirmed results of previous investigations showing that arsenic trioxide was indeed the main toxic material in the residue.

3) Pressure leaching

Tests on pressure leaching of Arsenic Plant Residue were conducted at Sherrit-Gordon. They showed that the residue could be further neutralized in an autoclave and that the ensuing gold recovery would be in the order of 95%. Tests on arsenic sludge showed that, when combined with iron-bearing feed material, the arsenic trioxide is neutralized as ferric arsenate.

4) Zinc precipitation

The Merril-Crowe zinc precipitation produced low recoveries unless arsenic was removed by iron/lime precipitation, in which case it reached 99%. Gold loadings in excess of 100 oz/ton of carbon can be achieved at over 95% recovery.

B) Roaster Calcine

New mineralogical methods introduced by CANMET and Surface Science Western enabled the characterization of sub-microscopic gold in the calcine residue. Arsenopyrite and pyrrhotite contain quite high values of this kind of gold (over 2 oz/ton). Pyrite has a small amount of gold (0.1 oz/ton). Iron oxides contain 0.2 to 0.4 oz/ton of sub-microscopic gold.

The following technologies have been used to find the best method of gold recovery from roaster calcine residue:

a) direct cyanidation after regrinding,

b) conventional pre-treatment and cyanidation

- hot water wash and cyanidation
- hot water wash and Carbon-in Leach (C-I-L)
- acid pre-wash
- hydrogen peroxide pre-wash
- atmospheric oxidation
- alkaline pre-wash
- resin-in-leach

c) pre-oxidation and cyanidation, and

d) pressure leaching.

Within the conventional methods, only cyanidation of weathered material gave good results (gold recovery of 87%). Pressure oxidation test work gave 85% recovery. These investigations included also toxicity and arsenic stabilization tests.

C) Tailings Gold Recovery

An extensive sampling campaign was conducted and afterwards the following technologies have been tried and evaluated:

- bio-leaching
- direct cyanidation
- flotation
- sequential cyanidation and flotation
- pressure oxidation of the flotation concentrate

Best results were obtained with pressure oxidation of the flotation concentrate followed by pressure leaching (recovery 95%). Bio-leaching of the flotation concentrate also gave excellent results.

D) Conclusions and Recommendations

This study proved that Arsenic Plant Residue, Roaster Calcine Residue and the Flotation Concentrate of Tailings can be successfully treated by Pressure Oxidation followed by Pressure Leaching in order to recover the contained gold and to reduce toxicity of tailings by converting reactive arsenic products to inert forms suitable for disposal (Stefanski and Martin, 1990).

Reference

Stefanski, M.J. and Martin, C.J.
1990: Toxic stabilization and precious metals recovery from by-products and residues, NERCO Con Mine; Canada Centre for Mineral and Energy Technology (CANMET), Open File report, 100p.

PRESSURE OXIDATION AND ENVIRONMENTAL STABILITY OF CYANIDE LEACH RESIDUES, NERCO CON MINE

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NERCO Con Mine, Yellowknife

Objectives
Approximately 140,000 ounces of gold are contained in the arsenic plant residue and sludge, calcine residue and mill tailings of the NERCO Con Mine. These have accumulated during 50 years of operation of the mine. The objectives of this project are to recover gold economically from these materials and to produce environmentally acceptable tailings.

Methods
The overall process is based on oxygen pressure oxidation of composites of the above materials under acidic condition and subsequent gold recovery by conventional alkaline cyanide leaching process from the pressure leach residue. Lakefield Research Limited was contracted to conduct all metallurgical tests.

The scope of work included:

1) Ten batch pressure oxidation tests

   These tests established the relationship between autoclave conditions, and sulphide oxidation and gold extraction. The tests were done in a Parr two litre titanium autoclave.

2) Eight continuous pressure oxidation tests

   These tests established the process criteria selected from the batch tests and investigated the effect of changes in feed composition on the stability of the final autoclave residue following neutralization.

   It was thought at the start of testwork that the autoclave residue could be leached in the regular mill circuit. This was shown to be possible in simulated leach tests. A Carbon-in Leach (CIL) test was carried out for comparison.

3) Analysis of test data

   All data were analyzed to provide information for an Engineering Feasibility Study and an Environmental Assessment Review.

Results
Pressure oxidation tests on mixtures of flotation concentrate, roaster calcine, and arsenic sludge from the NERCO Con Mine showed that 82 to 95% of the gold in the various mixtures could be recovered after pressure oxidation. The best autoclave conditions were 21°C, 90 minutes, and 20 to 25% solids (Haque et al, 1991). No advantage was found in further grinding of the feedstock.

The autoclave discharge thickened to 60% solids. Thickener requirements were 0.5 sq.m/ton/24 hr. A two stage Counter Current Decantation (CCD) circuit with a wash removed 85 to 90% of the autoclave discharge solution.

Due to the presence of carbonates, it is recommended that in future all the feedstock be pre-treated with acid.

Flotation tailings neutralize the autoclave discharge solution to pH 4. Neutralization requirements were 1 ton of tailings to 1 ton of autoclave feed solids to reach pH 4 and 2.5 tons of tailings to 1 ton of autoclave feed solids to reach pH 6.5.

As long as the autoclave feedstock mixture contained a ratio of 1.1:1 or more of iron to arsenic, the filtrates from the neutralized autoclave discharge were within environmental discharge specifications. X-ray Diffraction Analysis (XRD) analysis showed the formation of crystalline ferric arsenate. Cyanidation tests on the anticipated blend of ore and autoclave residue showed satisfactory gold dissolution of both feeds after 24 hours.

The cyanide residue was classified as acceptable waste according to the Ontario regulation 309 leachate procedure. A CIL test on the autoclave residue compared to direct cyanidation showed no pregnant solution robbing characteristics.

Conclusions

The scope of work was completed satisfactorily. The results were acceptable in terms of gold extraction and the environment as long as the autoclave feedstock mixture is 1.1:1 or more of Fe to As to ensure autoclave product stability.

The test results were submitted to an Engineering Feasibility Study. Based on this and other economic analyses, NERCO Con Mine Ltd. has decided to construct a production pressure oxidation facility to process refractory concentrates and to clean up arsenic sludge, using reclaim calcine as an additional source of iron.

It has been decided to run a 100 hour continuous autoclave test, using current mill flotation concentrate as feedstock mixed with arsenic sludge and calcine.

The products from the 100 hour test will be fully tested environmentally. In addition, the actual production circuit to treat the autoclave products will be modelled in the 100 hour test pilot plant flowsheet.

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APPENDIX B: BIBLIOGRAPHY OF THE GEOSCIENCE PROGRAM OF THE GEOLOGICAL SURVEY OF CANADA

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