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# M I N E R A L S C O L L O Q U I U M



## P R O G R A M W I T H A B S T R A C T S

G E O L O G I C A L S U R V E Y O F C A N A D A

O T T A W A C O N G R E S S C E N T R E

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Resources Canada

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**THE ENERGY OF OUR RESOURCES**

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Geological Survey of Canada  
**MINERALS COLLOQUIUM**

17-18 January 1990

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**Place:**

Halls A, E

Ottawa Congress Centre

55 Colonel By Drive, Ottawa

**Scientific Displays:**

Some 100 displays will be on view in hall A  
on Wednesday, January 17th from 17h00  
to 22h00 and on Thursday, January 18th  
from 9h00 to 12h00

**Social Event:**

An informal get-together with cash bar  
will be held in hall A during the  
opening session of the scientific displays,  
on Wednesday, January 17th from 17h00 to 22h00

# **Minerals Colloquium 1990**

## **Colloquium Organizer and Committee Chairman**

R.F.J. Scoates

## **Program Committee**

W.B. Coker  
W.D. Goodfellow  
P.G. Killeen  
W.D. Sinclair

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L.C. Richard  
S.A. Scully  
C.E. Vodden

The Minerals Colloquium Committee wishes to acknowledge GSC FORUM 1990 Committee members for their support and encouragement of this premier edition of the Minerals Colloquium.

Also, the committee thanks P. Côté, M.-F. Dufour, J. Gilliland and M.J. Kiel for their help during preparation of the first circular and this program volume.

## FOREWORD

Welcome to the Geological Survey of Canada's first Minerals Colloquium! The Colloquium is intended to highlight the results of the GSC Minerals Program and to promote communication between GSC scientists and their colleagues in the mineral industry, the universities and other government geoscience agencies. It is hoped that the Minerals Colloquium will become a regular event to be held on a biennial basis.

The GSC is of course only one of many organizations that carry out minerals-related research in Canada, and we are particularly pleased that numerous colleagues from provincial and territorial surveys, academia and the mineral industry have agreed to participate in the colloquium. This is indicative of the spirit of cooperation that will be the hallmark of successful research in the 1990's.

The Minerals Colloquium this year will focus on topics of immediate interest to the mineral industry. There are three oral sessions on the themes Exploration Research, Modern and Ancient Massive Sulphide Deposits and Precious Metals. In addition, more than 100 poster presentations provide a representative cross section of recent scientific results of GSC's minerals-related research.

A highlight of the Minerals Colloquium will be a keynote address in honour of A.H. Lang, one of GSC's foremost economic geologists. The 1990 Lang Lecture will be presented by D.H. Watkins and H.L. Gibson and is entitled "Noranda Massive Sulphide Deposits: A guide to Exploration and Seafloor Sulphide Research".

We hope that you will find much of interest among the oral and poster presentations at the Minerals Colloquium. We would be very pleased to receive your comments, not only concerning the format and content of the meeting itself, but also with respect to the direction and emphasis of GSC's minerals-related research.

**Elkanah A. (Ken) Babcock**  
**Assistant Deputy Minister**



A.H. Lang

## THE LANG LECTURE

The Geological Survey of Canada (GSC) Minerals Colloquium Committee takes great pleasure in honouring Arthur H. Lang, one of the GSC's foremost economic geologists through the presentation of a special invited lecture. The Lang Lecture, will be presented by geoscientists who have demonstrated outstanding accomplishments in mineral exploration or research. This year the Lang Lecture is entitled "Noranda Massive Sulphide Deposits: A guide to Exploration and Seafloor Sulphide Research" and will be presented by David H. Watkins of Minnova Inc. and Harold L. Gibson, of Falconbridge Nickel Mines Ltd.

## ARTHUR H. LANG

Arthur Hamilton Lang, born in the interior of British Columbia in 1905, is an honours geology graduate of the University of British Columbia. As a child he became interested in minerals and rocks and in several worked-out gold placers and lode prospects in his home region. Local prospectors befriended him and showed him maps and reports of the Geological Survey of Canada (GSC). A topographic map taken from G.M. Dawson's report on the region was on a wall of his father's office. A.H. Lang was employed as a student assistant on GSC parties in British Columbia from 1927 to 1929. He joined GSC in 1930, after completing his Princeton University doctoral thesis "Owen Lake Mining Camp, British Columbia". He was one of the last geologists to be engaged by GSC before the great depression caused a hiring freeze.

His first GSC work was in the Abitibi gold fields (Chibougamau, Waswanipi Lake, Palmarolle and Taschereau map-areas) where he pioneered the field use of air transport and reconnaissance, and use of air-photos in preparing topographic and geological maps. Later, he studied gold deposits of the Noranda-Bell River region of Quebec and the Cariboo District of British Columbia.

Soon after the outbreak of World War II, Lang enlisted in the R.C.A.F. However, GSC insisted on having this cancelled because the Metals Controller was increasingly demanding more projects related to strategic metals and minerals. Lang worked on several of these until petroleum became the main shortage. From 1941 to 1945 he undertook petroleum-related mapping, in the foothills of Alberta.

In 1944 the GSC assigned a few geologists to secret investigations of known uranium deposits and their surroundings. In 1947 the government, on the advice of Atomic Energy Control Board (formed the previous year), decided to permit and encourage private prospecting and mining for uranium. The GSC was made the official agent of the Board in matters related to prospecting and mining. To handle this the Radioactive Resources Division was formed with H.V. Ellsworth, a renowned mineralogist and chemist as Chief. Lang was put in charge of field work and maintaining and verifying an "inventory" of occurrences, which had been begun by Ellsworth during the period of secrecy. Lang succeeded Ellsworth as Chief in 1948. By 1955 uranium production had become well established, and as more attention to other metals was required, the name of the Division was changed to Mineral Deposits Division.

The requirement for reporting radioactive ore discoveries gave Lang unusually good data for preparing and publishing a metallogenic map for uranium. He then encouraged other GSC geologists to prepare such maps for other major, and many minor metals, many of which were published. He compiled two maps combining this information, which were published, with a short explanatory text, in A Preliminary Study of Canadian Metallogenic Provinces.

Soon after the formation of the Geology Division of the Canadian Institute of Mining and Metallurgy, about 1943, a sub-committee was formed to arrange for a special volume "Structural Geology of Canadian Ore Deposits" to mark the Jubilee year of 1948. Lang served as co-editor and contributed two papers. A few years later he undertook special geological research and prepared about half of an early compilation of the Geological Map of Canada at 1:5 000 000, which was refined by R.J.W. Douglas.

The first edition of Canadian Deposits of Uranium and Thorium was the first detailed account of uranium and thorium deposits and occurrences issued by any country. In his recent book Not For Gold Alone Franc Joubin, the founder of uranium mining in the Elliot Lake region of Ontario stated "Now, three years later, my interest in the area was rekindled by a newly published Geological Survey of Canada bulletin by A.H. Lang, entitled Canadian Deposits of Uranium and Thorium. It was a remarkable compilation of data for practically all known radioactive deposits in Canada".

The 3rd edition of Prospecting in Canada was reprinted three times within ten years and the 4th edition has been reprinted numerous times. It is used for adult education courses, and supplementary reading for university courses. It has been used as a textbook by the International Atomic Energy Institute in Vienna. A paperback containing the chapters on basic geology, minerals and rocks and an outline of the geology of Canada was prepared for use by high-schoolers. Lang is author of more than 100 publications on Canadian geology and mining, some of which have been translated and re-published in other countries.

After retirement from the Public Service in 1970, Lang was asked to undertake part-time contractual preparation of geological guidebooks for several national parks, four of which were published.

Throughout his career Lang presented many outstanding lectures and talks based on his original geological research and his study of uranium deposits. He took part in several international conferences on peaceful uses of atomic energy and on geological and metallogenic maps of the world.

He is a fellow of the Royal Society of Canada and the Geological Society of America, and a member of the Fifty-Year Club of the Canadian Institute of Mining and Metallurgy. His field work in British Columbia and Alberta, in areas where travel was largely by pack and saddle horses, gave him great admiration for western horses and for mountains. He skied from age 10 to 80 and golfed in later life when he spent more time in Ottawa.

# PROGRAM

Wednesday, 17 January 1990

## Hall E

13h30	Welcome and opening remarks	15h25	Exploration Science and Technology Initiative (EXTECH) at the Geological Survey of Canada <i>W.B. Coker</i>
13h45	Geophysics in the third dimension: an overview of downhole research and development at the GSC <i>P.G. Killeen</i>	15h40	The biogeochemical expression of skarn-hosted gold mineralization in British Columbia <i>C.E. Dunn</i>
13h55	Unravelling the structure of ore deposits with borehole mise-à-la-masse measurements <i>C.J. Mwenifumbo</i>	15h55	Drift prospecting in north-western Manitoba; techniques and exploration strategies <i>C.A. Kaszycki</i>
14h10	Mise-à-la-masse measurements at the Redstone Property; Timmins Nickel <i>K. Witherly, C.J. Mwenifumbo</i>	16h10	Regional till geochemistry of Labrador: an interpretive approach for mineral exploration <i>R.A. Klassen, F.J. Thompson</i>
14h25	Borehole geophysics at the Stratmat Main Zone, New Brunswick <i>K. Robertson, C.J. Mwenifumbo</i>	16h25	Spatial integration of Snow Lake, Manitoba data sets using GIS technology <i>G.F. Bonham-Carter, R. Reddy, D.F. Wright</i>
14h40	Borehole geophysics in the British Columbia mineral logging project; the Equity Silver deposit <i>P. Kowalczyk, P.G. Killeen, C.J. Mwenifumbo</i>	16h40	Assessment of regional mineral potential with GIS integration techniques, northern New Brunswick <i>G.P. Watson, A.N. Rencz</i>
14h55	<b>COFFEE BREAK</b>		
15h10	Application of gamma ray spectrometry in multi-element mineral exploration <i>B.W. Charbonneau, K.L. Ford, R.B.K. Shives</i>	17h00-22h00	Poster Session and informal get together in Hall A; cash bar

Thursday, 18 January 1990

Hall E

8h30	Modern and ancient massive sulphide deposits <i>J.M. Franklin</i>	12h10	LUNCH
			Poster Session ends
9h00	Modern and ancient SEDEX sulphide deposits: current concepts on ore genesis <i>W.D. Goodfellow</i>	13h45	Descriptive models of Canadian gold deposits <i>K.H. Poulsen, F. Robert, B.E. Taylor, J.A. Kerswill, R.I. Thorpe, D.C. Harris, J.M. Franklin</i>
9h30	The Jason Zn-Pb-Ag-barite deposit: exhalative and replacement processes along a Devonian syndepositional fault <i>R.J.W. Turner</i>	14h15	Canadian-Chinese co-operation: magmatic-hydrothermal gold deposits in North China Platform <i>B.E. Taylor, F. Robert, J.K. Mortensen, K.H. Poulsen</i>
10h00	COFFEE BREAK		
10h15	Geological setting of massive sulphide deposits in the Bathurst District, New Brunswick <i>C.S. van Staal</i>	14h45	Sulphurets, British Columbia: geology, geochemistry and mineralogy of a deformed porphyry copper, molybdenum and precious metal system <i>R.V. Kirkham, S.B. Ballantyne, D.C. Harris</i>
10h45	The Buchans Project: new concepts on the origin of the Buchans sulphide deposits, Newfoundland <i>J.G. Thurlow, R.V. Kirkham</i>	15h15	Chemical characteristics of magmatic Ni-Cu-PGE sulphide deposits as exploration guides <i>O.R. Eckstrand, L.J. Hulbert</i>
11h15	Lang Lecture introduction <i>D.C. Findlay</i>	15h45	End of colloquium
11h20	Lang Lecture: Noranda massive sulphide deposits: a guide to exploration and seafloor sulphide research <i>D.H. Watkins, H.L. Gibson</i>		

# TALKS

## **GEOPHYSICS IN THE THIRD DIMENSION: AN OVERVIEW OF BOREHOLE RESEARCH AND DEVELOPMENT AT THE GSC**

P.G. Killeen<sup>1</sup>

Some of the most significant advances in the application of new geophysical technology are being made in the area of borehole geophysics. At the GSC, research in borehole geophysics is concentrated in three areas 1) new applications, 2) quantitative measurements, and 3) development of new technology.

New applications for mineral exploration and mining development have been investigated in collaboration with mining companies, on deposits ranging from gold and silver to base metals and industrial minerals. In the area of quantitative measurements, calibration facilities and test boreholes are being developed. New technological developments have been made in several areas including the induced polarization (IP) method, and in borehole assaying.

Selected examples will illustrate some of these activities.

<sup>1</sup> Mineral Resources Division

## **UNRAVELLING THE STRUCTURE OF ORE DEPOSITS WITH BOREHOLE MISE-À-LA-MASSÉ MEASUREMENTS**

C.J. Mwenifumbo<sup>1</sup>

Ore deposits are often structurally deformed, offset by faults and generally consist of a number of ore lenses. Correlating ore intersections between holes is, therefore, often difficult. In the case of conductive massive sulphide deposits, borehole electrical methods including EM, IP and galvanic resistivity, have been applied to aid in interpreting the structure of ore deposits. Here we present an overview of how the mise-a-la-masse (or applied potential) method can be used in unravelling the structure of complex ore deposits. By directly energizing an ore intersection, it is easy to trace the continuity of that intersection in other holes, and thus establish its orientation. A field example will be presented illustrating the use of the method in mapping the orientation and continuity of conductive ore intersections.

<sup>1</sup> Mineral Resources Division

## **MISE-À-LA-MASSÉ MEASUREMENTS AT THE REDSTONE PROPERTY; TIMMINS NICKEL**

K. Witherly<sup>1</sup>, C.J. Mwenifumbo<sup>2</sup>

Mise-a-la-masse measurements were first carried out at the Redstone Nickel property in 1978 by Utah Mines Ltd to aid in the structural interpretation of this deposit. Surface mise-a-la-masse measurements, with current sources located in a number of drillhole ore intersections, successfully indicated the strike extent, dip and plunge of the deposit. A number of holes were drilled in 1989 to establish the limits of the deposit. One deep hole, drilled to test the down-dip continuity of the deposit, intersected economic mineralization at a depth well below the known limits. Hole-to-hole mise-a-la-masse measurements carried out by the Geological

Survey of Canada, indicate electrical and presumably structural continuity between mineralization intersected in this hole and the rest of the deposit. Confirmation of this interpretation awaits results of the deep drilling project scheduled late in the fall of 1989.

<sup>1</sup> BHP-Utah Mines Ltd., Toronto, Ontario

<sup>2</sup> Mineral Resources Division

## **BOREHOLE GEOPHYSICS AT THE STRATMAT MAIN ZONE, NEW BRUNSWICK**

K. Robertson<sup>1</sup>, C.J. Mwenifumbo<sup>2</sup>

The Stratmat Property is located in Northumberland County, New Brunswick and is adjoined to the south by the Heath Steele mine lease. The property is underlain by an east-west trending package of predominantly felsic volcanic and metasedimentary rocks of the Tetagouche Group. The favourable horizon is repeated by folding and massive sulphides are believed to be concentrated in the fold closure areas.

Diamond drilling of the Main Zone has outlined approximately 1.5 million tons of sulphides. The deposit is dominated by pyrite-chalcopyrite mineralization at the surface and grades into sphalerite-galena mineralization at depth.

In 1987 and 1988 Noranda surveyed the Main Zone with large loop borehole pulse E.M. The Geological Survey of Canada borehole geophysics research group visited the property in the summer of 1988 and collected a wide spectrum of borehole geophysical data. The geological and structural picture of the deposit has been enhanced as a result of this work.

<sup>1</sup> Noranda Exploration, Bathurst, New Brunswick

<sup>2</sup> Mineral Resources Division

## **BOREHOLE GEOPHYSICS IN THE BRITISH COLUMBIA MINERAL LOGGING PROJECT; THE EQUITY SILVER DEPOSIT**

P. Kowalczyk<sup>1</sup>, P.G. Killeen<sup>2</sup>, C.J. Mwenifumbo<sup>2</sup>

In the summers of 1986 and 1987 the GSC Mineral Logging System was used in British Columbia to collect a suite of drillhole logs at Kimberly, Goldstream, Equity, Chu Chua, Abermin, Buttle Lake, Equity, and Valley copper. During the second visit in 1987, the Equity property was visited again to acquire data in a fence of holes across a type section of the deposit.

The data collected illustrates the usefulness of borehole logs for both the estimation of in situ rock properties, and for the correlation of geologic units and mineralized zones from hole to hole. Differentiation of rock units on the basis of logged properties may be practical where visual identification is not reliable.

The logs recorded with a broad suite of tools form a good reference library of the response of these tools in a variety of rock types. This is of great value in planning mineral logging programs in routine mineral exploration.

<sup>1</sup> Placer Dome Inc., Vancouver, British Columbia

<sup>2</sup> Mineral Resources Division

## APPLICATION OF GAMMA RAY SPECTROMETRY IN MULTI-ELEMENT MINERAL EXPLORATION

B.W. Charbonneau<sup>1</sup>, K.L. Ford<sup>1</sup>, R.B.K. Shives<sup>1</sup>

The systematic acquisition of high sensitivity, quantitative, airborne gamma ray spectrometric (AGRS) data by the Geological Survey of Canada has helped to expand the role of gamma ray spectrometry beyond that of a uranium exploration tool. These expanded roles include applications to regional and detailed bedrock and surficial mapping, environmental studies, and mineral exploration.

Mapping of the radioelements K, U, and Th can be a significant mineral exploration tool. As pathfinders they can be of direct assistance to exploration for many commodities, most obviously U, but also Sn-W, rare and high technology metals. In certain cases the radioelements can also point to precious and base metal mineralization when their concentrations and ratios have been modified by the mineralizing process thereby altering the normal radioelement signature of the host lithology.

Rapid evolution in data manipulation and presentation techniques has and will increasingly provide novel ways to view and compare large high resolution multiparameter digital data sets. The AGRS data collected by the Geological Survey of Canada are available as a variety of line contour, profiles, colour maps (including ternary radioelement maps) and as digital data.

<sup>1</sup> Mineral Resources Division

## EXPLORATION SCIENCE AND TECHNOLOGY INITIATIVE (EXTECH) AT THE GEOLOGICAL SURVEY OF CANADA

W.B. Coker<sup>1</sup>

"Exploration Science and Technology", or EXTECH, encompasses a spectrum of geological, geophysical and geochemical mineral exploration methods. Activities involve both the design and demonstration of instrumentation and procedures, and the development of mineral deposit models and exploration concepts.

The prime objective of EXTECH is to develop integrated models for use in exploration for base metal deposits. The formulation of these models will require the development of new geophysical, geochemical and computer-based data integration and interpretive methodologies applicable to exploration for such deposits.

In 1989/90, in the Snow Lake and Rusty Lake areas, initial work consists of compilation of existing geoscience data using GIS/SPANS; geological reconnaissance of volcanogenic massive sulphide deposits including detailed mapping of the Chisel Lake deposit; completion of a multiparameter airborne GSC Skyvan survey and production of maps; completion of the design and manufacture of a downhole three-component magnetometer; and, assessment of the applicability of various geochemical and geophysical techniques to exploration for base metal mineralization.

<sup>1</sup> Mineral Resources Division

## THE BIOGEOCHEMICAL EXPRESSION OF SKARN-HOSTED GOLD MINERALIZATION IN BRITISH COLUMBIA

C.E. Dunn<sup>1</sup>

There are well over a hundred gold-enriched skarns in British Columbia, many of which are poorly exposed. Most occur in forested areas, hence studies have been conducted to determine if

the chemical analysis of tree and shrub tissues can assist in locating concealed mineralization.

The Nickel Plate mine is hosted by a 'world-class' skarn which is forested mainly by lodgepole pine. The ash of pine bark scales contains locally in excess of 2000 ppb Au and 1000 ppm As, compared to background concentrations of <20 ppb Au and <10 ppm As. Satellite deposits (e.g. Goodhope, French) have lesser, but highly significant concentrations in surrounding trees. The regional biogeochemical anomaly extends over an area of more than 100 sq. km.

Around the small skarns on Texada Island (Gulf coast) the vegetation is diverse, but Douglas-fir is commonly present. Analysis of the entire bark profile yields concentrations mostly of 10 to 50 ppb Au (background of <5 ppb), several hundred ppm As, and local enrichment of Mo, W, Sb and Se.

<sup>1</sup> Mineral Resources Division, GSC

## DRIFT PROSPECTING IN NORTHWESTERN MANITOBA; TECHNIQUES AND EXPLORATION STRATEGIES

C.A. Kaszycki<sup>1</sup>

Prior to 1982, recognition and application of drift prospecting as an effective method of geochemical exploration in northern Manitoba was virtually non-existent. Detailed till sampling near known mineralization was begun in the Lynn Lake region in 1982 (Erik Nielsen, Manitoba Energy and Mines), and in 1983, a program of systematic regional till sampling and surficial geologic mapping was begun in northwestern Manitoba, as part of the Canada-Manitoba Mineral Development Agreement. The primary objectives were: 1) to map out the patterns of glacial dispersal developed through glacial erosion and transport of distinctive bedrock lithologies; 2) to provide reconnaissance-level till geochemical data in order to outline regions with potential for mineralization (primarily base metals and gold); and 3) to provide the geologic framework for implementation of successful detailed drift prospecting programs within the region. Results and recommendations for mineral exploration within the region will be presented.

<sup>1</sup> Terrain Sciences Division

## REGIONAL TILL GEOCHEMISTRY OF LABRADOR: AN INTERPRETIVE APPROACH FOR MINERAL EXPLORATION

R.A. Klassen<sup>1</sup>, F.J. Thompson<sup>1</sup>

The geological record of glacial history, such as striae and erratics, provides a framework necessary for interpretation of regional geochemical surveys and their significance to bedrock composition and mineral exploration. Till is a glacial sediment derived from bedrock by glacial erosion, modified only by processes of glacial transport and deposition, and it bears the most direct compositional relationship with bedrock. Quaternary geology permits recognition of directions and distances of glacial transport, and discrimination between the effects of regional-scale (10's to 100's of km) glacial dispersal and variation in bedrock. In Labrador, glaciation has amplified the geochemical expression of some units, such as the Labrador Trough, compositionally masking the expression of other bedrock in surficial deposits, and its influence can extend over tens of kilometres in directions that are not prominently recorded in the geological record. Elsewhere, the effects of glacial transport are more limited, and regional till geochemistry can approximate the composition of underlying bedrock. Where dispersal is limited, geochemical analyses provide a basis for developing exploration strategies by indicating: i) compositional differences within large lithological units, such as the Flowers River Igneous Suite and the Red Wine Alkaline

Complex; ii) geochemical properties of buried sources that are poorly known.

<sup>1</sup> Terrain Sciences Division

### **SPATIAL INTEGRATION OF SNOW LAKE, MANITOBA DATA SETS USING GIS TECHNOLOGY**

G.F. Bonham-Carter<sup>1</sup>, R.K.T. Reddy, D.F. Wright<sup>1</sup>

A PC-based GIS system is being used to compile, display, interactively integrate and model geoscientific data related to base-metal mineralization in the Snow Lake area. The GIS employs a quadtree database structure which, because it involves a variable pixel size, is particularly efficient for handling geological maps that vary in scale. Maps digitized from a 1:50,000 scale provide complete regional coverage; 1:25,000, 1:15,840 and 1:5,000 sheets provide patchy but detailed coverage of specific areas. Regional geophysics, geochemistry, metamorphic facies, Landsat and structural elements are incorporated in the database.

Maps suitable for predictive modelling are first derived from the raw data. For example, anomaly maps are calculated from the geophysical and geochemical layers, and proximity maps are produced from the database showing distance to critical contacts or structures. The spatial association of each predictor map with the known mineral occurrences is calculated using a weights of evidence model. These weights are then used for integrating predictive layers to produce a map showing probability of mineralization.

<sup>1</sup> Mineral Resources Division

### **ASSESSMENT OF REGIONAL MINERAL POTENTIAL WITH GIS INTEGRATION TECHNIQUES, NORTHERN NEW BRUNSWICK**

G.P. Watson<sup>1</sup>, A.N. Rencz<sup>1</sup>

A GIS (geographic information system) is a powerful tool for the integration and analysis of multiple geoscience data sets. For an area near Bathurst, New Brunswick, regional data from ground-based geology, stream sediment and till geochemistry, airborne geophysical surveys and satellite imagery in a variety of digital formats are integrated with a desktop GIS. The data are used concurrently to model mineral favourability based on weights of evidence. The model uses the point locations of 75 known mineral occurrences and a subset of 26 gold-bearing occurrences from the study area. The calculations for the entire set and the subset are compared. The results, summarized as predictive maps, which show areas relatively favourable to the occurrence of mineralization, are evaluated with respect to estimation error and uncertainty. These maps can serve as a guide to exploration.

<sup>1</sup> Mineral Resources Division

### **MODERN AND ANCIENT MASSIVE SULPHIDE DEPOSITS**

J.M. Franklin<sup>1</sup>

Research on modern and ancient VMS deposits provides new insights. A subvolcanic magma chamber ( $\approx 300 \text{ km}^3$ ), emplaced 2-3 km below the seafloor, is an essential heat source. Metalliferous fluids are generated by seawater/basalt interaction at about 385°C; in basalts, semi-conformable, metal-depleted, quartz-albite-epidote-actinolite alteration may form. Buoyant fluid ascends rapidly along caldera- or rift-margin faults.

Alteration pipe assemblages vary; under deposits formed in relatively shallow water ( $<1000 \text{ m}$ ) broad-scale carbonate alteration is transected locally by siliceous, sericitic pipes; under those formed in deeper water, Fe and Mg chloritic pipes prevail.

Sulfide mounds grow by inflation, with zinc, lead and silver displaced outward from a copper-rich core. Gold, transported as HS<sup>-</sup> in fluid cooled by either boiling or limited mixing, precipitates efficiently at an oxidation front near the margins of deposits. Maximum preservation occurs where the sulfides are deposited within sediments, or are protected by rapid burial through renewed volcanism.

<sup>1</sup> Mineral Resources Division

### **MODERN AND ANCIENT SEDEX SULPHIDE DEPOSITS: CURRENT CONCEPTS ON ORE GENESIS**

W.D. Goodfellow<sup>1</sup>

SEDEX deposits represent an important mineral resource comprising 31% and 61% of the world's Pb and Zn reserves, respectively. Most deposits occur in rift-controlled intracontinental Proterozoic and Paleozoic sedimentary basins. SEDEX deposits are on average an order of magnitude larger than VMS deposits due perhaps to their formation by prolonged hydrothermal discharge from a restricted number of vents. The fine grained sediments which typically host SEDEX deposits act as an impervious barrier to hydrothermal discharge, except at established vents, and thermally insulate the crust thereby sustaining geothermal activity. Since crustal compositions exert dominant control on the fluid chemistry, deposits in basins floored by a sialic crust probably formed from neutral to weakly acidic, low  $f_{\text{O}_2}$ , H<sub>2</sub>S-poor basinal fluids. Because of their low H<sub>2</sub>S content, these fluids must mix with a reduced ambient water column to precipitate sedimentary sulphides. This requirement may explain the low sulphide content and relatively subtle nature of feeder pipes below many SEDEX deposits, and the preferential occurrence of deposits during periods of ocean stagnation.

<sup>1</sup> Mineral Resources Division

### **THE JASON ZN-PB-AG-BARITE DEPOSIT: EXHALATIVE AND REPLACEMENT PROCESSES ALONG A DEVONIAN SYNDEPOSITIONAL FAULT**

R.J.W. Turner<sup>1</sup>, B.E. Taylor<sup>2</sup>, W.D. Goodfellow<sup>2</sup>

Stratiform sulphide-barite lenses occur within a debris apron of diamictite, conglomerate and siltstone adjacent to a Late Devonian syndepositional normal fault. Isopachs of diamictite form lobes that thin away from the fault. Laminated barite, chert, sphalerite, galena and pyrite which form the bulk of the lenses are replaced adjacent to the fault by massive, vein and breccia ferroan carbonate, galena, pyrite and pyrrhotite that represent the upflow zone of a reduced, sulphur deficient, CO<sub>2</sub>-rich hydrothermal fluid. Replacement sulphides tend to have higher  $\delta^{34}\text{S}$  than laminated sulphides (8.5 to 23.5 versus 4.0 to 14.5) due to reduction of barite or introduction of heavy hydrothermal sulphur. High  $\delta^{18}\text{O}$  (6.2 to 14.1‰) calculated for the hydrothermal fluid suggests a very evolved basinal and metamorphic fluid. Initial strontium ratios in barite indicate deposition from an isotopically homogeneous fluid distinct from seawater such as a ponded brine pool.

<sup>1</sup> Mineral Resources Division, Vancouver, British Columbia

<sup>2</sup> Mineral Resources Division

## GEOLOGICAL SETTING OF MASSIVE SULPHIDE DEPOSITS IN THE BATHURST DISTRICT, NEW BRUNSWICK

C.S. van Staal<sup>1</sup>

The generally northwards younging volcanic rocks of the Tetagouche Group in northern New Brunswick are interpreted as a thrust stack. U-Pb zircon dating of the volcanics show that virtually all volcanic units were erupted at approximately the same time (470-466 Ma) and support the thrusting interpretation. The Tetagouche Group volcanics are interpreted as a bimodal rifting suite which is tectonically overlain by a dismembered ophiolite in the Armstrong Brook area, which represent the continuation of the Fournier Group in the Bathurst Camp. Both suites are interpreted to record the opening of a back-arc marginal basin that was telescoped in post Middle Ordovician times.

The massive sulphide deposits, which are invariably associated with felsic volcanic rocks, can be separated into three different sets on basis of stratigraphic position and are generally hosted by sediments. These three sets are in ascending order the Half-Mile Lake, Brunswick and Caribou sets and generally have characteristics of blanket-like, distal deposits. The sulphide blankets are interpreted to be deposited from dense bottom hugging metalliferous brines or formed as a result of dispersion of a metalliferous plume on mixing with a stratified water column, characterized by reducing, sulphidic bottom waters.

<sup>1</sup> Continental Geoscience Division

## THE BUCHANS PROJECT: NEW CONCEPTS ON THE ORIGIN OF THE BUCHANS SULPHIDE DEPOSITS, NEWFOUNDLAND

J.G. Thurlow<sup>1</sup>, R.V. Kirkham<sup>2</sup>

Volcanogenic Zn-Pb-Cu-Ag-Au-barite deposits of the Buchans camp occur within submarine, bimodal volcanic rocks of the lower Middle Ordovician Buchans Group. They are distinguished by the extensive development of transported ores in which sulphide fragments were carried downslope in ore-grade debris flows, possibly from an evolving resurgent dome in a submarine caldera. The debris flows were controlled by synvolcanic normal faults which were subsequently reactivated during thrust faulting. The thrusts have resulted in several repetitions of ore and host rocks in antiformal stacks, recognition of which has changed completely the exploration potential and approach at Buchans.

An important new development is the discovery of clastic-intrusive rocks which contain high-grade Pb-Zn clasts and abundant altered and mineralized fragments in a quartz-bearing, comminuted matrix. These syntectonic, sheared mixtures intrude and follow the thrust fault zones over an area 1 km by 2 km near Lucky Strike. Their sheet-like distribution mimics that of the thrusts and they cause local hydraulic dilation of antiformal stack structures. One particularly well-developed example of this intrusive layer occurs 500 m structurally below the orebodies, strongly suggesting an undiscovered source for the abundant high-grade clasts in it.

<sup>1</sup> B.P. Resources Canada Limited, Corner Brook, Newfoundland

<sup>2</sup> Mineral Resources Division

## LANG LECTURE: NORANDA MASSIVE SULPHIDE DEPOSITS: A GUIDE TO EXPLORATION AND SEAFLOOR SULPHIDE RESEARCH

D.H. Watkins<sup>1</sup>, H.L. Gibson<sup>2</sup>

Efficient and successful exploration for volcanic-associated massive sulphide deposits is dependant upon a predictive genetic

model. The Noranda camp is an excellent laboratory where a detailed volcanological and ore-process model has been developed and refined. Exploration and research employing detailed 3-dimensional mapping of volcanic facies, structure and hydrothermal alteration assemblages enabled reconstruction of a large cauldron subsidence structure and paleo-hydrothermal system which controlled the location of massive sulphide deposits within the Noranda camp. Research on seafloor sulphide deposits has provided insights into metal zoning, sulphide textures, and structural controls, but is limited by its 2-dimensionality and lack of hard geological data. More research in established mining camps, particularly thematic mapping, is required to further refine our genetic model and exploration strategy.

<sup>1</sup> Minnova, Inc., Toronto, Ontario

<sup>2</sup> Falconbridge Limited, Sudbury, Ontario

## DESCRIPTIVE MODELS OF CANADIAN GOLD DEPOSITS

K.H. Poulsen<sup>1</sup>, F. Robert<sup>1</sup>, B.E. Taylor<sup>1</sup>, J.A. Kerswill<sup>1</sup>, R.I. Thorpe<sup>1</sup>, D.C. Harris<sup>1</sup>, J.M. Franklin<sup>1</sup>

Canadian lode gold deposits can be classified into four subtypes based on their geological setting and the nature of the ore comprising the deposits. Quartz-carbonate vein deposits(1) that typify greenstone terrains of all ages typically contain ubiquitous but low concentrations of sulphide minerals(1-10%) within or adjacent to veins. There are, however, notable examples of lode gold deposits that are particularly rich in sulphide minerals (10-70%), that are stratabound, and that do not owe their sulphide distribution to that of adjacent veins. Such deposits have been termed "replacement" deposits in the past but, because of genetic implications, it is preferable to regard these gold sulphide deposits as belonging to one of two subtypes, those hosted typically by mica schists(2) and those hosted by iron formation(3). Epithermal gold deposits(4), by virtue of their formation near a paleosurface, possess chemical, mineralogical and structural characteristics that distinguish them from the other three subtypes.

<sup>1</sup> Mineral Resources Division

## CANADIAN-CHINESE CO-OPERATION: MAGMATIC-HYDROTHERMAL GOLD DEPOSITS IN NORTH CHINA PLATFORM

B.E. Taylor<sup>1</sup>, F. Robert<sup>1</sup>, J.K. Mortensen<sup>1</sup>, K.H. Poulsen<sup>1</sup>

Co-operative field work was conducted during May-June 1989 on polymetallic gold vein deposits in NW Liaoning Province and Inner Mongolia by GSC and Chinese geologists under a Memorandum of Understanding for joint research. Underground and surface mapping of structural and petrographic features in the Jinchanggouliang-Erdaogou area documented chemical (Cu-Pb-Zn-Au-As-Sb) and mineralogical zoning about a Cretaceous plutonic/volcanic complex. Observations thus far suggest formation of gold-bearing veins in a magmatically-heated Mesozoic geothermal system. Continuing mineralogic, isotopic and geochronologic studies will constitute the first integrated modern approach to the origin of gold deposits in this area.

Examination of gold deposits in the Jiaodong uplift included the Linglong and Jiaojia mines. These deposits bore some resemblance to shear zone-hosted deposits in the Canadian Shield, and represented perhaps a lower structural level of exposure than did the deposits in the Jinchanggouliang-Erdaogou area.

<sup>1</sup> Mineral Resources Division

**SULPHURETS, BRITISH COLUMBIA:  
GEOLOGY, GEOCHEMISTRY AND MINERALOGY  
OF A DEFORMED PORPHYRY COPPER, MOLYBDENUM  
AND PRECIOUS METAL SYSTEM**

R.V. Kirkham<sup>1</sup>, S.B. Ballantyne<sup>1</sup>, D.C. Harris<sup>1</sup>

The Sulphurets area in the Coast Mountains of northwestern British Columbia contains a succession of Triassic and Jurassic sedimentary, volcanic and alkalic intrusive rocks that host large, pyritic alteration zones with porphyry Cu and Mo and a variety of precious metal occurrences.

The area has been subjected to low-grade regional metamorphism, heterogeneous penetrative deformation, and a complex fault history. Extensive original Cu- and Mo-bearing quartz vein stockworks have been flattened into ptigmatic and dismembered vein structures and phyllic and argillic(?) alteration zones now form large areas of quartz, sericite, pyrite schist. In addition to the early synvolcanic and synintrusive deposits, some bonanza-grade Au- ( $\pm$  Ag) bearing quartz ( $\pm$  carbonate, K-feldspar and/or barite) vein systems are probably younger and formed by syntectonic processes.

Lithogeochemical studies indicate large areas with Cu-Au, Mo-Au, Cu-Mo-Au, As-Au and Sb-Ag-Au associations and other areas with Cu and Mo that contain negligible amounts of Au. Most major Sb-Ag-Au bearing quartz-carbonate ( $\pm$  barite) vein systems are characterized by argentian tetrahedrite, pyrargyrite, polybasite and electrum but other vein systems contain arsenopyrite and/or tennantite with only minor amounts of Ag.

<sup>1</sup> Mineral Resources Division

**CHEMICAL CHARACTERISTICS OF MAGMATIC  
NI-CU-PGE SULPHIDE DEPOSITS AS  
EXPLORATION GUIDES**

O.R. Eckstrand<sup>1</sup>, L.J. Hulbert<sup>1</sup>

Mafic and ultramafic intrusions that contain significant concentrations of Ni, Cu and Platinum Group Elements (PGE) have chemical characteristics that appear to distinguish them from comparable intrusions which are barren. The most obvious characteristic, the presence of sulphides, signals the previous existence in the magma of sulphide melt that acted as a collector of Ni, Cu and PGE. The sulphide melt also depleted the Ni content of coexisting olivine to identifiably low levels.

Sulphide saturation of the magma to produce sulphide melt could have been attained by 1) magma mixing, indicated in layered intrusions by the presence of chromitite layers, and stratigraphic discontinuities in incompatible element concentrations, Nd/Sm isotopic ratios and (Pt,Pd)/(S,Se) ratios; and/or 2) crustal contamination, indicated by non-mantle sulphur isotope ratios, high Se and As in sulphides, high Zn in chromite, and presence of graphite/organic C.

<sup>1</sup> Mineral Resources Division



# POSTERS

## THE SETTING OF GOLD MINERALIZATION AT THE SAN ANTONIO MINE, UCHI SUBPROVINCE, MANITOBA

D.E. Ames<sup>1</sup>, M.H.S. Lau<sup>2</sup>, L.W. Diamond<sup>3</sup>,  
W.C. Brisbin<sup>4</sup>, K.H. Poulsen<sup>1</sup>

The San Antonio Mine is a mesothermal vein type gold deposit hosted in a brittle deformed differentiated mafic intrusion within a relatively ductile matrix of volcanic rocks. Five fracture sets developed, in the leucogabbro, during the rotation of principal stress axes relative to the boundaries of the sill. Alteration dominated by carbonation with minor K and Na metasomatism postdates regional greenschist facies metamorphism and defines a series of alteration isograds concentrically zoned around all vein sets irrespective of gold content. There is no evidence for significant fluid evolution during the formation of veins. P-T constraints based on fluid inclusion studies indicate that during unmixing (retrograde boiling) the minimums are T=200-240°C and 500-700 bars whereas, fluid-mineral assemblages in the veins suggest maximums of 420°C and 3.5 kbars. Metamorphic fluid inclusions restrict the temperature to less than 340°C thus, P-T conditions of vein formation are generally lower than those assumed for other mesothermal lode gold deposits in the Superior Province.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Noranda Exploration Company Ltd., Yellowknife

<sup>3</sup> Ottawa-Carleton Geoscience Centre, Department of Earth Sciences, Carleton University, Ottawa

<sup>4</sup> Department of Earth Sciences, University of Manitoba, Winnipeg

## SEDEX AND MISSISSIPPI VALLEY TYPE DEPOSITS IN JURASSIC CARBONATES OF PAKISTAN

W.L. Anderson<sup>1</sup>, J.W. Lydon<sup>2</sup>

The Shirinab Formation of the Karachi-Quetta fold belt represents a transgressive marine sequence of Lower to Middle Jurassic age and comprises a lower Spingwar member of quartz arenites, a middle Lorelei member of bedded limestones, and an upper Angira member of interbedded limestones and shales. Sedex deposits occur within the Angira member. The Gunga deposit near Khuzdar has been estimated to contain 10 million tons of 5%-6% Zn + Pb. The Duddar deposit, about 200 km south of Khuzdar, is currently being assessed by drilling. Both deposits are characterized by a lower zone of pyrite, marcasite, sphalerite and galena associated with siliceous to carbonaceous argillites, and an upper zone of bedded barite. The Surumai deposits, a few kilometres south of Gunga, are Mississippi Valley Type deposits in the Lorelei member, and are characterized by bedding-controlled replacement by siderite, sphalerite, quartz, minor galena and late calcite. These MVT deposits probably represent sub-seafloor mineralization coeval with the Sedex deposits.

<sup>1</sup> Department of Technical Corporation for Development, United Nations, New York

<sup>2</sup> Mineral Resources Division

## Sm/Nd, Rb/Sr AND Pb-Pb ISOTOPIC STUDIES OF ARCHEAN GOLD DEPOSITS

C.D. Anglin<sup>1</sup>, J.M. Franklin<sup>1</sup>, K.B. Bell<sup>2</sup>

Three isotopic methods are examined for determining the age of Archean gold deposits; lead isotope compositions of alteration pyrite from the Geraldton and Val d'Or areas, Sm/Nd of scheelites from gold veins in the Timmins and Val d'Or areas, and Rb/Sr systematics of sheared rocks in the Yellowknife area. Alteration pyrite from mineralized felsic intrusions in the Geraldton and Val d'Or areas yield linear arrays on <sup>207</sup>Pb/<sup>204</sup>Pb vs <sup>206</sup>Pb/<sup>204</sup>Pb isotope diagrams, the slopes of which correspond to ages of 2534 ± 35 Ma and 2545 ± 20 Ma respectively. Sm/Nd isotopic analysis of scheelite from Timmins yield an excellent Sm/Nd isochron, defining an age of 2404 ± 29 Ma. Preliminary scheelite Sm/Nd data from the Val d'Or area also yields a linear array which defines an age of approximately 2590 Ma. The feasibility of the Rb/Sr system for dating shear zones is being tested on samples from the Giant Mine in Yellowknife.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Carleton University, Ottawa

## A LARGE PROTEROZOIC FOSSIL HYDROTHERMAL ALTERATION SYSTEM AND ASSOCIATED BASE METAL MINERALIZATION, CHISEL LAKE, MANITOBA

A.H. Bailes<sup>1</sup>, A.G. Galley<sup>2</sup>

At least 20 percent of Amisk Group volcanic rocks in the Snow Lake portion of the Proterozoic Flin Flon Belt are hydrothermally altered. Alteration near Chisel Lake, primarily silicification and Fe-Mg metasomatism, has affected rocks over a stratigraphic interval of 4 kilometres and is strongest in a semiconformable zone 0.5 to 2 kilometres stratigraphically below the Chisel-Lost-Ghost Lakes Zn-Cu massive sulphide deposits. Alteration is attributed to hydrothermal activity caused by heating of intracratonic waters by several large synvolcanic tonalite intrusions and a subvolcanic dacite dyke complex. Iron and magnesium leached during silicification are interpreted to have been transported within the hydrothermal system and deposited in footwall rocks to the massive sulphide deposits. The largest zone of alteration is semiconformable, and occurs 1 to 2 kilometres below the Chisel-Lost-Ghost Zn-Cu deposits. Localization of this large semiconformable alteration zone within a unit of heterolithic volcanoclastic wacke and breccia implies that primary permeability played a major role in focussing hydrothermal fluid flow and resultant alteration. A series of highly altered faults in this formation are interpreted to be synvolcanic; if this interpretation is correct they may have been channelways for fluid flow to the seafloor.

<sup>1</sup> Manitoba Geological Services Branch

<sup>2</sup> Mineral Resources Division

## **GOLD HYDROGEOCHEMISTRY: AN EXPLORATION METHOD FOR THE CORDILLERA**

S.B. Ballantyne<sup>1</sup>

The application of gold hydrogeochemistry to exploration for precious metals is currently being tested in the Cordillera. One litre sample collection followed by bromine-hydrochloric acid desorption of Au lost to container walls, evaporation and measurement by graphite furnace atomic absorption spectrometry are proposed as cost effective field and laboratory procedures.

This investigation has tested spring, stream, pond or lake and mine water. Regional orientation stream water survey data (NTS 104M) shows that most water (pH 5.9 - 7.5) contains less than 0.2 ppt Au, yet, anomalous results of up to 3.9 ppt were obtained. Stream water monitoring of Graham Creek (NTS 104M 9) yielded anomalous Au contents ranging from 1.0 - 7.0 ppt at pH 7.57 from year to year.

The data suggests that enhanced hydromorphic dispersion of gold may be restricted to specific gold-ore deposit types.

<sup>1</sup> Mineral Resources Division

## **GEOCHEMISTRY OF SULPHURETS AREA, BRITISH COLUMBIA**

S.B. Ballantyne<sup>1</sup>

Results from whole rock and trace element lithogeochemical studies of drill core, underground and regional surface outcrop samples are presented. Extensive quartz - sericite - pyrite alteration zones hosting both porphyry Cu  $\pm$  Mo, Mo and precious metal mineralization are characterized by geochemical enrichment of K<sub>2</sub>O (often >5 weight %) and S (~4 weight %) and strong Na<sub>2</sub>O depletion (consistently <1 weight %).

The distinctive Ag-Au-Sb enrichment anomaly describes the Brucejack Lake precious metal ores. At the Kerr Cu porphyry elevated Se concentrations are present in drill core samples from important Cu-Au zones.

Some Mo enriched areas are associated with F  $\pm$  W anomalies both in drill core and outcrop samples.

Geochemical classification based on whole rock analysis of unaltered samples is in progress. The volcanic suite includes rhyolite, rhyodacite, latite-andesite, quartz-latite, dacite, latite, trachyte, latite-basalt and basalt while the granitoid suite includes monzo-diorite, syeno-diorite, monzonite, syenite-granite, quartz-syenite and diorite.

<sup>1</sup> Mineral Resources Division

## **MOUNT MYE, YUKON, POLYMETALLIC SILVER-TIN BRECCIAS: A NORTHERN EXAMPLE OF BOLIVIAN PRECIOUS METAL DEPOSITS?**

S.B. Ballantyne<sup>1</sup>, D.C. Harris<sup>1</sup>

The Mount Mye - Cody Ridge breccia zones or veins are located east of Faro, Yukon in the mid-Cretaceous Anvil Batholith (NTS 105K).

Microprobe and SEM studies have documented repeated brecciation of early quartz veins with later introduction and microbrecciation of quartz-chalcedony, rhodochrosite (banded-colloidal to crystalline) and the polymetallic mineral assemblage which includes pyrite, non-silver-bearing galena, Fe-rich sphalerite, arsenopyrite, stannite, needle cassiterite, canfieldite, silver-bearing tetrahedrite, diaphorite, semseyite, miargyrite, pyrargyrite and acanthite.

Perhaps the first equivalents of southern Bolivian Ag-Sn deposits to be recognized in Canada, the fracture controlled mineralization may have formed as a consequence of caldera development of coeval South Fork Volcanics or repeated seismic movements related to regional extensional tectonism along the Tintina Trench fault system.

Anomalous Sn, Sb, Mn, Zn, Pb, As and Ag are distinctive features of National Geochemical Reconnaissance stream sediment data for the area.

<sup>1</sup> Mineral Resources Division

## **Pb-Zn-Ag VEIN DEPOSITS, NORTHERN KOKANEE RANGE, BRITISH COLUMBIA**

G. Beaudoin<sup>1</sup>, D.F. Sangster<sup>2</sup>

Vein deposits of northern Kokanee Range were prominent Ag-Pb-Zn producers at the turn of the century. The deposits are hosted by Middle Jurassic Nelson granodioritic batholith and by Cambrian to Triassic sedimentary and volcanic rocks up to 12 km from the batholith margin.

The Silvana mine is the only current producer in the area. The orebody is constrained within the Main Lode, an E-W striking fault zone with an average dip of 45° to the south and which displays an oblique, normal and left-handed sense of movement. The ore consists of siderite-galena-sphalerite lenses which rapidly pinch and swell in all directions. Emplacement of the ore followed development of penetrative fabrics in the fault zone. Subsequent to ore deposition, the lenses were strongly foliated during late deformation event(s).

Assay data from two stopes at Silvana are very similar, particularly in terms of metal ratios and grades. Regression analyses indicate significant Ag-Pb and Ag-Zn correlations.

<sup>1</sup> Ottawa-Carleton Geoscience Centre, University of Ottawa

<sup>2</sup> Mineral Resources Division

## **MINERAL PROSPECTING USING REMOTE SENSING TECHNIQUES FOR GOLD AND URANIUM MINERALIZATION IN AREAS OF ULTRABASIC ROCKS**

J.R. Bélanger<sup>1</sup>

Prospecting methods involving the study of vegetation are based on the principle that plants draw their nutrients from elements present in the soil and should therefore reflect the chemical composition of the soil around them. Soil geochemical anomalies can influence plant chemistry (including chlorophyll production), distribution of species and health conditions. Analysis of spectral signatures, particularly in the infrared region, makes it possible to identify various types of vegetation and to study their distribution. It also permits identification of certain stress conditions related to geochemical anomalies. In this study, remote sensing is used to identify both geobotanical and biogeochemical anomalies.

A study in southeast Quebec has shown that the high concentration of ultrabasic debris in the glacial till affects the distribution of tree species and also causes vegetation stress such as a decrease in chlorophyll production, late leaf development in the spring and early senescence in the fall. At Star Lake, it was not possible to identify any geochemical anomaly, as these are relatively small and the mineralization associated with gold occurrences (quartz filled fractures) are not toxic to plants. Research is still underway in the Wollaston lake area, and preliminary results of multitemporal Landsat imagery shows that uranium anomalies can be detected by remote sensing.

<sup>1</sup> Terrain Sciences Division

## METALLOGENIC CONCEPTS TO AID EXPLORATION FOR THE GIANT OLYMPIC DAM-TYPE DEPOSITS AND THEIR DERIVATIVES IN CANADA

R.T. Bell<sup>1</sup>, S.S. Gandhi<sup>1</sup>

The giant Fe-Cu-U-Au-Ag-REE Olympic Dam deposit in South Australia shares many features with other monometallic and polymetallic deposits such as Kiruna in Sweden and Pea Ridge in Missouri. These deposits belong to a clan that includes magnetite-rich veins, breccia-fillings, disseminations and skarns, in and adjacent to porphyrites.

Most of the deposits are related to ensialic, post-tectonic, rhyolite-dominated sequences, differing from subduction-related, andesite-dominated magmatic arcs. Their parent magmas were probably generated by crustal underplating. The most favourable conditions for the formation of these magmas developed with gradual decline in secular radiogenic heat which about 1.9 Ga ago led to major cratonization. Significant transfer of uranium to near-surface environments at this time marks an important episode in uranium metallogeny.

Discovery of the Olympic Dam deposit resulted from the search for a progenitor of Cu (+U+Fe) deposits in younger Adelaidean diapirs. As such these specific younger deposits are termed "derivative". Some deposits in the African Copperbelt and Wernecke Mountains in Yukon are of this type.

<sup>1</sup> Mineral Resources Division

## GRAVITY INTERPRETATION OF THE BLATCHFORD LAKE INTRUSIVE COMPLEX

T.C. Birkett<sup>1</sup>, W.D. Sinclair<sup>2</sup>, D. Richardson<sup>2</sup>

Interpretation of a gravity survey of the Blatchford Lake Intrusive Complex is constrained by surface geology and measured rock densities. The intrusive complex is a thin tabular body composed of mafic and felsic intrusive rocks. Early intrusive phases are mafic in composition and underlie the western lobe of the complex. Here, granitic rocks of the western lobe intruded the gabbroic rocks and overlie them. The eastern lobe of the complex, comprising the Grace Lake and Thor Lake phases, was emplaced later than the rocks of the western lobe, and was not associated with mafic intrusive rocks. The Grace Lake Granite in this portion of the complex is up to 1 km thick. A relatively narrow mafic root underlies the western lobe to a depth of some 4 km. The major portion of the complex is floored at a depth of 1.5 to 1 km.

<sup>1</sup> Québec Geoscience Centre, Ste-Foy, Québec

<sup>2</sup> Mineral Resources Division

## IS THE VAL D'OR FORMATION AURIFEROUS?

T.B. Birkett<sup>1</sup>, F. Robert<sup>2</sup>, D. Richardson<sup>2</sup>, S.B. Green<sup>2</sup>

Detailed sampling using a portable diamond drill, and interlaboratory comparison of selected samples have been combined with statistical studies of truncated populations to establish the gold content of several outcrops in the Val d'Or area. This study establishes that the gold content of the Val d'Or Formation is in the order of 4 ppb or less. This value is typical of many volcanic rocks of the Canadian Shield. Gold is distributed relatively homogeneously within the outcrops studied except for slightly increased concentrations within quartz - tourmaline veinlets. The variability of gold concentrations within the Formation forbids the testing of hypotheses involving large-scale gold mobility to form the gold deposits of the region. The Val d'Or Formation is not auriferous.

<sup>1</sup> Québec Geoscience Centre, Ste-Foy, Québec

<sup>2</sup> Mineral Resources Division

## GRAVITY AND ELECTROMAGNETIC INVESTIGATIONS OVER THE LEMIEUX DOME, GASPÉSIE, QUÉBEC

D.E. Boerner<sup>1</sup>, G.W. McNeice<sup>1</sup>, R.D. Kurtz<sup>1</sup>, A.G. Jones<sup>1</sup>

During August 1988, a controlled source audio-magnetotelluric (CSAMT) survey and a reconnaissance gravity survey were conducted over the Lemieux Dome in the northern Gaspé region of Quebec. The area is economically interesting because of the mineralized veins and strong mineral zoning found at surface. However, very little ore grade mineralization has actually been discovered at depth despite extensive drilling. The purpose of the surveys was to determine if the dome was uplifted by a deep intrusion and to re-examine the postulated history for creation and mineralization of the Dome. The gravity data defines a positive density anomaly in the northern part of the Dome (possibly correlated with skarns,  $\rho = 3.5 \text{ g/cm}^3$ ) while the EM survey indicates the presence of a very resistive body (the intrusive?) underlying much of the dome at depths greater than 800m. Complete results and preliminary interpretations of both surveys will be presented.

<sup>1</sup> Continental Geoscience Division

## SPATIAL INTEGRATION OF SNOW LAKE, MANITOBA DATA SETS USING GIS TECHNOLOGY

G.F. Bonham-Carter<sup>1</sup>, R. Reddy<sup>1</sup>, D.F. Wright<sup>1</sup>

A PC-based GIS system is being used to compile, display, interactively integrate and model geoscientific data related to base-metal mineralization in the Snow Lake area. The GIS employs a quadtree database structure which, because it involves a variable pixel size, is particularly efficient for handling geological maps that vary in scale. Maps digitized from a 1:50,000 scale provide complete regional coverage; 1:25,000, 1:15,840 and 1:5,000 sheets provide patchy but detailed coverage of specific areas. Regional geophysics, geochemistry, metamorphic facies, Landsat and structural elements are incorporated in the database.

Maps suitable for predictive modelling are first derived from the raw data. For example, anomaly maps are calculated from the geophysical and geochemical layers, and proximity maps are produced from the database showing distance to critical contacts or structures. The spatial association of each predictor map with the known mineral occurrences is calculated using a weights of evidence model. These weights are then used for integrating predictive layers to produce a map showing probability of mineralization.

<sup>1</sup> Mineral Resources Division

## STRUCTURAL SETTING OF ARCHEAN GOLD DEPOSITS, BERESFORD LAKE, SOUTHEAST MANITOBA

R. Brommecker<sup>1</sup>, C.J. Hodgson<sup>1</sup>, K.H. Poulsen<sup>2</sup>

Five small past-producing gold deposits, composed of quartz-carbonate veins in shear zones, occur in metavolcanic and metaplutonic rocks in the Beresford Lake area. The shear zones, along with cleavage and folds, formed during each of three increments of deformation. The youngest of these (D3), a shortening from the NNW, produced local crenulation cleavage, kink bands and conjugate sets of brittle faults and shear zones. These structures overprint D2 features which include mesoscopic folds (F2), a penetrative axial plane schistosity (S2), and a pronounced mineral and object lineation (L2) that is coincident with F2 fold axes. Shortening recorded by D2 was from the NE and also resulted in the common development of D2 shear zones. The

oldest deformation (D1) is inferred from local schistosity and shear zones that are overprinted by both D2 and D3 structures. Gold and carbonatization in the Beresford Lake area are controlled in most cases by D1 shear zones but locally by D2 structures.

<sup>1</sup> Queen's University, Kingston, Ontario

<sup>2</sup> Mineral Resources Division

## POTENTIAL FIELD DATA: A GUIDE FOR EXPLORATION IN THE ABITIBI GREENSTONE BELT

J. Broome<sup>1</sup>, E.J. Schwarz<sup>1</sup>, M.D. Thomas<sup>1</sup>

The Abitibi greenstone belt is extensively covered by glacial overburden. Gravity and magnetic potential field signatures provide a means of probing beneath it and significantly improving knowledge of bedrock geology. This is a vital contribution to mineral exploration. Various maps can be derived from fundamental potential field data sets, each of which may enhance particular features of the geophysical field, e.g. maps of the first vertical derivative and horizontal gradient. Further enhancement may be achieved by portraying maps in different formats such as grey-tone, colour or shaded images. Comparison of geological boundaries on the 1983 MERQ-OGS (1:500,000) map of the Abitibi belt with geophysical images reveals discrepancies in several areas: new areas of potential interest for base metal exploration are thus defined. Gold exploration may also benefit from structural information derived from magnetic and gravity maps: fault-bounded lozenge-shaped crustal blocks in the southern half of the belt may reveal themselves in geophysical images of the northern half where widespread overburden hampers geological mapping.

<sup>1</sup> Continental Geoscience Division

## DETAILED AIRBORNE RADIOMETRIC, MAGNETIC AND ELECTROMAGNETIC AND PRELIMINARY GROUND FOLLOW-UP OF RELIANCE AREA, NORTHWEST TERRITORIES

B.W. Charbonneau<sup>1</sup>, S.S. Gandhi<sup>1</sup>, D.R. Lentz<sup>2</sup>, S.M. Roscoe<sup>1</sup>

A detailed airborne survey of an area straddling the boundary of the Archean and Proterozoic terranes near Reliance at the northeast end of Great Slave Lake, was carried out in 1988 and published in 1989 as GSC Open File 1988.

The survey, which covers part of an area proposed as a National Park, revealed distinctly anomalous zones of U, Th, U/Th ratio and total counts, strongly magnetic zones, and weak electromagnetic anomalies.

A ground follow-up program conducted in 1989 revealed large bodies of garnetiferous coarse granites characterized by high total counts and high U/Th ratio, and of a Th-rich medium grained to subporphyritic granite forming a large circular pluton, in the Archean terrane. The body coincides with a circular magnetic anomaly, and is bounded by a ring fracture which is marked by a topographic low, and has an airphoto expression as a semicircle approximately 33 km in diameter. Exposures at a locality in the northern part of the ring fracture show brecciated granite with carbonate, quartz, hematite, sericite. It is conceivable that a deep-seated intrusion (possibly peralkaline) has caused the ring fracture.

<sup>1</sup> Geological Survey of Canada

<sup>2</sup> Ottawa-Carleton Geoscience Centre, University of Ottawa

## RESOURCE ASSESSMENT AND PREDICTIVE METALLOGENY OF VMS DEPOSITS IN THE QUEBEC ABITIBI

F. Chartrand<sup>1</sup>, P. Verpaalst<sup>1</sup>, D. Racicot<sup>1</sup>, C. Roy<sup>1</sup>, A. Simard<sup>1</sup>

In 1989, the SGNO initiated a high-priority, long-term project concerned with metallic resource assessment and predictive metallogeny of volcanogenic base metal deposits in the Quebec Abitibi belt. The following is a brief description of Phase 1.

The first phase involves an evaluation of the base metal deposits in the Rouyn-Noranda district contained within NTS map 32D/6. This area was chosen because: (1) the geology is well-known, and information is abundant; (2) the eastern portion (the control zone), centred on the Mine Series, includes most of the area's volcanogenic deposits; and (3) the favorable geological environment is widespread in the western portion (the test zone) of the Rouyn-Noranda camp where there have been few massive sulfide discoveries of economic significance.

Volcanogenic massive sulfides were chosen as a deposit type because: (1) their descriptive/genetic models are fairly well established; and (2) they are an important source of copper and zinc, metals whose reserves are forecast to decline in the coming years.

Quantitative models will be formulated by studying the frequency-of-occurrence of volcanogenic deposits in the well-explored control zone, grade and tonnage models, and the areal extent of zones of varying mineral potential.

The validity of the quantitative evaluation approach is clear, given the vast quantity of geological information available to the geologist today.

<sup>1</sup> Ministère de l'Énergie et des Ressources du Québec, Val d'Or

## THE BEHAVIOUR OF PLATINUM GROUP ELEMENTS IN THE SURFICIAL ENVIRONMENT IN CANADA

W.B. Coker<sup>1</sup>, C.E. Dunn<sup>1</sup>, G.E.M. Hall<sup>1</sup>, A.N. Rencz<sup>1</sup>, R.N.W. DiLabio<sup>2</sup>, W.A. Spirito<sup>1</sup>, J. E. Campbell<sup>3</sup>

Over the past few years a multidisciplinary geochemical study of the platinum group elements (PGE) has been under way at the Geological Survey of Canada (GSC). This includes examination of the distribution and dispersion, as well as the glacial dispersal, of the PGEs and associated elements within soils, tills, humus, vegetation and water at a number of locations. The objective is to develop an adaptable methodology that can be used to explore for PGEs under varied surficial conditions and degree of burial beneath glacial sediment cover.

This ongoing study shows that surficial materials and vegetation are effective in identifying areas of concealed PGE mineralization. Various pathfinder elements (e.g. As, Se, Sb and the base metals, particularly in the <2 µm B-horizon soils and tills) may be informative in a preliminary evaluation of the PGE potential of an area prior to undertaking the more expensive precious metal analyses. Both the humus and vegetation appear extremely effective and cost-efficient for identifying broad areas with PGE potential; whereas heavy mineral concentrates from tills appear most effective for zeroing in on PGE mineralization.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Terrain Sciences Division

<sup>3</sup> Saskatchewan Research Council, Saskatoon

## **GEOCHEMISTRY (TILL, GOSSAN AND LAKE SEDIMENTS) AND SURFICIAL GEOLOGY OF THE FERGUSON, YATHKYED AND CONTWOYT LAKES AREAS, NWT**

W.B. Coker<sup>1</sup>, W. A. Spirito<sup>1</sup>, R.N.W. DiLabio<sup>2</sup>, B. Hart<sup>1</sup>

Significant levels of platinum, palladium and associated elements are present in the Ferguson Lake gossan, but there is only limited dispersal of these elements in the till down-ice from mineralization. It appears that there is marked supergene enrichment of several elements including Pt, Pd, Au, Ni, and Cu in the gossan.

Reconnaissance and detailed till geochemical data outline the gold-bearing units in the Yathkyed Lake area. The newly observed sequence of ice flow directions in this area suggests that glacial transport from mineralized zones may be complex.

Reconnaissance till and lake sediment geochemical data delineate the gold-bearing units in the Contwoyto Lake area. Detailed till geochemical data reflect the presence of gold mineralization on the six grids examined. Indications are that reworking of till and other surficial sediments in Glacial Lake Contwoyto could affect the results of lake sediment and soil geochemical surveys by diluting element concentrations or distorting dispersal patterns.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Terrain Sciences Division

## **METALLOGENY OF VEIN GOLD DEPOSITS, ROUYN-NORANDA DISTRICT**

J.-F. Couture<sup>1</sup>, P. Pilote<sup>1</sup>

The Rouyn-Noranda district has produced 580 metric tonnes of gold to date, 144 of which originated from 28 vein-type deposits. The distribution of the deposits in relation to the geology of the mining camp illustrates well the different styles of gold mineralization.

Aside from the 436 metric tonnes extracted from massive sulfide deposits, gold is produced from quartz veins injected into mafic and felsic volcanics, sediments, and granitic intrusions. Furthermore, shear zones hosting disseminated sulfides also produce gold.

In 1989, the Ministère de l'Énergie et des Ressources du Québec undertook the study of gold deposits in the Rouyn-Noranda district, the goal being to document the diverse mineralization styles and to understand their fundamental relationships with the district geology. This study is predicated upon collaborative research between ourselves, university and industry geologists.

The gold deposits in the Rouyn-Noranda area are grouped into 5 categories with respect to the local geological environment as follows: (1) the Cadillac Fault; (2) the Destor Fault; (3) the Francoeur-Wasa shear; (4) faults within granitic intrusions; and (5) faults affecting volcanic piles where the structural context is poorly understood. Over the next few years, we will describe the geological context of deposits in each of the 5 categories. The deposits studied during the 1989-1990 year are the McWatters, Duquesne, Francoeur, Elder and Bellettre mines.

<sup>1</sup> Ministère de l'Énergie et des Ressources du Québec, Val d'Or

## **GEOCHEMICAL MAPPING IN NEWFOUNDLAND: ITS USE IN REGIONAL METALLOGENY**

P.H. Davenport<sup>1</sup>, W.L. Nolan<sup>1</sup>

Geochemical mapping based on drainage sediment geochemistry reflects a summation of geochemical processes active

within a survey area throughout its geological history, and of these processes those of ore-formation are typically well reflected in the drainage geochemistry, and can be further enhanced by integrating geochemical data with geological and geophysical data to reduce the variability caused by other geological factors. On a regional scale systematic geochemical mapping, such as Canada's National Geochemical Reconnaissance Program, provides an unique and objective overview of the distribution, scale, and geochemical nature of mineralizing processes. Mineral occurrence distribution maps and data banks are usually deficient in geochemical data and, because of the nature of the exploration process, are neither quantitative nor objective. These problems are worst in areas that have been little explored, whereas geochemical mapping data are consistent irrespective of exploration history (and perceived mineral potential).

In Newfoundland, the distributions of Au, Sb and W in regional lake sediment data provide good examples of how geochemical mapping can provide the logical starting point for developing regional metallogenic models for commodities for which there are no comprehensive models. The relationships between the regional distributions of these three elements, none of which has much history of exploitation in Newfoundland, to geology and the metallogenic implications are discussed.

<sup>1</sup> Geological Survey Branch, Newfoundland

## **GOLD-RICH SKARNS OF THE CANADIAN CORDILLERA**

K.M. Dawson<sup>1</sup>

Five types of skarn gold deposit are recognized in the Canadian Cordillera:

1. Skarns mined for Au alone have high Au, As, Bi and Te, low base metals, a higher clastic component in host rocks and more mafic associated intrusions relative to other skarn gold subtypes (i.e. Hedley, Tillicum Mountain, Quesnel River and Dividend-Lakeview).
2. Porphyry Cu, Au skarns are large, low in Au grade, and rich in andradite, diopside, disseminated Cu sulphides, magnetite and mehatite (i.e. Ingerbelle, Galore Creek, Cariboo Bell and Craigmont).
3. Cu, Au skarns are distinguished from porphyry Cu, Au skarns by lack of Cu and Mo sulphides in the more mafic-associated intrusions, and smaller, more massive and Au-rich orebodies (i.e. Greenwood District, White Horse Copper Belt).
4. Fe, Au skarns are associated with large calcic magnetite skarns in which Au is concentrated with erratically-distributed Fe and Cu sulphides (i.e. Coast Copper, Marble Bay, Oro Denoro, Emma).
5. Zn, Pb skarns, more commonly enriched in Ag than Au, include Midway, YP and Ray.

<sup>1</sup> Mineral Resources Division, Vancouver

## **REGIONAL METALLOGENY OF THE CRATON AND ACCRETED TERRANES OF THE CANADIAN CORDILLERA**

K.M. Dawson<sup>1</sup>

In the geologically diverse Canadian Cordillera, each terrane preserves a stratigraphic record different from those of neighbouring terranes. Characteristic suites of mineral deposits, as integral parts of their host terranes, reflect fundamental differences in their depositional environments.

Metallogenic analysis of craton, pericratonic and accreted terranes of the Canadian Cordillera demonstrates a consistent relationship between the lithotectonic character of host terranes and the type and composition of their typical suites of mineral deposits.

Present knowledge of the time of tectonic, plutonic and metallogenic events, although imperfect, allows classification of mineral deposition according to the accretionary history of the host or immediately adjacent terrane.

Pre-accretionary mineral deposits are predominantly stratiform types, hosted by sedimentary and volcanic strata. Accretionary deposits are minor, mainly due to the difficulty in ascribing the generation of a plutonic suite and attendant mineralization to a specific accretionary event. The majority of granitoid-related porphyry, skarn and vein deposits are post-accretionary.

<sup>1</sup> Mineral Resources Division, Vancouver

## STRUCTURAL HOSTED GOLD, GLENNIE LAKE DOMAIN, LOWER PROTEROZOIC TRANS-HUDSON OROGEN

G.D. Delaney<sup>1</sup>

Structurally controlled gold mineralization in the Glennie Lake Domain is illustrated by two examples: the Seabee Deposit and the Brownell-Maynard Lakes showings.

The Seabee deposit has proven and probable ore reserves of 585,134 tonnes grading 12.5 g/t Au and possible reserves of 332,869 tonnes grading 12.5 g/t Au. Seabee ore is hosted in discontinuous quartz-tourmaline veins in northeasterly trending shear zones, up to 200 m in length, in gabbroic and dioritic rocks of the Laonil Lake Intrusive Complex (ca 1889 ± 8.7 Ma). The auriferous quartz veins are flanked by a potassic alteration halo and show a distinct spatial association with narrow, sulphide-bearing feldspar porphyry bodies. Shear zone formation is thought to be contemporaneous with development of the major Laonil Lake Shear Zone at the southern boundary of the basic intrusive complex with the tonalitic Eyahpaise Lake Pluton.

There are several gold showings in the east-west trending Brownell Lake Greenstone Belt which comprises both supracrustal rocks and late stage composite intrusions. The belt is separated from the granitoid Oskikebuk Block to the south by the major Hartley Shear Zone. Many of the showings are in patchy irregular networks of quartz veins near the margins of a composite pluton. More economically significant gold concentrations are found, however, in two structural settings: 1) in narrow secondary shear zones, parallel or subparallel to the Hartley Shear Zone, that cut mafic to intermediate volcanics, 2) in heterogeneously sheared diorite of the Maynard Creek Pluton within a few hundred metres of the northern margin of the Hartley Shear Zone. The increasingly recognized association of gold mineralization and shear zones suggests that several recently identified structures in the southern Glennie Lake Domain warrant evaluation for gold potential.

<sup>1</sup> Saskatchewan Energy and Mines, Regina

## SHAPES AND SURFACE TEXTURES OF GOLD GRAINS IN TILL

R.N.W. DiLabio<sup>1</sup>

Gold grains that have been glacially transported often show evidence of their glacial and postglacial history in their shapes and surface textures. These features can help in drift prospecting for the gold's source by indicating the relative distance of transport, the possibility of recycling, and postglacial weathering effects. Sand- and silt-sized grains from till from several localities have been examined and have been classified into the following textural groups: pristine, curled, corroded, or striated. Pristine grains can be interpreted either as grains that have not travelled far or as

grains that have weathered out of unstable host minerals during the postglacial. Curled grains are characteristic of recycled fluvial gold, and where found in till, may indicate recycling of older fluvial sediments, and therefore would be difficult to trace back to a bedrock source. Striated grains are strong evidence of glacial transport, and they are the most useful type in exploration, especially when found in large numbers in till. Corrosion of gold (actually leaching of silver from a thin rim) is common on grains from oxidized till, but the original shape and texture of the grain is usually still visible, e.g., where striae are perforated by corrosion pits.

<sup>1</sup> Terrain Sciences Division

## CLASSIFICATION AND STRUCTURAL SETTING OF GOLD-ONLY DEPOSITS AND OCCURRENCES IN THE CANADIAN APPALACHIANS: A PRELIMINARY REPORT ON WESTERN NEWFOUNDLAND

B. Dubé<sup>1</sup>

In the last 10 years, significant gold-only deposits spatially associated with major fault zones have been discovered in the Canadian Appalachians. Most are in Western Newfoundland but some others in the Maritimes Provinces. Preliminary field investigations suggest that Western Newfoundland gold-only deposits can be morphologically subdivided into two main types: i) Disseminated stratabound sulphide gold deposits (DSSG); and ii) Mesothermal vein type. The former is subdivided into two subtypes: 1) DSSG in silicified rocks (Hope Brook); and 2) DSSG in sedimentary rocks (Nugget Pond); and the latter is subdivided into 1) quartz vein type (Cape Ray) and 2) altered wallrocks type (Stog'er tight). The influence of structural control on gold mineralization varies from deposits which do not exhibit any significant structural control (Nugget Pond), to deposits which seem more deformed by a major fault zone then genetically related to them (Hope Brook mine), to deposits genetically related to shear zones (Cape Ray). The latter appear to be located in second order structures or splays associated with major fault zones.

<sup>1</sup> Québec Geoscience Centre, Ste-Foy, Québec

## LITHOLOGICAL CORRELATION AND DETERMINATION OF PHYSICAL ROCK PROPERTIES WITH BOREHOLE GEOPHYSICS

B.E. Elliott<sup>1</sup>, C.J. Mwenifumbo<sup>1</sup>, P.G. Killeen<sup>1</sup>

Determining the structure of mineral deposits from geological logs of drill core and other geological data is a difficult problem for geologists. Hole-to-hole correlation can be facilitated with geophysical logs of the boreholes. Changes in physical properties, such as magnetic susceptibility, density, electrical resistivity, polarizability, thermal conductivity and natural radioactivity, which may not be visible in drill core, can provide characteristic signatures of the rocks intersected by the borehole for use in lithological correlation.

Knowledge of the Physical Properties of country rock, as well as the anomalous physical properties of the exploration targets is also important for surface and airborne geophysical exploration methods. Exploration for massive sulphides in the Cordillera has been constrained by the use of geophysical equipment optimized for rocks of the Canadian Shield.

The use of borehole geophysical logs in lithological correlation, and the derivation of physical property information will be illustrated for several deposits in British Columbia.

<sup>1</sup> Mineral Resources Division

## AEROMAGNETIC/GRADIOMETER/VLF-EM SURVEYS, NEW BRUNSWICK, NEWFOUNDLAND AND NOVA SCOTIA

B. Ellis<sup>1</sup>, P. Stone<sup>1</sup>, E. Ready<sup>1</sup>, D.J. Teskey<sup>1</sup>, J. Tod<sup>1</sup>

The existing aeromagnetic total field coverage of Nova Scotia was compiled as part of the National Earth Science 1:1 000 000 map series, on an 813 m grid. The data set includes federal-provincial and private regional surveys.

Between 1975 and 1983, the G.S.C. experimental surveys group carried out five experimental surveys to demonstrate the effectiveness of vertical gradiometry as a detail mapping tool. As a result, additional areas were either flown or purchased under the Nova Scotia-Canada Mineral Development Agreement 1984-1989. The lithological and structural information which will be gained from this higher sensitivity data is significantly greater than available from the older data set.

The results are available as digital profile and gridded data, as well as map products. Gradiometer and total field contour maps are available at 1:25 000, total field and gradiometer colour interval maps with VLF-EM profiles plotted on the reverse, at 1:50 000.

In 1984, 1985, 1986 and 1988 a total of 55,809 kilometres of helicopter aeromagnetic total field/gradiometer/VLF surveys lines were flown over the Miramichi tectonic zone under contract to the Geological Survey of Canada as a contribution to the Canada-New Brunswick Mineral Development Agreement.

The flight line separation was 300 m at a mean elevation clearance of 150 m.

Final survey products were in the form of digital data and 1:20,000 aeromagnetic total field and gradiometer contour maps. For years 1984 and 1985, 1:50,000 total field and gradiometer colour interval maps and in 1986 and 1988, 1:50,000 residual total field and gradiometer colour interval maps were produced. VLF-EM data, using stations at Cutler, Maine and Annapolis, Maryland, were presented in the form of profiles.

The Canada-New Brunswick MDA funded gradiometer surveys have made a significant contribution to the detailed mapping of the Miramichi volcanic-sedimentary belt.

A demonstration total field/gradiometer/VLF-EM survey was flown by the GSC's Queenair development team in the summer of 1983 between latitudes 48°45'N and 49°0'N and longitudes 56°0'W and 57°0'W in the Dunnage zone of Newfoundland. The purpose of this survey was to demonstrate the effectiveness of vertical gradiometry as a tool for detailed geological mapping of this important metallogenic zone.

During the Canada-Newfoundland Mineral Development Agreement 1984-89, additional surveys were flown to the south by Questor Surveys Ltd. in 1984/85 and by Aerodat Ltd. in 1986/87. All three surveys were flown with a line separation of 300 m and at a mean terrain clearance of 150 m. Products, in addition to the profile and gridded data are 1:25 000 gradiometer and total field contour maps and 1:50 000 total field and gradiometer colour interval maps with VLF stacked profiles plotted on the reverse.

The combined results of these three surveys have made a significant contribution to structural and lithological knowledge base of this zone.

<sup>1</sup> Geophysics Division

## GOLD POTENTIAL OF THE YELLOWKNIFE MINING DISTRICT, N.W.T.

H. Falck<sup>1</sup>

In 1934 the discovery of gold on the east side of Yellowknife Bay sparked a concerted exploration effort 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 mines and numerous smaller operations, attesting to the mineral wealth of the region.

Present exploration efforts are being concentrated on the following settings:

- Large anastomosing quartz-carbonate-sericite-chlorite shear zones in mafic Kam Group volcanic rocks.
- Shear zones with carbonate and sericite alteration haloes in Banting Group felsic and sedimentary rocks.
- Mineralized shear zones in early granitoid phases of the Western Plutonic complex.
- Early structural, pre-metamorphism quartz veins in greenschist to lower amphibolite grade Burwash Formation turbidite deposits.
- Strongly foliated iron-sulphide-rich pods in turbiditic Walsh Formation sediments.

In spite of a 50 year history of exploitation, the Yellowknife area still has great potential for new discoveries.

<sup>1</sup> Energy, Mines and Petroleum Resources, Government of the Northwest Territories, Yellowknife

## THE AGASSIZ METALLOTECT - A METALLOGENETIC CONCEPT

M.A.F. Fedikow<sup>1</sup>, D. Parbery<sup>1</sup>, K.J. Ferreira<sup>1</sup>

The Agassiz Metaltect is a 70 km long by 1 km wide sequence of picritic basalt, sulphide-, silicate- and oxide-facies iron formation, clastic sedimentary rocks and minor felsic volcanic rocks characterized by coincident magnetic and electromagnetic geophysical anomalies along its entire length. The sequence has been overprinted by a series of *en echelon* east-west trending shear zones that are significant in terms of mobilizing gold and base metal mineralization. Five gold ± silver deposits, including the MacLellan Au-Ag deposit (1 174 Mt grading 6.51 g/t Au and 18.89 g/t Ag), occur within this stratigraphy. The Aphebian Lynn Lake greenstone belt, containing the Agassiz Metaltect, offers excellent residual exploration potential.

<sup>1</sup> Manitoba Department of Energy and Mines, Winnipeg

## UTILIZATION OF GAMMA-RAY SPECTROMETRY IN MULTI-ELEMENT MINERAL EXPLORATION

K.L. Ford<sup>1</sup>, B.W. Charbonneau<sup>1</sup>, R.B.K. Shives<sup>1</sup>

The systematic acquisition of high sensitivity, quantitative, airborne gamma ray spectrometric (AGRS) data by the Geological Survey of Canada has helped to expand the role of gamma ray spectrometry to include applications to regional and detailed bedrock and surficial geological mapping, environmental studies and multi-element mineral exploration.

Mapping of the variations in the absolute and relative proportions of the three radioelements K, U, and Th offers assistance to exploration for many commodities, most obviously U, but also, when used as pathfinders, for Sn-W, rare and high technology metals. In special cases the radioelements can also point to precious and base metal mineralization when their concentrations and ratios have been modified by the mineralizing

process thereby altering the normal radioelement signature of the host lithology.

Although AGRS surveys are useful in most geological environments, they generally work best in granitic and gneissic dominated terranes where radioelement concentrations and contrasts are strong and aeromagnetic patterns may not be as well defined. Consequently the two techniques have a complimentary relationship.

<sup>1</sup> Mineral Resources Division

### COMPARATIVE STUDIES OF HYDROTHERMAL ACTIVITY ON THE JUAN DE FUCA RIDGE CREST

J.M. Franklin<sup>1</sup>, C.D. Anglin<sup>1</sup>, E.S. Kappel<sup>2</sup>

VMS deposits vary from isolated zinc-rich chimneys at Southern Juan de Fuca (SJDF), to zinc-copper sulfide mounds (200 to 400 m diameter) at Endeavour and Explorer segments, and to larger, pyrrhotitic deposits in sedimented ridges (Middle Valley). Their sizes and compositions are related to specific cyclical stages of ridge crest tectonism.

Stage 1, a period of excessive extrusive volcanism, builds a major elongate volcanic edifice. Large deposits (Explorer) formed immediately following volcanism, along major faults bounding the axial graben. Stage 2 is a period of volcanic quiescence; continued tectonic stretching forms a wide graben, with large deposits (Endeavour) along bounding faults. Stage 3 is a period of renewed volcanism, forming well-drained lava lakes that fill the broad graben; small sulfide deposits (SJDF) are confined to the narrow axial fissure.

The largest deposits from where either a volcanic edifice or sediment cover provides sufficient "insulation" to enable formation of a large, stable reservoir, at or near the top of the magma chamber, and allows hydrothermal fluid to ascend to the seafloor without significant cooling through mixing.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Joint Oceanographic Institutions Inc., Washington

### A GOLD RICH MASSIVE SULPHIDE DEPOSIT IN THE AXIAL SEAMOUNT CALDERA, JUAN DE FUCA RIDGE

J.M. Franklin<sup>1</sup>, G.E.M. Hall<sup>1</sup>, M. Hannington<sup>1</sup>, I.R. Jonasson<sup>1</sup>

Three fields of mounds and chimneys, each along a NE-trending fracture, include: 1) The ASHES field: three black smokers are discharging up to 328°C, Cl-normal (515-626 mmol kg<sup>-1</sup> fluid). The mature chimneys are zinc-rich (~25%) and copper poor (~1%). Immature vents contain anhydrite, overgrown and replaced by pyrite and sphalerite. A second group of 300°C vents have remarkably chlorine- and base metal-deficient fluids (179 mmol kg<sup>-1</sup> Cl). 2) The CASM site has only low-temperature (max. 100°C) vents, with chimneys dominated by barite, silica, sphalerite and pyrite. 3) EAST RIFT baritic chimneys are inactive, and have unusually high lead (ca. 4%), and silver (ca. 400 ppm).

Au and Ag are enriched (up to 5 g/t and 1000 g/t respectively) in all Axial sulphides cf. all other Juan de Fuca sites; precious metals correlate with Pb and Sb, and abound in the outer, coolest portions of chimneys. Boiling has effected the separation of the Cl-poor vapour phase; it contains abundant CO<sub>2</sub>, Au, Sb, As, H<sub>2</sub>S, and SiO<sub>2</sub>. Lowered temperature and increased pH induced by boiling promotes transport of Au as a bi-sulphide complex; oxidation of this complex causes deposition of abundant gold.

<sup>1</sup> Mineral Resources Division

### THE SUB-THELON FORMATION PALEOSOL, AND ITS CORRELATION WITH SIMILAR PALEOSOLS IN THE NORTHWESTERN CANADIAN SHIELD

Q. Gall<sup>1</sup>, J.A. Donaldson<sup>1</sup>

The sub-Thelon Formation paleosol developed on a variety of protoliths following extrusion of the 1.76 Ga Pitz Formation rhyolite, and prior to 1.72 Ga diagenetic apatite formation in the Thelon Formation. The saprolitic paleosol ranges in thickness from 1m to 100m. The paleosol characteristically displays a colour zonation from a green-grey base to a red top, and an upward increase in disruption of original protolith textures. Lithochemical trends in paleoweathered gneiss and granite show a consistent upward increase in SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>/FeO, and CIA values, and upward decrease in MnO, MgO, CaO, Na<sub>2</sub>O, K<sub>2</sub>O, V, Rb and Ba. Chronological constraints and similarity of physical and mineralogical features in the paleosol beneath the Hornby Bay, Elu and Athabasca basins, suggest that they formed during the same period of continental weathering following the amalgamation of Laurentia and prior to a relative sea-level rise and accompanying siliciclastic sedimentation.

<sup>1</sup> Ottawa-Carleton Geoscience Centre, Department of Earth Sciences, Carleton University, Ottawa

### GEOLOGIC SETTING OF THE CHISEL LAKE Zn-Cu VOLCANOGENIC MASSIVE SULPHIDE DEPOSIT AND ASSOCIATED ALTERATION, SNOW LAKE, MANITOBA

A.G. Galley<sup>1</sup>, A.H. Bailes<sup>2</sup>

The Chisel Lake deposit is hosted by strongly deformed Amisk Group volcanic and volcanoclastic strata metamorphosed to biotite-almandine grade, with original reserves of 9.85 million tonnes grading 10% Zn, 0.4% Cu, 2.31 gms Au/tonne and 53 gms Ag/tonne. The stratigraphic footwall comprises rhyolite flows and fragmental rocks underlain by more extensive dacite pyroclastic flows; the hangingwall consists of mafic volcanoclastic rocks. An extensive footwall alteration pipe has been divided into eight zones that include potassic-, iron-, magnesium-, aluminum- and magnesium-rich mineral assemblages, with the latter associated with sphalerite-rich stringer ore. The isoclinally folded orebody is composed of coarse-grained, banded sphalerite-pyrite, with associated precious metal-rich galena veins that parallel F<sub>1</sub> fold axes.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Manitoba Geological Services Branch, Winnipeg

### CONTROLS AND TIMING OF GOLD MINERALIZATION IN THE REINDEER ZONE, TRANS-HUDSON OROGEN

A.G. Galley<sup>1</sup>, D.E. Ames<sup>1</sup>, K.H. Poulsen<sup>1</sup>, J.M. Franklin<sup>1</sup>

Epigenetic, mesothermal gold deposits within the Early Proterozoic Reindeer Zone of the Trans-Hudson Orogen are hosted by faults that splay from, or are parallel to major dip-slip faults that parallel the flanks of the greenstone belts or, in the case of the Flin Flon Belt, cross-cut the volcanic domain at a high angle parallel to the Churchill-Superior boundary.

Alteration mineral assemblages associated with gold mineralization in amphibolite-grade terranes grade outwards from the veins from albite-ankerite-sericite through ferroan dolomite-oligoclase-actinolite-biotite-chlorite to andesine-hornblende, indicating a fluid composition change from alkali-rich through CO<sub>2</sub>-rich to H<sub>2</sub>O-rich. These assemblages overprint the prograde regional metamorphic assemblages.

Epigenetic gold mineralization occurred late in the tectonic history of the region, with associated dip-slip faults cross-cutting

the major fold events. Model lead ages indicate a close temporal relationship of mineralization with a regional metamorphic event.

<sup>1</sup> Mineral Resources Division

### POTENTIAL FOR OLYMPIC DAM-TYPE Cu-Au-U-Fe DEPOSITS IN THE GREAT BEAR MAGMATIC ZONE, DISTRICT OF MACKENZIE, N.W.T.

S.S. Gandhi<sup>1</sup>, R.T. Bell<sup>1</sup>

The Olympic Dam deposit in South Australia is a giant Cu-Au-Ag-U-REE-Fe(oxide) deposit hosted by breccia in an anorogenic, felsic volcano-plutonic setting of Helikian age. The Great Bear magmatic zone has the following features favourable for occurrence of large deposits of this type:

1. Dominantly felsic volcanic sequences deposited in Late Aphebian post-tectonic continental environment.
2. Metallogenic signatures of the felsic magmatism in the form of numerous copper, iron(oxide) and uranium occurrences.

Examples of the Olympic Dam-type deposits in the magmatic zone are the Sue-Dianne deposit (8 million tonnes; 0.8% Cu; some Au and U), and Mar and Damp prospects, in rhyodacite ignimbrite breccias with magnetite-specularite matrix. The magmatic zone also hosts many magnetite-apatite-actinolite veins that are comparable to the much larger iron deposits of the Kiruna and Bergslagen districts in Sweden and in the St. Francois Mountains of Missouri. These iron deposits of Late Aphebian and Helikian age have been interpreted as variants of the Olympic Dam deposit.

<sup>1</sup> Mineral Resources Division

### GEOLOGY OF THE EASTERN ORE BODY AND A SYNOPSIS OF THE CHARACTERISTICS OF THE BAYAN OBO FE-NB-REE DEPOSIT, INNER MONGOLIA, NORTHERN CHINA

W.D. Goodfellow<sup>1</sup>, D. Richardson<sup>1</sup>, D.F. Sangster<sup>1</sup>

The Bayan Obo deposits are hosted within Middle Proterozoic clastics and carbonates of the Bayan Obo group which unconformably overlies the Wutai group (2.2 b.y.). Within the Eastern Ore Body visited by the authors, the mineralization consists of a massive REE-enriched magnetite core surrounded by REE-carbonate-fluorite-amphibole-apatite-metasomatites cut by carbonate, fluorite, albite, and galena veins. The host slates are pervasively fenitized and cut by veined breccias. Multiple breccias containing mineral-zoned veins indicate several stages of fluid pressure buildup and release, and fluid chemical evolution with time. Published initial <sup>87</sup>Sr/<sup>86</sup>Sr ratios in dolomite and apatite, <sup>143</sup>Nd/<sup>144</sup>Nd ratios, delta <sup>13</sup>C values in dolomite, and delta <sup>34</sup>S values in sulphides span mantle values. A deep-seated carbonatitic origin for the Bayan Obo deposit is supported by i) mantle isotopic compositions; 2) the replacement, veined and brecciated nature of the deposit; 3) Sr-rich dolomite, purple fluorite, alkali feldspars, riebeckite and REE minerals; and, iv) the absence of any discernable sedimentary textures despite the low degree of metamorphism and deformation.

<sup>1</sup> Mineral Resources Division

### ISOTOPIC EVIDENCE FOR HYDROTHERMAL DISCHARGE INTO AN ANOXYC WATER COLUMN, SUDBURY BASIN, ONTARIO

W.D. Goodfellow<sup>1</sup>, R.E.S. Whitehead<sup>2</sup>, J.F. Davies<sup>2</sup>

The Errington and Vermilion SEDEX deposits occur within hydrothermal carbonate, chert and carbonaceous shales at the contact between the Onaping Formation and overlying Onwatin Formation. Combined ore reserves for Errington are 7.5 million

tons of 1.02% Cu, 0.75% Pb, 3.24% Zn, 1.49 oz/ton Ag and 0.017 oz/ton Au; Vermilion reserves are 2.9 million tons of 1.43% Cu, 1.10% Pb, 4.56% Zn, 1.78 oz/ton Ag and 0.020 oz/ton Au. Geochemical profiles spanning the ore horizon 17 km from the SEDEX deposits reveal that both S and C (org.) increase upwards in the Onaping Formation but maintain a S/C ratio of 0.36, indicative of diagenetic sulphide formed by biogenic sulphate reduction, a process that also accounts for <sup>13</sup>C-depleted carbonates in these rocks. Delta <sup>34</sup>S values in pyrite are close to 7 per mil throughout the entire section of black Onaping but decrease abruptly to 3 per mil at the base of the Onwatin slates. This marked decrease coincides with the first appearance of hydrothermal sulphides with S/C > 0.36 that persist into the Onwatin Formation. Fluid inclusion and oxygen isotope fractionation temperatures determined for hydrothermal carbonates reveal a systematic temperature decrease from 175°C at the Vermilion deposit to about 125°C, 17 km along the ore horizon.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Geology Department, Laurentian University, Sudbury, Ontario

### GEOLOGY, GEOCHEMISTRY AND ORIGIN OF THE TOM ZN-PB-AG-BARITE DEPOSIT, SELWYN BASIN, YUKON

W.D. Goodfellow<sup>1</sup>, J.W. Lydon<sup>1</sup>

The Tom deposit at Macmillan Pass occurs near the eastern margin of the Selwyn Basin in siliceous and carbonaceous shales of the Middle to Upper Devonian Lower Earn Group. Bedded mineralization occurs near the contact between a turbiditic sequence and an overlying succession of pyritic and baritic siliceous shales and radiolarian chert. Near the southern limit of the deposit, a vent complex is associated with scarp talus breccias, slumping of sand-banded argillite and thinning of pre-ore units, all indicating that the hydrothermal vents and abrupt termination of the stratiform mineralization was controlled by synsedimentary faulting. The ore lenses are texturally, mineralogically and chemically zoned about the vent due to infilling and replacement of hydrothermal sediments by vent fluids. In the most proximal Stockwork Facies, earlier formed sulphides and barite have been extensively replaced by ferroan carbonate, galena, sphalerite, pyrrhotite, pyrite, chalcocopyrite, arsenopyrite and tetrahedrite. The hydrothermal reduction of baritic sulphate has resulted in a marked increase of delta <sup>34</sup>S values in sulphides towards the vent complex.

<sup>1</sup> Mineral Resources Division

### GEOLOGICAL SETTING, SEDIMENTOLOGY, MINERALOGY AND ISOTOPE GEOCHEMISTRY OF THE MIDDLE VALLEY SULPHIDE DEPOSITS, NORTHERN JUAN DE FUCA RIDGE

W.D. Goodfellow<sup>1</sup>, J.M. Franklin<sup>1</sup>, I.R. Jonasson<sup>1</sup>, J.W. Lydon<sup>1</sup>

Hydrothermally active sulphide chimneys and mounds occur within Middle Valley, a sedimented rift at the northern extremity of the Juan de Fuca Ridge. Within the top 5m of mounds penetrated by coring, sulphide- and mud-clast sedimentary breccias are interbedded with hydrothermally altered and unaltered hemipelagic and turbiditic sediments. Sulphide clasts resemble chimney fragments dredged from the area and are characterized by an open interlocking network of hexagonal pyrrhotite with interstitial wurtzite containing central accumulations of isocubanite with chalcocopyrite lamellae. Cores from the smoker field are thermally indurated and desiccated and contain authigenic hydrothermal phases including Mg-smectite and talc, amorphous silica, calcite, barite, gypsum, and pyrite. Isotopically positive delta <sup>34</sup>S values combined with lead and strontium isotopic ratios which plot between MORB and hemipelagic sediment

compositions indicate that the hydrothermal fluids were probably generated in basaltic crust and were modified by reaction with an overlying sequence of hemipelagic and turbiditic sediments.

<sup>1</sup> Mineral Resources Division

#### **RARE EARTH ELEMENTS AND NIOBIUM IN IRON-FORMATION AT BAYAN OBO, INNER MONGOLIA, CHINA**

G.A. Gross<sup>1</sup>

More than 1000 million tonnes of iron ore containing 30 to 35% iron, 1 to 6% REE, 0.12% niobium, and 2% fluorite were indicated by 150,000 m of drill core in 2 of the 16 deposits of magnetite iron-formation located on the rifted northeast margin of the North China Platform. These deposits contain the world's largest resources of REE, and 15,000 tonnes of REE oxide were recovered with 2-3 million tonnes of magnetite ore-concentrate in 1987. The highly metamorphosed iron-formation is interbedded with Early Proterozoic dolomite, black slate-schist, argillite, tuffaceous shale, quartzite and arkose that are infolded and faulted in Archean granitoid gneisses. In spite of extensive metamorphism in several stages, relict primary sedimentary features in the iron-formation and microfossils in the dolomite beds are clear evidence of their sedimentary origin and syngenetic distribution of iron, REE, niobium and other metals within them.

<sup>1</sup> Mineral Resources Division

#### **THE GEOCHEMISTRY OF GOLD IN MODERN SEAFLOOR HYDROTHERMAL SYSTEMS**

M.D. Hannington<sup>1</sup>

Gold and trace metals were determined in sulfides and related deposits from (1) polymetallic sulfides forming at hydrothermal vents (N.E. Pacific and MAR), (2) metalliferous sediments, particulate plumes, and vent waters from the EPR and Explorer RidgeS, and (3) sub-seafloor stockwork in oceanic crust (DSDP Hole 504B). Gold in seafloor sulfides range from <0.1 ppm Au to 6.7 ppm Au (ave. 1 ppm Au, n=170); highest contents are in late-stage, low-T assemblages. Quenched products of 350°C vents indicate 0.1 ppb Au in end-member solutions. Most Au is lost to hydrothermal plumes, and deposited distally. Local sediments derived from mass-wasting of sulfide mounds have similar gold contents to the parent sulfides. Stockwork mineralization is uniformly gold-poor.

In a solubility model where gold mineralization is related to the composition of vent fluids, the high levels of H<sub>2</sub>S in vent fluids can sustain a high concentration of Au(HS)<sub>2</sub><sup>-</sup> down to ca. 200°C. Gold precipitates from the latter complex by oxidation by ambient seawater.

<sup>1</sup> University of Toronto

#### **GOLD IN SUPERGENE SULFIDES AND FE GOSSANS FROM THE MID-ATLANTIC RIDGE AND IN ANCIENT OCHRES FROM CYPRUS**

M.D. Hannington<sup>1</sup>, P.M. Herzig<sup>2</sup>

Massive sulfide deposits at TAG contain primary unaltered sulfides (0.2-5.5 ppm Au) and secondary Cu-sulfides and Fe-oxide gossans with native copper and free native gold. High Au (to 17.1 ppm) in secondary Cu-sulfides resemble some supergene gossans

overlying ancient VMS deposits. Au and Cu were dissolved in low-pH solutions during the reaction of oxidizing seawater with primary sulfides, and redeposited as native metals. Gold precipitated AuCl<sub>2</sub><sup>-</sup> complexes by an increase in pH where the oxidizing solutions met fresh seawater. Atacamite-bearing Fe-oxides (up to 23 ppm Au) represent the final stages in the progressive oxidation.

Chemical transport and redeposition of gold and copper during syndepositional oxidation caused supergene enrichment in some ancient deposits. High gold contents (to 28.4 ppm) occur in fossil submarine gossans (ochres) at Skouriotissa, Cyprus, possible analogues to gossans in the TAG field. The gold-rich ochres contain jarosite, goethite, minor hematite, and quartz with coarse-grained native gold.

<sup>1</sup> University of Toronto

<sup>2</sup> Institut für Mineralogie, RWTH Aachen, Wullner-strasse 2, D-1500 Aachen, West Germany

#### **MINERALOGY OF THE SULPHURETS-BRUCEJACK LAKE AREA, BRITISH COLUMBIA**

D.C. Harris<sup>1</sup>

The Sulphurets - Brucejack Lake area in northwestern British Columbia exhibits large pyrite-sericite alteration zones spatially related to copper and molybdenum porphyries and several precious metal styles of mineralization. The porphyry deposits contain molybdenite, chalcopyrite as the principal copper mineral and minor tennantite. Some of the Ag-Au zones are hosted in quartz vein-stockwork breccia systems that have Sb-enriched mineralization with electrum, native silver and silver sulfosalts (argentian tetrahedrite, pyrargyrite, polybasite). Associated ore minerals are sphalerite, galena and rare chalcopyrite. Other important gold zones are more arsenic enriched and depleted in silver and antimony. On a local scale complex multiple episodes of mineralization are evident both in gangue and sulfide mineralogy.

<sup>1</sup> Mineral Resources Division

#### **THE SLAVE PROVINCE - THELON TECTONIC ZONE BOUNDARY FROM AN INTEGRATED GEOLOGICAL, GEOPHYSICAL, GEOCHRONOLOGICAL AND GEOCHEMICAL PERSPECTIVE**

J.B. Henderson<sup>1</sup>, E. Hegner<sup>1</sup>, P.H. McGrath<sup>1</sup>,  
R.J. Theriault<sup>1</sup>, O. van Breemen<sup>1</sup>

A new 1:250 000 geological map (combined Healey Lake (76B) and Artillery Lake (75O) map areas) of part of the boundary area between the eastern Archean Slave Province and the early Proterozoic Thelon Tectonic Zone of the northwestern Churchill Province that lies between the McDonald and Bathurst faults is presented. U-Pb (zircon and monazite) ages indicate that activity within the Thelon Tectonic Zone and its juxtaposition with the Slave Province took place between 2.0 and 1.9 Ga while the Nd signature indicates the presence of a large Archean component. Distinctive regional gravity and magnetic anomaly patterns together with Rb-Sr geochronological and geological data indicate the central Slave Province along with part of the western 2.0-1.9 Ga Thelon Tectonic Zone was indented along the Bathurst and McDonald faults into the northwestern Churchill Province at about 1.74 Ga. Commodities of potential economic interest that have attracted attention include gold, lead, copper, zinc and nickel.

<sup>1</sup> Continental Geoscience Division

## APPLICATION OF AEROMAGNETIC VERTICAL GRADIENT/VLF SURVEY DATA TO MINERAL EXPLORATION PROGRAMS

P. Hood<sup>1</sup>, D.J. Teskey<sup>2</sup>, F. Kiss<sup>2</sup>

Since 1984, the GSC has been carrying out contracted aeromagnetic vertical gradient/VLFEM surveys under the various Federal-Provincial Mineral Development Agreement Programs. The results have been published as separate total field and vertical gradient line contour maps at either 1:20,000 or 1:25,000 scales and as coloured pixel maps at the 1:50,000 scale. It is clear that the aeromagnetic gradiometer technique combined with VLFEM is a superior mapping tool for unravelling areas of complex geology in mineral exploration programs because the presence of contacts, faults, intrusive stocks etc. are more readily apparent in the vertical gradient data and the magnetic expression of near-surface formations are emphasized with respect to those more deeply-buried. Examples of the use of airborne vertical gradient/total field/VLFEM data are presented from northern Manitoba, Quebec and Maritime surveys.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Geophysics Division

## PRECIOUS METAL DEPOSITS, DEPOSITIONAL HISTORY AND TECTONIC EVOLUTION OF THE ROSSLAND GROUP, A LOWER JURASSIC ARC SUCCESSION IN SOUTHEASTERN BRITISH COLUMBIA

T. Höy<sup>1</sup>, K. Andrew<sup>1</sup>

The Rossland Group is an arcuate belt of lower Jurassic rocks in the southern Omineca Belt of southeastern British Columbia. Dramatic changes throughout the Archibald Formation, the basal clastic succession in the group, from alluvial fan deposits in the southwest through turbidite facies to deep-water argillite and siltstone in the northeast, indicate early growth faulting along a basin margin. Volcanic rocks of the overlying Elise Formation record effusive shoshonitic volcanism followed by eruption of intermediate and mafic pyroclastic rocks. Coarse clastic rocks of the Hall Formation, at the top of the Rossland Group, were deposited in fault-bounded successor basins. Elise Formation shoshonite rocks may record arc volcanism as a subduction zone was dying just prior to plate collision, possibly involving accretion of Quesnellia to the North American craton. Continued compressional tectonics resulted in intense regional deformation. Large listric normal faults record extensional tectonics prior to intrusion of late Jurassic plutons.

Mineral deposits in the Rossland Group have produced more than 100 000 kg Au and 300 000 kg Ag. The distribution and tenor of these vein, skarn and shear-related deposits is controlled by both host lithologies and major structures.

<sup>1</sup> Geological Survey Branch, British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria

## SEDIMENTARY HOSTED NICKEL-ZINC MINERALIZATION IN THE SELWYN BASIN, YUKON

L. Hulbert<sup>1</sup>, C. Grégoire<sup>1</sup>, D. Paktunc<sup>1</sup>, G. Abbott<sup>2</sup>, R. Cathro<sup>3</sup>

A thin bed of stratiform Ni-Zn sulphide mineralization has been discovered at the base of a thick shale sequence in a Devonian to Permian age syncline within the Selwyn Basin.

The sulphide mineralization contains consistently high Ni values in the 2.3 to 7.8 percent range with corresponding zinc values of 0.29 to 1.3 percent. Selenium (610-2400), As (1900-4200), Mo (1411-2968), U (15-107) and Ba (1900-3800) ppm are present in abnormal concentrations. The Platinum Group Elements are also anomalous and in excess of that found in typical Sudbury ores. The

Rhenium concentrations associated with the nickel mineralization range from 9.6 to 61 ppm which appear to be the highest values recorded for nickel sulphide mineralization of any type to date.

Isotopic and mineralogical studies have clearly shown that the Ni-enriched sulphide horizon is distinct from that of other sulphide-rich horizons in the sedimentary sequence.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Exploration and Geological Services Division, Indian and Northern Affairs Canada, Whitehorse, Yukon Territory

<sup>3</sup> West Vancouver, British Columbia

## OBSERVATIONS ON STRATABOUND GOLD OCCURRENCES IN THE ARCHEAN HOOD RIVER BELT, BATHURST INLET REGION, DISTRICT OF MACKENZIE

C.W. Jefferson<sup>1</sup>, M.N. Henderson<sup>1</sup>, J.R. Henderson<sup>2</sup>, S. Schaan<sup>3</sup>

Three deformation phases are documented in the belt. Where distinguishable,  $S_1$  is parallel to  $S_0$  and is crenulated by  $S_2$ . The latter is marked by alignment of metamorphic minerals (cordierite and andalusite) which include  $S_1$ , indicating that the peak of metamorphism occurred during  $D_2$ . An upright, southwest plunging  $D_3$  antiform preserves reclined  $F_2$  and  $F_1$  on its hinge, implying horizontal transport during  $D_1$  and  $D_2$ . Tonalites were intruded during late stages of  $D_3$ , before  $D_2$  and before  $D_1$ . The stratigraphy of the supracrustal sequence, from the base, is: (1) greywacke, (2) iron formation, (3) angular unconformity, (4) polymictic conglomerate (James Falls Conglomerate), (5) complex sequence of arenite, conglomerate, volcanic, hypabyssal and volcanoclastic rocks, (6) greywacke. High strain zones border a central belt dominated by sequence (5). Stratabound gold prospects spatially coincide with macroscale  $F_3$  hinges in sulphidic iron formation (Fish-hook Lake, inf.) and sulphidic arenite (Turner Lake).

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Continental Geoscience Division

<sup>3</sup> Ottawa-Carleton Geoscience Centre, University of Ottawa

## STRUCTURE, STRATIGRAPHY AND FACIES CHANGES IN AURIFEROUS CHEMICAL SEDIMENTARY ARCHEAN ROCKS OF NORTHEASTERN SLAVE PROVINCE, DISTRICT OF MACKENZIE, NWT

C.W. Jefferson<sup>1</sup>, S. Fumerton<sup>2</sup>, K. Hudson<sup>3</sup>, R. Lustwerk<sup>4</sup>, M.B. Lambert<sup>4</sup>, R.A. Olson<sup>5</sup>

Three lithostratigraphically distinct iron-rich sedimentary sequences punctuate volcanic and turbiditic strata. Sequence A marks temporary cessation of volcanism and partial reworking of volcanic protoliths in the Back River complex. Sequence B continuously separates domal volcanic piles from overlying turbidites. Sequence C is hosted by turbidites with spatially-associated volcanoclastics and is widely distributed in the northeastern Slave Province. All sequences contain slate and laterally varied iron-formation facies. Sequences A and B begin, respectively, with calcite- and dolomite-cemented volcanic breccia and grit. Stromatolites and oolites of sequence B are located above rhyolite domes. Sequence C oxide facies are strongly magnetic; silicate and sulphide facies weakly so. Quartz veins and alteration zones transect many competent rocks in the region; gold is restricted to some structurally complex and sulphidic parts of iron-rich strata, mainly Sequence C.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Chevron Minerals Ltd., Timmins, Ontario

<sup>3</sup> Sirius Energy Corp. Ltd., Calgary, Alberta

<sup>4</sup> Continental Geoscience Division

<sup>5</sup> Trigg, Woollett, Olson Consulting Ltd., Edmonton, Alberta

# NON-RENEWABLE RESOURCE ASSESSMENT OF THE SOUTH NAHANNI RIVER AREA, DISTRICT OF MACKENZIE - NEW ZN-PB POTENTIAL AND LOST GOLD FOUND?

C.W. Jefferson<sup>1</sup>, W.A. Spirito<sup>1</sup>, S.M. Hamilton<sup>2</sup>, T.D. Bird<sup>3</sup>,  
F.A. Michel<sup>2</sup>, D. Paré<sup>4</sup>, K.M. Dawson<sup>1</sup>

This assessment is based on regional and follow-up data:

- (1) digitally compiled and locally updated 1:250,000 maps,
- (2) a metallogenic map relating minerals to nine rock-packages,
- (3) digital geochemical maps based on spatial-statistical analysis of stream silts and heavy mineral concentrates (HMCs),
- (4) geochemistry and statistical analysis of spring waters and
- (5) compilation and analysis of hydrocarbon exploration data.

As well as confirming the high mineral potential in much of the Ragged Ranges area and low-to-moderate hydrocarbon potential in the Tlogotsho Plateau area, unexpected high potential was indicated for:

- (a) gold by HMCs from gravels and silts in a 100 km north-trending zone from Mattson Creek to Tetcela River in Nahanni Karst, and
- (b) zinc-lead by silt and spring waters in the Meiller River valley.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Ottawa-Carleton Geoscience Centre, Carleton University, Ottawa, Ontario

<sup>3</sup> Canada Oil & Gas Lands Administration, Ottawa, Ontario

<sup>4</sup> Consor Mines Ltd., Hull, Québec

## GALAPAGOS RIDGE SULPHIDE DEPOSIT: A MODERN ALTERATION PIPE

I.R. Jonasson<sup>1</sup>, J.M. Franklin<sup>1</sup>, M.R. Perfit<sup>2</sup>

Massive sulfide deposits range in age from Archean to Recent and occur in volcanic rocks that almost always are of submarine origin. One of the larger Recent deposits is on the Galapagos Rift at 85°50.5'W, just west of the Inca Transform intersection. Our model envisages extensive crystallization of small magma bodies (<30 km<sup>3</sup>) at depths less than 2 km beneath the sea floor. Development of the Galapagos massive sulfide deposit occurred simultaneously with the intrusion of FeTi basaltic magma into shallow levels of the crust. A lack of magma replenishment and enhanced cooling rate resulted in extensive fractional crystallization. The highly differentiated lavas became enriched in globules of immiscible magmatic sulfides. Hydrothermal circulation of hot, acidic fluid remobilized and subsequently reprecipitated than as sulfides, along with silica and mixed clays in the overlying stockwork and sulfide mounds. These ephemeral chambers may develop as small cupolas above larger steady-state magma chambers or they could be related to relatively small offsets in the ridge crest.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> University of Florida, Gainesville, Florida

## DRIFT PROSPECTING STUDIES IN NORTHWESTERN MANITOBA

C.A. Kaszycki<sup>1</sup>, E. Neilsen<sup>2</sup>

Since 1983, a program of systematic till sampling and surficial geologic mapping has been conducted in the Lynn Lake-Leaf Rapids-Sherridon areas, as part of the Canada-Manitoba Mineral Development Agreement. The primary objectives were to map regional ice flow patterns, dispersal directions, and variations in chemical and mineralogical components of till that may be related to bedrock mineralization, as aids to mineral exploration within the region. Detailed till sampling programs have been carried out

in the vicinity of known mineralization in an effort to document the style and extent of glacial dispersal from various types of mineralized sources. In addition, detailed follow-up sampling has been carried out in areas of anomalous till geochemistry, identified on the basis of regional sampling. This presentation summarizes the results of this five-year program, emphasizing drift prospecting techniques, and the fundamental importance of the regional aspects of surficial geology and drift composition in interpreting regional and local till geochemistry.

<sup>1</sup> Terrain Sciences Division

<sup>2</sup> Geological Services Branch, Manitoba Energy and Mines

## PRECIOUS METALS IN DRIFT OF THE FRONTENAC ARCH AREA, EASTERN ONTARIO

I.M. Kettles<sup>1</sup>

The silt- and clay-sized fraction (<.063 mm) of 700 samples was analyzed for Au, Pd and Pt using fire assay and atomic fluorescence spectroscopy techniques. Ninety per cent of the samples contain <4 ppb Au, <2 ppb Pd and <2 ppb Pt. Concentrations of Au in drift are highest (>100 ppb at several sites) northeast of Flower Station, overlying or near rocks of the Robertson Lake Shear Zone. In the shear zone, disseminated gold, tetrahedrite, pyrite, chalcopyrite and pyrrhotite are associated with veinlets of quartz in dolomitic marble, carbonatized gabbro and mafic metavolcanics. Gold levels are also high (>25 ppb) in areas underlain by marble, metasedimentary or metavolcanic rocks north of Ompah, near Lavant, north of Sharbot Lake near Pennick Lake, and east of Mazinaw Lake between Mississogagnon and Kashwahamak Lakes.

<sup>1</sup> Terrain Sciences Division

## DEVELOPING A BOREHOLE ASSAYING TECHNIQUE FOR MINING APPLICATIONS

P.G. Killeen<sup>1</sup>, L.D. Schock<sup>1</sup>, B.E. Elliot<sup>1</sup>

The spectral gamma-gamma method (SGG) for assaying by logging in slim (46 to 76 mm) mineral exploration boreholes, has been tested in the field and in laboratory models. The SGG method is practical for mono-elemental deposits where the range of concentrations is considered to be 'ore' grade. In the field, quantitative results have been obtained in a lead deposit in Nova Scotia where assays, (ranging up to 8% Pb) of drill core at 10 cm intervals were compared to the SGG logs. In the Borehole Geophysics Laboratory, logging was done in models constructed with crushed lead ore (galena), pyrite and barite. This provided information on the behaviour of the SGG ratio as the ore material and grade were changed. The effect of hole parameters on the results is presently under investigation. Results of these investigations will be illustrated.

<sup>1</sup> Mineral Resources Division

## REGIONAL GEOLOGICAL SETTING OF GOLD MINERALIZATION IN THE CONTWOYT - NOSE LAKES AREA, N.W.T.

J.E. King<sup>1</sup>, W.J. Davis<sup>2</sup>, C. Relf<sup>3</sup>

Metaturbidites of the Contwoyto and Itchen formations and those of the Beechey Lake Group appear to be coextensive although an extensive domain of injection migmatite obscures the relationship between them. Most of the leucosome in the migmatites was injected at the exposed structural level and the margins of the migmatized domains therefore do not coincide with a metamorphic isograd. Orthogneisses comprising hornblende-biotite-plagioclase units injected by tonalite are preserved within

the migmatite domain. Two C3 (syn-volcanic) tonalite to monzogranite bodies were recognized, indicating that this phase of magmatism is more extensively preserved than previously thought. Numerous syn-D<sub>2</sub> hornblende-biotite gabbro to granodiorite and post-D<sub>2</sub> muscovite-biotite tonalite to syenogranite bodies occur across the entire map area. Previously defined structural elements (D<sub>1</sub> to D<sub>4</sub>) are also present across the area although D<sub>3</sub> and D<sub>4</sub> may have been contemporaneous and have been redesignated as D<sub>NE</sub> and D<sub>NW</sub>, respectively.

<sup>1</sup> Continental Geoscience Division

<sup>2</sup> Memorial University of Newfoundland, St. John's

<sup>3</sup> Queen's University, Kingston

## SULPHURETS AREA, BRITISH COLUMBIA: GEOLOGY

R.V. Kirkham<sup>1</sup>

The Sulphurets area in the Coast Mountains of northwestern British Columbia contains a succession of Triassic and Jurassic sedimentary, volcanic and alkaline intrusive rocks that host coeval large, siliceous and sericitic, pyritic alteration zones with porphyry copper and molybdenum and a variety of coeval and probably also younger precious metal occurrences. Since 1960 the area has been explored for copper, molybdenum and precious metals with major exploration programs in the area by several companies over the past few years.

The area has been subjected to low-grade regional metamorphism and heterogeneous penetrative deformation and a complex post- and syn-mineral fault history. Extensive original copper- and molybdenum-bearing quartz vein stockworks have been deformed into flattened, pyroclastic and dismembered vein structures and phyllic and argillic(?) alteration zones form large, penetratively deformed areas of quartz, sericite, pyrite schist with scattered buckle-folded quartz veins. In addition to the early synvolcanic and synintrusive deposits, some bonanza-grade Au-(±Ag) bearing quartz (±carbonate, K-feldspar and/or barite) vein systems were probably syntectonic and formed during later deformational and metamorphic events.

<sup>1</sup> Mineral Resources Division

## THE EFFECTS OF POSTGLACIAL WEATHERING ON TILL GEOCHEMISTRY, LABRADOR

R.A. Klassen<sup>1</sup>, F.J. Thompson<sup>1</sup>

Geochemical samples are collected within the near-surface weathering zone where compositional variations induced by weathering can be significant. The extent of alteration depends on soil-forming factors such as climate, relief, vegetation, and moisture, as well as 'primary' till composition. Within podzolic soils of Labrador, the pebble (2 to 4 mm), sand (0.250 to 0.063 mm), silt and clay (<0.063 mm) and clay (<0.002 mm) fractions show similar geochemical variations (Cu, Pb, Zn, Ni, Cr, Fe, Mn, and U) among soil horizons. Trace element concentrations are least within the eluviated (Ae) zone, and increase with depth, with the rate of geochemical change greatest in the B horizon, within 50 cm of the surface. As exceptions, lead and chromium can concentrate within the Ae horizon. Although trace element concentrations increase with decrease in grain size analysed, clay does not appear to 'scavenge' trace elements released by weathering, and trace elements do not accumulate within the B horizon.

<sup>1</sup> Terrain Sciences Division

## STRUCTURAL AND STRATIGRAPHIC CONTROLS OF ORE DISTRIBUTION OF THE LYON LAKE ZN-CU-PB-AG DEPOSIT, STURGEON LAKE, ONTARIO

E.R. Koopman<sup>1</sup>, J.M. Franklin<sup>1</sup>, K.H. Poulsen<sup>1</sup>

The Lyon Lake stratiform volcanogenic massive sulphide deposit occurs in a north-east dipping sequence of Archean volcanic and sedimentary strata. The deposit is hosted by quartz-phyric rhyolite underlain by interbedded felsic ash and lapilli tuff. Below these are volcano-sedimentary strata, including banded iron formation, greywacke, graphitic shale, massive po-py bodies and siltstone. The hanging wall andesite is in fault contact (thrust?) in turn with the rhyolite, ore and footwall sequence. Coarse grained sphalerite and pyrite are the dominant sulphides and occur as discontinuous and contorted bands in stacked or en echelon lenses.

The ore lenses are deformed by a major shallowly plunging open fold trending east-southeast. Sulphides in the fold hinge are thickened and shallow dipping in contrast with the steeply dipping attenuated limbs.

<sup>1</sup> Mineral Resources Division

## VEIN-HOSTED EPITHERMAL GOLD MINERALIZATION AT MOUNT SKUKUM, YUKON

D.A. Love<sup>1</sup>

The Mount Skukum deposit is 65 km southwest of Whitehorse. The hydrothermal system comprises two distinct facies: the mineralized Cirque, Brandy and Lake Zones, which occupy shear fractures, and are associated with adularia-sericite alteration envelopes; and a barren acid-sulphate alteration pipe, the Alunite Cap Zone. Whereas the advanced argillic alteration was controlled by synvolcanic faults, and has textural and mineralogical features strongly suggestive of formation from magmatic volatiles; the structures which host the mineralized veins display strike-slip movement, and are interpreted as later Riedel shear fractures controlled by regional stresses between the Tintina and Shaskwak transcurrent faults. As such, the mineralized veins are not related to either the acid-sulphate alteration system, or to the volcanic activity in general.

<sup>1</sup> Department of Geological Sciences, Queen's University, Kingston

## PORE FLUID CHEMISTRY AROUND HYDROTHERMAL VENTS ON SEDIMENTED RIDGES

J.W. Lydon<sup>1</sup>, W.D. Goodfellow<sup>1</sup>, W.C. Shanks, III<sup>3</sup>, P.G. Bélanger<sup>1</sup>, G. Gauthier<sup>1</sup>, K.N. Desilva<sup>1</sup>, G.E.M. Hall<sup>1</sup>, J.M. Franklin<sup>1</sup>, E.E. Davis<sup>2</sup>, R.A. Zierenberg<sup>3</sup>, I.R. Jonasson<sup>1</sup>

Pore fluids extracted from piston and gravity cores of hemipelagic muds and turbidites of Middle Valley and the Escanaba Trough show systematic chemical variations. At Middle Valley, the major variations are increases in the concentrations of calcium, barium, antimony and arsenic but decreases in potassium concentration and pH with depth and proximity to an active vent. The variations are explained better by temperature-dependant equilibria between pore fluid and minerals of the sediment than the contamination of indigenous pore fluids by hydrothermal fluids due to advection/diffusion around a conduit. Reasons for the chemical variations of the Escanaba samples are less obvious because of the shorter cores and wider spaced sampling sites. However, evidence for an end-member hydrothermal fluid component is not convincing.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Pacific Geoscience Centre, Vancouver

<sup>3</sup> United States Geological Survey

## THE RELATIONSHIP OF GOLD MINERALIZATION TO THE THERMAL AND TECTONIC HISTORY OF THE BAIE VERTE PENINSULA, NEWFOUNDLAND

J.W. Lydon<sup>1</sup>, J.G. Lavigne<sup>1</sup>, J.C.M. Roddick<sup>2</sup>

Recently discovered gold mineralization in the Baie Verte Peninsula is mainly shear-zone related type. Ar/Ar dating of hydrothermal muscovite associated with gold mineralization indicates an age of about 395 my. This age corresponds to the later stages of the geothermal perturbation associated with the closing of the Iapetus ocean and which covered the time span from ophiolite obduction prior to 470 my and subduction-related felsic magmatism from about 460 to 410 my of which the Cape St. John volcanic rocks are among the youngest manifestations. Some zones of gold mineralization have been further deformed by transcurrent faulting and south-directed thrusting during a thermo-tectonic event at about 350 my, corresponding to the collision of Africa and North America. Viewed from this broad perspective, the gold mineralization is an artifact of the migration of thermo-tectonic zones through a thermally retrograding slab (the ore host, consisting mainly of ophiolites and younger igneous rocks and sediments) as it moved upwards along a major suture (the Baie Verte Line) relative to a thermally prograding hydrous slab (the ore fluid source, consisting mainly of the Fleur de Lys sedimentary prism). The ore fluids were derived by distillation of the prograding slab, and introduced into the retrograding slab along thrusts and splays associated with differential motions of the slabs.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Continental Geoscience Division

## FLUID PENETRATION OF MAGMA CHAMBERS IN THE BAY OF ISLANDS OPHIOLITE, AND ITS IMPLICATION FOR MERENSKY-TYPE PGE CONCENTRATION

J.W. Lydon<sup>1</sup>, J.G. Lavigne<sup>1</sup>

Zones of anomalous compositions and textures occur in gabbros near the base of the crustal sequence in the Bay of Islands ophiolite. The lithological associations within these anomalous zones are similar to those associated with the Merensky Reef and consists of gabbro, norite, anorthosite, pegmatitic pyroxenite, sulphides and chromitite. Isotopic signatures of the anomalous zones are significantly different from mantle values shown by normal plutonic rocks of the ophiolite:  $\delta^{34}\text{S}$  range -7% to +10%;  $\delta^{18}\text{O} = +7.5 \pm 0.2$ ;  $^{87}\text{Sr}/^{86}\text{Sr} = 0.705 \pm 0.001$ . The direction of these isotopic shifts indicates reaction of the gabbro with a hydrous fluid derived from continental crust or seawater. Textural evidence indicates that the anomalous zones are due to the local remelting of the gabbro under the influence of the hydrous fluid, and whose main effects were the redistribution of pyroxene into pegmatitic veins and patches leaving an anorthositic restite, and concentration of sulphide in the partial melt in which Pt and Pd are enriched relative to other PGE.

<sup>1</sup> Mineral Resources Division

## VOLCANOGENIC MASSIVE SULPHIDE DEPOSITS OF CYPRUS: MECHANISMS OF SEAFLOOR ACCUMULATION OF SULPHIDES IN THE MATHIATI DEPOSIT

J.W. Lydon<sup>1</sup>, D.E. Ames<sup>1</sup>

Microscopic and macroscopic textures of samples from the massive sulphide lens of the Mathiati deposit indicate that surface detrital sedimentation and the subsurface cementation/replacement of these sediments were the main processes leading to its formation. Hydrothermal eruption contributed most of the coarse detrital fraction. Precipitation of sulphides around conduits is the main subsurface process for the

addition of mass to a massive sulphide lens. Within sand-sized detritus, conduits are marked by irregular concentrically banded sulphide "flues" (the subsurface equivalent of surface "chimneys"), which expand by interstitial cementation and replacement of detrital sulphide grains. "Propylite" pipes probably represent eruption craters which formed during the last hydrothermal pulse, and which preserve debris that has not been subject to high temperature hydrothermal maturation.

<sup>1</sup> Mineral Resources Division

## MOSS-MAT SEDIMENT GEOCHEMISTRY

P.H. Matyssek<sup>1</sup>

Scarcity of easily collected conventional stream sediments (fine sands to silts) is a common problem encountered in drainage surveys conducted over temperate wet mountainous environments. In response to this predicament, orientation surveys were conducted on Vancouver Island focusing on the applicability of fines-rich moss-mat sediments scrapped from boulders and logs found within active stream channels as an alternative sample medium. Assessment of field and multi-element analytical data obtained from detailed stream and moss-mat sediment sampling of over 40 drainage basins on Vancouver Island indicated that moss mats are ubiquitous, easily sampled and yield up to 200 per cent more -80 mesh (fine sands and silts) material than stream sediments. Furthermore, analytical results from 100 paired moss-mat and stream sediment samples indicated no significant differences for molybdenum, copper, lead, zinc, cobalt, iron, arsenic and mercury. More importantly, elements dispersed as heavy minerals appear to be concentrated up to 100 fold by the mats. As a result, analytical reproducibility is improved, anomalous dispersion patterns are longer and the background-to-anomaly contrast for gold is up to an order of magnitude greater than in stream sediments. As a result of these studies, moss-mat sediments were selected as the preferred sample media for the Province's Regional Geochemical Surveys on Vancouver Island.

<sup>1</sup> Geological Survey Branch, British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria

## REGIONAL HEAVY MINERAL GEOCHEMISTRY IN THE LOWER ST. LAWRENCE (APPALACHIAN) REGION OF QUÉBEC

Y.T. Maurice<sup>1</sup>

As part of the Eastern Quebec Development Plan (1983 - 1989), the geological Survey of Canada conducted a regional heavy mineral geochemical survey in a relatively unexplored region of the Quebec Appalachians. The area surveyed was approximately 8400 km<sup>2</sup> and included parts of Kamouraska, Témiscouata, Rivière-du-Loup and Rimouski counties.

The results show a 30 km-long zone of unusually high tungsten, lead, antimony and silver, with some mercury, copper and tin values near the villages of l'Esprit-Saint and Trinité-des-Monts. This unexpected anomaly seems to follow a major fracture zone in Cambro-Ordovician sediments and probably signals the presence of a hydrothermal system in the area. The zone was the focus of significant staking and mineral exploration activity during the summer of 1989, following the release of the data in GSC Open File 2036.

Other interesting results include a series of barium, lead and zinc anomalies that form arcuate patterns in the northern part of the survey area. Most of the anomalies occur within 20 or 30 km of the sub-economic barite/lead deposit at St. Fabien and could indicate an extension to the known mineralisation.

<sup>1</sup> Mineral Resources Division

## A LATE CRETACEOUS DIATREME RELATED TO RHYOLITIC VOLCANISM; THE ANTONIUK GOLD DEPOSIT, FREEGOLD MOUNTAIN, YUKON TERRITORY

B.I. McInnes<sup>1</sup>, W.D. Goodfellow<sup>2</sup>, J.H. Crocket<sup>3</sup>

The Antoniuk Diatreme is a large (450 x 300 m) sub-oval body of matrix supported brecciated country rock intruded by rhyolite and subordinate andesite dykes. It is one of three large breccia bodies in the Freegold Mountain area which may be structurally controlled by small transcurrent faults parallel to and coeval with the Tintina fault. The rhyolite dykes within the Antoniuk, dated at  $78 \pm 6$  Ma, increase in grain size and abundance at depth and appear to represent the uppermost portion of a medium-grained alaskite intrusion. The diatreme is interpreted to have formed by the explosive escape of volatile components evolved during the retrograde boiling of the alaskite at depths less than 1.5 km below the paleosurface. Gold is disseminated throughout the breccia complex and associated with arsenopyrite, pyrite and quartz. The gold content of the diatreme breccia is estimated at 3.7 Mt @ 1.14 g/t Au (Cathro and Main, 1986) and is currently considered subeconomic.

<sup>1</sup> Department of Geology, University of Ottawa

<sup>2</sup> Mineral Resources Division

<sup>3</sup> Department of Geology, McMaster University, Hamilton

## GOLD DEPOSITS IN THE INDIN LAKE SUPRACRUSTAL BELT, N.W.T.

J. Morgan<sup>1</sup>

The Indin Lake Supracrustal Belt is located at the western margin of the Slave Province 200 km northwest of Yellowknife. Deformation of the belt in Archean times was accompanied by metamorphism ranging from greenschist to amphibolite grade.

Significant gold deposits in the belt fall into two main categories: (1) quartz stockworks in or adjacent to brittle deformed, competent rock units such as rhyolite within metagreywacke and (2) quartz stockworks in or adjacent to shear zones that occur either within metavolcanic rocks or along volcanic-sedimentary contacts.

Some if not all gold mineralization took place before regional metamorphism and concomitant deformation. Mineralized quartz veins and surrounding rocks show evidence of deformation that post-dates and in terms of stress and strain relations is not consistent with emplacement of the veins. Garnet in at least one alteration zone is a product of metamorphism of pre-existing alteration minerals.

<sup>1</sup> Energy, Mines and Petroleum Resources, Government of the Northwest Territories, Yellowknife

## DEVELOPMENT OF A BOREHOLE ORIENTATION TOOL USING THREE COMPONENT MAGNETOMETERS

W.A. Morris<sup>1</sup>, D. Blohm, S.J. Balch<sup>2</sup>, P.G. Killeen<sup>3</sup>

Borehole surveying represents a specialized application of the more general global navigation problem. That is, given the location of a start point we wish to know the location of the finish point, and the geometry of the path traversed in moving between these two points using only information derived from measurements of the borehole geometry at sequential observation points.

Local borehole geometry is defined by two parameters: borehole dip; and borehole azimuth. Dip is easily derived from orthogonally oriented tiltmeters. Borehole azimuth presents a

more difficult problem. To establish the azimuth of the borehole relative to Geographic North it is necessary to determine the deviation between Magnetic and Geographic North both at the surface, and at all sequential observation points.

This study reports the preliminary results of a joint GSC/industry co-operative effort to develop a new generation of borehole orientation tools in which a combination of three component fluxgate magnetometers, and electronic tiltmeters are used to derive estimates of dip, magnetic azimuth, and magnetic deviation.

<sup>1</sup> Morris Magnetics Inc., Lucan, Ontario

<sup>2</sup> IFG Corp., Brampton, Ontario

<sup>3</sup> Mineral Resources Division

## THE VOLCANOLOGY OF THE SOUTH STURGEON LAKE AREA, ONTARIO

R.L. Morton<sup>1</sup>, G.J. Hudak<sup>1</sup>, J.S. Walker<sup>1</sup>, J.M. Franklin<sup>2</sup>

The South Sturgeon Lake area of northwestern Ontario is underlain by a well preserved Archean submarine caldera which is about 30 km in strike length. Within the caldera five ash flow tuff units have been recognized and these range from 100 to more than 1200 m in stratigraphic thickness. The ash flow units vary from massive and pumice-rich to bedded with quartz crystal-pumice-rich basal beds separated by well bedded ash units. The five known massive sulphide deposits (Mattabi, F-Zone, Sturgeon Lake, Lyon Lake and Creek Zone) occur within the caldera and are hosted by the ash flow tuff deposits.

Associated with the ash flow tuffs are coarse, heterolithic breccias which are composed dominantly of precaldern lithologies. The breccias underlay and, locally, are interlayered with the ash flow tuffs. The breccias vary from 100 to more than 1000 m in thickness and clast size ranges up to at least 100 m.

The five ash flow tuff units indicate five separate periods of explosive, silicic volcanism accompanied by caldera collapse; ore-forming hydrothermal activity was associated with at least four of these eruptive episodes.

<sup>1</sup> Department of Geology, University of Minnesota-Duluth, Duluth, Minnesota

<sup>2</sup> Mineral Resources Division

## CONTINUOUS TIME DOMAIN INDUCED POLARIZATION LOGGING IN MINERAL EXPLORATION

C.J. Mwenifumbo<sup>1</sup>

As part of an on-going borehole geophysics research program at the Geological Survey of Canada (GSC), experiments have been conducted with downhole continuous time domain induced polarization (IP) for the identification and delineation of polarizable sulphides. The GSC IP logging system is capable of transmitting and receiving signals at a variety of periods with the signal being transmitted digitally uphole. For continuous time domain IP logging, it is important to use transmitting periods as short as possible to obtain adequate spatial resolution at reasonable logging speeds. Field tests have been carried out at a number of mineral deposits in Canada to evaluate the effects of the following logging parameters on continuous IP measurements; logging speed, sample depth interval, period of the transmitted signal and the integration windows for determining the chargeability parameter. Results of these tests will be presented from a variety of geological environments.

<sup>1</sup> Mineral Resources Division

## BOREHOLE GEOPHYSICS IN EVALUATING ASBESTOS DEPOSITS

C.J. Mwenifumbo<sup>1</sup>, P.G. Killeen<sup>1</sup>, G. Bernius<sup>1</sup>,  
P. Mainwaring<sup>2</sup>, G. Bonin<sup>3</sup>

Multiparameter downhole logging measurements were carried out at the LAB Chrysotile asbestos mine, Black Lake, Quebec to evaluate the possibility of using borehole geophysics to delineate asbestos ore and estimate the ore grade. The geophysical measurements included natural gamma ray spectrometry, spectral gamma gamma, resistivity, induced polarization (IP), single point resistance, spontaneous potential, magnetic susceptibility, temperature and temperature gradient. The parameters which seem to best characterize the asbestos ore are magnetic susceptibility (MS), resistivity, IP and spectral gamma gamma density. Frequency of chrysotile bearing veins correlates with low resistivity, and because of the close association between the chrysotile veins and magnetite, increases in asbestos fibre veins also correlates with high MS and IP values. Preliminary measurements of the asbestos ore grade indicate the possibility of quantifying the geophysical measurements in terms of ore grade.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> CANMET

<sup>3</sup> LAB Chrysotile Mine, Black Lake, Quebec

## MISE-À-LA-MASSÉ CASE HISTORIES IN MINERAL EXPLORATION

C.J. Mwenifumbo<sup>1</sup>, K. Witherly<sup>2</sup>, K. Robertson<sup>3</sup>

Three field examples on the application of borehole mise-a-la-masse measurements in mineral exploration are presented. The first example illustrates the use of the method in mapping the orientation of conductive auriferous alteration zones in a structurally complicated geological environment in the Timmins area. The second example from the Redstone Nickel Mine near Timmins illustrates how the mise-a-la-masse technique was used to determine continuity of mineralized zones over distances in excess of 500 metres and thus establish the down-dip extension of the deposit. The final example is from the Stratmat main zone, Bathurst, New Brunswick. At this deposit, the borehole mise-a-la-masse measurements were used to resolve the structural relationship between two massive sulphide zones. These zones were believed to be connected close to the surface, however, the mise-a-la-masse measurements clearly established that the two zones were not connected.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> BHP-Utah Mines Ltd., Toronto, Ontario

<sup>3</sup> Noranda Exploration, Bathurst, New Brunswick

## GEOLOGY OF THE STEEN RIVER STRUCTURE, NORTHWESTERN ALBERTA

D. Nikols<sup>1</sup>, J. Wilson<sup>1</sup>

The Steen River Structure (SRS) is a circular basement feature, twenty-five km in diameter, located in northwestern Alberta. It consists of a central uplift, a rim syncline and at least one raised rim. There is a 1700 m throw between the central uplift and the deepest portions of the syncline. In addition to the basement, at least 1000 m of Devonian carbonates and evaporites are tectonically distributed by the structure.

Regionally, the SRS lies close to the Great Slave Lake shear zone, and is cut by the faulted boundary between the Hottah Accreted Terrain and the Great Bear Magmatic Arc. Within the raised rim, the SRS is tectonically very complex. It is surrounded by a tectonically simpler disturbed zone up to thirty km wide.

Current thinking suggests a mid-Cretaceous (approx. 95 my) impact origin for the feature. However, recent work questions this assumption and proposes an endogenic origin.

The SRS is also interesting within an international setting. It is very close in age (95 ± 7 my/100 ± 5 my) to the similar Boltys structure in the Ukraine. The Boltys has been extensively drilled and was the subject of a recent Canadian/Soviet study. The close ages of these two structures has recently been cited as evidence for a cratering peak at around 100 my. Proof of this would have far reaching implications for the theory of periodic cometary showers affecting the earth's climate and being a factor in major extinctions.

The presence of a large disturbed zone in an area known for its hydrocarbon potential, the presence of significant mineral deposits associated with similar structures elsewhere (eg. the Carswell Structure in Saskatchewan), and the proximity of the structure to major regional basement features such as the Great Slave Lake shear zone, make the Steen River Structure an intriguing subject for study.

<sup>1</sup> Alberta Geological Survey, Alberta Research Council, Edmonton

## GOLD METALLOGENY, SLAVE STRUCTURAL PROVINCE, N.W.T.

W.A. Padgham<sup>1</sup>

An empirical gold metallogenic map of the Slave Structural Province prepared in 1985 (EGS 1986-3) has been updated and revised in light of results from the past 5 years of intensive gold exploration in the Slave.

New discoveries of nearly 200 gold showings added to the 285 used to develop the original map have allowed refinement of the zoning shown in the earlier map. The main difference is the recognition of the Indin Lake domain as a zone in which there are no iron-formation-in-turbidite gold deposits, the type deposit in the central northeasterly trending belt of the province which extends from Russell Lake through Reagan to George Lakes and from Itchen Lake through Lupin to George Lake, thus surrounding the Indin Lake domain.

The remaining zones are much as they were in the earlier map. The southeastern zone is devoid of gold showings. The zone between it and the iron-formation zone is devoid of iron-formation-in-turbidite-deposits whose place is taken by quartz veins in turbidite.

A northwestern domain is characterized by quartz veins in granitic rock although new discoveries in the supracrustals of this domain are reported to be in shear zones.

The region east of Bathurst Inlet contains iron-formation hosted deposits and is tentatively included in the central zone that is characterized by that type of deposit.

<sup>1</sup> NWT Geology Division, Indian and Northern Affairs Canada, Yellowknife

## PRECIOUS METALS ASSOCIATED WITH URANIUM VEINS IN THE NORTHWEST TERRITORIES

A.D. Paktunc<sup>1</sup>, S.S. Gandhi<sup>1</sup>

Sporadic high concentrations of Pt, Pd, Au and Ag occur in uranium-bearing veins near the unconformity between the early Proterozoic Great Bear magmatic zone and middle Proterozoic continental siliciclastic sediments of the Hornby Bay Group. Veins containing a variety of sulphides, sulfarsenides, tellurides, barite, uraninite, pitchblende and coffinite carry 5-42 ppm Pt, 4- 57 ppm

Pd, 1-65 ppm Au and 1-47 ppm Ag. Precious metal-bearing minerals are affiliated with the sulphides.

Mineralization appears to be epithermal in character with Pt and Pd enrichment reflecting higher solubility over Os, Ir, Ru and Rh at low and intermediate temperatures. Preliminary thermodynamic considerations suggest that the mineralization can be explained by interaction of an oxidized acidic solution with a reduced neutral solution. The paleo-lateritic character of the unconformity provides a favorable environment for redox controlled deposition.

Although, no igneous source rock is exposed in the near vicinity of the veins, the area has been subjected to voluminous mafic igneous activity evidenced by the Mackenzie dike swarm, Muskox intrusion and Coppermine basalts. These rocks are believed to be the source of Pt and Pd. The age of the unconformity-related uranium mineralization at Hornby Bay and Athabasca Basin (Hoeve and Sibbald 1978) coincides with the intrusion of the Mackenzie dike swarm.

<sup>1</sup> Mineral Resources Division

#### PROTON-MICROPROBE ANALYSIS OF PRECIOUS METALS AND RELATED TRACE ELEMENTS IN PENTLANDITE, CHALCOPYRITE AND PYRRHOTITE FROM SOME NICKEL-COPPER SULPHIDE OCCURRENCES

A.D. Paktunc<sup>1</sup>, L.J. Hulbert<sup>1</sup>

Concentrations of platinum-group elements (PGE), Au, Ag, Ge, Ga, Zn, Cd, Pb, Bi, Se, Te and As in pentlandite, chalcopryrite and pyrrhotite have been determined by proton-induced X-ray emission (PIXE) microprobe at the University of Guelph. Two hundred sulphide grains from the Bushveld Complex, Muskox intrusion (N.W.T.), Rottenstone (Sask.), Namew Lake, Thompson and Cuthbert (Man.), Wellgreen (Yukon), St. Stephen, Mechanic and Goodwin Lake (N.B.) and Bay of Islands Ophiolite (Nfld.) have been probed using a 15  $\mu$ m beam at 3 MeV, 7.6-17.3 nA beam current.

Pentlandite is the only phase that accommodates detectable levels of Pd, to 566 ppm, Rh, to 41 ppm, and Ru, to 61 ppm. Ag occurs in almost all chalcopryrites, to 160 ppm, and in most pentlandites, to as high as 279 ppm. Zn partitions exclusively into chalcopryrite with concentrations as high as 4283 ppm. Bi, Pb and Te have no preference among the three phases, Se is equally partitioned, while Ga prefers pentlandite and chalcopryrite accommodates all Ge. Sulphides from the PGE-rich occurrences have Se/S ratios greater than or within mantle range, while PGE-poor Ni-Cu occurrences display depleted Se/S ratios.

<sup>1</sup> Mineral Resources Division

#### ZINC-RICH CHIMNEYS FROM THE PLUME SITE, SOUTHERN JUAN DE FUCA RIDGE

S. Paradis<sup>1</sup>, I.R. Jonasson<sup>2</sup>, G.M. LeCheminant<sup>2</sup>, D.H. Watkinson<sup>3</sup>

Structurally intact Zn-rich chimneys were collected by the submersible ALVIN from the Plume Site hydrothermal vent, southern Juan de Fuca Ridge. The chimneys display four mineralogically distinct, axially concentric zones; the outermost zone is A and innermost zone is D. Zone A is highly porous and consists predominantly of fine-grained dendritic sphalerite with minor pyrite and marcasite. Zone B is composed of linked aggregates of dendritic and colloform sphalerite with anhydrite, barite, and amorphous silica that fill cavities. Zone C consists of massive aggregates of sphalerite-wurtzite with minor pyrite and chalcopryrite. Zone D is composed of vuggy, porous aggregates of coarse-grained colloform sphalerite with minor wurtzite,

chalcopryrite, isocubanite, pyrite, pyrrhotite, and marcasite. The chimneys grew initially by rapid deposition of fine-grained dendritic sphalerite under relatively low-temperature conditions. Subsequent deposition of Zn and Fe-sulfides thickened the chimney walls, reduced porosity, and created a physical barrier that inhibited mixing of seawater and hydrothermal fluid within the chimneys. Increase of temperature of the venting fluids, led to inward-growth of Cu and Fe sulfides within the conduits.

<sup>1</sup> Québec Geoscience Centre, Ste-Foy, Québec

<sup>2</sup> Mineral Resources Division

<sup>3</sup> Ottawa-Carleton Geoscience Centre, Dept. of Earth Sciences, Carleton University, Ottawa

#### BA-ZN MINERALIZATION OF THE APPALACHIANS: THE EXAMPLE OF UPTON, QUEBEC

S. Paradis<sup>1</sup>, T.C. Birkett<sup>1</sup>, R. Godue<sup>1</sup>

The Upton stratabound barite deposit, hosted in carbonate rocks of the Upton Group of the Cambro-Ordovician Flyschoid belt of the Quebec Appalachians, contains approximately 950,000 tons grading 46.5% BaSO<sub>4</sub>, 1.9% Zn, 0.6% Pb, 0.15% Cu, 0.11% Cd and 13.5 g/t Ag.

The mineralization consists of grayish to white barite, sphalerite, chalcopryrite, pyrite and galena in a brecciated, massive, gray, locally fossiliferous limestone probably of late Cambrian or early Ordovician age. Barite occurs as clusters of blade-like crystals, rosettes, fine-grained aggregates, nodules and veins. The sulphides are disseminated through the limestone or form grain aggregates and veinlets.

The mineralized limestone is interbedded with black calcareous shales, mafic volcanic rocks, mudstones, siltstones, and barren white limestones here named the Upton Group. The hanging wall to the mineralized limestone consists of black calcareous shales and the footwall consists of mudstones and altered mafic volcanic rocks. The Upton Group is exposed as windows within the tectonically overlying Cambrian Granby nappe.

The Upton barite deposit may be the result of a submarine exhalative process contemporaneous to sedimentation or of an epigenetic process involving emplacement/replacement into a brecciated, porous limestone aquifer.

<sup>1</sup> Québec Geoscience Centre, Ste-Foy, Québec

#### AN INTEGRATED METALLOGENIC COMPUTER DATA FOLIO, KAPUSKASING-COCHRANE AREA, ONTARIO

W.N. Pearson<sup>1</sup>, P.K. Hoffman<sup>1</sup>, J.E. Kerr<sup>1</sup>, D.J. Robinson<sup>2</sup>

Standard, widely available commercial computer software has been utilized to develop an efficient method to record and compile mining exploration assessment data to aid metallogenic studies. The project test area is located in the Kapuskasing-Cochrane area of Ontario, bounded by latitude 48°45' to 49°30' and by longitude 81°00' and 82°30'.

Information from assessment files is entered into an interactive, menu driven database written in DBaseIII. This database includes file name, property locations, company names, description of exploration work completed, and summary logs for diamond drill holes. Summaries of this data can be displayed and a wide variety of reports can be generated.

Locations of all report areas, geophysical/geochemical anomalies, diamond drilling, mineral occurrences, and other pertinent data have been digitized into Autocad. The report file number is a unique number linking the Autocad information with the DBaseIII database. The layering scheme in Autocad has been

designed to allow maps with different types of information to be readily produced.

<sup>1</sup> Derry Michener Booth & Wahl, Toronto

<sup>2</sup> Robinson Exploration Services Ltd., Toronto

### GEOLOGY, MINERALOGY AND GEOCHEMISTRY OF THE WINDY-CRAGGY DEPOSIT, NORTHWESTERN BRITISH COLUMBIA

J.M. Peter<sup>1</sup>, S.D. Scott<sup>1</sup>

The Windy Craggy massive sulphide deposit is within the allochthonous Alexander terrane of the Insular tectonic belt in extreme northwestern British Columbia. Host rocks are a volcano-sedimentary succession of mixed graphitic argillites and mafic pillowed and massive volcanic flows of Upper Triassic age that have been intruded by mafic volcanic dikes and sills. The deposit consists of two or more sulphide bodies that have been folded, faulted, and possibly sheared in places. Reserves currently (end of September, 1989) are 120 million tons grading 1.9% copper with values in gold, silver, cobalt, and zinc. This reserve figure is a minimum, as a large part of the deposit has not been systematically drilled. Mineralization consists predominantly of massive pyrrhotite and/or pyrite with lesser chalcopryrite and magnetite. Minor and trace minerals include sphalerite, arsenopyrite, galena, valleriite, marcasite, cubanite, cobaltite, gold, electrum, and native silver. Gangue minerals are quartz, chlorite, calcite, ankerite, siderite, stilpnomelane, biotite, graphite, hematite, hisingerite, and cordierite. Mineralization comprises massive sulphide, stringer/stockwork, and finely bedded to laminated sulphides and exhalites. Mineralization occurs within both the volcanic and sedimentary rocks and therefore displays similarities with the "Besshi-type" class of massive sulphide deposits.

<sup>1</sup> Department of Geology, Earth Sciences Centre, University of Toronto,

### SEAFLOOR HYDROTHERMAL MINERALIZATION IN THE GUAYMAS BASIN, GULF OF CALIFORNIA

J.M. Peter<sup>1</sup>, S.D. Scott<sup>1</sup>

Hydrothermal mounds, chimneys, and spires occur at 2000 m water depth in the Southern Trough of Guaymas Basin, central Gulf of California. Many of these structures are actively venting hydrothermal fluid in excess of 300°C. The hydrothermal mineral precipitates are composed predominantly of carbonates (calcite, aragonite), sulfates (anhydrite, barite), silicates (amorphous silica, stevensite), metal sulfides (pyrrhotite, marcasite, pyrite, sphalerite, wurtzite, galena, isocubanite, and chalcopryrite) and iron oxides. Fluid inclusion microthermometric measurements made on primary inclusions in calcite from individual chimneys give mean trapping temperatures from 213 to 277°C and salinities of 4.1 to 5.8 equivalent weight percent NaCl. Trapping temperatures are in good agreement with temperatures of venting hydrothermal fluid measured with Alvin's thermocouple probe. Fluid inclusion salinities, however, cannot be reconciled with salinities measured from the presently venting fluids. This suggests that fluid inclusion studies can be used to delineate temporal and spatial variations in vent fluid chemistries. Mineral assemblages, compositions of individual minerals, and fluid inclusion measurements can be explained best by mixing of hot end-member hydrothermal fluid with cold ambient seawater. Most minerals are precipitated at the vent site largely in response to decreasing temperature induced by mixing with seawater.

<sup>1</sup> Marine Geology Research Laboratory, Department of Geology, University of Toronto

### LIQUID HYDROCARBON-BEARING INCLUSIONS IN MODERN HYDROTHERMAL CHIMNEYS AND MOUNDS FROM THE SOUTHERN TROUGH OF GUAYMAS BASIN, GULF OF CALIFORNIA

J.M. Peter<sup>1</sup>, B.R.T. Simoneit<sup>2</sup>, O.E. Kawka<sup>2</sup>, S.D. Scott<sup>1</sup>

Liquid hydrocarbon-bearing inclusions of variable shape (e.g., spherical, bowling pin, rod, and highly irregular) occur in hydrothermal minerals of chimneys and mounds in the southern trough of Guaymas Basin, central Gulf of California. The inclusions are preferentially trapped in amorphous silica which occurs as spherules and 0.01 mm encrustations on sulfides, sulfates, and carbonates. The inclusions are primary and were trapped during, not after, mineral growth. The inclusions are both two-phase (liquid hydrocarbon and vapour/gas) and three phase (liquid hydrocarbon, aqueous fluid and vapour), and range from 2 to 50 microns in diameter. The large range in hydrocarbon and aqueous fluid contents indicates that the hydrothermal fluid and hydrocarbons were never a homogeneous solution but hydrocarbons were transported as immiscible and, possibly, solvated forms. The hydrocarbons vary in colour from deep to pale orange-brown and fluoresce yellow during excitation by ultraviolet light, indicating a condensate composition. Measurable quantities of hydrocarbons within inclusions could not be isolated by solvent extraction upon mineral dissolution, which suggests that the more volatile components predominate. Two-phase hydrocarbon inclusions homogenized at temperatures ranging from 75 to 190°C; an unknown correction must be applied to obtain true trapping temperatures. However, the true trapping temperatures of these inclusions was determined by measuring trapping temperatures for adjacent aqueous inclusions, which range from 116 to 226°C. Geochemical modelling using these temperatures indicates that the amorphous silica was deposited from the hydrothermal fluid by conductive cooling and mixing with ambient seawater. The temperatures required for the formation of modern petroleum in the Guaymas Basin appear to coincide with those required for the abundant precipitation of amorphous silica in the Guaymas Basin hydrothermal system.

<sup>1</sup> Marine Geology Research Laboratory, Department of Geology, University of Toronto

<sup>2</sup> Petroleum Research Group, College of Oceanography, Oregon State University

### THE FRANCOEUR GOLD MINE, ROUYN-NORANDA DISTRICT, QUEBEC

P. Pilote<sup>1</sup>, J.-F. Couture<sup>1</sup>, A. Vachon<sup>2</sup>

The Francoeur mine, located in the township of Beauchastel, is presently the only gold producer in the western portion of the Rouyn-Noranda district. Originally discovered in 1923 and officially re-opened in 1988, it is shared equally by Les Ressources Minières Rouyn Inc. and Minerais Lac Ltée.

The deposit is situated in the Blake River Group along a regional E-W inverse shear zone known as the Francoeur-Wasa shear (FWS). This hundred-metre-wide shear dips 35° to 55° to the north. The mine lithologies are oriented E-W, and include mafic to intermediate volcanics, a large diorite intrusion, and red aphanitic dykes. These dykes are syn-tectonic and occur dominantly in the most intensely sheared units. The regional schistosity, also oriented in an E-W direction, dips steeply to subvertically to the north.

The presently-exploited gold mineralization consists of disseminated pyrite localized in three distinct shear zones within the FWS envelope. The host rocks are intensely hematized and carbonatized. Carbonatized rock and most of the gold appear to be restricted to thin mylonite zones that formed at the expense of the

sheared host rock. These mylonite zones carry up to 40 g/t Au, while the pyritized wallrock averages 3 to 10 g/t Au.

<sup>1</sup> Ministère de l'Énergie et des Ressources du Québec, Val d'Or

<sup>2</sup> Les Ressources Minières Rouyn Inc., Rouyn-Noranda

## A TECTONOSTRATIGRAPHY FOR THE ARCHEAN ROCKS OF THE TAVANI AREA, KEEWATIN, N.W.T.

S. Ralser<sup>1</sup>, A.F. Park<sup>1</sup>

The area, southwest of Rankin Inlet, is underlain by the Archean Kaminak Group, a greenstone supracrustal sequence, and is overlain by the Early Proterozoic Hurwitz Group. The Kaminak Group is divided into the volcanic and sedimentary Last Lake formation and the sedimentary Mistake Bay formation. Both formations were intruded by mafic and felsic plutons, and also show precious metal potential. Two regional phases of Archean deformation are recognized. Localized, polyphase deformation occurs along a décollement zone at the base of the Mistake Bay formation; this is progressive into D<sub>1</sub>. D<sub>1</sub> is characterized by bedding parallel high strain zones, a regionally pervasive S<sub>1</sub> foliation, and locally, F<sub>1</sub> folds. D<sub>2</sub> is characterized by open to tight folds and steeply dipping shear zones; both trending NE-SW. These shear zones show a complex movement history. Granitoids were emplaced syn-D<sub>1</sub> and post-D<sub>2</sub>. Regional metamorphic grade varies from sub-greenschist to upper amphibolite around granitoid complexes.

<sup>1</sup> Geology Department, University of New Brunswick

## AN EVALUATION OF THE RESOURCE POTENTIAL IN NORTHEAST ALBERTA

R.J.H. Richardson<sup>1</sup>, W.A.D. Edwards<sup>1</sup>

Alberta Energy and the Alberta Geological Survey (AGS) are undertaking a critical review of past geologic and mineral exploration work in the northeastern part of the province, in preparation for metallogenic studies centered in this region. The objective of this study is to compile all sources of relevant data and information, assess economic mineral occurrence data and develop a metallogenic mapping strategy for the Alberta portion of the Canadian Shield (exposed and underlying the Athabasca Group). All data will be entered into a Geoscience Information System (GSIS) using the commercial software package pcARC/INFO. Results will be presented in computer generated maps and in both digital and hard copy data sets.

The GSIS index will include the following sources of information: AGS's Mineral Deposits and Occurrences File, the National Mineral Inventory and Mineral Deposit and Occurrence File, the Alberta Assessment Report File, Geology, Geochemistry, Geophysics, Scientific Studies, Structural Mapping. The Alberta Assessment Report File includes information on mineralized showings, drill hole assays, and significant geophysical and geochemical anomalies.

Data of various types (geology, geophysics, etc.) will be ranked in terms of reliability and quantity. The final report will be prepared and presented as an AGS open file report. The output will be a series of maps presenting the data captured above, with synthesis maps to show areas of information deficiency, areas of promise or potential exploration targets. Recommendations for future work will be outlined in a short report as the first step in a metallogenic mapping plan for the Alberta Shield.

<sup>1</sup> Alberta Geological Survey, Alberta Research Council, Edmonton, Alberta

## VEIN AND STRAIN RELATIONSHIPS IN TWO ARCHEAN GOLD DISTRICTS, SUPERIOR PROVINCE

F. Robert<sup>1</sup>, K.H. Poulsen<sup>1</sup>

The Val d'Or (VD) and Mine Centre (MC) gold districts both occur at the boundary between northern metavolcanic-plutonic domain and southern domain of meta-turbidites, separated by major fault zones. Foliation and stretching lineations, as well as the dominant style of faulting indicate northerly directed shortening in both districts, accompanied by subvertical elongation at VD and subhorizontal elongation at MC. In both districts, gold-bearing veins are relatively late and occur in brittle-ductile shear zones and associated extensional fractures. VD deposits are typically associated with high angle reverse shear zones and horizontal extensional veins, whereas MC deposits consist of strike slip shear zones and vertical extensional veins. In both districts, vein patterns reflect the dominant structural style, compressive with vertical elongation at VD, and dextral transcurrent at MC. In both cases, the gold-bearing veins can be regarded as a late increment of regional deformation.

<sup>1</sup> Mineral Resources Division

## STATE OF THE ART ANALYSIS OF GEOLOGICAL MATERIALS BY XRF

R.M. Rousseau<sup>1</sup>

During the last three decades, X-Ray Fluorescence (XRF) analysis has undergone a spectacular evolution from all points of view: sample preparation, XRF spectrometers, methods and software.

Samples for XRF analysis can be prepared in the form of a fused disk or of a pressed pellet.

Wavelength dispersive spectrometers are very stable, very sensitive and completely computer controlled, making them very easy to use.

The author has proposed the fundamental algorithm to convert measured intensities into concentrations and it uses theoretical influence coefficients to correct for matrix effects.

The use of this algorithm requires very complex calculations which must be done by a computer. The author has written a program, named CiROU, to perform this task.

The program is very easy to use. It is a step-by-step guide to routine XRF analyses using a main menu bar containing six major options, which provide several other options inside a pull-down window system.

<sup>1</sup> Mineral Resources Division

## RELATIONSHIP OF SULPHUR ISOTOPIC STRATIGRAPHY TO STRATABOUND BASE METALS AND GOLD VEIN DISTRICTS, MEGUMA GROUP, NOVA SCOTIA

A.L. Sangster<sup>1</sup>, M.C. Graves<sup>2</sup>, M. Zentilli<sup>3</sup>

Sedex Zn-Pb and stratiform gold vein districts in the Meguma group are characterized by heavy  $\delta^{34}\text{S}$  ratios (average +8 to +20 ‰) in sandy flysch and carbonaceous, pyrrhotitic shaley flysch with similar values (range +8 to +35 ‰). Regionally extensive Mn-rich strata are associated with a negative  $\delta^{34}\text{S}$  excursion (0 to -5 ‰).

These data are interpreted to indicate an origin for sulphide sulphur in both the syngenetic and epigenetic deposits from seawater sulphate, in an ocean behaving as a closed system with respect to seawater sulphate. The sedex deposits formed by direct exhalation of metal-rich fluids into the anoxic water whereas this

$\delta^{34}\text{S}$  data and C/O isotopic data of others suggests that the gold deposits formed from fluids generated during prograde greenschist facies metamorphism. Mn-carbonate strata formed during a period of ventilation of Iapetus.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Cuesta Research, Halifax

<sup>3</sup> Dalhousie University, Halifax

#### MIDDLE PROTEROZOIC SEDEX DEPOSITS OF THE TANYAKOU-JIASHENGPAN POLYMETALLOGENIC DISTRICT, LANGSHAN-ZHAERTAISHAN REGION, INNER MONGOLIA, CHINA

D.F. Sangster<sup>1</sup>, W.D. Goodfellow<sup>1</sup>, D. Richardson<sup>1</sup>

This district, situated in the westernmost portion of the Inner Mongolia Autonomous Region, is roughly 220 km long and 100 km wide at its widest point. Within it are three operating stratiform base metal deposits (Hegeqi, Tanyakou, Dongshengmiao) and at least one developed prospect (Jiashengpan-Shanpiangou).

Host rocks are dominantly metamorphosed sediments ranging from mainly clastics in the western portion to mainly dolomite in the east; several lithological units can be tentatively correlated across the district. The western portion also contains variable amounts of mafic volcanics (or their metamorphosed equivalents). Stratiform deposits range from proximal Cu-Zn(Pb) in the west to distal Pb-Zn in the east, leading to the speculation that the district represents a westward-opening intracontinental rift.

<sup>1</sup> Mineral Resources Division

#### MVT AND SEDEX LEAD-ZINC DEPOSITS: A COMPARATIVE EXAMINATION

D.F. Sangster<sup>1</sup>

Mississippi Valley-type (MVT) and sedimentary exhalative (SEDEX) deposits together represent one-half to three-quarters of the world's production and reserves of lead and zinc. Eight parameters of these two deposit-types are reviewed: 1. Descriptive model; 2. Host rock lithology; 3. Regional setting; 4. Size/grade/metal ratios; 5. Age of host rock; 6. Lead isotopes; 7. Sulphur isotopes; and 8. Genesis.

The over-all conclusion from this review of two of the world's major lead-zinc deposit-types is that their similarities far outweigh their differences. The latter, for the most part, are contained in the morphological characteristics of each type. Beyond that, however, both types reflect their common derivation from fluids emanating from sedimentary basins.

<sup>1</sup> Mineral Resources Division

#### LOCATING BURIED POTENTIAL PLACERS BY GROUND MAGNETIC SURVEY NEAR ATLIN, BRITISH COLUMBIA

E.J. Schwarz<sup>1</sup>, N. Wright<sup>1</sup>

Computer modelling on thin (0.5-1.0 m), weakly magnetic horizontal plates (i.e. buried placers) at depths to 10 m showed that these could be detected as positive anomalies elongated in the river/valley direction using a modern proton precession magnetometer, short station to station distances (1 m), and good control of the diurnal variation. A test was run on terraces of the Chaudière river and some tributaries and of the Osgoode river in southeastern Quebec. The results show that magnetite concentrations in the alluvium e.g. buried potential placers can be detected by a detailed ground magnetic survey with good diurnal

control and probably by a high-sensitivity helicopter-borne survey flown at low altitude.

Results obtained in the Atlin area show features similar to those observed for the Chaudière area and can be interpreted in a similar way.

<sup>1</sup> Mineral Resources Division

#### VENT FLUIDS, SEDIMENT-HOSTED MASSIVE SULFIDE DEPOSITS AND HYDROTHERMALLY ALTERED SEDIMENTS, ESCANABA TROUGH, GORDA RIDGE

W.C. Shanks III<sup>1</sup>, R.A. Zierenberg<sup>2</sup>, J.K. Böhlke<sup>1</sup>

The sediment-hosted massive sulfide deposits of Escanaba Trough are associated closely with volcanic edifices and range in morphology from large pyrrhotite-rich mounds (up to 100 by 200 by 40 m) to small chimneys. 220°C hydrothermal fluids currently are venting at one site, but most of the deposits are inactive. Sulfide-talc breccia, smectite-altered sediments with cross-cutting veinlets of sulfide, and turbidites and hemipelagic sediments pervasively altered to near-pure chlorite occur within and adjacent to the sulfide mounds.

Sulfide minerals from mounds and chimneys have  $\delta^{34}\text{S} = 2.12\%$  and  $\text{H}_2\text{S}$  in the 220°C vent fluids have  $\delta^{34}\text{S} = 8\%$ . The  $\delta^{34}\text{S}$  values of Escanaba sulfides indicate derivation of sulfur from two sources: basaltic sulfide and  $^{34}\text{S}$ -enriched sulfide from hydrothermal reduction of seawater sulfate.

Unaltered turbidites and hemipelagic sediments have  $\delta^{18}\text{O} = 7.7\text{--}16.6\%$ , altered sediments and talc precipitates have  $\delta^{18}\text{O} = 2.2\text{--}8.7\%$ , and seawater-derived vent fluids have  $\delta^{18}\text{O} = 0.4\%$ . Reaction of sediment with heated seawater produced chlorite mud enriched in Mg and depleted in  $\text{SiO}_2$ , Na, K, Rb, Ca and  $^{18}\text{O}$ . Equilibrium oxygen isotopic fractionation calculations indicate that the alteration occurred at temperatures of 180-270°C.

<sup>1</sup> U.S. Geological Survey, Reston, Virginia

<sup>2</sup> U.S. Geological Survey, Menlo Park, California

#### BASE METAL DEPOSITS IN THE LOWER PROTEROZOIC HANSON LAKE METAVOLCANICS, SASKATCHEWAN

T.I.I. Sibbald<sup>1</sup>, M. Koziol<sup>2</sup>

The Lower Proterozoic (ca. 1881  $\pm$  6 Ma) Hanson Lake metavolcanics exposed 60 km west of Flin Flon host one historic lead-zinc producer, the Western Nuclear Mine, numerous sub-economic base metal showings and the recently discovered McIlvenna Bay volcanogenic massive sulphide deposit, containing in excess of 7 million tonnes of ore grading 1.1% Cu, 6.5% Zn, 34 g/t Ag and 0.7 g/t Au. The McIlvenna Bay deposit is located 5 km south of the Western Nuclear Mine, beneath a thin (ca. 15 m) cover of Ordovician dolomites and quartz-sandstones. Both deposits occur within felsic rocks, deformed and metamorphosed to upper greenschist-lower amphibolite facies during Hudsonian orogenesis. The exposed felsic edifice around the Western Nuclear Mine comprises predominant dacitic and rhyolitic lavas and pyroclastics overlain successively, by mixed felsic to mafic volcanics interlayered with oxide-silicate-sulphide facies iron formation and by greywackes. Subvolcanic, quartz-feldspar porphyry plutons intrude the felsic edifice and gabbroic sheets the overlying sequence. In the McIlvenna Bay deposit, copper-zinc mineralization occurs within metres of the base of the overlying mixed volcanics, in three lenses of massive sulphides, typically underlain by copper rich stringer 'ore' (reserves above are for lens 2 only). Host felsic rocks are finely laminated sericitic schists with chert (?) interlayers. Chloritic, silicic and argillic alteration is apparent below the massive sulphide lenses. The Western Nuclear

deposit is hosted by a similar sericite schist-chert (?) sequence, but appears to occupy a different and possibly lower level of the felsic edifice.

<sup>1</sup> Saskatchewan Energy and Mines, Regina

<sup>2</sup> Cameco, Saskatoon

#### **RARE-EARTH-BEARING APATITE, BENJAMIN RIVER, NEW BRUNSWICK**

W.D. Sinclair<sup>1</sup>, D.L. Kingston<sup>2</sup>

Rare-earth-bearing apatite near the Benjamin River in northern New Brunswick is associated with small plutons and dykes of feldspar porphyry that have intruded Silurian mafic volcanic rocks. The feldspar porphyry may be related to a nearby gabbroic to granitic intrusive complex of probable Devonian age. Apatite occurs with pyroxene, magnetite and minor epidote in small pegmatitic bodies emplaced along the margin of a small feldspar porphyry stock and in veins and vein/stockworks in adjacent volcanic rocks. Electron-microprobe analyses indicate that the apatite contains 1 to 2% rare earth elements (REEs) irregularly distributed in structural sites. REEs are also present in monazite and allanite inclusions in apatite. The abundance and distribution of REEs in the Benjamin River apatite are comparable to those in apatites associated with alkaline igneous rocks, carbonatites and apatite-bearing iron deposits.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> University of Western Ontario

#### **AIRBORNE GEOPHYSICS AND RADAR SURVEYS OF THE SUDBURY REGION**

V.R. Slaney<sup>1,2</sup>, J. Harris<sup>2,3</sup>, D.F. Graham<sup>2,3</sup>, K. Misra<sup>2</sup>

This poster presents an overview of synthetic aperture radar (SAR) applications to geology.

SEASAT images are being used to map fold and fault patterns across the Western Plains region of Canada. Faults can be identified which have influenced the formation of sedimentary basins and the accumulation of hydrocarbons. Seasat images of the Grenville Province are used to prepare reconnaissance maps in areas of western Quebec where the geology is not well understood.

The CCRS airborne SAR has flown more than 30 test sites for geologists. Examples of imagery from Sudbury, Ontario and from Newfoundland, demonstrate a wealth of structural and topographic information.

Airborne SAR scenes of eastern Nova Scotia have been digitally coregistered with Landsat Thematic Mapper images, with magnetic and gamma ray data, and with lake sediment geochemical data. The SAR images present a shaded relief view of the terrain onto which the geophysical or geochemical datasets are superimposed in colour.

<sup>1</sup> Mineral Resources Division

<sup>2</sup> Canada Centre for Remote Sensing, Ottawa

<sup>3</sup> Intera Technologies Ltd.

#### **VOLCANOGENIC MASSIVE SULPHIDE EXPLORATION USING WHOLE ROCK GEOCHEMISTRY IN THE CAMBRO-ORDOVICIAN VOLCANIC TERRANES OF CENTRAL NEWFOUNDLAND: A PALEOTECTONIC APPROACH**

H.S. Swinden<sup>1</sup>, G.A. Jenner<sup>2</sup>, B.F. Kean<sup>3</sup>, D.T.W. Evans<sup>1</sup>

Geochemical studies of mafic rocks have been carried out in ophiolitic (Betts Cove Complex, Lushs Bight Group) and volcanic-

volcaniclastic (Pacquet Harbour, Wild Bight, Victoria Lake groups) sequences that host Cambro-Ordovician volcanogenic massive sulphide (VMS) deposits in central Newfoundland. The results suggest that VMS deposits in these sequences, although of disparate stratigraphic setting, were all generated during intra-oceanic rifting, probably related to initiation of subduction or island arc rifting.

The ore-bearing environments are characterized by a volcanic association of 1) extremely incompatible element-depleted (refractory) mafic volcanic rocks; 2) felsic volcanics and, 3) normal arc tholeiites  $\pm$  calc alkalic basalts. In some cases, the refractory volcanic rocks are similar to boninites; in others they are tholeiitic. All are interpreted to have been generated by hydrous remelting of refractory mantle sources during the arc rifting event.

It is suggested that the anomalously high heat of the refractory magmas may have provided the energy to drive anomalously large, hot, and/or long-lived hydrothermal cells, and thereby promoted VMS deposition. Felsic volcanic rocks in these sequences probably did not have a cause and effect relationship with the VMS deposits. The presence of refractory volcanic rocks in an ancient arc setting may constitute a useful regional exploration tool for VMS deposits.

<sup>1</sup> Department of Mines, Geological Survey Branch, St. John's, Newfoundland

<sup>2</sup> Department of Earth Sciences, Memorial University, St. John's, Newfoundland

<sup>3</sup> Department of Mines, Mineral Resources Management Branch, St. John's, Newfoundland

#### **MULTIPLE PERIODS AND STYLES OF GOLD DEPOSITION AT MOSQUITO CREEK GOLD MINE, WELLS, BRITISH COLUMBIA**

B.E. Taylor<sup>1</sup>, F. Robert<sup>1</sup>

The Mosquito Creek gold mine occurs in the northern part of the 15 km long Cariboo Gold Belt. Au mineralization occurs principally in pyritic lenses in limestone layers ("replacement ore") and, to a lesser extent, in quartz veins. Diagonal quartz-carbonate-pyrite-sericite veins (oblique to lineation), and orthogonal quartz-carbonate-galena-sphalerite veins (normal to lineation) were more abundant in the adjacent Island Mountain and Cariboo Gold Quartz mines. Structural analysis indicates that pyritic lenses were folded together with their host limestone layers into asymmetric folds, whereas auriferous orthogonal and diagonal veins clearly postdate the folding.

Field and stable isotopic data are consistent with hydrothermal remobilization of gold from early pyritic lenses, in which fine grained pyrite contains economic concentration of gold whereas coarse porphyroblastic pyrite is almost barren, into the post-folding quartz veins.

<sup>1</sup> Mineral Resources Division

#### **GEOCHEMISTRY OF GRANITES RELATED TO TIN DEPOSITS IN THE NORTH ZONE AT MOUNT PLEASANT, NEW BRUNSWICK**

R.P. Taylor<sup>1</sup>, W.D. Sinclair<sup>2</sup>, G.J.A. Kooiman<sup>3</sup>

Three stages of granitic intrusion are present in the North Zone at Mount Pleasant; from oldest to youngest they have been designated Granite I, Granite II and Granite III. Potentially economic Sn deposits occur within or adjacent to Granite II. All of the intrusions are high-silica (>74 wt.% SiO<sub>2</sub>), fluorine-rich (>3000 ppm F) granites. Least altered samples of Granites II and III are peraluminous, anorthite-free rocks with differentiation indices of 96.7 to 97.4 and fluorine contents ranging from 0.40 to

0.85 wt.%. They are also characterized by elevated contents of Li (370-580 ppm), Ga (22-36 ppm), Rb (1011-1210 ppm), Y (136-196 ppm), Nb (51-71 ppm), Sn (6-30 ppm), Cs (15.4-32.4 ppm) and Ta (17.5-21.0 ppm); and low concentrations of MgO (<0.05 wt.%), CaO (<0.67 wt.%), TiO<sub>2</sub> (<0.05 wt.%), Sr (11-64 ppm) and Ba (22-61 ppm). REE patterns are slightly concave upward with large negative Eu anomalies. These data and the local occurrence of primary topaz in an aplitic contact phase of Granite II and as inclusions in quartz euhedra in Granite III suggest that Granites II and III are compositionally analogous to topaz granites.

<sup>1</sup> Carleton University, Ottawa

<sup>2</sup> Mineral Resources Division

<sup>3</sup> LAC Minerals

## NEW IDEAS ON BUCHANS GEOLOGY AND THEIR APPLICATION TO EXPLORATION

J.G. Thurlow<sup>1</sup>, R.V. Kirkham<sup>2</sup>

Volcanogenic Zn-Pb-Cu-Ag-Au-barite deposits of the Buchans camp occur within submarine, bimodal volcanic rocks of the lower Middle Ordovician Buchans Group. They are distinguished by the extensive development of transported ores in which sulphide fragments were carried downslope in ore-grade debris flows, possibly from an evolving resurgent dome in a submarine caldera. The debris flows were controlled by synvolcanic normal faults which were subsequently reactivated during thrust faulting. The thrusts have resulted in several repetitions of ore and host rocks in antiformal stacks, recognition of which has changed completely the exploration potential and approach at Buchans.

An important new development is the discovery of clastic-intrusive rocks which contain high-grade Pb-Zn clasts and abundant altered and mineralized fragments in a quartz-bearing, comminuted matrix. These syntectonic, sheared mixtures intrude and follow the thrust fault zones over an area 1 km by 2 km near Lucky Strike. Their sheet-like distribution mimics that of the thrusts and they cause local hydraulic dilation of antiformal stack structures. One particularly well-developed example of this intrusive layer occurs 500 m structurally below the orebodies, strongly suggesting an undiscovered source for the abundant high-grade clasts in it.

<sup>1</sup> B.P. Resources Canada Limited

<sup>2</sup> Mineral Resources Division

## GEOLOGY OF ONTARIO

P.C. Thurston<sup>1</sup>, G.M. Stott<sup>1</sup>, P.J. Barnett<sup>2</sup>, J.A. Fyon<sup>1</sup>

The Geology of Ontario project will result in the production of a comprehensive volume and accompanying provincial geologic, tectonic assemblage, metallogenic, Quaternary, and magnetic and gravity maps, to coincide with the Centennial of the Ontario Geological Survey in 1991. While these will be the visible products, the work is resulting in the reappraisal of our understanding of the geology and the interpretation of the tectonic assembly of the craton; previously unappreciated geological, tectonic, and metallogenic patterns are being revealed. This evolution in thought is a prerequisite to and bears directly upon our understanding of the localization and genesis of mineral deposits. Similarly, the Quaternary map provides a base with which to reinterpret the glacial history. Not only does this interpretation enhance the identification of areas covered by tills

which are suitable for drift exploration geochemistry, but it also assists in the assessment of aggregate resources. The empirical and interpretative constraints on the evolution of the craton and the tectonic setting of mineral deposits in Ontario will serve as a regional basis for further geoscience work by the Ontario Geological Survey.

<sup>1</sup> Precambrian Geology Section, Ontario Geological Survey, Toronto

<sup>2</sup> Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto

## THE MARG Zn-Pb-Cu-Ag-Au MASSIVE SULPHIDE DEPOSIT: A NEW DISCOVERY, SELWYN BASIN, YUKON

R.J.W. Turner<sup>1</sup>, G. Abbott<sup>2</sup>

The Marg Fe-Zn-Pb-Cu-Ag-Au volcanogenic massive sulphide deposit is located 40 km NE of Keno City, Yukon within a south-dipping imbricate thrust array of black carbonaceous, siliceous phyllite, quartz-sericite-chlorite-carbonate schist, and quartzite of Early Mississippian age. Indicated and inferred reserves are 1,922,000 tonnes grading 1.97% Cu, 5.19% Zn, 2.72% Pb, 1.97 oz/ton Ag, and 0.03 oz/ton Au. The sulphide body is an isoclinal fold above a northerly directed thrust fault. A linear paleo-vent complex is characterized by a ferroan carbonate-rich massive pyrite sulphide body with high Cu/Pb, Zn/Pb and Ag/Pb ratios and 'footwall' quartz phenocryst-bearing ferroan carbonate-quartz-sericite-pyrite schists. The sulphide body is zoned outward to a quartz-pyrite and outermost massive pyrite. Major sulfides are pyrite, sphalerite, galena and chalcopyrite with minor tetrahedrite and arsenopyrite. Altered 'footwall' volcanic rocks away from the paleo-vent are sericite-quartz or chlorite-quartz schists.

<sup>1</sup> Mineral Resources Division, Vancouver

<sup>2</sup> Exploration and Geological Services Division, Indian and Northern Affairs Canada, Whitehorse, Yukon Territory

## ANATOMY OF A PALEOZOIC GREENSTONE BELT IN NORTHERN NEW BRUNSWICK, WITH EMPHASIS ON THE GEOLOGICAL SETTING OF ITS MASSIVE SULPHIDE DEPOSITS

C.S. van Staal<sup>1</sup>

The generally northwards younging volcanic rocks of the Tetagouche Group in northern New Brunswick are interpreted as a thrust stack. U-Pb zircon dating of the volcanics show that virtually all volcanic units were erupted at approximately the same time (470-466 Ma) and support the thrusting interpretation. The Tetagouche Group volcanics are interpreted as a bimodal rifting suite which is tectonically overlain by a dismembered ophiolite in the Armstrong Brook area, which represent the continuation of the Fournier Group in the Bathurst Camp. Both suites are interpreted to record the opening of a back-arc marginal basin that was telescoped in post Middle Ordovician times.

The massive sulphide deposits, which are invariably associated with felsic volcanic rocks, can be separated into three different sets on basis of stratigraphic position and are generally hosted by sediments. These three sets are in ascending order the Half-Mile Lake, Brunswick and Caribou sets and generally have characteristics of blanket-like, distal deposits. The sulphide blankets are interpreted to be deposited from dense bottom hugging metalliferous brines or formed as a result of dispersion of a metalliferous plume on mixing with a stratified water column, characterized by reducing, sulphidic bottom waters.

<sup>1</sup> Continental Geoscience Division

## ASSESSMENT OF REGIONAL MINERAL POTENTIAL WITH GIS INTEGRATION TECHNIQUES, NORTHERN NEW BRUNSWICK

G.P. Watson<sup>1</sup>, A.N. Rencz<sup>1</sup>

A GIS (geographic information system) is a powerful tool for the integration and analysis of multiple geoscience data sets. For an area near Bathurst, New Brunswick, regional data from ground-based geology, stream sediment and till geochemistry, airborne geophysical surveys and satellite imagery in a variety of digital formats are integrated with a desktop GIS. The data are used concurrently to model mineral favourability based on weights of evidence. The model uses the point locations of 75 known mineral occurrences and a subset of 26 gold-bearing occurrences from the study area. The calculations for the entire set and the subset are compared. The results, summarized as predictive maps, which show areas relatively favourable to the occurrence of mineralization, are evaluated with respect to estimation error and uncertainty. These maps can serve as a guide to exploration.

<sup>1</sup> Mineral Resources Division, GSC

## GENESIS OF METALLIFEROUS SEDIMENTS IN THE ATLANTIS II DEEP, RED SEA

R.A. Zierenberg<sup>1</sup>, W.C. Shanks, III<sup>2</sup>

The Atlantis II Deep in the central Red Sea is the site of formation of the largest sulfide deposit discovered to date on the sea floor. The Atlantis II deposit formed from a seawater-derived hydrothermal fluid that is modified by high-temperature interaction with oceanic crust, and is genetically and geochemically similar to the other oceanic ridge crest sulfide deposits. However, in the Atlantis II Deep, the dissolution of evaporite strata adjacent to the rift results in a high salinity fluid that forms a submarine brine pool. The brine pool controls the depositional environment and determines the form and composition of the metalliferous deposit, deposits formed by low salinity buoyant plume hydrothermal systems typical of the midocean ridges are generally small mounds of massive sulfide confined to the area of active hydrothermal discharge. The interplay of the hydrothermal system with the depositional environment is one of the critical variables that controls the geometry, composition, preservation, and economic potential of submarine exhalative mineral deposits.

<sup>1</sup> U.S. Geological Survey, Menlo Park, California

<sup>2</sup> U.S. Geological Survey, Reston, Virginia

## MASSIVE SULFIDE DEPOSITION IN THE ESCANABA TROUGH, GORDA RIDGE, NORTHEAST PACIFIC OCEAN

R.A. Zierenberg<sup>1</sup>, R.A. Koski<sup>2</sup>, J.L. Morton<sup>2</sup>, W.C. Shanks III<sup>3</sup>

The Escanaba Trough is the slow spreading (2.3 cm/yr total spreading rate) southern part of the Gorda Ridge. The southern two thirds of the Escanaba Trough is covered by hemipelagic and turbiditic sediment that is 300-500 metres thick over the spreading axis and thins to the north. Several volcanic edifices 3-5 km in diameter rise up through and locally breach the sediment cover. Six major massive sulfide deposits and numerous sulfide occurrences have been discovered associated with the volcanic edifices. All of the deposits occur within the sediment. The volcanic edifices are both a topographic and thermal focus for hydrothermal fluids, resulting in long-lived discharge systems capable of forming large massive sulfide deposits. These sulfide deposits are enriched in Ag, As, Au, Bi, Pb, Sb, and Sn, relative to massive sulfide deposits formed on sediment free ridge crests, due to metal contribution from sedimentary sources.

<sup>1</sup> U.S. Geological Survey, Branch of Western Mineral Resources, Menlo Park, California

<sup>2</sup> U.S. Geological Survey, Branch of Pacific Marine Geology, Menlo Park, California

<sup>3</sup> U.S. Geological Survey, Branch of Eastern Mineral Resources, Reston, Virginia

## EVIDENCE OF A SEDIMENTARY EXHALATIVE ORIGIN FOR THE WALTON DEPOSIT, NOVA SCOTIA

J. Zinck<sup>1</sup>, D.F. Sangster<sup>2</sup>

During Visean (Early Carboniferous) time extensive, intra-continental syn-sedimentary rifting resulted in widespread marine sedimentation in Atlantic Canada. Because this combination of tectonics and sedimentary environment is one of the major metallotects for SEDEX deposits, a literature review of the geology within and surrounding Walton, the largest stratiform base metal deposit in Nova Scotia, was undertaken with a SEDEX model in mind.

Characteristic SEDEX elements, in addition to Pb and Zn, are Ba, Mn, and Fe. Basal Windsor Group sediments in the Walton area contain markedly more occurrences and higher concentrations of these elements than anywhere else in Nova Scotia. Within the Walton deposit itself, the conformable Pb-Zn(Cu) sulphide body, overlain by stratiform barite, is traceable for over 600 m along strike and is underlain by a discordant pyrite zone. These features, together with the presence of hematitic barite, siderite in the footwall, silicification of footwall sediments, and one occurrence of chert, are all compatible with a SEDEX origin. Walton possesses many features in common with Silvermines, a SEDEX deposit in the Carboniferous of Ireland.

<sup>1</sup> Albion Rd., Ottawa

<sup>2</sup> Mineral Resources Division



## AUTHORS

### **G. Abbott**

Exploration and Geological  
Services Division  
Indian and Northern Affairs  
Canada  
Whitehorse, Yukon  
(403) 667-3200

### **D.E. Ames**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-9754

### **W.L. Anderson**

Department of Technical  
Co-operation for Development  
United Nations  
New York, New York  
10017  
(212) 963-8788

### **K. Andrew**

Ministry of Energy, Mines and  
Petroleum Resources  
Parliament Buildings  
Victoria, British Columbia  
V8V 1X4  
(604) 356-2818

### **C.D. Anglin**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-4865

### **A.H. Bailes**

Manitoba Department of Energy  
and Mines  
Geological Services Branch  
535-330 Graham Avenue  
Winnipeg, Manitoba  
R3C 4E3  
(204) 945-4154

### **S.J. Balch**

IFG Corp.  
18 Bram Court, Unit 5  
Brampton, Ontario  
L6W 3R6  
(416) 451-5228

### **S.B. Ballantyne**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4836

### **P.J. Barnett**

Engineering and Terrain Geology  
Section  
Ontario Geological Survey  
9-77 Grenville Street  
Toronto, Ontario  
M7A 1W4  
(416) 965-1321

### **G. Beaudoin**

Ottawa-Carleton Geoscience  
Centre  
University of Ottawa  
Department of Geology  
Ottawa, Ontario  
K1N 6N5  
(613) 564-3480

### **P.G. Bélanger**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-6178

### **J.R. Bélanger**

Geological Survey of Canada  
Terrain Sciences Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-1856

### **K.B. Bell**

Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

### **R.T. Bell**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4611

### **G. Bernius**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-3850

### **T.D. Bird**

Canada Oil and Gas Lands  
Administration  
355 River Road  
Ottawa, Ontario  
K1A 0E4  
(613) 991-2054

### **T.C. Birkett**

Commission géologique du  
Canada  
Centre géoscientifique de Québec  
2700, rue Einstein  
C.P. 7500  
Sainte-Foy, Québec  
G1V 4C7  
(418) 654-2566

### **D. Blohm**

IFG Corp.  
18 Bram Court, Unit 5  
Brampton, Ontario  
L6W 3R6  
(416) 451-5228

### **D.E. Boerner**

Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-8844

### **J.K. Böhlke**

United States Geological Survey  
954 National Center  
Reston, VA 22092  
(703) 648-4000

### **G.F. Bonham-Carter**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-3628

### **G. Bonin**

Lab Chrysotile Mine  
P.O. Box 459  
Thetford Mines, Québec  
G6G 5T5  
(418) 338-7500

### **W.C. Brisbin**

University of Manitoba  
Department of Earth Sciences  
Winnipeg, Manitoba  
R3T 2N2  
(204) 474-9371

### **R. Brommecker**

Queen's University  
Department of Geological  
Sciences  
Kingston, Ontario  
K7L 3N6  
(613) 545-2597

### **J. Broome**

Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-6914

**J.E. Campbell**  
Saskatchewan Research Council  
15 Innovation Blvd.  
Saskatoon, Saskatchewan  
S7N 2X8  
(306) 933-7066

**R. Cathro**  
2460 Queens Avenue  
West Vancouver, British  
Columbia  
V6V 2Y8  
(604) 926-6003

**B.W. Charbonneau**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-2294

**F. Chartrand**  
Service Géologique du Nord-Ouest  
Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(819) 825-7514

**W.B. Coker**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-2378

**J.-F. Couture**  
Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(819) 825-7514

**J.H. Crockett**  
McMaster University  
Department of Geology  
Hamilton, Ontario  
L8S 4L8  
(416) 525-9140

**P.H. Davenport**  
Government of Newfoundland and  
Labrador  
Department of Mines and Energy  
Geological Survey Branch  
P.O. Box 8700  
St. John's, Newfoundland  
A1B 4J6  
(709) 576-2763

**J.F. Davies**  
Laurentian University  
Geology Department  
Sudbury, Ontario  
P3E 2C6  
(705) 675-1151

**E.E. Davis**  
Geological Survey of Canada  
Pacific Geoscience Centre  
100 West Pender Street  
Vancouver, British Columbia  
V6B 1R8  
(604) 356-6453

**W.J. Davis**  
Memorial University of  
Newfoundland  
Department of Earth Sciences  
St. John's, Newfoundland  
A1B 3X9  
(709) 737-8143

**K.M. Dawson**  
Geological Survey of Canada  
Mineral Resources Division  
100 West Pender Street  
Vancouver, British Columbia  
V6B 1R8  
(604) 666-0260

**G.D. Delaney**  
Saskatchewan Energy and Mines  
12-1914 Hamilton Street  
Regina, Saskatchewan  
S4P 4V4  
(306) 787-2526

**K.N. Desilva**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-8917

**L.W. Diamond**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

**R.N.W. DiLabio**  
Geological Survey of Canada  
Terrain Sciences Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-1380

**J.A. Donaldson**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

**B. Dubé**  
Commission géologique du  
Canada  
Centre géoscientifique de Québec  
2700, rue Einstein  
C.P. 7500  
Sainte-Foy, Québec  
G1V 4C7  
(418) 654-2669

**C.E. Dunn**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-2373

**O.R. Eckstrand**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-7258

**W.A.D. Edwards**  
Alberta Geological Survey  
Alberta Research Council  
Edmonton, Alberta  
T6H 5R7  
(403) 438-7623

**B.E. Elliot**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-3958

**B. Ellis**  
Geological Survey of Canada  
Geophysics Division  
1 Observatory Crescent  
Ottawa, Ontario  
K1A 0Y3  
(613) 995-0803

**D.T.W. Evans**  
Department of Mines  
Geological Survey Branch  
P.O. Box 4750  
St. John's, Newfoundland  
A1C 5T7  
(709) 576-2763

**H. Falck**  
Energy, Mines and Petroleum  
Resources  
Government of the Northwest  
Territories  
Yellowknife, Northwest  
Territories  
X1A 2L9  
(403) 920-3304

**M.A.F. Fedikow**  
Manitoba Department of Energy  
and Mines  
Geological Services Branch  
535-330 Graham Avenue  
Winnipeg, Manitoba  
R3C 4E3  
(204) 945-4154

**K.J. Ferreira**  
Manitoba Department of Energy  
and Mines  
Geological Services Branch  
535-330 Graham Avenue  
Winnipeg, Manitoba  
R3C 4E3  
(204) 945-4154

**K.L. Ford**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-1235

**J.M. Franklin**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4137

**S. Fumerton**  
Chevron Minerals Ltd.  
Box 360  
Balmerton, Ontario  
P0V 1C0  
(807) 735-2337

**J.A. Fyon**  
Engineering and Terrain Geology  
Section  
Ontario Geological Survey  
9-77 Grenville Street  
Toronto, Ontario  
M7A 1W4  
(416) 965-1321

**Q. Gall**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

**A.G. Galley**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-9754

**S.S. Gandhi**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4642

**G. Gauthier**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-4271

**H.L. Gibson**  
Falconbridge Ltd, Explorations  
Sudbury Operations  
P.O. Box 40  
Falconbridge, Ontario  
P0M 1S0  
(705) 693-2761

**R. Godue**  
Commission géologique du  
Canada  
Centre géoscientifique de Québec  
2700 rue Einstein  
Sainte-Foy, Québec  
(418) 654-2654

**W.D. Goodfellow**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-8163

**D.F. Graham**  
Intera Technologies Limited  
1525 Carling Avenue  
Ottawa, Ontario  
K1Z 8R9  
(613) 728-6111

**M.C. Graves**  
Cuesta Research  
154 Victoria Road  
Dartmouth, Nova Scotia  
B3A 1V8  
(902) 469-4763

**S.B. Green**  
Geological Survey of Canada  
Mineral Resources Division  
Ottawa, Ontario  
K1A 0E8  
(613) 996-7345

**C. Grégoire**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4213

**G.A. Gross**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4125

**G.E.M. Hall**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-6425

**S.M. Hamilton**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

**M. Hannington**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-4865

**D.C. Harris**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4495

**J. Harris**  
Intera Technologies Limited  
1525 Carling Avenue  
Ottawa, Ontario  
K1Z 8R9  
(613) 728-6111

**B. Hart**  
University of Western Ontario  
Department of Geology  
London, Ontario  
N6A 3K7  
(519) 679-2111

**E. Hegner**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4972

**J.B. Henderson**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-7826

**J.R. Henderson**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-5446

**M.N. Henderson**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-9858

**P.M. Herzig**  
University of Toronto  
Earth Science Centre  
22 Russell Street  
Toronto, Ontario  
M5S 3B1  
(416) 978-3022

**C.J. Hodgson**  
Queen's University  
Department of Geological  
Sciences  
Kingston, Ontario  
K7L 3N6  
(613) 545-2597

**P.K. Hofman**  
Derry Michener Booth and Wahl  
Suite 410-20 Richmond Street  
East  
Toronto, Ontario  
M5H 2Y4  
(416) 368-4636

**P. Hood**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4913

**T. Höy**  
Ministry of Energy, Mines and  
Petroleum Resources  
Parliament Buildings  
Victoria, British Columbia  
V8V 1X4  
(604) 356-2818

**G.J. Hudack**  
University of Minnesota-Duluth  
Department of Geology  
Duluth, Minnesota  
55811  
(218) 720-4294

**K. Hudson**  
Sirius Energy Corp. Ltd.  
Suite 200, 700-4th Ave.  
Calgary, Alberta  
T2P 3J4  
(403) 265-5997

**L.J. Hulbert**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-7216

**C.W. Jefferson**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-9862

**G.A. Jenner**  
Memorial University  
Department of Earth Sciences  
St. John's, Newfoundland  
A1B 3X5  
(709) 737-8143

**I.R. Jonasson**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-2766

**A.G. Jones**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-4968

**E.S. Kappel**  
Joint Oceanographic Institutions  
Inc.  
800-1755 Massachusetts Avenue  
N.W.  
Washington, D.C.  
20036  
(202) 232-3900

**C.A. Kaszycki**  
Geological Survey of Canada  
Terrain Sciences Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-5667

**O.E. Kawka**  
Oregon State University  
Petroleum Research Group  
College of Oceanography  
Corvallis, Oregon  
97331  
(503) 754-3504

**B.F. Kean**  
Department of Mines  
Mineral Resources Management  
Branch  
P.O. Box 4750  
St. John's, Newfoundland  
A1C 5T7  
(709) 576-2768

**J.E. Kerr**  
Derry, Michener, Booth and Wahl  
Suite 410-20 Richmond Street  
Toronto, Ontario  
M5H 2Y4  
(416) 368-4636

**J.A. Kerswill**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4586

**I.M. Kettles**  
Terrain Sciences Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-8323

**P.G. Killeen**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-2312

**J.E. King**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-4882

**D.L. Kingston**  
University of Western Ontario  
London, Ontario  
N6A 3K7  
(519) 679-2111

**R.V. Kirkham**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4656

**F. Kiss**  
Geological Survey of Canada  
Geophysics Division  
1 Observatory Crescent  
Ottawa, Ontario  
K1A 0Y3  
(613) 995-0743

**R.A. Klassen**  
Geological Survey of Canada  
Terrain Sciences Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-6234

**G.J.A. Kooiman**  
Consultant  
P.O. Box 77  
St. George, New Brunswick  
E0G 2Y0  
(506) 755-3998

**E.R. Koopman**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-8055

**R.A. Koski**  
United States Geological Survey  
Branch of Pacific Marine Geology  
345 Middlefield Road, MS 999  
Menlo Park, California  
94025  
(415) 853-8300

**P. Kowalczyk**  
Placer Dome  
P.O. Box 49330  
Bentall Postal Station  
Vancouver, British Columbia  
V7X 1P1  
(604) 682-7082

**M. Koziol**  
Cameco  
122-3rd Avenue North  
Saskatoon, Saskatchewan  
S7K 2H6  
(306) 956-6200

**R.D. Kurtz**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-4998

**M.B. Lambert**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-0938

**M.H.S. Lau**  
Noranda Exploration Company  
Ltd.  
26 Old Airport Road  
Yellowknife, Northwest  
Territories  
X1A 2P8  
(403) 873-5873

**J.G. Lavigne**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-8916

**G.M. Le Cheminant**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4686

**D.A. Lentz**  
Ottawa-Carleton Geoscience  
Centre  
University of Ottawa  
Department of Geology  
Ottawa, Ontario  
K1S 5B6  
(613) 564-3480

**D.A. Love**  
Queen's University  
Department of Geological  
Sciences  
Kingston, Ontario  
K7L 3N6  
(613) 545-2597

**R. Lustwerk**  
2150 Blossom Drive  
Ottawa, Ontario  
K1H 6G8  
(613) 523-3329

**J.W. Lydon**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-8243

**P. Mainwaring**  
Manager, Application Microscope  
Products  
Link Analytical  
Old Sauk Trails Park  
8017 Excelsior Drive  
Madison, Wisconsin  
53717  
(608) 836-3200

**P.F. Matysek**  
Ministry of Energy, Mines and  
Petroleum Resources  
Parliament Buildings  
Victoria, British Columbia  
V8V 1X4  
(604) 356-2818

**Y.T. Maurice**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4748

**P.H. McGrath**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4075

**B.I. McInnes**  
Ottawa-Carleton Geoscience  
Centre  
University of Ottawa  
Department of Geology  
Ottawa, Ontario  
K1N 6N5  
(613) 564-3480

**G.W. McNeice**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-8242

**F.A. Michel**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(614) 564-2630

**K. Misra**  
Canadian Centre for Remote  
Sensing  
2464 Sheffield Rd.  
Ottawa, Ontario  
K1A 0Y7  
(613) 998-6740

**J. Morgan**  
Energy Mines and Petroleum  
Resources  
Government of the Northwest  
Territories  
Yellowknife, Northwest  
Territories  
X1A 2L9  
(403) 920-3304

**W.A. Morris**  
Morris Magnetics Inc  
RR # 2  
Lucan, Ontario  
N0M 2J0  
(519) 227-1106

**J.K. Mortensen**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-8935

**R.L. Morton**  
University of Minnesota-Duluth  
Department of Geology  
Duluth, Minnesota  
55811  
(218) 720-4294

**J.L. Morton**

United States Geological Survey  
Branch of Pacific Marine Geology  
345 Middlefield Road, MS 999  
Menlo Park, California  
94025  
(415) 853-8300

**C.J. Mwenifumbo**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-6520

**E. Nielsen**

Manitoba Energy and Mines  
Geological Services Branch  
535-330 Graham Avenue  
Winnipeg, Manitoba  
R3C 4E3  
(203) 945-4154

**D. Nikols**

Alberta Geological Survey  
Alberta Research Council  
Edmonton, Alberta  
T6H 5R7  
(403) 450-5111

**W.L. Nolan**

Government of Newfoundland and  
Labrador  
Department of Mines and Energy  
Geological Survey Branch  
P.O. Box 8700  
St. John's, Newfoundland  
A1B 4J6  
(709) 576-2763

**R.A. Olson**

Trigg, Wollett, Olson Consulting  
Ltd.  
10504-103 St  
Edmonton, Alberta  
T5H 2V4  
(403) 425-8905

**W.A. Padgham**

Northwest Territories Geology  
Division  
Indian and Northern Affairs,  
Canada  
P.O. Box 1500  
Yellowknife, Northwest  
Territories  
X1A 2R3  
(403) 920-8210

**A.D. Paktunc**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-2859

**S. Paradis**

Commission géologique du  
Canada  
Centre géoscientifique de Québec  
2700 rue Einstein  
C.P. 7500  
Sainte-Foy, Québec  
G1V 4C7  
(418) 654-2651

**D. Parbery**

Manitoba Department of Energy  
and Mines  
Geological Services Branch  
535-330 Graham Avenue  
Winnipeg, Manitoba  
R3C 4E3  
(204) 945-4154

**D. Paré**

Concor Mines Incorporated  
89 rue Eddy  
Hull, Québec  
J8X 2W3  
(819) 770-6832

**A.F. Park**

University of New Brunswick  
Geology Department  
Fredericton, New Brunswick  
E3B 5A3  
(506) 453-4599

**W.N. Pearson**

Derry Michener Booth and Wahl  
Suite 410-20 Richmond Street  
East  
Toronto, Ontario  
M5H 2Y4  
(416) 368-4636

**M.R. Perfit**

University of Florida  
Department of Geology  
Gainesville, Florida  
32611  
(904) 392-2128

**J.M. Peter**

University of Toronto  
Department of Geology  
Earth Sciences Centre  
22 Russell Street  
Toronto, Ontario  
M5S 3B1  
(416) 978-3022

**P. Pilote**

Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(918) 825-7514

**K.H. Poulsen**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-2396

**D. Racicot**

Service Géologique du Nord-Ouest  
Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(819) 825-7514

**S. Ralser**

University of New Brunswick  
Geology Department  
Fredericton, New Brunswick  
E3B 5A3  
(506) 453-4666

**E. Ready**

Geological Survey of Canada  
Geophysics Division  
1 Observatory Crescent  
Ottawa, Ontario  
K1A 0Y3  
(613) 995-7176

**R. Reddy**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-3628

**C. Relf**

Queen's University  
Department of Geological  
Sciences  
Kingston, Ontario  
K7L 3N6  
(613) 545-2597

**A.N. Rencz**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4786

**D. Richardson**

Geological Survey of Canada  
Mineral Resources Division  
Ottawa, Ontario  
K1A 0E8  
(613) 992-7268

**R.J.H. Richardson**

Alberta Geological Survey  
Alberta Research Council  
Edmonton, Alberta  
T6H 5R7  
(403) 438-7623

**F. Robert**

Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-5120

**K. Robertson**  
Noranda Exploration  
920 Bridge Street  
Bathurst, New Brunswick  
E2A 3Z1  
(506) 548-0123

**D.J. Robinson**  
Robinson Exploration Services  
Ltd.  
96 Parklea Drive  
Toronto, Ontario  
M4B 2J8  
(416) 421-0565

**J.C.M. Roddick**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4018

**S.M. Roscoe**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4115

**R.M. Rousseau**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-6001

**C. Roy**  
Service Géologique du Nord-Ouest  
Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(819) 825-7514

**D.F. Sangster**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-5500

**A.L. Sangster**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-8603

**S. Schaen**  
Ottawa-Carleton Geoscience  
Centre  
University of Ottawa  
Department of Geology  
K1N 6N5  
(613) 564-3480

**L.D. Schock**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 996-3958

**E.J. Schwarz\***  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4298

**S.D. Scott**  
University of Toronto  
Department of Geology  
Earth Sciences Centre  
22 Russell Street  
Toronto, Ontario  
M5S 3B1  
(416) 978-3022

**W.C. Shanks III**  
United States Geological Survey  
954 National Center  
Reston, VA 22092  
(703) 648-4000

**R.B.K. Shives**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-4279

**T.I.I. Sibbald**  
Saskatchewan Energy and Mines  
1914 Hamilton Street  
Regina, Saskatchewan  
S4P 4V4  
(306) 787-2576

**A. Simard**  
Service Géologique du Nord-Ouest  
Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(819) 825-7514

**B.R.T. Simoneit**  
Oregon State University  
Petroleum Research Group  
College of Oceanography  
Corvallis, Oregon  
97331  
(503) 754-3504

**W.D. Sinclair**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-9810

**V.R. Slaney**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-1083

**W.A. Spirito**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4145

**P. Stone**  
Geological Survey of Canada  
Geophysics Division  
1 Observatory Crescent  
Ottawa, Ontario  
K1A 0Y3  
(613) 995-0753

**G.M. Stott**  
Precambrian Geology Section  
Ontario Geological Survey  
9-77 Grenville Street  
Toronto, Ontario  
M7A 1W4  
(416) 965-1321

**H.S. Swinden**  
Department of Mines  
Geological Survey Branch  
P.O. Box 4750  
St. John's, Newfoundland  
A1C 5T7  
(709) 576-2763

**B.E. Taylor**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4673

**R.P. Taylor**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

**D.J. Teskey**  
Geological Survey of Canada  
Geophysics Division  
1 Observatory Crescent  
Ottawa, Ontario  
K1A 0Y3  
(613) 992-9763

**R.J. Theriault**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-5401

\*deceased

**M.D. Thomas**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-5582

**F.J. Thompson**  
Private Consultant  
23 Kippewa  
Ottawa, Ontario  
K1S 3G3  
(613) 233-5448

**R.I. Thorpe**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4670

**J.G. Thurlow**  
B.P. Resources Canada Limited  
P.O. Box 7879  
Corner Brook, Newfoundland  
A2H 6G7  
(709) 639-7931

**P.C. Thurston**  
Precambrian Geology Section  
Ontario Geological Survey  
9-77 Grenville Street  
Toronto, Ontario  
M7A 1W4  
(416) 965-1321

**J. Tod**  
Geological Survey of Canada  
Geophysics Division  
1 Observatory Crescent  
Ottawa, Ontario  
K1A 0Y3  
(613) 995-0735

**R.J.W. Turner**  
Geological Survey of Canada  
Mineral Resources Division  
100 West Pender Street  
Vancouver, British Columbia  
V6B 1R8  
(604) 666-4852

**A. Vachon**  
Les Ressources Minières Rouyn  
Inc.  
68 rue Principale  
Rouyn-Noranda, Québec  
J9X 4P2  
(819) 797-2465

**O. van Breemen**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-0810

**C.S. van Staal**  
Geological Survey of Canada  
Continental Geoscience Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 995-4333

**P. Verpaelt**  
Service Géologique du Nord-Ouest  
Ministère de l'Énergie et des  
Ressources (mines)  
400, Boul. Lamaque  
Val-D'Or, Québec  
J9P 3L4  
(819) 825-7514

**J.S. Walker**  
University of Minnesota-Duluth  
Department of Geology  
Duluth, Minnesota  
55811  
(218) 720-4294

**D.H. Watkinson**  
Ottawa-Carleton Geoscience  
Centre  
Carleton University  
Department of Earth Sciences  
Ottawa, Ontario  
K1S 5B6  
(613) 564-2630

**D.H. Watkins**  
Minnova Inc.  
P.O. Box 91  
3970 Commerce Court W  
Toronto, Ontario  
M5L 1C7  
(416) 982-7270

**G.P. Watson**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-7885

**R.E.S. Whitehead**  
Laurentian University  
Geology Department  
Sudbury, Ontario  
P3E 2C6  
(705) 675-1151

**J. Wilson**  
Alberta Geological Survey  
Alberta Research Council  
Edmonton, Alberta  
T6H 5R7  
(403) 450-5111

**K. Witherly**  
BHP-Utah Mines Ltd.  
25 Adelaide St. E.  
Toronto, Ontario  
M5C 1Y2  
(416) 368-3884

**D.F. Wright**  
Geological Survey of Canada  
Mineral Resources Division  
601 Booth Street  
Ottawa, Ontario  
K1A 0E8  
(613) 992-3628

**N. Wright**  
University of Toronto  
Earth Sciences Centre  
22 Russell Street  
Toronto, Ontario  
M5S 3B1  
(416) 978-3022

**M. Zentilli**  
Dalhousie University  
Halifax, Nova Scotia  
B3H 3J5  
(902) 424-2358

**R.A. Zierenberg**  
United States Geological Survey  
MS 901, 345 Middlefield Road  
Menlo Park, CA 94025  
(415) 853-8300

**J. Zinck**  
1114-2975 Albion Road  
Ottawa, Ontario  
K1V 8S3  
(613) 521-1796

# AUTHOR INDEX

Abbott, G.	23,34	Ford, K.L.	8,19
Ames, D.E.	13,20,26	Franklin, J.M.	9,10,13,20,21,24,25,27
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Broome, J.	16	Henderson, J.R.	23
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Donaldson, J.A.	20	Kean, B.F.	33
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Eckstrand, O.R.	11	Kettles, I.M.	24
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Elliot, B.E.	18,24	King, J.E.	24
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Nolan, W.L.	17	Thorpe, R.I.	10
Olson, R.A.	23	Thurlow, J.G.	10,34
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Parbery, D.	19	Vachon, A.	30
Paré, D.	24	van Breemen, O.	22
Park, A.F.	31	van Staal, C.S.	10,34
Pearson, W.N.	29	Verpaelst, P.	16
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Peter, J.M.	30	Watkins, D.H.	10
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Poulsen, K.H.	10,13,15,20,25,31	Watson, G.P.	9,35
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