11TH INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM

April 28 - May 2, 1985
Toronto, Ontario, Canada

Programme and Abstracts

11th
International
Geochemical
Exploration
Symposium

April 28 - May 2, 1985
Metro Toronto Convention Centre
Toronto, Ontario, Canada

PROGRAMME AND ABSTRACTS

Sponsored by the

Association of Exploration Geochemists

CONTENTS

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Organizing Committee

Co-Chairmen	W.B. Coker	Derry, Michener, Booth and Wahl
	R.G. Garrett	Geological Survey of Canada
Secretary	R.E. Lett	Barringer Magenta Ltd.
Treasurer	R.G. Jackson	Novamin Resources Inc.
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Facilities and Social Program	L.B. Bloom	X-Ray Assay Laboratories Ltd.
Exhibition	E.L. Hoffman	Nuclear Activation Services Ltd.

WELCOME FROM THE CHAIRMEN

On behalf of the Organizing Committee it is our pleasure to extend a warm welcome to all registrants at the 11th International Geochemical Exploration Symposium. We hope that you will find the technical program interesting and stimulating, and that you will have time to participate in the social activities planned for you. We trust that you will enjoy the Symposium, your visit to Toronto and the field excursions, and if you are visiting us from abroad, your stay in Canada.

We express our gratitude to the many organizations who have supported us in preparing for this Symposium. Organizations and institutions have not only supported us financially, but have given time, and made various facilities available, to their staff who have been active in the organizational task. Session chairmen and co-chairmen undertook the work of reviewing the technical submissions and selecting the papers for presentation. We thank all of these, and the many others who have helped in countless ways, for their assistance to the 11th International Geochemical Exploration Symposium.

William B Coker   Robert G. Garrett

SUPPORTING ORGANIZATIONS

The Organizing Committee expresses its sincere thanks to the following organizations who have supported the 11th International Geochemical Exploration Symposium financially.

Assayers (Ontario) Limited
Billiton Canada Ltd.
B.P. Resources Canada Limited
Lac Minerals Ltd.
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Utah Mines Ltd.

In particular we thank the Geological Survey of Canada, Department of Energy, Mines and Resources, for a grant to cover the publication costs of this Programme and Abstracts volume.

ACKNOWLEDGEMENT

The Organizing Committee thanks Mrs. Joanne Belec and Mrs. Mary-Ann Blondin for their great help in preparing this Programme and Abstracts volume. Thanks are also due to Mrs. Ines Filicetti for all her help with the pre-registration.

SYMPOSIUM ADDRESSES

During the Symposium:

11th International Geochemical Exploration Symposium
Metro Toronto Convention Centre
255 Front Street West
Toronto, Ontario
M5V 2W6
Telephone: (416) 585-8000
Telex: 06-217584

After the Symposium:

Technical publication:

Dr. R.G. Garrett
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8
Canada
Telephone: (613) 995-4517
Telex: 053-3117 EMAR OTT

All other matters:

11th International Geochemical
Exploration Symposium
P.O. Box 523 (Metro Toronto)
Rexdale, Ontario
M9W 5L4
Canada

ACCOMMODATION

The following is a list of hotels in Toronto at which arrangements have been made for special convention rates.

L'Hotel
225 Front Street West
Toronto, Ontario
M5V 2X3

(416) 366-2214

Holiday Inn (Downtown)
89 Chestnut Street
Toronto, Ontario
M5G 1R1

(416) 977-0707

Royal York Hotel
100 Front Street West
Toronto, Ontario
M5T 1E3

(416) 863-6333

Delta Chelsea Inn
33 Gerrard Street West
Toronto, Ontario
M5G 1Z4

(416) 595-1975

GENERAL INFORMATION

Venue

The Symposium is being held in the new Metro Toronto Convention Centre, which is situated in the southwestern corner of the core of downtown Toronto. The Convention Centre is immediately adjacent to both L'Hotel and the CN Tower, the world's tallest freestanding structure (533 metres).

The technical sessions will be held in the Theatre, on the lower level of the Convention Centre. Both the Poster Presentation and Commercial Exhibition, which are open from Sunday evening to Tuesday afternoon at the close of coffee, are being held in Constitution Hall on the lower level of the Convention Centre. The pre-symposium workshops will take place in the Meeting Rooms West area on the street level of the Convention Centre on Saturday, April 27, and Sunday, April 28.

Transport

The Toronto Transit Commission (TTC) maintains a network of trams, busses and subways in Toronto. Riders have to purchase tokens, and transfer coupons are available for making connections. The nearest subway stations are Union Station or King Street, both about a five minute walk from the Convention Centre. The No. 19 Church bus travels south on Church St. and then west along Front St. past the Metro Toronto Convention Centre. The No. 27 Yonge and No. 6 Bay busses travel south along Yonge and Bay Streets respectively, and turn along Front St. with a stop at Union Station. From Union Station the Convention Centre is a five minute walk west along Front Street.

Parking

Vehicle parking is available at the Metro Toronto Convention Centre, parking fees for a full day are $5.00. Most of the major hotels have arrangements for parking at special rates for their guests. In general, you are advised to use public transport during your visit to Toronto. As in most major cities of the world both traffic and parking can pose frustrating problems for out-of-town visitors, it is best to avoid them.

Air Travel

The Symposium has been registered with Air Canada Convention Central who provide an exclusive discounted reservation service for delegates to the symposium.

Delegates should use the Zenith telephone number, 1-800-361-7585, and identify themselves as 11th IGES participants.

Registration services are being provided by Insight Planners Inc. of Toronto, whose staff will be on duty during the Symposium.

Registration

The registration desk will be open at the following times and locations in the Metro Toronto Convention Centre:

Sunday, April 28	4:00 pm - 9:00 pm	Entrance to the Exhibit Area, Constitution Hall
Monday, April 29	8:00 am - 5:00 pm	Entrance to the Theatre
Tuesday, April 30	8:00 am - 5:00 pm	Entrance to the Theatre
Wednesday, May 1	8:00 am - 12:30 pm	Entrance to the Theatre
Thursday, May 2	8:00 am - 12:30 pm	Entrance to the Theatre

For those participants involved in the pre-Symposium field excursions and workshops, their registration packages will be available to them when they join their excursion, or the workshops open.

Additionally, Insight Planners will have a sight-seeing tour desk to provide information on tours to local attractions, theatres, and sporting events in Toronto.

Name Badges

All registered participants and accompanying guests will be issued name badges. Admission to the technical sessions, displays and social events is limited to registrants only, and it is essential to display your badge at all times.

Meals

A light lunch will be provided free to all pre-registrants on Monday, April 29. A similar lunch will be provided to pre-registrants, and those who register before noon on April 29, on Tuesday, April 30. A cash bar will also be available. These luncheons will be available in Constitution Hall at the Convention Centre, which will permit registrants to view the poster presentations and commercial exhibits.

A full range of luncheon facilities may be found in the adjoining L'Hotel or downtown Toronto.

Refreshments

Coffee and tea will be served in Constitution Hall, on Monday and Tuesday, and outside the Theatre, on Wednesday and Thursday, during morning and afternoon breaks in the technical sessions.

SOCIAL PROGRAM

Welcome Reception

Sunday, April 28, 6:00 pm - 9:00 pm. Constitution Hall, Metro Toronto Convention Centre.

Hot and cold hors d'oeuvres and drinks will be served at a Sunday evening ice-breaker. Take this opportunity to see the poster presentations and commercial exhibits, and to meet old friends.

Cabaret Dinner Theatre

Tuesday, April 29, 6:00 pm - 11:00 pm.

An evening of fine dining and exciting entertainment in attractive cabaret surroundings. Toronto is now the third most active theatre centre in the world, with some fifty professional groups offering a wide range of dramatic entertainment.

The price of $50 (Cdn) per person includes transportation, dinner, show and all taxes and gratuities. The cost may vary slightly depending upon the number of persons attending. Arrangements to join the evening may be made through Insight Planners Inc. at the Registration desk.

CN Tower Banquet

Wednesday, May 1, 5:00 pm - 12:00 pm. Sparkles Night Club and the CN Tower Restaurant.

A remarkable evening at Toronto's CN Tower with cocktails and hors d'oeuvres at Sparkles Nightclub, followed by dinner in the restaurant 350 m above ground level. The restaurant revolves once every 75 minutes, on a clear evening you can see not only Toronto but also the mist from Niagara Falls on the far side of Lake Ontario. Following dinner, Sparkles Nightclub will be available for an evening of dancing and enjoying the company of friends.

The price of $45 (Cdn) per person includes hors d'oeuvres and two cocktails at Sparkles before dinner, your dinner, including wine, and all taxes and gratuities. Additional drinks may be purchased if you wish at Sparkles, and in the restaurant. Space is limited for the Banquet, if you did not buy your ticket with your pre-registration and you wish to attend you should contact the registration desk as soon as possible.

GUEST PROGRAM

Insight Planners Inc. has arranged for two tours. In addition, Insight can supply information on tours to other local attractions, e.g., the Royal Ontario Museum, theatres and sporting events in Toronto. However, it must be noted that the final availability of the tours, and their cost, will depend upon the level of participation.

Niagara Falls and Niagara-on-the-Lake

Wednesday, May 1, 8:30 am - 4:30 pm.

A visit to Niagara Falls, one of the world's scenic wonders, and a tour of one of Ontario's oldest towns, Niagara-on-the-Lake. The motor coach tour passes through the orchards and vineyards of the Niagara fruit belt, and crosses over the Welland Canal, that permits ocean going shipping access to Chicago and Duluth almost half way across the continent.

On arrival at Niagara Falls the Canadian, or Horseshoe Falls can be viewed from Table Rock. There will be time to visit other local attractions, e.g., the tunnels behind the Falls, or a boat trip on the Maid of the Mist to the foot of the falls.

Lunch will be provided in the revolving restaurant atop the Skylon tower. Following the drive down the Niagara Parkway to Lake Ontario, a tour will be made of historic Niagara-on-the-Lake, the Empire Loyalist town that was once capital of Upper Canada in the 18th century.

The cost of the tour, including transportation, lunch, taxes and gratuities is $50 (Cdn) per person.

City of Toronto and Casa Loma Tour

Wednesday, May 1, 1:00 pm - 4:00 pm.

To out-of-towners this is an excellent way to see the varied faces of Toronto, including the University with its historic buildings, the stately Provincial Parliament, Yorkville with its collection of boutiques, cafes and galleries, Old City Hall and the award winning ultra modern New City Hall, and the nearby avant-garde architecture of Bay Street and the financial district. In complete contrast are Casa Loma, the turreted castle of an eccentric millionaire, the beautiful homes of Rosedale, the St. Lawrence area with its famous market and the centre of the old town of York. Last, but not least the Toronto theatre district, nearby Chinatown, and the Art Gallery of Ontario - famous for its collection of Henry Moore sculptures.

All this for $20 (Cdn), which covers transportation, entrance fees where applicable, taxes and gratuities.

TECHNICAL PROGRAM

The technical program consists of six components. The main technical sessions are supported by poster presentations and a commercial exhibition. In addition, there is an afternoon of parallel activities consisting of a single technical session and a series of local tours to facilities and field exposures in the Toronto area. Immediately prior to the symposium a series of two-day workshops are being held, and both before and after the symposium a number of field excursions have been planned.

Field Excursions

The field excursions have been made available to pre-registrants. Very limited late registration for post-symposium field excursions may be possible if space becomes available due to cancellations.

Gold Deposits, Geology and Exploration Environments, Hemlo, Ontario
Leaders: R. Geddes and T. Muir
Dates: May 3 - 6
The excursion covers the regional geological setting of the district in addition to the detailed geology of the Hemlo gold deposits, including Noranda's Golden Giant Mine and the property of Lac Minerals. Also featured will be the surficial geology of the district, and how it has influenced the exploration procedures used in the Hemlo camp. The excursion will also pass through some of the classic geological exposures and scenery of Lake Superior's "North Shore".

Gold and Massive Sulphide Deposits. Bedrock and Surficial Geology, Timmins Area, Ontario
Leaders: M.J. Downes and A. Fyon
Dates: April 24 - 28
This excursion will visit new prospects under development in the Timmins area which have an exploration history involving the use of geochemical techniques. Visits will include Kidd Creek's Hoyle Pond prospect (Au), the Owl Creek open pit (Au) and an underground visit at the Kidd Creek Mine (Cu, Zn, Ag). To complement these visits various outcrops will be examined to illustrate the regional setting. A demonstration of drill rigs and equipment commonly used in overburden exploration, and a tour of an overburden sample preparation laboratory, will be included.

Glacial Sedimentology and Overburden Geophysics, Toronto Area
Leader: N. Eyles
Date: May 3
The stratigraphy and sedimentology of a large glaciolacustrine basin infill exposed in a 10 km section of the Scarborough Bluffs east of Toronto will be studied. Emphasis will be placed on differentiating various types of glacial diamict previously regarded as "basal till". The value of downhole geophysical logging in identifying the nature of subsurface glacial stratigraphic successions will be demonstrated at a calibration hole atop the Bluffs. The excursion will be of particular interest to explorationists working in lake plains and other areas of extensive glaciolacustrine cover.

Geochemical Laboratories, Toronto Area
Leaders: E.J. Brooker and others
Date: May 3
This all day excursion will be to the facilities of Assayers (Ontario) Limited, Technical Services Laboratories, Barringer Magenta Limited, X-Ray Assay Laboratories Limited, and the Ontario Geological Survey laboratories. These laboratories offer a range of services including: sample preparation; analysis using x-ray fluorescence, atomic absorption, plasma emission methods, etc.; assaying; and data processing.

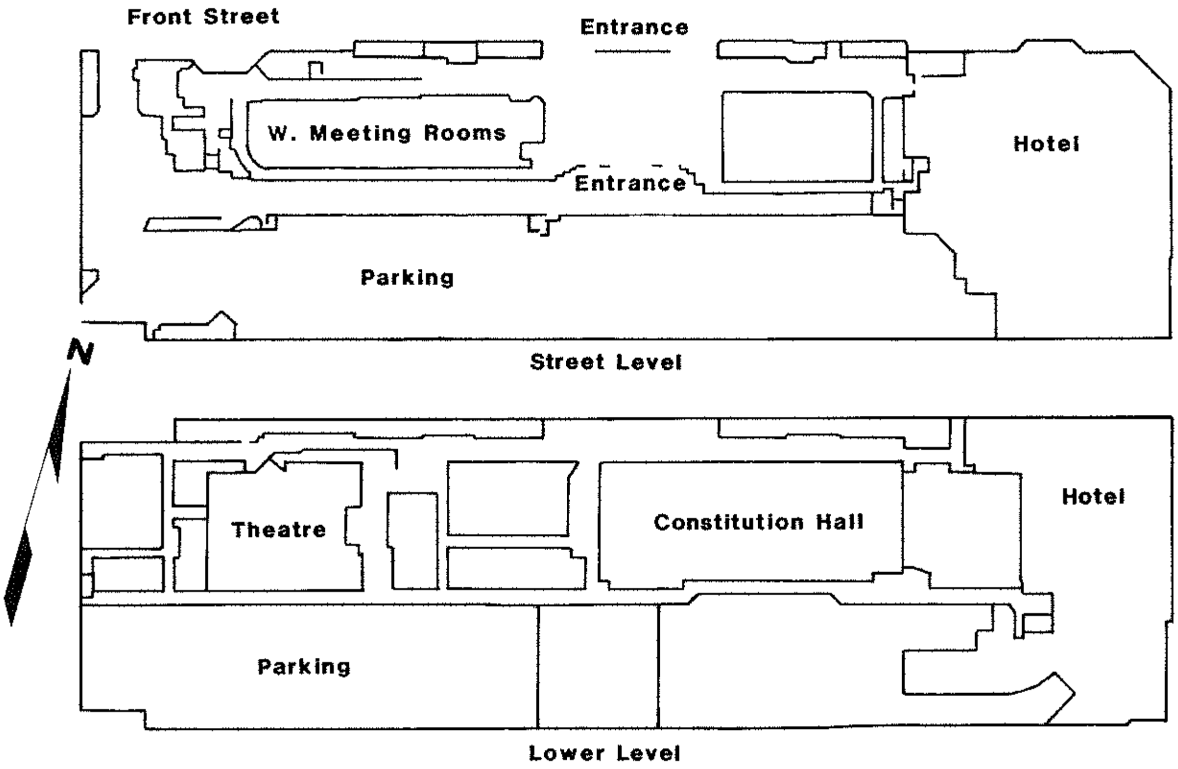
Local Excursions

On the **afternoon of Wednesday, May 1,** a series of excursions will be available. Pre-registration for these was requested, but there is some flexibility in organizing some of these excursions. If you have not pre-registered and would like to joint one of the excursions you should enquire at the registration desk.

Geochemical Laboratories, Toronto Area
Leaders: E.J. Brooker and others
The tour will travel to Hamilton, southwest of Toronto, to visit the facilities of Nuclear Activation Services Limited. NAS provide analytical services primarily based on the measurement of induced radioactivity (neutron activation analysis).

Ontario Centre for Remote Sensing, Toronto
Leader: S. Pala
The one hour tour of this internationally renowned research institute will demonstrate some of the technology at the OCRS's state-of-the-art facilities through completed and ongoing projects.

Glacial Sedimentology, Toronto Area
Leader: N. Eyles
This visit to the famous Don Valley Brickyard may be a last opportunity as the brickyard is no longer being worked. At this time the entire stratigraphy is still visible and participants will be able to view exposures of the last interglacial (Sangamon) and sediments of the preceding glaciation (Illinoian). The sequence provides an opportunity to view many aspects of glaciolacustrine sedimentation.



Metro Toronto Convention Centre

Workshops

Enrollment in the Workshops is by pre-registration. They will be held in the West Meeting Rooms, 201A to F on the street level of the Metro Toronto Convention Centre, on Saturday, April 27, and Sunday, April 28. Lunch, and morning and afternoon refreshments will be provided for registrants on both Saturday and Sunday. The workshops will be held concurrently from 8:30 am to 4:30 pm, and participants are expected to attend both days of the workshop they enroll in.

1. Biogeochemistry
Leader: C.E. Dunn, Saskatchewan Geological Survey, Regina, Saskatchewan, Canada.

2. Electrogeochemistry
Leader: B. Bolviken, Geological Survey of Norway, Trondheim, Norway.

3. Rare-Earth Geochemistry
Leader: P.C. Thurston, Ontario Geological Survey, Toronto, Ontario, Canada.

4. Till Geochemistry
Leader: I. Nichol, Queen's University, Kingston, Ontario, Canada.

5. Geochemical Anomaly Recognition
Leader: J.W. Aucott, British Geological Survey, Keyworth, United Kingdom.

Prizes

Through the generosity of Billiton Canada Limited four prizes will be awarded for best paper, best poster, best student paper, and best student poster presentations made at the symposium.

Technical Sessions

The oral presentations will be made in the Theatre of the Metro Toronto Convention Centre. The schedule of presentations is full and the time limited. The Organizing Committee has asked speakers to concentrate on summarizing, and drawing attention to the important results and conclusions of their work. Each speaker has been allocated 20 minutes, and is requested to leave a few minutes free for questions. Both speakers and audience are asked to be considerate of to each other by being on time and keeping to the published timetable.

MONDAY, APRIL 29

Opening Ceremonies

Chairmen: **W.B. Coker** and **R.G. Garrett**

08:45 Welcome to the 11th International Geochemical Exploration Symposium: W.B. Coker, Co-Chairman, Organizing Committee

Welcome on behalf of the Association of Exploration Geochemists: R.G. Garrett, President

Opening Address

Chairmen: **W.B. Coker** and **R.G. Garrett**

09:00 **J.J. Brummer, C.F. Gleeson,** and **J.A. Hansuld;** Historical perspective of exploration geochemistry in Canada, the first twenty-five years

Bedrock Geochemistry

Chairmen: **W.D. Goodfellow and S.E. Kesler**

09:40 **C.S. Rugless** and **G. Teale;** Lithogeochemical exploration for polymetallic Sn-Cu-Ag-Au-Pb-Zn vein mineralization at North Mammoth prospect, Northeast Victoria, Australia

10:00 **L.A. Clark;** Near-surface lithogeochemical haloes as an aid to discovery of deep unconformity-type uranium deposits, Athabasca Basin, Saskatchewan

10:20 Break

Geochemical Exploration for Mineral Deposits in Sedimentary Terranes

Chairmen: **W.D. Goodfellow** and **R. Saager**

10:40 **S.J. Hoffman, K.S. Crosby** and **J.A. Irvine;** Lithogeochemistry applied to the Millstream potash deposit, New Brunswick, Canada

11:00 **K.J. Moon;** Host-rock petrochemistry applicable to exploration in the Baegunsan syncline (Hambaeg basin), Korea

11:20 **P.R. Duller** and **P.K. Harvey;** Lithogeochemical exploration for stratabound arsenopyrite-gold mineralization in the Southern Uplands, Scotland

11:40 **F.M. Haynes** and **S.E. Kesler;** Fluid inclusion geochemistry in the exploration for Mississippi Valley-type deposits: An example from East Tennessee

12:00 Lunch

Advances in Analytical Chemistry

Chairmen: **G.E.M. Hall** and **J-P. Saheurs**

13:40 **S.E. Church, J.M. Motooka** and **E.L. Mosier;** Application of Inductively Coupled Plasma methods to partial digestions of stream sediments for reconnaissance geochemistry

14:00 **T.E. Eagles, E.J. Brooker** and **R.G. Smith;** Application of an Inductively Coupled Plasma Mass Spectrometer to the determination of lead isotope concentrations and related trace element abundances in minerals, waters and soils associated with some base metal and gold occurrences in Ontario: A preliminary report

14:20 **E.L. Hoffman** and **A. Pidruczny;** The application of low-cost multi-element data by neutron activation analysis suitable for exploration geochemical techniques

14:40 **P.K. Harvey** and **B.P. Atkin;** Automated XRF spectrometric analysis: A rapid cost-effective analytical technique for the mineral industry

15:00 Break

Geochemical Patterns and the Environment

Chairmen: **J.A.C. Fortescue** and **I. Thornton**

15:20 **R.A. Anderson** and **E.H. Carlson;** Re-examination of mercury pollution in the Ashtabula area, Ashtabula County, Ohio

15:40 **W.E. Sharp** and **G. Nardi;** A survey of the heavy metal pollution in the bottom sediments at Porto di Bagnoli (Naples), Italy

16:00 **D. Fredriksson;** Sulphur, uranium and trace elements in Swedish mires planned for fuel-peat production

16:20 **J. Ek;** Geochemical mapping of Sweden

16:40 Close

TUESDAY, APRIL 30

Biogeochemical Surveys

Chairmen: **C.E. Dunn** and **P.J. Peterson**

8:40 **J.D. Stednick, R.B. Klem** and **W.C. Riese**; Temporal variation of metal concentrations in biogeochemical samples over a mineralized complex in the Breckenridge Mining District, Summit County, Colorado, U.S.A.

09:00 **J.A. Dean** and **B.L. Gulson**; Biogeochemical prospecting using lead isotopes

09:20 **E.A.V. Prasad**; Geobotany and biogeochemistry in mineral exploration in the tropics

09:40 S **D.R. Cohen, E.L. Hoffman** and **I. Nichol**; Biogeochemistry: A geochemical method for gold exploration in the Canadian Shield

10:00 Break

Geochemical Exploration for Mineral Deposits in Igneous Terranes

Chairmen: **R.G. Darling** and **G.J.S. Govett**

10:20 **A. Beaudoin, G. Perrault** and **M. Bouchard**; Distribution of gold around the Dest-Or orebody, Noranda District, Abitibi, Quebec

10:40 ~~**Zou Zurong**; Geochemistry of the granite series and gold deposits on the eastern margin of the Northern Chinese~~ Platform

11:00 **E. Bloomstein, R. Kydd** and **A. Levinson**; Development of ammonium geochemistry as a new technique in precious and base metals exploration

11:20 ~~**E.G. Imeokparia**~~; Rock geochemical exploration for tin-tungsten mineralization in the Tibchi and Kaleri granite complexes, Nigeria

11:40 **G.R. Parslow**; Lithogeochemical data from the East Amisk area of the Flin Flon - Snow Lake volcanic belt: implications for mineral exploration

12:00 Lunch

Exploration Geochemistry in Glacial Overburden

Chairmen: **R.N.W. DiLabio** and **R.R. Stea**

13:40 **D.J. Bird** and **W.B. Coker**; Quaternary stratigraphy and geochemistry at the Owl Creek gold mine, Timmins, Ontario

14:00 **I. Thomson, J.G. Burns** and **F.H. Faulkner**; Gold exploration in deep glacial overburden: Experiences from the Belore case history

14:20 **J.A. Sauerbrei, E.F. Pattison** and **S.A. Averill**; Till sampling in the Casa Berardi area, Quebec: A case history in orientation and discovery

14:40 S **G.S. Shelp** and **I. Nichol**; Dispersion of gold in glacial till associated with gold mineralization in the Canadian Shield

15:00 Break

15:20 **R.A. Klassen**; Relationship between glacial history and drift composition

15:40 **U. Kramar, H. Simianer** and **H. Puchelt**; Till exploration for rare earth minerals at Bastnäs, Central Sweden: Anomaly follow-up using a mobile energy dispersive XRF

16:00 ~~**V. Peuraniemi**~~; On the mode of occurrence of Cu, Zn, Co and Ni in till at some sulphide prospects in Finland

16:20 Close

16:25 Annual General Meeting of the Association of Exploration Geochemists

WEDNESDAY, MAY 1

Stream Sediment Surveys

Chairmen: **E.H.W. Hornbrook** and **A. Bjorklund**

08:40 **L.W. Maassen** and **S.L. Bolivar**; A geochemical survey of St. Lucia, West Indies

09:00 **P.E. Drez**; Enhancement of stream sediment anomalies distal to Cu-Au porphyry systems in Papua New Guinea: Orientation survey

09:20 **W.K. Fletcher, P.E. Dousset** and **Y. bin Ismail**; Elimination of hydraulic effects in stream sediment data: Behaviour of cassiterite in a Malaysian stream

09:40 **F.R. Siegel**; Geochemical exploration for Mississippi Valley type stratabound Zn-(Pb) deposits with stream suspensates and associated sediments

10:00 Break

WEDNESDAY, MAY 1

Data Analysis and Presentation
Chairmen: **M. Mellinger** and **P. Leymarie**

10:20 S **C.R. Stanley** and **A.J. Sinclair;** Anomaly recognition for multi-element geochemical data: A background characterization approach
10:40 **C. Roquin** and **H. Zeegers;** Improving anomaly selection by statistical estimation of background variations in regional geochemical prospecting
11:00 **K.H. Esbensen, S. Wold, I. Lundholm** and **L. Lindquist;** Taking a close-up of the background: multivariate data analysis in geochemical prospecting
11:20 **A. Shepherd, P.K. Harvey** and **R.C. Leake;** The geochemistry of residual soils as an aid to geological mapping and mineral exploration: A statistical approach
11:40 ~~**A. Demetriades;**~~ Statistical interpretive procedures in exploration geochemistry: Greece

12:00 Lunch

13:00 Local Excursions begin

Geochemical Exploration for Tin Deposits
Chairmen: **S.B. Ballantyne** and **J. Richardson**

13:40 **P.J. Rogers** and **R.G. Garrett;** Lithophile elements and exploration using centre-lake bottom sediments from the East Kemptville area, Southern Nova Scotia
14:00 **D.R. Gladwell** and **M. Hale;** Multifractional analyses in geochemical exploration for tin mineralization
14:20 **T. Sirinawin, W.K. Fletcher, P.E. Dousset** and **Z. Hj Husin;** Geochemical survey for primary tin deposits in the Batu Gajah-Tanjong Tualang area, Perak, Malaysia
14:40 **S. Johari;** Relationship between Sn mineralization and geochemical anomalies in non-residual overburden in the Tebrong area, Belitung, Indonesia

15:00 Close

THURSDAY, MAY 2

Exploration Geochemistry in Regions of Residual and Other Non-Glacial Overburden
Chairmen: **I. Nichol** and **L.G. Closs**

08:40 **R.E. Smith;** Some conceptual models for geochemistry in areas of preglacial deep weathering
09:00 **R.N. Carver, L.M. Chenoweth, R.H. Mazzucchelli, C.J. Oates** and **T.W. Robbins;** "Lag", a geochemical sampling medium for arid regions
09:20 **G.J.S. Govett** and **P.R. Atherden;** Electrogeochemical patterns in surface soils: Detection of blind mineralization beneath exotic cover, Thalanga, Queensland, Australia
09:40 **J.S. Tooms;** Exploration for gold in the humid tropics

10:00 Break

Multi-Media Case Histories
Chairmen: **I. Thomson** and **M. Hale**

10:20 **J.W. McConnell** and **M.J. Batterson;** The Strange Lake Zr-Y-REE-Nb-Be deposit: An exploration geochemical profile
10:40 ~~**Shao Y. and Liu J.M.**~~; Geochemical exploration for kimberlites in China
11:00 **A.J. Davidson** and **I.D. Pirie;** The Rea gold massive sulphide deposits, Adams Lake, B.C.: A geochemical exploration study
11:20 ~~**M.N. Cagatay** and **S. Ikizer**~~; Geochemical exploration for carbonate-hosted stratabound lead-zinc deposits, Central Taurus region, Turkey
11:40 **M.A.F. Fedikow** and **E. Nielson;** Rock, basal till and vegetation geochemical signatures of the Agassiz stratabound Au-Ag deposit, Lynn Lake, Manitoba

12:00 Lunch

Regional Reconnaissance Geochemistry
Chairmen: **P.H. Davenport** and **J. Plant**

13:40 **G.A. Nowlan, F.C. Canney** and **F.H. Hood;** Preliminary results of regional geochemical studies, Sherbrooke and Lewiston $1^o \times 2^o$ quadrangles, Maine, New Hampshire and Vermont, U.S.A.
14:00 **A. Steenfelt;** Geochemical mapping and prospecting in Greenland: A review of results and experience
14:20 **C. Frick** and **S.W. Strauss;** Geochemical evolution of the Richtersveld area, South Africa, as deduced from regional geochemical maps of stream sediment samples
14:40 **A. Bjorklund;** Definition of ore-potential zones in the Baltic Shield by use of geochemical megastructures

15:00 Break

THURSDAY, MAY 2

Workshop Reports
Chairmen: **W.B. Coker** and **R.G. Garrett**
15:20 **C.E. Dunn**; Biogeochemistry
15:30 **B. Bolviken**; Electrogeochemistry
15:40 **P.C. Thurston**; Rare-Earth Geochemistry
15:50 **I. Nichol**; Till Geochemistry
16:00 **J.W. Aucott**; Geochemical Anomaly Recognition

16:15 **Closing Ceremonies**
Chairmen: **W.B. Coker** and **R.G. Garrett**

POSTER PRESENTATIONS

The poster presentations will be made in the Constitution Hall of the Metro Toronto Convention Centre. Authors should have their posters in place by 5:00 pm on Sunday, April 28, in order that delegates can view them at the Welcome Reception. The posters will remain on display until the end of the refreshment break, at 3:20 pm, on Tuesday, April 30. In order that delegates have ample opportunity to discuss the posters, authors have been asked to be in attendance by their posters on Sunday evening, and during one of the lunches on Monday and Tuesday. In order that poster authors can have the chance to see other posters, they will be by their posters during one of the lunches, and at only one of the morning and afternoon refreshment breaks on Monday and Tuesday. In the following list of poster presentations, the letter following the author's name indicates on which day's lunch i.e., Monday **(M)** or Tuesday **(T)**, and which refreshment break, i.e., 1 to 4 for Monday morning **(1)** through to Tuesday afternoon **(4)**, they are to be on duty.

R. Aario, K. Paakkonen and **T. Saarenketo (T,1);**
Glaciodynamic dispersion of uranium in a Rogen environment, Finland
~~**Y.M. Anwar, M.A. Morsy** and **A.M.A. El Makky (T,2);**~~
Geochemical prospecting in the Abu Dabbab area, Eastern Desert, Egypt
J.D. Appleton, R.C. Jones and **J. Ridgway (M,3);**
Spatial representation of geochemical data: Examples from the Overseas Programme Directorate, British Geological Survey
S. Aronoff and **W.D. Goodfellow (T,2);**
The application of image analysis techniques in mineral exploration using regional geochemical data

L.B. Bloom (M,4);
Pb-Zn-Ag dispersion in stream sediments in contrasting geological environments in the Yukon
S.L. Bolivar, D.E. Broxton, S.H. Freeman and **T.A. Weaver (M,3);**
The geochemical atlas of Alaska
B. Bolviken, J. Bergstrom, A. Bjorklund, M. Konti, P. Lehmuspelto, T. Lindholm, J. Magnusson, R.T. Ottesen, A. Steenfelt and **T. Volden (M,4);**
Regional geochemical mapping in northern Finland, Norway and Sweden
G.F. Bonham-Carter, P.J. Rogers and **D.J. Ellwood (T,1);**
Catchment basin analysis applied to surficial geochemical data, Cobequid Highlands, Nova Scotia

H. Chon and **M. Hale (M,4);**
Multi-element geochemistry of the Wolagsan granite mass and its relationship to mineralization in Korea
P.L. Churcher and **R.D. Dickhout (T,2);**
Total organic carbon analysis of ancient sediments: A new technique

S. Dijkstra, H.J. van den Hul, Y.M. Jubeli and **T.K. Sen (T,1);**
Use of selective extraction for anomaly classification
P.J. Doyle and **R.D. Morse (T,2);**
Use of National Geochemical Reconnaissance data to identify environmentally sensitive areas
W. Dyck and **D. Car (T,2);**
Detailed geochemical studies of a He-U anomaly in permafrost, Baker Lake area, N.W.T.

~~**H. Fauth, R. Hindel** and **U. Siewers (T,1);**~~
Results of a multi-element geochemical survey in the Federal Republic of Germany: Geochemical atlas of Germany
K.L. Ford, R.N.W. DiLabio and **A.N. Rencz (M,3);**
Preliminary results of multidisciplinary studies around the recently discovered Allan Lake carbonatite, Algonquin Park, Ontario
C. Frick (T,1);
Stream sediment geochemical anomalies for uranium on granite plutons with high and low zirconium contents

D.R. Gladwell and **R.E. Lett** (T,2);
Geochemical exploration for tin using suspended sediment sample media
M.D. Goodz, I.R. Jonasson, D.H. Watkinson and **D.M. Kingston** (M,4);
The Beaver-Temiskaming silver arsenide vein deposits, Cobalt: Vein and host-rock geochemistry with applications to exploration

~~**K. Hattori** and **E.M. Cameron** (T,1);~~ To papers
Pyrite of distinctive isotopic composition associated with the Hemlo gold mineralization

M. Ikramuddin (M,3);
An alternative approach to sampling problems in exploration for gold

~~**R.W. Klusman, R.E. Bisque, K.J. Voorhees** and **D.N. Bloom** (M,4);~~
Geochemical exploration for mineral deposits using a new integrative gas technique and pattern recognition
H. Kuzendorf and **K. Secher** (T,3);
Dispersion of niobium and phosphorus in soil overlying the Qaquassuk Carbonatite Complex, Southwestern Greenland

O.P. Lavin and **I. Nichol** (M,4);
Computer data-processing: A help or hindrance?

I.J. MacEachern and **R.R. Stea** (M,3);
Geochemical studies on gold in till in Nova Scotia
~~**K.S. Murty** (T,2);~~
Indian plants as indicators of mineral deposits

B.W. Oakes and **M. Hale** (T,1); To papers
Application of carbonyl sulphide to mineral exploration

~~**A.K. Pachauri** (M,4);~~
Geochemical exploration for copper sulphide deposits in the granite-greenstone belt of Central India
~~**S.K. Pande, A.N. Deshmukh** and **P.K. Shrivastava** (M,3);~~
Significance of metabolism on the reliability of twig samples in biogeochemical prospecting for uranium
L.R. Petersen and **H. Stendal** (M,3);
Tungsten exploration in the Valnesfjord region, Nordland, Northern Norway: A case history

S. Rehder and **A. Muller** (M,1);
MAX, a program system for multivariate data analysis of geochemical exploration data
~~**B.N. Rock** (T,1);~~
Geobotanical remote sensing: An overview

J.L. Seeley (M,3);
A new tool for the geochemical exploration of gold and associated elements
W. Shotyk (M,4);
The use of peatlands in geochemical exploration
D.B. Smith, B.R. Berger, R.M. Tosdal and **G.L. Raines** (T,2);
Geochemical studies in the Indian Pass and Picacho Peak Bureau of Land Management Wilderness Study areas, Imperial County, Southern California
E.J. Smith, S.E. Kesler and **E. Van Hees** (T,2);
Relationship of fluid inclusion geochemistry to wallrock alteration and lithogeochemical zonation at the Hollinger-McIntyre gold deposit, Porcupine District, Canada
R.E. Smith, J.L. Perdrix and **J.M. Davis** (M,3);
Dispersion into surface lateritic overburden from the Greenbushes mineralized Sn-Ta pegmatite system, Western Australia
R.J. Snow and **W.B. Coker** (M,4);
Overburden geochemistry related to the Sisson Brook, New Brunswick, W-Cu-Mo mineralization: An example of short and long distance glacial dispersion
G.C. Stephens, E.B. Evenson and **D.E. Detra** (T,1); To papers
Exploration geochemistry in active alpine-glaciated regions: A study of the Trident and Susitna Glaciers in Central Alaska

O. Toverud (T,2);
Vastana-Jarkvissle Sn-Li occurrence found by regional grid sampling of heavy mineral till concentrates in northern Central Sweden

J.B. Whyte and **I. Nichol** (T,1);
Geochemical alteration associated with the Selbaie copper-zinc-silver deposit

Xie X., Wang J.P. and **Zhu B.G.**;
Comparison of geochemical maps generated by laboratories using different analytical methods

ANNOUNCEMENT

INTERNATIONAL SOUTH EUROPEAN SYMPOSIUM IN EXPLORATION GEOCHEMISTRY

The Institute of Geology and Mineral Exploration (Greece) and the Association of Exploration Geochemists is sponsoring the International South European Symposium in Exploration Geochemistry. This Symposium will be held in Athens (Greece) from 10 to 11 November, 1986. The program includes two days of technical sessions (general and special sessions, poster presentations and exhibitions), field trips and program for guests and spouses.

Registration and welcoming reception on 9 November, 1986.

For information and registration forms write to:

Organizing Committee
International South European Symposium
in Exploration Geochemistry
Institute of Geology and Mineral Exploration
70, Messoghion Street
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COMMERCIAL EXHIBITION

The commercial exhibition will take place in the Constitution Hall of the Metro Toronto Convention Centre. The exhibition will be open during normal Symposium hours from 6:00 pm on Sunday, April 28, until the close of the afternoon refreshment break at 3:20 pm on Thursday, April 30. These organizations have supported the 11th International Geochemical Exploration Symposium by exhibiting:

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The above list of exhibitors is as of April 1, 1985, the date the Programme and Abstracts Volume went to press.

PROGRAMME CHANGES AND ERRATA

Paper Presentations:

Wednesday, 11:40: A Demetrides;
Statistical interpretive procedures in exploration geochemistry: Greece
Paper withdrawn and replaced by: **K. Hattori and E.M. Cameron**
Pyrite of distinctive isotopic composition associated with the Hemlo gold mineralization

Thursday, 10:40: Shao Y. and Liu J.M.;
Geochemical exploration for kimberlites in China
Paper withdrawn and replaced by: **R.J. Snow and W.B. Coker;**
Overburden geochemistry related to the Sisson Brook, New Brunswick, W-Cu-Mo mineralization: An example of short and long distance glacial dispersion

Thursday, 11:20: M.N. Cagatay and S. Ikizer;
Geochemical exploration for carbonate-hosted stratabound lead-zinc deposits, Central Taurus region, Turkey
Paper withdrawn and replaced by: **B.W. Oakes and M. Hale;**
Application of carbonyl sulphide to mineral exploration

Poster Presentations:

The following posters have been withdrawn:

H. Fauth, R. Hindel and U. Siewers;
Results of a multi-element geochemical survey in the Federal Republic of Germany: Geochemical atlas of Germany
R.W. Klusman, B.E. Bisque, K.J. Voorhees and D.N. Bloom;
Geochemical exploration for mineral deposits using a new integrative gas technique and pattern recognition

The following posters will now be presented as papers:

K. Hattori and E.M. Cameron;
Pyrite of distinctive isotopic composition associated with the Hemlo gold mineralization
B.W. Oakes and M. Hale;
Application of carbonyl sulphide to mineral exploration

The following poster presentations have been added:

J.S. Fox, E.J Brooker and T.E. Eagles (T,1);
The application of lake sediment geochemical surveying to gold exploration in the Canadian Shield
G. Hausberger, O. Schermann, E. Schroll and F. Thalmann (T,2);
Regional geochemical survey of Austria: Central Austro-Alpine Unit and Bohemian Massif
J. Hennessy and J. Robbins (T,1);
Remote detection fluoresence
E.H.W. Hornbrook, I.M. Kettles and W.W. Shilts (M,4);
Comparative study of the geochemistry of lake sediments and drift, Precambrian Shield of Southeastern Ontario
L. Martin (M,3);
Anomalies and anomalous areas

Errata:

Poster Presentations:

O. Toverud (T,2);
Vastana-Jarkvissle Sn-Li occurrence found by regional grid sampling of heavy mineral till concentrates in northern Central Sweden

In the abstract for the above paper, on page 91 of the Programme and Abstracts volume, please revise as follows:
Paragraph 2, lines 1-2 should read, "for at least 4000 m, over a width of 400 m, down-ice from a known mineralization".

The time allocation **(T,4)** was omitted for the **Xie X., Wang J.P. and Zhu B.G.** presentation.

Workshops:

Due to lack of participation, Workshop 2, Electrogeochemistry (B. Bolviken, Geological Survey of Norway), has had to be cancelled. There will therefore be no Workshop Report presented at 15:30 on Thursday, May 2, and all following reports will be moved ahead by 10 minutes. The Closing Ceremonies will therefore be held at 16:05.

FIRST CIRCULAR — CALL FOR PAPERS
MAY 12-14, 1986
GEOEXPO/86

You are invited to join us for the experience of a lifetime! Attend GEOEXPO/86 — a three day regional exploration symposium co-sponsored by the Association of Exploration Geochemists and the Cordilleran Section of the Geological Association of Canada — to be held in Vancouver, British Columbia, Canada from May 12 to 14, 1986. Technical sessions will cover a wide range of topics of current interest to the exploration community.

GEOEXPO/86 promises to be a unique conference. The symposium is being held at the University of British Columbia during EXPO-86, the largest special category World Exposition ever staged in North America. The university environment offers a relaxed atmosphere, and reserved accommodation at reasonable cost for delegates, in one of Canada's major centres of mineral exploration. Visit Vancouver while attending the symposium, a sparkling jewel of coastal port cities — sea to ski country — white caps to snow capped mountains, and attend EXPO-86. Make your plans now. Hotel space in Vancouver is likely to be very limited during EXPO-86 for those not reserving accommodations at the university. Information regarding reservations will appear in the second circular.

The regional symposium will highlight geological, geochemical, and geophysical techniques guiding mineral exploration in Cordilleran environments, from Mexico in the south to Alaska in the north. A special session is planned on black smokers, especially those on the Juan de Fuca ridge near Vancouver. Submission of topics of exploration interest looking towards the future is encouraged.

Call for Papers

Two full days of general sessions will be followed by one day of four simultaneous sessions attracting a more specific audience. A general poster session and commercial display will be held in conjunction with a wine and cheese party and will be available for viewing throughout the convention. Authors of technical papers are encouraged to prepare posters and be available to discuss their work with delegates. Presentations are invited on any aspect of exploration with preference being given to papers describing exploration in the North American Cordillera. Papers will also be considered describing experiences in Cordilleran environments elsewhere. Suggested themes might be:

(1) Geological overviews of deposit types
(2) Multidiscipline integrated exploration case histories
(3) Commodities base metals, precious metals, and specialty metals (i.e., beryllium, lithium, gallium, germanium, etc.).
(4) Advances in geochemical techniques —analysis, sampling methods, computer applications.
(5) Black smokers, their geology and geochemistry.
(6) Use of multielement geochemistry — ICP, XRF, etc.
(7) Lithogeochemistry
(8) Overburden — benefit or burden to mineral discovery?
(9) Comparative experience with geochemical techniques in diverse surficial or climatic environments
(10) Gas-vapour geochemistry — extensions of petroleum geochemical techniques to mineral exploration
(11) "Pearl Harbor" file — case histories of geochemical exploration program failures that should not have happened and how these can be avoided

Synopses of approximately 500 words are requested from potential participants. Deadline for receipt of synopses is November 15, 1985. Submission of geological papers will be forwarded to the co-sponsors of the symposium for their attention. Please submit synopses to:

GEOEXPO/86 Regional Symposium
Association of Exploration Geochemists
700 - 409 Granville Street
Vancouver, B.C V6C 1T8 (604) 685-3072
Canada

Other Activities

- Registration reception
- Wine and Cheese party — accompanies general poster session
- Pre and post symposium field trips
- Pre-symposium workshops
- Pre-symposium short courses
- Visits to geology department, and Triumf cyclotron at UBC, Geological Survey of Canada, commercial geochemical laboratories, computer bureaus servicing the mining industry
- Guests and/or spouses program
- Commercial displays
- EXPO-86

Further information will be sent to you as it becomes available if you clip this GEOEXPO/86 coupon and send it to:

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I plan to contribute a 500 word synopsis for consideration Yes ______ No ______ Maybe ______

Preliminary title ____________________

I plan to bring a guest Yes ______ No ______ Number ______

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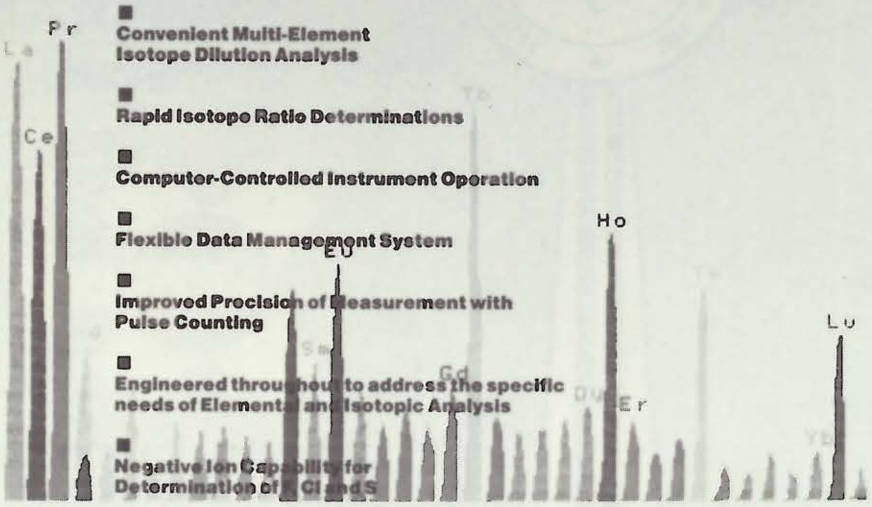

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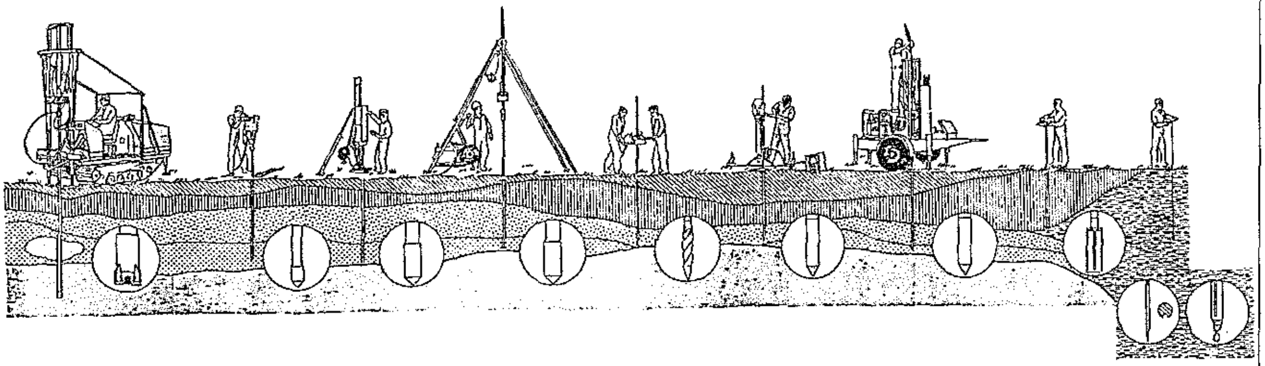

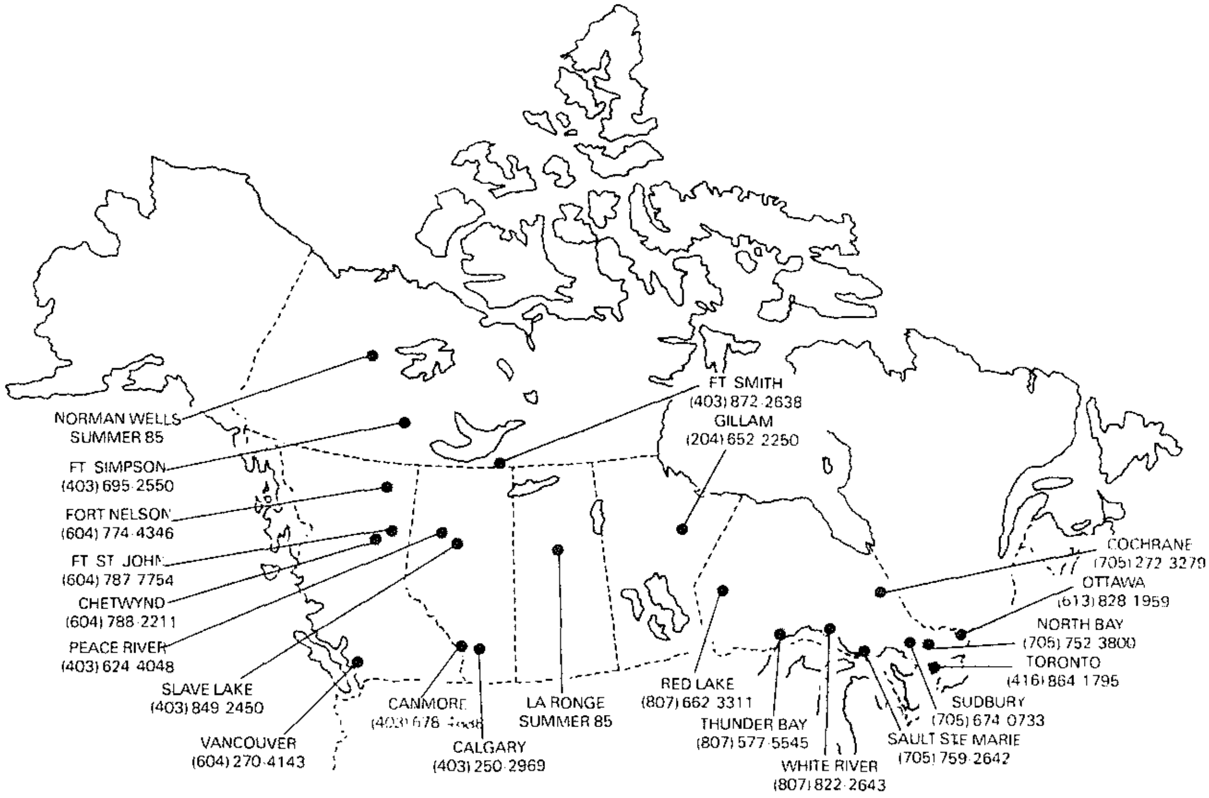

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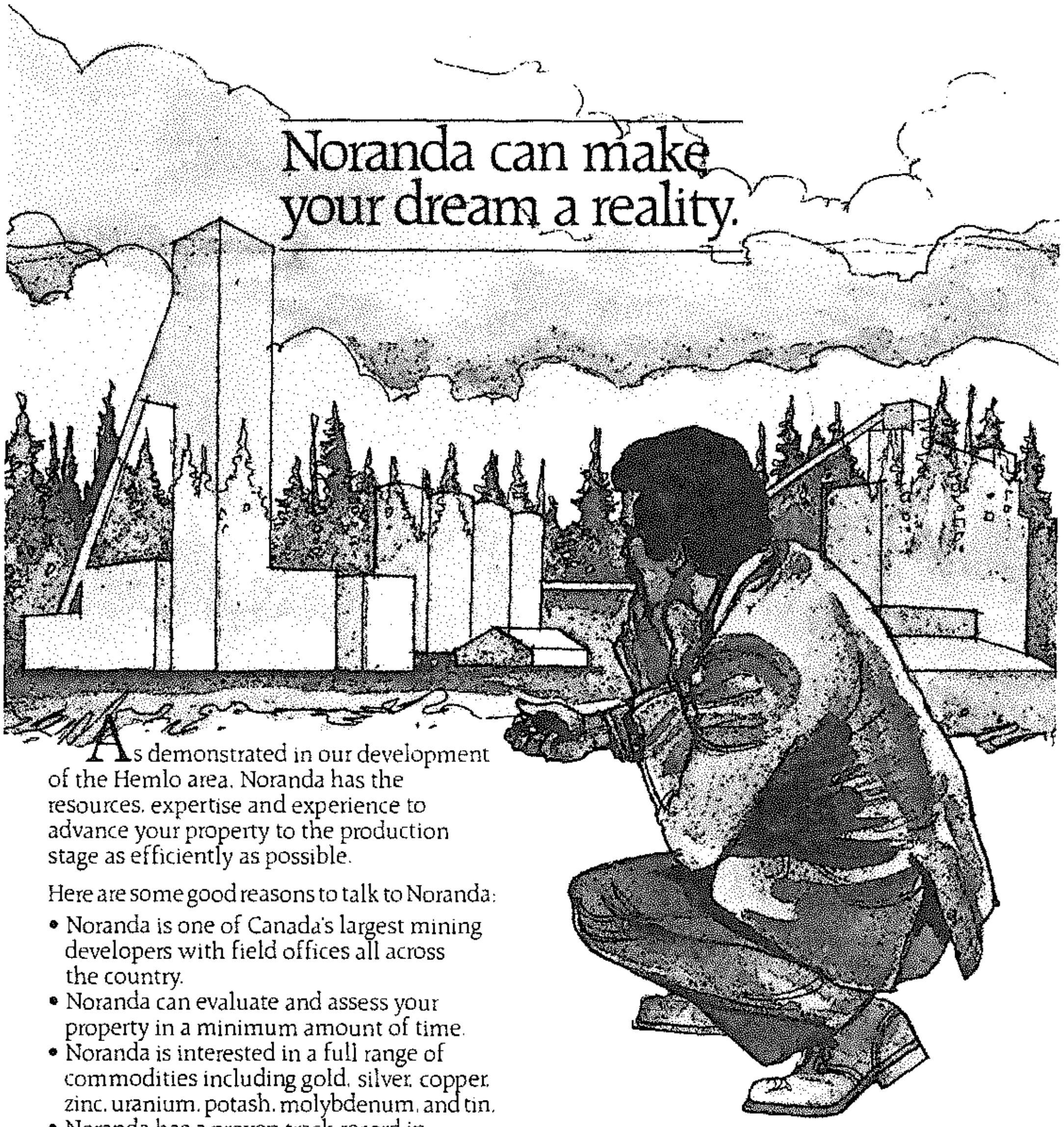

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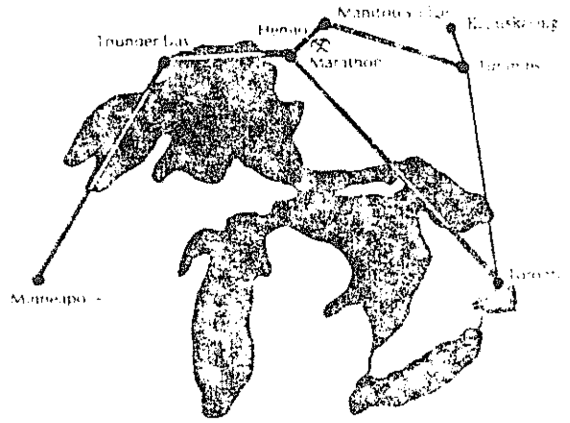
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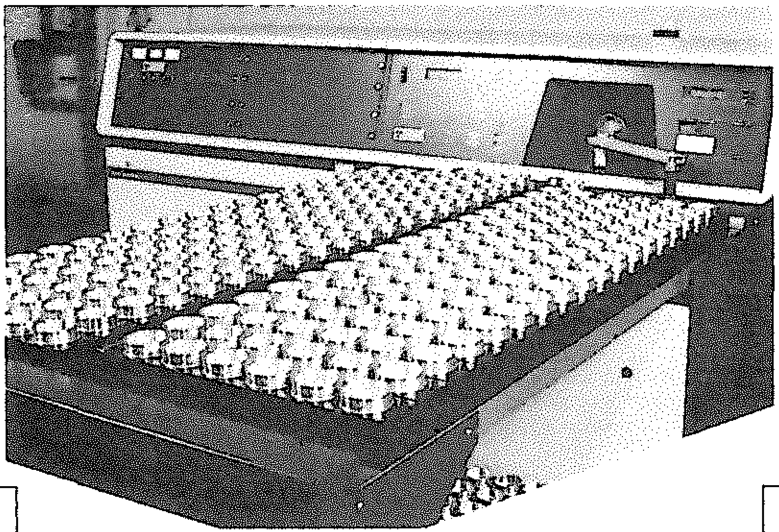

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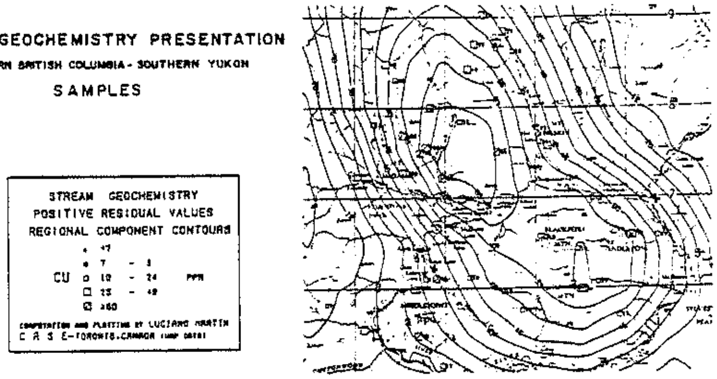
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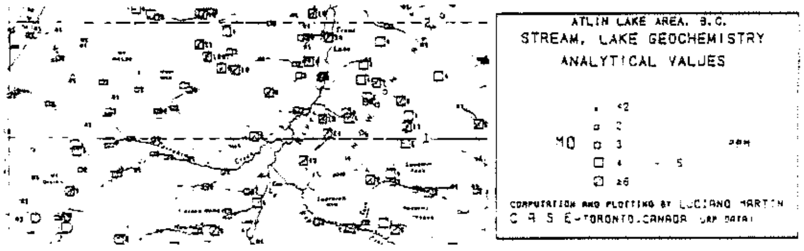
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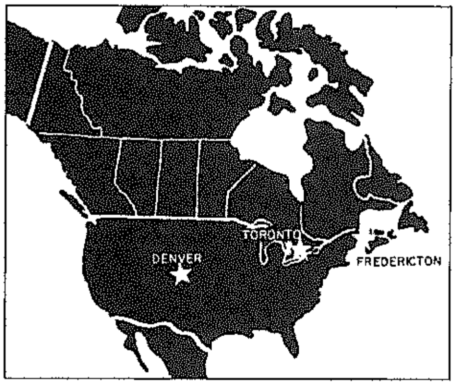

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Element	Humus	Vegetation	Element	Humus	Vegetation
Au ppb	1	0.1	Se ppm	2	0.5
As ppm	1	0.01	Sb ppm	0.1	0.01
Ba ppm	100	20	Ta ppm	0.5	0.2
Br ppm	1	0.01	Th ppm	0.5	0.1
Cr ppm	1	0.3	U ppm	0.1	0.02
Co ppm	1	0.3	W ppm	1	0.01
Mo ppm	0.5	0.05	Zn ppm	20	2

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	DETECTION LIMITS				DETECTION LIMITS		
Element	**Basic**	**Exploration**	**Research**	**Element**	**Basic**	**Exploration**	**Research**
Ag ppm	0.5	0.5	0.5	Mg %	—	0.01	0.01
Al %	—	0.01	0.01	Mn ppm	20	2	2
As ppm	5	2	1	Mo ppm	10	5	2
Au ppb	50	10	5	Na ppm	0.05	0.01	0.01
B ppm	—	10	10	Nb ppm	—	20	10
Ba ppm	1000	20	10	Ni ppm	5	1	1
Be ppm	—	10	1	P %	—	0.01	0.01
Bi ppm	—	0.5	0.1	Pb ppm	5	2	2
Br ppm	5	1	0.5	Rb ppm	100	20	10
Ca %	0.5	0.01	0.01	Sb ppm	1	0.2	0.1
Cd ppm	2	0.2	0.2	Se ppm	10	3	0.5
Co ppm	5	1	0.1	Si %	—	0.01	0.01
Cr ppm	10	2	0.5	Sr ppm	1000	20	10
Cs ppm	2	0.5	0.2	Ta ppm	2	1	0.5
Cu ppm	0.5	0.5	0.5	Ti ppm	—	100	10
Fe ppm	0.1	0.01	0.01	V ppm	—	10	2
Ge ppm	—	10	10	W ppm	10	3	1
Hf ppm	1	1	0.2	Y ppm	—	20	10
K ppm	—	0.01	0.01	Zn ppm	2	0.5	0.5
Li ppm	—	10	1	Zr ppm	—	20	10
Rare Earth and Actinide Elements							
Sc ppm	0.5	0.1	0.01	Tb ppm	—	—	0.1
La ppm	1	0.5	0.1	Dy ppm	0.5	0.5	0.5
Ce ppm	5	3	1	Yb ppm	0.5	0.2	0.05
Nd ppm	10	5	3	Lu ppm	0.2	0.05	0.01
Sm ppm	0.5	0.1	0.01	U ppm	5	0.5	0.1
Eu ppm	0.5	0.2	0.05	Th ppm	1	0.5	0.2

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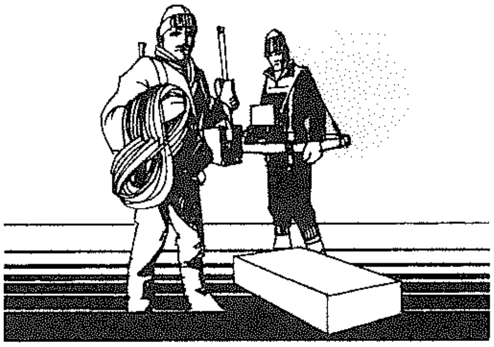

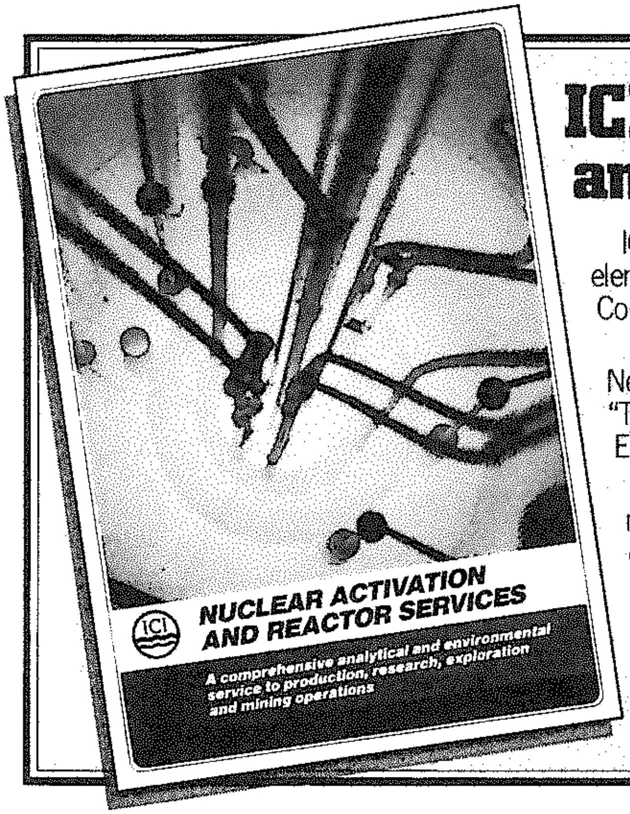

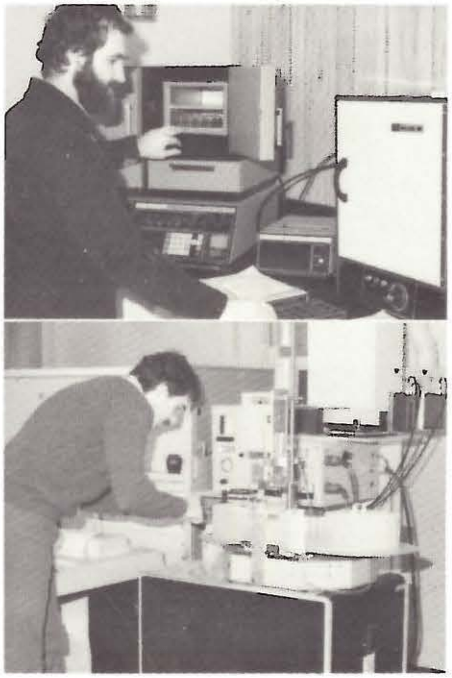

GLACIODYNAMIC DISPERSION OF URANIUM IN A ROGEN ENVIRONMENT, FINLAND

R. Aario, K. Paakkonen and T. Saarenketo

The uranium dispersion train studied cuts across a crescentic till ridge which belongs to a wide Rogen moraine located on Archaean granitoids at Kuohunki, Finland. The uranium was found to occur in erratics consisting of biotite-apatite gneiss.

A variety of field and laboratory techniques were applied in the study, including both surface mapping of the U-bearing erratics and geophysical measurements, as well as methods involving till lithology and geochemistry. These methods subsequently provided useful details about the glacial processes responsible for the uranium dispersion.

The till ridge was found to have a more densely packed sandy till core deposited during the initial phases of ridge development when the ice flow lines were still more or less even or gently wavy. This is also a common feature elsewhere in this Rogen area. The upper parts of the ridge are characterized by the existence of large, angular boulders, which are especially common on the frontal slopes. Quantities of this material were found to be quarried out from the neighbouring proximal trough only some tens of metres upcurrent. This suggests that during this depositional phase the bottom of the ice was divided successively into transverse zones of erosion and deposition.

The uranium-bearing rocks were also picked up from the proximal trough; they are most abundant at the surface of the till ridge, especially at the frontal slope. At greater depths the content is considerably lower. This is also true for the uranium of the finer fractions. The dispersion train was found to be very narrow. It was mapped carefully and clearly reveals an ice flow line during the formation of the ridge. The train begins from the trough, then heads at right angles towards the ridge, after which it makes an oblique angle on the ridge thus yielding to the general ice flow direction of the area. Farther downcurrent it soon peters out.

RE-EXAMINATION OF MERCURY POLLUTION IN THE ASHTABULA AREA, ASHTABULA COUNTY, OHIO

R.A. Anderson and E.H. Carlson

Environmental concern about mercury pollution in Lake Erie peaked in 1970 with most investigations being directed along the west end of the lake, around problems associated with Lake St. Clair. The Ohio Geological Survey subsequently (1970 - 1971) collected and analyzed stream and lake sediments in the vicinity of several industrial areas that border Lake Erie and reported signs of mercury pollution along the lower reaches of the Ashtabula River. Neither the intensity nor the center of the contamination was recognized in that study.

During a re-investigation of pollution at Ashtabula, 68 sediment samples were collected across an area of 90 km^2 in the late spring and early summer of 1982. The mercury that was released by heating the samples on a hot plate for one minute at 290°C was analyzed with a Gold Film Mercury Detector, Model 301, yielding a precision of ±20%. Mercury concentrations in the sediments had a median (background) value of 24.4 ppb and a mean content of 422 ppb, and showed a lognormal distribution that was bimodal.

Three samples that ranged from 1,550 to 20,600 ppb Hg are considered anomalous and come from the drainage of Fields Brook. Although no single industrial operation could be targeted as a source, high levels apparently are due to the past accumulation of waste mercury, rather than to recent discharge. Of the Ashtabula River samples, 16 obtained from south of the junction with Fields Brook had a mean value of 42.8 ppb Hg, while six to the north yielded a mean content of 118.5 ppb. The Lake Erie samples can be separated by the mouth of the Ashtabula River into the following four data sets (mean ppb Hg): shoreline-west (6.45) and -east (27.7), and nearshore-west (16.9) and -east (91.8). The four-fold increase on the eastern side of the discharge relative to that on the western side, in sediment of similar grain size, is due to the direction of longshore currents which, in the Ashtabula area, run from southwest to northeast. The concentration of mercury increases by a factor of three in nearshore sediments relative to that in the shoreline samples and is due to preferential concentration in the finer size fraction. The mercury levels obtained for nearshore sediments just east of the Ashtabula River are six times higher than those reported earlier by the Geological Survey, suggesting that accumulation of mercury has occurred.

GEOCHEMICAL PROSPECTING IN THE ABU DABBAB AREA, EASTERN DESERT, EGYPT

Y.M. Anwar, M.A. Morsy and A.M.A. El Makky

This report describes geochemical prospecting work carried out in the Abu Dabbab area, which is located in the central part of the Eastern Desert of Egypt, about 47 km northwest of Mersa Alam on the Red Sea coast.

In the studied area, a total of 100 stream sediment and soil samples were collected for regional and detailed lithochemical surveys. All the collected samples were sieved to -1 mm size fraction and were then analysed spectrographically for Sn, Be, Pb, Cu, Co, V and Ba.

The background and threshold values for the analysed elements were determined statistically by constructing cumulative frequency plots, which always gave patterns of the lognormal type. Other statistical parameters such as arithmetic mean, standard deviation, geometric mean and geometric standard deviation were also calculated for each element.

The stream sediment and soil sample data were presented by constructing geochemical maps for Sn, Be, Pb, Cu, Co, V and Ba. These geochemical maps indicated that tin can be considered as the more widely dispersed and abundant element both in the stream sediments and in the secondary dispersion aureoles. Furthermore, the largest number of samples were anomalous for tin, whereas only a small number of samples were anomalous for Cu, Be, Pb and V.

In order to select the indicator elements for tin in the Abu Dabbab area, the correlation coefficients between the analysed elements were calculated. This indicated that Cu, Ba and Be can be used as useful pathfinders for tin. Furthermore, tin can be used as an indicator for its deposits in the studied area.

The probable geological reserve of tin was estimated from the detailed lithochemical survey to be about 37,700 tons (Sn), which corresponds to category D_1 and indicates that Abu Dabbab area is promising.

SPATIAL REPRESENTATION OF GEOCHEMICAL DATA: EXAMPLES FROM THE OVERSEAS PROGRAMME DIRECTORATE, BRITISH GEOLOGICAL SURVEY

J.D. Appleton, R.C. Jones and J. Ridgway

Overseas exploration programmes are undertaken at a variety of scales and sample densities with objectives ranging from recognition of regional background highs to identification of specific anomalies which may be related to mineralization. Point source, moving average, factor score, standard deviation and multi-element anomaly maps all have a useful role to play in the exploration programme. The type of map employed depends on the sample density and distribution and aims of the survey. Examples from exploration projects in Bolivia, Kenya, Indonesia and Solomon Islands are presented.

APPLICATION OF IMAGE ANALYSIS TECHNIQUES IN MINERAL EXPLORATION USING REGIONAL GEOCHEMICAL DATA

S. Aronoff and W.D. Goodfellow

The use of image analysis in mineral exploration was evaluated by analysing geological, geochemical, topographical and satellite image data for the Quiet Lake, Yukon, map-area (NTS 105F). Since the area hosts several geologically distinct and geochemically unique mineral occurrences, streams draining the different types of mineralization were classified in terms of their element associations, and spatial relationship to particular geological formations and mineral occurrences. In the case of vein deposits, their association with mapped structures or lineaments delineated from Landsat images was also assessed. Other types of deposits, such as contact-metasomatic W skarns, were likewise evaluated from the viewpoint of their spatial relationships to known plutonic complexes. Discrepancies between the known occurrences and expected geochemical response in stream sediment were evaluated in terms of other factors, such as the area of mineralization exposed to weathering, the level of dilution and the chemical mobility of elements in a given stream system. Based on this evaluation, the analysis procedure was refined and used to identify new areas of mineral potential in the Quiet Lake map-area.

DISTRIBUTION OF GOLD AROUND THE DEST-OR OREBODY, NORANDA DISTRICT, ABITIBI, QUEBEC

A. Beaudoin, G. Perrault and M. Bouchard

Dest-Or Mine, property of Ressources Aiguebelle Inc., is located 30 km northeast of Noranda, Quebec. The principal orebody contains 2.24 Mt at 6.8 g/t Au.

Host rocks are tholeiitic basalts and gabbros of the Deguisier Formation (Archean). These rocks are bounded to the south by the Porcupine-Destor fault; they belong to the south limb of Abijevis syncline, strike generally E-W, face north and dip vertically. Locally, these are folded; they are fractured both N-S and E-W. The orebody occurs in one of the flexures; it strikes N-15-W and dips at 45° to the west.

There are four gold populations in and around the Dest-Ore orebody:

1) Host rocks of the Deguisier formation have a median at 3.6 ppm Au (P_{16} at 1.5 and P_{84} at 8.8, n=98);

2) Orezone halo rocks have a median at 9.4 ppb Au (P_{16} at 3.1 and P_{84} at 27, n=47);

3) Orebody halo rocks have a median at 42 ppb Au (P_{16} at 16 and P_{84} at 100, n=26);

4) Orebody gold values.

As, and Sb data can similarly be grouped. Normal values for host rocks are 2.5 ppm Au and 0.2 ppm Sb. Metal ratios also yield meaningful relationships to gold mineralization.

Areas of CO_2 metasomatism (1 to 4% CO_2) are extensive and generally centered on fracture zones. Around the orebody, CO_2 values are 4 to 12% and these values extend beyond the limits of the orebody halo.

Hydrothermal alteration associated with gold mineralization is of five types; intense carbonatisation, silicification, hematitisation followed by pyritisation, and K-addition. Except for the hematite-pyrite relationships, our observations do not allow clear conclusions as to synchronism of these various alterations. Alteration zones near the orebody show development of abundant illite, carbonate, quartz, pyrite, hematite. Chlorite, rutile and tourmaline are also locally present.

Through work at Ecole Polytechnique, under the direction of the senior author (G. Perrault), we now have five other well documented cases of distribution around gold deposits: Sigma, Lamaque, Doyon, New Pascalis, in addition to Dest-Or.

The Dest-Or case history will be compared to other case histories, and some constraints to the distribution of gold in country rocks and ore deposits will be established.

QUATERNARY STRATIGRAPHY AND GEOCHEMISTRY AT THE OWL CREEK GOLD MINE, TIMMINS, ONTARIO

D.J. Bird and W.B. Coker

The Owl Creek Gold Mine is located in Hoyle Township, approximately 20 kilometres northeast of Timmins, Ontario, Canada. The open pit mine exposes a sequence of altered, mineralized mafic tholeiitic bedrocks bounded to the north and south by greywacke and argillite. Gold occurs in the free state in quartz veins, often with graphite, and as fine gold on surfaces of, and within fractures in, pyrite.

The study was designed to determine the distribution and distance of transport of gold and associated elements down-ice from the deposit. This required an understanding of the glacial history of the area.

The Quaternary stratigraphy was studied and sampled by means of 17 sonic and 15 reverse circulation overburden drill holes near the open pit, and several overburden exposures in the open pit walls. A till pebble lithology study was done on the >2000 µm fraction of the sonic drill core.

Heavy mineral concentrates (specific gravity >3.3) were made from the >2000 µm fraction of all overburden samples from the drill hole and section sampling. The heavy mineral concentrates were subjected to mineralogical examination and then analyzed for Au, As and W by neutron activation and for Zn, Cu, Pb, Ag and Ni by a HNO_3/HCl digestion and direct current plasma emission spectrometry.

Stratigraphic studies have found that there were three major Wisconsinan (Weichselian) ice advances and one minor, late readvance in this area. Glacial striae show that the late "Cochrane" readvance was from the northwest towards 130°±10° and that the latest Wisconsinan, or "Matheson", advance was from the north towards 170°±10°. The presence of two underlying till packages indicates that two earlier ice advances, assumed to be Wisconsinan, occurred. Irregular bedrock topography in the area influences the distribution of all till packages.

Geochemically anomalous levels of gold in the overburden define a dispersal train, in till derived from ore zone materials, in the order of 600 to 700 m long. This conclusion is supported by the results of the till pebble lithology study.

The nature of the gold dispersal train is complicated by the effects of bedrock topography and multiple ice advances from various directions.

DEFINITION OF ORE-POTENTIAL ZONES IN THE BALTIC SHIELD BY USE OF GEOCHEMICAL MEGASTRUCTURES

A. Bjorklund

Contents of some 36 elements in the -62 µm fraction of till sampled at a density of one site per 300 km^2 over the whole of Finland, as well as one site per 30 km^2 over northern Finland, Norway, and Sweden (north of 66°N), and one site per 4 km^2 over some parts of central and southern Finland were used to study megascale geochemical patterns.

Total contents of most elements form a pattern of six NW-trending zones separated by linear geochemical discontinuities which at many localities cross lithological boundaries. Contents of elements of mafic signature (Cr, Mg, etc.) decrease, and those of felsic signatures (Al, Rb, etc.) increase, to the SW, supporting the view that the Baltic Shield was formed by accretion from the SW accompanied by evolution towards more felsic magmatism. A weaker NE-trending zonal pattern, interpreted as reflecting different erosional levels of rifted Precambrian crust, interrupts the NW-trending pattern.

One NW-trending zone is N. Lapland, another along the Main Sulfide Ore Zone, and a third in SW Finland are characterized by high aqua regia extractable heavy metals (especially Ba). These zones, where all Finnish economic ore deposits are situated, were probably loci of strong ore-forming processes with accompanying enrichment of the easily extractable component of heavy metals.

The NW-trending geochemical discontinuities and zones of contrasting geochemical signature coincide with geophysically defined deep crustal structures and a zonal pattern of gravity anomalies indicating a close relation to megastructures of the Baltic Shield. A discontinuity passing through, or close to, the mineralized areas of Outokumpu, Luikonlahti, Otanmaki (Finland), Gallivare and Aitik (N. Sweden) forms the main transition from mafic to felsic signature and may be the main junction line between the Archean terrain to the NE and the Proterozoic crust to the SW.

The results indicate that:

1. Economic sulfide ore deposits of the Baltic Shield are situated in areas where the easily extractable component of heavy metals in till in high. The discontinuity lines in the megascale geochemical pattern may indicate deep fractures in the crust and loci of strong ore-forming processes.
2. Geochemical patterns of local to regional dimensions form part of the architecture of megascale patterns detectable at very low sampling densities. The patterns are very similar at different scales, indicating that they follow the laws of fractal geometry. As a consequence the number of samples rather than sampling densities should be defined. It is suggested that at least 500, but not more than 1000, representative (composite) samples are required in a specific target area (may be one m^2, or a whole shield area) to describe the geochemical patterns needed for the definition of potential areas worthy of more detailed studies.

PB-ZN-AG DISPERSION IN STREAM SEDIMENTS IN CONTRASTING GEOLOGICAL ENVIRONMENTS IN THE YUKON

L.B. Bloom

This case history was develoed from exploration stream sediment surveys conducted in 1982 and 1983 on the Lady Di claims, in the Yukon Territories. The results emphasize the variation in Pb, Zn, and Ag dispersion in contrasting geological environments for adjacent creeks. The study was carried out in conjunction with an exploration programme directed at locating stratabound or skarn Pb-Zn-Ag mineralization. Rocks in the area have been correlated with members of the Devonian-age Earn Group, which host the MacMillan and Howard's Pass deposits.

Two zones of sulphide mineralization have been identified on the Lady Di claims. The Main Zone consists of 7 pods of massive pyrrhotite, sphalerite, galena and pyrite, up to 3 m. thick and 4 m. in strike length, over a distance of 150 m., at the top of a cliff. The sulphides are located at the contact between siltstone and overlying limestone units. West Creek does not intersect the Main Zone, but flows through the same carbonate units 400 m. south of the zone at the base of the cliff. Approximately 1300 m. southeast of the Main Zone another occurrence has been found within quartz veins in a sheared siltstone unit. Mineralization includes arsenopyrite, pyrite and galena. A gossan associated with the quartz veins is dissected by East Creek.

A total of 45 stream sediment samples were collected from the two creeks at approximately 200 m. intervals. The -80 mesh fraction of the samples was analyzed for a suite of 32 elements by commercial ICP techniques after aqua regia digestion.

The limestone unit of the Main Zone creates a high carbonate environment and alkaline physio-chemical conditions. This promotes the near source precipitation of Pb as insoluble carbonate complexes. There is apparently limited mechanical dispersion of Pb as evidenced by a discontinuous zone of Pb values greater than 200 ppm in soils, which extends 300 m. downslope from the showing. Lead values in stream sediments from West Creek are less than 56 ppm, which are considerably lower than values at East Creek.

The average Ag value for West Creek stream sediments is 0.8 ppm due to the low solubility of Ag carbonate complexes and the limited mechanical dispersion of Ag-bearing galena from the Main Zone. In contrast, Zn carbonates are highly soluble and anomalous Zn values in West Creek samples are directly attributable to the Main Zone mineralization.

There is a notable lack of carbonate units in the East Creek drainage basin, and outcrop is predominantly siltstone. Lead and Ag are readily dispersed in East Creek, primarily as Fe oxy/hydroxide compounds, along with As and Sb. The absence of sphalerite in the quartz vein style mineralization explains the relatively low Zn values in stream sediments of East Creek.

Manganese values are elevated in West Creek sediments relative to Fe due to (1) its ability to substitute for Ca^{2+} and (2) its greater mobility over a wider pH range than Fe. In contrast, Fe mobility is greater than Mn mobility in the vicinity of East Creek. Other elements which are elevated in West Creek sediments are Ca, Sr and Ba, which are also associated with the carbonate units.

It is important to be able to recognize carbonate-rich environments, as at West Creek, because of their effect on Pb and Ag mobilities. The proximity of a limestone units, or elevated Ca, Sr and Mn values, can be used to identify areas where Pb and Ag dispersion are likely to be restricted. These areas may exhibit Zn anomalies which occur without coincident Pb or Ag anomalies, but are worthy of follow-up exploration surveys.

The co-operation of Mr. J. Brock (President, Welcome North Mines) and Mr. C. Payne (Getty Mines) is gratefully acknowledged.

DEVELOPMENT OF AMMONIUM GEOCHEMISTRY AS A NEW TECHNIQUE IN PRECIOUS AND BASE METALS EXPLORATION

E. Bloomstein, R. Kydd and A. Levinson

Geochemical ammonium anomalies associated with volcanic-hosted and carbonate-hosted gold deposits have been recently discovered in central Nevada. The most prominant anomaly occurs at the Ivanhoe gold deposit and extends at least as far as the Dee gold deposit. The intensity of the anomalies is very high (up to 3% NH_4^+). Less intensive but definite ammonium anomalies (up to 0.2% NH_4^+) also have been found by the workers in massive sulphide deposits of Alaska and the Yukon. In both gold and massive sulphide deposits high concentrations of ammonium occur in clay minerals and feldspars of reduced and argillically altered host rocks. Ammonia complexes with gold, lead or zinc, in hydrothermal solutions strongly enhance metal transport. Exploration significance of the ammonium enrichment is discussed, using the Ivanhoe volcanic hosted gold deposit as an example.

The widespread use of ammonium geochemistry is hampered by the absence of a reliable and cost-effective analytical method. The best quantitative technique is based on infrared spectrophotometry of powdered rock samples. The NH_4^+ content is determined by measuring the depth of the NH_4^+ absorbance band at $1430 cm^{-1}$. The analytical procedure and possible interferences from carbonates are discussed.

Our results suggest that ammonium geochemistry can become a valuable guide to precious and base metal mineralization.

THE GEOCHEMICAL ATLAS OF ALASKA

S.L. Bolivar, D.E. Broxton, S.H. Freeman and T.A. Weaver

The Geochemical Atlas of Alaska is a 1:6,000,000 scale pictorial representation of reconnaissance-scale geochemical data. The surveys that provided the data for this atlas were conducted as part of the HSSR (Hydrogeochemical and Stream Sediment Reconnaissance) portion of the NURE (National Uranium Resource Evaluation) program. The HSSR portion of NURE was a nationwide, regional, geochemical survey designed to identify broad areas favourable for the occurrence of uranium deposits. Los Alamos National Laboratory was given responsibility for the HSSR in Alaska.

Methods

A total of 61,923 sediment samples, covering some 80% of the land area of the State, were collected between 1975 and 1975. Of these, 38,021 were from small streams and 23,902 were from small lakes. Sediment samples from small streams were the preferred sample type in regions having well-developed drainage systems; here a nominal sample density of one sample per $10 km^2$ ($4 mi^2$) was selected. Lake sediments from small lakes were sampled primarily in low, flat areas having poorly integrated drainages. A nominal density of one sample per $23 km^2$ ($9 mi^2$) was used.

Sediment samples were analyzed at Los Alamos by DNC (delayed-neutron counting), INAA (instrumental neutron-activation analysis), XRF (X-ray fluorescence), and arc-source emission spectrography. The suite of elements analyzed varied over the course of the analytical effort. However, in general, most samples were analyzed for Ag, Al, Au, Ba, Bi, Ca, Ce, Co, Cr, Cs, Cu, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Ni, Sc, Sn, Sr, Ta, Tb, Th, Ti, U, V, W, Yb, Zn.

Two type of colour contour images were used to display the geochemical data: single element images, which show the spatial and statistical distribution for each element; and a three-element image, which displays the spatial correlations of three elements simultaneously. For plotting purposes, data for most elements were statistically interpolated by universal kriging to a 5-km x 5-km grid. The use of colour images to project these data enables the reader to gain a synoptic overview of broad geochemical trends, place local geochemical patterns in their proper regional context, and observe correlations among the elements presented. Additionally, statistical summaries are provided for the single element distributions to aid in the interpretation of the single element images.

Results

The abundance and distribution of elements as determined from systematically collected and analyzed geochemical samples can provide valuable regional geologic information such as the nature of the bedrock and the approximate location of lithologic contacts. Regional geochemical trends and areas of widespread mineralization can also be mapped with these data. Used in conjunction with other available geochemical, geophysical, and geologic information, geochemical survey data provide a comprehensive data base on which future regional geologic and geochemical studies can be based.

However, caution must be exercised when interpreting the data. Because of its reconnaissance nature, these data cannot necessarily be used to pinpoint specific geochemical anomalies of single ore deposits. Secondly, interpretation of stream-sediment and lake-sediment data is not commonly straightforward and must take into account the many factors that can influence the composition of these sediments. Stream sediments and lake sediments are two distinct sample types, each of which is influenced by different factors, and some elements concentrate differently in lake environments than in stream environments. Upon careful examination of the elemental plates, together with the overlays of stream- and lake-sediment sample locations, differences in some elements (e.g., Fe) can be seen between the areas that were sampled predominantly from lakes and those sampled predominantly from streams. For most elements, these differences are insignificant and unobservable in the elemental plates. Nevertheless, for areal completenes of the atlas, both types of samples have been included in the same data base.

Examples described in the Atlas demonstrate the ability to map lithologies, particularly felsic plutons, at several levels of detail using geochemical data. Regional geochemical data can map a variety of major lithologies (and specific rock units) including granites, carbonates, mafic and ultramafic igneous rocks, and clastic sedimentary rocks of distinct provenance. The ability to recognize and delineate major lithologic units depends on several factors. Most importantly, outcrops of lithologies must be areally extensive and continuous enough that the samples collected adequately represent the unit. Lithologies having outcrop areas on the order of 10 km^2 may be represented by no more than one sample in this survey. Identification of rock types having such small outcrops is unlikely, particularly using kriged data. Secondly, recognition of distinct lithologies is facilitated where chemical signatures of adjacent units contrast sufficiently to allow differentiation. Finally, the elemental assemblages in lake sediments may be only indirect indicators of regional geochemical trends for some elements. Lake sediments have undergone a greater degree of chemical weathering and contain significant quantities of authigenic minerals and organic material that may be depleted or enriched in many elements present in the original parent rock. Stream sediments, on the other hand, are primarily the product of mechanical weathering and represent a composite sample of the geology of a stream basin.

These data may be used in mineral exploration to delineate favourable areas for more detailed investigations. Mineral deposits often occur in geochemical or metallogenic provinces characterized by enhanced concentrations of elements of economic interest. These provinces can be recognized because mineral deposits are generally associated with areas of widespread, low-level mineralization and tend to group into districts. The districts often cluster along specific stratigraphic or structural trends that extend over large areas. In some places, geochemical provinces can be recognized through the enrichment of elements over normal crustal values in one or more stratigrapic units within a region. Related exploration targets can be suitably limited to areas within these provinces.

In conclusion, if utilized with proper caution, the data in this atlas can be successfully used to: (1) identify broad geochemical patterns, (2) determine regional background values for the elements presented, (3) observe some correlations among these elements, and (4) select areas of interest for more detailed study.

REGIONAL GEOCHEMICAL MAPPING IN NORTHERN FINLAND, NORWAY AND SWEDEN

B. Bolviken, J. Bergstrom, A. Bjorklund, M. Konti, P. Lehmuspelto, T. Lindholm,
J. Magnusson, R.T. Ottesen, A. Steenfelt and T. Volden

The Nordkalott Project is a joint effort of the Geological Surveys of Finland, Norway and Sweden, involving compilation of geological, geophysical and geochemical data from most of the area north of the 66° parallel in the three countries, with its main aim to define provinces of ore potential. In the geochemical subproject up to six different types of samples (stream water, stream sediments, stream organic matter, stream moss, soil organic matter and till) were collected. Fine fractions and a heavy mineral fraction of till and sediments, were analyzed for up to 30 elements by various techniques including plasma spectrometry, X-Ray fluorescence and neutron activation. Maps of raw and manipulated data (element concentrations, principal components) as well as maps of interpreted results (selected geochemical provinces were made. Examples of results are presented, emphasis being put on the following points:

- Regional geochemical mapping with a sampling density of less than 1 sampler per 30 km^2 within a survey area of 250,000 km^2 disclosed large geochemical structures and lithological provinces, some of which may have ore potential.

- Apparently diffuse patterns of geochemical data within a limited survey area may be part of significant anomalies or provinces more easily recognizable when the data are seen in a broader context. This is evident when results from earlier, more detailed surveys of small areas within the region are compared with data obtained in the Nordkalott-Project. Furthermore, some of the large provinces defined in the Nordkalott Survey appear to belong to even larger geochemical megastructures.

- Experience from the project seems to indicate that the density of sample points necessary to define geochemical provinces, decreases as the size of the area under consideration increases.

CATCHMENT BASIN ANALYSIS APPLIED TO SURFICIAL GEOCHEMICAL DATA, COBEQUID HIGHLANDS, NOVA SCOTIA

G.F. Bonham-Carter, P.J. Rogers and D.J. Ellwood

The geochemistry of over 900 steam sediment and water samples from the eastern part of the Cobequid Highlands, Nova Scotia, has been studied by integrating the chemical data with topographic, drainage, and bedrock geological data.

A map showing outlines of catchment basins was prepared by hand from a topographic base. Each catchment basin corresponds to a single sample; some basins may contain nested sub-basins. A bedrock geology map was superimposed on the catchment basin map, and the area of each mapped unit was measured for each basin. Each sample can then be described not only by its location and chemical composition, but also by the geological composition and total area of its catchment basin.

Regression experiments show that a large proportion of the variance in the data set can be explained by predicting the levels of a geochemical element from the rock-type areas. This method can be used to predict background, either using all the sample points, or by removing outliers first. Improvement in prediction can be obtained also by adding Fe, Mn, loss on ignition, and CO_3^{--} as independent variables.

Where the cost of digitizing the geological and catchment area maps is prohibitive, a cheaper alternative, simply recording the presence or absence of rock types instead of areal proportions, can be carried out. Although less of the total variance can be explained using presence/absence data, for some elements this alternative is worthwhile.

Digitized map data are particularly valuable, however, for accurate measurement of catchment areas, to determine a mineralization rating after correcting anomalies (observed minus background) for dilution. Furthermore, raster plots of catchment basins, shaded according to chemistry (observed or corrected) provide useful maps for follow-up studies, and capture the spatial information in a form suitable for integration with digital images of other types (remote sensing, geophysics, etc.).

The Cobequid Highlands anomalies are compared with the location of known mineral occurrences.

HISTORICAL PERSPECTIVE OF EXPLORATION GEOCHEMISTRY IN CANADA, THE FIRST 25 YEARS

J.J. Brummer, C.F. Gleeson and J.A.Hansuld

Over half a century has passed since the first work in exploration geochemistry was undertaken by the Soviets, and later by the Swedes. Canada was to be a beneficiary of the knowledge gained in Sweden through Dr. Hans Lundberg who was familiar with the plant sampling work of N. Brundin and S. Palmqvist. Lundberg had come from Sweden to North America in 1924 and through the application of electrical geophysical techniques was responsible in 1926 for the discovery of the Lucky Strike and Oriental #1 base metal ore bodies at Buchans, Newfoundland. It was here, between 1938 and 1940 that Lundberg experimented with biogeochemistry, lake sediment geochemistry, and boulder tracing. This then is the first recorded use of exploration geochemistry in Canada. His early work and enthusiasm was to have a lasting effect on the development of exploration geochemistry in Canada. The idea of using trace elements as ore guides was conveyed by Lundberg to Herb Hawkes in 1940, and this then was one of the catalysts that ultimately led to development and application of exploration geochemistry in North America.

During the last half of the 1940s Dr. Harry V. Warren and his co-workers at the University of British Columbia commenced biogeochemical research in Western Canada. The idea of biogeochemistry was spawned by Warren in 1944 some two years before the beginning of the U.S. Geological Survey program. C.C. Star was one of the few geologists in the mining industry to make use of Warren's early research findings. J.S. Brown and P.A. Meyer Jr. (St. Joseph Lead Co.) instigated soil surveys in the Grenville province and T.S. Chisholm (Ontario Department of Mines) initiated soil and till sampling in the Kenora area, Ontario. The 1940s closed with the beginnings of lithogeochemical studies over massive sulphide deposits by J.E. Riddell (Quebec Department of Mines and McGill University) in the Noranda district, Quebec.

The 1950s were marked by a tremendous expansion in exploration geochemistry research in Canada. Warren and Delevault continued their biogeochemical research. R.W. Boyle (Geological Survey of Canada) initiated lithogeochemical studies related to gold and silver deposits as well as soil, water and stream sediments studies in permafrost areas and regional stream sediment programs in Nova Scotia. At McGill University J.E. Riddell and his co-workers (F.W. Cornwall and L.G. Murray) expanded their studies on major and trace element geochemical halos associated with volcanogenic base metal deposits. In the same period Riddell initiated geochemical studies involving lake sediments (R.C. Schmidt), tills (S.V. Ermengen), bogs, glacial sediments and mechanized overburden drilling (C.F. Gleeson), as well as soil gas radon (D.S. Sikka). During this decade H.E. Hawkes, H. Bloom, J.E. Riddell and J.S. Webb (Selection Trust Ltd.) were to launch the first regional stream sediment survey carried out in Canada and J.J. Brummer (Kennco Exploration Ltd.) initiated the first regional stream sediment surveys in the Cordillera and the Shield. Early till studies in northern Quebec were completed by C.T. Bischoff, in northern Ontario by G.F. Koehler, P.B. Hostetler and H.D. Holland, in Saskatchewan by A.R. Byers, and in Ontario, Quebec and New Brunswick by A. Dreimanis.

The 1960s were to see a refinement of many of the methods introduced in the 1950s. This was particularly so for overburden drilling techniques such as: the introduction of light percussion equipment by Rio Tinto Canada Ltd. (J.B. Boniwell and R.A. Dujardin); the successful application of the Atlas Copco percussion system in permafrost regions by United Keno Hill Mines (R.E. Van Tassell); and the use of the Failing Drill by the Geological Survey of Canada (J.A.C. Fortescue, and E.H.W. Hornbrook) to define the dispersal train from the Kidd Creek massive sulphide deposit, the application by Soquem (C.F. Gleeson and R. Cormier) of the light percussion overburden drill to find the Louvem Zinc Mine; and the development of the reverse circulation drill system for deep overburden sampling by Texas Gulf Ltd., and Bradley Brothers, Ltd. In the 1960s regional multimedia helicopter supported geochemical surveys were started by the Geological Survey of Canada in the Northern Cordillera, and soil surveys became a routine part of many exploration programs in the Cordillera and Appalachians.

Exploration geochemistry in Canada owes its start to a few dedicated individuals who with the support of some mining companies, several universities and governments were able to carry out significant research. In this paper the first twenty five years is reviewed - the difficult years of trial, error and skepticism. So far the second 25 years has been marked by extensive applications and refinement of established field techniques; also advances in analytical and computer techniques have been substantial. Most importantly, exploration geochemistry has been accepted by the majority of the Canadian exploration fraternity as another aid in finding mineral deposits. The story of the second 25 years undoubtedly will reveal the increased role that exploration geochemistry has played in mineral discoveries in Canada.

GEOCHEMICAL EXPLORATION FOR CARBONATE-HOSTED STRATABOUND LEAD-ZINC DEPOSITS, CENTRAL TAURUS REGION, TURKEY

M.N. Cagatay and S. Ikizer

Geochemical stream sediment and bedrock orientation surveys were carried out around some carbonate-hosted lead-zinc deposits and showings in the Hadim-district of the Central Taurus belt in Turkey. The deposits occur within the Hadim nappe, which comprises an assemblage of shelf carbonate and detrital rocks deposited during the Devonian and Late Cretaceous. In all cases, the mineralized zones are located in the Early Middle Permian Pseudoschwagerina-bearing limestones, which overly another characteristic limestone unit.

The ore bodies occur as pockets and lenses and, in places, as cross-cutting veins in limestones. Ore deposition was controlled by open-space filling, replacement, and solution brecciation processes that took place along bedding and fracture planes. The ores in the study area are dominantly of carbonate-type, consisting mainly of smithsonite and cerussite.

The chemical analyses of the carbonate ores show that most trace elements, such as As, Mo, V, F and Hg, generally occur in low concentrations. Cadmium is more enriched in the carbonate ore than in the primary sulphide ore, whereas Hg is more concentrated in the sulphide ores.

The widely exposed, limonite-cemented quartzite unit which overlies the Pseudoschwagerina limestone was found to be a useful bedrock sampling medium in outlining primary haloes associated with underlying lead-zinc deposits. In this rock unit, Zn and As was found to be the most effective indicator elements, demonstrating high anomaly contrasts, whereas the Pb and F exhibited relatively weak anomalies. Close-spaced bedrock sampling of the host limestone over some lead-zinc carbonate orebodies gave spurious profiles of Zn, Pb and F, which were difficult to interpret on a local scale.

Fluorine and Zn in stream sediments are effective pathfinder elements for stratabound lead-zinc deposits in this region; the stronger anomalies being related to mineralized zones, whereas weaker, apparently false anomalies are associated with exposures of a shale unit in the area. Zinc demonstrates a similar pattern to that of F, except for its relatively lower background variation. In the alkaline environment of the Central Taurus lead-zinc province where geochemical mobility of most elements is restricted, F and Zn in stream sediments can be effectively used together as indicator elements for stratabound lead-zinc deposits.

"LAG", A GEOCHEMICAL SAMPLING MEDIUM FOR ARID REGIONS

R.N. Carver, L.M. Chenoweth, R.H. Mazzucchelli, C.J. Oats
and T.W. Robbins

Desert land-surfaces are commonly characterised by a veneer or pavement of siliceous and/or ferruginous stony material. This material can be shown in most cases to be predominantly bedrock-derived, despite often severe modification by prolonged weathering, and can, therefore, be selectively sampled and analysed as an indicator of bedrock geochemistry in geochemical surveys.

Most pavements probably owe their existence to the interaction of several mechanisms. However, a common factor in all cases is the concentration of coarse particles at the selective removal by erosion of fine dilutant material. Hence the preferred name when used in the geochemical context is "lag".

In lag sampling, particles in the range 0.8-6.0mm are screened on site from the unconsolidated surface material. Material in this size range has been found to be quite uniformly distributed over a wide range of arid region environments, including areas where residual soils are severly diluted by transported alluvial and aeolian materials.

Data from exploration programmes for Au, Cu-Pb-Zn-Ba, and Ni allows comparison of results for lag sampling with those for alternative sample media in a variety of arid region environments. Analysis of lag samples for Au and As clearly indicates the presence of bedrock gold mineralization in the Paterson and Eastern Goldfields Province of Western Australia In these areas both lags and soils exhibit good anomaly contrast, but lags show more extensive lateral dispersion, leading to advantages in reconnaissance exploration.

Strong anomalies for Ni and Cu are developed in lags, compared with subdued response in fine fraction soils over a Ni sulphide occurrence in the Eastern Goldfields which has been subjected to deep lateritic weathering.

Lag geochemistry also clearly reflects subeconomic base metal and barite occurrences in the MacArthur Basin, N.T., in spite of the dilution of surface soils by sands probably related to a Mesozoic marine incursion. Orientation sampling over a Pb-Zn prospect in the Pine Creek Geosyncline has demonstrated maximum anomaly contrast in lag samples compared with various size fractions of the associated lithosols.

Variable dilution of lag samples by coarse quartz sand can be a problem in areas with substantial transported overburden. A simple procedure to 'correct' trace element values using regression analysis based on the Fe content of samples is described as a means of reducing 'noise' resulting from such matrix variations.

MULTI-ELEMENT GEOCHEMISTRY OF THE WOLAGSAN GRANITE MASS AND ITS RELATIONSHIP TO MINERALIZATION IN KOREA

H. Chon and M. Hale

Wolagsan granite mass, whose exposed area is about 360 km^2, lies in the central part of the Korean peninsula. The mass, of late Cretaceous age, is geologically assumed to be associated with copper-lead-zinc, tungsten-molybdenum, and fluorine mineralization. More than 60 mines or mineralized sites occur as hydrothermal veins or skarn-type ore deposits around the mass.

Lithogeochemical studies to determine the chemical variation of K, Na, Ca,, Mg, Fe, Mn, Al, Ti, P, Li, Rb, Be, Sr, Ba, La, V, Cr, Mo, W, Co, Ni, Cu, Ag, Pb, Zn, Cd, As, Sb, Bi, Te, and F in the mass and their relationship to differentiation trend and mineralization have been undertaken. Two groups of elements related to primary lithology were recognized from the cluster analysis of multi-elements data; K-Rb-Be-Pb and Ca-Ba-Sr-Mg-Fe-Ti-P-Co-Cr-V. Enrichment of the former group of elements and depletion in the latter are particularly characteristic in the mass.

Modal compositions of the selected samples from the mass indicates that the mass is composed of granite and quartz monzonite. However, the ternary relation between Rb, Ba and Sr in the mass indicates that most of collected specimens should be classified as strongly differentiated granites, except some samples of granodiorite and quartz diorite. The differentiation trend can be displayed very effectively on two diagrams, Rb-Ba-Sr and K/Rb-Ca/Sr. The differentiation trend may of been earlier in the southern part than the northern part of the mass. Enrichment of K, Li, Rb, Be and F, and depletion of Ca, Mg, Fe, Al, Ti, P, Sr, Ba, V, Cr, Co, Ni, Cu, Zn, As, Sb, Bi and Te are characteristic compared with other Mesozoic granitoids, which were collected regionally in the Korean peninsula. Tungsten, together with fluorine, shows anomalous primary dispersion owing to related mineralization, but copper, lead and zinc have no correlation with Cu-Pb-Zn mineralization.

The geochemical characteristics of the mass are indicative of a productive pluton, with particular reference to the ratios of selected elements such as Ba/Rb, Li/K, Rb/Sr, F(Li+Rb)/(Sr+Ba), and Mg/Li, etc. However, lack of tin mineralization around the mass could be due to its petrogenesis as a member of the magnetite-series granitoids.

APPLICATION OF INDUCTIVELY COUPLED PLASMA METHODS TO PARTIAL DIGESTIONS OF STREAM SEDIMENTS FOR RECONNAISSANCE GEOCHEMISTRY

S.E. Church, J.M. Motooka and E.L. Mosier

We have applied partial digestion procedures, primarily utilizing oxalic acid and aqua regia, to several regional geochemical reconnaissance studies carried out using inductively coupled plasma analytical methods. We have chosen to use these two acids because the oxalic acid primarily attacks those compounds formed during secondary geochemical processes whereas the aqua regia will digest primary sulfide phases as well as the secondary phases. Application of the partial digestion technique has proven superior to total digestion because the concentration of metals in hydromorphic compounds and the sulfides is enhanced relative to these metals bound in the unattacked silicate phases. The aqua regia digestion attacks and leaches metals from the mafic chain silicates and the phyllosilicates (coordination numbers of 6 or more), yielding a characteristic geochemical signature, but it does not leach appreciable metal from many other silicates.

In order to interpret the results from these studies, we have initiated an investigation of a large suite of hand-picked mineral separates. The study includes analyses of about two hundred minerals representing the common rock-forming minerals as well as end-member compositions of various silicates, oxides, sulfides, carbonates, sulfates, and some vanadates, molybdates, tungstates, and phosphates. The objective of this study is to evaluate the effect of leaching by acids of particular lattice sites in particular mineral structures. Presumably the concentration of a metal leached from a particular crystal lattice site will reflect the relative bond energy of that crystallographic site.

In addition to the data reflecting mineralization that is derived from the leaches, various lithologic signatures will also be reflected. A rock that contains hornblende, such as a granodiorite, when leached with aqua regia, will have a geochemical signature that reflects the hornblende. Likewise, a two-mica granite will reflect the leaching of the micas. Signatures of the mafic chain silicates and phyllosilicates can readily be distinguished from the geochemical signature of sulfide mineralization based on the partitioning of the first-series transition metals between silfude and silicate phases and the behavior of aluminum and magnesium. Application of one or both leaching procedures provides the exploration geochemist with selective methods that lead to a better data base for interpretation.

TOTAL ORGANIC CARBON ANALYSIS OF ANCIENT SEDIMENTS: A NEW TECHNIQUE

P.L. Churcher and R.D. Dickhout

A new total organic carbon analyzer has recently been developed by the authors following discussion on the accuracy and precision of values obtained from current commercial systems. It was noted by Macauley and Ball (1982) that TOC values obtained from different laboratories may vary by as much as 120 percent. A variance of 20 percent was observed by these authors. The problem of interlaboratory variation appears to be due to differences in equipment, standards, and methodology.

The new system utilizes a Lindberg quartz tube furnace, set at 800°C, instead of an induction furnace as used in other analyzers. This type of furnace has been proven to provide a more rapid and complete combustion without the need for accelerators. The amount of CO_2 produced by the sample is detected using a Beckman non-dispersive infrared analyzer, selective for CO_2. The system is calibrated using carbon standards developed by the authors and has an expected range from 0.01 to 20 percent TOC.

The validity and reproducibility of the tube furnace system results were tested thoroughly by combusting numerous "in-house" standards, over a period of four months. The mean values compare favourably with those obtained from the independent analysis and are believed to be accurate to within 5 percent.

The new system has many advantages over the commercial systems currently available. Firstly, it provides simple, rapid, accurate, and precise values over a wide range of TOC. Secondly, the system consists of standard laboratory equipment and can be built for a tenth the cost of a commercial system. Thirdly, operating costs are low, costs are approximately 25 cents per sample, excluding labour. Finally the system can be modified to analyze recent sediments for percent TOC, and carbonates for total inorganic carbon (percent carbonate).

TOC values obtained from the system, combined with other geochemical and geophysical signatures, were successfully used to define the extent of the Collingwood Member of the Lindsay Formation in the subsurface of the southwestern Ontario, using well cuttings and core. It is forseen that the main use of this system will be in oil shale and hydrocarbon source bed evaluation, but an application also lies in the exploration of ore bodies associated with organic deposits.

NEAR-SURFACE LITHOGEOCHEMICAL HALOES AS AN AID TO DISCOVERY OF DEEP UNCONFORMITY-TYPE URANIUM DEPOSITS, ATHABASCA BASIN, SASKATCHEWAN

L.A. Clark

Rich uranum deposits are being found to depths of more than 400 m where graphite-bearing rocks underlie the Athabasca sandstone unconformity. Exploration to date involves drilling along weak electromagnetic conductors that reflect the graphitic basement. At unconformity depths of 400-600 m each exploratory hole costs over $50,000. The deposits are believed to have formed through circulation of heated formation waters which vented essentially vertically above the deposits (Clark and Burrill, 1981). Geochemically detectable zones of alteration are reported for cross-sections through the Dielmann, Midwest, and McClean deposits (Sopuck, et al., 1983; and Wallis, et al., 1984). Areal dimensions of near surface haloes were required to define grid spacings and to justify drilling grids of shallow holes along conductors or favourable structures as a cost-effective exploration alternative to deep holes.

Orientation surveys were undertaken by sampling the first 10 m sandstone in a selection of holes from the Cigar Lake, Dawn Lake, and Sand Lake areas where the deposits are, respectively, 400-430 m, 100-160 m, and 180-210 m below surface. The first two deposits have published reserves of 385 and 30-40 million pounds U_3O_8, respectively, while Sand Lake may be much smaller. All samples were analyzed for an ICP-AA package of elements as well as for arsenic, boron, and both leachable and total uranium by fluorimetry, plus clay contents and species.

Well developed anomalies lie vertically above the richest portion of the Cigar Lake deposit in an area 150 x 600 m, and a weak anomaly in many elements continues over the 1800 m length that was sampled. Total and leachable uranium values are 20-15 times background with maximum values of 53 and 26 ppm, respectively. Anomalies of 32 to 6 times background are also evident for lead, vanadium, strontium, zinc, arsenic and sodium, and 5 to 2 times background anomalies for barium, thorium, phosphorus and yttrium.

Of the four Dawn Lake mineralized zones, the 11B Zone was studied, with only partial coverage over 11A Zone. Anomalies 50-100 m by 300-600 m in size are often displaced up to 100 m northeast of the 11B Zone. Boron, magnesium and both uranium anomalies are 30-15 times background with yttrium, lanthanum, strontium, and total clay at 7-3 times background.

By contrast, at Sand Lake deposit, only subdued anomalies occur for most of these elements. The unusual anomaly patterns may reflect post-alteration tectonism of the sandstone overlying the deposit.

Detection of near-surface lithogeochemical haloes using grids of shallow holes should facilitate discovery of deep deposits and reduce expensive, deep drilling.

BIOGEOCHEMISTRY: A GEOCHEMICAL METHOD FOR GOLD EXPLORATION IN THE CANADIAN SHIELD

D.R. Cohen, E.L. Hoffman and I. Nichol

This paper describes the results of an investigation of the potential of biogeochemical methods as guides in exploration for gold mineralization.

In areas of exotic overburden there may be no geochemical relationship between mineralized bedrock and the overlying material, thus limiting the potential of transported soils and tills as suitable geochemical sampling media. Vegetation has been noted to have the capacity to absorb metals from groundwater via the extensive root system, and accumulate those metals (such as gold) in various organs - needles, leaves, twigs and bark. In this way, the analysis of vegetation may serve as an indicator of local gold mineralization in areas where there is no geochemical indication in the surface overburden.

The investigation was undertaken in the Hemlo area, Ontario, where gold mineralization is stratabound within a series of altered felsic to intermediate volcanics and tuffs and is frequently associated with Mo, Sb, Ba and As. Glacial overburden is of diverse composition, depth and source. In some areas the till is calcareous and may affect element mobilities by increasing surface pH. Elsewhere, the till is clay-rich and may prevent the dispersion of metals away from the mineralization. There are also variations in the secondary environment, with mineralization occurring in areas of freely as well as poorly drained overburden. In low-lying areas, there is characteristically a poor geochemical response to gold mineralization in the B horizon soils and humus. In this situation, occasional spot anomalies and erratic anomalous patterns developed, and their erratic nature seriously limits the effectiveness of conventional overburden sampling. Over areas of some relief however, marked anomalies occurred in B horizon soils and humus associated with mineralization.

Selected organs of spruce, alder, balsam fir, birch and mountain maple were collected from a series of traverses extending over areas of gold mineralization into background in both freely and poorly drained ground to compare the anomalous responses in different organs and species with those in soil and humus. Samples were analysed dry by instrumental neutron activation.

At this time provisional data are available for the deciduous species leaves and twigs, but subsequent data on the bark and confierous species will be discussed.

The results indicate a strong response to gold mineralization in the leaves of alder, birch and maple. In areas of poor drainage or exotic overburden, the leaves of birch and alder produced consistent anomalies up to 150 feet (50 m) in width compared to spot anomalies in the soil and humus. In well drained areas, all species organs displayed good geochemical contrast and generated anomalies up to 500 feet (160 m) in width. Local and regional background levels were found to be comparable.

Various organs also displayed highly anomalous contents of Mo, Sb and Ba adjacent to mineralization, with Ba concentrated into birch leaves and Mo into alder twigs. In areas of good drainage, biogeochemical anomaly patterns of various elements were displaced in response to their relative mobilities.

All organs exhibited extensive seasonal variations with metal contents changing by up to 60% between spring and fall. Moderately large variations in the gold contents of identical adjacent species does occur, but in these cases this did not affect the distribution of anomalies.

In areas of poor drainage or exotic overburden, anomalous patterns developed in selected organs of vegetation species common to the Hemlo area. These anomalies are shown to be wider and more consistent than anomalies developed in B horizon soils or humus. Therefore, biogeochemical sampling is considered to be a more suitable sampling medium to locate gold mineralization in areas of exotic overburden where the surface expression of the mineralization in surface soils is indistinct.

THE REA GOLD MASSIVE SULPHIDE DEPOSITS, ADAMS LAKE, B.C.: A GEOCHEMICAL EXPLORATION STUDY

A.J. Davidson and I.D. Pirie

The Rea Gold base metal-gold massive sulphide deposits are located approximately 100 km northeast of Kamloops, B.C. The property was optioned from Rea Gold Corporation by Corporation Falconbridge Copper in November 1983 after the discovery of an outcrop of massive sulphides that returned values of 1.32 oz/ton Au, 7.3 oz/ton Ag, 2.6% Cu, 3.2% Zn, and 7.8% Pb. Since then diamond drilling has delineated two ore lenses totalling 150,000 tons and grading 0.43 oz/ton Au, 3.5 oz/ton Ag, 0.7% Cu, 3.6% Zn and 3.1% Pb.

The deposits are hosted by a complex assemblage of volcanics and sediments of the Upper Paleozoic Eagle Bay Formation which is also host to a number of subeconomic deposits such as the Homestake Mine and the Mosquito King. The Rea deposits occur at the top of the pile of mafic volcanics in a sequence of laminated and brecciated cherts and sediments. The major sulpides present are pyrite, arsenopyrite, sphalerite, galena and chalcopyrite. Profiles of metal concentrations in the massive sulphides from the footwall through to the hangingwall show significant zoning from an As-Zn-Pb base to a Ba-Ag top.

The original showing was discovered by Mr. A. Hilton as a result of persistent prospecting using a colorimetric field geochemical kit. Anomalous soil and silt samples localized the prospecting to an area of active logging which revealed a red hematitic gossan overlying massive sulphides. Later heavy mineral stream sediment sampling by CFC also highlighted the deposit area. A detailed B horizon soil survey both up and downslope from the original showing accurately located both massive sulphide lenses although the downslope dispersion of some elements is significantly greater than others. Further soil sampling has defined a new mineralized chert horizon at a lower stratigraphic level. Drill testing of this horizon has also confirmed the soil results.

Major element geochemistry of the highly altered footwall rocks indicates that they were originally basaltic in composition. Both footwall and hangingwall rocks show significant additions and depletions of major (Na, Mg, Ca) and trace (Ba, Cu, Zn) elements.

Exploration is still in the early stages and the search for additional lenses is continuing. Geochemistry is being used in the surface exploration stage to locate new horizons, in the initial drilling stages to define stratigraphy, and in the detailed drilling stage to aid in locating and defining ore lenses.

BIOGEOCHEMICAL PROSPECTING USING LEAD ISOTOPES

J.A. Dean and B.L. Gulson

One aspect of CSIRO's continuing investigations into the use of lead isotopes in mineral exploration, particularly for concealed mineralization, involves the analysis of vegetation.

Because lead isotopic ratios are not changed by weathering or biological processes, the technique offers the following advantages over conventional biogeochemical prospecting:

1. Species selection is not as critical.
2. The plant organ (e.g. twigs versus leaves) is not critical.
3. There does not have to be quantitative uptake of Pb by the vegetation.

The major disadvantage of the lead isotope technique is cost, and thus detailed regional vegetation surveys are not feasible at the present state of technology.

Techniques have been perfected to remove the Pb from vegetation under rigorously clean conditions for isotopic analyses. Pilot studies over partially concealed mineralization of the Koongarra-X uranium anomaly (Northern Territory) and the Benambra Cu-Pb-Zn volcanogenic massive sulfide deposit (N.E. Victoria) have given encouraging results.

In many instances, the lead isotopic analysis of vegetation offers no advantages over that of soils. However, the technique should be useful in cool climates where glaciation causes major exploration problems as in Canada, Scandinavia and Tasmania and in densely vegetated or frozen areas where soil sampling is difficult.

These investigations have been partially sponsored by 15 companies through the Australian Mineral Industry Research Association.

STATISTICAL INTERPRETIVE PROCEDURES IN EXPLORATION GEOCHEMISTRY: GREECE

A. Demetriades

An attempt to combine analytical data gathered in detailed geochemical exploration programmes by different organisations working in neighbouring areas and using different analytical methods created almost insurmountable problems. The necessity to present the two sets of data on a unified map led to the construction of element distribution maps, using standardized data (z-scores) and probability (percentile) level isopleths. The two methods are compared and their usefulness in geochemical exploration assessed.

Geostatistical structural analyses of reconnaissance and follow-up stream sediment (random samples) and detailed (regular samples) level geochemical data are being examined. The merits of using the semivariance function in geochemical exploration are evaluated, initially with respect to known mineralized trends by the use of iso-semivariance plots, and later extended to other structures outlined by these diagrams, but not explained by geology. The variation of the range of influence of the samples with direction in gridded data is examined, and its usefulness in choosing the most appropriate grid dimensions is assessed and contrasted to other methods.

The techniques developed may be useful in (a) presentation and interpretation of geochemical data resulting from the use of different analytical methods, (b) delineation of indistinct mineralized trends, and (c) choice of the optimum grid dimensions peculiar to the area under investigation.

USE OF SELECTIVE EXTRACTION FOR ANOMALY CLASSIFICATION

S. Dijkstra, H.J. van den Hul, Y.M. Jubeli, M.V. Ramanamurthy, and T.K. Sen

In any geochemical survey, the following steps are involved: (1) planning; (2) sample collection; (3) measurements; (4) data analysis; and (5) data interpretation.

However, it is a known fact that most surveys suffer from producing too many anomalies, of which too few are related to mineralization. This suffering could be reduced by a more appropriate selection of chemical data in the planning stage, and a better awareness of the potential advantages and shortcomings of suitable methods of data collection, analysis and interpretation.

This holds especially true for the use of selective extraction techniques (also called: partial dissolution techniques, which have recently been reviewed by Chao. Practical application of these techniques so far seems to focus on improvement of anomaly contrast and the selection of proper sample media, such as organic matter or oxide coatings. However, even more important applications may be the determination of the mode of occurrence of elements of geochemical interest and the classification of anomalies.

The determination of the mode of occurrence, in the opinion of the authors, still suffers from the relative lack of specificity of selective extractants, caused in part by the presence of buffers required for a fairly rigorous control of pH, but introducing large amounts of ions (e.g., acetate ions) that are known complexing agents for many trace elements.

Anomaly classification does not suffer as much from non-specificity. Anomalies of any given trace element may be classified according to their selective extraction patterns, that in turn may be compared with the patterns of anomalies for that element related to known mineral deposits. Such a pattern may be obtained both by a series of single dissolutions with a variety of extractants, or by a sequential multiple dissolution. Here, the usefulness of single extraction patterns in a sense compares with, and is complementary to, multi-element discriminant analysis is geostatistics. Hence, selective extraction patterns may also assist in differentiating between anomalies created by human pollution and natural anomalies. As far as natural anomalies are concerned, the extraction patterns may be used to isolate anomalies related to mineralization from the majority of anomalies relating to other natural phenomena.

Experiments and Results

The authors have carried out an extensive program of extraction experiments on model samples, as well as samples from actual field surveys, with special reference to Pb and Zn.

Model samples are samples in which given amounts of known metal phases have been added to a low-metal carrier. Experiments on these samples clearly demonstrate the non-specificity of many so-called selective extractants. However, in some cases they serve to identify the mode of occurrence of trace elements in primary and secondary minerals.

One particular application is the use of a very simple method in which increasing quantities of sample are added to dilute HCl, giving rise to increasing shifts in pH, presumably caused by ion-exchange and/or consumption of protons by minerals dissolving from the soil phase. In this way, the rate of extraction as a function of pH can be studied without the interference of buffer zones.

The results show a fairly good separation between primary and secondary mineral phases, both in model samples and in anomalous field samples, and show potential for the classification of anomalies.

In a second group of experiments, selective extraction patterns have been determined for "natural" and "man-made" anomalies, the last from a variety of sources, e.g., heavy-mineral contaminated sludge from the port of Rotterdam, highway banks, the surroundings of a metal-working plant, and mine dumps.

Finally, a series of results will be shown for selective extraction patterns of anomalies over known deposits in different geological settings. The results show that similar deposits indeed give rise to similar patterns. These patterns could in principle be supplemented by a large number of patterns from the literature, obtained for a variety of elements, geological environments and anomaly types. However, at present, differences in selective extraction methods and conditions used, are too large to enable an unambiguous comparison of these patterns.

USE OF NATIONAL GEOCHEMICAL RECONNAISSANCE DATA TO IDENTIFY ENVIRONMENTALLY SENSITIVE AREAS

P.J. Doyle and R.D. Morse

Examination of National Geochemical Reconnaissance (NGR) maps of Canada, showing trace element concentrations in selected streams of Southern British Columbia, reveals areas where uranium levels are significantly elevated. Some of the values reported, including those for streams used as sources of domestic water, approach the 20 µg/L maximum acceptable concentration for drinking water. In order to evaluate the usefulness of NGR data in identifying areas of possible public health concern a follow-up sampling program was undertaken, sponsored by the B.C. Ministries of Health, and Energy, Mines and Petroleum Resources. Five areas were selected for study, including two where streams were indicated to be enriched in uranium (concentrations 2-20 µg/L). Both surface and ground water samples were obtained from several sites within each area, on a monthly basis, over a period of from one to two years. The parameters measured were total uranium, gross alpha and gross beta radioactivity, conductivity and pH.

Data for uranium enriched streams show distinct temporal variations, with samples taken in the fall and winter months containing the highest uranium concentrations and those obtained in late spring and early summer the lowest. Uranium levels in ground water were typically higher and more temporally stable than those in associated surface streams.

Values for conductivity, like those for uranium, were normally highest in the fall and winter and lowest in the late spring and early summer. Data for pH and gross radioactivity, on the other hand, exhibit little systematic temporal variability. Gross activity levels are generally low, indicating that concentrations of uranium daughters, particularly Ra-226, are within acceptable limits.

Uranium distribution patterns shown on NGR maps were generally confirmed, with concentrations of up to 40 µg/L occurring periodically in streams within previously identified uranium enriched areas. Furthermore, absolute values recorded during June, July and August agree favourably with NGR map data measured on samples collected up to four summers previously. Thus the NGR data base can and should be used as a very valuable source of information for identifying areas of environmental and public health concern.

ENHANCEMENT OF STREAM SEDIMENT ANOMALIES DISTAL TO Cu-Au PORPHYRY SYSTEMS IN PAPUA NEW GUINEA: ORIENTATION SURVEY

P.E. Drez

Stream sediments were collected from eight areas in Papua New Guinea during 1981, including five previously described prospects. These areas were chosen to provide a wide range of geological, geochemical, and weathering environments to study the mobility of metals and their ore-related dispersion. The areas studied included: Yandera (Central Highlands), Plesyumi, Uasilau and Esis (New Britain), and Legusulum (New Ireland). The samples were analyzed to determine metal speciation between size/mineral fractions and to ascertain whether a particular fraction or partial leaching technique might improve detectability of more distal anomalies in stream sediments away from ore.

No significant differences were noted between the composition of the bulk sediment and both the -20 to +40 and -40 to +80 mesh fractions. In areas of low sulfide content, the -80 mesh fraction was very close in composition to that of the bulk sediments. In areas of mineralization, higher values of aluminum and trace elements were noted in the -80 mesh fraction.

Copper analyses of the four size fractions showed approximately the same size anomaly for each prospect. The -80 mesh fraction gave a better anomaly contrast than that found in the bulk sediments for four of the five prospects studied. The magnetic and nonmagnetic fractions also gave higher contrasts than the bulk sediment but overall not as high as the -80 mesh fraction. At two prospects, mineralization was detected farther downstream from ore in the -80 mesh fraction than the other three size fractions.

Results from all five prospects studied show that the maximum anomaly to background contrast was achieved by the EDTA-leachable copper in the -80 mesh fraction. Results from two prospects showed EDTA-leachable copper anomalies in large streams distal to ore, which were not seen in the total digestion analyses of the four fractions used. The copper values of the EDTA leach of the -80 mesh fraction provided the best contrast and most distal anomalies for four of the five prospects.

Based on a limited amount of molybdenum data from two prospects, molybdenum appears to outline the extent of mineralization at prospects containing significant Mo.

Gold analyses of bulk sediments and -80 mesh fraction samples provided good outlines of the extent of mineralization at two prospects studied in detail. Many "low" values of gold were noted within areas of mineralization, therefore requiring a higher sample density for gold than copper to define an area of mineralization.

LITHOGEOCHEMICAL EXPLORATION FOR STRATABOUND ARSENOPYRITE-GOLD MINERALIZATION IN THE SOUTHERN UPLANDS, SCOTLAND

P.R. Duller and P.K. Harvey

A study of the fundamental geochemical composition of stratigraphically distinct lithopetrographic units within a lower Palaeozoic turbidite succession, included the survey of over 200 km^2 of Upper Silurian strata, centred upon the known stratabound arsenopyrite-gold and vein stibnite mineralisation at Glendinning, in Southern Scotland.

Preliminary evaluation of some 22,000 major and trace element lithogeochemical analyses from both regional and mineralised drillcore samples indicated that:-

a) The changes in chemical composition of the greywacke, due to alteration are larger than those related to initial compositional variations.

b) Pervasive hydrothermal alteration at Glendinning may be characterised by the extensive depletion of sodium, which together with minor depletions of iron and magnesium is counterbalanced by silicification and potassic metasomatism. In general Al, P, Ca and Ti are immobile.

c) A zinc depletion zone ('zinc hole') surrounds the known mineralisation.

d) The presence of gold in solid-solution within the arsenopyrite (up to 2.97%) justifies the use of arsenic as a pathfinder element for stratabound gold mineralisation in this region.

The geochemical nature of the alteration may be summarized as follows: The following elements, in order of importance, have undergone addition, As, Sb, S, Pb, Cu, Ni, K_2O, SiO_2, Sr, Rb, Co, V, Au, Ga, and Tl; whilst the following elements, again in order of importance, have undergone depletion, Na_2O, Zn, Fe_2O_3 and MgO.

An exploration model is proposed based upon the recognition of depletion zones to delineate broad target areas for detailed study. As the visual and mineralogical changes within the greywacke are more extensive and obvious than the disseminated sulphides a diffusive colour system is suggested as an empirical field guide, to detect areas of hydrothermal bleaching (up to 400 m wide) and thus potential mineralisation. This investigation extends the strike length of the stratabound mineralisation at Glendinning to over 1 km and has pinpointed at least four prospective areas for further study.

DETAILED GEOCHEMICAL STUDIES OF A HE-U ANOMALY, IN PERMAFROST, BAKER LAKE AREA, N.W.T.

W. Dyck and D. Car

A strong He-U anomaly, discovered in the Thelon basin of the N.W.T. during a regional geochemical survey in 1981, was studied in detail in 1982. The anomaly is confined to a 3 km^2 lake situated 160 km northwest of Baker Lake. Lake bottom water and sediment samples taken in June through the ice on a 50 m x 50 m grid, were analysed for a number of trace and minor elements.

In the lake sediments He and U were highly anomalous and parallel the strong anomaly patterns of He observed in the water. Median and maximum values in the sediments were 57 ppm and 396 ppm U and 296 nL/L and 13870 nL/L He. Regional medians were 4.3 ppm U and 50 nL/L He. Se and V in sediments gave weak but similar anomaly patterns to those observed for U and He.

The anomaly is an enigma. The unusually high U content indicates an oxidizing, hence, near surface, water regime; whilst the highly anomalous He flux into the lake and a thick cover of permafrost in the region indicate a very deep source where conditions are normally reducing, rendering U immobile. Coincident anomaly patterns and increasing concentrations of minor and trace elements and gases with depth in the lake water prove that groundwater is the source of the anomalies. Contoured element maps indicate that this groundwater enters the lake in at least four places.

The fact that up to 35 ppb U, and virtually no Fe and Mn, were detected in lake waters above groundwater entry points indicates that the groundwaters were oxidizing with respect to these elements. This is indeed surprising because permafrost is believed to be about 300 m thick in the region; below such a depth groundwaters are usually rich in Fe and void of U.

The highly anomalous He in this lake indicates deep fractures which serve as conduits for mineralized water which enters the lake from depth and creates a frost-free window in the permafrost. The fractures probably penetrate well into the basement for only major deep fractures are known to produce such strong He anomalies as were observed in this lake. The additional presence of anomalous U suggests U mineralization at depth.

APPLICATION OF AN INDUCTIVELY COUPLED PLASMA MASS SPECTROMETER TO THE DETERMINATION OF LEAD ISOTOPE CONCENTRATIONS AND RELATED TRACE ELEMENT ABUNDANCES IN MINERALS, WATERS AND SOILS ASSOCIATED WITH SOME BASE METAL AND GOLD OCCURRENCES IN ONTARIO: A PRELIMINARY REPORT

T.E. Eagles, E.J. Brooker and R.G. Smith

Lead isotope data obtained on ground waters and soils associated with some Ontario base metal and gold deposits is presented together with trace element associations peculiar to the various isotopic configurations. Some preliminary information in progress with rare earth and platinum group element analysis will be discussed.

With the delivery of the first few ICP/MS production models during the summer of 1984 several research groups have had an opportunity to appraise this new instrument first hand. As might be expected a number of technical problems related to instrument functions have been encountered. The manufacturer has been dealing with these problems to the best of his ability.

In spite of these setbacks the group at XRAL has concentrated on attempting to use the instrument in this "reduced performance level" mode. Results have been encouraging. Topics of study include a continuation of the lead isotope work done earlier on the prototype instrument.

Precision and accuracy achieved indicate that ICP/MS Pb isotope data will be quite useful in many geochronological studies. Comparative analyses are presented to support this view.

GEOCHEMICAL MAPPING OF SWEDEN

J. Ek

A governmental regional geochemical mapping programme is being carried out by the Geological Survey of Sweden (SGU) since 1982. About 30 major and minor elements are analysed by X-ray fluorescence (Na, K, Mg, Al, Si, Ti, Fe, Mn, S, P, Cu, Pb, Zn, Ni, Cr, Co, Mo, Rb, Sr, Y, U, Zr, Nb), and by atomic absorption and delayed neutron activation for Se, Cd, As, Hg and Au. Two types of samples are used: Organic stream sediments for mobile elements and heavy mineral concentrates from till for weathering-resistent elements. For organic stream sediments, the selected elements are processed by a stepwise linear regression analysis in order to normalize the samples with respect to environmental factors, such as coprecipitation with limonite and organic content. The corrected values are then processed by Kriging in order to visualize the large scale geochemical patterns.

The results from the organic stream sediment mapping has revealed that the geochemical patterns are primarily related to the geochemistry of the bedrock. Superimposed on these patterns are, however, patterns related to human influence such as airborne pollution, agriculture and acid rain. These influences are strongest in southern Sweden and in the industrialized parts of the country. Knowledge of such patterns is essential for the environmental control programme and for selecting anomalous patterns of significance for mineral prospecting.

The heavy mineral technique gives anomalous patterns that are more directly related to the geological environment. Several new regions with potential for Sn and W mineralization have been discovered. The technique has also given reliable results for certain mobile elements such as Zn and U due to the fact that these elements are present in higher than normal concentrations in resistant minerals within mineralized areas.

Geochemical reference stations have been established at 24 locations throughout the country in the vincity of natural springs. At these stations chemical and physical parameters of the spring water are being monitored at regular time-intervals of about 4 months every year. The geochemistry of organic stream sediments, the weathering profile of the soil and of forest moss (Hylocomium splendeus) are also being investigated at regular time-intervals. These measurements have given valuable information about the behaviour of heavy metals in the secondary environment with respect to:

- geological environment
- variation in climate
- airborne pollution
- acid rain

The geochemical reference stations are a valuable complement to the regional mapping programme in that they provide the necessary information about background and threshold levels in various geological, physiological and climatological environments.

TAKING A CLOSE-UP OF THE BACKGROUND: MULTIVARIATE DATA ANALYSIS IN GEOCHEMICAL PROSPECTING

K.H. Esbensen, S. Wold, L. Lundholm and L. Lindquist

Geochemical prospecting in glaciated terrains commonly employs a multielement approach, whereas subsequent data analysis all too often is carried out in the univariate regime. Considerable efforts are spent trying to define statistically operative single element "threshold"-values in order to delineate geochemical anomalies, while the experience of the last two decades has clearly shown that geochemical anomaly patterns (statistical as well as geographical) are very often multielement signatures. The trend from global, to regional, to local thresholds is telltale in this respect, as is the authoritative critique of the threshold concept by Govett (1983, chap. 3).

By using a suitable bilinear projection (principal components) for Soft Independent Modelling of data Class Analogies (SIMCA), it is possible to simultaneously define both a regional geochemical background and to quantify a concept of multivariate geochemical anomalies. This type of data analysis ensures an optimal splitting of geochemical prospecting data into a systematic part (multivariate background trends) and an unsystematic residual trend (deviating concentrations, relative to this complementary background model).

A 4000 km^2 area in northernmost Sweden has been investigated employing both till heavy mineral separates (weakly- and non-magnetic fractions: 2 x 1160 samples) as well as organic stream sediment samples (1850). All three data sets have been analysed for some 30 elements. Careful SIMCA data analysis showed that the inherent complexity in this sample type corresponded to low-order (3 or 4 components) background models, and allowed classification of multielement outliers (anomalies). The background population(s) scores were plotted in their geographic context using kriging interpolation techniques and colour cartography. Overlays are also used to show the anomaly characteristics.

The background patterns show marked geographical trends which correlate well with underlying geophysical and geological bedrock features, though both media purportedly reflect secondary, clastic (till heavy mineral) or secondary-tertiary (organic stream sediment) dispersion. The spatial disposition of the anomalies also nicely reflects major tectonic bedrock features.

Advanced data analysis (PLS) further permits the comparison and integration of the background models from these media types, and thereby evaluate their relative information content related to the prospecting process. The PLS analysis also makes possible the construction of one, mutually enhanced, super-model that integrates both geochemical and geophysical (as well as petrophysical) information (-where such is at hand) by using a common discrete pixel format; 2 x 2 km for regional investigations.

This pixel-based PLS model can be further analysed, e.g., used as input to a cluster analysis. The geographical relationships between a 16-cluster assignment show good concurrence with the regional airborne magnetic map as well as with the geological map. This type of data analysis of original till heavy mineral geochemical data, integrated with low-cost airborne geophysical measurements, results in a first order approximation map of the buried geology. The PLS data analysis thus allows a "tele-geological mapping" of the underlying bedrock without any overburden drilling or field geology surveys. The advantages of this approach to the economics of the first stages of prospecting campaigns would appear obvious.

RESULTS OF A MULTI-ELEMENT GEOCHEMICAL SURVEY IN THE FEDERAL REPUBLIC OF GERMANY: GEOCHEMICAL ATLAS OF GERMANY

H. Fauth, R. Hindel and U. Siewers

The investigations for the Geochemical Atlas of the Federal Republic of Germany have now been completed and the results are presented and discussed. During the seven-year project about 70,000 stream sediment and 70,000 water samples were taken all over the Federal Republic of Germany.

The samples were analysed for the following elements, using atomic absorption spectrometry, fluorimetry, photometry, and optical emission techniques: Pb, Cu, Zn, Cd, Ni, Co, U, F (water and stream-sediment samples), Ba, Sr, Li, Cr, V, W, Sn (only in stream-sediment samples). Coloured maps at a scale of 1:2,000,000 are presented for these elements and also for pH and conductivity. Statistical parameters for these elements were calculated for different geological environments, as well as for stream sediment and water samples from contaminated rivers.

An interpretation of the element distribution maps is given with special emphasis on the influence of old mines, lithological units, and pollution. In various anomalous areas discovered during this study further detailed investigations were carried out. Results of these investigations are presented with special emphasis on discrimination techniques which distinguish between natural and anthropogenetic anomalies.

ROCK, BASAL TILL AND VEGETATION GEOCHEMICAL SIGNATURES OF THE AGASSIZ STRATABOUND AU-AG DEPOSIT, LYNN LAKE, MANITOBA

M.A.F. Fedikow and E. Nielsen

The Agassiz stratabound Au-Ag deposit is located 8 km northeast of the town of Lynn Lake in northern Manitoba. The deposit is situated in the northern arm of the Aphebian Lynn Lake greenstone belt comprising metamorphosed volcanic, sedimentary and plutonic rocks with a length of 130 km east-west and a maximum width of 60 km. Regional metamorphism in the belt has attained upper greenschist to upper amphibolite facies. The immediate host rocks to the Agassiz deposit are north-facing, steeply dipping, inter-layered siliceous and biotite-rich siltstone, oxide, sulphide and silicate facies iron formation and high Mg-Cr basaltic flows and tuffs. The hanging-wall rocks are fragmental, aluminous basalt and the foot wall comprises actinolite-chlorite-rich basaltic flows. Gold occurs as 10-50 micron sized particles concentrated at the rims and as inclusions within sulphide minerals. Silver occurs in the native form and in association with freibergite which is present as inclusions (20 microns) in galena. Disseminated and thin solid sulphide layers characterized by variable contents of pyrite, pyrrhotite, sphalerite, arsenopyrite and galena occur in the deposit. This mineralization is crosscut by auriferous carbonate-quartz-sulphide veins. Diamond drilling centered on the deposit has delineated the Agassiz stratigraphic sequence for 1500 m; however, interpretation of vertical field gradiometer surveys substantiated by geological mapping has indicated that this metallotect, characterized by coincident electromagnetic and magnetic anomalies, has an overall strike length of 60-65 km. The deposit contains 3.2 Mt. of 5.7 g/ton Au and 13.0 g/ton Ag based on geological reserves above the 1600 foot level.

Rock Geochemistry

Multi-element haloes have been defined through the hangingwall to footwall section and may be ranked in terms of vertical extent about the mineralization as: Sb>Mn, Pb>Au>Zn, As>Ni, Co. Major element changes in the host rocks are less diagnostic and appear as sporadic Na depletions and Mg, P, Mn and K enrichments in the basaltic flow/tuff units. Anomalous concentrations of the halo forming elements persists in the host rocks for 1500 m along strike.

Till Geochemistry

A total of 42 unoxidized basal till samples with spacing of 5-10 m were collected over the Agassiz deposit. The <2 micron size fraction and the heavy mineral concentrates (S.G.>2.96) indicate metal dispersion fans up to 120 m down-ice of the deposit. These elements and their concentrations (Au-ppb; others-ppm) adjacent to the deposit are: Au (500) in the heavies, As (100), Cu (100), Pb (100), Zn (200) and Ni (100) in the clay-sized fraction. The follow-up survey with 75-100 m sample spacing identified a dispersion fan for Au (10-100 ppb; heavies) and As (10-80 ppm; clay-sized) for 0.5 km down-ice of the deposit.

Vegetation Geochemistry

Black spruce (Picea mariana) twig and needle samples collected from the area of the deposit are characterized by distinct but low contrast anomalies hydromorphically dispersed down slope from the subcropping mineralization. Cu, Zn, Mo, Fe (AAS; needles) and Au, As (INAA; twigs) are indicators of proximity to mineralization.

ELIMINATION OF HYDRAULIC EFFECTS IN STREAM SEDIMENT DATA: BEHAVIOUR OF CASSITERITE IN A MALAYSIAN STREAM

W.K. Fletcher, P.E. Dousset and Y. bin Ismail

Geochemical patterns for elements, such as Sn, W and Au, present in drainage sediments as resistate heavy minerals are often erratic and difficult to interpret. To investigate the source of these problems and develop methods of eliminating them we have compared the behavior of Sn, present as cassiterite, and associated pathfinder elements downstream from a small primary tin deposit in Perak, Peninsular Malaysia.

Dispersion trains for the pathfinder elements are characterized by smooth decay patterns, and differences in concentrations between high and low energy environments, characterized by coarse and medium grained sands respectively, are not significant. In contrast, Sn (and magnetite) concentrations are extremely erratic with significantly high concentrations in high compared to low energy environments. As a result the Sn dispersion train exhibits no regular decay pattern away from its source. These findings suggest that the action of the stream is analagous to that of a sluice box, with light minerals being winnowed away and cassiterite, together with magnetite, accumulating. For all but the finest size fractions this process, which is most efficient in high energy environments, causes considerable local variability in Sn content of the sediments. However, because the hydraulic behavior of cassiterite and magnetite is similar, but magnetite is not associated with the primary mineralization, the Sn/magnetite ratio can be used to eliminate Sn anomalies resulting from local variations in hydraulic conditions.

The concept of hydraulic equivalence of cassiterite and magnetite was extended to examining the relationship between Sn and different size fractions of the light minerals that constitute the bulk of sediments. Greatest contrast, is obtained when the Sn content of the minus 270-mesh fraction is re-expressed as its hydraulic equivalent concentration in minus 65+100-mesh material. For exploration purposes it is concluded that:

(i) providing cassiterite is present in the fine size fractions, sampling of this material will reduce hydraulic effects, thereby reducing data variability, and can also increase the length of the anomalous dispersion train.

(ii) hydraulic effects can also be reduced by re-expressing Sn concentrations as ratios to magnetite (provided this mineral is not associated with the primary Sn mineralization) or an hydraulically equivalent size fraction of the light minerals that constitute the bulk of the sediment.

Similar principles probably apply to interpretation of geochemical data for other elements dispersed in drainage sediments as heavy minerals: this warrants further investigation.

PRELIMINARY RESULTS OF MULTIDISCIPLINARY STUDIES AROUND THE RECENTLY DISCOVERED ALLAN LAKE CARBONATITE, ALGONQUIN PARK, ONTARIO

K.L. Ford, R.N.W. DiLabio and A.N. Rencz

Reconnaissance airborne gamma ray spectrometric data collected in 1978 defined a prominent high thorium-low uranium anomaly in the northeastern part of Algonquin Provincial Park. Follow-up ground investigations lead to the discovery of a glacial dispersal train of thorium-rich till and thorium-bearing carbonatite boulders.

During 1984 a variety of techniques were used to study and further delineate the dispersal train. Detailed, simultaneous airborne gamma ray spectrometric, low resolution total field magnetic, and VLF electromagnetic data were collected. The spectral features of the vegetation and possible correlation with the dispersal train was also examined using an airborne multi-detector electro-optical imaging scanner (MEIS). Ground investigations included the geochemistry of lake water, lake sediment, till, and anomalous boulders, leaf-tissue biogeochemistry and in-situ gamma ray spectrometry, total field magnetics and gradiometer surveys.

The detailed airborne gamma ray spectrometric survey clearly outlined the anomalous dispersal train, which is traceable in a south-southwesterly direction for approximately 5 km. Maximum concentrations of equivalent uranium and equivalent thorium measured by airborne gamma spectrometry are 5 and 53 ppm respectively with background concentrations near 1 and 4 ppm. Unlike many other carbonatites, this one lacks a prominent magnetic anomaly.

Limited lake water sampling showed that the small lake which the carbonatite underlies contains 2 to 3 times greater concentrations of Ca, Mg, F and $CaCO_3$ compared to background lakes.

Till geochemistry indicates anomalous concentrations of 10-20 times background for Ba, Nb, Th, Ce, La, Zn, Mn and Fe. Elevated concentrations of 5-10 times background for Y, P, Cu, Pb, Mo, Co and U also define the dispersal train. Maximum concentrations for the anomalous elements are: Ba-7,100 ppm; Nb-660 ppm; Th-550 ppm; Ce-3,230 ppm; La-2,780 ppm; Zn-2,780; Mn-3.4 pct and Fe-39.0 pct. Zr, Ni and Cr showed little or no variation across the train.

In-situ gamma ray spectrometry showed maximum overburden radioelement concentrations of 5 ppm equivalent uranium and 365 ppm equivalent thorium with background concentrations of 2 and 5 ppm respectively.

Limited outcrop, restricted to the fenitic aureole immediately surrounding the lake, is dominated by biotitic and garnetiferous quartzo-feldspathic gneiss with extensive hematitic veining and local brecciation. Carbonatitic boulders are predominantly ankeritic and dolomitic with locally abundant hematite. A lamprophyre dyke and a series of radial, hematite-rich dykes were also discovered. Whole-rock and trace element analysis of selected carbonatite and hematitic float are characterized by high concentrations of MnO, P_2O_5, BaO, Nb, F, Zn, Th and REE. Maximum concentrations of these elements are: MnO-8.6 pct; P_2O_5-15.3 pct; BaO-5.4 pct; Nb-887 ppm; F-1.5 pct; Zn-8,830 ppm; Th-3,610 ppm and total REE-5.94 pct.

Although the carbonatite has no significant outcrop, glaciation has produced a distinctive dispersal train of carbonatite-rich till. The dispersal train is detectable directly by boulder mapping and by till geochemistry and it is detectable indirectly by airborne and ground gamma ray spectrometry, and by multi-detector electro-optical imaging. Recent diamond drilling has confirmed the presence of the carbonatite at the up-ice end of the dispersal train.

SULPHUR, URANIUM AND TRACE ELEMENTS IN SWEDISH MIRES PLANNED FOR FUEL-PEAT PRODUCTION

D. Fredriksson

In planning for oil consumption reduction in Sweden one goal is to reach a fuel peat production of 5 TWh per year. This, in connection with new laws and restrictions for sulphur dioxide emissions, is one reason for the investigation of sulphur, uranium and trace element contents of mires planned for fuel peat production presented here.

The proposed law for sulphur emissions is the following: For small burning sites, the sulphur emissions shall not exceed 0.17 g sulphur per MJ fuel. For large burning sites, the upper limit is set at a level of 0.10 g S per MJ fuel. This means a sulphur content in the fuel-peat, calculated on dry basis, of 0.36% and 0.21% sulphur respectively.

These levels are relatively high. Of about 150 mires, which have been investigated up till now, approximately 23% exceed the higher level and 74% the lower level. We also know that some mires in Sweden have a relatively high uranium content. There are no environmental law restrictions regarding uranium, but in some rare cases it is known that radium is enriched in the peat and may cause radiologic toxicity.

Together with sulphur, uranium and radium we have studied the geochemistry of some trace elements which seldom are investigated in Swedish mires. These elements, Hg, As, Tl, Se, Sb, F, Cd, and B, were determined in four mires with different geochemical backgrounds. All samples were collected with specified volume, and humification was calculated according to the von Post scale. The botanical composition was classified according to the Finnish system of peat factors. This system makes it possible to quantify the botanical constituents and to process them, together with humification and chemical compositon, etc., by computer.

The sampling was undertaken using a square 150 meter net over the mires. A sample of 0.5 m length was collected every meter down to the mineral soil.

The first mire is a mesotropich fen (Storflyten) situated in an area underlain by cataclastic granite with a moderate uranium content. The fen, which is 3.5 m deep and about 60 ha large, is proposed for fuel-peat production. The content of uranium is high, 500-1000 ppm (in ash content) with a maximum of 7500 ppm. Even the sulphur content is quite high, 0.25-1.0 %. Uranium, sulphur and trace elements are related to cataclastic zones in the Precambrian rock and the geobotanical history of the mire.

The second mire is situated in an area underlain by upper Cambriam black shales. This shale (Alun shale) has a uranium content of 50-300 ppm and 5-7% pyrite bound sulphur. Elements like Cu, Zn, Pb, Cd, Ag, Au, V, Mo, Ni, As, Bi, Sb, Se and Ca are also enriched in the Alun shale. This shale is also the major rock constituent in the clay rich till on which the mire has developed. This mire (Skettmyren) is termed a composite mire, partly a mesotropic to eutropic fen and partly a slightly raised ombrogene bog. Both sulphur and uranium show big differences in content in different positions in the mire. In deep holes, and in connection with supposed groundwater outflows, the uranium content rises to 5000 ppm and sulphur to 6%. But in the ombrogene parts of the mire the uranium content is less than 10 ppm and the sulphur is less than 0.05%.

The third mire (Ralbormossen) is partly a fen and partly an ombrogene bog. Both parts are developed from a stage of the Baltic Sea with a supposed salinity of >1.5%, which is reflected in the high boron content of the peat.

The fourth mire (Björkebergsmossen) is a raised bog in southern Sweden composed of low humified sphagnum peat, partly lying directly on permeable sand and silt, and partly lying over a thin layer of low permeable carex sphagnum peat. A characteristic of this bog is that the top layer contains high Cd, Zn and As, as well as sulphur, contents to a depth of as much as two meters. The underlying strata have low metal and sulphur contents, with the exception of the very bottom layers, which is the rule for this kind of bog. It is common that many elements are enriched by a factor of 10 in the top 0.5 m in this kind of bog. The reasons can be several, for example, airborne pollution or biological regeneration, which follows the living mire plant species as the mire grows. It can also be through root uptake and capillary transport to the surface of the mire. To date, we think that this deep and strong irregularity is caused by an increase in air pollution and the special hydrological nature of this bog.

For fuel-peat production, mires with a high potential energy content are required which have good production possibilities and a sulphur and trace element content equal to that of a "good" coal. This is not always the situation, therefore, it is necessary to undertake mire studies using proper sampling and analysis procedures. To correctly interpret the results a knowledge of the local geology and the mire genesis is essential.

STREAM SEDIMENT GEOCHEMICAL ANOMALIES FOR URANIUM ON GRANITE PLUTONS WITH HIGH AND LOW ZIRCONIUM CONTENTS

C. Frick

During the routine geochemical mapping programme of the Geological Survey of South Africa, using stream sediment samples, contrasting geochemical anomalies for uranium have been observed on different granite plutons in Namaqualand, in the western Cape Province. Two granite plutons, the Kuboos granite and the Tatasberg granite in the Richtersveld area of Western Namaqualand are marked by pronounced uranium anomalies which are present in every one of the first order streams draining the granite plutons that were sampled. Towards the east, the DeBakken granite, which is much older than the Kuboos and Tatasberg granites, is marked by the absence of coherent uranium anomalies, but yields a few spot uranium anomalies which have considerably higher concentrations than any of the uranium anomalies associated with the Kuboos or Tatasberg plutons.

The mineralogy, petrology and trace element geochemistry of the two types of granite are discussed, and it is shown that the Kuboos and Tatasberg granites, with a model age of approximately 550 Ma, are fractionated granites in which Zr has become enriched in the most fractionated granite phases. The DeBakken granite on the other hand is much older, with a model age of approximately 1100 Ma. The latter granite is also a very fractionated granite, but in this case Zr is depleted in the most fractionated portions.

The regional geochemical maps for Zr, Nb, U, Ti, P and Th are discussed for the Kuboos and Tatasberg granites, and it is shown that the anomalies result from the enrichment of resistant detrital mineral phases such as monazite, apatite and zircon. An electron microprobe study shows that the uranium in these stream sediment samples is contained in zircon grains derived from the granite plutons, and that the Th is mostly present in monazite and apatite. The Nb is situated mainly in ilmenite and rutile.

An investigation of the spot anomalies along the rivers draining the DeBakken granite indicates that these anomalies are present in the immediate vicinity of nodular calcrete deposits, and that the uranium is present mainly as carnotite in the calcrete nodules. An investigation of the rock chips from water boreholes showed that the uranium in the top 27 metres of the granite has been leached relative to Th and Zr and that a slight increase in the uranium concentration at the water table level is usually present. An electron microprobe investigation of heavy mineral concentrates of the DeBakken granite shows that the uranium is mostly present as uraninite, or as a replacement in biotite. This is ascribed to the fact that the granite becomes depleted in zirconium during fractionation. It is shown that the top 27 metres of the DeBakken granite pluton have been leached since the start of the Miocene, and that the nodular calcrete has been derived from an earlier pedogenic calcrete surface which has formed on the DeBakken granite during the Pliocene and Pleistocene. The initial uranium enrichment in the calcrete resulted from the vertical leaching of the uranium and the deposition thereof in a palaeo-pedogenic calcrete. This palaeo-pedogenic calcrete weathered during the Holocene, and was redeposited to form the carnotite deposits along the streams draining the DeBakken granite.

The airborne radiometric anomalies of the two granites are shown, and from this it is also clear that granites, such as the Kuboos and Tatasberg plutons, in which the uranium is present in resistent mineral phases can easily be detected by both stream sediment sampling and radiometric mapping, but that low zirconium granites, such as the DeBakken granite cannot be detected readily by either of the techniques. Therefore a lithogeochemical approach is clearly the best technique. It is further shown, that the latter type of granites, in which the U does not substitute in zircon, are the most promising granites if exploration for "episyenitic" uranium deposits is to be carried out. Clearly, such a lithogeochemical approach has severe limitations in areas where chemical weathering is severe, or where there is a thick cover of Pleistocene tillite over the granite plutons. The longterm advantages of a lithogeochemical mapping programme using both water boreholes and core samples in this type of exploration programme is highlighted.

GEOCHEMICAL EVOLUTION OF THE RICHTERSVELD AREA, SOUTH AFRICA, AS DEDUCED FROM REGIONAL GEOCHEMICAL MAPS OF STREAM SEDIMENT SAMPLES

C. Frick and S.W. Strauss

The two degree square area, bounded by 16° and 18° W and 28° and 29° S has been mapped geochemically using stream sediment samples collected from first order streams on a 1 km sampling grid. The samples have been analysed for 20 elements, and geochemical maps on a scale of 1:250,000 have been prepared for each of the elements.

The Richtersveld area constitutes the western most part of South Africa and is bounded in the north by the Orange River which marks the boundary between South Africa and Namibia (South West Africa). The surface topography is briefly discussed, and it is shown that the western part of the area consists of sand flats which are covered by Tertiary sand and gravel. The eastern part is a mountain desert consisting of several mountain ranges with sand filled valleys. The area supports no or very little vegetation, with an annual rainfall of less than 10 mm.

The geology of the area is discussed and an account is given of the different mineralized provinces which were known before the geochemical mapping programme started. In addition, a generalized mineral occurrence map is presented to show the larger mineral prospects known from this area.

Geologically the entire area is underlain by the Vioolsdrift Suite of basement granites (1730 to 1900 Ma), in which metasediments and metavolcanics of the Orange River Group are present. The latter have been dated at 1800 Ma. In the eastern portion of the area a large basin consisting of Nama sediments (approx. 600 Ma) is present. This basin consists of sandstones of the Fish River Formation and limestone and shales of the Schwartzkalk Formation in the northern part of the sedimentary basin. A similar basin bounded by faults, and consisting of a typical graben is present in the central and eastern part of the area. The latter graben contains only sandstones belonging to the Fish River Formation. In the western portion of the area, forming the Atlantic seaboard, sediments of the Gariep Complex overlie the Vioolsdrift batholith. The sediments in this sequence, which are approximately 800 Ma, consist of quartzite, schists and highly deformed sandstones and tillites.

The western portion of the area (Gariep Complex) is separated from the eastern portion (Vioolsdrift Suite and the Orange River Group) by very prominant mountains consisting of quartzites of the Stinkfontein Formation. These quartzites were deposited in a basin on the Vioolsdrift Suite granite, and this basin is approximately 900 Ma, in contrast with the younger Nama basins.

Intrusive into the younger sediments are three large granite plutons with model ages close to 550 Ma. These plutons are the Kuboos pluton, the Tatasberg pluton, and the multi-stage Richtersveld Complex.

The coastal strip is covered by typical coastal and marine limestones and calcified sandstones which are Tertiary to Quaternary in age. These marine and beach deposits also host one of the largest diamond fields of South Africa, and currently supports four mining operations.

The geochemical maps for all 20 elements are discussed, and are correlated with the geological data. It is shown that each major geological unit can be recognized from every geochemical map and that each of the mineralized provinces can be recognized. The geochemical maps also indicate the existence of several, hitherto undiscovered mineral provinces. In addition they show that some of the mineralized provinces can be followed from known areas, beneath sedimentary basins, and to their continuations on the other side.

The geochemical maps, notably Sr, Be and Rb, allow for the chemical subdivision of the petrographically homogenous Vioolsdrift Suite, and for the recognition of fundamental differences within this large granitic batholith. The geochemical signature of the Vioolsdrift Suite, and the recognition of granitic and granodioritic phases thereof, offers the possibilty that the provenance areas for the younger sedimentary basins can be recognized. This in itself offers new exploration targets because it is clear that sediments which derive from the pegmatite belt and the tungsten province south of Vioolsdrift have the potential of containing detrital deposits of heavy minerals enriched in wolframite. The existence of a large heavy mineral accumulation in some of the younger sediments, especially in the Stinkfontein Formation, are indicated.

The geochemical maps were also used to evaluate the conceptual models currently used to explain the mineralization in specific mineral provinces in this area. For instance, it is shown that the tungsten mineralization south of Vioolsdrift is always present along the contact between the granitic phase of the Vioolsdrift Suite and the acid metavolcanics of the Haib and Hom Formations of the Orange River Group, and that these deposits only occur where the acid volcanics have been subjected to metsomatic alteration.

Examples are also shown of instances where the interpretation of specific anomalies, using one element only can be very misleading, and where a multi-element approach enables a clear distinction between valuable and incidental anomalies. For example the uranium anomalies on some of the granite plutons, which coincide with Zr, Nb, Ti etc. anomalies, are purely a function of the accumulation of heavy minerals. In contrast, the anomalies of uranium which do not coincide with any of the elements diagnostic of heavy mineral concentrations, but which coincide with elements such as a strontium and phosphorous in the Tertiary marine sediments, are indicative of uranium mineralization and merit further investigation. Similarly anomalies of uranium by itself, or associated with strontium in large pans or in Tertiary calcrete deposits may be significant and worthy of further investigation.

MULTIFRACTIONAL ANALYSES IN GEOCHEMICAL EXPLORATION FOR TIN MINERALIZATION

D.R. Gladwell and M. Hale

Stream sediment surveys play a major role in exploration for Sn mineralization. Since the principal ore mineral of Sn, cassiterite, is dispersed in drainage systems as clastic fragments, consideration of the hydrodynamic behaviour of clastic particles in a fluvial system can be valuable in subsequent data interpretation. Detailed studies of hydrodynamic behaviour of several heavy minerals have been previously used to aid the understanding of their dispersion in fluvial systems, although to date such studies have not included cassiterite. These studies suggest, by analogy, that cassiterite grains travelling along an active stream channel would tend to be more readily deposited than less dense minerals of the same grain size. This tendency would lead to relative cassiterite enrichment in some grain size fractions on the stream bed and impoverishment in others.

Multifractional analyses of stream sediment samples from two localities in the U.K. where streams drain known cassiterite mineralization demonstrate the existence of zones of cassiterite enrichment and depletion with grain size within the samples. These zones are attributed to the principal modes of sediment transport in fluvial channels and are therefore interpreted by the authors as a traction enrichment zone, saltation enrichment zone and a supension depletion zone for cassiterite.

It is clear that the degree of cassiterite enrichment in, for example, particles of about 3 phi diameter is likely to have a marked effect on the total cassiterite content of sediment samples and on subsequent data interpretation. To avoid spurious interpretation of geochemical tin data, it is essential to quantify the extent of traction, saltation and suspension transport at each stream sediment sample site (the sedimentary environment) and adjust Sn data from different sites to a common base (environmental correction).

Attempts to classify different sedimentary environments using size fraction analysis have been carried out by a number of workers. Implicit in their work is the assumption that the size distribution of the sediment is a function of, and in equilibrium with, the prevailing sedimentological conditions. Provided this is the case, it is possible to make a relative environmental correction of data by comparing the grain size distribution of the sediment as a whole with the grain size distribution of any particular heavy mineral.

The grain size distribution of the sediment was compared with the grain size distribution of cassiterite bound Sn for the stream sediment samples collected from the two localities in the U.K. (Porthtowan, Cornwall; Diebidale River, Scotland). This comparison showed that there was three basic types of relationship between the sediment and Sn. A linear relationship between sediment and tin was commonly found immediately downstream from cassiterite mineralization. This relationship suggests that the cassiterite and sediment are responding in a similar manner to the prevailing sedimentary environment, implying the presence of composite cassiterite-sediment grains. Further downstream from mineralization a sigmoidal relationship was commonly found between sediment and Sn. This relationship demonstrates the existence of discrete cassiterite grains on the stream bed which have formed traction or saltation enrichment zones within the sample. The sigmoidal cassiterite-sediment relationship was found to be typical of sedimentary environments with potential for placer cassiterite development. In the third type of relationship between sediment and cassiterite most of the Sn is concentrated in the finer fractions and there are no enrichment zones. This relationship was found to be typical of background stream sediment samples.

When dealing with a large number of samples, graphical comparison of sediment and Sn grain size distributions is too cumbersome to afford rapid appreciation and interpretation of the data. In order to obviate this problem, two coefficients were developed to conveniently summarize the relationship between sediment and Sn. These two coefficients, termed psi and gamma are high for samples showing linear and sigmoidal sediment-Sn relationships respectively.

The spatial distribution of psi values at the two localities studied demonstrate it is far superior to geochemical analysis of a single sediment size fraction for location of primary Sn mineralization. The distribution of gamma in the same field areas showed that secondary cassiterite accumulations were effectively identified by this coefficient. the coefficients appear to be largely unaffected by the gross mining contamination of drainage systems common in Cornwall or by variable distance of the stream channel from primary mineralization as observed in Scotland.

The methods of environmental correction for cassiterite in stream sediments are considered to be suitable in principal to any heavy mineral which is transported with material of substantially lower specific gravity in a fluvial system such as gold and tungsten.

GEOCHEMICAL EXPLORATION FOR TIN USING SUSPENDED SEDIMENT SAMPLE MEDIA

D.R. Gladwell and R.E. Lett

Previous investigations have shown that there is widespread depletion of tin in the fine fraction of stream sediments. This depletion may reflect the ubiquitous unavailability of fine-grained cassiterite for incorporation into the sediment or, more likely, preferential partitioning of fine-grained cassiterite into the suspended washload of drainage systems. Despite the importance of suspended load relative to the total material transported by streams, analysis of suspended sediments for metals (including tin) has not been widely used in geochemical exploration. Results of orientation studies in Canada and England to investigate the feasibility of suspended sediment analysis for cassiterite in geochemical exploration for tin deposits are described in this paper. Study areas in Cornwall, England; southern Nova Scotia and central British Columbia were selected in order to compare tin dispersion in the suspended stream sediment load under contrasting secondary environments.

In each area, suspended sediment was recovered from stream water by filtering a volume of the water and the filtrate analyzed for cassiterite tin by an ammonium iodide attack - volatile hydride atomic absorption spectrophotometric technique. Conventional stream sediments were also collected to compare the partitioning of tin between the two sample media. In southwest Cornwall, analysis of conventional sediments from streams draining mineralized areas indicated dispersion trains were normally very short whereas anomalous cassiterite tin levels (greater than 12.6 ppb per litre Sn) in suspended sediments could be detected up to 10 km from known tin deposits.

Suspended sediments recovered from a stream draining the east Kemptville deposit in Nova Scotia contained 32.6 ppt per litre cassiterite tin compared to levels in background streams of less than 10 ppt per litre. Anomalous tin values were also detected in the suspended sediment from several streams in an area roughly 15 km east of the deposit where no tin occurrences are known although high bedrock tin levels were found in the area by this study.

Anomalous cassiterite tin values were also detected in streams draining base metal occurrences reported to contain stannite in the Sandon area of British Columbia. These data clearly show that tin anomaly contrast and persistance is increased using a suspended sediment sample medium. The application of this method to exploration for tungsten and precious metal deposits will also be discussed.

THE BEAVER-TEMISKAMING SILVER SULPHARSENIDE VEIN DEPOSITS, COBALT: VEIN AND HOST ROCK GEOCHEMISTRY WITH APPLICATIONS TO EXPLORATION

M.D. Goodz, I.R. Jonasson, D.H. Watkinson and D.M. Kingston

Assessment of geochemical and mineralogical data derived from studies of vein silver deposits of the Beaver-Temiskaming mine, Cobalt, Ontario, has defined more areally extensive exploration targets. Silver veins in the Cobalt area have a complex Co-Ni-Fe sulpharsenide mineral assemblage. These veins are commonly surrounded by, and sometimes terminate in, sulphide-rich stratiform units, regardless of whether the host was Archean volcanic or Proterozoic sedimentary rocks. Sulpharsenide veins in the Nipissing diabase also grade into sulphide assemblages. The Beaver-Temiskaming silver-sulpharsenide veins, hosted by Archean volcanic and interflow sedimentary rocks, are <50 m from (and commonly adjacent to) sulphide-bearing units; the sulphides are both syngenetic with the host volcanic rock and epigenetic (silver vein-related).

Vein-related metal enrichment of the wallrocks defines a somewhat symmetrical halo about the veins, which is 2-3 orders of magnitude wider than the vein. Mineral zoning is observed both along the veins and perpendicular to them. Parallel to the vein walls galena and sphalerite are dominant; laterally outward into the host rocks, the dominant sulphides are sphalerite + chalcopyrite, then chalcopyrite + pyrrhotite and finally pyrrhotite + pyrite. Longitudinal zoning is apparent as middle parts of veins contain a Co-As (skutterudite-safflorite-cobaltite) assemblage, and outer parts a Co-Ni-As (safflorite-nickeline-cobaltite) assemblage grading into a Ni-As (nickeline-rammelsbergite-gersdorffite) assemblage at vein intersections.

Silver, present as native metal, Ag-Sb-Hg alloys and Cu-Ag sulphosalts, is highest grade where the Co-As and Co-Ni-As assemblages are dominant; Fe-rich, arsenide-poor assemblages are comparative Ag-poor. Sb/Bi ratios (0.4 - >14) increase with the grade of silver and Sb contents provide a useful indicator for Cu-Ag sulphosalt assemblage. Whole rock analyses of Archean volcanic wallrocks, define an enrichment halo of Co, As, Ni, Fe and Ag, peripheral to the silver veins. Sulphur isotope studies show that syngenetic basement sulphides have a mean ^{34}s value of +4.0 per mil, while epigenetic silver vein-related sulphides are lighter, at +2.3 per mil; isotopic compositions are related to distance from the vein.

These mineralogical and geochemical trends in the rocks which contain veins, may be used to indicate the proximity to silver-sulpharsenide veins and to define mineral assemblages of highest grade silver ore.

ELECTROGEOCHEMICAL PATTERNS IN SURFACE SOILS: DETECTION OF BLIND MINERALIZATION BENEATH EXOTIC COVER, THALANGA, QUEENSLAND, AUSTRALIA

G.J.S. Govett and P.R. Atherden

Data from Elura and Mt. Bulga in New South Wales by Govett et al., (1984), showed that electrogeochemical techniques on surface soils could be used, under Australian conditions of very thick and conductive overburden to detect massive sulphide deposits. The overburden at Elura and Mt. Bulga is essentially residual, and a test case was sought to determine whether the techniques would work under the far more difficult conditions of transported overburden. The Thalanga stratiform massive sulphide deposit was selected because mineralization ranges from a gossan outcrop to being covered by 70 m of transported overburden, geochemical exploration has been largely by deep auger and RAB drilling; in this study samples were taken within a few cm of the surface.

The Thalanga deposit has about 4 million tonnes of 15% combined Zn+Cu+Pb. The main sulphide lens (about 6 m wide) lies at, or close to, a contact between rhyolitic and dacitic volcanic assemblages of Cambro-Ordovician age. The footwall rhyolitic sequence has alteration zones of silicification, sericitization and pyritization. The rocks are regionally metamorphosed to the lower greenschist facies. The main ore lens has a surface expression as a gossan about 6 m wide over a strike length of 550 m. Beyond the gossan to the east and west, mineralization is covered by a variable thickness (up to 70 m) of cemented terrigenous clayey sandstones and grits of the Tertiary Campaspe beds. These beds are highly conductive with saline pore water. A partly eroded laterite profile exists over much of the area.

Geochemical soil samples were collected at intervals of 12.5 and 50 m at a depth of 2 to 5 cm along 5 N-S traverses. Each traverse was 1 km long. Only one line crosses exposed mineralization; the Campaspe Beds vary from less than 1 m thick to about 70 m thick along the other lines.

Characteristic 'rabbit-ear' anomalies of H^+ occur over the massive sulphides. The width of the anomaly ranges from 250 m where the campaspe beds are thin or absent, to 400 m where they are 50 m thick. The patterns are better defined where there is a significant thickness of the Campaspe beds.

HNO_3^- and EDTA-soluble Cu and Zn show a very pronounced 'rabbit-ear' anomalies. The total width of the Cu anomaly is 400-500 m and the Zn anomaly is 250-550 m wide. The lateral peak over the stratigraphic hanging wall for both Cu and Zn is generally markedly higher than the lateral peak over the stratigraphic footwall.

The pattern of the distribution of H^+, Cu and Zn is explainable by electrochemical processes. Return ionic current must be channelled along the base of the highly conductive Campaspe beds, and therefore upward movement of ions by electrochemical means is not likely. Mobile ions will accumulate lateral to the sulphide at the base of the Campaspe beds and the mechanism of transport to the surface must be presumed to be diffusion.

It is argued that the results of this work conclusively demonstrate that surface soil samples may be used reliably to detect massive sulphide deposits even where they are effectively blind beneath a considerable thickness of transported and conductive overburden.

AUTOMATED XRF SPECTROMETRIC ANALYSIS: A RAPID, COST EFFECTIVE ANALYTICAL TECHNIQUE FOR THE MINERAL INDUSTRY

P.K. Harvey and B.P. Atkin

X-ray fluorescence spectrometry is a well established analytical technique which has for many years been capable of producing reliable high precision geochemical data. It is, however, only with recent developments in instrumentation and computer technology that the speed of analysis has been increased to a point where the technique has become cost effective for use in geochemical exploration. Modern instruments are often equipped with relatively powerful mini-computers which, in addition to XRF processing tasks, can be used for geochemical data processing immediately analysis is complete. This contribution is intended to show how such precise low cost analysis can be achieved.

Sequential wavelength dispersive spectrometers are capable of determining most elements from atomic number nine (F) upwards over an elemental range of a few parts per million, or less, up to 100%. The detection limit generally increases as the atomic number deceases. Developments in instrumentation in recent years have included temperature stabilisation, the use of micro-electronic circuitry and all around improvements in the components which make up the X-ray path through the goniometer (collimators, counters and analysing crystals all deserving special mention). The combined effect of these improvements has been to produce more stable instrumentation, significantly higher count-rates and greatly improved spectral resolution compared with spectrometers only a few years older. In addition, improvements in the microprocessor control of spectrometers has increased the versatility and in turn the speed at which the instruments can be operated. Probably the most significant development, however, to the geochemist, is the availability of a high power (3 kW) rhodium anode X-ray tube. The latter can be used to determine almost all the elements of geological interest (Ag, Cd and In are exceptions), minimising the need to change X-ray tubes, a relatively slow procedure.

It should be noted that the low detection limits, high precisions and range of elements discussed here cannot readily be obtained on simultaneous XRF spectrometers (because of the usual lack of background measurements and basically fixed geometry) or on energy dispersive XRF spectrometers (because of relatively poor precision).

In XRF analysis elemental concentrations are normally determined by measuring the count-rate of a spectral peak together with one or two background positions. The precision of the measurements and therefore the detection limit of the element are a direct function of the counting time used. In this way the count times, which vary upwards from two seconds, can be chosen to achieve any reasonable precision and therefore detection limit for an individual element. For multi-element analysis longer and shorter count times (i.e., high and low precisions) are easily mixed to provide a level of versatility that is difficult to achieve by almost any other analytical method. In our laboratories the count-times employed in a typical measurement program are designed to give analytical precisions for trace elements of ±10% at the 100 ppm level and allow some 20,000 element determinations to be made per week.

For most applications related to geochemical exploration sample preparation can be rapid, requiring only the preparation of a pressed disc of the sample from finely ground material. The procedure used in our laboratories requires no weighing, thus eliminating weighing errors, and one operator in a commercial laboratory could prepare about 150 samples a day. The pressed discs are not damaged during analysis and are easily stored for future use and reanalysis for other elements. Unlike virtually all other analytical techniques the quantity of material actually analysed depends upon the wavelength of the measured X-ray line. Sample weights normally vary from about 8 grams to less than 1 gram at the longer wavelengths.

One of the most powerful features of automated XRF spectrometry is the ease with which quality control can be maintained. It is normal practice, particularly where trace and minor element analysis are involved to ratio count-rates against a monitor sample which is retained in the spectrometer at all times. This monitor sample is measured periodically during the analysis of a batch of samples. In addition, samples of 'known' composition (standards), ideally of similar composition to the 'unknown' samples, should be run with each analytical batch. A typical analysis batch hence consists of measurements on 'unknowns' and 'standards' with monitor data dispersed periodically. Given data for the analytical batch the following quality control procedures are normally carried out:

1. Check on 'within batch' drift using the variation in the monitor throughout the run; very rarely significant with modern instruments.

2. Check on the instrument itself by comparing the monitor count rates with reference count-rates for the monitor held on computer file.

3. Check of instrumental precision by comparing 'between monitor' variation for all monitors run during the batch.

4. Check on 'accuracy' by comparing the values obtained on the standards (as 'unknowns) against their 'recommended' or 'certified' values which are held on a reference file. The same test is, of course, a check on the instrumental calibration.

In addition, because of the non-destructive nature of the technique the same standard samples can be used for consecutive batches of unknowns; in this way long term consistency can be maintained between batches in an on-going project. With appropriate software the whole quality control procedure may be done automatically; semi-automatically so that each stage may be monitored by trained geochemists, thus minimizing the possibility of erroneous data due to unexpected sample compositions etc. not being detected.

One of the main problems in establishing an efficient analytical system has concerned the availability of suitable software. A good computer system should a) be able to minimise the time during which a spectrometer is not analysing; b) be capable of handling a wide range of correction procedures; c) be able to perform all laboratory management tasks (record keeping, report generation, etc.) and d) prepare data files for further processing and transfer to other computer compatible media. Software available from instrument manufacturers is, at present, generally unsuitable and it has been necessary to develop a completely independent software system to perform the tasks outlined above. The latter will be described in some detail as it raises a number of issues (quality control, laboratory planning and efficiency) that cannot be solved by simply purchasing the right equipment.

The whole analytical procedure will be discussed in terms of a specific exploration example concerning the search for gold, using pathfinder elements, in Scotland, with particular reference to the commercial costs and turn-around times involved.

PYRITE OF DISTINCTIVE ISOTOPIC COMPOSITION ASSOCIATED WITH THE HEMLO GOLD MINERALIZATION

K. Hattori and E.M. Cameron

Most sulphide of Archean age, whether of igneous or sedimentary origin, has sulphur isotopic compositions ($\delta^{34}S$) close to $0^{o}/oo$. This is because during the Archean there was a lack of sulphate and the oxidation-reduction processes of sulphur that are required for isotopic fractionation. A notable exception is found in certain gold deposits of hydrothermal origin, that contain sulphate and sulphide minerals, both of which show variations in sulphur isotopic composition. Among these is the Hemlo gold deposit, near Marathon, Ontario.

The Hemlo deposit has current reserves of $\geq$80 million tons with average grade of 0.23 oz/ton Au. It occurs within the Archean Heron Bay group, which consists of mafic to felsic metavolcanic rocks and metasedimentary rocks. The mineralization is stratiform to the host rocks and occurs near the interfingering boundary between volcaniclastic and epiclastic sedimentary facies.

The basal part of the main ore zone is formed of massive barite, which overlies muscovite schist. This is the first recorded occurrence of stratiform barite in the Archean of North America. The ore zone is rich in pyrite and muscovite.

The deposit is metamorphosed and has been deformed by shearing. This has led to debate about the origin of the mineralization, whether it is syngenetic or epigenetic. Features that suggest synsedimentary origin are: the stratiform nature of the ore; low $^{87}Sr/^{86}Sr$ values for sulphate minerals, consistent with formation approximately contemporaneously with the host rocks; asymmetrical mineralogical, chemical and isotopic distributions in stratigraphic sections across the deposit; intense hydrothermal alteration in the footwall rocks; and stratiform barite of similar isotopic composition intercalated in less deformed metasedimentary rocks approximately on strike from the deposit.

Pyrite of very distinctive isotopic composition, depleted in ^{34}S to a minimum $\delta^{34}S$ of -17.5 ^{o}/oo, occurs throughout the deposit. The grade of gold is not correlated with the pyrite content, but is strongly correlated with the isotopic composition of the sulphide; the higher grades being in strata that contain pyrite most strongly depleted in ^{34}S. Beds of barren pyrite and pyritic graphitic shale have $\delta^{34}S$ values close to 0^{o}/oo.

Low sulphur isotopic values for pyrite from the Hemlo deposit can be explained by isotopic exchange between sulphide and sulphate in the hydrothermal system that produced the gold mineralization. The gold was likely carried as a gold-sulphur complex, with its transportation and precipitation controlled by the oxidation conditions of the system. Pyrite of this distinctive isotopic composition is thus indicative of hydrothermal systems suitable for the migration and precipitation of gold.

The possible use of isotopic data for pyrite in mineral exploration will depend on not only the distinctiveness of the values but also on it having a wider spatial distribution than the gold. We have identified strongly ^{34}S-depleted pyrite in baritic strata that are at approximately the same stratigraphic horizon as the deposit 21 to 27 km west of Hemlo. We have also identified similar pyrite with the gold mineralization at the recently discovered occurrence of Lytton Minerals Ltd. at Heron Bay, 30 km west of Hemlo.

FLUID INCLUSION CHEMISTRY IN THE EXPLORATION FOR MISSISSIPPI VALLEY-TYPE DEPOSITS: AN EXAMPLE FROM EAST TENNESSEE

F.M. Haynes and S.E. Kesler

SEM energy dispersive analyses of fluid inclusion decrepitates in sphalerite and dolomite from the Mascot-Jefferson City Mississippi Valley-type district of East Tennessee reveal a marked increase in the Ca/Na ratio of fluids associated with ore. These high Ca contents have been interpreted as being the result of limestone dissolution at or near the site of mineralization caused by the acid-producing, sulfide depositing reaction ($ZnCl_2 + H_2S = ZnS + 2HCl$). The exploration potential of this variation in fluid inclusion chemistry was evaluated by analyzing fluid inclusion decrepitates from white sparry dolomite along a 500 m traverse in the New Market Mine. The traverse extends from the central portion of a large domal collapse-breccia orebody with >3% Zn, into the dolomite-veined but unmineralized Knox Group limestone. Dolomite stratigraphy (revealed by cathodoluminescence) was used to distinguish contemporaneous dolomite zones and only decrepitates from similar zones were compared.

$CaCl_2/NaCl$ ratios as high as 1.2 were common in dolomite-hosted decrepitates from the high-grade collapse ore, and low grade (<1.0% Zn) portions within the collapse zone also contained Ca-rich decrepitates. This anomalous decrepitate chemistry was not observed in gangue dolomite outside the ore zone; dolomite gangue less than 50 m from the "limestone edge" yielded background $CaCl_2/NaCl$ ratios (0.2 to 0.5). Although the data from this traverse indicate that anomalies in decrepitate chemistry are too local to be of use in regional exploration, the method could prove useful in evaluting the potential of areas adjacent to drilled intercepts containing marginal (0.5 to 1.5% Zn) mineralization.

THE APPLICATION OF LOW-COST MULTI-ELEMENT DATA BY NEUTRON ACTIVATION ANALYSIS SUITABLE FOR EXPLORATION GEOCHEMICAL TECHNIQUES

E.L. Hoffman and A. Pidruczny

A multielement analytical package utilizing neutron activation analysis is described. This package contains up to 50 elements, which can be determined using both long and short-lived isotopes and prompt gamma analysis. The automated data collection and analysis routines used are also described.

The application of INAA multielement analysis data is discussed with particular reference to heavy mineral concentrates obtained from stream sediments and overburden drilling. The use of vegetation with respect to biogeochemical exploration for gold deposits is also discussed. The multielement approach to gold exploration using neutron activation analytical techniques has proven to be very cost effective.

Heavy mineral concentrates

Prospecting for gold using overburden drilling techniques, either reverse circulation or sonic drilling, is generally very expensive. The heavy mineral concentrates prepared from the overburden samples are also relatively expensive to obtain. In many cases all that is available are a few grams of material. A technique is described whereby all of the heavy mineral concentrate obtained can have gold and other elements determined by INAA simultaneously without the requirement of grinding the sample. This is important, because in milling the sample it is possible to loose gold which plates out on the mill. INAA is non-destructive and the sample can be examined after analysis to determine the mineralogical character of the concentrate, shape and particle size of the gold. Routine chemical techniques for gold determination usually require that a fire assay be performed on the milled sample. There is potential gold loss inherent in this procedure. To be representative the whole sample usually must be analysed, precludes the determination of other elements by other techniques.

Vegetation and humus sampling

The root structures of trees have the remarkable ability to dissolve gold and absorb the cyanogenic or humic complexes of gold and other elements. These elements are usually transported up the trees to the leaves or needles. The tree acts as an effective drilling and sampling medium, sampling an area defined by the root structure of the tree. This may be more effective than a point source soil sample due to the inhomogeneous dispersion of gold. One reason for the lack of use of this technique has centered on the inability of chemical techniques to analyze these materials because of the very low sensitivity required. Ashing should be avoided unless one can be sure that there will be no losses of gold. Documentation in the literature shows ashing losses to be a serious potential problem. The INAA technique is relatively simple vegetation is ground in a Wyllie Mill and 8 g are briquetted and irradiated. A multielement analysis can be rapidly obtained at low cost with the sensitivity for gold at 0.1 ppb or better on most materials. Because of the simplicity of the technique the chance of contamination is much lower than with chemical techniques. This is important because significant anomalies are usually only a few ppb. Various types of sample media are discussed as well as examples given of actual metal concentrations and background levels associated with a gold showing.

LITHOGEOCHEMISTRY APPLIED TO THE MILLSTREAM POTASH DEPOSIT,NEW BRUNSWICK, CANADA

S.J. Hoffman, K.S. Crosby and J.A. Irvine

The Millstream Basin is one of the three structural satellite basins of the northeasterly trending Moncton sub-basin of New Bruswick, Canada, known to contain high order sodium and potassium salts of the Mississippian Windsor group. The Millstream Potash deposit, of BP Resources Canada Limited, contains several layers of high grade potash within an evaporite sequence which is locally conformably to unconformably and disconformably overlain by non-marine deltaic and alluvial sediments. Intense regional compression and tilting produced broad, open folds, reverse and normal faults, and local salt tectonics comprising salt flowage, slumpage, fracturing and secondary potash recrystallization. Interpretation of stratigraphy within the deposit presented a formidable task, and in view of the importance of unravelling stratigraphic relationships prior to economic evaluation of the deposit, geochemical investigations were initiated to provide an independent evaluation of local stratigraphy.

Lithogeochemical studies were undertaken by analyzing regularly-spaced cut samples of drill core for a suite of 30 water soluble elements using an inductively coupled plasma (ICP) system. The same elements were determined following an aqua regia digestion of the insoluble residue. No element in either fraction was able to uniquely fingerprint a particular horizon but multielement combinations were able to characterize distinctive sublithologies within sylvinite, halite and carnallitite sections.

Geochemically, sylvinites fall into four major groups which correspond to the geological horizons SI, SIIA, SIII, and SIV. Sylvinites SI and SIIA are very clearly differentiated because sylvinite SI contains only about half the trace element content of sylvinite SIIA. The contrast in iron content is particularly noteworthy, as sylvinite SI contains only 1/3 the average concentration of sylvinite SIIA. SIIA is also noticeably richer in soluble potassium than SI.

The transition between SI and SIIA is marked by a significant decrease in background concentrations of aluminum and magnesium in the residue fraction; from 0.44% to 0.22%, and from 0.6% to 0.3%, respectively. These distributions may indicate destabilization of magnesium-aluminum clays in the presence of high soluble potassium contents. The end of SIIA deposition is marked by the appearance of carnallite and a significant reduction in the residue-contained potassium, from the 0.04% to the 0.005% level. The change may reflect destabilization of potassium-bearing clays by high soluble magnesium contents.

Each sylvinite intersection is unique. For example, a 10X difference in boron content of the residue fraction distinguishes SIII from SIV. Boron and strontium in water soluble form, and lead, barium, manganese, and cobalt in the residue also exceed a 50% average difference from SIII and SIV.

Lowermost sylvinite occurrences in all holes are accompanied by relatively low contents of clastics and the initial appearance of an insoluble boron mineral boracite. Soluble potassium background increases from 0.1% to 0.2% to 0.3%. Basin history is marked locally by periods of fresh water introduction accompanied by a high clastic content. This arrests sylvinite deposition and reduces soluble potassium and residue boron contents almost to pre-sylvinite levels.

Carnallitites overly SIIA. Some similarities are evident amongst carnallitite units from each hole, however, differences are also common. Carnallitite composition can appear transitional to adjacent sylvinite. A major subdivision of one carnallitite section can be suggested by its metal-poor character overlain by a metal-rich section. This unit may represent an altered carnallitite partly transformed into a secondary sylvinite. A similar genetic model has been proposed for SI throughout the basin because of its relatively high magnesium content in both water soluble and insoluble forms.

AN ALTERNATE APPROACH TO SAMPLING PROBLEMS IN EXPLORATION FOR GOLD

M. Ikramuddin

Recently several workers have pointed out the natural inhomogeneous occurrence of gold in geologic materials and the problems associated with sampling in exploration for the precious metal. In order to obtain a truly representative value of Au in a rock, it is necessary to collect a large sample (about 20 lbs.) and use special sample preparation methods. An alternate approach of utilizing K/Tl ratios is presented, which is simple and provides more meaningful information for exploration purposes.

In order to determine the variations in concentration of Au with sample size, background and mineralized samples of volcanic, alkaline and sedimentary rocks were analyzed for Au, K and Tl. In each case, a 10-20 lb. sample was divided into 10 sub-samples of 1-2 lbs., which were crushed, pulverized and analyzed for Au, K and Tl. The variations in the concentrations of Au, K and Tl in the background samples were found to be negligible. The 10 splits of mineralized samples of volcanic, alkaline and sedimentary rocks showed a wide variation in the concentrations of Au, but the K/Tl ratios in each set of splits remained almost constant, suggesting that the K/Tl ratio is insensitive to changes in sample size.

Geochemical data, obtained on several gold deposits from the western United States, also suggests that the rocks associated with gold mineralization cannot be partitioned successfully into background and anomalous populations on the basis of the abundances of Au alone. To separate background rocks from mineralized rocks, it may be necessary to either, make a thorough petrographic study, or take extra care in collection and preparation of samples for analysis. On the other hand, the K/Tl ratio is found to be very useful in partitioning the data into different populations without giving consideration to the factors mentioned above.

The present study suggests that meaningful data can be obtained for exploration of gold, even with collection of small size samples, if K/Tl ratios are used as an exploration tool. In the initial stage, all samples should be analysed for Au, K and Tl. The hydrothermally altered and mineralized rocks normally show high concentrations of Tl and low K/Tl ratios compared to background rocks. Once a potential area is located with low K/Tl ratios (or preferably with low K/Tl ratios and gold values of greater than 10 ppb), this area can be revisited, larger samples collected and analyzed for Au with special sample preparation methods. The use of K/Tl ratio, as an alternate approach to the Au sampling problem, may prove to be even more useful in the case of soils and stream sediments.

ROCK GEOCHEMICAL EXPLORATION FOR TIN-TUNGSTEN MINERALIZATION IN THE TIBCHI AND KALERI GRANITE COMPLEXES, NIGERIA

E.G. Imeokparia

The Tibchi and Kaleri Complexes form part of the known Younger Granite Complexes of northern Nigeria. Lithologically they are both composed of peralkaline, metaluminous and peraluminous granites. Mineralization in the two complexes is confined dominantly to the peraluminous (biotite granite) phase and occurs as magmatic disseminations and greisen lodes and veins. In the Tibchi Complex Sn-W and sulphides of Zn and Cu occur in a series of braided quartz-rich greisen veins formed along joints and fractures coalesing to form what is known as the Kogo lode which is about 1.5 km long. In the Kaleri Complex mineralization occurs dominantly as magmatic disseminations and in dispersed greisen veins without alteration haloes in a multiphase peraluminous (biotite) granite. No lode mineralization is associated with the Kaleri Complex.

The localization of Sn-W mineralization along fracture zones in the Tibchi Complex suggests that the rapid unroofing of the pluton following its emplacement produed dilatancy and shear fractures which acted as channel ways for mineralizing fluids which were probably internally generated.

Geochemical studies show that in the Tibchi Complex, the peraluminous biotite granite (in which mineralization is localized), is characterized by strong enrichments in Sn, W, F, Li, Rb, Th, Y, Zn and depletions in Sr, Ba and Zr. This enrichment and depletion factor increases in the vicinity of the lode system.

Trace element concentrations in this granite show enrichment or depletion over the limits set by Tischendorf (1976) for metallogenetically specialized granites. In the Kaleri Complex, however, where multiple-phases of biotite granite occur, the above geochemical enrichment observed in the Tibchi biotite granite is not shared by all the biotite granite phases. Results indicate that some of the phases can be distinguished as tin-bearing while others are barren, or have limited ore-bearing potential.

Although this distinction can be made successfully using certain covariance element relationships (e.g. Ba/Rb, Zr/Rb), it is shown that applying discriminant analyses to the analytical data guarantees 100% success in separating the barren and the ore-bearing groups. However, from the results of the discriminant analysis, the following elements, Sn, Nb, Li, Rb, Ba, Th and Y, were found to be most useful in distinguishing the ore-bearing granites from the barren granites. It is therefore recommended that discriminant analysis should be utilized during the orientation survey stage of a rock geochemical exploration program. This allows an optimum set of pathfinder elements to be chosen from the multi element analyses carried out on a relatively small sample populations thereby avoiding the subsequent analyses of hundreds or thousands of rock samples for variables that prove to be ineffective in defining geochemically anomalous rocks.

RELATIONSHIP BETWEEN Sn MINERALIZATION AND GEOCHEMICAL ANOMALIES IN NON-RESIDUAL OVERBURDEN IN THE TEBRONG AREA, BELITUNG, INDONESIA

S. Johari

The Southeast Asia Tin Research and Development Centre (SEATRAD C) initiated a project to study the relationship between Sn mineralization and geochemical anomalies in non-residual overburden at and around Tebrong in the Lenggang district of eastern Belitung, Indonesia. Belitung, which is one of the Indonesian tin islands, is located by 400 km north-northeast of Jakarta with a land surface area of about 5,000 km^2. The island forms the easternmost expression of the Southeast Asian tinbelt. The study area lies within the latitudes 2°N and 5°S and longitudes 107°E and 109°E.

There is essentially no outcrop, only minor scattered float in the study area. Drainage is very poorly developed and consists of several small creeks. The climate is tropical with a mean daily maximum temperature of 33°C and an average annual rainfall of about 2,000 mm. The watertable is at approximately 5 m depth depending on seasonal rainfall and local elevation.

The oldest rock sequence in the study area is a Triassic metasediment consisting of sandstone, phyllite, claystone, mudstone and quartzite. This sequence is intruded by a Trias-Cretaceous granitic pluton. The Tebrong area is underlain by low grade mineralization (<0.1% Sn) consisting of swarms of <0.5 cm thick subvertical quartz-tourmaline-kaolinite-chlorite-cassiterite veins. In general, cassiterite occurs in quartz veins as fracture fillings in the country rocks mainly sandstone. These rocks are unconformably overlain by quartenary alluvium carrying cassiterite (kaksa). Residual lag kaksa typically occurs on Belitung.

The soil is mostly transported material in the central part of the study area where there is a thick alluvial cover. Surface geochemical anomalies are absent but near bedrock, weak anomalies can delineate the stanniferous.

Based on the findings of the initial survey it can be concluded that distribution of Sn in non-residual overburden does not reflect bedrock Sn distribution. However, geochemical soil profiling, using a motorised auger, can be usefully employed to delineate target areas for further exploration for placer tin.

RELATIONSHIP BETWEEN GLACIAL HISTORY AND DRIFT COMPOSITION

R.A. Klassen

Glacial history and drift composition have been studied in central Labrador and in the area of Baker Lake, District of Keewatin, by the Geological Survey of Canada as a basis for developing techniques of drift prospecting. Sampling was designed to establish a framework within which glacial dispersal trains at regional (hundreds of kilometres), local (tens of kilometres) and detailed (kilometres to hundreds of metres) scales could be recognized by geochemical analyses of the clay-size (<0.002 mm) fraction of till (Cu, Pb, Zn, Ni, Cr, U, Mn, Fe) and lithologic analysis of the pebble-size (4-6 mm) fraction.

In central Labrador, two major independent dispersal centres that were distinct in age and geographic location controlled the dispersal of debris in the area between western Quebec and the Labrador coast. Striae recording flow from the two centres can differ in orientation by more than 90° on a single outcrop. Regional-scale patterns of dispersal can be recognized by the distribution of iron formation derived from the Labrador Trough and of arkosic sandstone likely derived from the Seal Group. Both types of erratics are widespread, and are known in glacial deposits as far east as the coast, over 200 km from their source areas. Glacial dispersal patterns in the Labrador interior reflect eastward to southeastward transport directions of the last prominent phase of ice flow, although rare clasts are known that must have been initially transported during earlier northeastward flow. Near the coast, drift composition is the product of both phases of flow. Consequently, the proportions of debris eroded and transported during each phase of flow markedly vary across central Labrador. Some debris has undoubtedly been transported during both phases.

In the Baker Lake area, preferential erosion of relatively soft sandstone has created a local-scale dispersal train characterized by abundant (40%) sandstone debris and by relatively low trace metal content. The train extends down-ice over fifty kilometres, well beyond the bedrock source, masking the geochemical expression of comparatively metal-rich crystalline bedrock that it overlaps.

Results of drift composition research indicate that; 1) the transport history of indicator erratics can be complex, related to shifts in the location of dispersal centres within the Laurentide Ice Sheet, 2) far-travelled (>50 km) debris can form a significant component of glacial deposits, 3) Bedrock that is easily eroded and that has distinctive geochemical character can produce regional and local scale trains that dominate the composition and geochemical character of drift and can significantly mask the expression of smaller-scale trains developed within them.

GEOCHEMICAL EXPLORATION FOR MINERAL DEPOSITS USING A NEW INTERGRATIVE GAS TECHNIQUE AND PATTERN RECOGNITION

R.W. Klusman, R.E. Bisque, K.J. Voorhees and D.N. Bloom

Geochemical techniques using volatiles are being used to an increasing degree in exploration for concealed mineral deposits. Most of the deposits with obvious surface expressions have been found by conventional methods. Gas techniques can be subdivided into measurements of free soil gas or gases adsorbed on soil materials. The free soil gas measurements can be instantaneous, or integrative where the collection period is over a period of days or weeks.

Data for three gases from a long-term experiment in a background area demonstrate meteorological and seasonal variations. Considerable portions of this variance can be accounted for by meteorological variables, with the proportion being a direct function of the period of sample collection.

This information was used to develop an integrative gas collection/analysis system for hydrocarbons and other volatiles (K-V technique). The volatiles are collected by an adsorbent on a ferromagnetic wire. The wire is transported to the laboratory in a sealed tube, thermally desorbed, and analyzed by mass spectrometry. The methods are currently being applied to petroleum, mineral and geothermal exploration and selected environmental problems. The flux data are interpreted with the aid of pattern recognition. A group of samples collected at the location of known mineralization is used to develop a geochemical model. The survey samples are then quantitatively compared to this model, and mapped for interpretation and synthesis with other data.

A small group of samples collected over a surface exposed epithermal gold deposit, the El Plomo ore body in south central Colorado, showed distinct separation when interpreted with the aid of cluster analysis. Visual differences occur in the mass spectra, but quantification of these differences is difficult without pattern recognition.

The intergrative method allows collection of species which are not normally gaseous, but have a finite vapor pressure at ambient temperatures. These higher molecular weight species are normally observed only over high permeability zones such as faults fracture and vein systems. Mass spectra of soil gasses from an exposed vein with Tertiary age gold mineralization from Colorado demonstrate the presence of high molecular weight species. Individual compounds, or classes of compounds, demonstrate the presence of the vein by either an increase in the flux over the vein or an increase on either side in the form of a halo. Halo features are difficult to interpret because these may not be a definitive indication of whether a sample location with low flux is inside, or outside the halo.

Two small vein-type gold deposits in the Canadian Shield were used to develop a geochemical model of the volatile emanations from this type of deposit. A nearby area having a continuous cover of 40-70 feet of glacial till and several buried conductors was evaluated using the K-V technique. One of the conductors had been drilled and gold mineralization intersected. A line of K-V collectors placed perpendicular to the structure was used to characterize the emanations. The calculation of a similarity value from the geochemical model of the known gold occurrences allowed the precise determination of the location of the mineralized subcrop from the surface. Use of volatile flux alone would have directed exploration to the north of the mineralization.

Active hydrothermal systems have been evaluated at Long Valley, California, and in Japan using the K-V technique. Geochemical models were developed for deep thermal sources and successfully used to map emanations in the surrounding area. Models developed around active hot springs are not useful in exploring for deeper sources.

TILL EXPLORATION FOR RARE EARTH MINERALS AT BASTNAS, CENTRAL SWEDEN: ANOMALY FOLLOW UP USING A MOBILE ENERGY-DISPERSIVE XRF

U. Kramer, H. Simianer and H. Puchelt

The rare earth elements are of high economic importance. Their major applications are in metallurgy (34%), glass and ceramics (31%) and for catalysts (35%). The worldwide implementation of exhaust gas catalytic converters in cars will lead to an increase in rare earth metal consumption.

As a part of investigations concerning the genesis of the rare earth (REE)-mineralizations at the Bastnas deposit a geochemical till survey has been carried out in order to detect further REE-mineralization. The Bastnas deposit (Riddarhyttan district) is situated in the Skinnskatteberg region in the province of Vastmansland, about 150 km WNW of Stockholm. The oldest rocks in the Riddarhyttan district are leptites, mica-schists, and limestones of Precambrian age. The younger rocks consist of more or less gneissic granites and diabase dykes. The limestones of the leptite series are often replaced by skarns accompanied by different types of Fe-ores, complex sulphides and small occurrences of REE-mineralization. The Bastnas REE-mineralization is a part of a striking NNW iron ore 'belt'.

To enable anomaly follow-up a mobile computerized tube excited energy-dispersive X-ray (EDXRF) laboratory was set up close to the Bastnas deposit.

With regard to the direction of ice movement in the last glaciation period (NNE to SSW) a set of some 150 training samples had been taken from south and west of the Bastnas deposit in order to test sampling conditions and to determine the useful indicator elements. The samples were collected using an earth auger from a depth of 60-90 cm below surface.

The samples were dried at 60°C, sieved to -80 mesh (<177 µm) and analyzed by EDXRF for Mn, Fe, Ni, Cu, Zn, Ga, As, Br, Rb, Sr, Y, Zr, Nb, W, Bi, Pb and Th. Of these elements Cu and Y gave distinct anomalies. Additionally, Ba, La and Ce were analyzed and La and Ce also exhibited anomalies related to the mineralization. The best contrast between background and anomaly was observed for La and Ce. Consequently the conditions for analyses were adjusted for the simultaneous determination of Cu, Y, La and Ce.

The study area extended 200 m south of Bastnas, 2000 m to the north and 2000 m to the west. In total some 600 samples were collected and analyzed immediately in the field. The localities of about 200 of these samples were chosen on the basis of the previous results. Strong Cu, Y, La and Ce anomalies were found south of the known Bastnas deposit. An additional traverse proved the connection between this strong anomaly and a weak anomaly in the south. Further strong anomalies were observed in the northern part of the survey area. Some of these anomalies showed a very uncommon Ce/La ratio (up to 20), whereas other strong anomalies were characterized by a 'normal' Ce/La ratio of 1.5-3 (Fig. 2).

One strong anomaly with a high Ce/La ratio was chosen as a center of a sampling grid with the aim of finding the origin of these uncommonly high Ce/La ratios. This sample material will be analyzed for its mineral content, chemical composition of different grain size fractions and the chemistry of individual mineral separates. Two reasons for these high Ce/La ratios are possible. Firstly, the anomalies are produced by minerals with high initial ratios of Ce/La, but all known analyses of REE-minerals from this locality show Ce/La-ratios of 1 to 4; or secondly, Ce is separated from the other REE's by oxidation to Ce^{4+} during weathering and fixed e.g. adsorbed on clay particles, while the other REE's are removed.

A reconnaissance traverse in the western part of the survey area showed some occasional values above the background. Two additional traverses (100 m and 300 m to the north) were sampled and analyzed to check these possible 'anomalous' values. Both check traverses showed only background values and sampling was suspended in this region. The reconnaissance and one 'check'-traverse crossed old open pits which were formerly mined for iron ore. Even in the neighbourhood of these pit only background values were obtained for Cu, Y, La and Ce. This fact and the lack of REE anomalies in these three traverses may indicate that this part of the survey area is free of outcrops with REE-mineral accumulations.

The results of this survey give indications of REE-mineralizations north of the old Bastnas mine. The presence of a mobile EDXRF-laboratory in field was helpful in minimizing the number of samples necessary to detect the anomalies. Even the difficult analyzable REE's can be determined rapidly and with ease. The computerized form of the analytical results enables rapid statistical interpretation and mapping.

DISPERSION OF NIOBIUM AND PHOSPHORUS IN SOIL OVERLYING THE QAQARSSUK CARBONATITE COMPLEX, SOUTHWESTERN GREENLAND

H. Kunzendorf and K. Secher

The Mesozoic Qaqarssuk Complex is located on the west coast of Greenland. It covers 15 km^2 and includes a predominantly carbonatite ring dyke structure surrounded by fenitised basement. The suite of igneous rocks known from the complex comprises carbonatites (sövite and rauhaugite) and various ultramafites. Carbonatite dykes (beforsite) the complex and its surroundings, and late magmatic vein fillings of calcite, dolomite and/or rare earth carbonates are observed. The fenitised basement rocks are of the Na-fenite type.

The complex is covered by at least 0.5 m of arctic soil of mixed glacial and residual pedigree. It is argued that Nb and P are enriched in the soil and thus, regolithic accumulations might occur, developed during the short time available since last glaciation.

Soil sampling on a 10 m grid (304 samples) was carried out and rock samples (102 samples) were taken within the complex and from carbonatite dykes outside the complex. All the samples were analysed for a number of major and trace elements by X-ray fluorescence techniques and by delayed-neutron counting for U.

Major elements in the rocks clearly outline the transition from gneiss to carbonatite by increasing contents of CaO, MgO and P_2O_5 and decreasing SiO_2 and Al_2O_3. Fenitisation if flagged by an increase of Na_2O. The carbonatites can be grouped as originating from two magmatic phases according to their CaO and MgO contents. Carbonatites have an average of 1.7% P_2O_5.

Based on the soil sampling, it is concluded:

1) Soils are significantly depleted in Ca and subsequently enriched in Mg and Fe (solution of calcite in CO_2-bearing waters).

2) P is enriched by a factor of 2 or more compared to carbonatites. Soils with P accumulations have often low Ca contents. CaO/MgO ratios of less than 1.5 in soils may point to secondary apatite enrichment in the Qaqarssuk environment.

3) Nb and U anomalies, not usually coinciding with apatite enrichment, reflect pyrochlore rich rocks beneath the soil cover (upwards migration of Nb and U). The investigated soils have received little or no contribution from glacial material. Secondary precipitated apatite was not observed. The carbonate mineral content in the primary carbonatites and overlying soils shows a pronounced difference, with a predominance of dolomite in the latter.

In general, geochemical exploration methods using arctic soil sampling within the Qaqarssuk Complex have proven to be suitable for mapping and prospecting at a local or regional scale.

COMPUTER DATA-PROCESSING: A HELP OR HINDRANCE?

O.P. Lavin and I. Nichol

Computer-based processing and interpretation of geochemical exploration data are becoming increasingly common. As with other technological developments these offer some distinct advantages, but at the same time pose some potential hazards.

There has been a great proliferation of readily accessible data-processing and computer packages. Geochemical literature abounds with examples of the adoption of computer-based data-processing and interpretation involving a range of procedures ranging from the simplest to the ultrasophisticated.

Individual exploration programmes have specific needs in terms of data-processing and interpretation. In the first instance it is that essential these needs are identified (e.g. the interpretational problems defined in geological terms) prior to the use of any computer-assisted procedure. Subsequently, the feasibility of meeting the data-processing and interpretational requirements using graphical or mathematical procedures by means of available computer software needs to be examined. It is of critical importance to ensure that any computer-based procedures adopted are suited to the individual requirements of the programme. It is dangerous to adopt procedures used successfully elsewhere without first checking that the interpretational problem is the same.

Geochemical exploration is characterized by data sets consisting of large numbers of samples with various items of field and analytical data relating to each sample. Recognition of anomalous patterns within the data can only be achieved with the data plotted in map form, a time-consuming and arduous task when undertaken manually. Firstly, computers offer tremendous economic advantages for the routine handling and plotting of data, once the appropriate procedures have been identified. Secondly, present day computer-based systems readily allow the testing of possible relationships within data sets, which have been recognized from visual examinations of the data, thus facilitating the possible confirmation of significant relationships. Thirdly, computer-based systems can be used for multivariate analyses to identify hitherto unrecognized features of the data. Whilst in a number of cases the adoption of such procedures has been essential to the solution of particular problems. there are instances where unnecessarily sophisticated methods have been applied, or alternatively, sophisticated procedures have been totally misapplied.

Overall, the major benefits of computer-based data-processing and interpretation lie in cost-saving procedures associated with undertaking simple data-handling and interpretation. In certain cases they may be useful for undertaking multivariate procedures.

In all cases it is crucially important for the geologist to ensure that all computerized procedures are suited to the needs of the project. The computer can be a slave to a geologist, but disaster threatens if a geologist abandons his responsibility for thinking to a computer.

A GEOCHEMICAL SURVEY OF ST. LUCIA, WEST INDIES

L.W. Maassen and S.L. Bolivar

The Los Alamos National Laboratory recently conducted a geochemical survey on the island of St. Lucia for the purpose of assessing the country's mineral resource potential. A total of 307 stream-sediment samples was collected at a nominal density of one sample per 2 km^2. Fifty-five beach-sand samples were also collected. All samples were analyzed for 51 elements. This study was financed and supported by the Government of St. Lucia, the Caribbean Development Bank, the United States Agency for International Development, and Los Alamos National Laboratory.

St. Lucia is a tropical island some 40 km long and up to 20 km wide, covering an area of about 620 km^2. It is part of the Lesser Antilles island-arc chain on the eastern edge of the Caribbean plate. The island is comprised of Tertiary through Quaternary age volcanic rocks. The oldest rocks are the 18 m.y. old basalts in the extreme northern portion of the country (Briden et al., 1979). The volcanics generally become progressively younger southwards and range in composition from basalts in the north, to andesites in the central region, to dacites in the south (Newman, 1965).

The sampling program was largely patterned after other successful geochemical surveys conducted by Los Alamos (Bolivar, 1981; Earth and Space Sciences Division, 1984). For stream sites, a composite sample of fine-grained material was collected from three adjacent spots in the active stream bed. About 1 kilogram of sediment was collected from every site to ensure that at least 25 g of usable sediment would be obtained after the sample was dried and sieved to -100 mesh. Beach sands were collected above high tide level and were not sieved. Samples were analyzed at Los Alamos for 51 elements by delayed-neutron counting, instrumental neutron-activation analysis, and X-ray fluorescence.

Stream sediment samples were collected at irregular intervals due to geography, access, etc. To make the analyses amenable to visual display, the data were interpolated to a grid. Based on sample density, a grid cell resolution of 1 km^2 was selected. This resulted in a 35 x 50 grid, or 1750 cells. Universal Kriging was used to interpolate the data to each grid cell plotted on a Universal Transverse Mercator projection.

Colour plates were used to display regional geochemical characteristics of the stream sediment data. The use of colour images enables the geologist to rapidly visualize broad geochemical trends, place local geochemical patterns within the regional framework, and to observe correlations among the elements presented. Beach-sand samples were too irregularly distributed to be amenable to colour display; consequently, only black and white concentration plots and basic statistics were used in interpretation.

Two types of visual displays were used with the geochemical data: a colour-contour image, which shows the spatial and statistical distribution for each element; and a three-element image, which projects the spatial correlations for three elements simultaneously. A colour-contour image displays an elemental concentration in each grid cell as a colour, whereas a three-element image projects each element in a different primary colour (red, green, or blue) simultaneously. When all three are projected simultaneously, new colours are created by the rules of colour addition. If all three elements have concentrations in the same percentile ranking with respect to their individual populations, a shade of gray or white is generated.

An "anomaly threshold" was subjectively chosen to delineate samples with concentrations higher than background levels. The median values were determined to be the best estimates of average background. Anomaly thresholds were assigned based upon the histograms and published data for the average contents of each element for individual rock types.

The element with the greatest possibilities for development under present economic conditions, and with a reasonable chance of being found in St. Lucia's geological environment, is gold. Therefore, although the data indicate several areas with some chance for other types of mineralization, only those that indicate the presence of gold mineralization are emphasized.

The two most significant gold anomalies on St. Lucia are located within the Roseau River and Ravine Souffre drainage areas. Although the stream sediments themselves do not contain enough gold to be an economic source of the metal, there are several indications for a possible vein system within the volcanic terrane. Samples from the Roseau River drainage area contain some of the highest gold concentrations found (0.07 ppm), as well as anomalous concentrations of arsenic, antimony, and selenium, all of which are known pathfinders for hydrothermal gold deposits. Samples from the Ravine Souffre anomaly near Marc Marc are characterized by fewer gold values, but contain anomalous concentrations of several pathfinder elements. In addition, samples from both the Roseau River and Ravine Souffre anomalies contain higher than average base metal concentrations (copper, nickel, lead, tin), which is another favourable indication of mineralization. Lastly, both of these anomalies lie within arcuate-shaped depressions that may be collapse calderas. If so, faults and fractures associated with these calderas would of provided convenient conduits for hydrotheral solutions. Consequently, these two areas have several favourable indications of mineralization and should be the primary targets for future detailed studies.

The beach-sand data reveals no economic concentrations of the elements that might be expected to accumulate in beach placer deposits. Instead, the beach sand geochemistry generally reflects the onshore geology.

GEOCHEMICAL STUDIES ON GOLD IN TILL IN NOVA SCOTIA

I.J. MacEachern and R.R. Stea

In an effort to aid gold exploration in Nova Scotia, till geochemistry studies were conducted at two former gold mines in the Province. The Fifteen Mile Stream and Forest Hill gold districts were chosen for study because of the excellent till profiles exposed in trenches which are cut to bedrock and oriented perpendicular to the strike of both the veins and host strata of the deposits.

The purpose of the Fifteen Mile Stream study was to document the distribution, character and composition of gold in the till overlying the deposit. Twenty-one sample sets of A, B and C horizon material were collected at 10 m intervals along two trenches which are in en echelon formation and directly overlie the deposit. Geochemical analyses for gold, silver, lead and arsenic were performed on samples of the B horizon and four (4) size fractions of the C horizon. Samples of the A horizon were analyzed for gold only.

The <250μ fraction of the C horizon, with a mean gold content of 217 ppb, contains higher concentrations of gold than other size fractions and horizons analyzed. The gold occurs as foliated flakes which are morphologically similar to gold particles from the mine tailings. That the gold is not far travelled is evident from the lack of surface striations or other deformational features indicative of abrasive transport.

Microprobe analyses of gold from the till gave unexpected compositions which differed significantly from those of the presumed source. Gold from the till has an average composition of 69% copper, 10% gold, 9% zinc and 1% silver as compared with gold from the mine tailings which averages 91% gold and 9% silver. This discrepancy in composition is thought to be due to a hydromorphic redistribution of gold in the till.

The purpose of a more comprehensive study conducted at Forest Hill was to develop and refine effective geochemical tools for gold exploration in Nova Scotia. It consisted of an integrated survey involving the correlation of bedrock, till and soil geochemistry. The till was systematically profile-sampled at 1 m intervals at each station. Stations were located at 25 m intervals along nine trenches totalling 3.5 km in length. The till stratigraphy and gold distribution (in till) was extensively studied.

Three major surficial units characterize the study area. Unit I is a till and is overlain by an oxidized and cemented gravel. This sequence is overlain by Units II and III, which are tills characterized by a sandy matrix and locally derived granitic and metasedimentary clasts. Unit II is compact and rests upon bedrock with southeastward-trending striations. It is interpreted as an Early Wisconsinan deposit of an ice sheet that covered all of Nova Scotia. Unit III is less compact and locally has a strong fabric indicating a southwestward ice movement of Late Wisconsinan age. These tills (Units II and III) are commonly separated by a reddish-brown alteration zone interpreted as a paleosol.

A poor correspondence was found to exist between the panning results of the study and the geochemical data for gold. This is a consequence of the nugget effect. It was concluded that both panning and geochemical exploration techniques should be used in gold exploration programs in Nova Scotia.

The coarse fraction (1-2 mm) of the tills probably reflects the elemental ratios and abundances inherent to the bedrock; however the fine fraction (<63µm) of the tills shows evidence of a hydromorphic redistribution of mobile elements, thus implying that the tills at Forest Hill are at least partially altered by post-depositional chemical processes. Elevated values of Au and relatively mobile elements such as Cu, As and Mn in the fine matrix of an Fe-Mn cemented till suggest that gold is carried hydromorphically.

The dispersion of gold at Forest Hill is largely a manifestation of mechanical transport by a major southeastward ice-advance. The gold dispersion fans are three-dimensional bodies which come to the surface 200 to 300 m down-ice from gold-bearing veins. Peaks in gold abundance north of the veins in an area of Fe-Mn cemented till outcrop suggest downslope movement of gold by hydromorphic processes. Gold in the till occurs in both small flakes and small nuggets. The surfaces of these particles appear rough and pitted and exhibit little evidence of abrasive glacial transport.

THE STRANGE LAKE Zr-Y-REE-Nb-Be DEPOSIT: AN EXPLORATION GEOCHEMICAL PROFILE

J.W. McConnell and M.J. Batterson

The Strange Lake Alkalic Complex, located 145 km west of Nain, Labrador, hosts one of the world's largest known deposits of Zr, Y, REE, Nb and Be. The deposit was discovered in 1979 by the Iron Ore Company of Canada through follow-up exploration of a lake sediment and lake water anomaly outlined in a reconnaissance survey conducted by the Geological Survey of Canada.

In the reconnaissance data, the down-ice dispersion from the complex is reflected by Pb (lake sediment) and by F (lake water) in nearly continuous zones for 40 km and 25 km respectively. Uranium in lake water and U, F and Zn in sediment also give indications of the complex, but do not define it as clearly. This very extensive dispersion train, due largely to a fortuitous combination of glacial events and level of exposure, was a major factor in the discovery of the deposit. Because similar deposits are unlikely to be so clearly delineated, we have conducted detailed lake, stream and till studies to characterize the geochemical dispersion patterns in the surficial environment in order to provide an exploration model for this deposit type.

The complex which contains the deposit is a high level peralkaline granite of Helikian age with a roughly circular 32 km^2 subcrop exposure. It intrudes Aphebian gneissic and Helikian granitic terrain.

The complex is very poorly exposed. Till is ubiquitous, comprising 60% of surficial deposits, and underlies both organic accumulations and significant areas of glaciofluvial deposits. Till thicknesses up to 16 m occur in the vicinity of the mineral deposit.

Analyses of peralkaline bedrock (both strongly and weakly mineralized) indicate that, relative to other peralkaline granites, the complex is modestly to extremely enriched in the following elements: Li, Be, Zn, F, Rb, Sr, Y, Zr, Nb, Sn, REE, Pb, Th, and U.

Lake and stream sediment and till samples were analyzed for the elements Li, Be, F, Mn, Fe, Co, Ni, Cu, Zn, Mo, Ag, Cd, Pb and U. In addition, stream sediment and till samples were analyzed for V, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce and Th. Stream water was analyzed for F, Y, U and pH; lake water for Be, F and pH.

All sample media yield good dispersion patterns for appropriate elements. Elements may be usefully separated into two groups: (1) those which produce a distinctive geochemical expression for the entire peralkaline pluton, and (2) those which focus on the mineralized portion of the pluton. In the first group, fluorine in water gives the sharpest and most homogeneous pattern. Other elements in this group include La and Ce in stream sediment and F in lake and stream sediment. In the second group, elements which best reflect mineralization include Nb, Be and Pb in sediment and till samples and Y in both water and clastic samples. Also good, but somewhat less definitive, are the patterns of Th, Rb, Zr and Zn. Interpretation of the till data is uncompleted; however, comparing lake and stream data, the sharpest resolution of the dispersion pattern from the mineralized portion of the pluton is given by a composite factor determined for stream sediment samples by aggregating the normalized log values of Be, Zn, Rb, Y, Zr, Nb, Pb and Th.

HOST-ROCK PETROCHEMISTRY APPLICABLE TO EXPLORATION IN THE BAEGUNSAN SYNCLINE (HAMBAEG BASIN), KOREA

K.J. Moon

Sediments of the (Cambro-Ordovician) Baegunsan Syncline include the Jangsan Quartzite, the Myobong Slate and the Great Limestone Series. Most of the important ore-deposits, such as the Sangdong (W), Geodeo (Cu-Fe) and Yeohwa (Pb-Zn) mines are localized within limestone layers interbedded with the Myobong Slate, and at the base of the Great Limestone Series on the southern limb of the synclinorium. The northern limb has a high exploration potential for deposits of the same types. Sediments around the Sangdong deposit have been analyzed to test the potential of petrochemistry in exploration of the northern limb.

The uppermost interbedded limestone in the Myobong Slate was sampled at intervals of 500 m along a strike length of 16 km. SiO_2, CaO, Fe_2O_3, Zn and Cu are anomalous in areas where exploration drilling has located non-outcropping tungsten-bearing skarn at depths of 400 m. In the Myobong Slate, Fe_2O_3/FeO is lower (about 0.2) near mineralized zones than near barren zones (about 0.6). This is consistent with the formation of the tungsten skarns by relatively reduced fluids. The Sn contents of rocks and ores suggests that the alteration (observed in the rocks around the orebody) is of hydrothermal metasomatic origin, since most of rocks in the mineralized zone show distinctively higher contents of tin than unmineralized zones.

Geochemical haloes such as those described may prove applicable in exploration for blind orebodies.

INDIAN PLANTS AS INDICATORS OF MINERAL DEPOSITS

K.S. Murty

Varahamihira (505-587 A.D.), an Indian astronomer, devotes one full chapter in his 'Brihat Samhita' to the Art of exploring for underground water with the help of plants and animals. Symbiotic trees, Lianas (creepers) with termite mound at their base, trees developing whiteness on their stems, presence of a canopy of plants and trees with hanging branches downwards are mentioned as indicators of groundwater. Indeed, there are references to plant indicators in much earlier works like the Rigveda.

In the modern period, besides other methods, indicators plants have been used in India in geochemical exploration for mineral deposits. In the Sukinda ultramafic belt, Shorea robusta, Tenoinalia tomentosa and Combretum decandrum were used as indicator plants, while Impatiens balsania has been found growing selectively on zinc dumps in the lead-zinc belt of Rajasthan. In Andhra Pradesh, Polycarpeacorymbosa Lamk is quite common near the ancient copper mine workings of Agnigundala, and it is absent in the adjoining lead-zinc mineralised ground. In Madhya Pradesh, Bassia latifolia, Diospyros and Scheichara trijuga are indicator plants for copper mineralisation in the Chandidongri shear zone. Hyptis sauveolense may be an indicator of tungsten, when develops dwarfism and pseudo-wholed arrangement of leaves on the stem in such areas.

In Bihar, Polycarpea corymbosa, Eugenia Jambolaana, Diospyros melanoxylon, Veronica cinerea and Combretum nanum have been found to be indicators for copper mineralisation. Waltheria indica Sterculiaaeae has been widely found in the base metal mineral zone in Tamil Nadu, particularly in the molybdenum-bearing Mamandur area.

Recent additions to such plant indicators are 'cometes surattensis burmvar ambajiensis' for copper, lead and zinc mineralisation in Gujarat, and 'Tulsi' plant for chromite in the Kondapalli area of Andhra Pradesh.

PRELIMINARY RESULTS OF REGIONAL GEOCHEMICAL STUDIES, SHERBROOKE AND LEWISTON 1° X 2° QUADRANGLES, MAINE, NEW HAMPSHIRE, AND VERMONT, U.S.A.

G.A. Nowlan, F.C. Canney and F.H. Howd

A geochemical survey of the Sherbrooke and Lewiston 1° x 2° quadrangles was conducted from 1979 to 1982 by the U.S. Geological Survey as part of the Conterminous United States Mineral Assessment Program. The area covers about 9,000 mi^2. The region is characterized by a temperate climate, abundant rainfall, and dense forests. The topography ranges from rolling and subdued to mountainous. Bedrock is generally covered by glacial deposits, lakes, or bogs. The bedrock includes metamorphic and plutonic rocks ranging in age from Precambrian to Cretaceous. Regional metamorpism ranges from chlorite to sillimanite grade. Mineral deposits within the area include massive-sulfide deposits, Cu-Mo porphyry deposits, minor base-metal veins, minor argentiferous Pb-Zn veins, minor Sn-bearing veins, minor Be-bearing skarn deposits, and low-grade disseminated Th-U deposits.

Stream sediments were the primary sample medium chosen because, (1) drainages are extensively developed, (2) bedrock is poorly exposed, and (3) previous studies had established stream-sediment sampling as a viable procedure for reconnaissance geochemical studies in this region. The data from more than 2,000 stream-sediment samples collected in earlier U.S. Geological Survey programs were included to give a total of almost 7,000 samples of stream sediment. At about 1,400 sites, samples of heavy-mineral concentrate from stream sediment were also collected. Most of the heavy-mineral concentrate samples were from the Lewiston quadrangle. Both sample media were analyzed for as many as 32 different elements: Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, U, V, W, Y, Zn, and Zr.

Some significant findings are (1) nonmagnetic heavy-mineral concentrates are a valuable sample medium in the region to show the distribution of Sn and W; (2) extremely high concentrations of Sn occur in samples from streams draining certain granites; (3) clusters of heavy-mineral concentrate samples containing anomalous concentrations of W occur in several locations; (4) the geochemical expression of some known massive-sulfide deposits is subtle, therefore weak anomalies in areas of no known deposits may be significant; (5) clusters of samples anomalous in Cu, Pb, Zn, and Mo occur in areas where no known mineral deposits exist; (6) a prominent linear trend of stream-sediment samples containing high Cr is probably due to glacial transport of mafic or ultramafic rock material for distances as great as 80 miles; (7) glacial transport must be considered in the interpretation of data for elements, such as Cr, W, and Sn, that commonly for resistate minerals, and in the interpretation of data from elements, such as Co, Cu, and Ni, that occur as trace elements in chromite or other resistate minerals; and (8) glacial action appears to be a minor factor in the dispersion of elements from sulfide deposits.

APPLICATION OF CARBONYL SULPHIDE TO MINERAL EXPLORATION

B.W. Oakes and M. Hale

Any gas which is liberated during the oxidation of sulphide minerals and is sufficiently chemically stable to migrate by diffusion and mass flow away from its source creates a dispersion aureole of potential significance in prospecting. Such a dispersion aureole assumes particular importance if it is detectable at or near to the ground surface in exotic overburden which is devoid of a more conventional geochemical expression of any mineralization concealed in bedrock at depth.

Gaseous sulphur compounds are perhaps the most obvious gaseous products of sulphide oxidation. The relative abundance of carbonyl sulphide (COS), its stability in air and detection during in vitro oxidation of moist sulphide minerals have prompted the development of convenient sampling and analytical techniques for the determination of COS in overburden materials and research into the occurrence of COS dispersion aureoles over concealed sulphide mineral deposits. In temperate to tropical regions with podzolic soils, samples are taken below the normal rooting depth of vegetation; in arid and semi-arid areas with sparse vegetation, the surface microlayer of the overburden is collected. The analytical procedure involves the thermal desorption of COS from the -150 µm fraction of overburden materials and its quantification by gas chromatography. Data are expressed as the weight of COS liberated per unit weight of overburden material; the limit of detection of the technique is approximately 2 pg g^{-1}.

At Johnson Camp, 110 km east of Tucson, Arizona, tabular bodies of lowgrade chalcopyrite-sphalerite mineralization sub-outcrop at depths of 10 to 150 m beneath sandy alluvium with lenses of caliche. Analysis of a grid of surface microlayer samples revealed a discontinuous zone of anomalous COS concentrations above the sub-outcrop of oxidizing mineralization concealed beneath some 60 m of exotic overburden. At Ash Sha'ib, 500 km southeast of Jeddah, Saudi Arabia, sphalerite-chalcopyrite mineralization, assumed to be originally stratabound, occurs in steeply dipping metasediments. The mineralization outcrops as a gossan on a low hill but along strike is concealed beneath several metres of wadi sediments. A grid of surface microlayer samples over the wadi revealed a COS background of up to 600 pg g^{-1} and discontinuous zones of anomalous samples reaching 1200 pg g^{-1} and trending sub-parallel to the projected strike of the outcropping gossan. There are several further examples of COS anomalies related to mineralization, ranging from anomalies associated with porphyry style mineralization to anomalies in glacial till overlying fault hosted sphalerite-galena.

GEOCHEMICAL EXPLORATION FOR COPPER SULPHIDE DEPOSITS IN THE GRANITE-GREENSTONE BELT, CENTRAL INDIA

A.K. Pachauri

The Precambrian Granite-Greenstone belt of Central India is similar to such belts in other shield areas of the world e.g. South Africa and Australia. The area chosen for geochemical exploration comprised pyroxenite, charnockites and granites. Studies based on primary and secondary dispersion in this Precambrian Terrain have led to the discovery of copper good deposit (13 million tons) in Chandarpur District of Maharashtra State in Central India.

The present paper describes the geochemical work, i.e., soil and lithogeochemical surveys, carried out around a silicified quartz vein that shows differentiation from a granitic mass to a core of quartz which is highly brecciated. The country rock is pyroxenite/charnockite. The area is flat in a subtropical zone with the only ridge in an area of about 1000 km^2 being the quartz mass. The mineralisation comprises gossans, malachite, stains and quartz veins in the southern part of the area where exposures in the Wainganga river show sulphide impregnations.

Anomalous values of Cu, Pb, Zn, and Co occur in the soil B horizon in this area. Some of the higher values along the side ridge are probably due to contamination from old workings and dumps. The isochemical values were plotted for copper, these approximately delineated the targets for drilling, which have been successfully tested the mineralisation to a depth of 50-60 m.

SIGNIFICANCE OF METABOLISM ON THE RELIABILITY OF TWIG SAMPLES IN BIOGEOCHEMICAL PROSPECTING FOR URANIUM

S.K. Pande, A.N. Deshmukh and P.K. Shrivastava

On the basis of leaf development, the intensity of metabolic activities has been classified as Relented, Active and Vigorous. Three plant species viz., Shorea robusta, Emblica officinalis and Lagerstroemia parviflora, were selected for sampling on the basis of their (1) high population density and uniform distribution, and (2) selective uranium absorbing tendency. These species were grid sampled at the Jajawal uranium prospect, and twigs in different metabolic stages were collected. Five nutritional elements, calcium, magnesium, sodium, potassium and phosphorus, three essential elements, iron, manganese and copper, and uranium, have been chemically determined in the ashed twig samples.

Significant intermetal relationships indicate that the K-P positive link,a nd the K-Ca and P-Ca negative links are consistent irrespective of metabolic stages. Moreover, it is clear that the K-P positive link completes a triangle with either (or both) of the three essential elements, copper, manganese or iron. It is also clear that the U-Na relationship is significant and positive during the vigorous metabolic stage, insignificant during the active, and significant and negative during relented metabolic stage.

The relationship between the combined influence of metal ions (Ca, F, P, Cu, Mn) on uranium, on one hand, and the biogeochemical contrast for uranium on the other, has been found to be linear and inverse. Accordingly, the twigs of Shorea robusta in the vigorous metaboic stage have exhibited higher influence of metal ions and poorer contrast for uranium. Twigs of Emblica officinalis in the active metabolic stage have shown a lower influence by metal ions and medium contrast for uranium, while twigs of Lagerstroemia parviflora in the relented metabolic stage have exhibited the lowest influence and fairly high biogeochemical contrast for uranium.

Interestingly, the biogeochemical uranium anomalies delineated on the basis of twigs of Lagerstroemia parviflora in the relented metabolic stage, with higher contrast for uranium, have coincided perfectly with the actual disposition of uranium anomalies in the area.

Therefore, twigs in the relented metabolic stage constitute the most reliable sampling medium for uranium prospecting to be undertaken in countries endowed with a tropical climate.

LITHOGEOCHEMICAL DATA FROM THE EAST AMISK AREA OF THE FLIN FLON-SNOW LAKE VOLCANIC BELT: IMPLICATIONS FOR MINERAL EXPLORATION

G.R. Parslow

The east Amisk area of Saskatchewan represents a small portion of the Flin Flon-Snow Lake volcanic belt; it is different from much of the Saskatchewan part of the belt in that pillowed basalts and gabbro intrusions predominate over more felsic volcanics and volcaniclastics (typical of other areas). The area also hosts the three economic (Cu) massive sulphide deposits (Flexar, Birch Island, and Coronation) known within the volcanic belt in Saskatchewan. The area is one of mature bush with lichen covered outcrops, which makes the field identification of specific rock types difficult. In addition, the pervasive effects of low grade metamorphism have essentially destroyed all the original mineralogy. More obvious textures, such as pillows, grading, and cross bedding are the only palimpsest fabrics to survive Hudsonian tectonism and accompanying metamorphism. As such, the area represents one ideal for a geochemical approach to assessing its mineral potential.

A research contract with Saskatchewan Energy and Mines resulted in the analysis of over 800 samples for major elements and 14 trace elements. The oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, P_2O_5) and V were determined using ICP; the remaining trace elements (Ba, Cr, Cu, Nb, Ni, Pb, Rb, Sr, Th, U, Y, Zn, Zr) by XRF; the alkalis (Na_2O, K_2O) by AAS; the volatiles (H_2O^-, LOI) by gravimetry; FeO by titration. Complete details of analytical procedures, precision, accuracy, and raw data can be found in Parslow and Gaskarth (1984). This paper concerns only one aspect of the use of this large data base.

Because of the difficulty in making specific field identifications of the basic and intermediate rocks, other than extrusive or intrusive, the samples were subdivided using a simple SiO_2 classification to create subfiles. The files created by this method were: ultrabasic, basalts, basaltic andesites, andesites, dacites, rhyolites, gabbros, diorites, granodiorites, granites, and volcaniclastics. Only the original total data file, the rhyolite file and the volcaniclastics file show summary statistics with slightly higher means and larger standard deviations for Cu, Pb, and Zn. It can be argued that the total data file is, in effect, suggesting the area as a whole has "mineral potential" and inferred that the rhyolites, which form a narrow belt passing "through" the mineral occurrences, represent the target within the area. A geographic plot of the volcaniclastic rocks does not show any particular spatial relationship with the known massive sulphides. Since the rhyolite file is small (n=18), an attempt was made to find other corroborative evidence to link rock type and mineralization within the large basalt and gabbro files (which represent over 60% of the data).

Plots of the immobile elements on various discriminant diagrams, as part of a separate study to consider the tectonic association of the basaltic rocks of the area, clearly demonstrate that the "basalt-gabbro" suite has ocean floor (i.e. MORB) affinities. This contradicts earlier observations that the volcanics fit an island arc model. Certainly, other areas to the west and north of the area under study do fit a subduction related model; however the east Amisk area is convincingly rift related. From the basalt and gabbro histograms, used to study possible lines of liquid descent prior to plotting discriminant diagrams, it is clear that subgroups exist, particularly in the immobile elements. Most importantly the elements Ti, Nb, Zr, and to a certain extent Y and Sr, exhibit two or possibly three subpopulations. These data were used to create three subgroups defined by $TiO_2<1.00\%$, 1.00-2.00%, and >2.00%. The resulting subfiles reveal that the immobile elements have a positive correlation with each other; that is, there is a low Ti, Nb, Zr, Y, Sr file, and a mid and high file of the same elements. Geographic plots of these subfiles illustrate that the low Ti, etc. basalts and low Ti, etc. gabbros are spatially associated with the massive sulphides; other subgroups are not. Summary statistics for the new subfiles of basalts and gabbros are most indicative of "mineral potential" in that the means and standard deviations of Cu and Pb in the low Ti, etc. files are higher than the other files.

It is concluded that, in an area where precise field identification is impossible, rocks require careful chemical classification (as exemplified in this particular case by Ti, Nb, Zr, Y and Sr distributions). Without this as the basis for chemo-stratigraphy the correlations of known mineralization to the geology may be difficult and the definition of exploration guidelines for an area impossible.

TUNGSTEN EXPLORATION IN THE VALNESFJORD REGION, NORDLAND, NORTHERN NORWAY: A CASE HISTORY

L.R. Petersen and H. Stendal

The Valnesfjord area is dominated by three lithological units: 1) The "sparagmite" series consisting of fine-grained, sandy and homogeneous rocks often foliated and containing layers (1-2 m) of more mica-bearing schist and carbonaceous intercalations (calc-silicate rocks). 2) East of the "sparagmite" series occurs the caledonian nappe units mainly mica schist (± garnet), dolomite, limestone and quartzite. 3) The transition zone between the "sparagmite" and the nappe units is distinct in the landscape due to a tectonic zone ("shearzone"). The "shearzone" is 100-300 m wide and made up of a heterogeneous rock sequence consisting of carbonates (dolomite, limestone), carbonaceous schist, biotite-garnet schist, tourmalinites, mafic rocks and pegmatites. In addition to these rock units quartz pegmatites occur as layers and boudins. Pyrrhotite is common in some of the schists and the mafic rocks.

At each sampling site in 1st and 2nd order streams a heavy mineral concentrate and a stream sediment sample was collected. Soil samples are collected from C horizon at a depth of 30-120 cm, which means in most cases at the top of the bedrock. Five litres of soil were collected, 200 g were taken for chemical analyses and the rest was preconcentrated by panning and the scheelite grains counted.

The raw data from the scheelite counting were all normalised to a one litre sieved position (minus 1 mm fraction) of the panned sediment. The threshold value is 30 grains of scheelite in the normalised samples, and the peak value from the regional survey was 126 grains of scheelite. The majority of the anomalous samples (8) were related to the "shearzone". The detailed follow-up survey revealed scheelite mineralization in a zone in the lowermost part of a dolomite-limestone sequence or a carbonaceous biotite schist. The peak anomaly was 1000 grain of scheelite. The soil samples gave peak values up to 2500 grains of scheelite.

Three types of mineralization were found by UV investigations in the field: a) tourmalinites with large scheelite crystals in vugs, b) small crystals of scheelite in quartz pegmatites, and c) disseminated scheelite in carbonaceous biotite schist. The latter is the most interesting from an economic point of view.

Tungsten exploration in the Valnesfjord area was successfully carried out during two field seasons, with two men for four weeks (1983) and one man for 7 weeks (1984). Work started with a reconnaissance/regional survey, and the next year followed-up with detailed studies of an anomalous area. The stepwise approach, with concluding detailed investigations, revealed the source rock hosting the scheelite mineralization in the Valnesfjord area.

The project is supported by the Geological Survey of Norway.

ON THE MODE OF OCCURRENCE OF Cu, Zn, Co AND Ni IN TILL AT SOME SULPHIDE PROSPECTS IN FINLAND

V. Peuraniemi

The mode of occurrence of metals in till is an important feature to study when interpreting the anomaly type and locating the source of the anomaly. This study deals with base metals (Cu, Zn, Co, Ni) in one target area (Vahajoki) in northern Finland, and in two target areas (Katumajarvi and Saajanmaki) in southern Finland. A copper- and cobalt-bearing iron ore, which has been considered as skarn type, occurs in Vahajoki area. Magnesia metasomatised volcanic rocks in Katumajarvi contain sulphide dissemination. Saajanmaki is an area of basic volcanic rocks where a small Cu-Zn mineralized zone has been found. The overburden consists of basal till in all three areas.

Till sampling was undertaken with a light-weight percussion drill. The samples were dried and sieved into three grain size fractions: <0.06 mm, 0.06-0.25 mm and >0.25 mm. The finest fraction was analyzed chemically by AAS. First, the total metal contents were determined by dissolving the samples in a mixture of perchloric, hydrochloric, nitric and hydrofluoric acids. Two weaker solvents were also used. One was citric acid, which dissolves the weakly bound metals, the so-called hydromorphic component. The other was a mixture of ascorbic acid and hydrogen peroxide, which preferrentially dissolves the metals bound in sulphides, but not the metals included in the lattices of silicate and oxide minerals.

The sand fractions of the samples were separated in tetra-bromoethane. The heavy fractions were studied mineralogically using a polarizing microscope, a scanning electron microscope, an electron microprobe, and X-ray diffraction. The results show that the most important mode of occurrence of the metals studied is as sulphides. This indicates the predominance of mechanical dispersion. Only in some samples is the amount of the weakly bound metal significant.

Interesting features can be seen in the weathering of the sulphide minerals. Pyrite, pyrrhotite and chalcopyrite have to variable extents been altered to goethite. Chalcopyrite and bornite have been altered in places to covellite. As weathering products of sulphide minerals two rare iron sulphates, szomolnokite ($FeSO_4 \cdot H_2O$) and melanterite (Fe, Zn, Cu, Co, Mg) SO_4 $7H_2O$ were found.

It is important to determine, if anomalous samples contain such secondary minerals as covellite, which is more copper-rich than chalcopyrite. If such minerals occur abundantly in samples, the geochemical anomaly may be enhanced as compared to the mineralization in fresh bedrock. The occurrence of melanterite is an indication that weathering of copper and zinc sulphides has produced free copper and zinc ions.

GEOBOTANY AND BIOGEOCHEMISTRY IN MINERAL EXPLORATION IN THE TROPICS

E.A.V. Prasad

The ancient Sanskrit text 'Brihat Samhita' (i.e., Master Collection) by Varahamihira (A.D. 505-587) described the fundamental concepts of bioindicators, chiefly plants and termite mounds, to locate ground water and mineral resources in arid and semiarid regions. Only recently have similar studies been revived.

The occurrence of an aquifer or a mineral deposit gives rise to environmental heterogeneity, with a microenvironment characterized by, respectively, a high relative humidity or heavy metal toxicity. The ecotypes and the ecophenes with environmentally-induced morphologic or mutational changes constitute the bioindicators for nonbiotic natural resources.

Recent studies in southern India have attempted to identify plant indicators in certain selected mineralized areas which include: Kondapalli chromite in Krishna District in Andhra Pradesh (A.P.); Byrapur chromite in Hassan District in Karnataka; barytes deposits in Cuddapah District (A.P.); Agnigundala base metal deposits in Guntur District (A.P.), and mica pegmatite in the Nellore District (A.P.). In all these districts there are plant species tolerant to heavy metal toxicity in the mineralized areas. Some, with full growth, occur even on the concentrated ore dumps.

Amongst these plant indicators Tulsi of the Labiaceae (mint) family (hyptis and ocimum species) has extraordinary tolerence for soils rich in Cr, Pb, Zn, Cu and Ba, and for a serpentine bedrock.

The ubiquitous thorny shrub Prosopis juliflora has an extraordinary ecologic amplitude and tolerance for a wide variety of heavy metals. Similarly Calotropis gigantea and Cassia auriculata exhibit tolerance for many heavy metals in the soils and bedrock. Among the tree species, neem (Azadarichta indica) and certain Ficas sp. are tolerant to heavy metal toxicity.

Givotia rottleriformis, which is most common and widespread in the Kondapalli hill range on different rock types, exhibits profuse flowering, whereas in the presence of chromite it is devoid of flowers.

In granitic terrain, bush shrubs of thorny Gymnosporia falconeri indicate a permatite bedrock. When the pegmatite and associated mica, beryl, and tourmaline is mined, G. falconeri is replaced by Prosopis juliflora demonstrating the antagonistic relationship between these two thorny species.

Gymnosporia falconeri is common in barytes mineralized zone associated with dolomite and basalt. Where copper concentrations are high and Ba and Sr low, G. falconeri has pink and red foliage; however, where copper is low and ther are high concentrations of Ba and Sr normal green foliage is present.

Phyllite and dolomite comprise the country rocks of the Agnigundala base metal deposits. Albizzia amara is an indicator of phyllite, while the presence of Barleria longifolia, indicates domomite. Gymnosporia falconeri, Hardwickia binata, Zizyphus xylopyrus, Chomelia asiatica, and Cassia angustifolia growing on dolomite have higher metal contents than those growing on phyllite.

Termite mounds constitute important tools in mineral exploration. Maintenance of constantly high relative humidity in the mounds is an essential prerequisite for the very survival of the species in arid and semiarid regions. The termites penetrate deep down into the subsoil to reach the water table. Along with the soil particles for the construction of their mounds and ground water carried out by the termites, any ore elements present are also removed to the surface. Hence it has been found that the concentration of ore elements in the mounds it locally much higher than in adjacent soils.

Furthermore, indicator plants growing on a termite mound have higher concentrations of some ore elements than the same plant species developed on adjacent soils. Thus the excellence and efficacy of the termite mound as an important tool in geochemical prospecting in tropical regions has been firmly established, even in areas devoid or outcrops and covered by a thick soil mante.

MAX, A PROGRAM SYSTEM FOR MULTIVARIATE DATA ANALYSIS OF GEOCHEMICAL EXPLORATION DATA

S. Rehder and A. Muller

Micro computers can be very powerful tools for the field geologist. The Federal Institute for Geosciences and Natural Resources (BGR) developed the program system MAX for an Apple II. It includes programs for data base management, univariate and multivariate statistic interpolation, mineral characterization and special exploration programs. MAX has been proven in many exploration projects. The poster session will display some of the outputs.

GEOBOTANICAL REMOTE SENSING: AN OVERVIEW

B.N. Rock

The use of remote sensing data to assess vegetation response to geochemically induced soil anomalies requires an understanding of how plants are likely to respond to a variety of adverse conditions, and how that response will be recorded by various sensor systems. Such geobotanical anomalies may be expressed in a number of ways: (1) anomalous distribution of species and/or plant communities, (2) altered phenological cycles in which fall foliage display may be early and spring leaf flush delayed, (3) stunted growth and/or reduced percent cover, and (4) alteration of leaf pigment complexes and/or transpirational rates. All of these vegetation responses can be remotely detected and used in an exploration strategy.

The Joint NASA/Geosat Test Case History provides several examples of the remote detection of geobotanical anomalies, which in turn led to the discovery of soil anomalies. The Lost River, WV Test Case Study will be presented as an example of a vegetation distribution anomaly related to adverse soil conditions associated with hydrocarbon microseepage, while the Patrick Draw, WY Test Case Study will be presented as an example of stunted growth and reduced percent cover in vegetation also in response to hydrocarbon microseepage. Although both geobotanical anomalies are associated with high levels of soil hydrocarbons, metal concentrations, notably manganese, within plant tissues, are also anomalous , and may be useful as part of an exploration strategy. Details of work undertaken at each site will be presented, and will be used to emphasize the value of remote sensing in the discovery of both sets of soil anomalies.

LITHOPHILE ELEMENTS AND EXPLORATION USING CENTRE-LAKE BOTTOM SEDIMENTS FROM THE EAST KEMPTVILLE AREA, SOUTHERN NOVA SCOTIA

P.J. Rogers and R.G. Garrett

The East Kemptville tin deposit in southwestern Nova Scotia was discovered in 1978 by Shell Canada Resources, Ltd. using regional till exploration. In 1977 and 1978, southern Nova Scotia was covered by a regional centre-lake bottom sediment survey (1 site per 5 km^2) for Cu-Pb-Zn-Ag-Ni-Co-Fe-Mn-Ca-Mg-Mo-Hg-As-U-LOI. Detailed lithogeochemical studies on drill core from East Kemptville have demonstrated significant roles for the elements Zn-Cu-Th-Li-F-Sn-Cl-Rb in the hydrothermal mineralization. Most of these significant mineralizing elements were not analyzed as part of the lake sediment survey.

To test the applicability of lithophile elements in regional centre-lake bottom sediment geochemical programs, a subset of 55 lake sediment samples from the deposit area was analyzed for Sn, Rb, F and Cl. Sn values were found to range from 1 to 32 ppm, Rb from 10 to 207 ppm, F from 25 to 410 ppm, and Cl from 240 to 1660 ppm. All of the anomalous values of F, Rb and Sn form a distinct halo of elevated levels southwest, southeast and northeast of the East Kemptville deposit, which appears to lie in an area of background values. The detailed till geochemistry carried out by Shell at East Kemptville for Sn, W, Cu and Zn provided information on the probable source of the material found in the centre-lake bottom sediments.

The main mineralization at East Kemptville comprises cassiterite and wolframite, both minerals contributing to the Sn and W till anomalies. Heavy minerals were separated from a bulk lake sediment sample from Moosefly Lake (the site of the 32 ppm Sn value from the regional survey subset) using methylene iodide. Spot analyses by scanning electron microscope indicate the presence of angular discrete grains of cassiterite in the centre-lake bottom sediment, in addition to numerous grains of zircon, monazite and magnetite.

The Sn anomaly in the centre-lake bottom sediment is due at least in part to the presence of discrete cassiterite grains. The lack of abrasion would indicate derivation from nearby known cassiterite-rich tills. The lack of correlation of Sn data with organic content (as LOI), and the other elements, probably indicates the dominance of mechanical over chemical dispersion processes in moving Sn from the tills to the lake environment.

Refractory mineral phases in the lake sediments from East Kemptville produced the Sn anomalies, whilst the F, Cl and Rb are more likely associated with clay or silt particles from the till. In either case, anomalous areas were identified using these lithophile elements in centre-lake bottom sediments. The presence of the Sn anomaly, and confirmation of the cassiterite in the centre-bottom organic-rich lake sediments, is evidence that clastic dispersion processes should be taken into account when interpreting conventional lake sediment data. A common dispersion model is one of initial glacial clastic transport, followed by subsequent hydromorphic dispersion into the lake basins. Now, whilst still recognizing the dominance of hydromorphic processes, it is clear that clastic dispersion models must be considered. It also follows that centre-lake bottom surveys may have greater application than previously presumed in the search for lithophile elements commonly dispersed as refractory grains.

IMPROVING ANOMALY SELECTION BY STATISTICAL ESTIMATION OF BACKGROUND VARIATIONS IN REGIONAL GEOCHEMICAL PROSPECTING

C. Roquin and H. Zeegers

Background values of base metals, Cu, Pb, and Zn, are very sensitive to primary or secondary environmental factors. In regional geochemical prospecting high background samples and weak, but significant, anomalies are not systematically different for these elements. An adjustment of the background is therefore required to take into account the influence of the environment and to extract the "useful" component of the geochemical signal more closely related to mineralization.

To investigate the role of the primary and secondary environments the present study, based on numerous data collected as part of the French Mineral Resources Inventory programme, was undertaken in two parts.

The first part is devoted to the description of the influence of environmental factors on geochemical data. Thirty lithological units corresponding mainly to schist and granite formations from basement areas were selected in Brittany, the Vosges and the Massif Central. They are represented by 4,971 samples analyzed by plasma emission spectrometry for iron and 21 trace elements.

Influence of environmental factors on this data was assessed in two ways. Firstly, directly, by comparing element contents between groups of samples defined by coded field observations (lithology, sampling media, vegetation); and secondly, indirectly, by interpreting the results of multivariate analysis displaying geochemical associations between elements. Two main differentiation factors have been identified in most of the selected areas, a dilution effect by a barren siliceous phase (quartz?), and the scavenging of transition metals by iron and manganese hydroxides.

The dilution effect is characterized by positive correlations between all analysed elements, so that they tend to cluster together around the first factoral axis in a P.C.A. It is shown by comparison with field observations that this effect is related to various environmental parameters, such as lithology (acidity of bedrock, sandy overburden, loess) or sampling media (leaching of fine clay particles in stream sediment). The coprecipitation effect is particularly strong for zinc, and to a lesser degree for copper. It is characterized by the association of these elements with Fe, Mn, Co, Ni. In Brittany, it appears to be more influential in stream-sediments than in soils. Generally, these factors related to the mineralogy of the samples are better characterized by multi-element analysis than by field observations.

In the second part, an example of background estimation and correction is given for the Nort-sur-Erdre 1/50,000 sheet in Brittany. Multi-element analytical data for 1,530 soil and stream-sediment samples have been described like those in the first part of the study.

Analysis of variance results show that lithology or type of sample material, as recorded by field observations, explain less than 10% of the background variation for Zn, Cu and Pb.

However, strong correlations between Cu, Zn and the other elements (Fe_2O_3, Mn, Ba, P, V, Ni, Cr, Co, Y) representative of environmental factors, indicate another possibility for correction by regression analysis. The latter explanatory variables are themselves strongly correlated and can be synthesized in a single factor through P.C.A. (50% variance explained). Obviously this factor is rather complex, but it seems to represent a dilution effect of ferromagnesian and hydroxide minerals by a barren siliceous phase. Taken as the explanatory variable in a simple linear regression model, it can explain an important part of the variation for Zn (75%) or Cu (43%), but only 12% for Pb.

Nevertheless, a graphical display of the residuals shows that the linear model does not perfectly fit the data, even after a logarithmic transformation. The hypotheses of independance and homoscedasticity of the residuals are not fully satisfied, and that leads to statistical bias in the estimation.

Consequently, another technique of regression by local estimation (known as "regression par voisinage") was applied. It consists of comparing the zinc, copper or lead contents in one sample with those observed in the nearest samples - "the neighbours" - in the space of explanatory variables. The arithmetic mean and standard deviation of each metal in this neighbourhood provide an estimate of background, and the precision of this estimate.

Various anomaly indices are then available for each base metal by considering the three following parameters, raw values, residual component, and local standard deviation. The residual component can be considered alone, but in order to enhance the anomalous part of the signal in the most diluted samples it is normalized either by the raw values or by the local standard deviation. The three indices are discussed and several kinds of maps are presented to help in the last stage of interpretation and anomaly selection.

LITHOGEOCHEMICAL EXPLORATION FOR POLYMETALLIC Sn-Cu-Ag-Au-Pb- Zn VEIN MINERALIZATION AT NORTH MAMMOTH PROSPECT, NORTHEAST VICTORIA, AUSTRALIA

C.S. Rugless and Teale

Several en-echelon transported goethite gossans occurring in an arcuate, 20 m wide by 200 m zone provided the initial target for a three hole diamond drilling programme at the North Mammoth prospect in Northeast Victoria, Australia. The terrain in the area is rugged with hills rising 400 m above uplifted juvenile river valleys. The drilling programme intersected massive pyrite veins containing sub-economic tin, copper, silver, gold, zinc and lead mineralization. The hydrothermal mineralization occurs in weakly altered metasediments which contain numerous fracture filled quartz, barite and ankerite veins adjacent to intrusive quartz feldspar porphyry dykes which form part of the Mammoth prophyry complex.

The main intrusive of the Mammoth porphyry complex extends for at least 3.5 km and achieves a maximum width of 0.5 km. The porphyry attenuates to the north and south where it is apparent as a series of dykes and related heterolithological breccias. The porphyry complex has been pervasively argillically altered. Rapid emplacement of the intrusive effectively brecciated the metasedimentary country rock producing the distinctive heterolithological breccia. Preliminary studies indicate an Early to Middle Devonian Age for the Mammoth porphyry based on petrographic and immobile trace element (Ti, Zr, Y) similarities with documented felsic plutonic and volcanic rock in Northeast Victoria.

The potential for additional scree-covered veins in the north Mammoth area prompted the implementation of a broad-scale lithogeochemical exploration programme. An orientation survey of 27 samples was collected at approximately 100 m intervals across the mineralized zone. A 0.5 - 1 kg aggregate of rock chips was collected over a one square metre area at each site. The samples were dried, crushed, pulverised and analysed for Mg, K, Ca, Mn, Fe, Ti, Rb, Sr, Y, Zr, Ba, Mo and Sn (total) by XRF methods, and Na, Cu, Pb, Zn, As and Au (ppb levels) by AAS (hydride generation and carbon furnace) methods. Acid soluble Sn analysed by AAS, and water soluble F analysed by selective ion electrode, were also investigated. The results showed that Sn (total), Au, Pb and As provide the best anomaly contrast, with less definitive trends apparent as Ba, K, Fe, Na, Sr, Cu, Ag and Rb enrichment, and Zr and Y depletion. Calcium Mg, Zn, Mo, Mn, Ti, Sn (acid soluble) and F (water soluble) were least effective in defining the mineralized zone. Simple ratios including K/Na, Fe/Mg, Rb/Sr, Zr/Y and Ti/Zr failed to extend the anomaly width defined by single elements.

The lithogeochemical survey was based on samples (123) collected at approximately 100 m intervals along compass and tape surveyed tracks, ridges and spurs, at a sample density of 65 sites per km^2. Anomalous Sn, Au, Pb, and Ba haloes effectively outlined potentially mineralized areas east of the main porphyry, including north Mammoth prospect. Strongly anomalous zones within the haloes provide priority targets for more detailed exploration methods.

Exploration lithogeochemistry, applied to the broad scale, has clearly identified potential targets in a difficult exploration area. The extent of the haloes indicate that the mineralizing processes associated with the vein mineralization are more pervasive than is readily apparent to the eye.

TILL SAMPLING IN THE CASA BERARDI AREA, QUEBEC: A CASE HISTORY IN ORIENTATION AND DISCOVERY

J.A. Sauerbrei, E.F. Pattison and S.A. Averill

In April 1981, Inco Limited discovered gold in northwestern Casa Berardi township, Quebec. The discovery, known as the Golden Pond zone, is located under approximately 45 m of overburden. Diamond drilling at Golden Pond up to August 1983 indicated two main zones of gold mineralization on either side of a major east-west trending graphitic fault zone. The mineralization consists of pyrite-arsenopyrite-native gold bearing quartz-carbonate veins in carbonatized Archean sediments and volcanics. A reverse circulation overburden drilling program was undertaken in the vicinity of the Golden Pond zone in December 1983. The program, under the management of Overburden Drilling Management of Ottawa, was designed to test for glacial dispersion of the known mineralization and thereby to evalute the effectiveness of till sampling as a gold exploration method in the Casa Berardi area. Gold and arsenic anomalies related to the Golden Pond zone are found mainly in heavy mineral concentrates of the lower till that lines the bedrock depression in which the mineralization occurs. These anomalies occur south of the known mineralization and constitute a classical glacial dispersion train. Most of the till gold grains are very fine (50-150 microns). The gold grains in the till 100 m south of the Golden Pond zone are delicate while the majority of those encountered 400 m to the south are either irregular or abraded indicating greater transport.

Following the success of the orientation survey, till sampling was used as a screening tool to evaluate geophysical and/or stratigraphic targets east and west of the Golden Pond zone prior to diamond drilling. During the initial sampling program in early 1984, targets were commonly tested at intevals of either 300 m or 400 m along strike and 25 m to 100 m down-ice. Closer spaced sampling was undertaken to further define anomalous dispersion trains prior to diamond drilling. Two reverse circulation holes drilled 300 m apart in April 1984 to test the continuation of the Golden Pond geophysical anomaly encountered an anomalous gold-arsenopyrite dispersion train 2.5 km to the east. Follow-up till sampling in June 1984 further defined the anomalous dispersion train. The heavy mineral concentrate from the basal till sample of a hole 100 m east of the earlier anomalous hole contained approximately 700 very delicate gold grains, mostly in the 50 to 100 micron size range, and was concluded to be at source. Diamond drilling in July 1984 confirmed the existence of the Golden Pond East Zone.

GEOCHEMICAL EXPLORATION FOR KIMBERLITES IN CHINA

Shao, Yue and Liu Ji Min

Geochemical orientation surveys were carried out around some known kimberlite occurrences in Liaoning and Shandong. The purpose of the study is: (1) the selection of indicator elements for kimberlite exploration; (2) the study of element zoning in kimberlite pipes in order to evaluate the erosion level and productivity of kimberlte pipes; and (3) the search for techniques to detect blind kimberlite pipes.

Stream sediment anomalies for Cr, Ni, La, Nb, Zr, Y, and Yb occur up to 2.5 km downstream from kimberlite occurrences and have a contrast of 2-17. These elements can be used as pathfinders in regional stream sediment surveys to delineate favorable broad targets for kimberlites.

Analysis of kimberlite samples taken from cross-cuts at different levels indicated that multiplicative values can be used to evaluate the level of erosion of kimberlite pipes. As the productive diamond zone is often located in the upper-middle part of kimberlite pipes, it may be possible to use the rare earth zoning pattern to evaluate the productivity of kimberlite outcrops and thus determine if the productive zone has been eroded or not.

Discriminant analysis was used to discriminate between kimberlitic breccia and non-kimberlitic breccia using Hg, As, Sb, Y, and Yb as parameters. Several unclassified breccia pipes were tested by this method, and four of them were discriminated as kimberlitic breccia. Small veins of kimberlite were discovered after trenching two of these breccias, indicating probable kimberlite pipes at depth.

A SURVEY OF THE HEAVY METAL POLLUTION IN THE BOTTOM SEDIMENTS AT PORTO DI BAGNOLI,NAPLES, ITALY

W.E. Sharp and G. Nardi

During the past decade the pollution of the Mediterranean sea has become of considerable concern among the nations that border it. Each year the sea must absorb intolerable amounts of sewage with associated detergents, pesticides, mercury, chromium, lead, zinc and petroleum products. As a specific test case, the sea bottom just off shore from the large industrial complex at Porto di Bagnoli (7 km west of Naples) was selected for investigation.

Chemical analyses on 40 cores using standard exploration-geochemical methods were carried out for the heavy metals: Zn, Cu, Pb, Ag, Ni, Co, Cd, Cr, As and Hg on sediment at the bottom interface. Anomalously high values were found for all of the heavy metals and the median values for Zn, Pb, Ag, Cd, and As were several times above the average for marine shale. A correlation analysis showed two major suites of elements associated with each other consisting of Pb-Cd-Zn-As-Co-Ag and a secondary suite of Ni-Cr-Co-Ag. The chemical data for the elements Pb, Zn, and Cd were sufficiently numerous and showed sufficient continuity that contour maps were constructed. The pattern for these three elements are conformable and highs are positioned between two 'pontile' jutting into the bay. A comparison with observed grain size showed no direct relationship between sediment type and the heavy metal content.

The highest values were found in samples taken with depth in 2 of 4 selected cores with maximum values occurring near a depth of 26 cm. From an estimated average rate of sedimentation of 0.4 cm/year, this would yield a date of 65 years ago for the period of maximum heavy metal deposition. The sedimentation rate was based on the occurrence of an oil layer at widely scattered sites at a depth of 13 to 19 cm which is taken to have been deposited in 1942-43.

Although it is clear that a major source of the heavy metals is from pollution at the industrial complex at Porto di Bagnoli the elevated median values observed suggest it is still possible that there is a natural component as a result of heavy metals from metalliferous hydrothermal solutions flowing into the Gulf of Pozzuoli. The area investigated is situated along the edge of an ancient caldera known as the Phlegrean fields which is still the site of many active fumeroles, and the nearby town of Pozzuoli has been shaken in recent years by a renewal of earthquake activity postulated to be related to magma movement.

DISPERSION OF GOLD IN GLACIAL TILL ASSOCIATED WITH GOLD MINERALIZATION IN THE CANADIAN SHIELD

G.S. Shelp and I. Nichol

The results described relate to an investigation into the nature of gold dispersion in glacial till as a basis for identifying optimum search techniques for use in exploration for gold mineralization.

The diversity of gold mineralization, in terms of the host rock lithologies, mineralogy and grain size of the gold would be expected to give rise to a variation in the secondary response in the associated overburden. Common exploration procedures involve the analyses of the heavy mineral fraction or a particular size fraction of the tills. However, having regard to the expected variable response of gold in associated glacial till, attributed to variations in primary mineralization, effective exploration requires that the methodology employed be capable of locating all types of gold mineralization.

Bulk till samples were collected from various sites associated with the Owl Creek deposit near Timmins and the Hemlo deposits. Grain size analyses were carried out on the till samples and on the heavy mineral concentrates. The concentration of the gold in the various fractions was determined by Instrumental Neutron Activation Analysis.

Preliminary results allow a number of provisional conclusions to be drawn.

Grain size analysis of the -2 mm fraction of tills indicates that the silt and clay fraction constitute 20-50% of that fraction. In contrast, grain size analyses of the equivalent heavy mineral concentrates indicates them to be dominantly composed of -500 +63 µm material, in other words biased towards the coarser fractions of the till, suggesting the heavy mineral concentrate is unsuited to the detection of fine grained gold deposits in cases where the gold occurs as liberated particles.

The proportion of the total gold of till samples recovered in the heavy mineral concentrate ranges from 4-13%. Examination of the size distribution of gold within the heavy mineral concentrate indicates that 86-99% of the gold is contained in the -500 µm fractions with increasing proportions of gold with decreasing grain size, suggesting that the recovery of the -2 mm +500 µm heavy mineral fraction makes little contribution to the total gold content.

Considering the partitioning of gold between equivalent size fractions of the heavy mineral concentrate and light mineral fraction, there is a marked preferential concentration of the gold in the coarse to intermediate fraction of the heavy mineral fraction but a poor separation in the -63 µm fractions. In the latter case often equal contents of gold may occur in the heavy and light mineral fractions showing essentially no preferential concentration of gold in the heavy mineral fraction. This suggests that the heavy mineral concentrate does not provide a good measure of the gold contained in the -63 µm fraction.

Comparison of duplicate heavy mineral concentrates obtained by the same laboratory and different laboratories indicate a high level of reproductibility.

The concentration factor (the original sample weight divided by the heavy mineral concentrate weight) varies up to seven fold between samles due presumably to the differing proportions of heavy minerals. This situation gives rise to varying gold contents in heavy mineral concentrates, related to gold deposits of equivalent economic significance, according to the quantity of heavy minerals present. More significant interpretation can be achieved by re-expressing the gold contents of heavy mineral concentrates in terms of the gold content of the original sample.

Analyses of the silt and clay size fraction indicates anomalous gold contents within this fraction of the tills collected from Owl Creek and Hemlo, extending over 500 m down-ice from mineralization at Hemlo. Analyses of the silt and clay size fraction is suitable for the detection of fine grained gold deposits that are not amenable to detection on the basis of heavy mineral concentrate analyses. Additionally, analysis of the silt and clay fraction reduces the sample representativity problems associated with analysing coarser fractions.

In conclusion, although the results are based on relatively few samples, their consistency permits some general conclusions to be drawn. The silt and heavy mineral concentrate analyses provide different information and in view of the diversity of exploration targets and surface environments exploration reliability can be increased by analysing both the silt and clay fraction and the heavy mineral concentrate.

Future work will be directed towards:

1) Substantiating the validity of the preliminary results by analysing more samples from different ore deposit types and with varying spatial relationship to mineralization,

2) Investigating the mineralogical mode of occurrence of gold in silt-sized fractions,

3) Examining the representivity of samples collected by a variety of drilling system and ways of improving the representivity of samples collected using these different systems, and

4) Examining ways of improving the reliability that can be attached to interpretation of gold analyses of heavy mineral concentrates.

THE GEOCHEMISTRY OF RESIDUAL SOILS AS AN AID TO GEOLOGICAL MAPPING AND MINERAL EXPLORATION: A STATISTICAL APPROACH

A. Shepherd, P.K. Harvey and R.C. Leake

The Lizard Peninsula in south Cornwall has been an area of great geological interest and controversy for the last 75 years. The Lizard Complex consists of an assemblage of serpentinites (originally harzburgitic and lherzolitic periodotites), gabbro, amphibolites, basic dykes, metasediments and gneisses covering an area of some 100 km^2.

Due to problems of cliff access and an almost total lack of exposure inland nearly all of the previous work has been concentrated along only about half of the 43 km of coastal exposure. The interpretation of the inland geology has been based largely on mapping by the British Geological Survey prior to 1912, with minor revisions Flett (1946), which was based largely on float identification. Though gravels of exotic origin were recognized at the time as capping the topographically highest part of the Complex, recent soil sampling and deep power augerinng has shown that the gravels are more widespread than previously thought and that, in a significant area at least, surface boulders upon which some mapping was based are of a transported rather than residual origin. This clearly undermines the basis of the original interpretation of the geology.

Following work initiated by the BGS in the mid-late 1970's, which led to the discovery in inland drillholes of a previously unrecognized cumulate complex (Leake and Styles, 1984), it was decided to approach the problem of mapping the inland area using the geochemistry of the largely residual soils of the area to identify in detail the underlying lithologies and to assess their mineral potential. This contribution discusses the success of this approach. The following comments are based on the analysis of some 2500 rock and soil samples analysed by XRF for 24 elements.

A training set of 261 soil and 232 rock samples were taken from areas of 'undisputed' geology immediately adjacent to coastal exposures. Using the geochemical data from these samples a classification scheme has been established which allows the identification of over a dozen mappable units. Using the same set of soil samples as a test set, fewer than 2% of the samples are misclassified. This classification procedure was then applied to samples from selected inland areas for mapping purposes. At approximately 250 sites it was possible to check the geological predictions from the soil samples directly against material obtained from the base of power auger holes (average 4.6 m deep into rotted bedrock). At these sites agreement was found to be excellent, and often at variance with that which could be deduced from nearby surface boulders.

As some of the geochemical differences between units can be small a classification scheme was required which would enable the recognition of not only gross differences such as that between ultramafic and gabbroic rocks but also between different varieties of each. For this, no single classificatory strategy is adequate in itself, and as such an identification algorithm had to be developed to take this into account. In this algorithm each succesive stage involves a binary decision, the result of which may either identify the sample or pass it onto the next appropriate stage until it has been identified or declared as unidentified. The binary decision may be based on a variety of classification stategies using a combination of empirical and statistical techniques as described below:

a) Simple discriminants (e.g. Cr >500 ppm) giving a true or false answer,

b) Linear discriminant function, and

c) A non-hierachical K-means clustering technique (modified after MacQueen, 1967).

This has resulted in a package of interactive computer programs and subroutines for use on a minicomputer that have the following features:

a) The ability to be used easily for more than one classification task, all the classificatory control parameters being held in a single file. The latter, which has a Direct Access structure, has in each record all the information required for one decision making stage, and is easily edited, and

b) Capability to handle large numbers of samples. All the data for the unidentified samples are held in one or more computer files on a standard format.

The most distinct units are removed from the scheme at an early stage. These include samples reflecting minor superimposed base-metal vein mineralization which may affect the classification at a later stage with their anomalous contents of such elements as Cu, Pb and Zn, or the recognition of soil developed over the ultramafic rocks (characteristically high Cr, Ni, Co). The latter could then be further separated into a harzburgitic or lherzolitic group OB with a linear discrimination function. Those samples which are less distinct chemically would accordingly take longer to identify and as a final stage of treatment are separated using a K-means subroutine using seed centroids for all the 'known' groups. This subroutine also has the ability to identify an 'unknown' group by using a maximum permitted value of distance between the seed centroid and sample centroid.

This approach to mapping has already allowed several major revisions to be made to the established geological map and structural interpretation of the Complex and the recognition of units which do not outcrop in coastal sections. This is especially the case for the rocks of gabbroic composition which are far more complex and variable than is apparent from the coastal outcrop. At least three major gabbroic units have currently been identified. This new geological insight into the Complex has enabled a much more effective appraisal of its mineral potential than was hitherto possible.

As a reconnaissance tool the mapping and data treatment techniques described can be of general use in delineating both lithologies and areas favourable for mineralization (in poorly exposed ground) prior to subsurface investigations by geophysics or drilling. Furthermore, it is clear that non-parametric statistical techniques could usefully play a more important role in the treatment of exploration related multi-element geochemical data. Their advantages include, no requirement for normality or many of the other assumptions made for parametric statistical methods, the need for relatively little computer storage space (a serious problem with hierachical clustering algorithms), and their rapidity.

THE USE OF PEATLANDS IN GEOCHEMICAL EXPLORATION

W. Shotyk

Peatlands are an important feature of the earth's surface, covering 450 x 106^6 ha or approximately 3% of the earth's land area. Canada contains 170 x 10^6 ha of peatlands; corresponding to approximately 17% of the surface area of the country. The chemistry of these soggy environments needs to be better understood if explorationists are to use them to their advantage.

Although there have been reports of very high concentrations of metals in some peats, not all peat deposits are good metal scavengers. Ombrotrophic Sphagnum bogs receive their inorganic inputs entirely from atmospheric deposition. Clearly, sampling the surface layers of these peatlands would be useless as far as exploration is concerned. The lag zone surrounding these bogs and their basinal peat layers are both fed by local groundwaters; collecting samples from these areas would be more useful. Minerotrophic peat deposits such as fens, marshes and swamps receive most of their inorganic inputs from local groundwaters; these peatland types could be utilized successfully in exploration programs.

In this study the four major classes of peatlands are described: bogs, fens, marshes and swamps. The vegetational ecology of each is described in an effort to help explorationists recognize the different peatland types. In addition, the chemistry of the peatland waters is described (pH, DOC, anions, major cations) and the implications of this for metal solubility (Cr, Mn, U) is discussed. Finally, the chemical composition (ash, Cr, Cu, Fe, Mn, Ni, Pb, U, V and Zn) of bog peats (poorly decomposed Sphagnum) is compared with that of fen peats (well decomposed Carex).

EXPLORATION FOR MISSISSIPPI-VALLEY TYPE STRATABOUND Zn-Pb ORES WITH STREAM SUSPENSATES AND ASSOCIATED SEDIMENTS

F.R. Siegel

Suspended sediments were collected from stream waters, together with equivalent active sediments, from western and eastern stream bottoms at 84 sites bordering a ridge with the Bowers-Campbell Zn-Pb mineralization, Rockingham County, Virginia (USA), to evaluate the relative effectiveness of suspended and bottom sediment in the geochemical exploration for stratabound Mississippi Valley type Zn-Pb ores. The orebody is composed of sphalerite, pyrite stringers, and minor amounts of galena with some chalcopyrite, strikes parallel to the enclosing dolomite beds at N34°E, and cuts vertically across the 30°SE dip. Oxidation of the ore extends to about 100 m.

Zn was effective in detecting the mineralized zone, and Zn in the suspensates provided a denser anomaly cluster (seven strong and two moderate anomalies) than Zn in the -100 mesh size fraction of bottom sediment, either as total Zn or that extracted with cold 3% HCl. Suspensate Zn had a 700 m dispersion downstream from the mineralized zone and was complemented by suspensate Cu. Pb was detected only in the cold acid extraction. In combination with Pb, Cu and Zn presented an extensive overlapping cluster of multielement anomalies that pinpointed the ore zone and had a downstream dispersion of 1500 m. The Pb cluster extended latitudinally about 900 m upstream and 400 m downstream of the known mineralization. All of these anomalies are located along the eastern side of the cited ridge. The extension of cold acid extractable Pb anomalies upstream from known mineralization, abetted somewhat by suspensate Zn anomalies, suggests that the mineralization projects to the NE along strike and gives a target for detailed exploration. The drainage along the western border of the ridge has comparatively few anomalies and lacks the clustering found to the east.

The concentration of anomalies in the eastern drainage and anomaly disposition with respect to known mineralization result from structural control on the hydromorphic dispersion of metals from the orebody. This structural geology influence is further emphasized if eastern and western drainages are treated as two populations. Higher metal concentrations occur in the eastern drainage samples, and frequency distributions reinforce the structural geology influence. These are asymmetrical positive, and generally biomodal or polymodal; this results from integrating the eastern and western populations, and a third population from the mineralization. Correlation coefficients indicate that element association in the mineralization and adsorption (after hydromorphic dispersion into the stream system) are the factors that influence interelement relationships in the samples.

GEOCHEMICAL SURVEY FOR PRIMARY TIN DEPOSITS IN THE BATU GAJAH-TANJONG TUALANG AREA, PERAK, MALAYSIA

T. Sirinawin, W.K. Fletcher, P.E. Dousset and Z. Hj Husin

Despite the fact that cassiterite was found in polysulphide and greisen-bordered veins on the western flank of the famous Kinta Valley, little attention was paid to this by the miners. However, depletion of the alluvial deposits has increased the focus on exploration for primary tin deposits. The Southeast Asia Tin Research and Development (SEATRAD) Centre in cooperation with the Geological Survey of Malaysia have been conducting geochemical surveys in the Batu Gajah-Tanjong Tualang area, Perak, to access the tin potential of this area.

The area approximately 60 km^2 south of Ipoh, is located in the southwestern part of the Northern Kinta Valley. It is underlain by Carboniferous metasediments consisting mainly of schist and minor metaquartzite. The Changat Kantan-Tronoh-Tanjong Tualang granitic mass occurs to the west and south of the undulating terrain of metasedimentary rock.

Drainage sediments and heavy mineral concentrates were collected at an average sample density of 6 km were also collected. Samples were then analyzed for tin, tungsten, arsenic, copper, lead, zinc and iron in -80 mesh fraction. Results indicate that two tin anomalous areas occur in the south part of Batu Gajah and Jeta Estate, Tanjung Tualang. Tin anomalies coincidently occur with those of arsenic, lead, zinc and copper. Notably low contents of tungsten are observed throughout the area. Highly significant amounts of cassiterite in the heavy mineral concentrates are supported by geochemical drainage results.

Follow-up grid soil sampling with 80 m by 20 m spacing was conducted at the Jeta Estate anomaly. Samples were analyzed for tin the -80 mesh and -28+65 mesh fraction. Size analyses of bulk soil samples indicate that more than 70 percent of the tin is confined to the coarse size fraction (>300 u). Greater contrast between anomaly and background is obtained by using -28+65 mesh results.

More detailed work is required to prove the occurrence of tin mineralization in this area. However, it is concluded at this stage that multi-element geochemical drainage surveys using arsenic, lead, zinc and copper as the pathfinders in conjunction with heavy mineral concentrates can define target area. Close spacing follow-up soil sampling using tin in -28+65 mesh fraction should adequately localize tin anomalies.

GEOCHEMICAL STUDIES IN THE INDIAN PASS AND PACACHO PEAK BUREAU OF LAND MANAGEMENT WILDERNESS STUDY AREAS, IMPERIAL COUNTY, SOUTHERN CALIFORNIA

D.R. Smith, B.R. Berger, R.M. Tosdal and G.L. Raines

The U.S. Geological Survey has conducted geochemical studies in the Indian Pass (124 km^2) and Picacho Peak (23 km^2) Wilderness Study Areas (WSA's) as part of a program to evaluate the mineral resource potential of designated areas in the California Desert Conservation Area. These two WSA's are of particular interest because they lie within a region which has inntermittently produced significant quantities of gold since the mid-1800's and is currently the site of much exploration activity for additional gold resources. Within a 15-km radius of the WSA's, there is one actively producing gold mine, a major deposit scheduled for open-pit operation in 1985, and one recently announced discovery.

A reconnaissance geochemical survey was conducted in the two WSA's using minus-80-mesh stream sediments, heavy-mineral concentrates from stream sediments, and rocks as sample media. LANDSAT images were used to map the generalized distribution of limonitic materials as a guide to hydrothermal alteration and rock samples were collected from areas of observed alteration.

We identified two regions of interest within the WSA's using multiple element anomalies in heavy-mineral concentrates. The first region is characterized by anomalous W, Bi, Cu, Pb, and Mo. The region is underlain primarily by the Mesozoic Orocopia Schist which has been intruded by monzogranite of Oligocene age. Alteration and mineralization seem to be localized near the intrusive contact. The mineralized rock at the surface contains secondary Cu and Fe minerals where the monogranite intrudes the meta-basite horizons of the Orocopia Schist and scheelite where the monzogranite intrudes marble within the Orocopia Schist.

The second region defined by analysis of heavy-mineral concentates is characterized by anomalous As, Sb,Ba, B, and Sr. Geologically, this region is underlain by metasedimentary and metavolcanic rocks of Jurassic(?) age; a biotite monzogranite of Jurassic(?) age; and Tertiary volcanic and hypabyssal rocks composed of flows, domes, and tuffs of intermediate to silicic compositions. All these rock types are cut by a set of north-south striking normal faults. The anomalies in the heavy-mineral concentrates are believed to be related to silica-clay alteration observed in the vicinity of some of these faults.

A third region of interest is that underlain by a gneiss of Precambrian(?) and Mesozoic age that composes the upper plate of the Chocolate Mountains thrust. Samples of this rock show anomalous values of Au, Ag, As, Hg, W, and Te.

RELATIONSHIP OF FLUID INCLUSION GEOCHEMISTRY TO WALLROCK ALTERATION AND LITHGEOCHEMICAL ZONATION AT THE HOLLINGER-MCINTYRE GOLD DEPOSIT, PORCUPINE DISTRICT, CANADA

E.J. Smith, S.E. Kesler and E. Van Hees

Gas chromatographic analyses of fluid inclusions in quartz-carbonate veins from the Hollinger-McIntyre gold deposit indicate that the mineralizing fluid was a H_2O-CO_2 mixture. Locally, CH_4-rich fluid inclusions are associated with veins that occur in graphitic and/or carbonaceous wallrocks. Fluid inclusions in ore bearing veins have higher CO_2 contents than those in non-ore veins. Extensive sampling and analyses of veins from a 1 x 2 km area surrounding the deposit reveals a well developed zonation of CO_2 contents about the main zone of mineralization. Low CO_2 levels (1-2 mole %) in veins are peripheral to the deposit and increase to over 12 mole % in mineralized zones.

Wallrock alteration patterns are also well developed around the ore zone. Carbonate alteration assemblages in the mafic metavolcanic host rocks, proceeding inward from background greenschist facies rocks to alteration envelopes enclosing individual veins, consist of: 1) quartz-albite-chlorite-epidote-actinolite-(calcite), to 2) quartz-albite-chlorite-calcite-epidote, to 3) quartz-albite-chlorite-ankerite, and to 4) quartz-albite-ankerite-sericite. These assemblages resulted from the addition of CO_2 to the wallrock, which is consistent with the observed zoning of CO_2 in the fluid inclusions. Lithogeochemical zoning is observed as variations in whole rock abundances of As, Au, Ba, Rb, and Sb. The most useful zoning patterns are provided by As and Ba, which outline individual ore zones as well as broader trends of mineralization.

The results of this study indicate that fluid inclusion gas haloes are at least as large as the broadest elemental haloes that surround the Hollinger-McIntyre deposit. Gas haloes such as these should be useful in evaluting areas with scattered outcrops containing veins of unknown potential, particularly in view of the fact that the gas content of the inclusions will be much more homogeneously distributed throughout the veins than will be Au values.

SOME CONCEPTUAL MODELS FOR GEOCHEMISTRY IN AREAS OF PREGLACIAL DEEP WEATHERING

R.E. Smith

In some glaciated regions around the world weathered mantles, inheritances from previous climatic regimes, were not always eroded bare by glacial activity but instead lie buried. Probably the most prominent early example in the literature is Goldich's (1938) study of rock-weathering in a lateritic region (late Cretaceous weathering) in Minnosota, from locations along the banks of the entrenched Minnesota River. This deeply weathered mantle occurs throughout much of western Minnesota where the highly prospective Superior Province is buried beneath up to 200 m of glacial sediments. Recently reference has been made to other areas of deep weathering lying beneath glacials: northern Lapland, parts of the USSR, and areas of arctic Canada (Shilts, 1984; Shilts and Salminen, 1984).

It is obviously important that expectations for geochemical exploration in such terrain take into account some of the unique regolith features, and the purpose of this paper is to attempt some first ideas. It draws upon experience in geochemical exploration in deeply weathered terrain in Australia as well as some observations in U.S.A.

In order to assess glacial situations of this sort one needs first to look at the characteristics of geochemical targets in deeply weathered terrain. The ultimate target for exploration, the mineral deposit, is commonly separated from the most easily collected (surface or near-surface) sample media by a saprolitic zone of weathered bedrock. This tends to lower the contrast of many geochemical anomalies. Whilst there is no doubt that weathering creates problems to explorationists it can also create some relatively large dispersion anomalies, and certain of these need to be assessed for relevance to glaciated regions.

Duricrust anomalies. Some of the largest geochemical haloes about mineral deposits in weathered terrain owe their origin to accumulation and dispersion on duricrusts related to peneplain formation. Smith et al., (1985) describe a duricrust anomaly that exceeds 200 km^2 in area. More usual types are smaller, nevertheless many exceed 20 km^2 in area. Where they have been investigated these anomalies are seen to have resulted from several processes: elements dispersed hydromorphically and then trapped in goethite, mechanical dispersion of goethite with any enclosed elements, and mechanical dispersion of elements in resistate minerals. The best known geochemical anomalies in duricrusts are those recognized in orientation studies about concealed mineral deposits. However, recent research suggests that primary leakage haloes, also recognizable in duricrust geochemistry, might yield targets some 10 or 20 km long. Clearly more needs to be known about them.

Secondary anomalies after source beds. Several people including Boyle (1979) have proposed that certain marine metal-rich shale and tuff units represent deposition in situations analogous to present-day "black smokers" and may represent ancient source beds for hyrothermal polymetallic sulphide/Au deposits. These units would form targets as long as the strike of the weakly mineralized source beds, sometimes perhaps tens of kilometres long. In a duricrust situation across-strike dispersion could lead to anomalies 2 or 3 km wide.

Three conceptual models are considered where glacial action infringes upon deeply weathered terrain. The critical factor in each is the depth of truncation of the weathering profile. All three models are clearly dynamic systems and, in reality, a wide range of intermediate situations must be expected.

Model 1 shows a complete weathering profile buried beneath glacial till, the weathering profile being largely undisturbed. The key characteristic is preservation of the duricrust cap, frequently a part consolidated quasi-residual blanket which may contain areally large (20-200 km^2) but thin (1-10 m) geochemical anomalies). The most efficient geochemical exploration could be based upon wide-spaced overburden drilling directed at sampling the duricrust. For reconnaissance, holes could be based upon a 1 km grid where targets are stratabound massive polymetallic sulphide/Au deposits. Alternatively wider spacing could be tried where larger targets are expected. It would be critical firstly that the duricrust be sufficiently continuous to allow a reasonable success rate in sampling, and secondly that the duricrust be recognizable in drill spoil.

Model 2 is characterized by a weathered profile that was partly stripped prior to glaciation. The essential feature is a vertically zoned saprolite profile, leached high in the weathering profile and likely to contain enrichments of leachable elements lower down. Any gossans would show strong vertical zonation. Direct drilling for relatively large targets in saprolite could be considered, for example where till is thin, but the range of suitable intermediate targets in saprolite would be small. Examples would be the detection of weathered primary haloes or secondary haloes about gossans. Such intermediate targets would seldom have dimensions greater than about 200 m x 500 m. Gossans themselves could be targets but this would require more intensive drilling. Most geochemical techniques developed for use with saprolite drilling in weathered terrain would be appropriate. Rock type identification could be difficult and techniques such as that described by Hallberg (1984) could prove useful. Gossan recognition and discrimination techniques such as those of Taylor and Scott (1982) and Smith, et al., (1983) would be important. Alternatively geochemical dispersion patterns in till could be sought. Important sources for such dispersion are likely to be enriched gossans where erosion has cut deep into the profile, zones of supergene enrichment of ore deposits, and supergene ore deposits themselves. Sources likely to be weak and therefore would provide very poor till dispersion trains would be leached gossans, weathered primary haloes, and secondary haloes in saprolite. Furthermore in many situations saprolite under glacials would be too soft to provide the boulders so important in conventional till prospecting.

The essential ingredient in **Model** 3 is continued and progressive glacial planing away of the weathering profile. Thus any halo in duricrust is first dispersed, followed by dispersion of progresively deeper levels of saprolite. If taken deep enough the supergene enriched zone of a mineral deposit could add to the glacial dispersion. A broadly zoned anomaly would be expected. Distally the anomaly would be characterized by elements from the former duricrust anomaly, proximal to the source one could expect elements more characteristic of supergene zones. Basal till geochemistry is expected to be suitable. A broad element suite would be needed to provide appropriate information over the likely distal to proximal range. Where saprolite stripping is deep, interpretation of till geochemistry should focus upon elements characteristic of subsurface enriched gossans.

A regolith situation of deep weathering covered by glacial sediments obviously poses an extreme challenge to the exploration geochemist. Nevertheless some rationale can be applied. The intensity of weathering and the nature of any duricrust need be assessed, also the degree and variabilty of stripping. Where preservation allows it, probing for duricrust geochemistry beneath the glacials probably offers the most appropriate methodology. Where glacial cover is thin much of the progress in saprolite geochemistry in Australia should be applied. Research directed at identifying dispersion trains in till must assimilate the common features and characteristics caused by having a deeply weathered mantle as the intermediary between the till sample and the sought mineral deposit.

DISPERSION INTO SURFACE LATERITIC OVERBURDEN FROM THE GREENBUSHES MINERALIZED Sn-Ta PEGMATITE SYSTEM, WESTERN AUSTRALIA

R.E. Smith, J.L. Perdrix and J.M. Davis

A study of dispersion into lateritic overburden in the Archaean Greenbushes mineralized pegmatite district reveals a geochemical anomaly that measures some 20 km by 12 km centered on the ore deposits that prior to commencement of mining operations were concealed. The anomaly is broadest for As, Sb and Sn, all of which show well-defined centres over the swarm of mineralized pegmatites. Coincident highs of Nb, Ta and Be also define the 5 km by 1 km anomaly centre. Over the strongest part of the multi-element anomaly the following levels in ppm are reached in the pisolitic laterite: As 1150, Sb 75, Sn 4200, Nb 75, Ta 75, Li 100 and Be 40. Anomaly contrast in terms of the ratio of anomaly shoulder to regional background are as follows (with the peak to background ratios in brackets): As 27(65), Sb 12(75), Sb 12(75), Sn 100(240), Nb 3(6), Ta 40(75), Li 40(100) and Be 10(20).

The immediate source for the dispersion anomaly is a swarm of soft, weathered pegmatites, most of which occur within a 5 km by 1 km area, elongated along strike. The source, as judged from past production plus soft pegmatite reserves, was a mass of some 30 to 40 million tonnes with an approximate average grade of 220 ppm Sn, 25 ppm Nb and 30 ppm Ta. (Drilling reveals higher grades than this at depth).

The medium used for sampling was the surface duricrust. At many sites this consists of partly cemented pisolites and nodules and at other sites loose pisolites and nodules. One-kilogram samples were taken for crushing and analysis with a separate 1 kg sample being kept uncrushed for reference. Preference was given to pisolites and nodules in the size range 1 cm to 2 cm; these were hand picked over a radius of about 5 cm to 10 cm on the ground. In the initial orientation, samples were collected along roads and access tracks at intervals of 1 km, expanding to 3 km intervals away from the central pegmatite swarm. This irregular-spaced sampling on a 1 km triangular grid pattern, but some distortion of the grid was allowed for ease of collection.

The lateritic duricrust is developed on a gently undulating peneplain, loosely ascribed to the Tertiary, with general elevations ranging from 240 m to 310 m. In places post-Tertiary incision by the main river to depths of 150 m beneath the peneplain has stripped the lateritic duricrust from part of the landscape. The pisolitic and nodular layer of the duricrust typically is visible at surface on the peneplain. Alternatively it may be covered generally by less than a metre of sandy or loamy soil. Where the lateritic duricrust is soil covered sufficient access to the sample medium was generally provided around tree trunks as a result of upward soil heave during growth, or by collecting in ground disturbed by uprooted trees resulting from forestry activity or natural phenomena.

A belt of relatively resistant amphibolite hosts the pegmatite swarm at Greenbushes and has resulted in a culmination of the duricrust surface. The raised topographic expression and resulting slopes have favoured wide dispersion.

The climate of the area is characterized by warm summers (average February maximum of $30^{\circ}C$, minimum of $13^{\circ}C$), cool winters (average August maximum of $15^{\circ}C$ and minimum of $4^{\circ}C$) with an average rainfall of 953 mm consisting of very regular winter falls. Part of the area retains its indigenous forest vegetation consisting of tall stands of jarrah (*Eucalyptus marginata*), karri (*E. diversicolour*), marri (*E. calophylla*) and banksia (*Banksia grandis*). The remaining part of the area has been for mixed farming, or in the immediate vicinity of Greenbushes, cleared for mining activities.

The geochemical expression of the multi-element anomaly can conveniently be expressed in a map of pegmatite associated elements. For example, the index PEG-4 uses a weighted linear combination as follows: 0.09xAs + 1.33xSb + Sn + 0.14xGa + 0.4xW + 0.6xNb + Ta (where values for each element are in ppm). The multiplication factors result in a weighting designed to convert strengths of each element to a similar numerical value. Another useful index, particularly for proximity predictions, has been one which sums the number of anomalous elements, based on the premise/observation that as mineralization is approached the number of anomalous elments frequently increases.

Predictions for gross bedrock characteritics have been made by observing and manipulating the abundances of Ti, Cr, V and Zr in the lateritic duricrust.

Investigation of dispersion processes shows that mechanical dispersion of cassiterite and columbo-tantalite took place during laterite formation along gradients ranging from 5 m to 20 m per km for distances of 15 km. The occurrence of anomalous As in the skins of pisolites indicates hydromorphic dispersion during laterite formation, but mechanical dispersion of goethitic material with scavenged As has also taken place.

The size of the geochemical dispersion anomaly, together with its contrast and consistency, shows that is is feasible to explore for concealed mineral deposits using low-density surface sampling. Sample spacings of 1 km and 3 km are being tested in an extension of this approach to exploration.

OVERBURDEN GEOCHEMISTRY RELATED TO THE SISSON BROOK, NEW BRUNSWICK, W-Cu-Mo MINERALIZATION: AN EXAMPLE OF SHORT AND LONG DISTANCE GLACIAL DISPERSION

R.J. Snow and W.B. Coker

During 1982 and 1983 a surficial geology and overburden geochemistry survey was carried out on the Sisson Brook Mining Licence. The property is located in York County about 55 km northwest of Fredericton, New Brunswick, Canada.

On the Sisson Brook Mining Licence, W-Mo-Cu mineralization occurs in quartz veins, as disseminations adjacent to quartz veins in metasedimentary, and metagabbroic bedrock. Three zones of mineralization have been outlined; Zones I and II contain mainly wolframite with chalcopyrite and pyrrhotite, whereas Zone III has mainly scheelite and molybdenite.

The glacial history of the area was studied during 1982 and 1983 to provide a framework for interpreting the geochemical results. A review of the available literature, till fabric analysis, pebble lithologies, glacial sediment characteristics and airphoto interpretation of landforms were employed. Backhoe and hand-dug excavations were used to examine the overburden. Ice movement varied from $160^{\circ} \pm 10^{\circ}$ towards the south during the Main Bantalor phase (hiatus ≈13,500 years BP) to $130^{\circ} \pm 10^{\circ}$ toward the southeast during the Late Bantalor phase. Rapid changes in dominant pebble lithologies occur immediately upon crossing bedrock contacts. This suggests a very short distance of transport *on* the property. The glacier, butted against the Nashwaak Ridge, quickly sheared bedrock debris up into the body of the ice by compressive flow. Upon melting, most of this debris was deposited a short distance from source. Some debris appears to have been sheared up higher into the ice sheet, transported over the Nashwaak Ridge, and deposited approximately 8 km down-ice with no interconnecting dispersal train. The tills in the study area cover a wide spectrum of genetic classes which reflect their complex depositional history in subglacial, supraglacial and ice marginal environments.

In 1982, a geochemical orientation survey was carried out to determine the most informative elements and sample medium which could be most economically used in the search for W-Mo-Cu mineralization. Fifteen backhoe trenches and 9 hand-dug pits were excavated. Soil horizons and glacial sediments were sampled, and three size fractions ($<2000\ \mu m \geq 80\ \mu m$, $<80\ \mu m \geq 75\ \mu m$, and $<75\ \mu m$) were analyzed for Cu, Pb, Zn, Ni, Ag, Mo and Fe (HNO_3/HCl digestion, atomic absorption spectrophotometry); As (colourimetry); F (ion-selective electrode); W (fusion and colourimetry); Sn (X-ray fluorescence) and Bi (HNO_3 digestion, atomic absorption spectrophotometry). Heavy mineral concentrates (specific gravity >3.3) were prepared and similarly analyzed for all glacial sediment selected soil samples.

Within the property area, both whole tills and heavy mineral concentrates defined the zones of mineralization (W, Mo, Cu) and associated geochemical dispersion trains (W, Mo, Cu, As, F). In later work samples were not analyzed for As and F because they provided no additional information. The geochemical contrast between values in whole till samples derived from subcropping mineralization and those derived from barren bedrock is adequate to outline mineralization. Geochemical analysis of the whole till was used in later work because the sample preparation costs are considerably lower than those for heavy mineral concentrates. Trace element patterns were diffuse in soils, with the highest values occurring at variable distances down-ice from mineralization.

In 1983, the overburden in 43 backhoe trenches was sampled and studied. The objective was to define glacial dispersion from the known mineralization and to explore for additional mineralization. Whole tills were sieved to <2000 µm, ground to <75 µm and analyzed for Cu, Mo and W. Data from this survey indicate a dispersal train 300 to 400 metres long. Tungsten values up to 1400 ppm and Mo values up to 260 ppm in whole till occur immediately down-ice from the main subcropping W-Mo mineralization. The element associations (i.e. W-Mo and W-Mo-Cu) in the till reflect the elemental composition of the source mineralization (i.e. Zone III and Zones I and II).

Backhoe trenching is a useful and cost effective technique to expose Quaternary sediments. Examination of the overburden sections provides an understanding of the glacial history which aids in tracing geochemical dispersal trains up-ice to their bedrock sources. In this case, whole till geochemistry was adequate for the follow-up survey, and the additional cost of preparing heavy mineral concentrates was unnecessary. Orientation surveys should be used to determine the optimum geochemical, and most effective, sample medium before studying glacial dispersion from subcropping W mineralization. Similar orientation surveys would also be useful in areas with anomalous W located by reconnaissance overburden or stream sediment heavy mineral concentrate surveys.

ANOMALY RECOGNITION FOR MULTI-ELEMENT GEOCHEMICAL DATA: A BACKGROUND CHARACTERIZATION APPROACH

C.R. Stanley and A.J. Sinclair

Modern analytical techniques rapidly producing multiple element determinations for geochemical samples have forced geochemists to consider only a few relevant pathfinder elements, and rarely allow them the opportunity to interpret the data from a multivariate perspective.

The 'Background Characterization Approach' to anomaly recognition allows the geochemist to, both, focus his attention on the pathfinder elements and utilize the remaining elements in the data set to recognize the anomalous samples. It involves characterizing the multi-element geochemical signature of the background population and recognizes as anomalous those samples which differ from this signature.

Many geochemical surveys result in samples from several anomalous populations related to different types of mineralization, anomaly dispersion mechanisms, and/or contamination sources. Likewise, geochemical surveys might contain samples from several background populations, generally related to the underlying lithology, sample type, and/or local chemical environment. Grouping the data set based on these primary background criteria creates subsets which ideally contain a single background population, and an unknown number of anomalous populations.

In the simple bimodal case, a subset is partitioned into two populations comprised of three concentration ranges (background, mixed, and anomalous) using a probability plot analysis. Samples from the purely anomalous or background groups are of known classification, whereas samples from the mixed group (the zone of overlap of the anomalous and background populations) are not easily classifiable. A regression function of a pathfinder element against all other elements in the data set is then calculated for the background group. When applied to mixed group samples, those from the high tail of the background population will, theoretically, have small 'residuals' (the analyzed concentration minus the concentration predicted by the regression function), while those from the anomalous population will have large 'residuals' (their different multi-element geochemical signature will react differently to the regression function). Consequently, samples from the zone of population overlap can be classified by comparing them to the 'average' background signature.

This approach offers advantages over traditional anomaly recognition techniques, in that it 1) does not impose arbitrary thresholds, 2) will not automatically define a proportion of samples as anomalous if no anomalies are present, 3) removes ambiguity by discriminating anomalous from background samples in the mixed group, 4) allows recognition of multiple anomalous populations (their different multi-element geochemical signatures will each react differently to the regression equation), and 5) leads to ranking of anomalies based on the understanding of signature similarities among anomalous samples.

An example of the 'Background Characterization Approach' to anomaly recognition is presented for regional stream sediment data over a part of the Belt Supergroup in Western Montana.

TEMPORAL VARIATION OF METAL CONCENTRATIONS IN BIOGEOCHEMICAL SAMPLES OVER A MINERALIZED COMPLEX IN THE BRECKENRIDGE MINING DISTRICT, SUMMIT COUNTY, COLORADO, U.S.A.

J.D. Stednick, R.B. Klem and W.C. Riese

This study investigated temporal variations of elemental concentrations in lodgepole pine (Pinus contorta Dougl. ex. Loud.). Samples of lodgepole pine needles, twigs, and wood were collected every two months for six sampling periods, May 1983 to May 1984, at sixty-five points at 15-meter intervals along a transect line.

The study area was the Royal Tiger Mine in the Breckenridge Mining District of Colorado, U.S.A. The mine workings are were located within a fault-bounded breccia complex which is well mineralized with Cu, Pb, Zn, Au, Ag, and Bi. The mineralization consisted of pyrite, galena, sphalerite, pyrrhotite, galenobismutite, chalcopyrite, and native gold. The transect line extended over the complex, into unmineralized areas to the east. The mine workings provided underground geologic control. Soil chemistry was related to the underlying geology.

Wood samples ranged from 0.2 ppb to 9.5 ppb Au, while needle and twig samples ranged from <0.3 ppb to 200 and 900 ppb respectively. The highest Au concentrations were measured in the fall of each year. The Au anomalies, as measured by Au concentrations, were identified in less than half the sampling periods. Au concentrations in needles were consistently lower, but parallel Au concentrations in the twigs.

Cu concentrations in wood samples ranged from <0.5 to 8 ppm and no coherent anomalies were identified. Concentrations of Cu in needles and twigs consistently identified coherent anomalies.

Concentrations of Zn in wood, needle, and twig samples consistently indicated the location of anomalous concentrations, although peak concentrations themselves varied over time. Cu and Zn concentrations in needle samples paralleled twig samples.

Mo, Pb, and Ag concentrations were low in soil samples and in all plant organ samples. No coherent anomalies were identified.

This study identified certain metal translocation phenomena as evidenced by metal concentration changes. The processes regulating this translocation need to be identified and applied to other plant species to increase the utility of biogeochemical sampling.

GEOCHEMICAL MAPPING AND PROSPECTING IN GREENLAND: A REVIEW OF RESULTS AND EXPERIENCE

A. Steenfelt

Reconnaissance and regional geochemical surveys based on stream sediment and stream water have been carried out by the Geological Survey of Greenland in various parts of Greenland over the past 10 years. The areas covered represent a wide variety of geological environments and present considerable differences in physiographic conditions. The surveys comprise low density sampling (1 sample per 20 to 30 km^2)in Archean gneiss terrain in West Greenland and in the North Greenland Paleozoic platform and fold belt. In East and South Greenland regional multielement surveys were conducted as part of uranium exploration programmes. In addition various prospects and anomalies have been sampled in detail, and the dispersion of elements in stream sediment, stream water, soil, and aquatic moss is currently being studied in new areas.

The conditions for geochemical dispersion in North and Northeast Greenland are comparable with those of desert terrains. The streams flow periodically and the weathering and transportation are predominantly mechanical. The dispersion trains are rather short, and depend on topography and the flow rate. Variations in the chemical composition of stream sediment at a sample site can be considerable. The terrain of West and South Greenland resembles Scotland and northern Scandinavia. A thin cover of morainic drift supports a low vegetation, and the influence of ground water and organic matter in the dispersion processes is noticed to a varying degree.

The low density and regional stream sediment surveys show that the geochemistry of the Archean differs considerable from that of the Proterozoic mobile belt. In the Archean a NE-SW trending region display elevated contents of incompatible elements and this may indicate a significant change in crustal level. Two carbonatite complexes in the Archean are displayed by high Nb and Sr in the low density sampling. The caledonides of East Greenland compare geochemically well with similar geological environments in Scotland. The geochemical survey in the Proterozoic belt in South Greenland proved the existence of a uranium province and the significant addition to the crust of alkaline magmas is clearly expressed in the geochemical pattern.

A study of sample materials shows that aquatic moss has a great potential as a sampling medium, as indicated by a test in a uranium district. The aquatic moss is also capable of taking up gold and base metals, and these results are being evaluated.

The Geological Survey of Greenland intends to continue geochemical mapping in North and West Greenland by low density sampling of stream sediment and stream water. The experience from Greenland, and particularly from the comprehensive geochemical mapping of northern Norway, Sweden and Finland (the Nordkalott Project), will be used during the statistical treatment and interpretation of the results.

EXPLORATION GEOCHEMISTRY IN ACTIVE ALPINE-GLACIATED REGIONS: A STUDY OF THE TRIDENT AND SUSITNA GLACIERS IN CENTRAL ALASKA

G.C. Stephens, E.B. Evenson and D.E. Detra

In mountainous regions containing extensive glacier systems there is a dearth of suitable material for conventional geochemical sampling. Soils and vegetation are patchy or non-existent and streams are ephemeral and confined to ice margins. Access for bedrock sampling is difficult, time consuming and expensive. In most geochemical sampling programs, stream sediment samples are collected from, or near, the terminus of each valley glacier. At best, these samples represent mixtures of glacial and non-glacial debris. As an alternative a new technique for systematically sampling the medial moraines of valley glaciers for geochemical exploration has been developed. Moraine sampling provides geochemical information which is site-specific and which can be related to particular bedrock sources. Additionally, systematic examination of pebbles, cobbles and boulders in each medial moraine provides information about lithologies, visible mineralization, hydrothermal alteration and minor structural features.

Medial moraines form as rock debris falls from a valley wall onto the edge of a tributary glacier and is then transported by normal glacier flow. At the point where two tributary glaciers meet, their two adjacent lateral moraines merge to become a single compound medial moraine. Because the ice moves by nearly perfect laminar flow, each medial morain retains its characteristic geochemical and lithologic identity for several kilometers, until melting and ablation become pronounced near the glacier terminus.

In practice the proposed technique is quite simple, a single traverse is made across the glacier to collect fine-grained geochemical samples. In addition, fifty pebbles are collected at each sample site for archival purposes and fifty boulders are examined and described. These size fractions yield valuable information about the nature and abundance of lithologies present in the catchment area, the extent and nature of visible mineralization, the presence and intensity of hydrothermal alteration as well as the existence of veins, dikes, and other minor structural features. Each medial moraine can be traced back to its bedrock source on aerial photographs. Therefore, if the field examination reveals visible mineralization, or if the geochemical analysis reveals anomalously high metal contents, the corresponding bedrock source can be accurately located and additional follow-up studies conducted. By integrating the lithologic, mineralogic and geochemical data the probable geologic setting of the anomaly can be determined and a morain-based geologic map can be compiled. Results from Alaska demonstrate that this new technique provides a means for the rapid and accurate evaluation of the resource potential of actively-glaciated, mountainous regions.

GOLD EXPLORATION IN DEEP GLACIATED OVERBURDEN: EXPERIENCES FROM THE BELORE CASE HISTORY

I. Thomson, J.G. Burns and F.H. Faulkner

Since 1982 Placer Development Limited (as operator) and Belore Mines Ltd. have been exploring in McCool Township, 100 km east of Timmins, Ontario, where the favourable geologic stratigraphy lies beneath a sand plain on the east flank of the Munro Esker. From the inception of the project the search has been for gold mineralization blind beneath a cover of thick glacial sediments.

Detailed ground magnetics and VLF electro magnetics were applied initially to provide information on bedrock structure and stratigraphy. Diamond drilling, undertaken to quantify the geological understanding, unexpectedly encountered high grade gold mineralization in a narrow quartz vein. Further drilling failed to prove any extension to this occurrence but did serve to confirm confidence in the geological potential of the area. Following a review of available options, deep overburden geochemical sampling using reverse circulation rotary drilling was selected for systematic evaluation of the property.

Two phases of deep overburden sampling have been completed, these reveal anomalous concentrations of gold scattered in two till sheets beneath up to 80 m of glaciofluvial sands and silts. Mineralogical and multielement chemical analysis of heavy mineral concentrates prepared from till samples have permitted recognition of discrete trains from sub-outcropping mineralization. Problems with logging and sampling the glacial sediments, sample preparation, analysis and interpretation were encountered and experience gained in confronting these difficulties is described.

Reliable identification and classification of glacial sediments from the wet slurry returned in reverse circulation rotary drilling is usually difficult and sometimes impossible. Nevertheless, recognition of the two till sheets illustrates the importance of conscientiously logging the drill sections. Accurate topographic control is necessary to resolve relationships in the glacial sediments. Mapping of the bedrock topography is essential since ice movement, and hence the orientation of glacial dispersion fans, was found to be strongly influenced by local bedrock ridges.

Stratigraphic sampling of glacial till was confirmed as being the only satisfactory technique since it permits genetic interpretation of anomaly patterns. Possible loss of fine gold with the overflow from the returning water circulation remains an unresolved question.

Gold analysis by conventional techniques was found to be unsuitable. Determination of gold abundance by direct neutron activation analysis of the entire heavy mineral concntrate and simultaneous calculation of the abundance based on the dimensions of visible gold grains was found to be essential and provided a powerful interpretive technique. Observation of the size, frequency and morphology of the free gold grains gave additional criteria for interpretation.

Samples of bedrock chips recovered from each drill hole were used in a systematic lithogeochemical study. Lithogeochemical classification of the rocks provided a framework for geological mapping which could then be used for the extrapolation of ground geophysical data. Patterns of carbonate alteration, and potassium and trace element enrichment suggesting the presence of geochemical aureoles around mineralization were identified. The destruction of magnetite during carbonatization, recognized in the chemistry of the drill cuttings, could be traced in the ground magnetics.

Follow-up diamond drilling of targets defined by anomalous gold dispersion trains in the till and qualified by the lithogeochemical study has led to the discovery of gold mineralization in bedrock in several settings.

Applied properly, systematic deep overburden geochemical sampling is a powerful, cost effective technique for gold exploration in glaciated parts of Canada and Europe.

EXPLORATION FOR GOLD IN THE HUMID TROPICS

Tooms, J.S.

Exploration for hard-rock gold deposits has been undertaken by the United Nations Revolving Fund for Natural Resources Exploration (UNRFNRE) in a considerable number of countries. This paper summarizes the experience gained in areas of tropical rain forest in northern South America and in West Africa and is illustrated by results from Suriname and Liberia in particular. In the presentation, data being accumulated in Sierra Leone will also be used to illustrate conclusions.

Reconnaissance prospecting has been mainly by visually estimating the gold content of heavy mineral concentrates prepared by panning. Gold was detected in samples collected both from the sediment/bedrock interface and from active stream sediments. Potentially significant bedrock gold mineralization, both in Liberia and Suriname, gave rise to appreciable quantities of gold in the active stream sediments downstream from the sources, as well as in the basal (bedrock interface) gravels. Minor mineralization, particularly in Suriname, was associated with gold in the gravels at the bedrock interface downstream, but with only minor erratically detectable gold in the active stream sediments. It is concluded that the amount of gold in the basal gravels is controlled by the environmental setting, including the nature of the bedrock surface, stream energy, and the history of the sediment, i.e., the amount of reworking and the length of time the sediment has remained at the site, as well as to the grade and size of gold deposits being (or having been) eroded higher in the catchment area. The gold content of the active sediments is related, in particular, to the grade and size of mineralizations currently shedding gold and their location relative to the streams, but obviously will also be affected by reworking of auriferous alluvium and stream sediments.

Comparative studies have also been undertaken of prospecting by panning stream sediment and by analyzing the stream sediment fines (-80 mesh fraction). Gold mineralized zones crossed by a number of streams are generally outlined by both methods. However, results at individual sites, not uncommonly, are highly divergent, e.g. where much gold is recovered in the pan only background quantities of gold may be recorded by analysis of the -80 mesh fraction of sediment and vice versa. These observations appear to apply irrespective of whether or not the gold is associated with quartz veins (Suriname). Even when the gold in the source is most probably very fine grained (Liberia) abnormally large amounts of gold are typically recovered in the pan (e.g., more than 250 particles per four pans). It is suggested that during lateritization, much of the gold accumulated in the soil, at or close to the B/C horizon gradational interface, will tend to be in pan recoverable particles. Erosion of this horizon will give rise to anomalous concentrations of gold particles in the streams detectable by panning surveys.

Limited trials of broad scale reconnaissance soil sampling (200 x 1000 m), similar to that applied in French Guyana were not considered to be cost effective in the Fund's exploration areas compared with stream sediment sampling (panning or screening and analysis). Apart from the cost of the survey the methodology is based on the assumption of a wide primary or secondary dispersion, and all anomalies, including single point very weak anomalies, should be investigated. Furthermore, unless the direction of strike of mineralization controls (veins, strata outcrops) are known and consideration is given to the effect of topography, etc., ground will still be eliminated with only a low degree of confidence.

Investigations of areas indicated as of potential by stream sediment panning or analysis has been dominantly by soil sampling. Dispersion patterns from discovered auriferous quartz veins in Suriname are widest and strongest in the surfaces oil (0-2 cm) on hill slopes. This is considered to reflect sheet wash dispersion and the elutriation of light fines from the surface leaving a concentration of heavy fines. At the base of slopes no systematic difference is noted in the gold content at surface and at 30 cm depth, presumably due to accommodation of colluvium and mixing.

Trials of loaming of the soils (in Suriname) gave very variable results and the maximum number of gold particles (or weight of gold) was not indicative of bedrock sources exposed in trenches. The reason for these poor results was not established, and only soil analyses were utilized in both areas.

Sources potentially exploitable, e.g., >1 m wide quartz veins carrying >10g/t of gold over economically significant strike lengths in Suriname, gave rise to broad zones of highly anomalous gold in the soils. Both in Suriname and Liberia there are extensive homogeneous areas where the content of the soils exceed 1000 ppb Au.

Minor gold mineralization occurring, for example, as auriferous quartz pods or stringers, gave rise to low magnitude anomalies or isolated erratic high values, albeit sometimes well exceeding 1000 ppb Au.

In Liberia the most homogeneous and highest magnitude soil anomalies were demonstrated by trenching the overlying strongly weathered and lateritized metavolcanics (?) containing broad zones assaying ca. 2 g/t (2000 ppb). Little quartz is observed in the auriferous zones and occasional quartz veinlets in the bedrock are not associated with higher gold values. The consistency of the gold values and their repeatability would suggest that the gold is dominantly very fine grained, but this has not been tested. In the general vicinity of these weathered bedrock gold sources there are, in places, numerous large indurated laterite (duricrust) blocks. High gold values are not associated, in general, with these duricrust remnants. Whilst there may have been some leaching and redeposition of gold during soil (laterite) formation this is unlikely to have been a major factor in determining the grade of gold in the residuum.

In Suriname there is some evidence of gold enrichment below or at the base of the duricrust in areas of gold mineralization. However, the evidence is inconclusive.

Although successful methodologies have been established a number of problems remain. Outstanding are: (i) determining the magnitude of secondary accumulations of gold from economically insignificant bedrock sources in the B/C horizons of laterites, and (ii) rapid (low cost) recognition of let down anomalies and anomalies related to mineralization in long since captured (by other rivers) catchments.

VASTANA-JARKVISSLE Sn-Li OCCURRENCE FOUND BY REGIONAL GRID SAMPLING OF HEAVY-MINERAL TILL CONCENTRATES IN NORTHERN CENTRAL SWEDEN

O. Toverud

Regional prospecting for tin in Sweden by LKAB Prospektering has, since the early 1980's, been based on the use of heavy-mineral concentrates from till. The sampling density, using roadside sampling, has been 0.5-1.0 sample/km^2 with an uneven distribution of sample points within the areas investigated.

The dispersal of tin in heavy-mineral till concentrates in northern central Sweden can be expected to occur for at least 1500 m, over a width of 200-400 m, down-ice from a known mineralization. On the basis of this, the design of the regional sampling grid in this study has been based on a statistical analysis to answer the following question: What sample density and grid-spacng should be used to recognize and intersect the anomalous target with a probability greater than 95%.

The statistical analysis indicates that using a rectangular grid, 750 x 1500 m (0.88 sample/km^2), the probability of intersecting an anomalous target is 100%. Heavy-mineral till concentrate sampling using this grid design in northern central Sweden in 1981 gave one single, extremely high, sample with 4662 ppm Sn in the area north of the village of Jarkvissle.

In 1982-1983, while boulder tracing up-ice from the anomalous sample point, cassiterite- and spodumene-bearing boulders and outcrops were found. Two parallel mineralized pegmatites with grades of 0.04-0.07 % Sn and 0.40-0.92 % Li_2O have recently been located northwest of Jarkvissle within an area of approximately 5000 mi^2.

Semi-regional (250 x 500 m) sampling of till in 1982 up-ice from the anomalous regional sample point yielded only one sample with a high lithium value close to one of the mineralized outcrops. However, anomalous lithium and tin values were obtained further to the north in the direction of strike (north-south) from the known mineralization.

Local (20 x 20 - 160 m) sampling of till in 1983 by percussion drilling south of the mineralized pegmatites gave anomalous values of tin and lithium in both surface and basal till samples. These samples can be correlated with the occurrence of some mineralized boulders, and one of the mineralized outcrops.

A simplified technique for preparing the mineral concentrates (from the local sampling) has been tested. Conventional techniques for separating the heavy, non-magnetic, fraction sometimes give too small a yield of material, and sophisticated enrichment techniques involve high sample preparation costs. The new method is based on a mechanical enrichment of the heavy-minerals from till using a rotary automatic panning device named the Goldhound.

The test results obtained from the samples collected in this tin and lithium mineralized area in northern central Sweden, indicate that the sample preparation of till using the Goldhound device gives a sufficient amount of material and an enrichment of cassiterite and spodumene in the final heavy fraction. The equipment can thus be recommended for use in future geochemical prospecting for tin and lithium ores in Sweden.

GEOCHEMICAL ALTERATION ASSOCIATED WITH THE SELBAIE COPPER-ZINC-SILVER DEPOSIT

J.B. Whyte and I. Nichol

The Selbaie copper-zinc-silver deposit, in northwestern Quebec, is atypical of base metal deposits in the Canadian Shield as mineralization occurs in epigenetic veins and disseminations in volcanic wall rocks rather than in massive stratiform bodies. The object of this study was to identify patterns of primary lithogeochemical dispersion in the wall rocks of the A1 and A2 zones of the deposit, and to ascertain whether bedrock geochemistry could be applied in exploration for deposits of this type.

The deposit comprises three mineralized zones in felsic tuffs and quartz porphyry. The A1 and A2 zones consist of quartz-carbonate veins, which carry chalcopyrite, sphalerite, and pyrite, and accesory sulphide minerals. The B zone consists of lens-like quartz-carbonate veins, which carry chalcopyrite, sphalerite, chalcocite, pyrite, and accessory minerals.

Drill core from sections crossing the A1 and A2 zones was sampled. Samples were analyzed for total Si, Al, Fe, Mg, Ca, Na, K, Ti, Mn, P and S by X-ray fluorescence and for aqua-regia extractable Cu, Zn, Ni, Pb, Fe and Mn by atomic absorption.

Distribution of individual element concentrations showed that rocks close to mineralization have higher SiO_2, Fe_2O_3, Cu, Zn, Fe and S contents, and lower Al_2O_3 and K_2O contents, than rocks more distant from the zones. MgO content shows an irregular distribution and may also increase toward mineralization. CaO and Na_2O contents are very low in all pyroclastic rocks.

Bedrock type appeared to have a considerable effect on the distribution of most elements so in order to estimate the effect of rock type on the distribution of elements, linear regression was performed on a set of analyses from the least altered samples, to predict normal concentrations of elements based on concentration of SiO_2. Spatial distributions of residual values of element concentration, (measured minus predicted concentrations) indicated that rocks close to mineralization had higher residual Fe_2O_3, Cu, Zn, Pb and Fe contents, and lower residual Al_2O_3 and K_2O contents, compared to the least altered rocks.

In view of the indicated enhancement or depletion of certain elements around mineralization discriminant analysis was used to identify the optimum combination of elements that could be used to define a larger exploration target. Various discriminant functions were calculated, and it was found that SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O and extractable Zn, Ni, Pb and Fe were helpful in discriminating the most altered rocks from the least altered. Areal distributions of discriminant scores outlined an anomalous area up to 200 m beyond the ore zone and thereby represented a more extensive exploration target than the deposit.

Petrographic studies of selected samples identified high SiO_2 and low Al_2O_3 content with silicification in the most altered rocks. Fe_2O_3, MgO and extractable Fe concentration were found to be linked to abundance of chlorite and carbonate. Sulphides were thought to be the principal carriers of S, Cu, Zn and Pb and subsidiary carriers of iron. Sericitization appears to result from increases in Al_2O_3 and K_2O concentration relative to SiO_2 concentration.

On this basis bedrock geochemistry demonstrates that anomalously high or low concentrations of element associations, revealed by discriminant analysis, occur in large coherent zones exceeding the size of the deposit itself and are potentially very useful as exploration guides.

COMPARISON OF GEOCHEMICAL MAPS GENERATED BY LABORATORIES USING DIFFERENT ANALYTICAL METHODS

Xie Xuejing, Wang Ji Ping and Zhu Bao Guo

Five laboratories in China joined in a project to analyze stream sediment samples from a 1:100,000 map region (more than 1600 km^2) in Guangdong. The purpose of this project was to examine the similarity or dissimilarity of geochemical maps generated by laboratories using different analytical methods and their bearings on the interpretation of regional geochemical trends and local anomalies.

This project is part of the efforts to maintain the consistency of geochemical data which are and will be obtained by so many laboratories using diversified analytical methods over the long span of some ten years in China's Regional Geochemistry-National Reconnaissance Project (RGNR Project).

The data for 24 elements in each map area were obtained by using emission spectrographic, ICP quantometric, X-Ray spectrometric, atomic absorption, atomic fluorescence, colorimetric and polarographic methods were resolved into regional (background trends) and local (anomalous) components. The background and anomalous patterns on each map and also on a reference map constructed by averaging the data from the five laboratories (outliers were deleted) are compared. The results are very encouraging, and the consistency of regional trends is anomalies are better than expected.

Overall map similarity and geographical setting, intensity and dimension of anomalies were studied by comparing various parameters, including overall correlation coefficient, map mean, map coefficient of variation, average log deviation from recommended values of GSD standard samples, drift of "center of gravity" of anomalies and normalized areal productivity (NAP). The conclusion drawn from these studies is the same as with visual comparison of map components.

Similarity of Ag, Be, Co, La, Nb, P, Y, Zn and Zr maps was inferior when comparised with 13 other element maps. Some significant anomalies on reference maps were absent on certain laboratory maps. All these are worthy of further studies.

GEOCHEMISTRY OF THE GRANITE SERIES AND GOLD DEPOSITS ON THE EASTERN MARGIN OF THE CHINESE NORTHERN PLATFORM

Zou Zurong

The eastern margin of Chinese Northern Platform includes the east on parts of Liaoning Province and Shandong Province and the area east to the Tancheng-Lujiang Fault, and constitutes a mobilizated platform. Archean and Lower Proterozoic metamorphic rocks and granitoids developed widely and igneous activity occurred on a large scale at the end of the Paleozoic and Mesozoic Eras, resulting in three series:

1. Hercynian and India-China series: comprising of gneissic, medium grained, equigranular biotite- and biotite-muscovite-granites, which crop out as large and medium sized plutons an abundance of metamorphic rock enclaves in the border parts. The U-Pb ages are often disconcordant. Age-dating gives ages of about 250-150 m.a. Petrochemistry varies slightly; high Si (SiO_2 70-75%), Al oversaturated, $K_2O \geq Na_2O$, high Al (Al_2O_3 17-19%), and low Mg biotites are characteristic. The plutons were formed from low melting-point granite magma and had deep emplacement in company with the formation of many pegmatites and some migmatization of the surrounding rocks. Their trace element character is as follows: medium Rb/Sr ratio (0.3-0.5); low content of Fe grade transition elements; Ni 2-4 ppm; Cr 10 ppm; positive Eu; and low REE (around 100 ppm). The petrochemistry and trace elements of the migmatites varys with the degree of migmatization and the character of the surrounding rocks.

2. Yanshan series: comprising a diorite-grandiorite-biotite granites, which outcrops over several tens to several hundreds kilometers and contains many very fine grained diorite enclaves. U-Pb age-dating is nearly concordant, 120-160 m.a. The magma had a highly fractioned character with SiO_2 varying from 58-73%, following a calc-alkaline evolutional trend. The biotite has low Al (Al_2O_3 13-14.5%), high TiO_2 (>5%) and a relative higher Mg/Fe ratio. Numerous phenocrysts of potash feldspar occur in some plutons. The geochemistry of Rb, Sr, Ba, Fe group transition elements, and REE (250-75 ppm) of the whole rock and single minerals proves that this series has the characteristics of a deep source, highly fractionated, higher level emplacement. The plutons are accompanied by numerous diorite porphyrite, granite porphyry and lamprophyre dykes.

3. Later Yanshan series: comprising a single feldspar alkaline granite series present as small plutons. The U-Pb age is quite concordant, 116 m.a. The series is characterized by high Na perthite (NaO 5.3%, KO 6.64%), a high Rb/K ratio and low contents of Fe-group transition elements.

These three granitic series can be compared with S type, I type (Chappel, B.W. et al, 1977) and A type (Collins, W.J., 1982) granites. The evolutional process of the magma series indicates that this region was a rapidly elevated block the during Mesozoic Era.

The gold deposits can be related to the I type diorite-granodiorite- biotite granite series (deep source, calc-alkaline character). The REE geochemical study of pluton-dyke-ore veins proves this genetic relationship. The Cl activity of the calc-alkaline series is higher than that of the other series and is coincident with the higher Cl content of the mineralizing solutions (as indicated by the gas-liquid inclusions in the quartz in the gold veins). The elements in the ore bodies vary regularly with the distance between ore bodies and source rock. Variations of the S and Pb isotope composition shows that mixing feature of ore bodies increases with the distance from the source rock.

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