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IGES Welcome Message

On behalf of the Local Organising Committee for IGES2003 it gives me great pleasure to welcome you to the 21st biennial International Geochemical Exploration Symposium here at the University College campus in Dublin.

IGES is the principal platform for the AEG for the presentation and dissemination of discoveries, developments and the sharing of experiences in the field of geochemistry. Although founded as an association catering for the needs of the mineral exploration community, the AEG now embraces a much wider remit covering, for example, the fields of environmental geochemistry and the field of geochemistry in relation to human health.

With technical sessions, a trade exhibition, poster sessions, field trips, short courses and a vibrant social programme the Symposium will afford participants an opportunity to network, exchange ideas, open up collaborative ventures and develop partnerships. In addition, this year's Symposium is being run in conjunction with the 3rd North Atlantic Minerals Symposium (NAMS). NAMS is organised under the aegis of a Memorandum of Understanding between the Government of Ireland and the Government of Newfoundland and Labrador. The combination of the two meetings affords even greater opportunities for interaction among delegates.

I would like to take the opportunity to thank our sponsors for the Symposium, especially our Organising Sponsors: The Geological Survey of Ireland, The Department of Communications, Marine and Natural Resources (Republic of Ireland), The Geological Survey of Northern Ireland, The Department of Enterprise, Trade and Investment (Northern Ireland), The Environmental Protection Agency, The Irish Association for Economic Geology and our Gold Sponsors: Geosoft and AngloAmerican

I urge you to participate in all the elements of the Symposium. We hope you enjoy the hospitality that will be on offer, and wish you a very successful Symposium.

Gerry Stanley
Chairperson Local Organising Committee
IGES2003

NAMS Welcome Message

It gives us great pleasure to welcome all delegates to the third North Atlantic Minerals Symposium. NAMS has developed under the aegis of a Memorandum of Understanding between the Government of Ireland and the Government of Newfoundland and Labrador. The initiative is being led by the Geological Survey of Ireland, the Geological Survey of Newfoundland and Labrador, and the Exploration and Mining Division of the Department of the Communications, Marine and Natural Resources (Ireland).

With technical sessions, a trade exhibition, poster sessions, field trips, short course and a vibrant social programme, the Symposium will afford participants an opportunity to network, exchange ideas, open up collaborative ventures, and develop partnerships. In addition, this year's Symposium is being run at the same time as the 21st International Geochemical Exploration Symposium (IGES). IGES is the principal platform for the Association of Exploration Geochemists for the dissemination of developments in the field of exploration geochemistry.

At a time when the minerals sector is at a low in the economic cycle, it is heartening to note that there have been positive developments for the industry in both Ireland and Newfoundland. In Ireland Arcon have recently announced the discovery of a very high grade zinc deposit within 150m of their existing Galmoy mine. Also the Navan Mine (operated by Outokumpu Tara Mines) continues to add reserves to their SWEX zone while they are also in the process of developing the Nevinstown part of the orebody. In Newfoundland and Labrador development of the giant Voisey's Bay nickel orebody has commenced with production scheduled for 2006, and gold exploration in the Botwood Basin continues at a high pace.

We urge you to make the most of this opportunity and to participate in all the elements of the Symposium. We hope you enjoy the hospitality that will be on offer and wish you a very successful Symposium.

Gerry Stanley — Baxter Kean
Co-chairs, North Atlantic Minerals Symposium

IGES • NAMS Organising Committees

IGES Scientific Programme Committee: Gerry Stanley, Eibhlín Doyle, John Pyne, Tracey Minton

NAMS Scientific Programme Committee: Gerry Stanley, Andrew Kerr

IGES Organising Committee: Gerry Stanley (Chairperson), Eibhlín Doyle (Secretary), Jacqui Connolly, John Gowen (Treasurer), Ben Kennedy, Micheál MacCárthaigh, Frank McDermott, Miller O'Prey, John Pyne, Christian Schaffalitzky

NAMS Organising Committee: Gerry Stanley (Co-chair), Baxter Kean (Co-chair), Brian Breslin, Jacqui Connolly, Eibhlín Doyle, Andrew Kerr, John Pyne.

Exhibitors

The following companies and organisations are exhibiting at IGES • NAMS, 2003:

Activation Laboratories Ltd. (Actlabs) is recognized in the mineral exploration industry as one of the most innovative laboratories developing new geochemical technologies for the discovery of blind mineral deposits. Actlabs also excels at providing routine assaying and environmental analysis requirements. Actlabs is accredited to the ISO/IEC 17025 Quality System for specific registered tests.

Maxwell GeoServices is an independent consultancy of experienced geoscientists and IT professionals dedicated to providing information system and data management solutions to the mining and exploration industry. Our solutions are seamless and cost effective - incorporating database design and management,the Maxwell Database Models, training, auditing and recommendations.

Alcontrol
Operating from a new purpose built building in Ballycoolin, Dublin, our laboratory covers 8000sq ft, employs 25 staff and offers a full range of analysis of soils and groundwaters in line with IPC and EPA requirements. Our Chester laboratory (formerly Geochem) has over 30 years experience in Petroleum geochemistry and 15 years in

The **Newfoundland and Labrador Chamber of Mineral Resources** is a non-profit organization that represents the interests of all groups and individuals active in Newfoundland and Labrador's mineral industry. Its mandate is to foster the development of the mining industry throughout the province.

General Information

DUBLIN
Dublin, the capital of the Republic of Ireland, is increasingly the venue for a variety of international conferences. Today, it is a city of fine Georgian Buildings, excellent stores and shops, pubs and restaurants, museum and antique shops, all combining to make it one of the most enjoyable cities in Europe.

CONFERENCE VENUE
The conference will be held in University College Dublin, located about 6km from the city centre. This modern campus, surrounded by attractive landscaped gardens, is an ideal location for conferences with a large number of well equipped theatres. Also on campus are banking, travel agency, shopping, self-service laundry and extensive sporting facilities. The main symposia building is the Science Block. All areas are fully accessible by wheelchair.

SOCIAL AND EXCURSION DESK
Enquiries for the following should be made at the registration desk:
- General Information regarding the symposia
- Social events
- Daily Excursions

LUNCH
A light lunch of soup and sandwiches, tea/coffee will be served on campus in the main restaurant. Lunch on Tuesday will be off site at the Radisson Hotel. Coaching will be provided. This lunch is sponsored by the Department of Mines and Energy, Government of Newfoundland and Labrador.

SERVICES IN THE SCIENCE BLOCK
The following services are available in the Science Block:
- Photocopying
- Public Telephone
- Student Restaurant

BANK
There is a bank on campus (see map on page 6) for foreign exchange on Monday to Friday only. There is an automatic teller machine on site which can be accessed 24 hours a day.

SHOPPING
Dublin has a busy city centre shopping area around Grafton Street and across the river. In Henry Street there is a large range of products to bring home - from traditional Irish handmade crafts to international designer labels. Things to buy: woollen knits, tweeds, crystal, Claddagh rings, pottery, silver and music. Shopping hours are from 9.00am to 6.00pm Monday to Saturday, with shops open until 8.00pm on Thursdays, and most shops open from 12noon - 6pm on Sundays.

SMOKING POLICY
Smoking is only permitted in designated smoking areas.

MESSAGES
Urgent messages may be left on the message board at the registration desk

LIST OF DELEGATES
A list of registrants at the conference will be available at the registration desk.

TIPPING
At your discretion. In most hotels and restaurants, a service charge of 10-15% is added to your bill. A small tip is appreciated for good service. Tipping is not usual in pubs and bars. Tip cabs 10% and porters 60c per bag.

INSURANCE
The Conference Organising Committee or its agents, will not be responsible for any medical expenses, loss or accidents incurred during the symposia. Delegates are strongly advised to arrange their own personal insurance to cover medical and other expenses including accident or loss. Where a delegate has to cancel for medical reasons, the normal cancellation policy will apply. It is recommended that citizens from EU countries bring with them a current E111 form.

SPEAKER PREVIEW ROOM
The Speaker Preview Room is located at room 104, located off the Lower Concourse of the Science block. Your presentation must be handed in 4 hours in advance, during the tea/coffee break or at lunchtime to the technician in the room where you are presenting.

Social Programme

IGES WELCOME RECEPTION

Date: Thursday, 28th August, 2003
Venue: Conservatory, O'Reilly Hall, U.C.D.
Time: 18:00 - 19:30
A welcome reception of canapes and drinks will take place in the conservatory of the O'Reilly Hall, which will provide an opportunity for delegates to meet in a relaxed environment.

A TRADITIONAL IRISH NIGHT (OPTIONAL)

Date: Saturday, 30th August, 2003
Venue: The Old Jameson Distillery
(Please note change of venue from final announcement)
Coach: 19:00
Departure Point: Outside Merville Accommodation, UCD; Jurys Montrose; Radisson SAS St. Helen's Hotel.
Cost: €59.00. Tickets can be purchased at the registration desk.
A traditional Irish evening will take place at the world famous Old Jameson Distillery. Your evening begins with a drinks reception and guided tour of the distillery. Guests may also join a whiskey tasting session. This relaxed evening includes Irish music and contemporary "Riverdance" style dancing, paired with a delicious meal.
A cash bar will be available for beverages.

STATE RECEPTION

Date: Monday, 1st September, 2003
Venue: Dublin Castle, Dame Street
Time: 19:00 - 20:30
Coach: 18:30
Departure Point: Outside Merville Accommodation, UCD; Jurys Montrose; Radisson SAS St. Helen's Hotel.
John Browne, T.D., the Minister of State at the Departments of Communication, Marine and Natural Resources will host a reception in the historic State Apartments of Dublin Castle. Situated on an ancient Celtic Site, Dublin Castle was used by the British as the seat of government from the time of Elizabeth I until Irish independence.

LUNCH

Date: Tuesday, 2nd September, 2003
Venue: Radisson SAS St. Helen's Hotel
Time: 12:15 - 14.30
All delegates are invited to lunch kindly sponsored by Department of Mines and Energy, Government of Newfoundland and Labrador. Return transportation will be provided from UCD.

GALA DINNER

Date: Tuesday, 2nd September, 2003
Venue: The Dining Hall, Trinity College
Coach: 19:30
Departure Point: Outside Merville Accommodation, UCD; Jurys Montrose; Radisson SAS St. Helen's Hotel.
Cost: €79.00. Tickets can be purchased at the registration desk.
Situated in Trinity College, Dublin, located in the heart of the campus, the Dining Hall is one of the most prestigious venues in Dublin. Drinks before dinner will be served in the Atrium situated just to the left of the hall. The AEG Awards will take place at the Gala Dinner.

THEATRE NIGHT (OPTIONAL)

We would be delighted to make recommendations and bookings for the Theatre. Please contact the registration desk.

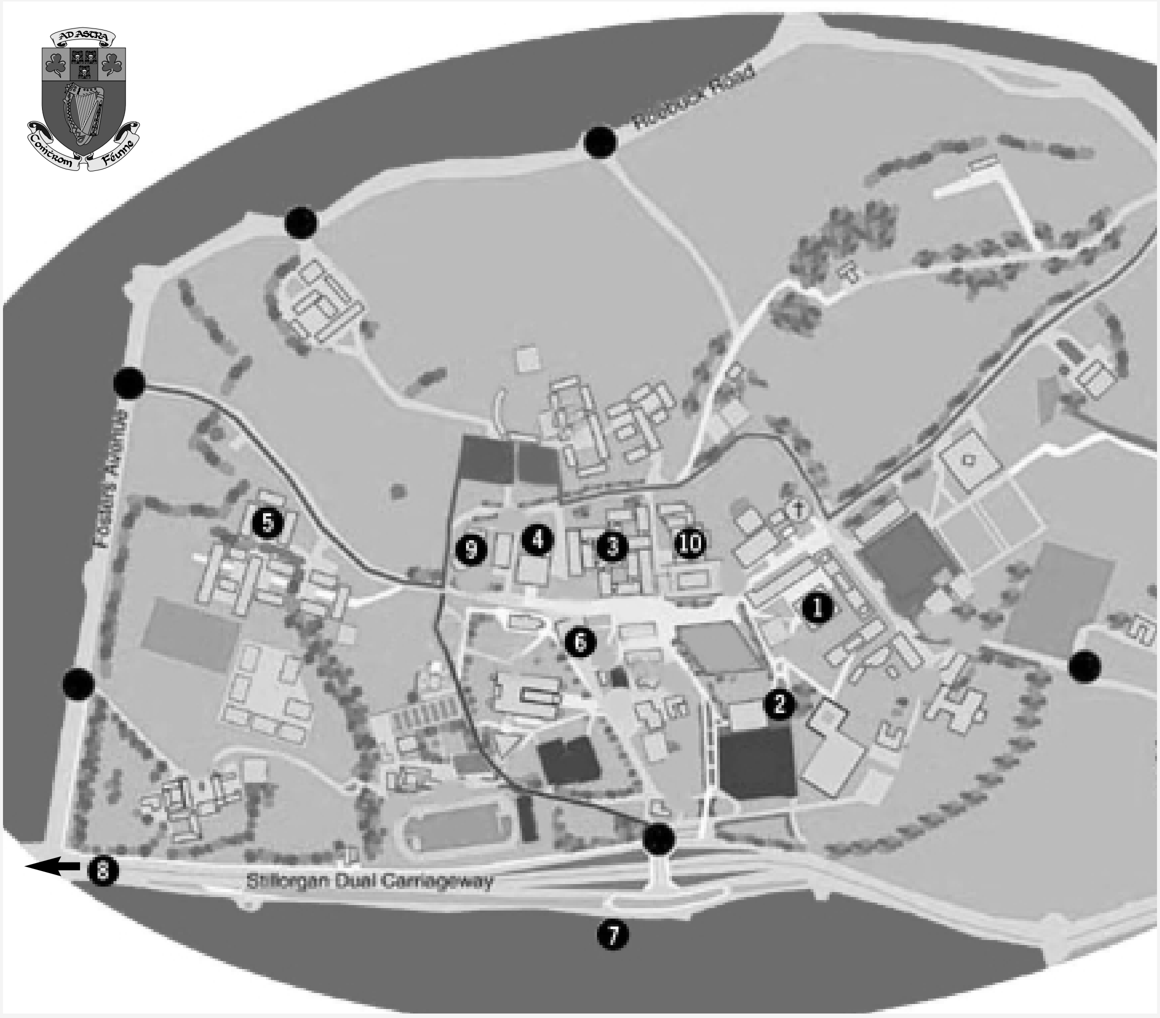
GOLF (OPTIONAL)

Conference Partners will be happy to book tee times at nearby golf courses as required.

POST CONFERENCE TOURS

If delegates require assistance in arranging post conference tours or accommodation please contact Conference Partners who will be happy to advise you and make necessary reservations.

Map of UCD and Conference Hotels



1. Science Block
2. O'Reilly Hall
3. Arts Block
4. Main restaurant for lunch
5. UCD Merville Accommodation & Shop
6. Bank
7. Jurys Montrose Hotel
8. This way to Radisson SAS St. Helen's Hotel
9. Bar
10. Travel Agent

IGES Programme at a Glance

Wednesday 27th August 2003			
09.30 – 17.30	Short course	Exploration for hidden deposits using geochemistry	Room 128
Thursday 28th August 2003			
09.30 – 17.30	Short course	Quality control in geochemical databases	Room 128
14.00 – 18.00	Registration		Upper Concourse
14.00 – 17.30	Short course	Metallogenic modelling as a basis for geochemical exploration	Room 129
18.00 – 19.30	Welcome reception		Conservatory, O'Reilly Hall
Friday 29th August 2003			
08.00 – all day	Registration		Upper Concourse
09.00 – 09.20	Official opening		Theatre A
09.20 – 11.00	Session 1	The future of geochemistry	Theatre A
11.00 – 11.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.30 – 12.50	Session 2	The role of geochemistry and geochemical engineering in mine site rehabilitation	Theatre A
12.50 – 14.00	Lunch		Restaurant
14.00 – 16.00	Session 3	Environmental geochemistry	Theatre A
16.00 – 16.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
16.00 – 17.30	Session 3 continued	Environmental geochemistry	Theatre A
Saturday 30th August 2003			
08.00 – all day	Registration		Upper Concourse
09.00 – 10.40	Session 4	Geochemical exploration in areas of previous mining and contamination	Theatre A
10.40 – 11.10	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.10 – 12.50	Session 5	Irish experiences	Theatre A
12.50 – 14.00	Lunch		Restaurant
14.00 – 16.00	Session 6	Modern geochemical techniques for exploration in glaciated terrains	Theatre A
16.00 – 16.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
16.00 – 17.30	Session 6 *continued*	Modern geochemical techniques for exploration in glaciated terrains	Theatre A
19.00 – late	Irish Night		Old Jameson's Distillery
Sunday 31st August 2003			
Free day			

IGES Programme at a Glance cont'd

Monday 1st September 2003			
08.00 – all day	Registration		Upper Concourse
08.40 – 11.00	Session 7	The use of indicator minerals in exploration	Theatre A
11.00 – 11.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.30 – 12.30	Keynote Address	Ross Large: Collaborative research and education ventures to assist the global exploration industry	Theatre A
12.30 – 14.00	Lunch		Restaurant
14.00 – 16.00	Session 8	The role of isotopes in geochemical exploration and environmental studies	Theatre A
16.00 – 16.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
16.30 – 17.30	AEG AGM		Theatre A
19.00 – 20.30	State Reception	Hosted by Mr. John Browne T.D. (Department of Communications, Marine and Natural Resources)	Dublin Castle
Tuesday 2nd September 2003			
08.00 – all day	Registration		Upper Concourse
09.00 – 11.00	Session 9	Hydrogeochemistry in the search for ore deposits	Theatre A
11.00 – 11.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.30 – 12.50	Session 10	Biogeochemistry in the search for ore deposits	Theatre A
12.50 – 14.30	Lunch	Hosted by Hon. Walter Noel, Minister for Mines and Energy (Newfoundland and Labrador)	SAS Radisson Hotel
14.30 – 16.10	Session 11	Lithogeochemistry in the search for ore deposits	Theatre A
16.10 – 16.40	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
16.00 – 18.00	Session 11 *continued*	Lithogeochemistry in the search for ore deposits	Theatre A
20.00 – late	Gala Dinner	Hosted by Mr. Noel Treacy (Department of Agriculture and Food)	Dining Hall, Trinity College
Wednesday 3rd September 2003			
08.00 – all day	Registration		Upper Concourse
09.00 – 10.40	Session 12	Developments in geochemical data processing and presentation	Theatre A
10.40 – 11.10	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.10 – 12.50	Session 13	Regional multi-element geochemistry	Theatre A
12.50 – 13.00	Official closing		Theatre A
Wednesday 3rd September to Saturday 6th September 2003			
	Field trip	The Irish carbonate hosted base metal mines.	
Thursday 4th September to Friday 5th September 2003			
9.30 – 17.30	Short Course	Hydrothermal geochemistry	Lecture theatre, Geological Survey of Ireland

NAMS Programme at a Glance

Saturday 30th August 2003

19.00 – late	Irish Night		Old Jameson's Distillery

Saturday 30th August to Sunday 31st August 2003

9.30 – 17.30	Short Course	The use of GIS in Mineral Potential Mapping	Lecture theatre, Geological Survey of Ireland

Monday 1st September 2003

08.00 – all day	Registration		Upper Concourse
09.00 – 09.20	Official Opening		Theatre C
09.20 – 11.00	Session 1	Challenges for mining in the 21st century	Theatre C
11.00 – 11.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.30 – 12.30	Keynote Address	Ross Large: Collaborative research and education ventures to assist the global exploration industry	Theatre A
12.30 – 14.00	Lunch		Restaurant
14.00 – 15.20	Session 2	Practical solutions to challenges facing the mining sector	Theatre C
15.20 – 15.50	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
15.50 – 17.20	Session 3	The competitiveness of nations	Theatre C
19.00 – 20.30	State Reception	Hosted by Mr. John Browne T.D. (Department of Communications, Marine and Natural Resources)	Dublin Castle

Tuesday 2nd September 2003

08.00 – all day	Registration		Upper Concourse
09.00 – 11.00	Session 4	Geology in the digital age	Theatre C
11.00 – 11.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.30 – 12.50	Session 5	Developments in mineral potential mapping	Theatre C
12.50 – 14.30	Lunch	Hosted by Hon. Walter Noel, Minister for Mines and Energy (Newfoundland and Labrador)	SAS Radisson Hotel
14.30 – 15.10	Session 6	Exploration opportunities 1	Theatre C
15.10 – 15.40	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
15.40 – 18.00	Session 7	Recent developments in Ireland	Theatre C
20.00 – late	Gala Dinner	Hosted by Mr. Noel Treacy (Department of Agriculture and Food)	Dining Hall, Trinity College

NAMS Programme at a Glance *cont'd*

Wednesday 3rd September 2003

08.00 – all day	Registration		Upper Concourse
09.00 – 11.00	Session 8	Exploration opportunities 2	Theatre C
11.00 – 11.30	Tea / coffee; Trade Exhibition and Posters		Upper and Lower Concourses
11.30 – 13.30	Session 8 *continued*	Exploration opportunities 2	Theatre C
13.30 – 13.40	Official closing		Theatre C

Wednesday 3rd September to Saturday 6th September 2003

	Field trip	The Irish carbonate hosted base metal mines.	

Friday 29th August

Time			Venue
08:00		**Registration** Science Block	Upper Concourse
09:00 - 09:20		**Official Opening**	Theatre A
		The Future of Geochemistry **Chairpersons:** ***Gerry Stanley, Steve Amor***	Theatre A
09.20-10.20	O1	The Future of Exploration Geochemistry **KEYNOTE Speaker:** *Jeff Jaacks*	
10.20-10.40	O2	Some results from the study of a geogas survey in China **Speaker:** *Wang, M.*	
10.40-11.00	O3	Geochemistry's new directions: the environment and human health **Speaker:** *Plant, J.*	
11.00-11.30		COFFEE BREAK & POSTER VIEWING	Concourse
		The Role of Geochemistry and Geochemical Engineering in Mine Site Rehabilitation **Chairpersons:** ***Mike Boland, Rob Bowell***	Theatre A
11.30-12.10	O4	The Role of Geochemistry and Geochemical Engineering in Mine Site Rehabilitation - an Overview **KEYNOTE Speaker:** *Mike Cambridge*	
12.10-12.30	O5	The role of geochemistry in optimising engineering design **Speaker:** *Bowell, R.J.*	
12.30-12.50	O6	The performance of waste rock covers to prevent AMD; Rum Jungle as a case study **Speaker:** *Taylor, G.F.*	
12.50-14.00		LUNCH	Main Restaurant, UCD
		Environmental Geochemistry **Chairpersons:** ***Jonathon Derham, Gwendy Hall***	Theatre A
14.00-14.40	O7	Environmental Geochemistry for the Mining Industry **KEYNOTE Speaker:** *Dick Glanzman*	
14.40-15.00	O8	Acid generation and contamination from the abandoned Brukunga Pyrite Mine, South Australia **Speaker:** *Taylor, G.F.*	

IGES Scientific Programme

Friday 29th August cont'd

Time			Venue
15.00-15.20	O9	Atypical and typical zinc geochemistry in a carbonate-setting, Sä Dena Hes Mine, Yukon Territory, Canada **Speaker:** *Day, S.J.*	Theatre A
15.20-15.40	O10	Sediment contamination related to arsenic mining activities in the Zarshuran stream, Takab area, Northwest Iran **Speaker:** *Modaberri, S.*	
15.40-16.00	O11	Iron oxyhydroxide minerals as pH indicators in the exploration for precious metals **Speaker:** *Hauff, P.L.*	
16.00-16.30		COFFEE BREAK & POSTER VIEWING	Concourse
16.30-16.50	O12	Monitoring groundwater pollution from a landfill in Canet de Mar (Barcelona, Spain) **Speaker:** *Carmona, C.M.*	Theatre A
16.50-17.10	O13	^{210}Pb derived chronology in sediment cores evidencing the anthropogenic occupation history at Corumbati River Basin, Brazil **Speaker:** *Bonotto, D.M.*	
17.10-17.30	O14	Identification of sources of lead in children in a primary zinc-lead smelter environment **Speaker:** *Gulson, B.L.*	

Saturday 30th August

Time		Venue	
08.00		Registration	Upper Concourse
		Geochemical exploration in areas of Previous Mining and Industrial Contamination **Chairpersons:** ***Christian Schaffalitzky, Dave Kelley***	Theatre A
09.00-9.40	O15	Using mass-loading studies to identify sources of trace metals to streams affected by historical mining: a potential exploration tool **KEYNOTE Speaker:** *Katie Walton-Day*	
9.40-10.00	O16	Dispersion of low abundance elements determined using commercial ICP-ES/MS: case studies from Cornwall, England **Speaker:** *Moon, C.J.*	
10.00-10.20	O17	Contribution of pyritic ores to As pollution in tributaries of Caudal River, Spain **Speaker:** *Loredo, J.*	
10.20-10.40	O18	Australian case studies of field portable x-ray fluorescence spectrum analysers used successfully during mineral exploration and soil contamination projects **Speaker:** *Houlahan, T.*	
10.40-11.10		COFFEE BREAK & POSTER VIEWING	Concourse
		Irish Experiences **Chairpersons:** ***Pat O'Connor, Ron Holman***	Theatre A
11.10-11.50	O19	Mineral Exploration in Ireland; Case Histories - successes and other experiences **KEYNOTE Speaker:** *John Clifford*	
11.50-12.10	O20	Regional geochemical mapping in the Caledonides of Southeast Ireland **Speaker:** *O'Connor, P.*	
12.10-12.30	O21	Discovery of bedrock orthomagmatic platinum group mineralization at the Tertiary Carlingford Complex: a biogeochemical prospecting success in Ireland **Speaker:** *Smyth, D.*	
12.30-12.50	O22	Differences between heavy metal concentrations in sediments analysed by two methods and their effect on multivariate statistical analyses **Speaker:** *Zhang, C.*	
12.50-14.00		LUNCH	Main Restaurant, UCD

IGES Scientific Programme

Saturday 30th August

Time			Venue
		Modern Geochemical Techniques for Exploration in Glaciated Terrains **Chairpersons:** ***John Pyne, Bill Coker***	Theatre A
14.00-14.40	O23	Modern geochemical techniques for exploration in glaciated terrains - an overview **KEYNOTE Speaker:** *Bill Coker*	
14.40-15.00	O24	Deep-penetrating geochemistry: the Spence Porphyry Deposit, Chile **Speaker:** *Cameron, E.*	
15.00-15.20	O25	Electrochemical transport of metals due to redox gradients; highly predictive and somewhat problematic - but whose problem? **Speaker:** *Hamilton, S.M.*	
15.20-15.40	O26	Seeing through thick glacial overburden with geochemistry **Speaker:** *Hall, G.*	
15.40-16.00	O27	Possible mechanism for rapid transfer of ions to surface from oxidizing ore-bodies **Speaker:** *Mann, A.W.*	
16.00-16.30		COFFEE BREAK & POSTER VIEWING	Concourse
16.30-16.50	O28	Detection of concealed kimberlites: a preliminary evaluation of SDP soil gas geochemistry **Speaker:** *Thiede, D.S.*	Theatre A
16.50-17.10	O29	Drift prospecting and exploration geochemistry in glaciated terrain, Northwestern New Brunswick, Canada **Speaker:** *Parkhill, M.*	
17.10-17.30	O30	Surface dispersion of palladium from sulphur-poor palladium-rich rocks and mineralization in Northwestern Ontario, Canada **Speaker:** *Cameron, E.M.*	
17.30-17.50	O31	Geochemical and mineralogical dispersion models in till: physical process constraints and impacts on geochemical exploration interpretation **Speaker:** *Stanley, C.R.*	
19.00		**Coaches depart** from Merville Accommodation, UCD; Jurys Montrose, Radisson SAS St. Helen's Hotel	
19.30-23.00		**Traditional Irish Night** *(Optional Event)*	Old Jameson Distillery

IGES • NAMS Scientific Programme

IGES Monday 1st September

Time			Venue
08.00		Registration Commences	Upper Concourse
		The Use of Indicator Minerals in Exploration **Chairpersons:** ***Mary Doherty, Beth McClenaghan***	Theatre A
08.40-09.00	O32	Use of indicator minerals in exploration **KEYNOTE Speaker:** *Beth McClenaghan*	
09.00-09.20	O33	Regional distribution of kimberlite indicator minerals, Slave Craton, Northwest Territories and Nunavut, Canada **Speaker:** *Armstrong, J. P.*	
09.20-09.40	O34	Case history of an indicator mineral survey for nickel exploration, Canada **Speaker:** *Doherty, M.E.*	
09.40-10.00	O35	Indicator minerals for Ni-Cu-PGE exploration **Speaker:** *Averill, S.*	
10.00-10.20	O36	Forecasting lode gold potential from physical and chemical characteristics of placer gold grains - an example from French Guyana **Speaker:** *Kelley, D.*	
10.20-10.40	O37	Hydrothermal Zircon: a resistate mineral with potential use as an indicator/pathfinder in exploration **Speaker:** *Lawrie, K.*	
10.40-11.00	O38	Rutile geochemistry as a guide to mineralization at the Northparkes Porphyry Copper Deposit, New South Wales, Australia **Speaker:** *Scott, K.*	
11.00-11.30		COFFEE BREAK & POSTER VIEWING	Concourse

NAMS Monday 1st September

Time			Venue
08.00		Registration Commences	Upper Concourse
09.00-09.20		**Official Opening**	Theatre C
		Challenges for Mining in the 21st Century **Chairpersons:** ***Gerry Stanley, Baxter Kean***	Theatre C
09.20-10.00	O1	Challenges for mining in the 21st Century **KEYNOTE Speaker:** *Corina Hebestreit*	
10.00-10.30	O2	The proposed directive on the management of extractive industry waste in the European Union **Speaker:** *Dhonau, B.*	
10.30-11.00	O3	Sustainable minerals: applying the principles **Speaker:** *Petterson, M.*	
11.00-11.30		COFFEE BREAK & POSTER VIEWING	Concourse
11.30-12.30	O4	Collaborative research and education ventures to assist the global exploration industry **IGES•NAMS KEYNOTE Speaker:** *Ross Large*	Theatre A
12.30-14.00		LUNCH	Main Restaurant, UCD
		Practical Solutions to Challenges facing the Mining Sector **Chairpersons:** ***Michael Daly, Ben Dhonau***	Theatre C
14.00-14.20	O5	SD indicators that work: lessons learned from Canada's minerals and metals indicators initiative **Speaker:** *LeClaire, K.*	

IGES Monday 1st September

Time			Venue
11.30-12.30	O39	Collaborative Research and Education Ventures to Assist the Global Exploration Industry **IGES•NAMS KEYNOTE Speaker:** *Ross Large*	Theatre A
12.30-14.00		LUNCH	Main Restaurant
		The Role of Isotopes in Geochemical Exploration and Environmental Studies **Chairpersons:** ***Piers Gardiner, Cliff Stanley***	Theatre A
14.10-14.40	O40	The role of isotopes in geochemical exploration and environmental studies **KEYNOTE Speaker:** *Adrian Boyce*	
14.40-15.00	O41	Nd- and S-isotope signatures of South Australian Fe-Oxide Cu-, Au-systems: fingerprinting 'rich cousins' v's 'poor cousins' **Speaker:** *Bastrakov, E.N.*	
15.00-15.20	O42	Nitrogen and sulphur isotopes in soils as a guide for regional exploration in Northern Chile **Speaker:** *Oates, C.J.*	
15.20-15.40	O43	Pb isotope discrimination of geochemical anomalies using terrain-specific models - the Proterozoic of Northern Australia **Speaker:** *Carr, G.R.*	
15.40-16.00	O44	Continuous leach ICP-MS as a technique in exploration geochemistry **Speaker:** *Kyser, T.K.*	
16.00-16.30		COFFEE BREAK & POSTER VIEWING	Concourse
16.30-17.30		**AEG AGM**	Theatre A
19.00		Coaches depart from Merville Accommodation, UCD; Jurys Montrose, Radisson SAS St. Helen's Hotel for State Reception and NAMS Welcome Reception, Dublin Castle	
19.30-20.30		**State Reception and NAMS Welcome Reception**	Dublin Castle

NAMS Monday 1st September

Time			Venue
14.20-14.40	O6	Risk management associated with mining sulphur-bearing ore bodies **Speaker:** *Briggs, T.*	Theatre C
14.40-15.00	O7	Mineral exploration business: innovation required **Speaker:** *Hall, D.J.*	
15.00-15.20	O8	Inventory of mine waste sites in the Republic of Ireland **Speaker:** *Lally, P.*	
15.20-15.50		COFFEE BREAK & POSTER VIEWING	Concourse
		The Competitiveness of Nations **Chairpersons:** ***Peadar McArdle, Gerry O'Connell***	Theatre C
15.50-16.30	O9	The Competitiveness of Nations ***KEYNOTE Speaker:*** *Phillip Crowson*	
16.30-17.00	O10	The global mineral resource assessment project: a cooperative international project to assess the world's resources **Speaker:** *Johnson, K.*	
17.00-17.20	O11	Mineral exploration in Europe: activities, advantages and problems **Speaker:** *Large, D.*	
19.00		Coaches depart from Merville Accommodation, UCD; Jurys Montrose, Radisson SAS St. Helen's Hotel for State Reception and NAMS Welcome Reception, Dublin Castle	
19.30-20.30		**State Reception and NAMS Welcome Reception**	Dublin Castle

IGES Tuesday 2nd September

Time			Venue
08.00		Registration Commences	Upper Concourse
		Hydrogeochemistry in the Search for Mineral Deposits **Chairpersons:** ***Frank McDermott, TBC***	Theatre A
09.00-09.40	O45	Hydrogeochemistry in the search for mineral deposits **KEYNOTE Speaker:** *David Gray*	
09.40-10.00	O46	Mapping of mineralized groundwater discharge into lakes and rivers: a non-invasive exploration method in glaciated terrains **Speaker:** *Hostetler, B.*	
10.00-10.20	O47	Groundwater flow systems: a framework for interpreting geochemical anomalies in complex regolith landscapes **Speaker:** *Lawrie, K.*	
10.20-10.40	O48	Trace element chemistry of stream water from Arctic Greenland reflecting lithology and mineralization **Speaker:** *Steenfelt, A.*	
10.40-11.00	O49	Geochemical and isotopic characterisation of kimberlitic waters - a proposal for new exploration techniques **Speaker:** *Sader, J.A.*	
11.00-11.30		COFFEE BREAK & POSTER VIEWING	Concourse
		Biogeochemistry in the Search for Mineral Deposits **Chairpersons:** ***Loreto Farrell, Colin Dunn***	Theatre A

NAMS Tuesday 2nd September

Time			Venue
08.00		Registration Commences	Upper Concourse
		Digital Geological Information **Chairpersons:** ***Ben Kennedy, Frank Blackwood***	Theatre C
09.00-09.40	O12	A vision for geoscience information? A perspective from the British Geological Survey ***KEYNOTE Speaker:*** *Ian Jackson*	
09.40-10.00	O13	Digital geoscience information for Newfoundland and Labrador - a node on the Canadian geoscience knowledge network ***Speaker:*** *Nolan, L.*	
10.00-10.20	O14	Mining the data at the GSI - digital developments ***Speaker:*** *Verbruggen, K.*	
10.20-10.40	O15	Conflict or consensus? Digital information and tools to assist in management of mineral resources in England ***Speaker:*** *Bloodworth, A.J.*	
10.40-11.00	O16	Developing a system for on-line mineral claim staking ***Speaker:*** *Andrews, K.*	
11.00-11.30		COFFEE BREAK & POSTER VIEWING	Concourse
		Developments in Mineral Potential Mapping **Chairpersons:** ***Garth Earls, Richard Wardle***	Theater C

IGES Tuesday 2nd September

Time			Venue
11.30-12.10	O50	Recent developments in biogeochemical methods applied to mineral exploration Processing and Presentation **KEYNOTE Speaker:** *Colin Dunn*	Theatre A
12.10-12.30	O51	Biogeochemical exploration in arid terrains – an example from the Rosebud Mine, Pershing County, Nevada **Speaker:** *Smith, S.C.*	
12.30-12.50	O52	Biogeochemistry - new data from South Australia **Speaker:** Lintern, M.J.	
12.50-14.30		LUNCH, Sponsored by Department of Mines & Energy, Government of Newfoundland and Labrador. Coaches depart: Car Park beside O'Reilly Hall	Radisson SAS St. Helen's Hotel
		Lithogeochemistry in the Search for Mineral Deposits **Chairpersons:** ***Miller O'Prey, Stephen Cook***	Theatre A
14.30-15.10	O53	Lithogeochemistry in the search for mineral deposits - past and future **KEYNOTE Speaker:** *Robert Jackson*	
15.10-15.30	O54	The use of quartz as a sample medium in lithogeochemistry and regolith exploration studies **Speaker:** *Van Moort, J.C.*	
15.30-15.50	O55	Pyrites at Pajingo: textural and chemical vectors to epithermal gold ore **Speaker:** *Baker, T.*	
15.50-16.10	O56	Lithogeochemical halos related to Australian VHMS and SEDEX deposits **Speaker:** *Large, R.*	

NAMS Tuesday 2nd September

Time			Venue
11.30-12.10	O17	Recent advances in mineral prospectivity mapping and analysis **KEYNOTE *Speaker:*** *Gary Raines*	Theatre C
12.10-12.30	O18	A geochemical survey of western Northern Ireland **Speaker:** *O'Prey, M.*	
12.30-12.50	O19	Aggregate potential mapping: modelling protocols in use in Ireland **Speaker:** *Stanley, G.*	
12.50-14.30		LUNCH, Sponsored by Department of Mines & Energy, Government of Newfoundland and Labrador. Coaches depart: Car Park beside O'Reilly Hall	Radisson SAS St. Helen's Hotel
		Exploration Opportunties **Chairpersons: *Brian Breslin, Andy Kerr***	Theatre C
14.30-14.50	O20	Supply and demand of strategic minerals: to many eggs in too few baskets **Speaker:** *Bonel, K.*	
14.50-15.10	O21	Geology and mineral resources of the Fennoscandian Shield – with an emphasis on Finland **Speaker:** *Ekdahl, E.*	
15.10-15.40		COFFEE BREAK & POSTER VIEWING	Concourse
		Recent Developments in Ireland **Chairpersons: *Eibhlín Doyle, Gerry Kilfoil***	Theatre C
15.40-16.00	O22	The discovery and geology of the R-Zone at the Galmoy Mine, Co. Kilkenny **Speaker:** *Bowden, A.*	

IGES Tuesday 2nd September

Time			Venue
16.10-16.40		COFFEE BREAK & POSTER VIEWING	Concourse
16.40-17.00	O57	Lithogeochemistry and hydrothermal alteration at the Pajingo low sulphidation epithermal gold vein deposit, Drummond Basin, Queensland **Speaker:** *Stanley, C.R.*	Theatre A
17.00-17.20	O58	Ratio analysis in lithogeochemistry: how to quantify alteration around hydrothermal ore deposits, and integrate the results into exploration efforts **Speaker:** *Whitbread, M.A.*	
17.20-17.40	O59	Lithogeochemical exploration in deep regolith at the Golden Grove volcanic hosted massive sulphide deposit, Western Australia: an example of mineralogically constrained geochemical projective geometry to identify hydrothermal alteration in intensely weathered rocks **Speaker:** *Stanley, C.R.*	
17.40-18.00	O60	Identification and chemical fingerprinting of a Neoproterozoic large igneous province (LIP) in Western Australia **Speaker:** *Morris, P.*	
19.30		**Coaches depart** from Merville Accommodation, UCD; Jurys Montrose, Radisson SAS St. Helen's Hotel for Gala Dinner, Trinity College	
20.00		**Gala Dinner** (Optional Event)	Trinity College

NAMS Tuesday 2nd September

Time		Venue	
16.00-16.20	O23	The geology, alteration and mineralisation of the Pallas Green prospect, Co Limerick ***Speaker:*** *Blaney, D.*	Theatre C
16.20-16.40	O24	An economic cost benefit analysis of resource and environmental survey of Ireland ***Speaker:*** *Bullock, C.*	
16.40-17.00	O25	The Longford-Down Massif – a new gold province in the Appalachian-Caledonian orogen ***Speaker:*** *Smith, M.*	
17.00-17.20	O26	The Lisheen zinc/lead mine – an update ***Speaker:*** *Fusciardi, L.*	
17.20-17.40	O27	Merging digital geophysical data from airborne surveys, Ireland ***Speaker:*** *Kilfoil, G.*	
17.40-18.00	O28	Tara mines – a leading zinc mine in Europe ***Speaker:*** *Luukkonen, K.T.*	
19.30		**Coaches depart** from Merville Accommodation, UCD; Jurys Montrose, Radisson SAS St. Helen's Hotel for Gala Dinner, Trinity College	
20.00		**Gala Dinner** (Optional Event)	Trinity College

IGES • NAMS Scientific Programme

IGES Wednesday 3rd September

Time			Venue
		Developments in Geochemical Data Processing and Presentation **Chairpersons:** ***Jacqui Connolly, Tracey Minton***	Theatre A
09.00-09.40	O61	Developments in Geochemical Data Processing and Presentation ***KEYNOTE Speaker:*** *Eric Grunsky*	
09.40-10.00	O62	Estimation bias of mineral deposits caused by grade-based staging of multiple analyses in samples exhibiting a 'nugget effect' ***Speaker:*** *Stanley, C.R.*	
10.00-10.20	O63	Signature detection in geochemical data using singular value decomposition and semi-discrete decomposition ***Speaker:*** *Cohen, D.R.*	
10.20-10.40	O64	Maximizing your exploration assets through the effective use of data and software technologies ***Speaker:*** *Dobush, T.*	
10.40-11.10		COFFEE BREAK & POSTER VIEWING	Concourse
		Regional Multi-Element Geochemistry **Chairpersons:** ***Eibhlín Doyle, Tim Dobush***	Theatre A
11.10-11.50	O65	Multi-medium, multi-element regional geochemical mapping in the European Arctic: the Kola ecogeochemistry project **KEYNOTE Speaker:** *Clemens Reimann*	

NAMS Wednesday 3rd September

Time			Venue
		Mineral Exploration **Chairpersons:** ***Larry Nolan, Katrina Cooley***	Theatre C
09.00-09.40	O29	Lessons from Voisey's Bay for the Exploration Geologist **KEYNOTE Speaker:** *Tony J. Naldrett*	
09.40-10.20	O30	Platinum-group-element deposits: concepts, controversies and their relevance to exploration strategy **Speaker:** *Kerr, A.*	
10.20-10.40	O31	Negative pathfinders in gold exploration **Speaker:** *Breen, J.*	
10.40-11.00	O32	Gold in Northern Ireland **Speaker:** *Ausburn, K.*	
11.00-11.30		COFFEE BREAK & POSTER VIEWING	Concourse
11.30-11.50	O33	The Mineral Industry in Newfoundland and Labrador, an overview **Speaker:** *O'Connell, G.*	
11.50-12.10	O34	Potential of gold and VMS deposits in the Precambrian of west and south Greenland **Speaker:** *Stendal, H.*	
12.10-12.30	O35	Gold recovery at a sand and gravel plant in the Segre River area (Balaguer, NE Spain) **Speaker:** *Viladevall, M.*	

IGES Wednesday 3rd September

Time		Venue
11.50-12.10	O66 The role of surface geochemistry in the discovery of the Babel and Nebo magmatic Nickel-PGE deposits **Speaker:** *Baker, P.M.*	Theatre A
12.10-12.30	O67 Implication for exploration with the use of high resolution ICP/MS technology **Speaker:** *Hoffman, E.L.*	
12.30-12.50	O68 The Baltic soil survey: ultra low density multi-element geochemical mapping of Northern Europe **Speaker:** *Reimann, C.*	
12.50-13.00	**Official Closing**	Theatre A

NAMS Wednesday 3rd September

Time		Venue
12.30-12.50	O36 The history of gold exploration in the Botwood Basin in central Newfoundland **Speaker:** *Dalton, B.*	Theatre C
12.50-13.10	O37 Grass-roots exploration in an under-explored diverse geological environment employing world-class mineral deposit models: Newfoundland examples **Speaker:** *Basha, M.*	
13.10-13.30	O38 The Reid Property – A gold porphyry in Newfoundland **Speaker:** *Dimmell, P.*	
13.30-13.40	**Official Closing**	Theatre C

IGES Oral Abstracts

The Future of Geochemistry

O1 Keynote
THE FUTURE OF EXPLORATION GEOCHEMISTRY

Jeffrey A. Jaacks
Lodestone Resources

In the last decade, many changes have occurred within the mining industry. Companies have downsized and corporate mergers have transformed the industry. Geochemistry staffs at the larger companies have been reduced in numbers and exploration geochemical research has plummeted. With the consolidation of majors, this has released a wealth of mid-level and top management who have formed many startup exploration firms. These firms are prospect oriented and need to drill in order to attract investor money. To service these small companies attempting to grow we need to become geochemical entrepreneurs. The role of the geochemist within industry needs to evolve to accommodate these changes.

At the same time, the field of exploration geochemistry has undergone a dramatic evolution with several breakthroughs in the areas of analytical chemistry, data analysis and interpretation, and information management utilizing GIS. While the typical explorationist thinks in terms of geochemistry playing an important role in reconnaissance (through the use of stream sediment sampling) and property evaluation (using rock/soil samples), the knowledge and use of biogeochemistry, selective extractions, and soil-gas have revolutionized local-scale exploration and evaluation. In the last decade biogeochemistry has become an accepted tool within the exploration community. Introduction of ICP-MS into production laboratories, revolutionized analysis and allowed us to reexamine the area of selective extractions. Several companies have started to utilize soil-gases to explore for deposits beneath exotic cover.

As these new tools have been utilized in different terrains over mineral deposits, we are starting to observe common patterns and consistent signatures, which cause us to question the accepted beliefs for migration of metals in the secondary environment. There has been a paradigm shift within the geochemical community from thinking about geochemistry in terms of anomalies to thinking in terms of geochemical process accompanied by the utilization of pattern recognition to identify process.

What is lacking is geochemical research into process, and the field studies to characterize geochemical signatures of world-class deposits in a variety of environments. These environments need to be explored in terms of which process or combination of processes dominates movement of metals in the secondary environment. Surveys utilizing selective extractions need to be focused on obtaining optimal samples to enhance contrast to identify reproducible patterns for target identification.

Coincident patterns regardless of media type, collected at the same scale, suggests that geochemists need to examine the role of geomicrobiology and vapor geochemistry and how element migration is affected by these factors and expressed in geochemical signatures above buried ore deposits. New concepts of migration involving the role of organic compounds, biologically mediated metal migration, and nano-particle movement via carrier gases needs to be investigated. New analytical technologies need to be developed that can utilize this knowledge to develop new reconnaissance-scale tools in a cost effective manner to screen large areas quickly.

As we move into the next decade, companies seek to rejuvenate their exploration programs by exploring frontier areas or developing new ore bodies under cover but within sight of mining operations. In frontier areas, we should be developing new portable analysis instruments where the key issue is not detection of subtle anomalies, but rapid screening for anomalies within detection limit capabilities of this instrumentation. In brownfields exploration there is another frontier area looking for additional deposits often buried by exotic cover. The company that effectively utilizes selective extractions, soil-gas, and understands and incorporates pattern recognition to identify process to delineate targets will enjoy a greater degree of discovery success.

O2
SOME RESULTS FROM THE STUDY OF A GEOGAS SURVEY IN CHINA

Wang Mingqi* and Yang Zhongfang
***China University of Geosciences, Beijing**

Since the "geogas" survey, which some later called "Nanoscale metals in Earth gas", was applied to mineral exploration by K. Kristiansson and L. Malmqvist in the mid 1980s, a number of exploration Geochemists from China have been involved in the study of methodology of geogas. However, no significant progress has been made over a dozen of years, neither in understanding its mechanism nor in the testing procedures. People doubt how it forms and what reliable observations can be made. One of main obstacles is how to catch it effectively using a good catcher when knowledge of its forms is lacking. Solid catchers, such as polystyrene, polyurethane foamed plastics and activated carbon, were used before 1999. One big problem with the solid catchers is that they contain various amounts of metal and non-metal elements in the blank and cannot be purified. So it is hard to identify the sources of test elements from the catcher blank or soil gas. A liquid catcher began to be tested after ICP/MS became a regular analytical approach in China in 1999. In our study ultra-pure water with a low concentration of ultra-purified HNO3 or aqua regia was used as a geogas catcher and ICP/MS was used as an analytical method for different deposits. The test results show: (1) big differences between the blank catcher and loaded samples. Since the liquid catcher blank can be controlled to a very low level, with little variation, the conclusion can be easily drawn that the geogases do exist in soil gas; (2) in comparison with HNO3, aqua regia is a much more effective catcher of some elements with the exceptions of some elements like Cr, V, which can be accurately determined in aqua regia media by ICP/MS; (3) a similar distribution of elements related to mineralization in the residual soil and the soil gas may indicate that much of the geogas elements come directly from surface soil rather than from the deep ore bodies; (4) poor reproduction of anomalies implies that geogas survey is far from mature and more careful observations should be taken in the future.

O3
GEOCHEMISTRY'S NEW DIRECTIONS: THE ENVIRONMENT AND HUMAN HEALTH

Jane Plant*^, Anna Korre, Shaun Reeder, Barry Smith and Nick Voulvoulis
*** British Geological Survey**
^Imperial College London

In recent decades, the impact of chemicals on the environment and human health has been the cause of increasing concern. In this paper we consider the availability of data and knowledge about the principle groups of chemicals of concern from the national to international scale.
The main groups of chemicals considered are:
1. Inorganic chemicals, including elements such as Se, F, Cr and I, which are discussed with particular reference to their essentiality and potential harmful effects depending on their levels, speciation and bioavailability. Potentially harmful elements and species, known to have adverse physiological effects at relatively low levels, including As, Cd, Pb, Hg and NO_3^- are also discussed.
2. Radioactive substances, including the naturally occurring radioisotopes such as ^{238}U and its decay products ^{226}Ra and ^{222}Rn which are of concern for human health, are also

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considered, together with data on isotopes such as ^{137}Cs from the nuclear industry, with particular reference to accidental releases such as those from Chernobyl in 1986.

3. Synthetic chemicals, including persistent organic pollutants - POPS – such as DDT, PCB's and, of more recent concern, polybrominated flame retardants are also considered. These chemicals are characterised by their persistence, bioaccumulation (normally lipophylicity) and toxicity (PBT) properties in the environment and man. Other synthetic chemicals such as PFOS and acrylamide, which are not lipophylic and have different bioaccumulation properties are also considered.

We also review the increasing evidence of the presence of pharmaceuticals from veterinary and human medicines in the environment. These substances are of particular concern because they are designed to target specific receptors in the body and hence can have deleterious effects at exceptionally small (nanomolar) concentrations.

The Forum of European Geological Surveys (FOREGS) and British Geological Survey, geochemical databases and some airborne radiometric surveys, which provide systematic information on levels of inorganic chemicals and radioactive substances in the environment, are used to demonstrate how geochemical baseline monitoring and modelling systems of strategic importance from the national to global scale, can be developed. It is argued that such information is crucial for the sustainability of the environment into the twenty first century.

The Role of Geochemistry and Geochemical Engineering in Mine Site Rehabilitation

O4 Keynote

THE ROLE OF GEOCHEMISTRY AND GEOCHEMICAL ENGINEERING IN MINE SITE REHABILITATION – AN OVERVIEW

Mike Cambridge
Cantab Consulting

Mine site rehabilitation has been a topic of particular governmental concern over the last two to three decades. Projects such as Summitville in the USA and Wheal Jane in the UK have exacerbated these concerns, and emphasised the potential long-term and environmentally detrimental legacy of mineral extraction projects. This legacy and the environmental consequences are generally perceived to be associated with prematurely closed operations, or those without suitable closure planning or finance. In Europe in particular, the legacy of 3,500 years of mining has left its mark, with historic mining in southern Spain, central Portugal, Sardinia, Greece and the south-west of England resulting in major impacts on the environment, principally, but not exclusively, on landscape. Though the geochemical signature of the residual wastes arising from abandoned mine sites may be similar, the impacts have led to industrial and social dereliction in many areas, and in others to tourism. Though public perception is clearly otherwise, it is evident that environmental decay and degradation does not inevitably arise from mine closure. The obvious implication, therefore, is that the approach to mine site rehabilitation, like ore geology, is site specific and a prescriptive approach inappropriate.

This paper presents a review of current trends in contamination legislation as related to mine site rehabilitation. Comparison is made between the approach adopted in North America and that in Europe, with particular respect to the guidance on soil contamination developed in Canada and the Netherlands, and to new EU soil protection initiatives. The prescriptive and risk-based approaches to rehabilitation and after-use criteria are explored in the context of both modern and historic mine sites. The question is posed as to whether recent trends in adopting an over-prescriptive approach to mine site clean-up can be justified, and whether a more scientific risk-based approach might not be more appropriate, cheaper, more responsive and environmentally more productive.

O5

THE ROLE OF GEOCHEMISTRY IN OPTIMISING ENGINEERING DESIGN

ROB J. Bowell*, and Andrew McCracken,
***SRK Consulting**

The aim of this presentation is to demonstrate the importance of geochemistry in engineering design throughout the mine life cycle and particularly on closure and subsequent rehabilitation.

During initial development of a mine understanding of rock reactivity helps in identifying those units that will be reactive, and thus prone to failure, and those that will be more inert and therefore of more use as primary development zones. This will be demonstrated through examples from metal and coal mines in Greece, Colombia and the USA.

In the optimisation of metal recovery, geochemistry plays a role in the evaluation of metal leaching potential, chemical interferences and in identifying minerals that will either be susceptible to reaction or those that are inert within a given ore material. Examples from metal mines in Kazakhstan, Tanzania, Mexico, and the USA.

Perhaps one of the most significant contributions of geochemistry is during the planning of mine closure and rehabilitation of a mining area. Using examples from Ireland and elsewhere, the presentation will demonstrate how geochemical characterization influenced rehabilitation planning of mine site facilities and present conclusions that have important implications for mine closure and rehabilitation.

O6

THE PERFORMANCE OF WASTE ROCK COVERS TO PREVENT AMD; RUM JUNGLE AS A CASE STUDY

Graham F. Taylor*, A. Spain, A. Nefiodovas, G. Timms, V. Kuznetsov and J. Bennett
***CSIRO Land and Water**

The Rum Jungle mine in the Northern Territory, produced uranium and copper concentrates for three open-pits during the period of 1952-1971. Waste rock was dumped at four separate locations which together with tailings for the processing plant, heap leach piles, acid dam and open cuts had considerable impact on the local environment and ecology of the Finnis River.

Soil covers were placed on the sulphuric waste rock dumps during 1984-85. These covers were designed to reduced the water infiltration to less than 5% of incident rainfall by both water–shedding and storage-release mechanisms. Continuous monitoring demonstrated that the covers met with the design specifications for around 10years, but subsequently deteriorated with infiltration being up to 10% of incident rainfall.

This paper looks at the impact of AMD on the local environment and Finnis River; results of covering the waste rock dumps; the reasons for and impacts of deterioration of cover performance. It also makes suggestions as to the design of covers for tropical monsoonal climates.

Environmental Geochemistry

O7 Keynote

ENVIRONMENTAL GEOCHEMISTRY FOR THE MINING INDUSTRY

Richard K. Glanzman
CH2M HILL

Environmental concerns about mining emphasize and expand the need and role of exploration geologists, geophysicists and, particularly, geochemists. The exploration geochemist not only has a responsibility for

the successful detection and definition of the mineral deposit, but is commonly also the first “environmental geochemist” on site!
The trend in more restrictive and broader environmental regulations continues with more elements of concern at lower concentrations. Appropriately collected and analysed data developed during the exploration phase provides an invaluable database for subsequent environmental impact assessment. These data can considerably reduce duplication of sampling and analytical work needed for subsequent mine design, mineral processing and reclamation.
Reclamation of mine sites and mine closure programs have repeatedly demonstrated the benefit of obtaining multi-media, pre-mining background data. Case histories, involving arsenic as the primary element of concern, are presented to illustrate the need for data developed in the exploration stage to solve subsequent environmental assessment issues.
Integration of geology, geophysics and geochemistry in the field reduces the time needed to evaluate the prospect. Geochemists now have instruments allowing multimedia geochemical relationships to be developed in the field.
Early detection of anomalous elemental concentrations on a property provides significant benefits serving both exploration and environmental data purposes. Mining companies need to integrate or cross train geochemists to handle both purposes to reduce time and expense in overall project assessment. On a broader scale, unification and standardization of environmental policies within the mining industry is necessary to respond to both current and future environmental issues and concerns.

O8

ACID GENERATION AND CONTAMINATION FROM THE ABANDONED BRUKUNGA PYRITE MINE, SOUTH AUSTRALIA

Graham F. Taylor*, Raymond C. Cox
***CSIRO Land and Water**

The Brukunga pyrite mine was operated from 1955 to 1972 to supply feedstock for sulphuric acid production in the South Australian fertilizer industry. The ore was finely crushed and concentrated on site and the concentrates transported off-site for roasting. Waste rock was dumped at two locations on the western side of Dawesly Creek and the tailings pumped to a valley-fill storage facility on the eastern side.
Production of 1.5Mt concentrate resulted in 3.5Mt tailings and 8 Mt waste rock.
Acid seepage from the waste rock dumps, quarry faces, tailings storage facility and retention ponds has resulted in contamination of Dawesley Creek, its sediments and soil with sulphate, Al, Fe, Mn, Cd, Zn and Ni. Presently an estimated 60% of seepage is collected and neutralised prior to discharge into the creek.
A variety of techniques have been utilised to reduce acid seepage generation with some success. There is on-going monitoring of water flows, water quality and riparian ecosystems.
The paper examines previous mine operations, environmental contaminations, monitoring and rehabilitation techniques as well as research and community involvement.

O9

ATYPICAL AND TYPICAL ZINC GEOCHEMISTRY IN A CARBONATE-SETTING, SÄ DENA HES MINE, YUKON TERRITORY, CANADA

Stephen J. Day and Robert J. Bowell*
***SRK Consulting**

The Sä Dena Hes Mine produced lead and zinc concentrates from a polymetallic Manto deposit in 1991 and 1992. Ownership of the mine was assumed by Sä Dena Hes Operating Corporation (Teck Cominco and Pan-Pacific Metal Mining Corporation) in 1994. Sphalerite and galena ore bodies with negligible iron sulphide were processed by conventional flotation methods resulting in carbonate-rich tailings.

This paper will present evaluations of atypical and typical zinc geochemistry under non-acidic conditions using laboratory testing, mineralogy and simple modelling.

Atypical behaviour is shown by drainage containing 40mgZn/L from a short adit. The zinc load contained in the mine drainage is not apparent in a spring fed stream a few hundred metres down gradient. Results of an attenuation test to mimic field conditions showed that zinc was removed to concentrations of less than 0.001 mg/L. Spherical aggregates with 60% zinc were found in the column residues using SEM. The aggregates are likely a zinc hydroxide or basic carbonate.

Likewise, elevated zinc concentrations (up to 56 mg/L) have been found in pH neutral pore waters near the water table in the tailings deposit. Zinc concentrations generally decrease to below 1 mg/L just below the water table and below 0.1 mg/L in seepage from the tailings dam. However, in this case, simple dilution modelling and thermodynamic equilibrium modelling of the tailings pore water chemistry showed that decrease in zinc concentrations could be attributed to the formation of zinc carbonate. Electron microscopy confirmed the presence of smithsonite ($ZnCO_3$) in the tailings, in addition zinc also occurred as a trace element in other carbonate phases.

O10

SEDIMENT CONTAMINATION RELATED TO ARSENIC MINING ACTIVITIES IN THE ZARSHURAN STREAM, TAKAB AREA, NORTHWEST IRAN

Soroush Modaberri* and Farid Moore
***Department of Geological Sciences, College of Sciences, Shiraz University**

The Zarshuran Au-As deposit is a Carlin-like deposit located in the Takab area, northwest of Iran. Au is associated with As, Sb, and Hg mineralization at Zarshuran, which occurs mainly in the Precambrian black shales and limestones.

The main arsenic-bearing minerals are orpiment, realgar, arsenical pyrite, As-sulphosalts, getchelite and some other accessory minerals.

Zarshuran has a long mining history for gold, orpiment and realgar. Thousands of tons of gangue materials have been accumulated in a valley next to the portal of exploitation tunnel. Their arsenic content ranges from 0.1 to several percents. The black shales and limestones also have a high grade of arsenic, which in some samples reaches to 0.09% and gradually increases to higher amounts in the vicinity of veins.

The sediments of the Zarshuran stream have high As contents, from 36600ppm at the tunnel portal and 125000ppm immediately downstream from the mine. This figure reduces to about 180ppm in a distance of approximately 9 km downstream. The Sarouq River sediments, beyond the confluence with the Zarshuran stream, are also polluted but the arsenic content is lower because of dilution by the large volume of sediments carried by the Sarouq River sediments. As content is about 27ppm after their confluence. Other watercourses also indicate high arsenic contents between 100-150ppm.

In conclusion, from sediment chemical analysis it could be inferred that the main source of As contamination is high arsenic background in geologic formations, especially in the Precambrian units.

O11

IRON OXYHYDROXIDE MINERALS AS pH INDICATORS IN THE EXPLORATION FOR PRECIOUS METALS

Phoebe L. Hauff*, David Bird, Douglas C. Peters, David W. Coulter, Eric C. Prosh, Matthew A. Sares and Frederick B. Henderson III.
***Spectral International, Inc**

In the course of a research project, funded by the National Aeronautics and Space

Administration, investigating natural Acid Rock Drainage systems in Colorado watersheds using satellite and airborne sensors, a striking correlation was observed between water pH and specific iron oxyhydroxide minerals. Secondary phases are precipitated as stream rock coatings. Iron sulphates and oxyhydroxides, such as jarosite, schwertmannite, melanterite, copiapite, and ferrihydrite are created by acid conditions and modified to more neutral goethite, lepidocrocite, maghemite and haematite as they migrate down the drainages. These minerals have well defined pH stability fields. A geochemical model has been constructed for them for this watershed. Mineral zoning tracks progressive pH changes from jarosite and schwertmannite, pH (2.3-4.0), close to the sulphide source; to moderately acid pH of 4.0-6.0, where ferrihydrite dominates; to neutral pH of 6.0-7.0 in the lower parts of the drainages, furthest from the source, where goethite is the major secondary mineral. Mixing zones occur at the confluences of acid tributaries with neutral drainages. Low pH conditions indicate possible sulphide sources in the tributaries. This is a method, which can be used for both exploration and environmental monitoring. The iron minerals are field identified with a portable infrared spectrometer. These acid minerals are pathfinders for precious metal bearing sulphides and poor water quality. The study area includes the Upper Arkansas River Basin in Colorado, which hosts the Leadville Mining District, and the Lake Creek watershed near Aspen. The sulphide sources are sub economic porphyry systems with sulphides and aluminium silicates. This paper will discuss the field method integrated with hyperspectral imagery.

O12

MONITORING GROUNDWATER POLLUTION FROM A LANDFILL IN CANET DE MAR (BARCELONA, SPAIN)

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The Canet de Mar landfill was in operation from 1974 to 1993. It is located on weathered granite rocks in the catchment area of a small valley. The total volume of waste occupies approx 150,000 m^3. The wastes are in isolated cells separated by compacted layers of soil and silt. Nevertheless, this structure does not prevent groundwater pollution downstream.
This work seeks to characterise and quantify this pollution and to differentiate it from other sources of pollution in the region.
Waters in the surroundings of the landfill were studied. Hydrochemical and bacteriological analyses were carried out. Characteristic elements of this pollution and their inter-relationship were identified. Moreover, electromagnetic geophysical methods were used to study the spatial and temporal variation of the associated plume.
Three types of pollution were identified: 1) diffuse agricultural pollution characterized by anomalous contents of NO_3^- and SO_4^{2-}; 2) local pollution caused by pathogenic bacteria from septic tanks in the vicinity; and 3) pollution from the landfill.
The last type is not related to the others and is associated with leached liquids that descend through the non saturated zone reaching the aquifer where they form a plume of slightly acidic waters with a low oxidizing capacity, a high electrical conductivity, a raised content of Cl^-, Na, HCO^3, TOC, Cu and B, a moderated content of Fe^{2+} and a significant content of Ni.

O13

^{210}Pb-DERIVED CHRONOLOGY IN SEDIMENT CORES EVIDENCING THE ANTHROPOGENIC OCCUPATION HISTORY AT CORUMBATAÍ RIVER BASIN, BRAZIL

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The constant rate of supply (CRS) model was successfully used to assess ^{210}Pb data from its granddaughter ^{210}Po in two widely spaced locations in the Corumbataí River basin, São Paulo State, Brazil, i.e. upstream and downstream from Rio Claro city, that has been recognized to be the main source responsible for modifications on the surface water quality. Activity profiles of excess 210Pb combined with chemical data determined in sediment cores provided new insights on the reconstruction of historical inputs of anthropogenic constituents, contributing for improving the management strategies of the hydrological resources in the basin, since most of the municipalities extensively utilise them for drinking purposes, among others. Excellent significant relationships between LOI (loss on ignition) and organic matter were found for sediments of both analysed profiles. Silica was found to be inversely related to organic matter at both analysed profiles, being its decrease accompanied of an increase on the specific surface of the sediments, confirmed by a great number of inverse significant correlations among silica and oxides Na_2O, K_2O, CaO, MgO, Al_2O_3, P_2O_5, Fe_2O_3, MnO, and TiO_2. It was possible to identify the organic matter role on the adsorption of several oxides/elements in the core sediments profiles, with some of them reflecting the formation of metal-organic compounds. Apparent sediment mass accumulation rates corresponding to 224 and 802 $mgcm^{-2}yr^{-1}$ were obtained, being compatible with field evidences indicating a higher value associated to sand mining activities interfering on the natural/normal sedimentation process, which increases due to modifications on the channel drainage.

O14

IDENTIFICATION OF SOURCES OF LEAD IN CHILDREN IN A PRIMARY ZINC-LEAD SMELTER ENVIRONMENT

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We have compared high precision lead isotopic ratios in teeth and environmental samples, to evaluate sources of lead in a small group of children from a primary zinc-lead smelter community at North Lake Macquarie, New South Wales, Australia. Teeth were sectioned to allow identification of lead exposure in utero and in early childhood. Blood leads in the children ranged from 10 to 42 mg/dl and were maintained at elevated levels for a number of years. For most children, only a small contribution to tooth lead can be attributed to gasoline and paint sources. In one child with a blood lead concentration of 19.7 µg/dl, paint could account for about 45% of lead in her blood. Comparison of isotopic ratios of tooth leads with those from vacuum cleaner dust, dust fall accumulation, surface wipes, ceiling (attic) dust and an estimation of the smelter emissions indicates that from approximately 55 to 100% could be derived from the smelter. For a blood sample from another child, greater than 90% of lead could be derived from the smelter. There has been varying amounts of in utero -derived lead in the teeth. In spite of the contaminated environment and high blood lead concentrations in the children, the levels of lead in the teeth are surprisingly low compared with those measured from other lead mining and smelting communities.

Geochemical Exploration in Areas of Previous Mining and Industrial Contamination

O15 Keynote

USING MASS-LOADING STUDIES TO IDENTIFY SOURCES OF TRACE METALS TO STREAMS AFFECTED BY HISTORICAL MINING: A POTENTIAL EXPLORATION TOOL

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Mass-loading studies using tracer dilution and synoptic sampling have been conducted to identify sources of trace-metal loading in headwater streams affected by historical mining in the western United States, and when combined with additional geologic data, may represent a new exploration technique. Estimates of stream discharge are obtained by injecting a conservative tracer, of known mass flow, into a stream and sampling the downstream dilution of the tracer. Stream-discharge data are combined with trace-metal concentrations from samples collected during synoptic sampling to construct spatial profiles of instantaneous mass load (in units of mass per time). Decreases in mass load along the stream indicate reaches where in-stream chemical reactions remove metal from the water column. Increases in mass load along the stream indicate stream reaches containing sources of metal loading. In some cases, sources of metal loading can be related to draining adits or mine-waste locations. In other cases, however, ground-water inflow is the source of metal loading to the stream. Ground-water inflows having elevated concentrations of trace metals may be caused by flow from mineralized or altered zones, or hydraulically conductive fractures that intersect such alteration. Tracing the flow paths of metal-rich inflows to their sources may be aided by a thorough understanding of local and regional geology and structure, and additional research is needed to test this hypothesis. Mass-loading studies, when combined with other geologic and hydrologic data, may represent a new method to locate undiscovered mineral deposits in previously mined terrain.

O16

DISPERSION OF LOW ABUNDANCE ELEMENTS DETERMINED USING COMMERCIAL ICP-ES/MS: CASE STUDIES FROM CORNWALL, ENGLAND

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Improvement in analytical instrumentation (combined ICP-ES/MS) allows the determination of 50 elements at low detection limits in commercial laboratories. Although many data have been generated for commercial mineral exploration, there is little published information to aid the interpretation of patterns of potential pathfinder elements with low abundances, such as In or Re. In order to provide this information subsets of a previously interpreted and well-constrained soil and stream sediment survey from Cornwall were re-analysed. The geology and mineralization in both areas are well understood and soil geochemistry is available for most of the stream sediment area, as are digital elevation models.

The stream sediment survey was taken north of the St. Austell Granite but the area is relatively uncontaminated. The Castle-an-Dinas W deposit is clearly detected by W and As reflecting the known soil anomalies. Other elements associated with this mineralization are Nb, Ta, Be, Bi, Cu. Pathfinders of U shows are Bi, Co, Pb and Sb but not U. The Mulberry-Wheal Prosper Sn- base metal veins can be detected using Cs, In, Nb, Ta as well as Sn, W and Cu. The Pb shows associated with the Staddon Grits appears to be restricted to Pb, Zn and Cd.

At Wheal Jane soil sampling replicated the previously described positive Sn, As and Cu anomalies and negative anomalies for Fe Mn, Mg. ICP-MS analysis detected strong Bi, In, acid soluble Sn and W anomalies as well as weaker Sb and Hg highs. A broad Pb high may reflect cross-cutting late Bi sulphosalt mineralization. Soil Zn and Cd anomalies are lacking, possibly because of leaching, although the In remains at surface possibly because of the insolubility of $In(OH)_3$.

The multi-element and low detection limit nature of ICP-ES/MS data allows anomalies to be defined with confidence.

O17

CONTRIBUTION OF PYRITIC ORES TO As POLLUTION IN TRIBUTARIES OF CAUDAL RIVER (SPAIN)

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As water pollution is a widespread phenomenon in many abandoned mining districts of the world. In Asturias (Northern Spain), mine drainage and waste piles from abandoned Hg mines constitute important As sources. At the site of Los Rueldos, in the Morgao stream catchment, mine drainage reaches concentration up to 8.3 mg l-1 As, with pH ranging from 1.6 to 2.6 units. At this catchment, the contribution of polluted water (mine drainage and spoil heap leachates) constitutes approximately 1 % of the total flow of the catchment. In this area, groundwater has a neutral pH but significant As content (about 9 mg. l^{-1}). In order to understand the As pollution mechanism, it is necessary to know in what way it is associated with non specific As minerals such as pyrites, which are present both in the ore paragenesis and in the enclosing rocks. Pyrite in advanced oxidation state is the most abundant sulphide in the abandoned mine works and spoil heaps. Therefore, electronic microprobe analyses of representative pyrite samples have been undertaken. A high As content, reaching up to 5.73 %, was found at the site of Los Rueldos Mine. The physicochemical properties of the ore and the site-specific conditions adversely affect the weathering rate of pyritic ores and wastes, which must be considered as the main As sources. As remobilisation by ore and wastes weathering is believed to be the main factor contributing to As water pollution in tributaries of Caudal River.

O18

AUSTRALIAN CASE STUDIES OF FIELD PORTABLE X-RAY FLUORESCENCE SPECTRUM ANALYSERS USED SUCCESSFULLY DURING MINERAL EXPLORATION AND SOIL CONTAMINATION PROJECTS

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X-Ray Fluorescence Spectrum Analysers (XRF) are common laboratory instruments that have been utilised by commercial and mine site laboratories for many decades to provide quantitative elemental assay data of samples collected as part of mineral exploration and to a lesser extent, contaminated soil projects. Advances in the miniaturisation of electrical components have allowed bulky, stationary instruments to be reduced to highly portable, hand held units. This paper evaluates the performance of field portable X-Ray Fluorescence Spectrum Analysers used commercially during various mineral exploration and soil contamination projects in Australia over the past 5 years. Each case study will outline the method of FPXRF use within each project, include a comparison of the FPXRF project data and corresponding confirmatory laboratory data and will discuss the specific advantages that real time data provided by a FPXRF brought to each project. In an economic environment where exploration finance is increasingly difficult to obtain, the use of scientifically proven and accepted techniques that can provide more efficient use of exploration expenditure will be increasingly utilised. The paper will conclude that the opportunity to obtain reliable quantitative geochemical data immediately upon sample collection using a FPXRF can provide significant financial benefits to the global mineral exploration industry.

Irish Experiences

O19 Keynote

MINERAL EXPLORATION IN IRELAND; CASE HISTORIES – SUCCESSES AND OTHER EXPERIENCES

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Modern Irish exploration in the period 1959 - 2003 can be logically sub-divided into four phases generally coincident with each of the decades.

Mineral discoveries, prior to 1960, were predominantly hosted within the relatively well exposed Lower Palaeozoic terrains, were typically of vein type, and were discovered primarily through traditional prospecting. Such deposits formed the backbone of an active industry in the early to mid-19th century. However, as a result of declining metal prices and increasing depth there was a virtual cessation of mining around 1870.

The difficulty in securing raw materials during and immediately after the Second World War rekindled interest in indigenous resources. The Avoca copper-pyrite deposit was re-opened, first as a source of sulphur and later as a copper producer. The Abbeytown lead - zinc deposit also saw production during the 1950's. The Finance Act of 1956, which exempted profits from the first four years of mining activity from tax, proved a significant catalyst for exploration.

Beginning in the late-1950's, but in particular from about 1960, exploration by Irish expatriate and Irish-Canadian groups began in a sustained way. The early exploration programs were concentrated in areas with historic evidence of mining or mineralization. The approach they adopted was the application of the then innovative stream sediment and shallow soil geochemistry techniques, with field analyses using cold extraction methods. Geophysical systems were also used, primarily induced polarisation, to discriminate geochemical anomalies. There was a ready willingness to proceed with early drill tests. This methodology, in which geochemistry was the dominant targeting tool, proved very successful. Significant discoveries followed almost on an annual basis. Over the course of the decade, 10 deposits with a combined resource of approximately 135 million tonnes of ore grade mineralization were defined. Three of these - Tynagh, Silvermines and Gortdrum - were brought into production during the decade, and a fourth - Navan - with a resource tonnage of almost 90 million tonnes, became the largest resource of zinc-lead in Europe.

However, the Navan discovery heralded a change. By then most of the prospective Lower Carboniferous sequences had been covered by shallow soil sampling and the potential for the discovery of further near surface mineralization by conventional geochemical methods of exploration was limited. It was realised that the future discoveries would be hidden beneath peat bog, glacial cover or by barren rock, or is a different style and type of mineralization in other geological environments.

Throughout the decade of the 1970's geochemical exploration within the Lower Carboniferous terrains involved the taking of samples at increasing depth within the glacial cover, using hand-held and tractor-mounted percussion drills. Geophysical systems also evolved with widespread coverage by IP and hand-held VLF. There were some technical successes, but nothing of the scale made during the 1960's.

The 1970's also saw the extension of exploration into Lower Palaeozoic environments in the search for other commodities, such as lithium, tin, tungsten and uranium. The European Community in part funded this latter activity. The exploration approach was to apply the traditional methodologies. Prospecting, as follow-up to car-borne radiometric surveying, in County Donegal proved very effective in identifying economic grade uranium mineralization. In County Carlow geochemical surveys detected significant uranium concentrations in peat bogs. Similar surveys proved effective in Connemara.

The dramatic increase in the gold price in the late-1970's gave the impetus to re-assess the geological terrain with this potential in mind. There was extensive historic reference to gold in Ireland, but no known commercial deposit. The Sperrin Mountains in Northern Ireland was one area which was attractive geologically, and which had historic reference to gold. Exploration, again using traditional prospecting and deep overburden sampling methods, proved successful and a significant discovery was made in 1983. Other discoveries, in similar geological settings in the west of Ireland, followed.

Meanwhile on the base metals front it was proving increasingly difficult to attract exploration investment. The traditional exploration approach had proved wanting and the need was clear to either develop a new methodology or to refine the old. Various methods were researched. Soil and hydrocarbon gas geochemistry was investigated, as were analyses for elements, such as barium, which are commonly associated with the zinc - lead mineralization. Study of the lithogeochemical signature around the known deposits indicated some potential as an exploration tool. Systematic application of this methodology resulted in the 1984 discovery of hitherto unknown oxide zinc mineralization at Silvermines.

Research on geophysical systems was also progressed through this period. These systems, coupled with geological modelling, were the primary tools used in the next discoveries - Galmoy (1985) and Lisheen (1990), although both of these deposits also have weak geochemical soil anomalies.

The exploration approach through the 1990's was dominated by geophysics, in particular airborne magnetics and electromagnetics, surface gravity and electromagnetic surveys. It was increasingly recognised that basement structure had a major control on Lower Carboniferous tectonics and sedimentation, and quite possibly on localising mineralization. The target depths were growing ever greater, with 200 - 300m quite normal. The most significant discoveries were made in "brownfield" sites near to known deposits. At Navan area, through detailed geological study and a willingness to drill, a new zone of mineralization was discovered down-dip to the southwest. At Galmoy a new ore zone, with grades significantly higher than anything seen in Ireland to-date, was discovered within 100m of the known deposit through the drill testing of a gravity anomaly. On the grassroots front however only one discovery was made - at Pallas Green, County Limerick. Here geological modelling; with supportive airborne magnetics, IP and deep overburden geochemistry, has guided a drilling program which has intersected economic grade mineralization with a style reminiscent of that at Silvermines and Lisheen.

The first decade of the 21st century has had a poor start from the mineral exploration point of view. Current metal prices are at an all-time low. As a result, and in common with many other areas of the world, exploration budgets in Ireland have been slashed. Today, there is virtually no grassroots exploration activity with the only active programs in the immediate vicinity of the three mines that are currently operating. The Lower Carboniferous remains prospective. However, the targets are deeper, more expensive to locate and require a commitment to sustained drilling.

Looking back over the exploration record we can recognise some common threads, which were important in the discoveries. Every deposit has a geochemical signature of some nature. The signature for the early discoveries was generally large, intense and coherent. Later, as at Lisheen and Galmoy, the geochemical responses were much more subtle and their importance not recognised until other data, in particular geophysical and geological, was acquired. Increasing understanding of the geology, the age relationships between the geology and mineralization, and the importance of the basement structures in controlling the Lower Carboniferous tectonics and sedimentation are powerful exploration tools. However, the end analysis is that once it is recognised that the geological setting is prospective for ore grade mineralization then the ultimate key to exploration success is a willingness to drill.

O20

REGIONAL GEOCHEMICAL MAPPING IN THE CALEDONIDES OF SOUTHEAST IRELAND

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***Geological Survey of Ireland**

A regional geochemical mapping programme, based on samples of active stream sediments and rocks, has been completed for the paratectonic Caledonian terrane of southeast Ireland. A total 2200 stream sediment samples, including field replicates, was collected at 1884 locations over an area of c. 6000 km2. First and second order streams were sampled above their confluence. Over 500 rock samples were collected from most of the lithological units delineated on the geological map of southeast Ireland. Geochemical analyses of 36 elements were carried out using both INAA and AAS. Data analysis of stream sediment samples employed resistant non-parametric techniques (EDA, Exploratory Data Analysis) for objectively selecting outlier values and class boundaries for the distribution of each element.

The paratectonic Caledonides of southeast Ireland comprise a thick and varied Lower Palaeozoic succession of marine turbidites and shales, with volumetrically important Ordovician volcanic rocks, that have undergone polyphase deformation and low grade regional metamorphism. The emplacement of the S-type Leinster Granite into the volcano-sedimentary succession at 405 Ma coincided with the last major Caledonian deformational event in southeast Ireland. Significant minor intrusive rocks include pegmatites, tonalites, dolerites, appinites and serpentinite. Mineralization is widespread and includes Au, Cu, Pb-Zn, Li-Ta, W-As-Sn and Cr-Ni deposits.

The geochemical data demonstrate strong geochemical coherence between major stratigraphic groups and many formations in southeast Ireland, both for stream sediments and rocks. The data can distinguish easily between stratigraphic formations of different ages and lithological composition. Relative to average upper crust compositions the Leinster Granite and most sediment-dominated groups are enriched in Li, while all stratigraphic groups are depleted in Na and enriched in As and Sb. Outlier values for stream sediments can be correlated directly with known bedrock mineralization. The geochemical signatures of individual lithological units can be used to help constrain models for metallogenesis in the region.

O21

DISCOVERY OF BEDROCK ORTHOMAGMATIC PLATINUM GROUP MINERALIZATION AT THE TERTIARY CARLINGFORD COMPLEX: A BIOGEOCHEMICAL PROSPECTING SUCCESS IN IRELAND

Dermot Smyth
Independent Consultant

Hitherto biogeochemical prospecting has received little research or industry attention as a potential mineral exploration technique in Ireland. The identification of "novel" techniques for mineral exploration in an Irish context has resulted in the first large-scale field trial of biogeochemical prospecting in Ireland. At Carlingford, historical mineral exploration datasets have been digitised, integrated and re-interpreted as part of a co-existing university research and industry exploration program (BHP-Billiton). Two primary targets have been identified, a soil Cu anomaly (560ppm) and a separate Ni anomaly (210ppm). A multi-element soil geochemical and biogeochemical survey (110 samples) of Bell heather (Erica cinerea) has been conducted over the soil Cu anomaly. Combined statistical and spatial analysis of both soil and vegetation datasets has resulted in a number of conclusions. At Carlingford biogeochemical prospecting is more effective than conventional soil geochemical prospecting. Biogeochemical samples are easier to collect, surveys proceed more rapidly and samples are easier to prepare. Spatial plotting of the vegetation and soil copper concentration (percentile scale) has resulted in two anomaly maps, both indicate a prospective locality in a 1km2 block. In contrast to the soil plot the vegetation plot defines a copper anomaly that pinches out upslope. Follow-up field investigation of the biogeochemical pinch out anomaly source has resulted in the immediate discovery of blebs of chalcopyrite-pyrrhotite mineralisation hosted in a pegmatitic and vari-textured gabbro zone, which can be traced upslope. Analysis of the "bleb-style" mineralization reveals the presence of trace PGE (9ppb Pd, 1ppb Au, 283ppm Cu, 76ppm Ni).

O22

DIFFERENCES BETWEEN HEAVY METAL CONCENTRATIONS IN SEDIMENTS ANALYSED BY TWO METHODS

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Chemical components in geochemical samples are usually measured by more than one method, and it is necessary to evaluate if the results from these methods are consistent or not. A total of 1,884 sediment samples taken from the Leinster area of Ireland were analysed by NAA for 26 elements and 5 of them (Co, Cr, Fe, Ni, and Zn) were also analysed by AAS.
Scatter plots, statistical tests and GIS mapping techniques were used to compare the differences between the results from the two analytical methods. The poor accuracy of NAA for low concentrations close to or below the detection limits was observed and also possible errors in the NAA processes may have happened for some samples. Statistical results showed that there were significant differences between concentrations measured with the two methods at the level of $p<0.001$, and the average differences were as high as 20%-30% for the 5 elements. Spatial distribution patterns were identified on the GIS maps of differences revealing possible systematic errors, and they were also found related to the high detection limits of NAA. Results of correlation, principal component and cluster analyses illustrated that the differences between the two methods did not have a serious effect on multivariate relationships, especially for Co, Fe and Ni, but there were some effects on Cr and Zn. It is suggested that care should be taken in choosing an appropriate laboratory measurement in order to establish geochemical databases of high quality.

Modern Geochemical Techniques for Exploration in Glaciated Terrains

O23 Keynote

MODERN GEOCHEMICAL TECHNIQUES FOR EXPLORATION IN GLACIATED TERRAINS – AN OVERVIEW

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Mineral exploration in regions that were glaciated during the Quaternary can be hampered by the scarcity of outcrops and by the variable thicknesses of allochthonous glacial drift that mantle and conceal the bedrock and mineral deposits beneath. Both conventional and newer "deep penetrating" exploration geochemical techniques are being employed for mineral exploration in glaciated terrains.
Conventional exploration geochemical techniques involving the sampling and analyses of surficial till or stream sediments derived there from either fine fraction or heavy minerals have been successful in exploration in areas of generally thin glacial drift (a few to 10s of metres). This is especially so, when used in a context of a good understanding of the glacial history, i.e. glacial sediment stratigraphy and associated ice movement direction(s), of the area. Provided the glacial history and stratigraphic framework have been established, overburden drilling techniques can be successfully employed in mineral exploration in areas of

thicker (several 10s to 100s of metres) glacial drift. In addition, drainage sediments (i.e. lake and stream) have been successfully used to detect secondary hydromorphic dispersion associated with concealed mineralization in glaciated terrains.

In recent years, considerable effort has been focused on the development of surficial geochemical techniques to “see through” thicker, compositionally complex, sedimentary (glacial, marine, etc.) sequences. In this context, i.e. discovery of economic mineral deposits concealed beneath thick cover, a number of modern “deep penetrating” surficial geochemical techniques, that focus on giving an in situ response vertically above the target mineralization, have been developed. These include a variety of selective extraction, soil gas, physiochemical, electrochemical and biological (bacterial and microbial, etc.) techniques. The key to the successful application of these targeting techniques for “seeing through thick cover” is understanding the processes controlling the elements/compounds “vertical redistribution” to and modification within the near surface environment.

The application of both conventional and the newer “deep penetrating” surficial geochemical techniques in mineral exploration programs have shown their effectiveness to locate concealed mineralization. Research on these “deep penetrating” surficial geochemical techniques is now starting to identify the complexity of the mechanisms involved in the release, transport and fixation of elements/compounds from a buried source to their being reflected in the surface environment directly above the target mineralization.

O24

DEEP-PENETRATING GEOCHEMISTRY: THE SPENCE PORPHYRY DEPOSIT, CHILE

Eion M. Cameron* and Matthew I. Leybourne
***Eion Cameron Geochemical Inc.**

The CAMIRO Deep-Penetrating Geochemistry project carried out studies of ten buried deposits and prospects in Chile, Nevada and Ontario. In all cases geochemical expressions of the buried mineralization were found at the surface of cover materials that varied from glacial clays in Ontario to piedmont gravels in Chile.

Spence contains 400 Mt of 1% Cu and is covered by 30-180 m of gravel. RioChilex discovered the deposit by grid drilling based on geological insight. We carried out geochemical and isotopic studies on soils and groundwaters. Soils over the deposit have strong anomalies by five selective leaches for Cu and other pathfinder elements. The anomalies occur along fracture zones in the gravels that may represent the upward propagation of basement faults. Elements anomalous in the soils are similar to those present in groundwater at 80 m depth. We interpret the anomalies to be caused by seismic pumping of mineralized groundwater to the surface (Geology, v. 30, p. 1007). Elements thus reaching the surface were redistributed by the rare rainfall of the Atacama Desert. Cations, such as Cu^{2+}, readily adsorbed by oxides, are retained at the surface, whereas elements forming anions, such as Re and As, are removed to >40cm depth. Elements were then incorporated into carbonate and iron and manganese oxide minerals. For each element, minerals contain different proportions of exogenous (from the deposit) to endogenous (derived from primary soil minerals) origins. Selective leaches with the best anomaly to background contrast are those that dissolve the mineral with the highest exogenous/endogenous ratio for a given element.

O25

ELECTROCHEMICAL TRANSPORT OF METALS DUE TO REDOX GRADIENTS; HIGHLY PREDICTIVE AND SOMEWHAT PROBLEMATIC – BUT WHOSE PROBLEM IS IT?

Stew M. Hamilton*, Gwendy E.M. Hall, M.Beth McClenaghan, Eion M. Cameron and Keiko H. Hattori
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Since 1999, a series of case studies over deeply buried sulphide deposits, kimberlites and other oxidizable bodies have indicated the presence of 'reduced chimneys' in saturated overburden. The chimneys had been predicted to occur in a geochemical transport model (Hamilton, 1998, 2000), as were a number of other phenomena that were also observed in the case studies, including near-surface acid generation, metal deposition, SP responses, carbonate remobilisation, and soil gas responses. These latter features had previously been observed over mineralization at other locations world-wide but reduced chimneys had never been observed, nor had all of these features been considered as part of a single redox-related geochemical process caused by the underlying mineralization.

The electrochemical transport model presented in 1998 was controversial but has been demonstrated to be predictive. It is therefore appropriate to critically re-evaluate the theory and determine if the controversial issues have been resolved. Some issues are easily addressed, such as the ability of redox processes to cause metal zonation, pH responses and carbonate phenomena. A more difficult, and consequently more interesting, question is the nature of the metal transport. It has not been explicitly recognised in geological literature that the transport of redox-active species due to a redox gradient is largely supposition and is not accounted for in physics. Contrasting this with the weight of geological evidence supporting redox transport reveals an enigma that points us in a fascinating new research direction.

O26

SEEING THROUGH THICK GLACIAL OVERBURDEN WITH GEOCHEMISTRY

Gwendy Hall*, Stew Hamilton, M. Beth McClenaghan, Eion M. Cameron, Bahram Daneshfar
***Geological Survey of Canada**

Cross Lake, VMS (Zn-Cu-Pb-Ag) mineralization of Archaean age, continues to be a prominent site for studying partial leach geochemical signatures and genesis in near-surface soils. Located ca. 50km southeast of Timmins in the Abitibi Greenstone Belt of Ontario, this deposit is hosted by felsic pyroclastic rocks and is covered by thick glacial sediments (ca 8 Ka) to a depth of 30-50m. It is currently the focus of an OMET (Ontario Mineral Exploration Technology)-funded project being carried out by the Geological Surveys of Canada and Ontario. Two lines, Lines 6 and 40, studied in detail, provide the different surficial terrains typical of the region: clay, sand and peat. On Line 6, gleysolic soils formed on silty-clayey glacio-lacustrine sediments, whereas on Line 40, podzolic soils formed on sandy glacio-fluvial sediments. A trench, 2-300m long, was centred over mineralization on each line and samples taken every 5m along its length. Samples (O, Ah, Ae, B) were collected at 10 1cm intervals, from surface to ca 70cm.

The soils have been analysed for 50-60 elements following aqua regia, Enzyme Leach, ammonium acetate (at pH 5 and 7) and weak HCl digestions, and for various other parameters in addition to pH and oxidation-reduction potential (ORP). Principal component analysis helps to group the element patterns according to lithology, nature of terrain (e.g. reduced environments in water-saturated v's highly oxidised in sand), soil-forming processes, atmospheric deposition and the effects of the reduced chimney over oxidising mineralization. This presentation will focus on differentiating these signals to highlight those due to element migration from the deposit at depth.

O27

POSSIBLE MECHANISM FOR RAPID TRANSFER OF IONS TO SURFACE FROM OXIDIZING ORE-BODIES

Alan W. Mann*, Tobias F. Foster, David A. Mann
***MMI Technology**

The aim of this presentation is to show, by a combination of some simple laboratory modelling experiments and chemical calculations, that the heat developed by oxidizing ore-bodies might provide the basis for convection and convective cells to play a part in transfer of ionic material to the near surface.

Evidence from empirical observations (particularly using selective extraction techniques) from a number of different environments suggests that vertical migration of ions through transported overburden can and does occur. One of the problems commonly associated with this phenomenon, is that there is not yet a single simple mechanism, which can explain the apparent rapidity (and consequent sharpness) of ion accumulation in surface material. For example, calculations show that chemical diffusion based on Fick's Laws of diffusion, do not provide the time or the spatial distribution for ion accumulations being observed in, for example, glacial overburden. Simple geochemical models with blue dyes in saturated sand contained in clear plastic boxes are used to show that very small "hot zones", of the order of one degree centigrade, produce vertical ascension. These zones are produced artificially by inserting a small light globe (controlled by a rheostat) into the profile and produce small density differences, which within days, result in a strong vertical component to a convective cell. Chemical calculations show that the heat generated by oxidizing sulphides will produce sufficient heat to provide similar small temperature gradients in nature. In some cases these have been measured. It is contended that, where oxidation occurs, these may provide a mechanism for rapid vertical migration of ions beneath the water table to the near surface. Above the water table, capillary rise is likely to occur, a fact also demonstrated in the laboratory modelling.

O28

DETECTION OF CONCEALED KIMBERLITES: A PRELIMINARY EVALUATION OF SDP SOIL GAS GEOCHEMISTRY

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Kimberlite exploration in terrain with transported cover sequences relies heavily upon geophysical methods. However, it is difficult to distinguish kimberlites from mafic intrusives in the case of magnetics, or from other low-density features such as karst holes in the case of gravity data. SDP soil-gas geochemistry is a depth penetrating geochemical method, which has the potential to provide a geochemical evaluation of multiple geophysical targets. SDP analyses a large number of gas species including hydrocarbons, sulphur gases, organo-halide and organo-sulphur compounds that are adsorbed on the 0.2-2.0 micron size fraction in soil. The data set is extensively processed using a form of discriminant analysis to derive a multi-component geochemical signature or template of the target. Later SDP exploration data are then processed using a previously determined deposit template to locate similar geochemical patterns in the survey area. We present data from a variety of kimberlite and non-kimberlite geophysical targets. The test areas cover a wide geographical and climatic range including the Lac de Gras region of Canada, the Kalahari Desert of Botswana and covered areas in South Africa. The cover sequences sampled range from arctic tills to transported desert sands. The SDP method was generally successful, both in detecting the kimberlite pipes below the cover sequences and in discriminating between pipe and non-pipe geophysical targets. In addition, the SDP geochemical templates of some kimberlite

pipes appear to have wide geographic application. A template derived from a Lac de Gras kimberlite detects pipes in South Africa and Botswana when applied on a blind basis.

O29

DRIFT PROSPECTING AND EXPLORATION GEOCHEMISTRY IN GLACIATED TERRAIN, NORTHWESTERN NEW BRUNSWICK, CANADA

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Drift prospecting in northwestern New Brunswick complements stream sediment, geophysical, and bedrock mapping surveys. Most of the area is covered by thin (< 1m thick), locally derived basal till or a veneer of broken bedrock/weathered bedrock/colluvium overlying Lower Paleozoic sedimentary rocks within the Chaleur Uplands and Edmundston Highlands. Glacial striations indicate that ice movement was parallel to major valleys in a general east-southeast to southeast direction. Several outcrops in the extreme western part of the area indicate ice flow in a westerly direction. Boulder erratics, some transported from as far away as the Canadian Shield, were found throughout the area.
Geochemical results of detailed surveys in the vicinity of the Patapedia, Legacy and Popelogan skarn occurrences indicate anomalous concentrations of base metals and Au and pathfinders in till directly over and up to 500 m down-ice from the surface expression of the mineralization. Isolated anomalous concentrations were also detected throughout the regional till dataset (1380 sites).
A large area of anomalous Ni and Co in till is coincident with magnetic and stream sediment anomalies. Sediments containing the highest concentration of Ni occur in streams draining the till-covered plateau where the highest Ni concentrations in till are found. This area is underlain by fine-grained, sedimentary rocks of the Upper Ordovician Boland Brook Formation. Anomalous Ni concentrations in till east of the magnetic anomaly and east of a large area of regolith containing colluvium and broken bedrock reflect eastward glacial dispersal. Till overlying sedimentary rocks of the Devonian Fortin Group in the western part of the study area, generally contains the lowest concentrations of metals.

O30

SURFACE DISPERSION OF PALLADIUM FROM SULPHUR-POOR PALLADIUM-RICH ROCKS AND MINERALIZATION IN NORTHWESTERN ONTARIO, CANADA

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The Lac des Iles area in northwestern Ontario contains one Pd mine and many showings of Pd-rich PGE mineralization. Mineralization is characterised by low contents (<5 vol. %) of sulphides and is enriched in Pd, Pt, Au, Ni, Co and Cu. Among these, base metals are not suitable as pathfinder elements because they are concentrated elsewhere without Pd. Concentration profiles in soil show that Pt is essentially immobile. By contrast, Pd is mobile and is removed during the conversion of C-horizon to B-horizon soil. The liberated Pd is fixed down-slope in organic-rich soils in swamps and lake sediments. Good mobility of Pd is also shown by high Pd contents in bark of spruce trees, up to 600 ppb Pd, and significant concentrations in surface waters, ~ 16ppt. Palladium in dilute solutions is likely dissolved as neutral and anionic OH- complexes, which are not adsorbed on negatively-charged Fe oxides in B-horizon soils.
The study area is directly east of the Nipigon area that is underlain by ~ 1.1 Ga rift-related igneous rocks with elevated Pd, ~ 15ppb. Southwest moving glaciers spread cobbles and sands derived from these rocks across the study area in eskers; Pd leached from the eskers has produced Pd anomalies in many lake sediments. Such anomalies can be distinguished from mineralization-related anomalies by factor analysis.
The findings of this study are also applicable to exploration for sulphide-rich PGE deposits.

Palladium analysis of humus along drainages and swamps is inexpensive and provides a vector to the mineralization.

O31
GEOCHEMICAL AND MINERALOGICAL DISPERSION MODELS IN TILL: PHYSICAL PROCESS CONSTRAINTS AND IMPACTS ON GEOCHEMICAL EXPLORATION INTERPRETATION

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Mineralogical and geochemical dispersion models in till have historically employed 'exponential' and 'linear' dilution/enrichment equations to explain concentration variations down-ice from anomalous rocks. Functional analysis of these models indicates that they are fundamentally inconsistent with sub-glacial physical process constraints. Under the assumption that the 'erodability' of homogeneous bedrock does not change significantly from place to place (at least on average), dilution/enrichment of sub-glacial material concentrations should be described by an 'inverse' function. Neither 'exponential' nor 'linear' are equivalent to the 'inverse' function family; thus both models are inappropriate.
An alternative 'aggradational dispersion model' is proposed to replace the 'exponential' and 'linear' dilution/enrichment models. This alternative model explains both ('pseudo-exponential' and 'pseudo-linear') forms of mineralogical and geochemical dispersion observed down-ice from anomalous lithologies, suggesting that a continuum exists between these two end-member patterns. The 'aggradational dispersion model' employs a conceptual multi-layer till scheme that erodes, transports, and deposits from each underlying sub-layer to produce each overlying sub-layer. Most importantly, the 'aggradational dispersion model' bears a direct physical relationship with accepted sub-glacial processes that erode bedrock, and transport and deposit glacial till. It also incorporates an 'inverse' dispersion function in its formulation. Thus, this model represents a more accurate model for down-ice dispersion.
Numerical simulations using the 'aggradational dispersion model' produce different dispersion patterns for different degrees of bedrock erodability. Comparison of these predicted patterns with real dispersion patterns from mineralization or distinctive lithologies will provide tests of the 'aggradational dispersion model'.

The Use of Indicator Minerals in Exploration

O32 Keynote
USE OF INDICATOR MINERALS IN EXPLORATION

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Indicator minerals are mineral grains that indicate the presence of a specific mineral deposit, alteration, or rock lithology. Ideal indicator minerals are found in few if any rocks other than the host deposit or lithology. Their physical and chemical characteristics allow them to be readily recovered from exploration sample media (e.g. stream, alluvial, glacial or eolian sediments), are sufficiently abundant and include characteristics such as visual distinctiveness, moderate to high density, silt or sand-size, and ability to survive weathering and/or clastic transport. Most often their abundance in a sample is reported, however, grain morphology, surface textures, or mineral chemistry also may provide significant information about the bedrock source. Indicator minerals have become an important exploration method in the past 10 years and now include suites for detecting a variety of ore deposit types including diamond, gold, Ni-Cu, PGE, porphyry Cu, massive sulphide, and W deposits.
One of the most profound events in the

application of indicator mineral methods in the past 10 years has been the explosion in diamond exploration activity in the glaciated terrain of Canada and Fennoscandia and the resultant changes in sampling and processing methods and improved understanding of kimberlite indicator mineral chemistry. At the same time, technological advances have led to increased sophistication of determining mineral chemistry (electron and proton microprobe and laser ablation ICP-MS) for all indicator minerals. The aim of this presentation is to provide an overview of indicator mineral methods and demonstrate their application in a variety of terrains around the world through case studies.

O33

REGIONAL DISTRIBUTION OF KIMBERLITE INDICATOR MINERALS, SLAVE CRATON, NORTHWEST TERRITORIES AND NUNAVUT, CANADA

John P. Armstrong

C.S. Lord Northern Geoscience Centre, Indian Affairs and Northern Development

Since 1991 over 350 kimberlites have been discovered in the Archaean Slave Craton (190,000 km^2), northern Canada. Some of the kimberlites discovered contain economic concentrations of diamond and production from two diamond mines has placed Canada as the 5th most important producer in the World, by value, of rough diamonds. Exploration for kimberlites has relied heavily on the application and use of indicator mineral sampling with glacial till the preferred sample medium. Results from some kimberlite indicator mineral (KIM; pyrope garnet, chrome diopside, chromite, illmenite, Mg-olivine) sampling programmes conducted by exploration companies were filed with the Government of Canada to maintain mineral claim tenure.

Each particular kimberlite field is identifiable by KIM till anomalies that are resolvable on the scale of the Slave Craton. Individual kimberlite clusters and fields shed particular suites of KIM's and the dispersion trains display variable features. On an individual basis most indicator trains have a pencil rather than a fan-shaped dispersion with down ice dispersion distances up to 80 kilometres or more. The young (47-55 Ma) Lac de Gras field (~ 200 kimberlites) hosts volumetrically significant volcaniclastic to re-worked volcaniclastic kimberlite that has shed prodigious quantities of KIMs. Older kimberlite fields are dominated by hypabyssal to diatreme facies kimberlite and are characterized by lower overall abundances of indicators potentially consistent with longer erosional histories.

O34

CASE HISTORY OF AN INDICATOR MINERAL SURVEY FOR NICKEL EXPLORATION, CANADA

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***International Geochemical Consultants, LLC**

Geochemical exploration surveys focused on potential for Ni-Cu mineralization were carried out over a region of interest extending 200 km south from Ungava Bay, Quebec, Canada by WMC Exploration personnel. Despite glacial till cover in a majority of the project area, WMC geologists identified regionally extensive mafic-ultramafic sills and an outcropping Ni-Cu enriched gossan in the footwall of one sill (McKinnon-Matthews, 2000). Following identification of this gossan, a comprehensive geochemical program was initiated to evaluate exploration potential of the broader region, during which stream sediment heavy indicator minerals and fine fraction sediments were collected.

Pervasive presence of chromite, Cr diopside and olivine in the stream sediment heavy fraction provided evidence for mafic-ultramafic sills throughout the area. The Ni-enriched gossan was clearly identified by low pH water (pH < 6.5), by Ni-Cu-Cr in fine fraction stream sediments, by chalcopyrite in heavy fraction sediments, and indirectly, by presence of orthopyroxene in the stream sediment heavy fraction. Stream sediment REE and U-Th signatures outline granitic domains and support location of the craton margin as indicated in geophysical data. Occurrences of sillimanite, kyanite and staurolite defined 4 distinct geologic domains also supported by geophysical data.

Regional steam sediment heavy minerals were useful to the nickel exploration program by providing indicators of bedrock lithology and Ni-Cu mineralization underlying glacial till. The minerals most diagnostic and useful for this survey included chalcopyrite as a direct indicator of Ni-Cu mineralization, chromite, olivine, and Cr-diopside and orthopyroxene as indicators of permissible host mafic-ultramafic sills, and sillimanite, kyanite and staurolite as indicators of major geologic domains.

O35

INDICATOR MINERALS FOR Ni-Cu-PGE EXPLORATION

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Ni-Cu-PGE indicator minerals are transported heavy mineral grains that can be used effectively at a regional scale to identify Ni-Cu-PGE fertility in mafic/ultramafic intrusions or komatiites. They contain special indicator elements, principally Mg, Al and Cr, which are related to the gravitational and alteration processes that concentrate Ni-Cu-PGE mineralization. Physically extracting and observing the indicator minerals instead of analysing samples for these elements dramatically improves detection levels.

Many indicator minerals are available for Ni-Cu-PGE exploration because Ni-Cu-PGE metallogenesis is a three stage process and each stage generates useful minerals. The three stages are: (i) gravitational (cumulus) settling of silicate and oxide mineral grains from the mafic/ultramafic magma; (ii) assimilation of felsic, sulphidic country rocks by the magma; and (iii) uniting of the assimilated S with Fe and Ni-Cu-PGE from the magma to form a heavy, immiscible sulphide liquid.

The Stage 1 cumulus indicator minerals include olivine, orthopyroxene, Cr-diopside and chromite. Their presence indicates the passage of a sufficient volume of mafic/ultramafic magma to form a significant Ni-Cu-PGE deposit. The Stage 2 indicator minerals include hercynite, corundum and green Cr-garnet. They are hybrid, refractory minerals having both mafic and felsic components, and their presence indicates that the mafic magma assimilated a significant quantity of felsic country rock. The Stage 3 indicator minerals are those actually containing S, Ni, Cu and PGE or related elements such as Co and As. They include sulpharsenide and arsenide minerals and PGE alloys and one marginally stable sulphide, chalcopyrite. Their presence confirms that the assimilated felsic rocks contained significant S and that sulphide mineralization separated from the magma.

Indicator mineral exploration for Ni-Cu-PGE deposits requires 10 kg samples of coarse-grained sediments such as till or alluvial gravel. Typical collection and processing costs are $250 U.S. per sample but indicator mineralogy is so hypersensitive that very few samples are required. Furthermore, with mineral grains from the three stages of Ni-Cu-PGE metallogenesis being mapped separately, an exceptionally clear view is obtained of both the overall fertility of the mafic/ultramafic target and the locations of any mineralized sites.

O36

FORECASTING LODE GOLD POTENTIAL FROM PHYSICAL AND CHEMICAL CHARACTERISTICS OF PLACER GOLD GRAINS- AN EXAMPLE FROM FRENCH GUIANA

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Gold grains in heavy mineral concentrates from streams in two placer gold areas in French Guiana were studied to determine if the physical and chemical characteristics could be used to predict a nearby preserved lode gold source. One area, Wayamaga has a significant known upstream bedrock lode source defined, whereas the other area, Cokioco, after >US$1million of exploration expenditure, has no lode source identified.

Six samples from Cokioco and eight from Wayamaga were obtained by panning 10 litre samples of gravel from streams. Gold grains were extracted and classified according to size and degree of physical wear. Representative suites of grains from each area were examined by scanning electron microscope and analysed by energy dispersive x-ray spectrometry.

Gold grain characteristics from Cokioco suggest effective placer concentration but they lack evidence of a proximal or preserved lode gold source. This is indicated by:

1. complete reshaping of all grains
2. coarser average grain size (median 125-200 microns)
3. complete leaching of any alloyed silver in the core and rims of grains
4. absence of unstable mineral inclusions
5. possible presence of supergene gold in aluminosilicate inclusions

Characteristics of gold grains from Wayamaga suggest that gold is being actively shed from a proximal lode source. This is indicated by:

1. incomplete (~80%) reshaping of all grains
2. finer average grain size (median 50-125 microns)
3. incomplete leaching of silver with average inner fineness of 953
4. presence of unstable mineral inclusions

This study suggests that the physical and chemical characteristics of placer gold grains can be used to forecast lode gold potential in a tropical rainforest environment.

O37

HYDROTHERMAL ZIRCON: A RESISTATE MINERAL WITH POTENTIAL USE AS AN INDICATOR/PATHFINDER IN EXPLORATION

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Several resistate minerals such as rutile, apatite and tourmaline have previously been suggested as suitable indicator minerals in exploration for porphyry Cu deposits. In this paper we outline the methods we have used to characterise and chemically fingerprint hydrothermal zircon, which is present in a wider range of deposit types than previously recognised, and may also be of potential use as an indicator or pathfinder mineral in the exploration for a range of hydrothermal ore deposit types.

Trace element composition and zonation within hydrothermal zircons was measured by the CSIRO-GEMOC nuclear microprobe and LA-ICPMS analysis. Zircons within high sulphidation epithermal Au deposits at Gidginbung (N.S.W., Australia) and Nena (Papua New Guinea) are characterised by enrichment and zonation in As, Sb, Th, Yb, U, Y, and Hf, and Fe, Cu, Yb, Th, Sn, Sb, Ba respectively. The Dam porphyry-related, breccia-hosted Au-Cu oxide deposit (N.S.W., Australia) contains zircons that are characteristically enriched in Fe, Cu, Sn, Sb, and Ba. Zircons within the Enterprise intrusive-related aureole-hosted vein Au deposit (N.T., Australia) are distinctively enriched in Cu, As, Ag, Sn, Sb and Ba. Hydrothermal zircons in the Gidginbung Volcanic Belt also have distinctive Ce and Hf compositions in comparison with magmatic zircons.

Zircons are a relatively stable 'resistate' mineral under most conditions of weathering, erosion and transport, and are often concentrated in heavy mineral fractions in sediments. These factors, and their distinctive chemistry, make them a useful indicator mineral in the exploration for a range of hydrothermal mineral deposit types.

O38

RUTILE GEOCHEMISTRY AS A GUIDE TO MINERALIZATION AT THE NORTHPARKES PORPHYRY COPPER DEPOSIT, NEW SOUTH WALES, AUSTRALIA

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Accessory minerals formed during hydrothermal processes may reflect those mineralizing processes by their textures and compositions, e.g., porphyry-related rutile has a low (Nb+Ta):(Cr+V) ratio(Williams & Cesbron,1977) and V-Sb-W-rich rutile defines the Au zone at Hemlo (Harris, 1989). Furthermore, if the accessory minerals are stable during weathering processes, such resistate minerals should be able to be used as a guide to mineralization when the sulphides are weathered out.

This paper reports results from 2000 analysis of rutile grains from 81 samples in both fresh and weathered rock about the E 26 porphyry Cu deposit at Parkes, central western NSW. There Cu-Au mineralization occurs as disseminated or veined sulphides in lower Palaeozoic K-rich trachyandesites intruded by quartz monzonite porphyries.

Results from Northparkes indicate that rutile within 100m of ore contains larger rutile grains (length x breath >2000 mm2) than grains further from ore (length x breath <1500 mm2). The rutile grains closer to ore also are zoned and contain V-rich portions in which V contents are >0.2% (commonly >0.4%) whereas barren rutile generally contains <0.15%V. Nb can also be elevated in the mineralized and altered zone with contents >0.15% common. V- (and Nb-) rich rutile is present in both the saprolite and soils derived from mineralized rocks at the deposit.

IGES • NAMS Joint Keynote Address

O39 Keynote

COLLABORATIVE RESEARCH AND EDUCATION VENTURES TO ASSIST THE GLOBAL EXPLORATION INDUSTRY

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Due to the relative decline in both government and industry funding for minerals geoscience research it has become necessary to better focus research allocations and to increase the level and nature of collaborations between local and international research groups.

In Australia this led to the establishment of a government funded Research Centres program, which has successfully operated for the last ten years. The impetus for this program was, that because Australia has limited internal research funds, then individual Australian researchers were disadvantaged on the world stage, and yet our mining and exploration industry was a significant global player. By forming a series of focussed Research Centres, each with a critical mass of 20 to 50 geoscientists, it has become possible for Australia to continue to be a significant research contributer in the area of minerals-related geoscience. The following University-based centres have been established since 1989. Centre for Landscape Evolution and Mineral Exploration, Centre for Global Metallogeny, Centre for Ore deposit Research, Economic Geology Research Unit, Centre for Geochemistry and Metallogeny, Centre for Predictive Mineral Exploration, these centres are commonly funded jointly by Government and Industry grants with a limited funding term of six to nine years. The Centres usually involve collaboration between several University geoscience departments, government organisations (CSIRO, Geoscience Australia) and groups of mining companies.

Although the centres have focussed on research collaboration, there have been recent moves to establish teaching collaboration, especially in the Honours and postgraduate course-work area, for example, a course-work masters program in mineral exploration has been developed jointly by three Australian Universities (Western Australia, Tasmania and James Cook), involving exchange of course units, lecturing staff and students. The mining industry has been strongly supportive of such collaborations, especially where the research and postgraduate courses are designed specifically to produce graduates with knowledge and skills relevant to the industry.

Similar geoscience research collaborations have been gaining momentum in Europe and North America. The GEODE consortium, funded by the European Science Foundation to collaborate on Geodynamics and Ore Deposit Evolution, has been a particularly good example. GEODE involves over 50 geoscientists from over sixteen European countries who are collaborating on seven major research projects in the following metallogenic regions: SW Iberia, Fennoscandian Shield, Alpine-Balkan-Carpathian-Dinaride Province, Southern Urals, sedimentary basins of western and central Europe and the Central French Massif.

A spin-off of the GEODE program has been the development of the Global Volcanic-Hosted Massive Sulfide Project. This project was established to study and compare a number of the world's major VHMS districts in order to define the key geological events that control the distribution and timing of high-value VHMS deposits; and thereby develop new criteria for locating these deposits. The project explores the connection between ore formation, volcanism, and extensional tectonics in each VHMS district, and will develop criteria to recognise this connection in the field. A network has been created of leading scientists who together have extensive experience in all the major VHMS districts, and 12 districts have been chosen as key study areas. The 12 districts comprise 7 major, massive sulphide, mining districts (Skellefte-Sweden, Iberian Pyrite Belt-Spain and Portugal, Southern Urals-Russia, Green Tuff Belt-Japan, Mount Read Volcanics-Tasmania, Bathurst-New Brunswick, Abitibi-central Canada), 4 less established but highly prospective regions (Peru, Greenland, Nunavut-Canada, India), and the Manus and Lau Basins as modern analogues. Multi-disciplinary scientific teams will work concurrently in each of the 12 districts under a common theme. Via close collaboration among the scientific teams, skills will be cross-fertilised from one district/research team to the others and lift the knowledge and expertise in each district to a level where detailed comparisons can be made across several disciplines. The information from the 12 districts will be synthesized to produce innovative scientific papers, and new databases and ore deposit models for mineral exploration. The strategy followed to set up the Global VMS Project has been to first concentrate on setting up the northern Sweden (Skellefte district) component of the project, funded by the Swedish Georange program, and then use this as a template to set up projects in the other districts.

Collaborative research between the mining industry and University research groups in Australia has been greatly assisted by AMIRA, the Australian Mineral Industry Research Association. The core business of AMIRA is the development, brokering and facilitation of collaborative research projects in mineral exploration, resource transformation and sustainable development, which are sponsored by member companies. Similar organizations have been operating in Europe (MIRO) and Canada (CAMIRO). As the mining industry has become increasingly globalised there has been recent pressure for stronger links between these research facilitation organisations.

The Role of Isotopes in Geochemical Exploration and Environmental Studies

O40 Keynote

THE ROLE OF ISOTOPES IN GEOCHEMICAL EXPLORATION AND ENVIRONMENTAL STUDIES

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For decades, stable (e.g. S, O, H, C) and radiogenic (e.g. U-Pb, Rb-Sr, Sm-Nd) isotopes have been used to support programmes of geochemical exploration. Have they delineated many successful targets for exploration? No. And, up until recently, they have been relatively expensive. So - why bother? What are they good for?

To date their most successful contribution has focussed on genetic modelling to better inform exploration and exploitation strategies. As in any geochemical endeavour, sound geology and paragenesis are critical to successful interpretations. The understanding of fluid interaction and component sources obtained especially from S, O and H isotope analyses is exceptional. An example where the successful use of stable isotope geochemistry has led to a paradigm shift in genetic models is the case of the massive sphalerite (Saint Salvy) and fluorite (Mont Roc) vein systems of the SW Massif Central (Munoz et al, Appl. Geochem., 14, 447-458), which emphasised interaction with adjacent Mesozoic basins rather than the central role of Hercynian granites. On a deposit scale, fluid transport vectors can be delineated by detailed traverses across structural lineaments and thus elucidate feeder structures with attendant impact on exploitation (Blakeman et al., Econ. Geol., 97, 73-91). The scale of analyses is a vital ingredient in successful strategies with appropriate metallogenic questions to be answered using tools from the recently developed in situ laser systems to bulk concentrate analyses (Fallick et al., Econ. Geol., 96, 883-888) – each offers a unique insight and new continuous flow mass spectrometers.

As for quality radiogenic age dating – hands up who doesn't want to know the age of their ore?

O41

Nd- AND S-ISOTOPE SIGNATURES OF SOUTH AUSTRALIAN Fe-OXIDE Cu-Au SYSTEMS: FINGERPRINTING 'RICH COUSINS' VS 'POOR COUSINS'

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Mesoproterozoic and Palaeoproterozoic basement of the eastern Gawler Craton of South Australia hosts the giant Olympic Dam Cu-U-Au deposit, as well as many Cu-Au±U prospects. Here we report Nd- and S-isotopic compositions of several prospects and compare them with the published data from the Olympic Dam deposit.

Sm-Nd isotopic analysis of Cu-Au mineralised samples from the sub-economic Emmie Bluff and Manxman prospects yielded eNd values (calculated at 1590 Ma) from –9 to –5, compared to the range of –4 to 0.5 reported for ore samples from Olympic Dam (Johnson and McCulloch, 1995).

Previous S-isotope work by WMC on Olympic Dam showed values of d34S around –7‰ for chalcopyrite. Our new d34S data for the metasediment-hosted Emmie Bluff prospect range from +8 to +12‰ for chalcopyrite in magnetite- and hematite-bearing samples. Three other prospects yielded d34Schalcopyrite values from –6‰ to +2‰ in magnetite-pyrrhotite or hematite-pyrite assemblages.

The Sm-Nd isotope data suggest dominantly crustal (local?) sources for Nd in the sub economic Cu-Au prospects, as compared to a greater input from primitive sources such as mantle-derived rocks and/or magmas in the REE-enriched Cu-U-Au ores at Olympic Dam. Similarly, the S-isotopic data are compatible with a greater relative input of sedimentary

rock-derived sulphur in the sub-economic mineralization as compared to a possibly dominant input of igneous-derived sulphur at Olympic Dam.
In conjunction with regional geological and other discriminators under consideration, Nd- and S-isotope geochemistry can assist in distinguishing the weakly mineralised ‘poor cousins’ from their ‘rich cousins’.

O42
NITROGEN AND SULPHUR ISOTOPES IN SOILS AS A GUIDE FOR REGIONAL EXPLORATION IN NORTHERN CHILE

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***Anglo American plc.**

By combining the isotopic composition of extractable N and S in soil samples from regional traverses in Chile, the origins of these elements can be discerned, including those associated with known porphyry Cu systems. This is the first application of N isotopes in regional exploration geochemistry.
The isotopic compositions of N, O and S indicate that salts in soils and salars from regional traverses throughout northern Chile originate primarily from dissolution of these components in the volcanic rocks, including elements from hydrothermal systems associated with porphyry Cu deposits. Younger (i.e. ca. 40 Ma) Cu-porphyry systems have similar $\delta^{34}S$ values but distinctly higher $\delta^{15}N$ values than their smaller and older counterparts (i.e. 55 Ma) and all of these deposits have N and S in soluble salts from proximal soils that are isotopically distinct from N and S derived from seawater or background volcanic rocks. Both N and O isotopes in extractable nitrates from soils indicate a contribution from atmospheric N, although most of the nitrogen in the nitrates comes from either volcanic rocks or ore deposits. In contrast, the oxygen isotopic composition of extractable sulphates in the soils indicate that most of the oxygen in the sulphates originates from groundwater, but during a period of time in the past when the climate was wetter.
N, S and O isotopes in nitrate and sulphate components in soils in the environs of ore deposits in some environments may be definitive indicators of specific styles of economic mineralization once their geochemical cycles have been revealed.

O43
Pb ISOTOPE DISCRIMINATION OF GEOCHEMICAL ANOMALIES USING TERRAIN SPECIFIC MODELS – THE PROTEROZOIC OF NORTHERN AUSTRALIA

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***CSIRO Exploration & Mining**

Pb isotope signatures, whether in fresh rock or regolith material, have been used for the past 25 years to discriminate between geochemical anomalism associated with a major hydrothermal event from that associated with uneconomic mineralization. Some of the uncertainties in the use of Pb isotope signatures have related to the confidence of estimating the range of expected ratios for specific metallogenic events. Terrain specific models relate Pb isotope evolution to accurate measurement of the ages of magmatic, metamorphic and hydrothermal events determined by independent techniques such as U-Pb and $^{39}Ar/^{40}Ar$ and thus provide much higher confidence discrimination.
A terrain-specific model developed from a detailed assessment of the Pb isotope signatures of mineralization in Northern Australian Proterozoic Basins accurately discriminates the major metallogenic events over the period from 1850 Ma to 1500 Ma. The model was developing by comparing recently published zircon U-Pb data on magmatic and metamorphic units from the region with high precision Pb isotope analysis of the same units. At least 17 separate hydrothermal events have

been defined, of which 6 were metallogenically significant and formed such deposits as Cannington (1670 Ma), Mount Isa Zn-Pb (1655 Ma), HYC (1640 Ma), Century (1575 Ma) and Mount Isa Cu (~1550 Ma). In each case, the main stage of mineralization can be isotopically discriminated from minor, slightly younger overprint events.

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O44

CONTINUOUS-LEACH ICP-MS AS A TECHNIQUE IN EXPLORATION GEOCHEMISTRY

T. Kurt Kyser*, W. R. MacFarlane, D. G. Chipley, C. J. Oates and D. Lawie

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Continuous Leach (CL)-ICP-MS is a novel technique that provides reliable information on the specific sites and mineral phases from which elements are being released. The sample is placed in-line with a high-resolution ICP-MS and leached with solutions of increasing reactivity to generate real-time data. CL analyses result in real time data generated by continually analysing the leachate as progressively reactive solutions are pumped through a sample and into a high resolution (HR)-ICP-MS. The basic framework from which to evaluate CL data was established using mono-mineralic samples based on their abundance in natural soils and ore samples and mixed minerals to produce synthetic soil analogues to evaluate matrix interference and re-precipitation effects. CL interpretations were confirmed by SEM analysis after each stage of the leaching process. Analysis of ore samples by CL indicates that the element release characteristics of mobile element sources can be determined generating complete and accurate pathfinder element suites. In a study of soils from an area with Irish-type mineralization, partial dissolution techniques indicate anomalous concentrations of Cu, Ag, Hg and Zn in some areas whereas CL results show that both barren and anomalous samples have equivalent mobile pathfinder element concentrations. In addition to elemental concentrations, precise Pb isotope data are also collected as part of CL analyses. Pb isotope ratios can be correlated with associated elements such as U and Th to verify the presence of "unsupported Pb".

This technique addresses some of the shortcomings of bulk leach techniques while overcoming many of the uncertainties associated with selective extraction.

Hydrogeochemistry in the Search for Mineral Deposits

O45 Keynote

HYDROGEOCHEMISTRY IN THE SEARCH FOR MINERAL DEPOSITS

David J. Gray

CRCLEME c/o CSIRO Exploration & Mining

Hydrogeochemistry may assist exploration for various commodities, including Au and base metals. However, before utilising groundwater results it is critical to understand groundwater dispersion processes and how they are influenced by varying chemical effects. This talk will discuss case studies from a variety of environments: fresh to hyper-saline; highly acid to alkaline; and reducing to highly oxidising. These water quality parameters, along with other factors such as Fe and Mn chemistry, profoundly affect the chemical composition of the groundwater. For example, the median dissolved Au concentration around different ore deposits may vary by 2 orders of magnitude, depending on a complex interplay of various groundwater parameters. In contrast, the main environmental control on base metal concentrations is pH. There are also

major changes in the balance between colloidal and true solution transport. Such variations clearly effect what will be considered an anomalous concentration in a hydrogeochemical exploration program. Indeed, a groundwater concentration strongly indicating mineralization in one site may be considered background elsewhere.

It is also important to understand flow characteristics, in order to vector to mineralization. An exploration site may be an area of active recharge or discharge, or other effects, such as density driven convection, may be important. A good understanding of all these factors will lead to effective use of groundwater data, both for exploration and in providing information on how various materials are weathering. This enhances understanding of active dispersion processes and assists in the development of weathering and geochemical models, which are essential for effective exploration in regolith-dominated terrains.

O46

MAPPING OF MINERALIZED GROUNDWATER DISCHARGE INTO LAKES AND RIVERS: A NON-INVASIVE EXPLORATION METHOD IN GLACIATED TERRAINS

Blair Hostetler*, James Ray, Gary Grabowski, Richard Dyer and Ross Kelly
***Aquapath Canada Ltd.**

Groundwater enters lakes and rivers in glaciated terrains through faults and fractures in bedrock and through glacial deposits such as eskers. This groundwater usually contains a locally derived geochemical signature of the bedrock and any mineralization with which it has been in contact. In some instances when the groundwater has traversed through a glacial deposit formed from more distant lithologies it will contain a stronger regional signature.

Over the last five years through field trials in Northeast Ontario, Canada, a cost effective, non-invasive mineral exploration method has been developed through actively mapping groundwater discharge into lakes and rivers, systematically identifying groundwater plumes, and collecting water samples for geochemical analysis. Direct sensor measurements of parameters such as dissolved oxygen (DO), total dissolved solids (TDS), and oxidation-reduction potential (ORP) allow the identification of groundwater plumes and the prevailing geochemical conditions affecting trace metal mobility. These direct measurements are collected every 30 seconds about 1 metre off the lake or river bottom from a slowly moving boat, allowing up to 15 kilometres of mapping per day. Further mapping at intermediate levels during the summer season when lakes are thermally stratified allows the modelling of circulation cells and estimation of the rate of groundwater influx.

Groundwater anomalies with strong geochemical fingerprints for various ore types have been identified in lakes and rivers of Northeast Ontario proximal to known ore deposits and, additionally, in areas where no deposits have been previously documented. Barium, gallium and europium have been used as indicators of potential volcanogenic massive sulphide (VMS) deposits. The method is also applicable to glaciated terrains in other geological provinces.

O47

HYDROTHERMAL ZIRCON: A RESISTATE MINERAL WITH POTENTIAL USE AS AN INDICATOR/PATHFINDER IN EXPLORATION

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***Cooperative Centre for Landscape Environments and Mineral Exploration (CRC LEME) & Geoscience Australia**

Several resistate minerals such as rutile, apatite and tourmaline have previously been suggested as suitable indicator minerals in exploration for porphyry Cu deposits. In this paper we outline the methods we have used to characterise and chemically fingerprint hydrothermal zircon, which is present in a wider range of deposit types than previously recognised, and may also be of potential use as an indicator or pathfinder mineral in the exploration for a range of hydrothermal ore deposit types.

Trace element composition and zonation within hydrothermal zircons was measured by the CSIRO-GEMOC nuclear microprobe and LA-ICPMS analysis. Zircons within high sulphidation epithermal Au deposits at Gidginbung (N.S.W., Australia) and Nena (Papua New Guinea) are characterised by enrichment and zonation in As, Sb, Th, Yb, U, Y, and Hf, and Fe, Cu, Yb, Th, Sn, Sb, Ba respectively. The Dam porphyry-related, breccia-hosted Au-Cu oxide deposit (N.S.W., Australia) contains zircons that are characteristically enriched in Fe, Cu, Sn, Sb, and Ba. Zircons within the Enterprise intrusive-related aureole-hosted vein Au deposit (N.T., Australia) are distinctively enriched in Cu, As, Ag, Sn, Sb and Ba. Hydrothermal zircons in the Gidginbung Volcanic Belt also have distinctive Ce and Hf compositions in comparison with magmatic zircons.

Zircons are a relatively stable 'resistate' mineral under most conditions of weathering, erosion and transport, and are often concentrated in heavy mineral fractions in sediments. These factors, and their distinctive chemistry, make them a useful indicator mineral in the exploration for a range of hydrothermal mineral deposit types.

O48

TRACE ELEMENT CHEMISTRY OF STREAM WATER FROM ARCTIC GREENLAND REFLECTING LITHOLOGY AND MINERALISATION

Agnete Steenfelt*, Gwendy Hall and Judy Vaive

***Geological Survey of Denmark and Greenland**

Stream water samples have been collected regularly together with stream sediments during reconnaissance geochemical mapping of Greenland conducted by the Geological Survey of Denmark and Greenland, but only conductivity, uranium and fluorine have been measured routinely. Concentrations of 43 trace elements have been determined in 210 stream water samples with the aim of studying the chemical relationship between bedrock and stream water, and evaluating the usefulness of stream water in mineral exploration.

Samples selected for analysis were collected in central West Greenland within different lithologies, including a lead-zinc deposit. The 100-ml polyethylene sampling bottles and screw caps were rinsed in the stream prior to sampling, but no filtering or addition of acid or other chemicals was made at the sampling site. The samples were stored in the bottles for two years until they were further prepared and analysed by ICP-MS at the Geological Survey of Canada.

Conductivity varies between 5 and 620 mS cm^{-1}, the highest values obtained in streams draining the lead-zinc deposit. Many of the element distribution patterns are clearly related to bedrock lithology and metamorphic grade, while others are difficult to interpret. Elevated Al, Be, Cd, Co, Cu, Li, Mn, Ni, Rb, and Zn values reflect prominent rust zones, and the highest Zn, Mo, Cd, Sb, Ba and Pb occur in streams draining the lead-zinc deposit.

Correlation between element concentrations in stream water and corresponding stream sediment is rare. The stream water data are therefore valuable to complement, not replace, stream sediment data. Despite the fact that the treatment during sampling and storage does not follow published recommendations, many of the regional element variations appear reliable and can be related to lithology and mineralization.

O49

GEOCHEMICAL AND ISOTOPIC CHARACTERIZATION OF KIMBERLITIC WATERS – A PROPOSAL FOR A NEW DIAMOND EXPLORATION TECHNIQUE

Jamil A. Sader*, Matthew I. Leybourne, M. Beth McClenaghan and Stewart M. Hamilton
***Geosciences Department, University of Texas at Dallas**

An aqueous geochemical investigation has been carried out as part of the Geological Survey of Canada's Targeted Geoscience Initiative (TGI) in the Lake Timiskaming and Kirkland Lake kimberlite fields of northeastern Ontario, to understand kimberlite-water interaction and to develop a new kimberlite exploration tool. Groundwater from exploration drill holes were sampled at five kimberlites: B30, C14, A4, Diamond Lake, and 95-2. Waters demonstrate reducing conditions with average pH and Eh values of 9.5 and 80 mV respectively and waters in kimberlites B30, C14 and A4 demonstrate pH and Eh values in the range of 11.00 to 12.45, and –100 to –536 mV, respectively. Stable isotopes δ^2H and $\delta^{18}O$ from all waters but A4 plot along a local meteoric water line suggesting modern recharge for kimberlite waters. A rayleigh distillation process H_2 + CH_4 generation) may be responsible for A4's δ^2H deviation. The $\delta^{13}C$ ratios display a wide range of values (-3 ‰ to -24 ‰) suggesting multiple processes including water-carbonate reactions and methanogenesis. For all waters, the K contents increase with increasing pH (up to 39600 mg/L). K/Mg, K/Ca and K/Rb ratios relative to pH suggest that with increasing pH, Mg, Ca and Rb are being buffered out of the waters and being incorporated into alteration minerals such as brucite, serpentine and possibly magnesite. Kimberlitic waters compared to waters from Archaean host rock suggest that aqueous geochemistry can aid in diamond exploration in regions with thick overburden.

Biogeochemistry in the Search for Mineral Deposits

O50 Keynote

RECENT DEVELOPMENTS IN BIOGEOCHEMICAL METHODS APPLIED TO MINERAL EXPLORATION

Colin E. Dunn
Consulting Geochemist

Increasing refinement of ICP-MS instrumentation and methodology is providing new insight to the distribution of trace elements in and among plant species. Commercial laboratories now offer routine low-cost packages for precisely determining small traces of up to 60 elements in just 0.5 g of dry plant tissue. For most elements there is no longer the need to 'ash' plants prior to analysis. However, losses from ashing at 470°C have been quantified and, provided ignition conditions are carefully controlled, losses are quite consistent, and therefore the spatial relationship of element distribution patterns is valid. In general, losses are <25% for most elements, with some significant exceptions being S and Cr (>70%), Br (90%), and Hg (~100%). Of note is that Hg in plant tissue is retained even after heating to 1100C.

Studies that demonstrate the fluxes (e.g. As, Cu) and locations of elements within plants further demonstrate the critical importance of consistent and careful collection of plant tissues for meaningful interpretation of biogeochemical survey data, and for optimising anomaly to background contrast. This information is of relevance to recent studies comparing the geochemical signature of treetops to hyperspectral imagery. In addition, regional surveys using treetops have outlined zones of PGE and pathfinder element enrichment in the boreal forests of Canada, and have assisted in defining the biogeochemical signatures of concealed kimberlites. Recently, detailed surveys have provided focus for locating precious metals, base metals and kimberlites in a broad spectrum of environments from around the world.

O51

BIOGEOCHEMICAL EXPLORATION IN ARID TERRAINS - AN EXAMPLE FROM THE ROSEBUD MINE, PERSHING COUNTY, NEVADA

Shea Clark Smith
Minerals Exploration & Environmental Geochemistry

More than two decades of mineral exploration using biogeochemical methods in the arid regions of the southwestern United States has added considerably to our knowledge about trace metal accumulation in common desert shrubs and trees as it relates to the discovery of ore deposits. It is estimated that between 1981-2000 approximately 300,000 vegetation samples from Nevada and Arizona have been analysed. This represents a significant baseline of information for further exploration and other studies such as those related to environmental issues.

The use of biogeochemistry in mineral exploration begins with mineral / ground water interaction. In arid environments this zone can be several hundred feet deep, and it is from these depths that trace metals in plant tissue seem to be derived. These depths are beyond root penetration, so mass gradients, created by evaporation and evapo-transpiration, are invoked to explain ion migration across this extreme hiatus. Secondary ion pathways include capillary action, redox cells, CO_2 gas flux, and microbial activity. Micro- and macro-structures provide important conduits for ion migration, which make biogeochemical surveys excellent mapping tools for obscured geologic structures.

There are unfortunately few examples where biogeochemical data can be directly linked to a mined ore deposit. However, the Rosebud Mine in northern Nevada provides one of these rare opportunities. In 1989 a sagebrush survey was done while the prospect was being evaluated during a campaign of exploratory drilling. Now that the last of the ore has been removed ($250 opt valuation) and the mine closed (2001), detailed comparisons between biogeochemical patterns and mineralization are possible. This paper presents a close look at toxic and precious metal accumulations in sagebrush as they compare to ore grade mineralization, as it existed 200 to 1200 feet from the surface.

O52

BIOGEOCHEMISTRY - NEW DATA FROM SOUTH AUSTRALIA

Melvyn J. Lintern
CSIRO Exploration & Mining

Preliminary regolith studies (including geochemistry) have recently been completed in the Gawler Craton in South Australia. They were part of a broader project investigating the geochemical dispersion and landscape evolution in selected areas of South Australia, and its significance to mineral exploration in deeply weathered terrain.

Case studies across several gold prospects (e.g. Birthday, Edoldeh Tank, Boomerang and Challenger) from the Gawler Craton will be presented. These studies included biogeochemistry, regolith geochemistry and regolith stratigraphy. Biogeochemical results will be compared with other sample media (such as drill cuttings, soil and calcrete) and the relationship of anomalies in vegetation with underlying mineralization will be examined.

The presentation will show that whereas biogeochemical surveys can indicate underlying mineralization, other sample media (principally calcrete) are currently being used to greater effect because they are more closely related to their bedrock source and more consistent. Anomalies generated by biogeochemistry are commonly spatially separated from other regolith anomalies and bedrock sources, and are therefore difficult to interpret.

Lithogeochemistry in the Search for Mineral Deposits

O53 Keynote

LITHOGEOCHEMISTRY IN THE SEARCH FOR MINERAL DEPOSITS – PAST AND FUTURE

Robert G. Jackson
Consulting Geochemist

The role of lithogeochemistry in mineral exploration, apart from quantifying the grade of commodity elements, is to use the distribution and zonation of elements around ore deposits to develop vectors toward ore. These vectors can then be applied to the search for blind ore bodies in similar geologic settings. Much of the literature on this subject has focused on: 1) discriminating between productive and unproductive lithologic packages; 2) regional zonation vectoring using multivariate statistics; 3) quantifying and mapping alteration using alteration indices; and 4) using trace elements to increase the size of the anomalous halo around a deposit.

Many deposits occur within a laterally extensive blanket of anomalous geochemistry along which vectors to ore are represented by cross-cutting plumes. Others occur within concentric shells of anomalous geochemistry, often centred on an intrusive body. Zonation schemes in these systems are usually documented in the direction orthogonal to these features as expressed along drill holes. From a vectoring standpoint, it may be as critical to develop lateral vectors in the plane of these features between drill holes. Recognising zonation relationships may be complicated by: 1) the oblique slice of the topographic surface through the zonation scheme, and 2) geochemical modification by surficial weathering processes. The recent development of 3D visualisation software and new ways of displaying down-hole data are making it possible to discern zonation relationships more clearly and in so doing, the stage is set for lithogeochemistry to play a greater role in mineral exploration than ever before.

O54

THE USE OF QUARTZ AS A SAMPLE MEDIUM IN LITHOCHEMISTRY AND REGOLITH EXPLORATION STUDIES

JC Van Moort
School of Earth Sciences, University of Tasmania

Trace element geochemistry is a powerful technique to identify materials ranging from quartz veins to primary and secondary alteration haloes in rocks. The approach relies on the fact that quartz derived from mineralising fluids preserves distinctive trace elemental compositions caused by substitutions and defects in the mineral lattice or specific solid and fluid inclusions. The inclusions may also represent intergrowths with other minerals. Material not related to mineralization invariably yields purer quartz.

The method does not rely on primary quartz only: quartz concentrates from wall rock and regolith alteration products can be used to delineate alteration haloes and surface expressions dispersion trails well beyond what can be obtained with bulk rock geochemistry.

The chemical patterns, as determined in a series of PhD thesis and postdoctoral studies, vary: 1) Hypothermal auriferous quartz veins Beaconsfield and Lefroy goldfields in Tasmania and Fosterville in Victoria: auriferous quartz characterised by elevated Li, Ge, As, Na, K and Al values. 2) Carlin, USA, silicified auriferous carbonates, characterised by elevated Li, F, Al, K, Ti, Rb, V, Y and Zr values. 3) Jim's Find, Tanami goldfield, silicified metasediments and basalt, Rand Pit, Randy Mine near Meekatharra, auriferous metadolerite, Mystery Zone, Mt. Percy Kalgoorlie, mineralized goldbearing porphyries with adjacent fuchsite-carbonate alteration within serpentinites, all three case studies located in WA; mineralization constantly defined by high Al, Cr, Ga, K, Rb, V and W values. 4) Cobar district, NSW. Gold and base metal deposits in metasediments and volcaniclastics; mineralization in veins, disseminated and massive sulphides. Cu, Zn, Pb, As and Ni are ore indicators in rock and regolith. Low Ca, K, Fe, V, Mn, Ga, Rb and Sr are indicators of wall rock alteration. 5) Mt Read Volcanics, Tasmania, large VHMS deposits in rhyolitic-dacitic lavas and volcano-sedimentary sequences. Fe, Mn, Ba, Zn, Pb, K, Rb, F are ore indicators. Al, Ca, Na, Ti and Sr are depleted in alteration zones. Orebodies are located at intersection of ore-indicator lineaments and general wall rock lineaments. Data manipulation enables formulation of reliable 'vectors' indicating in which direction the ore will be and of numerical criteria to distinguish between false and true 'anomalies'.

O55

PYRITES AT PAJINGO: TEXTURAL AND CHEMICAL VECTORS TO EPITHERMAL GOLD ORE

Tim Baker, R. Mustard, V. Brown, C.J. Stanley, N. Radford and I. Butler

***EGRU, *School of Earth Sciences, James Cook University**

The Carboniferous Pajingo Epithermal System comprises several low sulphidation Au-Ag ore zones that have a total resource of ~ 2 M.oz. The main Vera-Nancy vein is hosted by andesite that contains alteration which zones from inner silica-pyrite to argillic to distal propylitic alteration. Pyrite is ubiquitous in both alteration and vein. In the latter pyrite is a minor component (< 1 %), but the dominant sulphide, and occurs as fine-grained (< 50mm) bands or disseminations. Coarse (up to 0.5 mm) euhedral pyrite is most abundant (up to 10 %) in the silica-pyrite alteration whereas in argillic alteration pyrite (< 50 to 250mm) occurs as round to subhedral forms either as infill in narrow veinlets or as replacement. Fine-grained (< 50 mm) pyrite occurs in propylitic alteration along rims of earlier mafic phenocrysts and has a low abundance (< 1%). In-situ laser ablation-inductively coupled plasma-mass spectrometry was carried out on the pyrite in order to test the chemical variations between pyrite in different alteration zones. Preliminary results indicate that Mo and Ag concentrations vary over two orders of magnitude from the outer alteration zones (Mo ~ 0.1ppm; Ag ~ 0.5ppm) to the proximal vein alteration (Mo ~ 30ppm; Ag ~ 20ppm), and are the best micro-chemical vectors to ore veins.

O56

LITHOGEOCHEMICAL HALOS RELATED TO AUSTRALIAN VHMS AND SEDEX DEPOSITS

Ross R Large

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Lithogeochemical research on ten Palaeozoic VHMS and five Proterozoic SEDEX deposits in Australia over the past eight years has revealed the presence of complex and extensive alteration halos that depend on the metal content of the ores and their sedimentary/volcanic controls. In simple terms, the size of the alteration footprint is commonly related to the size of the ore deposit and its accumulated metal content.

Cu-Au VHMS deposits (Mt Lyell, Highway-Reward, Mt Morgan) range from stratabound massive pyritic lenses to crosscutting pipes and are encased by extensive alteration halos dominated by sericite-chlorite assemblages, which extend well into the hanging wall volcanic rocks. Cu-Zn-Pb-Ag-Au VHMS deposits (Rosebery, Hellyer, Hercules, Que River, Thalanga, Scuddles) are commonly stratiform sheets and lenses of banded sulphides aligned parallel to volcanic stratigraphy, which formed on or just below the seafloor. Alteration halos for these deposits show lesser penetration into the hanging wall volcanic rocks, compared with the Cu-Au VHMS, but halos can be very extensively developed along the favourable stratigraphy marking the position of the palaeo-seafloor at the time of mineralization. Both types of VHMS deposit show alteration zonation of quartz → Fe-Mg chlorite → sericite → carbonate passing from the centre to the margins of the halo. Extensive, low level thallium and antimony halos occur in the hanging wall volcanic rocks surrounding the zinc-rich VHMS deposits (Rosebery), and provide an important exploration guide. Similar halos do not occur around the Cu-Au deposits.

Proterozoic stratiform sediment-hosted Zn-Pb-Ag deposits (SEDEX; HYC, Century, Lady Loretta, Mt Isa) have very subtle, but far more extensive, alteration halos than the VHMS deposits. The ores are hosted by dolomitic and pyritic black shales and siltstones. The major mineralogical/chemical change in the halo sediments is the development of Fe and Mn bearing sedimentary-hydrothermal carbonates in place of the normal marine dolomite. The common zonation passing outwards from ore, both vertically and laterally, is: ore à Mn-siderite à Mn-ankerite à Fe-Mn-dolomite à dolomite. At HYC, for example, the Mn-ankerite halo extends at least 15km along strike from the ore deposit, and several hundred meters into the hanging wall sediments. Thallium is commonly enriched, at levels of 1 to 100's ppm throughout the Fe-Mn carbonate halo. Carbon, oxygen and strontium isotopes show systematic variations in the halo carbonate, defining mixing between a hydrothermal fluid isotopic signature and a normal marine sedimentary signature. A combination of lithogeochemistry with isotopic chemostratigraphy provides a mechanism to discriminate potential sedimentary horizons for mineralization. The Ti and Mn halos associated with SEDEX deposits are commonly one to three orders of magnitude greater in extent than those associated with VHMS deposits, and provide a valuable exploration guide. Several new alteration indices have been defined to assist in characterising alteration halos related to both VHMS and SEDEX deposits. Graphical plots utilising these indices, and other geochemical parameters, have been developed as vectoring tools to facilitate exploration targeting.

O57

LITHOGEOCHEMISTRY AND HYDROTHERMAL ALTERATION AT THE PAJINGO LOW SULPHIDATION EPITHERMAL GOLD VEIN DEPOSIT, DRUMMOND BASIN, QUEENSLAND

Clifford R. Stanley*, Tim Baker, Roger Mustard, Veronica Brown, Nigel Radford and Ian Butler
***Dept. of Geology, Acadia University**

The Pajingo low sulphidation epithermal gold vein deposit is located within the Drummond Basin of east-central Queensland. Steeply dipping quartz veins host gold mineralization with a total resource of 4.2 Mt averaging 14.6 gpt. The quartz veins cut andesite flows, breccias, and shallow intrusive dykes, sills, and plugs. These andesite volcanic rocks contain variable amounts of plagioclase, hornblende and clino-pyroxene phenocrysts, and are everywhere metamorphosed/altered to a propylitic mineral assemblage of chlorite, calcite, albite, quartz, pyrite, apatite and rutile. Distal to the veins, the calcite and chlorite have been further altered to ankerite and pyrite that is associated with an argillic assemblage of illite and kaolinite occurs. Proximal to the veins an alteration assemblage of illite, siderite, quartz and pyrite predominates.

Lithogeochemical analysis results of samples from fresh and hydrothermally altered rocks have been examined using Pearce element ratio analysis. This analysis confirms fractionation control of plagioclase, hornblende, and clinopyroxene in fresh rocks. Conserved element ratios such as Ti/Zr have also been used to discriminate between subtlely different volcanic compositions, in spite of hydrothermal alteration, allowing development of a chemostratigraphy for the volcanic pile at Pajingo. Metasomatic elemental material transfers associated with each hydrothermal mineral assemblage, determined using PER analysis, have been coupled with the reactant and product mineral assemblages, observed and measured using electron microprobe analysis, have allowed identification of the net hydrothermal reaction responsible for each alteration zone. These reactions have allowed identification of geochemical parameters (molar element ratios) specific to different forms of hydrothermal alteration. These parameters have been plotted down-hole, and assist in geological mapping of alteration about veins. Results have provided a comprehensive hydrothermal alteration zoning model for the low sulphidation quartz veins at Pajingo.

O58

RATIO ANALYSIS IN LITHOGEOCHEMISTRY: HOW TO QUANTIFY ALTERATION AROUND HYDROTHERMAL ORE DEPOSITS, AND INTEGRATE THE RESULTS INTO EXPLORATION EFFORTS

Michael A. Whitbread
University of Canberra

The aim of this presentation is to demonstrate how Pearce Element Ratio (PER) and General Element Ratio (GER) analysis can quantify the degree of alteration around hydrothermally deposited ore deposits, and then be applied in exploration programs for similar targets.

CONTENT SUMMARY: Geochemical changes due to alteration can be obscured by closure and pre-existing variations in the host rocks. PERs and GERs are formulated as molar ratios (which removes closure effects). PERs require the use of a conserved element as the denominator, while GERs do not. A linear mineralogical model in PER diagrams accounts for background variation, with deviations from this, reflecting potentially ore-related processes. Slopes on PER diagrams can then be used to quantify the degree of alteration. In GER plots, minerals can be plotted as points (rather than lines). A tie line can be established between altered and background mineral suites and sample proximity to an alteration 'node' can be used to assess its exploration significance.

Numbers reflecting degree of alteration (derived from PERs and GERs) can be plotted spatially to provide vectoring information in exploration projects at varying stages of maturity. Ratio diagrams can also be used to examine mineralogical controls on trace element pathfinders. PERs and GERs may also allow the identification of alteration in weathered environments.

Some case study examples from Australian base metal deposits will be included in the presentation.

In conclusions PERs and GERs can be used to quantify alteration. Numerical output from these ratio diagrams, reflecting intensity of alteration, is readily applied in exploration projects.

O59

LITHOGEOCHEMICAL EXPLORATION IN DEEP REGOLITH AT THE GOLDEN GROVE VOLCANIC HOSTED MASSIVE SULPHIDE DEPOSIT, WESTERN AUSTRALIA: AN EXAMPLE OF MINERALOGICALLY CONSTRAINED GEOCHEMICAL PROJECTIVE GEOMETRY TO IDENTIFY HYDROTHERMAL ALTERATION IN INTENSELY WEATHERED ROCKS

Clifford R. Stanley* and Nigel Radford
***Dept. of Geology, Acadia University**

Mineral exploration in areas of thick regolith poses significant challenges for the geochemist. Dissolution, hydrolysis and oxidation reactions significantly modify the original rock mineralogy, and substantially alter its geochemistry. Nevertheless, metastability of some hypogene minerals ensures their survival in the regolith profile, and indicates that not all weathering reactions reach completion. As a result, incompletely weathered samples can be used to project regolith compositions back to the precursor rock compositions before weathering. Using this approach, original volcanic compositions can be identified, and the fresh and hydrothermal mineral assemblages of the country rocks can be predicted. As a result, lithogeochemical examination of regolith can be used to determine the chemostratigraphy of the host rocks to mineral deposits, and to map alteration vectors to mineralization.

Molar element ratio analysis of whole rock lithogeochemical data from rotary air blast samples was undertaken at the Golden Grove volcanic hosted massive sulphide deposit, Western Australia to examine such projections. A variety of element ratio diagrams were designed using mineralogical information derived from X-ray diffraction analysis. Geochemical compositional controls associated with primary volcanic fractionation processes and weathering, were projected from on these diagrams, so that only compositional variations associated with hydrothermal alteration could be identified and quantified. Results reveal coherent spatial patterns that allow identification of sericite alteration zones, chlorite alteration pipes, and productive stratigraphic horizons within the camp. Furthermore, conserved element ratio diagrams were used to develop a chemostratigraphy for the host volcano-sedimentary succession. All results have contributed significantly to geological and exploration knowledge within the camp, and will be useful in further exploration for undiscovered VHMS deposits within the host greenstone belt.

O60

IDENTIFICATION AND CHEMICAL FINGERPRINTING OF A NEOPROTEOZOIC LARGE IGNEOUS PROVINCE (LIP) IN WESTERN AUSTRALIA

Paul A. Morris*, Franco Pirajno, and Michael T. D. Wingate

***Geological Survey of Western Australia**

Large volumes of mafic magma emplaced in the crust, termed large igneous provinces (LIP), can affect the hydrosphere and biosphere and provide information on mantle dynamics, as well as hosting significant base metal and platinum group element (PGE) deposits, and providing a heat source for driving hydrothermal systems. Combined regolith mapping and geophysics, detailed bedrock mapping, U-Pb mineral chronology, palaeomagnetism, and whole-rock lithogeochemistry has shown that dolerite sills extending over > 1300km and covering approximately 250,000km^2 in central western Australia, form a newly recognised LIP emplaced at about 1070 Ma. Subtle changes in rare earth element, large ion lithophile element, and high field strength element chemistry (e.g. Th/Nb) separate these 1070 Ma LIP rocks from an older, locally interleaved sequence of sills dated at c. 1440 Ma, and from a younger LIP dated at c.500 Ma. Localised crustally-contaminated sills may indicate Noril'sk-type magmatic sulphide mineralization, whereas the 1070 Ma LIP emplacement can explain the widespread largely vein-hosted mineralization found in siliciclastic rocks into which LIP dolerites have been emplaced. The LIP forms part of a Neoproterozoic rift sequence, which includes intrusive rocks of the Umkondo area in Southern Africa, and the Midcontinental Rift System (Keeweenawan) in the USA.

Developments in Geochemical Data Processing and Presentation

O61 Keynote

DEVELOPMENTS IN GEOCHEMICAL DATA PROCESSING AND PRESENTATION

Eric C. Grunsky

Geological Survey of Canada

The evaluation and interpretation of geochemical data can be carried out using numerical and graphical methods in the domain of the compositions and in the geographical domain. Geochemical data analysis typically involves two principal objectives; the recognition of individual or groups of samples that may be associated with a target area (i.e. mineralization or pollution source), and characterization of background populations that typically represent geochemical responses unrelated to target areas.

Geochemical data can be evaluated using computer based data analysis and visualization packages and desktop mapping systems (i.e. GIS). Data analysis/visualization software allows for extraction and enhancement of geochemical processes and desktop mapping systems show the results of the data analysis in a geographical context that can be integrated with other layers of geoscience information (geology, geophysics and topographical data).

A sequence of analysis is recommended for assessing and interpreting geochemical data, which includes:

- Generate histograms, box & whisker plots, Q-Q plots, scatter plot matrix.
- Create summary statistical tables, geographic presentation of data.
- Adjust of data for censored values (< lower limit of detection).
- Apply transformations if necessary.
- Select thresholds for distinction between target and background populations.
- Calculate robust estimates to compute means and co-variances to minimize the influence of atypical samples.
- Delineate structure in the data. Methods such as principal components analysis, cluster analysis, multidimensional scaling, c2 plots, weighted sums and spectral analysis.
- Establish target groups that characterise specific areas of interest. Establish background groups of samples that represent background features/processes.
- Carry out analysis of variance and canonical-variate analysis test the statistical uniqueness of the background and target groups.
- Apply allocation/typicality procedures to test unknown samples against the probability of belonging to none, one or more of the background or target groups.

O62

ESTIMATION BIAS OF MINERAL DEPOSITS CAUSED BY GRADE-BASED STAGING OF MULTIPLE ANALYSES IN SAMPLES EXHIBITING A 'NUGGET EFFECT'.

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Mineral deposits that exhibit poor sampling precision due to a 'nugget' effect are sometimes evaluated using replicate analyses of samples. As a consequence, mineral resource databases and exploration data sets from these deposits may contain concentrations that are the arithmetic average of these multiple analyses. In some cases, geologists have used the reported initial grade to trigger re-analysis of samples (with subsequent averaging) to reduce the impact of the 'nugget effect'. Unfortunately, a staged re-analysis protocol can result in significant grade bias.

A probabilistic simulation of a representative grade-based staged replicate sampling and analysis procedure using the 'equant grain model' and Poisson statistics provides insight into the magnitude of this bias. This simulation, based upon a true case history, involves the re-analysis of one additional sub-sample for initial grades > 2 and < 5 gpt, and re-analysis of three additional sub-samples for initial grades > 5 gpt. A range of nugget sizes and number of nuggets per sub-sample were considered; simulated true grades ranged from < 0.001 gpt to > 15 gpt. In samples with small nuggets, no significant bias was observed. However, in samples with larger nuggets, the sampling bias becomes very significant. Furthermore, in samples with a small number of coarse nuggets, the grade was under-estimated. Conversely, in samples with a large number of coarse nuggets, the grade was over-estimated. Because the size and number of nuggets in samples are not typically known in advance, a staged replicate sampling and analysis protocol will produce bias whose magnitude and direction are unpredictable.

As a result, sampling bias of samples subject to a nugget effect can only be avoided by treating all samples in the same manner.

O63

SIGNATURE DETECTION IN GEOCHEMICAL DATA USING SINGULAR VALUE DECOMPOSITION AND SEMI-DISCRETE DECOMPOSITION

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This study demonstrates the application of a new technique for recognising partial geochemical extraction signatures in surface regolith samples over deeply buried mineralization.
Existing multivariate data processing methods assume that signatures related to the effects of mineralisation take the form of separated or outlying clusters. Trace element patterns are typically more subtle, including situations where signatures influenced by mineralization take the form of denser sub-clusters within larger clusters. We show that a technique using a combination of singular value decomposition and semi-discrete decomposition (SVD-SDD) is able to subdivide clusters to reveal their internal structure. Two data sets are investigated: one from an area of glaciolacustrine cover (Cross Lake, Canada) and the other from an area of thick alluvial cover (Mandamah, Australia). At Cross Lake there are very strong patterns of trace element depletion and enrichment above mineralization in the raw data, whereas at Mandamah there are few discernible patterns. The SVD-SDD cluster with the strongest association with mineralization in the Cross Lake data occurs at a depth between 30 and 60 cm below surface and spanning a zone defined by depletion of Ca and a low soil pH. Samples at depths greater than 60 cm appear in clusters that include samples distal to mineralization. In the Manadamah data, SVD-SDD displays some weak clustering of samples from above mineralization, despite the lack of distinct patterns in the raw data. These results provide a useful guide to the combination of sampling media, partial extractions and elements that may discriminate mineralized from non-mineralized signatures.

O64

MAXIMIZING YOUR EXPLORATION ASSETS THROUGH THE EFFECTIVE USE OF DATA AND SOFTWARE TECHNOLOGIES

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Geosoft Inc.

Successful exploration programs rely on high quality data. Mineral exploration companies typically spend millions of dollars on the acquisition of geological, geochemical and geophysical data to support the discovery process. Maximizing the return on investment from this geoscientific data means rapidly and reliably converting high volumes of data into information that supports effective the company's knowledge base.
In this paper, we look at how mining companies can maximize the business value of high volume data (HVD) through implementation and integration of Exploration Data Management (EDM), Data Processing and Analysis (DPA) and GIS software technologies into the exploration workflow. The application of this concept will be examined in the context of a 300km2 project area of the Yilgarn Craton in Western Australia that contains over 8000 drillholes, 300,000 assay records, 15,000 line km of 20m line-spaced aeromagnetic surveys, geological outcrop maps and orthophotography.
High-quality geoscientific data, together with the appropriate software technologies can raise the productivity and success rates for mineral exploration companies through improvements in target delineation, increased efficiencies and cost effectiveness.
In the end, improved decision-making will result in better discovery success rates.

Regional Multi-Element Geochemistry

O65 Keynote

MULTI-MEDIUM, MULTI-ELEMENT REGIONAL GEOCHEMICAL MAPPING IN THE EUROPEAN ARCTIC: THE KOLA ECOGEOCHEMISTRY PROJECT

Clemens Reimann
Geological Survey of Norway

A multi-medium, multi element regional geochemical mapping project was carried out during 1995-1998 in the European Arctic. The project area starts at the Polar Circle and ends at the coast of the Barents Sea covering territories of Finland, Norway, and Russia. The Russian nickel industry on the Kola Peninsula is in the centre of the project area. The aim of the Kola Ecogeochemistry Project was to study the impact of emissions from industry versus natural element sources.

Terrestrial moss, and the O-, B-, and C-horizon of Podzol profiles were collected at an average density of 1 site per 300km^2 from the 188,000km^2 project area and analysed for more than 50 chemical elements. Industry in Russia is surrounded by haloes of high values for a multitude of chemical elements, e.g., Ag, Al, As, Au, Bi, Cd, Co, Cr, Cu, Fe, Mo, Ni, Pd, Pt, Sb, and V. These are detectable at surface (moss, O-horizon), not however, in the deeper soil layers. These high values decrease fast with distance from source. Background levels are reached between 100-200km from industry. Natural element sources, e.g. unusual bedrock types and the steady input of marine aerosols near coast have an important influence on element levels observed in the different sample materials. Vegetation zones (bio-productivity) have an important influence on element levels as measured in moss and O-horizon samples.

Multi-element, multi-medium regional geochemical mapping provides an important tool to understand origin, cycling and fate of chemical elements in the environment.

O66

THE ROLE OF SURFACE GEOCHEMISTRY IN THE DISCOVERY OF THE BABEL AND NEBO MAGMATIC NICKEL-PGE DEPOSITS

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The successful use of conventional reconnaissance surface geochemistry in locating the significant Babel and Nebo ortho-magmatic Ni-Cu-PGE deposits in a region dominated by aeolian sand cover.

The Babel and Nebo Ni deposits are located in the western Musgrave Block in central Australia. This arid and sparsely populated region of Western Australia straddles the border between the Great Victorian Desert to the south, and the Gibson Desert to the north. The region is covered by extensive aeolian sand sheets and longitudinal dunes between the small outcropping ridges of basement rock.

This presentation covers the discovery history, with particular emphasis on the choice and role of the deflation lag sampling in locating these deposits; an introduction to the geology and physical environment in this part of central Australia; and why, even with such extensive aeolian sand cover and sparse outcropping basement rocks, the deflation lag sampling was so sensitive to mineralization.

The Babel and Nebo deposits are significant Ni, Cu and PGE sulphide deposits that were targeted and explored for in an area previously unknown for this type of mineralization.

The deposits were initially located by conventional inexpensive broad spaced deflation lag sampling. This sampling has effectively explored 80% of the area despite the apparent dominance of aeolian landforms. The reconnaissance sampling produced 2 samples that were clearly related to Ni and Cu sulphide mineralization by their multi-element signature. This signature discriminated these samples from others with stronger Ni and Pt concentrations.

O67

IMPLICATIONS FOR EXPLORATION WITH THE USE OF HIGH RESOLUTION ICP/MS TECHNOLOGY

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***Activation Laboratories Ltd**

Conventional quadruple ICP/MS technology has revolutionized geochemical analysis. Large 60+ element packages at low cost and with detection limits in some cases several orders of magnitude better than ICP/OES technology became available at least a decade ago. The ICP/MS technology although available 25 years only began to enjoy widespread use in geochemical laboratories with the fourth generation machines around 7 years ago.

Newer technology, namely the magnetic sector–high-resolution mass spectrometer promises to continue this revolution in geochemical applications. Advantages of the HR-ICP/MS technology over the conventional quadruple ICP/MS technology include an improvement in sensitivity of 1 to 2 orders of magnitude and the elimination of most spectral interferences by the selection of medium or high-resolution modes. This elimination of interferences has the ability of allowing analyses of elements previously impossible like fluorine or severely impaired by analysis by conventional ICP/MS in certain matrices. Some of these elements are Se,V,As and Cr in an HCl or aqua regia matrix.

Hydrogeochemical application for gold and the PGE still did not have the required sensitivity with conventional ICP/MS without pre-concentration techniques. Gold and PGE also had the deterent of collecting a reasonably sized sample and preventing the metals from adsorbing onto the walls of the polyethene container so that they could be removed. Research and development at ACTLABS has developed a method whereby samples as small as 100 ml can be collected in the field without acidification. On return to the laboratory a lixivent is added which removes most of the Au and PGE from the walls of the bottle and complexes them in solution. The detection limits with HR-ICP/MS are in the ug/L to sub ng/L level allowing for the direct determination at natural levels for these and other common pathfinder elements.

Biogeochemical exploration historically has applied the INAA technique on dried vegetation and ashed vegetation. Analysis of vegetation ash by digestion and quadruple ICP/MS, typically using aqua regia if Au and the PGE were required, came into routine usage around 1999. The requirement of ashing with subsequent possible partial loss of some elements like Au, the possible formation of insoluble PGE (carbides?) compounds, the interference of some elements in the sample matrix on some elements like Pd and the lack of sensitivity for Au and the PGE compromised the potential of the technique. Direct analysis by digestion only without ashing and subsequent analysis by HR-ICP/MS to the required detection limits now becomes possible with this technology.

Application of isotopic analysis for exploration and environmental applications have been reported on by a number of people. Lead isotopic analysis with quadruple ICP/MS has been routinely available with a precision of around 0.5%. With the use of HR-ICP/MS precision improves to better than 0.1% and now allows the analysis for example of selective extraction solutions like Enzyme Leach to determine the source of the lead.

Coupling of the capillary electrophoresis technology to HR-ICP/MS provides a significant boost to environmental and perhaps mineral exploration studies. Samples of extremely small amounts of fluids (as low as 5 micro-litres) can be squeezed from sediments and speciated for elements like As, Se, Fe, Cr etc., providing data on the inorganic and organic species. This aids in the determination of toxicity and may have implications in mineral exploration by mapping reduced and oxidized species and perhaps unique species associated with mineral deposits.

O68

THE BALTIC SOIL SURVEY: ULTRA LOW DENSITY MULTI-ELEMENT GEOCHEMICAL MAPPING OF NORTHERN EUROPE

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***Geological Survey of Norway**

Ultra low-density (1 site per 2500 km^2) soil sampling can be used to construct reliable geochemical maps of large regions.

Soil samples of the A- and B- and/or C-horizon were collected from c. 750 sites in ten northern European countries (western Belarus, Estonia, Finland, northern Germany, Latvia, Lithuania, Norway, Poland, northwestern Russia, and Sweden). The sample sites were evenly spread over a 1,800,000 km^2-area, giving an average sample density of 1 site / 2500 km^2. The <2 mm-fractions (Poland: <1 mm) of all 1,500 samples were analysed for up to 62 chemical elements following ammonium acetate-, aqua regia- and HF-extractions and for total element concentrations by X-ray fluorescence spectrometry (XRF).

Regional scale geochemical patterns emerge for all 62 analysed chemical elements. Results provide important information for both, exploration and environmental geochemists. Mapped patterns show the influence of such factors as geology, agriculture, pollution, topography, input of marine aerosols, and climate. Natural, weathering related processes have by far the largest impact on the measured element concentrations in the soils. Industrial pollution is seen as a local process, reaching no further than 100 – 200km from any source. For all elements, natural variation in concentration ranges from 2 to 4 orders of magnitude.

IGES Poster Abstracts

Environmental Geochemistry

P1

DNAPL GROUNDWATER POLLUTION IN THE RIERA DE SANT POL ALLUVIAL AQUIFER (BARCELONA-SPAIN)

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The Riera de Sant Pol is a typical Mediterranean stream characterized by an irregular regime. The source of the stream is situated 10 km northwest in the Montnegre Mountains and the stream flows into the Mediterranean Sea. Associated Quaternary alluvial materials (gravels, sands and silts) constitute an aquifer traditionally exploited for agriculture and urban uses. Weathered granites form the aquifer basement. The groundwater has an essentially calcium bicarbonate composition which becomes sodium chloride near the coast.

In November 1998 anomalous chlorinated organic compound levels were detected (PCE and TCE) in the water supply network for domestic use of Sant Pol de Mar. This water came from the aquifer adjacent to the coast.

PCE and TCE together constitute a risk to health at levels higher than 10 mg/L (EU Directive 98/83/CE). In this aquifer the groundwater concentrations were considerably higher than 10 mg/L. Consequently the health authorities closed the wells for domestic use and imported water from other sources. The groundwater continues to be polluted.

The aim of this study is to determine the hydrochemical composition of the groundwater and to study the PCE and TCE pollution, analysing their spatial, time and fate evolution.

The most important findings are that the pollutant plume was delimited and characterized, and that the contaminant source was identified as a spatial and time point source located some meters upstream where the aquifer is crossed by a motorway. This determination is essential in order to carry out the aquifer remediation.

Geochemical Explorations in Areas of Previous Mining and Industrial Contamination

P2

ARSENIC CONTAMINATION IN SOILS AND VEGETATION FROM LEAD, ZINC AND SILVER MINE TAILINGS IN CENTRAL MEXICO (ZIMAPAN DISTRICT)

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Arsenic is one of the most toxic chemicals present in the environment and may pollute air, soil, sediments and water, causing health hazards to both human and animal life. Higher arsenic contamination is generally attributed to a mining environment or to natural processes.

The area of Zimapán is located in the western part of the State of Hidalgo, 126 kilometres northwest of Pachuca. This is a historical mining district and the mines have been exploited for the last 450 years continuously until the present. Hydrothermal sulphides, mainly arsenopyrite, pyrite, galena, sphalerite and chalcopyrite are exploited. In the 1920s the capacity of flotation plants increased the amount of mineral treated up to 750 tons per day.

A preliminary biogeochemical and soil survey was carried out near the town of Zimapán, where the mine tailings are more abundant. The vegetation species employed for this survey is the Californian pepper tree (Schinus molle L.), a tree widespread in all the area. A sample collection profile oriented east to west across the Toliman River was performed, upstream to downstream of Zimapán. A stream sediment survey in the Toliman River and tributaries was simultaneously performed. As, Se, Pb, Sb, Zn, Au and Ag anomalies were found in leaves and fruits of Californian pepper trees and in soils in the proximities of Zimapán. The same element anomalies were found in stream sediments collected near the mine tailings of Zimapán. Risk of poisoning to humans and animals is possible due to the use of leaves and fruits of this tree in food and in medicine.

Schinus molle leaves and fruits are revealed as an excellent tool for detecting toxicity in the environment, and also for geochemical prospecting for Au, Pb and Zn mineralization.

P3

ATMOSPHERIC EXPLORATION IN AN AREA WITH ABANDONED MERCURY MINING IN NORTHERN SPAIN.

Jorge. Loredo*, J. Soto and A,. Ordóñez.

***E.T.S. Ingenieros de Minas, Universidad de Oviedo**

Mercury is a trace element of interest due to its toxic effects on the environment and human health. Volatilisation is one of the main pathways by which it is released to the atmosphere by natural and/or anthropogenic sources. Currently, the understanding of the biogeochemical cycle of mercury is incomplete. One of the major uncertainties is the relative significance of non-point source emissions, such as mined areas or mineralised substrate, compared to point source emissions like coal fired power plants, or incinerators. In general, areas surrounding Hg deposits are naturally enriched in this metal, and the magnitude of the Hg release to the atmosphere is governed primarily by the Hg concentration in the substrate and/or in the anthropogenic source (mine wastes, smelting operations, etc.). Environmental parameters such as temperature, incident sunlight, rainfall, wind direction, etc., influence the magnitude of Hg emissions. In the atmosphere, Hg0 vapour is the dominant chemical form and it is slow to oxidise to more soluble species. The objective of the study presented in this paper is to quantify the mercury emissions in mined areas in Asturias (Northern Spain) and compare them with emissions in undisturbed Hg enriched sites. Then, in order to understand the environmental significance of Hg emissions from abandoned mines/ mine wastes, and naturally enriched areas, a field exploratory campaign has been completed using the analytical equipment Mercury Tracker-3000, with periodical and systematic measurements at different heights above the ground. The paper discusses the Hg emission data and the factors controlling the emissions.

Modern Geochemical Techniques for Exploration in Glaciated Terrains

P4

APPLICATION OF THE MOBILE METAL ION PROCESS FOR EXPLORATION IN AREAS OF THICK OVERBURDEN: A CANADIAN PERSPECTIVE.

Hugh A. F. de Souza*, Alan W. Mann, Cris Dragusanu
***SGS Minerals Services**

Our aim in this presentation is to describe how the Mobile Metal Ion (MMI) process has been used to successfully identify blind mineralization under thick glacial overburden in Canada.
The extreme heterogeneity characteristic of overburden in glaciated terrains has generally presented a major challenge to the successful application of purely geochemical methods for the detection of blind mineral deposits. However, new methods developed in the last decade have demonstrated that mobile ions present in surface soils can be used to detect blind mineralization, even in areas of thick overburden. In a departure from existing methodology, samples are collected in the A horizon and at a constant depth along a traverse. Weak partial extractions are key to successful extraction of the mobile metal ion population; the problem of controlling post-extraction re-adsorption phenomena is addressed by use of strong ligands in the extracting solutions. The mobile metal ion signal is generally at the part per billion level or lower requiring use of sensitive ICP-MS instruments for analysis. The application of the MMI process over the Cross Lake VMS deposit and a kimberlite in Ontario, and, over a newly discovered gold camp at Assean Lake in Manitoba are described. These case studies demonstrate that mobile metal anomalies can be detected directly over mineralization and that the MMI process is an effective tool in exploring for mineral deposits under cover.

P5

TILL GEOCHEMISTRY AT THE CLEAR LAKE SEDIMENTARY EXHALATIVE DEPOSIT, YUKON TERRITORY, CANADA

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ICP-MS has led to a resurgence of interest in use of weak extractions to detect geochemical anomalies above buried mineralization. However, the dispersion processes that form such anomalies remain controversial. Here we describe geochemical patterns from a Pb-Zn-Ag massive sulphide deposit concealed by up to 25m of compact till with permafrost at depths of <1m. Till samples from the C horizon were analysed with a weak hydroxylamine hydrochloride extraction and a conventional aqua regia digestion.
Rather than a positive geochemical anomaly, the most notable feature in both the weak extraction and the aqua-regia data is a depletion zone that forms a "hole" over and adjacent to the deposit. Within this zone the till is moderately acidic and concentrations of Pb, Zn and Ca are notably lower than in the alkaline tills on either side. This low zone cannot have resulted from glacial dispersal of material and must, therefore, be a consequence of leaching of elements from the

till over the massive sulphide. This is supported by the relatively low pH of the depleted zone, and the extreme acidity (pH <3) and high dissolved Zn content (> 1ppm) of the nearby Clear Lake. These conditions also suggest that acid leaching of the till is still active despite the presence of permafrost.

P6

SOIL GAS GEOCHEMICAL ORIENTATION STUDIES AT THE CRANDON VOLCANOGENIC MASSIVE SULFIDE DEPOSIT, WISCONSIN, USA.

R. Patrick Highsmith, L. Graham Closs, Jeffery A. Jaacks, and Ronald W. Klusman.
ALS Chemex

Areas blanketed with thick alluvium, glacial deposits, and volcanic flows provide one of the greatest challenges for mineral exploration in the twenty-first century. Oxidizing sulphide minerals generate acids that react with the wall rocks of mineral deposits. This process consumes significant amounts of oxygen and generates measurable amounts of carbon dioxide. Soil gas geochemistry offers an opportunity to inexpensively prospect through cover. This presentation describes a soil gas geochemistry orientation survey conducted over the world class Crandon volcanogenic massive sulphide deposit (published ore reserves of approximately 65 million tonnes grading 5.8% zinc and 1.4% copper) Wisconsin, USA, which sub-crops under 20 to 60 meters of glacial sediment.

This study characterises the carbon dioxide and oxygen soil gas responses over the Crandon deposit. The soil gas response over the deposit is compared with the soil geochemical response from aqua regia digestion / ICP-ES analyses. Strong, multi-point anomalies in carbon dioxide and oxygen occur over the Crandon deposit. The width and contrast of the gas anomalies are superior to the soil geochemical responses along the same traverses.

The soil gas technique is very effective at identifying deeply buried mineralization. It can be used as a sole exploration method or as a complement to geophysical techniques in separating graphite from sulphide conductors. Weather conditions must be carefully considered when designing and conducting soil gas surveys. Field procedures developed in this study allow rapid, low cost sampling and instantaneous analysis of in-situ soil gases. The result is a practical, highly flexible, exploration tool for prospecting through exotic cover.

P7

GEOCHEMICAL PROSPECTING IN ICE MARGINAL SETTINGS: INSIGHTS FROM RARE METAL PEGMATITE EXPLORATION IN THE BRAZIL LAKE AREA, SOUTHWESTERN NOVA SCOTIA

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Small northeast-trending dykes of albite-spodumene pegmatite, with elevated concentrations of rare metals (Ta, Cs, Be, Rb), have been identified in the Brazil Lake area, Yarmouth County, Nova Scotia. The continuous glacial drift and complex ice flow history in the Brazil Lake area make prospecting for mineral occurrences in this glaciated terrain problematic. Detailed overburden mapping indicates that a highly variable till stratigraphy exists. Along the Yarmouth-Digby coast, glacial stratigraphy is complex, but in the Brazil Lake area (12 km inland), a single lodgement/ablation till sequence exists. Glacial flow directions, investigated using aerial photographs, shaded relief maps, till textures, and clast orientations, are inconsistent and equivocal. This complexity is likely due to glacial reworking processes produced by the interplay and migration of regional ice sheets, local ice caps, and ice divides.

Consequently, mineral exploration in the Brazil Lake area requires in-depth study of the local glacial stratigraphy, provenance, and dispersion controls. Interpretation of pebble count, and trace element concentration patterns have proven to be instrumental in determining the predominant southward ice flow direction. Glacial transport distances are short (<1 km), and are evident in both lodgement and ablation till. Anomalous geochemical concentrations occur proximally in coarser size fractions and distally in finer size fractions, tracking grain size reduction with increasing dispersal distance. As a result, geochemical exploration in this ice marginal setting requires relatively high survey densities and benefits from geochemical analysis of a range of grain sizes to allow estimation of dispersion distance.

P8

SUBGLACIAL TILL – THE 'UPWARDLY MOBILE' SEDIMENT

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Glacial erratic material appears at the till surface down-glacier of the source subcrop having ascended gently through the till profile. The separation between source and surface expression is an important consideration in geochemical exploration and is an integral part of erratic train modelling (Klassen, 2001). However the mechanism that transports subglacial sediment upwards remains ambiguous. Consequently the applicability of erratic dispersion modelling is restricted by the limitations inherent in the analysis of observed erratic trains when used as an analogue for newly discovered surface fans.

Rotational structures of aggregated material together with discrete shearing observed using micromorphological (sediment thin section) techniques, have been proposed as a sediment transfer mechanism (van der Meer, 1997). Three dimensional computer analysis of the erratic train associated with the Tynagh Pb, Zn, Cu, Ag deposit, Co. Galway, Ireland has enabled identification of appropriate sites for pit excavations to depths of ≥ 5m allowing detailed 3D field observations, sedimentological and micromorphological analysis of the till down-glacier of the orebody. The evidence obtained will be used to investigate the hypothesis. An attempt will also be made to reconstruct the probable palaeoice-flow direction over the Tynagh area.

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Use of Indicator Minerals in Exploration

P9

PUBLIC DOMAIN COMPILATIONS OF KIMBERLITE INDICATORS AND THEIR MINERAL CHEMISTRY FROM AN EMERGING DIAMOND REGION: ARCHEAN SLAVE CRATON, NORTHERN CANADA

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Prompted by the discovery of a diamondiferous kimberlite at Point Lake in 1991, the area underlain by the Slave Craton in northern Canada has seen sustained exploration for kimberlites. To date over 350 kimberlites have been discovered in the region underlain by the Slave Craton. A portion of the data generated by exploration companies was filed with the Government of Canada as assessment work to keep mineral claims in good standing. Data for kimberlite exploration has consisted of glacial till sampling and kimberlite indicator mineral (KIM) picking results, electron microprobe analyses of indicator minerals, airborne magnetic and electromagnetic surveys, and diamond drilling.

The majority of this data was filed as hardcopy. A series of projects were initiated to digitise, scan, and merge the public domain diamond exploration data into a series of integrated GIS compilations. As a result over 135 000 till sample locations and KIM picking results, >110 000 mineral analyses, >1500 drill hole logs, and over 1200 geophysical images have been compiled and made available to clients representing one of the most integrated, publicly available datasets for an Archaean craton with known diamond potential. Demonstrated applications include use as a primary exploration tool, modelling of kimberlite bodies, modelling the dispersion of kimberlite indicator minerals in glacial till, and understanding the nature of the Slave craton's subcontinental lithospheric mantle.

P10

GLACIAL DISPERSION STUDIES OF INDICATOR MINERALS IN QUATERNARY TILL FROM TWO KIMBERLITES IN EASTERN FINLAND

Marja L. Lehtonen
Geological Survey of Finland

In 2001-2002 the Geological Survey of Finland carried out sampling of Quaternary till around two kimberlites in eastern Finland. The objective was to study their indicator mineral signatures in the surrounding basal till. Pipe 7 in Kaavi is a 2-ha Group I kimberlite that belongs to the Neoproterozoic Eastern Finland Kimberlite Province. The Mesoproterozoic Dyke 16 in Kuhmo, 200km NE of Kaavi, has characteristics of both olivine lamproite and Group II kimberlite. The dyke swarm intrudes a 300 x 600m area, with approximately 20% of the area being kimberlitic. The bedrock in the Kaavi area is mainly composed of Paleoproterozoic mica schists, whereas in Kuhmo Archaean gneisses with remnants of greenstones dominate. Till and moraine formations in both areas date back to the Late Weichselian. The down-ice sampling areas were ca. 2 x 3km in size each. Till samples (10-80kg) were taken by excavator and drill rig. Concentration of indicator grains (>0.25mm) was made using a modified Knelson Concentrator. The indicator fan derived from Pipe 7 and an adjacent kimberlitic body discovered 300 m down-ice from it could be followed at least 2 km in basal till. In Kuhmo the results from basal till indicate a kimberlitic dispersion of some kilometres from Dyke 16. Overall the study illustrates how crucial it is to consider regional features in Quaternary geology as well as in the bedrock when planning and carrying out a sampling program, and above all, careful, well-documented field-work is critical.

Hydrogeochemistry in the Search for Mineral Deposits

P11

DISCHARGE RELATED VARIATION IN TRANSPORT OF SEDIMENT AND GOLD IN HARRIS CREEK, SOUTH-CENTRAL BRITISH COLUMBIA

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Previous studies have indicated the importance of flood events in the transport and deposition of gold by streams. However, there have been no studies of the variation in quantities of sediment and gold transported within and between years or of the effects of such variations on geochemical anomalies in sediments. Here we address this using Helley-Smith bedload samples from Harris Creek, a gold-rich stream in British Columbia, to develop equations of the form Ri = aQb that relate transport rates (Ri) of sediment, magnetite and gold to discharge (Q).

These equations, together with stream hydrographs, are used to estimate the amounts of sediment, magnetite and gold transported in 1991, 1992 and 1993.

Results show that the amount of material transported annually varies by orders of magnitude depending on the size and duration of the snowmelt flood. For example, in 1992 and 1993 discharges >10 $m^3 sec^{-1}$, lasted for 23 and 354 hours, respectively. The associated amounts of sediment and gold transported were 5600 tons of sediments and 0.006 g of gold in 1993 versus only 20 tons of sediment and 0.0001 g of gold in 1992. Combined with the preferential deposition of gold at bar-head sites, these very large discharge-related variations in the amount of gold transported can account for year-to-year changes in the magnitude of gold anomalies in drainage sediments.

P12

GEOCHEMISTRY OF SURFACE WATERS IN THE RÍO COYA BASIN, EL TENIENTE DISTRICT, CHILE

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Results of a hydrogeochemical study of surface waters of the Río Coya Basin (El Teniente mining district) and the relation with existing lithological types is presented. The research area is located 20 km northeast of the city of Rancagua, VI Region, Chile. This study has allowed, for the first time, a determination of the background values of the analysed elements and discrimination among the different possible sources of contribution.

Water sample collection was carried out between March and May 2003. Fifty stream sampling sites, free from any mining or industrial activity influence were selected. Water samples were filtered and the dissolved concentration of 16 elements, 7 major and 9 trace, were analysed (i.e. As, Cu, Fe, Mo and Zn).

Data analysis methodologies are divided into three parts: (1) univariable analysis of elements in solution, allows determination of background threshold values; (2) multivariable analysis (principal component factor analysis), allows determination of the relationship between elements and their possible relation with source types (lithological), and (3) aqueous geochemical modeling, allows a prediction of the speciation of some heavy metals from mine waters.

Waters from the sampled streams are classified as calcium-sulfate to calcium-sulfate-carbonated waters. The interpretation of these results are related with sulphide (pyrite, chalcopyrite) oxidation processes and weathering of anhydrite bearing rocks of the El Teniente copper deposit and surroundings.

Biogeochemistry in the Search for Mineral Deposits

P13

NON-BARRIER BIOGEOCHEMICAL PROSPECTING FOR SILVER IN THE TRANSBAIKAL, SOUTH TAIGA

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Non-barrier Biogeochemical Prospecting (NBP) for ore deposits provides new focus for applying biogeochemical methods. The best case history of NBP with ore-grade prediction is for Ag in the Transbaikal south. The Ag-bearing Gilbera Zone of Deep Faults (GZDF) is 20 km long and a few kilometres from rail, road and services. On four occasions between 1970-1985 the Industrial Geological Organization “Buryatgeologia” conducted detailed soil geochemical and geophysical surveys for Ag at a scale of 1:10,000. From recent investigations on geology, geochemistry and biogeochemistry, development of the NBP for Ag deposits has generated the most significant results. Exploration of NBP for Ag in GZDF involved analysis for 47-70 elements in ~25,000 biogeochemical and 4,000 rock samples. This has resulted in delineation of >250 ‘Supposed Ore Biogeochemical Anomalies’ (SOBA) of Ag. Trenching of 29 SOBA has revealed 27 ‘Veined Silver Ore Bodies’.

During development of the NBP several problems were resolved: 1) Quantitatively informative, non-barrier bio-objects (i.e. tissue types) of dominant plants species were identified: namely, suberized cones of a Scots pine (Pinus silvestris), and rotted stumps of pine and larch (Larix dahurica). 2) These three sample media outlined >250 SOBA of Ag up to 8x20-200 m with 70-3,000 ppm Ag in the ash of pine and larch stumps. These are the highest recorded concentrations of Ag in plants. 3) Within an area of ~10km^2 , 11 zones were outlined, ranging from 100x150m to 250x400m. 4) A predictable relationship between Ag in rocks and Ag in plants was established. From this work, sample traverses 40-60m apart and sample spacing of 1-3m are recommended. 5) Three estimates of a plant-ore coefficients were determined, based upon the relationship between the Ag content of plant ash and Ag at the bottom of 2-3 m deep trenches.

P14

THREE PROCESSES OF ELEMENT UPTAKE BY ROOTS

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Chemical elements accumulate in all plant organs, but highest concentrations are mostly in roots. Carbon and gaseous phases of some chemical species may accumulate via the atmosphere, whereas roots accumulate elements from solids, liquids and gases. Consequently, from these phases three main models of root uptake have been developed, with most situations involving complex interactions of all three. This approach has revealed previously unknown biogeochemical 'provinces' and anomalies where there is a high concentration of an element in plants, yet a low content in soil as a result of elements being intensely absorbed from water and gaseous phases.

Three distinct types of biological accumulation coefficient are recognized: 1) Plant-soil coefficient (PSC); 2) Plant-water coefficient (PWCr); and 3) Plant-gas coefficient (PGCr), where 'r' reflects the root uptake. The greatest magnitudes of concentration are obtained from PGCr (up to 300,000). Concentration magnitudes of PWCr are up to 3,000. PSC show significant dependence on the form and grain size of minerals in contact with roots, but an average PSC is ~1, with similar average concentrations in lithosphere and in plant ash. Thus, the ratios of PSC:PWCr:PGCr are 1:3,000:300,000.

Atmobiogeochemical (i.e. gas) and hydrobiogeochemical provinces and anomalies can generate a high intensity of element absorption. Of the atmobiogeochemical processes, we have investigated only Hg. Similar processes are anticipated for Se. Hydrobiogeochemical provinces and anomalies are possible for most elements, because of the migration of water containing dissolved elements. Lithobiogeochemical provinces and anomalies with high concentrations of elements in plants and low contents in associated soils can be caused by either: 1) mineralization, giving rise to a PSC of ~10-100 (e.g. Zn and B); or 2) the presence of element enrichments in the nutritient-bearing soil horizons (e.g. humus). Such anomalies can occur where roots penetrate thin zones of allochthonous sandy cover. An example of the latter is the large "Zharchikha" Mo deposit, masked by Aeolian deposits, which was discovered from an intense biogeochemical anomaly of Mo in bark of Scots Pine (Pinus sylvestris).

P15

GEOCHEMICAL SURVEY USING THE PLANE TREES IN BARCELONA (SPAIN)

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Biogeochemical prospecting was carried out using plane trees (Platanus Hybrida) to detect the atmospheric contamination levels in Barcelona. The plane tree is the most common

tree in the city. Leaf sampling was carried out in autumn in Barcelona. Soil sampling was also performed to compare the plant - soil relationship.
The leaves were analysed by INAA and AA in the ACTLABS laboratories of Canada. Strong gold anomalies (70 - 40 ppb) were detected in plane leaves in the central part of the city. The main lead anomaly was observed in the main street of the city and around the harbour. Copper, antimony, mercury and bromide anomalies were also detected in some parts of the city. Lead, copper, mercury and antimony anomalies are attributed to fuel and bromine to marine aerosol.
Samples obtained in the city and near main roads outside the city were contrasted with those obtained from rural areas removed from traffic. High levels of gold, lead, copper, mercury and antimony were detected near roads whereas low levels of these elements were observed in rural areas. Therefore, the gold content in plane tree leaves can be attributed to car fuel combustion.
Sampling Platanus Hybrida leaves is an excellent tool for surveying the atmospheric contamination coming from fuel pollution.

Lithogeochemistry in the Search for Mineral Deposits

P16

PARTIAL GEOCHEMICAL EXTRACTION PATTERNS OF COPPER IN TEPHRA IN SULAWESI AND JAVA, INDONESIA.

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This study investigates the form and distribution of Cu in volcanic tephra covering mineralization in a wet tropical environment, using nine selective/partial geochemical extractions (PGEx).
Epithermal Au-Ag mineralization at Toka Tindung (Sulawesi) is draped by 1-2 m of basaltic andesite tephra with an immature soil veneer. Levels of PGEx Cu in the tephra is mainly related to variations in total Cu, the proportion of glass and degree of weathering. Porphyry Cu-Au-Mo mineralization at Ciemas (Java) is covered by residual and transported regolith overlain by up to 10 m of deeply weathered tephra. Mineralization is reflected by elevated Cu, Au, As and Mo in residual regolith and colluvium. Incorporation of saprolite fragments and abraded magnetite in basal tephra indicates syn- and post-depositional reworking of tephra. Along ridges where the tephra is >3m thick there is no response to mineralization in total or PGEx Cu in upper tephra samples. In topographic lows where the tephra is <3m, total and various PGEx display elevated Cu and Au above mineralised saprolite.
Inter-element patterns in tephra at both sites suggest the extractions are more partial than selective. Upper tephra PGEx Cu delivers no advantage over total Cu in detecting lateral hydromorphic and mechanical dispersion of Cu through thin tephra cover. Where PGEx are used, however, consideration should be given to the effects of variation in inherited concentration and mineralogical forms of trace metals in tephra on PGEx extractability (Toka), and the extent and nature of mechanical re-working of tephra and saprolite in determining source vectors (Ciemas).

P17

GEOCHEMICAL CHARACTERISTICS AND TECTONIC SETTING OF HASSAN-ABAD AND DARREHZERESHK GRANITOIDS (SW YAZD, IRAN) AND COMPARISON WITH SOME WORLD SKARN GRANITOIDS

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Many studies have shown that there is a systematic correlation between the composition of plutons worldwide and the metal content of associated skarns (Kuscu et al,

2002). This paper is the first attempt of such a study on the Hassan-Abad and Darrehzereshk granitoids and their related skarns.

The Hassan-Abad and Darrehzereshk granitoid intrusions, 70 km southwest of the Yazd City (Iran), are located in the Sahand-Bazman tectonomagmatic belt. This belt is well known for its porphyry copper deposits, and in some parts hosts calcic skarn zones. Both granitoids have intruded Eocene volcano-sedimentary and Cretaceous carbonate rocks and according to mineralogical, petrological and geochemical studies, have I-type characteristics ranging in composition from granodiorite to quartz-diorite, with sub-alkaline, calc-alkaline and weakly peraluminous to metaluminous characteristics, like most worldwide skarn granitoids.

A syn-collisional tectonic setting is proposed on the basis of field evidence and trace element geochemistry. Plots of harker diagrams suggest that the Hassan-Abad and Darrehzereshk granitoids are result of a magma differentiation. Major and trace elements when plotted on binary diagrams, especially, MgO vs SiO2, FeOt + CaO + Na_2O /K_2O vs. SiO_2, Fe_2O_3/Fe_2O_3 + FeO vs SiO_2 and V vs Ni, resemble the geochemical characteristics of plutons associated with worldwide Cu and possibly Au skarns. This suggests new exploration possibilities for copper and gold in the Hassan-Abad and Darrehzereshk district.

P18

RARE-EARTH-ELEMENT AND SELECTED TRACE-METAL SYSTEMATICS OF MASSIVE SULPHIDES IN THE BATHURST MINING CAMP, NEW BRUNSWICK: EXPLORATION TO PETROGENETIC IMPLICATIONS

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Massive sulphides and iron formation in the Bathurst Mining Camp are hosted by a Middle Ordovician greenschist-grade deformed bimodal volcano-sedimentary sequence. The hydrothermal architecture has been preserved in many deposits, with base-metal and trace-element zonation evident in massive sulphide lenses.

Major and trace elements including rare-earth-elements (REE) were determined for 212 samples of massive sulphide from 41 deposits. Overall, ∑REE concentrations average 34.0 ppm, exhibit a strong Spearman Rank correlation with Y (r'=0.86) and a strong positive Eu correlation with P_2O_5 (r'=0.71), indicating accessory minerals such as xenotime and apatite. Chondrite-normalized REE profiles for massive sulphides exhibit a consistent positive Eu anomaly (Eu/Eu*) averaging 6.0 with values as high as 30.4, correlating with In (r'=0.50) and Sn (r'=0.60).

Strong inter-element correlations between Al_2O_3, TiO_2, Zr, Sc, Th, Hf, and Nb indicate variable terrigeneous input (mass change effect), which masks low abundance hydrothermal components like the REE. Using these immobile elements as monitors, and assuming Yb immobility, the mass contribution from intercalated terrigeneous sediments can be calculated, accounted for and stripped revealing the net hydrothermal contribution to the exhalative sediment. Yb-based mass balanced REE data from the Heath Steele B zone reveals a strong increase in Eu/Eu* in the proximal bedded sulphide facies with anomalies as high as Eu/Eu*=1767, due to lower HREE and LREE contents. The underlying chalcopyrite-pyrrhotite-rich zone contains higher REE contents and a smaller Eu/Eu* (avg.=18.0), likely a result of REE saturation during high temperature-low pH fluid reaction (cooling, neutralization, and exchange) during zone refining of the massive sulphide system.

P19

MINERAL HOSTS FOR PATHFINDER ELEMENTS IN THE COBAR GOLDFIELD, NSW, AUSTRALIA

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The Cobar goldfield contains structurally controlled, sediment-hosted polymetallic sulphide deposits. In addition to predominant Au and Cu these deposits have associated Zn, Pb, Ag, Bi, As, Sb and W, which provide useful pathfinders in geochemical exploration. The goldfield has undergone prolonged and intense chemical weathering since the Mesozoic and there has been extensive chemical leaching of the regolith. Effective geochemical exploration requires a thorough understanding of element dispersion pathways and the distribution of target and pathfinder elements within the regolith to advise appropriate sampling protocols, media and interpretation.

This study examines the regolith mineralogy and mineral distribution of major, minor and trace elements through the weathering profile at three mineralised sites. It also investigates the final residence sites of pathfinder elements in the abundant surface lag and the geochemical evolution of this lag with transport. Lag has been widely used as a surface sampling medium for exploration in the region and throughout Australia.

Results show that abundant goethite and lesser hematite are the major hosts for target and pathfinder elements within the weathering profile. However less abundant manganese minerals (lithiophorite, cryptomelane group) are also important as they commonly contain higher concentrations of elements such as Pb, Ba, Cu, Zn, Ni and Co. Transformation of goethite to hematite and formation of maghemite near surface has resulted in redistribution of trace elements. During dispersal, the ferruginous lag has undergone further physical and chemical evolution that has significantly altered the content of Fe as well as trace and pathfinder elements. These variable modifications need to be taken into account when interpreting lag geochemistry.

P20

DISPERSION INTO MESOZOIC COVER FROM THE ELOISE Cu-Au-Ag DEPOSIT, QUEENSLAND, AUSTRALIA

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CRC LEME

Cu-Au-Ag mineralization (3.3 Mt at 5.8% Cu, 1.5 g/t Au and 19 g/t Ag) in Proterozoic metamorphic rocks of the Mt Isa Inlier is covered by 50-70 m of Mesozoic and Cainozoic sediments. To date, the most effective exploration in these Mesozoic basins has been by drilling geophysical targets. The intent of a complementary geochemical approach was to investigate the basal Mesozoic unconformity, a thin probably discontinuous layer of coarse sediment developed on and from the almost unweathered basement. This could retain mechanical or hydromorphic dispersions from the mineralization. The palaeo-topography of the unconformity was reconstructed from water bores and near-mine drilling. The main sequence of the Mesozoic sediments contained no recognisable dispersion. However, there are indications of mechanical down-slope dispersion in the basal sediments along or just above the unconformity that may have extended about 100 m from the mineralization or from mineralised faults. Drilling 3 km distant from the mine also indicated some small anomalies, just above the unconformity that appear to be directly down the palaeo-slope from Eloise.

Use of mechanical dispersions of Cu, Au, As and Sb in coarse sediments at the Cretaceous unconformity seems to be a valid prospecting method in areas of unweathered or slightly weathered Mesozoic cover and may be used to detect a 'near miss' when drilling a geophysical target. The relief and form of the pre-Mesozoic landscape governs dispersion directions so this needs to be thoroughly understood.

P21

REMOTE DETECTION OF HYDROTHERMAL FLUID PATHS BY SPATIAL ANALYSIS OF GAMMA-RAY AND HYPERSPECTRAL IMAGERY

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In the Panorama district of the Archean Pilbara Craton of Western Australia, excellent exposure reveals a complete fossil hydrothermal alteration system and associated volcanogenic massive sulphide deposits. The fluid paths manifest as a sequence of geochemically and mineralogically altered zones, related to evolving (sea-water derived) hydrothermal fluid composition, increasing temperature, and changing wall-rock composition. Key parameters for the identification of this sequence of alteration zones are potassium concentration, white mica abundance and white mica composition. Potassium concentration is determined from airborne gamma-ray spectrometry and white mica composition and abundance are extracted from hyperspectral imagery. Silicified zones with aluminium-rich white micas and potassic-altered zones with aluminium-poor white micas reflect seawater infiltration and conformable alteration. Potassium-depleted iron-magnesium altered zones reflect transgressive alteration near vent sites. Spatial analysis of the key parameters in a GIS reveals the hydrothermal fluid paths and provides a vector to hydrothermal vent sites associated with VMS mineralization. The spatially continuous nature of the airborne imagery and the excellent exposure provide a unique insight into this fossil hydrothermal alteration system.

P22

GEOCHEMICAL CHARACTERISTICS OF ALI-ABAD AND DARREH-ZERRESHK INTRUSIONS IN SHEARED ZONES, IMPLICATION FOR FORMATION OF PORPHYRY CU-MO MINERALIZATION, YAZD PROVINCE, CENTRAL IRAN

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The Ali-Abad and Darreh-Zerreshk granitoid intrusions and Cu-Mo mineralization are located in the southwest part of the Yazd province in central Iran. These intrusions of Oligocene-Miocene (?) age cut into Eocene volcano-sedimentary and Cretaceous conglomerates and carbonate rocks. These intrusions were emplaced along the northwest-southeast trending Dehshir-Baft strike-slip fault and its shear zones. The aim of this study, is to determine the geochemistry and structural controls of the granitoid and its porphyry copper-molybdenum mineralization. These aspects are characterized, based on synthesis of lithogeochemical, geological and structural data. To investigate the lithogeochemical factors of these granitoids in the sheared zones and porphyry copper-molybdenum mineralization, 40 samples were collected from both intrusions. Field observations and analyses of geochemical and structural data indicate that the formation of Ali-Abad and Darreh-Zerreshk porphyry copper deposits are a result of a coincidence of processes including: (1) differentiated granitoid arc activity, (2) shear zones in relation with strike-slip fault systems, (3) development of phyllic alteration in shear zones, and (4) a structurally controlled distribution of Cu-Mo mineralization.

Regional Multi-Element Geochemistry

P23

INTERPRETATION OF LARGE REGIONAL GEOCHEMICAL OPEN-FILE DATA SETS USING GIS: AN EXAMPLE FROM SW IRELAND

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The re-interpretation of open file geochemical data poses many problems, in particular comparison of data collected using different sampling methods, digestions and laboratories. In general data are available for Cu, Pb and Zn for large areas in the Irish Midlands.

A large (~23,000) sample soil data set was digitised and combined with geology at 1:100,000 scale, a satellite derived digital elevation map and SPOT imagery. The geochemical data were subset and median levelled before comparison using non-parametric statistical display. Peat areas were identified from the SPOT imagery and a separate cover generated.

Background values for individual lithologies were identified from the median levelled total data set using box and whisker plots. Anomalies were then extracted and scored on their geochemical signatures, proximity to buffered structures and favourability of lithology using Arcview. The dispersion paths for the anomalies can be identified using the DEM and SPOT imagery.

Analytical Techniques

P24

OPTIMISATION OF PARTIAL EXTRACTION CHEMISTRY FOR AN ACETATE LEACH

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In order to chemically optimise the response of a partial extraction used in geochemical exploration, the response must be evaluated in terms of the contrast between mineralised and non-mineralised signatures, while still extracting a statistically significant amount of the target elements of interest.

One approach to optimisation is demonstrated for a buffered Na-acetate leach, using regolith samples from a number of mineral deposits in eastern Australia. The three conditions optimised were temperature, the concentration of the active salt and the H+/HA ratio (which controls pH). For almost all elements maximum extraction were obtained at either low pH, high concentration of the active salt, or a combination of these two. In almost no case did temperature variations affect the leach. The experimental designs and patterns of correlation also yield information concerning the nature and groupings of the extracted elements. Comparison of various regolith materials and mineral deposit types demonstrate that while there are significant similarities between the element reactivities, there are also important differences, hence there is a significant degree of media-specific response for this leach.

This study has successfully demonstrated that, in some cases, adequate optimisation of reaction conditions is necessary to permit detection of partial (or selective) extraction geochemical anomalies related to mineralization. The use of experimental designs as an initial step also provides information specific to a site, as well as determining elemental relationships, without having to infer information, which is dependant upon spatial variance.

P25

PERFORMANCE OF COMMERCIAL LABORATORIES IN ANALYSIS OF GEOCHEMICAL SAMPLES FOR GOLD AND THE PLATINUM GROUP ELEMENTS

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Twenty-six international geological certified reference materials (CRM) and two in-house soil control samples were gathered and submitted ‘blind’ in duplicate to five commercial geochemical laboratories for the determination of Au and the platinum group elements (PGEs). The methods employed comprise: Pb fire assay (PbFA) combined with inductively coupled plasma mass spectrometry (ICP-MS); NiS fire assay combined with ICP-MS or instrumental neutron activation analysis (INAA); and aqua regia ICP-MS, with and without prior roasting of the sample at 600 oC. The CRMs vary widely in their matrix and PGE concentrations, ranging from a background soil (e.g. GPt-1), sediment (e.g. GPt-2, JSd-2), and rock (e.g. WGB-1, CHR-Bkg) to altered rocks (e.g. WPR-1) and ore material (e.g. GPt-6, SARM-7b, WMS-1). The results of this 'round-robin' are presented in this poster.

Results for Au showed the greatest variation across the laboratories, with one evidently encountering significant and spurious contamination. Comparison of the two fire assay techniques for Au, Pt and Pd was difficult as the number of data points was low and the variance within each technique across laboratories was too high. In general, PbFA-based methods for Au, Pt and Pd produced more accurate and precise results than those by NiS fusion and the data support PbFA detection limits for a 5-10 g sample of 1, 0.1 and 0.5 ppb for Au, Pt and Pd, respectively. A PbFA dataset for Rh demonstrated that this element is not recovered efficiently using an Ag inquart. Measurement of Rh by INAA rather than ICP-MS following NiS fusion facilitates detection below 1 ppb to c. 0.1-0.2 ppb. NiS/ICP-MS results for Ru, Os and Ir support detection limits of 1-2, 2-3 and 0.1 ppb, respectively; mean precision for these elements is in the range 10-15% RSD. Recovery of Os was very low by one laboratory, probably caused by its volatilization as OsO4 during final digestion in the NiS procedure. As expected, recovery of the analytes by aqua regia was low and highly variable across the different matrices for Pt, Ru, Os and Ir but that for Au and Pd was often >80%; prior roasting of the samples had mixed effects.

P26

Pb-ISOTOPE RATIOS IN SANDSTONES NEAR UNCONFORMITY-RELATED URANIUM DEPOSITS IN AUSTRALIA - A GUIDE FOR EXPLORATION

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(i) Pb isotope ratios were obtained from sandstones above Australian unconformity-type uranium deposits using partial-leach extraction (2% HNO_3 for 2 hours). Results show these isotopes to be potential vectors toward this style of deposit.

(ii) $^{206}Pb/^{204}Pb$ ratios along the unconformity are typically radiogenic (> 30). Unconformity samples within 1 km of known mineralization have $^{206}Pb/^{204}Pb$ ratios > 100 and are unsupported by co-existing U. Similarly, fracture zones in silicified sandstone are an area of post-mineralization permeability and many contain anomalous levels of U-unsupported radiogenic Pb on their surfaces. This indicates that radiogenic Pb was introduced from the deposits during post-mineralization fluid flow. Alternatively, sandstone samples distal to known mineralization and sandstones cemented by quartz during early burial diagenesis have Pb isotope ratios close to those of common Pb, indicating no post-mineralization contribution. Pb isotope ratios close to mafic volcanics are another highly anomalous area in the basin (>100), but co-existing U concentrations are very high (up to 1100ppm), indicating much of the radiogenic Pb is produced in situ. A new analytical technique (Continuous Leach-ICP-MS) is providing reliable information regarding the specific geochemical sites and mineral phases from where the U and Pb are being released. Radiogenic Pb is weakly bound to diagenetic minerals in samples with low U concentrations and is readily released during water and weak acid leaching. However, in samples with high U concentrations, CL-ICP-MS shows that the radiogenic Pb is leached from refractory phases during moderate to strong acid leaching.

(iii) These data show that with careful petrography and a reasonable geochemical understanding, Pb ratios can be a valuable

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means of assessing the relative prospectivity of a given basin for uranium deposits.

P27

PARTIAL LEACH SOIL GEOCHEMISTRY IN EXPLORATION FOR VHMS IN WESTERN TASMANIA

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More than a century of prospecting and exploration for base metals in the Mount Read Volcanics is thought to have located all significant (>3m.t.) deposits within 150m of the surface, in areas of shallow (<10m) post-Cambrian cover. There is a need for exploration methods to search for deep blind deposits and beneath thick cover. Partial leach soil geochemistry has the potential to be such a method.

Experiments with partial leach methods commenced in western Tasmania in the 1970's, e.g., the 'Huminex' method, with more recent surveys near the Hellyer Mine using Ca (NO3)2 and 'IONEX'. Apparently successful orientation surveys using 'MMI' encouraged Pasminco to trial a range of leaches at several sites. Based on these trials a Na-pyrophosphate leach was selected for use on the acid, organic-rich soils of western Tasmania.

Sampling procedures, including the use of randomised sample numbers and sampling at a consistent depth, analytical and quality control procedures are described. Problems associated with low post-digest solution pH and with anthropogenic contamination have been recognised. Anomalous partial leach data are interpreted in combination with conventional soil results, either from a database of approximately 100,000 historical samples, or by re-analysis of the partial leach samples.

Four of five targets generated from partial leach geochemistry have resulted in sub-economic mineralised drill intersections. Results from two prospects (Beatrice and Rosebery Mine) are presented. Partial leach soil geochemistry is not a 'silver bullet' for deep VHMS exploration in Tasmania, however it is a useful tool in a multi-disciplinary exploration programme.

P28

NON-NORMALITY FEATURE AND LARGE SAMPLE SIZE PROBLEM OF A COMPLEX GEOCHEMICAL DATABASE

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We investigated the probability distributions for concentrations of 27 chemical elements (Al, Ca, Fe, K, Mg, Na, P, Ti, Ba, Ce, Co, Cr, Cu, Ga, La, Li, Mn, Nb, Nd, Ni, Pb, Sc, Sr, Th, V, Y, Zn) in a total of 16511 sediment and soil samples collected by the National Geochemical Survey (NGS) Program in the U.S. Geological Survey. The graphical methods of histograms and normal quantile-quantile plots and a Kolmogorov-Smirnov (K-S) test were applied. It is observed that none of the 27 chemical elements can pass the K-S test for either a normal or a lognormal distribution, and large sample size is considered as an important factor causing the non-normality.

To investigate the effect of sample size on probability distribution, the number of 50, 100, 200, 500, 1000, 2000, and 5000 samples were randomly selected from the total 16511 samples for 100 times, and the K-S test was applied. The results show that when the sample size is small, the statistical test is weak, and it is easy for a data set to pass the normality test at both the significance levels of $p<0.05$ and $p<0.01$. With the increase of sample size, the statistical test is getting powerful and with a large sample size, e.g. larger than about 1000, it is hard for any data to pass a test for normality due to a minor departure. This shows it is a misconception of "the more samples, the better" in terms of using statistical tests.

Soil and Regolith Geochemistry in the Search for Mineral Deposits

P29

GEOCHEMICAL SOIL SURVEYS FOR Au EXPLORATION IN THE KENIEBA DISTRICT IN MALI, AFRICA

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Geochemical soil surveys were carried out over an area of 50 km2 in southwestern Mali in order to select promising areas for gold occurrences. The area is located within the Kenieba inlier, which is almost entirely composed of Birimian sediments (lower Proterozoic) and/or volcanics and younger granitoids and mafic intrusions, but it is difficult to identify parent source rocks and to observe outcrops, because the survey area has been weathered intensively.. There are two main regional fracture directions: N-S and ENE.
Two sampling surveys were conducted. Sampling patterns for the reconnaissance survey comprise 37 traverse lines (259 km in total length) spacing 200 m along NS direction with a sampling interval of 100 m, and a total of 2,597 soil samples were collected. During the detailed survey, a total of 2,146 soil samples were collected from the grids of 26 traverse lines (53 km in total length) spacing 200 m along NS direction with a sampling interval of 25 m. In the detailed survey, a total of 80 termitaria samples were also collected from the upper portion of the termite mounds. All samples were analysed for Au and As.
Contour maps are plotted using kriging as a gridding method. In the reconnaissance survey four Au anomalous areas and three As anomalous areas were finally selected. The anomalous areas show similar patterns to the main regional fracture direction (NS). The detailed geochemical survey was carried out over an area of 10 km2, which was selected from the reconnaissance survey. Considering geochemical data, two Au anomalous areas and two As anomalous areas were finally proposed as promising prospects for Au. In general, Au content of termitaria is high in soils having high Au. Because the upper portions of termite mound represent the characteristics of lower soil horizons, it is necessary to survey the subsurface of the sample point having high Au content in termitaria soils in order to identify the sources of Au.

P30

CONTROLS OF ELEMENT DISPERSION IN AEOLIAN SAND AND CALCRETE DOMINATED REGOLITH ASSOCIATED WITH AU MINERALIZATION IN THE KRAAIPAN GREENSTONE BELT, SOUTH AFRICA.

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Processes leading to the emplacement of surface geochemical anomalies and the controls of element dispersion in aeolian sand dominated regolith are to date still poorly understood, resulting in the lack of adequate conceptual and methodological models for explorations in such terrains. This paper therefore focuses on the geochemical controls and associated patterns of element dispersion in aeolian sand-calcrete regolith overlying the Goldridge Au mineralization in the Kraaipan Greenstone Belt, South Africa and discusses possible sampling strategies.
Regolith in the Goldridge area consists of in-situ weathered basement rocks, which are overlain by colluvium and valley filled sediment sequence comprising of carbonate impregnated pebbly to coarse/medium-grained sands at the base, followed by an upper reworked friable/laminated calcrete. The above are unconformably overlain by a

fine to medium grained ferruginized aeolian sand. The thickest and most laterally extensive regolith sequence occurs along major drainages with broad valleys and deep channels, which permitted widespread development and preservation of thick colluvial and alluvial sediments, which were subsequently overlain by aeolian sand.

Gold shows variable dispersion curves in aeolian sand, often with peak Au concentration occurring in the central portions of the profile, coinciding with the transition zone between deep red and reddish brown sands, that is characterized by up to 2 fold enrichment of Fe relative to Mn. The underlying calcite rich laminated carbonate facies with siliceous nodules and hardpan laminated carbonate facies are accompanied by enhanced contents of CaO, MgO, Fe_2O_3, LOI, H_2O and a decrease in SiO_2 contents. The laminated calcretes are associated with the highest accumulation of Au in the entire regolith while the calcrete impregnated basal pebbly to sandy zone shows sporadic high or generally low Au gold content.

The laminated to hardpan carbonate horizon and the basal zone of the aeolian sand horizon should therefore be identified and preferably sampled during exploration. An understanding of the spatial distribution of these regolith zones is essential to maintain a consistent sampling.

P31

THERMALLY SPECIATED MERCURY IN MINERAL EXPLORATION

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Mercury is recognized as a universal pathfinder to most hydrothermal metal ores, petroleum deposits, and geothermal occurrences, and because of the high fugacity of this element and its various mobile compounds and complexes, it is well suited as an indicator of blind and deeply buried mineralization. The relative ease with which mercury is oxidized and reduced, by the influences of both inorganic and organic processes, gives us an opportunity to look at the speciated components of the total mercury flux. By comparing the various mercury species that are detected in soils overlying deep zones of metal enrichment, vectoring strategies that relate near surface to deep ore can be explored.

Recent investigations using novel fingerprint methods and stepped thermal desorption have revealed differences between naturally occurring and anthropogenic sources of mercury. These methods, however, focus on data derived from thermal desorptions above 100 dC. This paper presents results from soils that were thermally desorbed between 40-110 dC as they relate to the discovery of ore, and sub-economic ore, several meters to hundreds of meters beneath the surface. The extremely low reduction enthalpies used by these methods suggests that extremely volatile mercury compounds, possibly organo-Hg complexes, are responsible for the anomalies that appear to indicate the deepest ore.

Several examples from recent survey work over a volcanogenic massive sulphide, a mesothermal vein Au-Ag system, and an on-trend carbonaceous shale-hosted “Carlin” Au prospect will be used to demonstrate this geochemical exploration method.

P32

DEEP-PENETRATION GEOCHEMICAL EXPLORATION FOR HIDDEN SANDSTONE-TYPE URANIUM DEPOSITS IN THE TUHA BASIN, NORTHWESTERN CHINA

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The Tuha basin covers an area of approximately 50 000 km2 in Xinjiang, northwestern China. Its center hosts oil and gas. Recently, sandstone-type uranium deposits were discovered on the edge of the basin. The deposits are at a depth of 300m

hosted in Jurassic sediments composed of sandstone, mudstone and coal beds. Previous geochemical methods were prohibitive due to overburden concealing prospective bedrock sequences. The study is to develop sampling, analytical and interpretation approaches for regional and detailed exploration using deep-penetration geochemistry.

Orientation samples were collected from loose sand, weakly cemented and well-cemented horizons over the deposit. After sieving to 20, 60, 100 and 160 mesh, samples were processed for total analysis and sequential selective leaching analysis. 30 elements were determined by ICP-MS.

The data shows many elements are enriched in fine fraction of -160 mesh in weakly cemented horizon. Uranium is largely present as an adsorbed and exchangeable form making up 30-40% of total content. High U and Mo contents show a direct correlation with the hidden deposit.

A wide-spaced sampling survey was carried out to delineate regional targets in the whole basin. Sampling density is approximately 1 / 100 km2. Three geochemical provinces were delineated across the whole basin. One of them is consistent with the explored uranium deposits, and the others have very high potential for the discovery of new prospects.

This study shows that deep-penetration geochemistry is effective in detecting hidden sandstone-type uranium deposits and wide-spaced sampling can supply a powerful cost-effective tool for delineation of regional targets in concealed terrains.

Miscellaneous

P33

EFFECTS OF LOGGING ON GOLD ANOMALIES IN STREAM SEDIMENTS IN THE SUNGAI KULI REGION, SABAH, MALAYSIA

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Increased erosion of soils caused by clearing of tropical forest and subsequent agricultural practices can severely dilute gold anomalies in drainage sediments. However, although selective logging of tropical rainforest is also widespread and is known to increase rates of soil erosion, its effects on geochemical anomalies in stream sediments have not been studied. Here we compare gold anomalies in a gold-rich tributary of the Sungai Kuamut before (1999) and after (2001) selective logging.

The pre-logging study found a strong, but extremely erratic, gold anomaly in the sand size fractions from both cobble and gravel sites. After logging, there is a slight increase in the abundance of the medium and coarse sand fractions and average concentrations of gold are similar or even slightly higher to those prior to logging. In the upper reaches of the study area there is also visual evidence of deep, post-logging scouring of the stream channel that is likely related to the effects of logging together with several exceptionally heavy rainfall events of >100 mm per day. It seems likely that the post-logging flood events that scoured the channel would mobilize any gold deeply buried in the stream-bed and also flush fine sediment from the stream channel. Both processes would counteract any dilution of the gold anomaly that might have resulted from increased soil erosion after logging.

P34

FORMATION CONDITIONS FOR PLATINOID BLANKET-FORM ELUVIAL DEPOSITS

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The discovery of platinoid blanket-form eluvial deposits (BEDs) in the silver-bearing Gil'bera zone of deep faults (GZDF) was unexpected, given that they are situated in alkaline syenites and monzonites with an absence of bazites. To date seven separate deposits have been discovered in the area. The authors consider that these BEDS have a secondary hydrogenic or biohydrogenic origin. The occurrence of typically less than 1mm (up to 5mm) disseminated primary native Pt is considered to have a hydrothermal, pneumatolytic or hydropneumatolytic origin. The origin of Os and Ir within the weathering crust remains uncertain. Using scintillation spectral analysis (SESA) the composition of these BEDs is considered to comprise 10-30mm platinoid minerals- mostly Pt, Pd, Ir, Os, Rh, Au, Ag with rare two-element "alloys": Pt + Pd, Pt + Rh, Pd + Au, Pd + Ag, Au + Ag, Au + As, Ag + As. Three or four-element "alloys" with Ru are also probable.

A biohydrogenic model for these deposits would involve.

1. Intensive contact absorption of the disseminated platinoids by roots of plants utilising a lithobiogeochemical model, which includes the chelatic organic acids of root excretions. The participation of biogenic chelatic root excretions produces ten times the absorption for Pt than Au.
2. Leaching of soluble biogenic platinoids from plants by rain-waters via an acid reaction, enriched by chelates – complex organic acids.
3. Downwards migration of platinoids leached from upper soil horizons (A, B, C) within this solution
4. Enrichment of rain and snow waters, passed through humic horizons by acid biogenic chelates, which further dissolves platinoids from horizons A, B, C.
5. Deposition of platinoids from the solution caused by neutralisation reactions in 'alkaline syenite' eluvium. Grains larger than 0.1mm result form extended periods of deposition and crystallisation on earlier grains.

The processes of hydrogenic platinoid enrichment within soil horizons has been extensively studied and modelled. The results of this work can effectively explain the formation of the large platinoid nuggets discovered in these deposits.

The conditions necessary for the formation of the platinoid BEDs studied are:

1. Primary enrichment of disseminated platinoids in alkalic rocks
2. Dense vegetation, ensuring intensive biogeochemical circulation of platinoids with acid biogenic chelates;
3. Abundant atmospheric precipitation ensuring percolation down to alkaline eluvium, which acts as a natural sink for the dissolved platinoids in the acid, biogenic-chelatising solution.

P35

LIGHT HYDROCARBON GAS LITHOGEOCHEMISTRY AS A POTENTIAL INDICATOR OF MINERALIZATION IN THE IRISH UPPER CARBONIFEROUS

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2500 rock samples collected from the Irish Upper Carboniferous were analysed for Cu, Pb, Zn, Mn, Fe, insoluble residue and a range of hydrocarbon species. The geochemical concentrations were transformed in two ways: firstly, concentrations were contrast enhanced by subtracting the minimum concentration from each concentration, dividing the result by the concentration range (producing a value between 0 and 1), and then raising the power of the result to a value chosen to create a new variable that exhibits spatially contrasting patterns in the data (this typically occurred when the variance of the transformed variable was maximized). Secondly, an angular transform (the arcsine of the square root of the concentration, expressed as a proportion) was applied; this assumes that the predominant source of variability in the variable is binomial sampling error. This angular transform is essentially a 'variance-stabilising transformation', and produces a new variable where the sampling error is constant across the range of the data. Both of these transformations were also applied to the soluble-fraction normalised concentrations (where the soluble fraction = 100% - insoluble residue). The transformed data were then imported into ArcGIS to allow geographical investigation. Elements plotted were Cu, Zn, Pb, Fe, Mn and methane, propyne and total hydrocarbon. Geochemical thresholds were selected to classify the transformed data into groups and colour coded symbols were used to highlight anomalous results. Spatial correlations between anomalies and several known deposits occur; other, unexplained anomalies identify areas where further investigation may be warranted.

P36

LEVELLING DISPARATE SOIL CU, PB AND ZN DATA: AN EXAMPLE FROM CO. MEATH IN THE NORTHEAST OF THE REPUBLIC OF IRELAND.

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***Geological Survey of Ireland**

The Geological Survey of Ireland (GSI) holds much historic exploration data for the country on Open File. One of the most widespread datasets is that of shallow soil geochemistry. Shallow soil datasets, were collected by different companies, using different sampling protocols, laboratories and analytical procedures at different times from the 1960s to the 1990s. Samples were for the most part collected on square grids with a side of either 400 or 500ft. The purpose of this study is to attempt to integrate these disparate datasets to form a common platform for data interpretation. For the study Co. Meath is chosen. Co. Meath occurs in the northeast of the Republic of Ireland covers some 2,340 km2. Seventy-six Prospecting Licences cover the county and Europe's largest zinc mine occurs at Navan, in the centre of the county. In addition to the datasets held by the GSI, Tara Mines Ltd. has made available confidential data around the Navan Mine. In total there are twenty-seven different datasets.

As a first step a log-transformation is applied to produce a normal distribution in the data. Next the data are levelled using mode levelling and levelling by percentiles to produce a series of maps for Cu, Pb and Zn across the county. Data processing is carried out using Microsoft EXCEL while data presentation, interpretation and analysis is carried out using ESRI's ArcGIS software.

A ratio analysis of Zn/(Zn+Pb) is also carried out in an attempt to differentiate clastic anomalies from hydromorphic anomalies. These anomalies are coincidental with a number of magnetic lineaments within the crystalline basement of Co. Meath that may be related to the formation of Irish-Type deposits. Data levelling appears successful; fewer discrepancies across datasets are apparent with percentile levelling but mode levelling gives a greater contrast between background and anomalous values. Statistical processing of old geochemical data in a GIS environment does yield useful information when interpreted in conjunction with other datasets such as hydrology, soils, Quaternary geology, bedrock geology and magnetics.

Challenges for Mining in the 21st Century

O1 Keynote

CHALLENGES FOR MINING IN THE 21ST CENTURY

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Euromines

The presentation will try to elaborate on the challenges and the answers of the international and European extractive industry linked to a sustainable supply of minerals for the growing demands in terms of quantity and quality. Taking the Global Mining Initiative and the MMSD report "Breaking new ground" as a starting point the European industry is in the process of embarking on a new business development strategy for the next ten years, including new approaches to environmental performance, social responsibilities, customer relations, and competitiveness.

The presentation is going to show in particular how the European mining industry is going to secure its legal framework for operating whilst at the same time improving its public perception and improving its acceptability, that is the "license to operate".

Whilst taking positions on major EU policy actions such as the

- EU Integrated Product Policy,
- EU Waste Prevention and Recycling,
- EU Natural Resource Strategy,
- EU Chemicals Policy,

the industry is increasing its consultations with stakeholders, that is regional offices and authorities, the trade unions and NGOs.

The upcoming EU legislative proposals on mine waste management, groundwater management and soil protection are of high priority for the sector and will be dealt with in cooperation with the European authorities.

However, legislation can only change performance to a certain extent, therefore concerning the actual performance the sector is launching major activities with regard to the implementation of internationally developed schemes such as ISO 14000/9000, emergency response systems (APPELL), the International Cyanide Management Code, as well as European schemes such as guides on crisis and risk communication, as well as sustainable development indicator reporting.

But ensuring an appropriate legal framework and ensuring good environmental performance is not sufficient for securing the extractive industry in the future. Its competitiveness needs to be strengthened by further RTD and product and market development. The EU minerals industry's research network NESMI will contribute to the identification of the sector's RTD needs. Therefore new proposals for the whole sector under the EU's 6th framework programme are under preparation, which will hopefully result in major breakthroughs in processes and products to secure the future of the sector in Europe.

All this will be part of the new "Roadmap 2015" that is under preparation for the European mining industry.

O2

THE PROPOSED DIRECTIVE FOR THE MANAGEMENT OF EXTRACTIVE INDUSTRY WASTE IN THE EUROPEAN UNION

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INTRODUCTION

The general principles of Waste Management in the European Union were set out in 1975 in the Waste Framework Directive. Its objective is the protection of human health and the environment from waste through consistent legislation and procedures across all Member States. Waste is defined as "all substances or objects, which the holder discards, or intends or is required to discard". This is a very wide definition, and the European Court has ruled that it includes, for instance, granite blocks stored at a quarry in the hope that they might become saleable at some time in the future.

There was, however, an exemption from the Directive for extractive industry waste where it was already covered by other legislation.

It had been accepted for many years that national legislation was sufficient for the exemption to apply and, in consequence, little attention was paid to extractive industry waste at EU level. In 1998, this position changed drastically as a result of the major escape of tailings at Aznalcóllar in Spain, followed by other incidents such as that in 2000 at Baia Mare (Romania). As a result of these, the European Commission produced a Communication on Safe Operation of Mining Activities. It also revised its legal opinion on the exemption of mining waste from the Framework Directive, and decided that Community legislation was required to make it applicable. This opinion is likely to be confirmed by the European Court of Justice.

The Communication included a number of proposals intended to improve the management of mine and quarry wastes, including bringing some mines into the SEVESO Directives, which deal with major accident planning and response; a BAT note on management of mine tailings and waste rock; and a new Directive. The Commission's proposal for this last item, entitled "The Management of Waste from the Extractive Industry" was published in June 2003, following extensive discussions with stakeholders, including Governments, Industry Associations and NGOs. The Directive will now be considered by the Council of Ministers and the European Parliament, in conjunction with the Commission and the final text will require the agreement of all three parties.

CONTENTS OF THE PROPOSED DIRECTIVE – COM(2003) 319 FINAL

The aim of the Directive is prevent or reduce as far as possible adverse effects on the environment and people from extractive industry waste, by setting minimum regulatory standards across the Union. It is particularly concerned with the prevention of water pollution and ensuring stability of large deposits of waste, especially tailings.

The proposal covers on-site management of waste from the on-shore extractive industry with the exception of exploration. It includes mines and quarries of all sorts and also some down-stream processing, such as alumina refining, but not smelting. All phases from design, through operation, to closure and after-care are covered. Given the wide definition of waste in the Framework Directive, many materials-handling operations that are normally barely considered to involve waste, such as overburden stripping and backfilling (surface and underground) are included.

Operators will have general obligations to consider the amount of waste to be produced and its characteristics, and provide a waste management plan to ensure that best practice is used, guided by the BAT note for the more sensitive wastes.

A variable permitting regime is proposed depending on the possible risks and hazards. Producers of inert waste, such as many aggregate quarries will only have to produce acceptable waste management plans, and be generally obliged to prevent water pollution. Most other operators will be required to obtain a permit, which will set out the conditions that will have to be met for their waste management, covering design, construction, operation and closure of waste disposal facilities. Various general obligations must be met under any permit, especially ensuring stability of waste facilities and prevention of water pollution, and a "competent person" must be in charge of the facility. Closure plans and a financial surety for closure costs must be in place before operations start. The highest level of obligation will rest with operators producing waste considered to represent a real hazard to the environment, who will also have to have an accident prevention and emergency response plan approved. Many mines producing tailings will fall into this category, if they do not fall under the SEVESO 2 Directive. An integral part of the proposal is that there should be opportunities for public participation throughout the permitting process.

The Directive recognises that a wide variety of operations will be covered, and, therefore, does not seek to impose specific design or operating conditions, but allows competent authorities discretion on what waste management techniques are acceptable in individual cases, provided that the requirements of the Directive are met.

PRELIMINARY CONCLUSIONS

It is too early to reach any firm conclusions on the effects of the proposed Directive, especially since it may well be considerably revised before a final text is agreed. However, it does seem clear that a real effort has been made to reconcile two potentially conflicting requirements. Firstly, even though the Aznalcóllar and Baia Mare incidents do not seem to have resulted in irreparable long-term damage, it was widely perceived that there needs to be an EU-wide system for better management of at least those extractive industry wastes which have the potential to cause major problems. On the other hand, the industry operates on narrow margins and, in many cases, its waste obviously poses little or no hazard to either human health and safety or to the environment. Many of these operations produce essential raw materials, such as aggregates, and an overly strict regime would have unnecessary and damaging effects on the EU's competitiveness.

The additional burdens, economic or managerial, which may result from this proposal, will depend very much on both the nature of the operation and the regulatory regime already in place. Thus, relatively modern operations operating under a tight regime (such as the Irish mines) should not be much affected. However, older mines or those currently subject to a looser regime may find it more difficult and expensive to comply. However, it is certainly more appropriate than the Landfill Directive, which includes measures that conflict with best practice for the extractive industry.

All in all, a cautious welcome for the principles may be reasonable, but much work remains on the details to ensure that it is workable and effective in practice.

O3

SUSTAINABLE MINERALS: APPLYING THE PRINCIPLES

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TWENTY FIRST CENTURY CHALLENGE

A key challenge for this century will be to develop a deeper and more refined definition of sustainable development applied to minerals. Any new approach must recognise that the sustainable development paradigm is a dynamic interplay of ideas, concepts and evolving thinking: it is not a precise science (this may be hard at times for scientists to understand in cultural terms – we prefer less 'soft' approaches). To be of real benefit sustainability must evolve to the point where it can be of practical assistance to real problems, real situations, and real people. In the context of this paper this means developing processes and solutions for all 'mineral stakeholders' not only those which in the past were considered the only stakeholders (e.g. mining companies and governments.)

A THEORETICAL FOUNDATION: WHAT IS 'SUSTAINABLE MINERALS'?

The original sustainable development theory was given birth by the 1987 Brundtland report. From a minerals perspective the most comprehensive body of work to date is the 'Breaking New Ground- Mining, Minerals and Sustainable Development' report (IIED 2002 / Global Mining Initiative). This paper focuses on the practical application of sustainable principles from the perspective of a national Geological Survey. 'Sustainable minerals' is clearly not a way of making a finite non-renewable resource infinite and 100% renewable. It is about developing a range of methodologies for maximising and sustaining economic, environmental and social benefits and minimising the negative impacts which accrue from mineral development. The key idea is that an optimal balance is attained between the three fundamental areas of concern: economics, environment and community. Sustainable minerals must find a consensual way forward which: a) generates sufficient minerals-oriented wealth to attract capitalist-oriented private-sector industries; b) encourages mining companies to operate to highest international environmental standards; c) develops methodologies and approaches which maximise lasting benefits to communities and governments at local, regional and national levels; and d) adopts a mutual-respect approach to all stakeholders, involving as wide a representation as possible in consultation and decision making.

THE BRITISH GEOLOGICAL SURVEY (BGS) APPROACH TO SUSTAINABLE MINERALS Evolving Policy

As part of the world geoscientific community the BGS has a responsibility to encourage a mineral resources custodianship ethos which: a) maximises resource usage and recycling; b) minimises waste production and negative physical environmental impacts; c) encourages lasting benefits for local communities and economies; d) encourages responsible mineral stewardship at local, regional, national and international levels; and e) avoids the 'export' of mineral stewardship where unnecessary – e.g. presenting holistic arguments for local rather than global supply solutions where possible.

Policy Application:

BGS has found that the practical application of the sustainable minerals approach involves: reinterpreting and re-brigading its geoscientific information and knowledge legacy (and of course generating new information) for customised and specific end-uses and end-users; learning from past unwise mining practices and encouraging best-practice; modelling mineral lifecycles; assisting with policy development at a range of levels; and consulting with communities and stakeholders. A sustainable minerals approach must communicate the message (with evidence) that the Developed World in particular, has an ever-growing need for minerals, which underpins a wide range of economic benefits and quality of life and attempt to move mineral development forward in a consensual, strategic manner.

CASE STUDIES DEMONSTRATING THE SUSTAINABLE MINERALS APPROACH: Space precludes detailed discussion of case studies, which have involved the BGS in recent times. However the presentation will at least describe key issues linked to the following: 1) The materials paradox of the Developed World, particularly those countries which are low producers and high consumers: e.g. ball clay in Dorset and barytes in Scotland; 2) The costs and benefits of stakeholder participation in Melanesian mineral development; 3) Using a sustainable minerals approach to assist in the rebuilding of government and a peace economy in Afghanistan.

Figure 1 A war damaged building in Kabul: a graphic image of the current state of Afghanistan. Visionary politicians are exploring ways in which a sustainable minerals approach can help restore a peacetime economy and government.

IGES • NAMS Joint Keynote Address

O4 Keynote

COLLABORATIVE RESEARCH AND EDUCATION VENTURES TO ASSIST THE GLOBAL EXPLORATION INDUSTRY

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Due to the relative decline in both government and industry funding for minerals geoscience research it has become necessary to better focus research allocations and to increase the level and nature of collaborations between local and international research groups.

In Australia this led to the establishment of a government funded Research Centres program, which has successfully operated for the last ten years. The impetus for this program was, that because Australia has limited internal research funds, then individual Australian researchers were disadvantaged on the world stage, and yet our mining and exploration industry was a significant global player. By forming a series of focussed Research Centres, each with a critical mass of 20 to 50 geoscientists, it has become possible for Australia to continue to be a significant research contributer in the area of minerals-related geoscience. The following University-based centres have been established since 1989. Centre for Landscape Evolution and Mineral Exploration, Centre for Global Metallogeny, Centre for Ore deposit Research, Economic Geology Research Unit, Centre for Geochemistry and Metallogeny, Centre for Predictive Mineral Exploration. These centres are commonly funded jointly by Government and Industry grants with a limited funding term of six to nine years. The Centres usually involve collaboration between several University geoscience departments, government organisations (CSIRO, Geoscience Australia) and groups of mining companies.

Although the centres have focussed on research collaboration, there have been recent moves to establish teaching collaboration, especially in the Honours and postgraduate course-work area. For example, a course-work masters program in mineral exploration has been developed jointly by three Australian Universities (Western Australia, Tasmania and James Cook), involving exchange of course units, lecturing staff and students. The mining industry has been strongly supportive of such collaborations, especially where the research and postgraduate courses are designed specifically to produce graduates with knowledge and skills relevant to the industry.

Similar geoscience research collaborations have been gaining momentum in Europe and North America. The GEODE consortium, funded by the European Science Foundation to collaborate on Geodynamics and Ore Deposit Evolution, has been a particularly good example. GEODE involves over 50 geoscientists from over sixteen European countries who are collaborating on seven major research projects in the following metallogenic regions: SW Iberia, Fennoscandian Shield, Alpine-Balkan-Carpathian-Dinaride Province, Southern Urals, sedimentary basins of western and central Europe and the Central French Massif.

A spin-off of the GEODE program has been the development of the Global Volcanic-Hosted Massive Sulfide Project. This project was established to study and compare a number of the world's major VHMS districts in order to define the key geological events that control the distribution and timing of high-value VHMS deposits; and thereby develop new criteria for locating these deposits. The project explores the connection between ore formation, volcanism, and extensional tectonics in each VHMS district, and will develop criteria to recognise this connection in the field. A network has been created of leading scientists who together have extensive experience in all the major VHMS districts, and 12 districts have been chosen as key study areas. The 12 districts comprise 7 major, massive sulphide, mining districts (Skellefte-Sweden, Iberian Pyrite Belt-Spain and Portugal, Southern Urals-Russia, Green Tuff Belt-Japan, Mount Read Volcanics-Tasmania, Bathurst-New Brunswick, Abitibi-central Canada), 4 less established but highly prospective regions (Peru, Greenland, Nunavut-Canada, India), and the Manus and Lau Basins as modern analogues. Multi-disciplinary scientific teams will work concurrently in each of the 12 districts under a common theme. Via close collaboration among the scientific teams, skills will be cross-fertilised from one district/research team to the others and lift the knowledge and expertise in each district to a level where detailed comparisons can be made across several disciplines. The information from the 12 districts will be synthesized to produce innovative scientific papers, and new databases and ore deposit models for mineral exploration. The strategy followed to set up the Global VMS Project has been to first concentrate on setting up the northern Sweden (Skellefte district) component of the project, funded by the Swedish Georange program, and then use this as a template to set up projects in the other districts.

Collaborative research between the mining industry and University research groups in Australia has been greatly assisted by AMIRA, the Australian Mineral Industry Research Association. The core business of AMIRA is the development, brokering and facilitation of collaborative research projects in mineral exploration, resource transformation and sustainable development, which are sponsored by member companies. Similar organizations have been operating in Europe (MIRO) and Canada (CAMIRO). As the mining industry has become increasingly globalised there has been recent pressure for stronger links between these research facilitation organisations.

Practical Solutions to Challenges Facing the Mining Sector

O5

SD INDICATORS THAT WORK: LESSONS LEARNED FROM CANADA'S MINERALS AND METALS INDICATORS INITIATIVE

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The purpose of this paper is to comment on the significant technical and strategic challenges and lessons learned in developing effective national level Sustainable Development (SD) indicators for the minerals and metals sector in Canada. The paper describes the Minerals and Metals Indicators (MMI) framework and possible indicators, potential applications of the framework, and future business and policy implications of the use of SD indicators in decision-making.

One of the key issues that faces policy-makers in all fields is to determine the most appropriate way in which to implement concepts and theories of sustainable development that truly work in practice. For SD indicators, this is particularly challenging since an absence of appropriate implementation following the development of indicators themselves has been a major problem. This continues to be an issue of primary concern in the development of indicators for the minerals and metals sector in Canada.

To date, various exercises to develop SD indicators in natural resource sectors have yielded valuable lessons for both policy-makers and practitioners. Significant strategic and technical challenges have been identified including the need for comparability among sectors, the necessity of involving 'end users' in the development and selection of SD indicators, linking national level SD indicators to local actions, identifying linkages between sectoral activities and their impacts, recognising problems related to the integration of SD indicators into policy development, implementation and evaluation as well as identifying SD indicators which work in practice.

The objectives of the framework for Canada's Minerals and Metals Indicators Initiative is to capture the "collective national status" of the

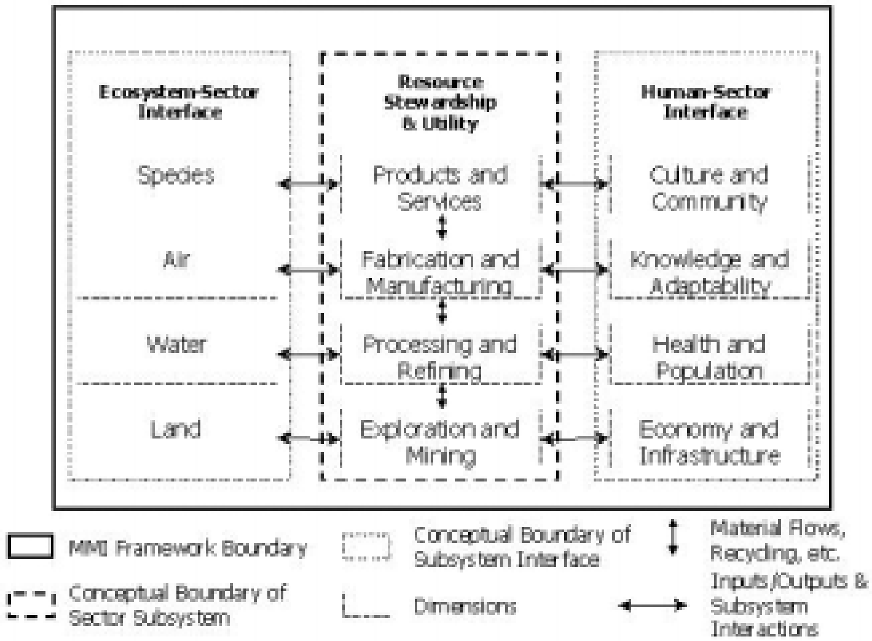

Figure 1. MMI Framework Dimensions

sector, including activities of all communities of interest across the full mining and product life cycles. Canada's Minerals and Metals Indicators (MMI) framework provides a template for the development of SD indicators and other assessment tools (e.g. certification systems, performance measures) at international, national, regional, local and site-specific scales through the identification and assessment of key components of the environment, economy and society (the components that are necessary for a holistic understanding of sustainability). Using a systems approach, which considers the interactions (inputs/outputs) of the minerals and metals sector with the ecosystem, society and economy as well as management capacity within the sector across the mining and product life cycles, the MMI framework aims to provide an overall assessment of the sector's contributions to SD and management capacity for resource stewardship and utility.

There are positive implications for business that may result from the use of SD indicators including the ability to demonstrate more effectively the linkages between sustainable mining practices and sustainable performance. For business, SD indicators can translate into real value in terms of improved operational efficiencies and cost savings, increased confidence (investment) in the sector, improved resource and market access, and enhanced social performance of minerals and metals operations. In the future, potential applications of SD indicators may be codes of conduct, best practices and certification systems for sustainability.

For policy-makers, there are significant benefits to using SD indicators including increased public understanding of the contribution of the sector to sustainable development, co-ordinated policy and planning, the development of sustainability-based criteria for environmental assessment, legislation and regulations and holistic, cross-sectoral comparison of sustainable performance. Even though SD indicators can be useful in reporting progress toward sustainability in the minerals and metals sector, they are only tools to assist policy-makers and the public in making well-informed decisions.

When developed in a systematic manner and integrated into planning, decision-making and policy development, SD indicators may assist in the identification of potential policy failures and the degree of programme effectiveness. Targeting resources to particular activities in order to improve efficiencies translate into real cost savings and improved public accountability for both governments and companies. As is evident in changing attitudes in business, measuring profitability in the future will not be limited to financial accounting. A holistic view of growth is emerging, providing a unique opportunity for SD indicators to contribute to the measurement and realisation of sustainable prosperity.

O6

RISK MANAGEMENT ASSOCIATED WITH MINING SULPHUR-BEARING ORE BODIES

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***Western Metals**

The mining of sulphide-bearing operations requires consideration of the hazards associated with blasting, and the potential for 'Sulphur Dust Explosions' or the presence of 'Reactive Ground'. These hazards can cause significant delays to operations and potentially lead to fatalities, providing a significant challenge for mining in the 21st Century.

Sulphur Dust Explosions (SDE) involve the ignition of sulphides when firing, and are a direct result of blasting in underground ore bodies such as the Kapok Zn-Pb mine. The Kapok mine is one of a number of Mississippi Valley Type deposits on the Lennard Shelf in the remote North West of Australia. A production rate of 0.5Mtpa is achieved by using a top down sequence of sublevel long hole retreat on 15 metre sublevels, and since production commenced in 1997, Kapok has infrequently been affected by up to six SDE per year in development headings.

A SDE occurs when a cloud of combustible dust is exposed to an ignition source from the explosives of sufficient temperature and energy to ignite the dust cloud in the presence of oxygen. This process can occur in two stages with a primary flame that is a direct result of blasting, and a secondary front, which ignites the previously settled dust on the underground walls. The products from the reaction include haematite, and sulphur dioxide gas that can be fatal. The resulting flame front damages services such as cables and vent bag, requiring rehabilitation once the area is safe to re-enter.

The main method of control employed at Kapok is the calculation of the Sulphide Dust Content in active development headings. This is calculated based on the visual estimates of zinc, lead and iron in a face, and using the following formula:

SDC = 0.33 x Zn% + 0.14 x Pb% + 0.79 x Fe%

The factors used are based on the percentage of sulphur in each element. If this number is greater than 15%SDC, then the area is classed a SDE Risk and the SDE procedure is implemented. This procedure requires the use of water foggers to greatly eliminate the secondary reaction, and can involve the smart use of explosives - det cord - stemming to reduce the risk of the primary reaction. The placement of the burn in the non-iron bearing footwall also works as a preventative measure. Re-entry with SO2 /O2 monitors and self-rescuers is also an important part of the procedure.

Reactive Ground is a chemical reaction that occurs between the rock and the explosive prior to blasting, and can occur underground or in open cut environments such as the Century Zn-Pb-Ag mine. The Century mine is one of a number of Sediment-Hosted deposits located within the Mt.Isa Inlier in Northern Australia. Mining is undertaken by conventional drill and blast, and shovel-truck, load and haul methods, at an ore production rate of 5mtpa. In December 1998, an exothermic reaction was observed between spilt ANFO explosives onto shale drill cuttings from a blasthole. Since this initial discovery and the introduction of a rigorous set of procedures no further incidents have been identified.

Reactive Ground involves a series of complex chemical reactions that occur between the sulphur-bearing rocks and ammonium nitrate based explosives, which can lead to premature detonation or deflagration of explosives in charged blast holes. Unlike SDE, reactive ground does not require the initiation of the explosives to cause the reaction. The process contains three stages, an induction period which can last from minutes to months with the explosives and sulphur bearing rocks in contact with each other. This is followed by a typically shorter intermediate period that produces a moderate amount of heat and includes the build-up of certain catalysts. The third stage of the reaction produces a large amount of heat in a very short time interval, and it is this stage, which is of most concern for safe mining.

A characterisation study was undertaken at Century on the different rock units for analysis of their potential reactivity with ammonium nitrate. The results showed that pyrite bearing shale units, were classed as potentially reactive and required the use of the more costly inhibited emulsion based explosives. Areas classed as non-reactive (limestone & sandstone) are still able to be loaded with ANFO, however daily blast-hole logging is undertaken by the geology department to ensure that no potentially reactive units will be exposed. The use of laboratory tested inhibited emulsion, reduced sleep times and vigilance on checking blast patterns has greatly reduced the risk of any reaction occurring.

The issue of SDE and reactive ground requires a continual risk management approach. The first step involves the recognition of the hazard, which can be present in any mining operation that involves blasting of a sulphide-bearing unit in either the ore or waste. The formulation of a suitable set of safe working procedures should involve the technical services department, mining department and the explosives supplier. There is also a requirement to determine what level of daily management of the potential hazard is required. The result of this approach at Kapok has meant that no one has been exposed to a SDE and at Century there have been no further recorded instances of reactive ground since the initial incident.

O7

MINERAL EXPLORATION BUSINESS: INNOVATION REQUIRED

David J. Hall* and Stewart D. Redwood.
***MinMet plc.**

THE STATE OF THE INDUSTRY

The mining industry is small relative to other sectors. The total market capitalization of the mining sector on the London Stock Exchange is £73.523 billion (as of 30/6/03) and is dominated by three companies: Anglo American plc (£13.641 billion), BHP Billiton (£7.799 billion) and Rio Tinto (£12.215 billion). This is in comparison to BP in the oil sector with a market capitalization of £93.945 billion, and GlaxoSmithKline in the pharmaceuticals sector with a market capitalization of £74.763 billion. We have seen since 2000 a spate of mergers and industry consolidations that has resulted in the disappearance of a number of familiar mining names, such as Homestake, Rio Algom, and North. The acquisition by XStrata of M.I.M. in June sees yet another company disappear. The overall result of this activity, therefore, is that the total number of major participants in the mining industry has declined, with sector consolidation continuing apace as the winners build critical mass, adopt "best practice" philosophies, and become "global" corporations. The remaining smaller companies in the exploration and mining industry will be providing these corporations with a service, whether it is the supply of new deposits to exploit, provision of mining/processing equipment, or specialist advice. Clearly, despite low commodity prices and exploration cutbacks, there is always going to be a demand for new, high-quality projects, because the major mining houses (MMH) must strike a balance between growth strategies of exploration versus acquisition — the product they deal in is finite and has to be replaced. This fact bodes well for companies involved in exploration and discovery (E&D),

especially for successful ones capable of providing returns for investors on a par with, or even better than, the high-technology and dot.com sectors.

THE BUSINESS OF EXPLORATION: MEASURING SUCCESS

Given the importance of research and development and its high cost, many companies struggle to determine how well R&D is doing. In order to determine whether or not exploration is profitable, exploration as a cost item must be compared with the return generated as a result of this expenditure. The most direct evidence that exploration is profitable in the long term is provided by the survival and growth of individual companies. From the perspective of the exploration industry, the market should provide an indication of actual and expected profits through valuation of exploration companies and availability and cost of funds required for exploration. The average cost of exploration should not exceed the average return from exploration. From a corporate perspective, this is the bottom line for survival. If the profits from the development and production of economic deposits do not outweigh the costs of finding (or acquiring) them, then economic ruin will be the long-term outcome.

The market for the exploration business is global mining corporations. Non-success in terms of lack of discovery or product will ultimately see an E&D company die. Yet in major company exploration departments this urgency rarely exists. If the company is successful in discovery, but the market does not want the product on the basis of size, location, or whatever, then the company might consider the option of developing it itself. However, this choice will likely be decided by the resource banking sector: does it consider the deposit worthy of funding? Of course, as soon as a company goes from E&D to mining, it immediately faces the same questions as a major mining company with regards to exploration and the role of this activity within the company.

The message is therefore "perform or die". Exploration companies must innovate if they are to compete and be successful. The definition of innovation is "change that creates a new dimension of performance".

THE BUSINESS OF EXPLORATION: COMPARISON WITH R&D

Exploration and discovery is to the mining industry what research and development is to other industries, a suitable comparison being the pharmaceutical sector. GlaxoSmithKline state on their website - "creating a new medicine is a complex business, costing over $300 million and typically taking between 12 and 15 years. Regulatory hurdles are increasingly stringent, yet escalating costs, medical need and the pressure of competition demand that the whole process is condensed into as short a time as possible". This sounds very similar to the mineral extraction industry, and is something that needs to be explained to the investment market.

The first-generation biotechnology firms revolutionized how drugs were made and also created a new kind of company environment. The focus was on productivity, not established corporate behaviour. Scientists were supported by management and touted as the key ingredient for success. The biotechnology industry showed itself to be extremely adept at creating new ways to support the front end of the process — discovery. The industry became so successful that the large pharmaceutical companies now devote a hefty share of their R&D budget to supporting research within these smaller biotechnology companies. It has long been recognized that managing R&D at a corporate scale often does not produce results proportional to the expenditure — you can't just throw money at it — and that smaller R&D companies are far more successful in this regard because they are focused. Similarly the concept of the lean, hungry, small hunting pack has been much discussed in the minerals exploration industry.

Typical biotechnology/big pharmaceutical company deals include:

- An up-front licensing fee that gives the big pharmaceutical partner rights to use

the technology;
- R&D funding for the life of the agreement (typically 3 to 5 years initially) that covers the people and supplies used by the biotechnology partner to carry the work;
- Milestone payments that give the biotechnology partner rewards for moving the project forward and reaching benchmarks that are significant for product commercialisation (for example, filing for FDA to start clinical testing, starting Phase I / II / III trials, filing for marketing permission, product launch);
- A purchase of equity in the biotechnology partner by the big pharmaceutical partner.

Although associations between major mining companies and exploration companies have occurred, there is a need for innovative financing models that require less capital to get to discovery, which means that we need management teams that can do more with less.

THE BUSINESS OF EXPLORATION: MANAGING FOR SUCCESS

The notion of people, i.e. the use of quality economic geologists is a recurring theme in analysis of exploration success. The best people are a company's distinctive capability. For the purposes of strategy, the key distinction is between distinctive capabilities and reproducible capabilities. Distinctive capabilities are those characteristics of a company that cannot be replicated by competitors, or can only be replicated with great difficulty, even after competitors realise the benefits they yield for the originating company. In terms of exploration management, one must identify the distinctive capability of the company — i.e., quality people — and seek to surround them with a collection of reproducible capabilities or complementary assets that enable the company to sell its distinctive capabilities in the market in which it operates; e.g., exploration focused in a certain region or deposit type.

But just assembling a quality team of geologists is not enough; their value is enhanced by maximizing the rock contact time of the exploration team. It is often stated that the high cost of exploration is one of the main disincentives for exploration. However, if people — the geological team — are one of the critical factors in exploration success, this is actually a relatively low-cost investment. Essentially, the systematic testing of ideas is what enables E&D companies to discover and define resources. What is critical in E&D is that unpromising properties are eliminated at the earliest possible time before expenditure becomes too high, instead of becoming an expensive mistake. If exploration geologists are to play a leading role they have to understand the real business difference between ore and mineralization.

CONCLUSIONS

The exploration business needs to attract investment, and if exploration geologists are going to play a leading role in this business, they must innovate. The business must get better in terms of shortening the time frame to discovery, and being as cost effective as possible without wasting vital funds. It must also find better financial models and must learn to manage people better. People, i.e., the quality of the geological team, are the only competitive advantage an exploration company has over its rivals. The ability to motivate these people is a part of the innovative capacity that management must develop.

O8

INVENTORY OF MINE WASTE SITES IN THE REPUBLIC OF IRELAND

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Geological Survey of Ireland

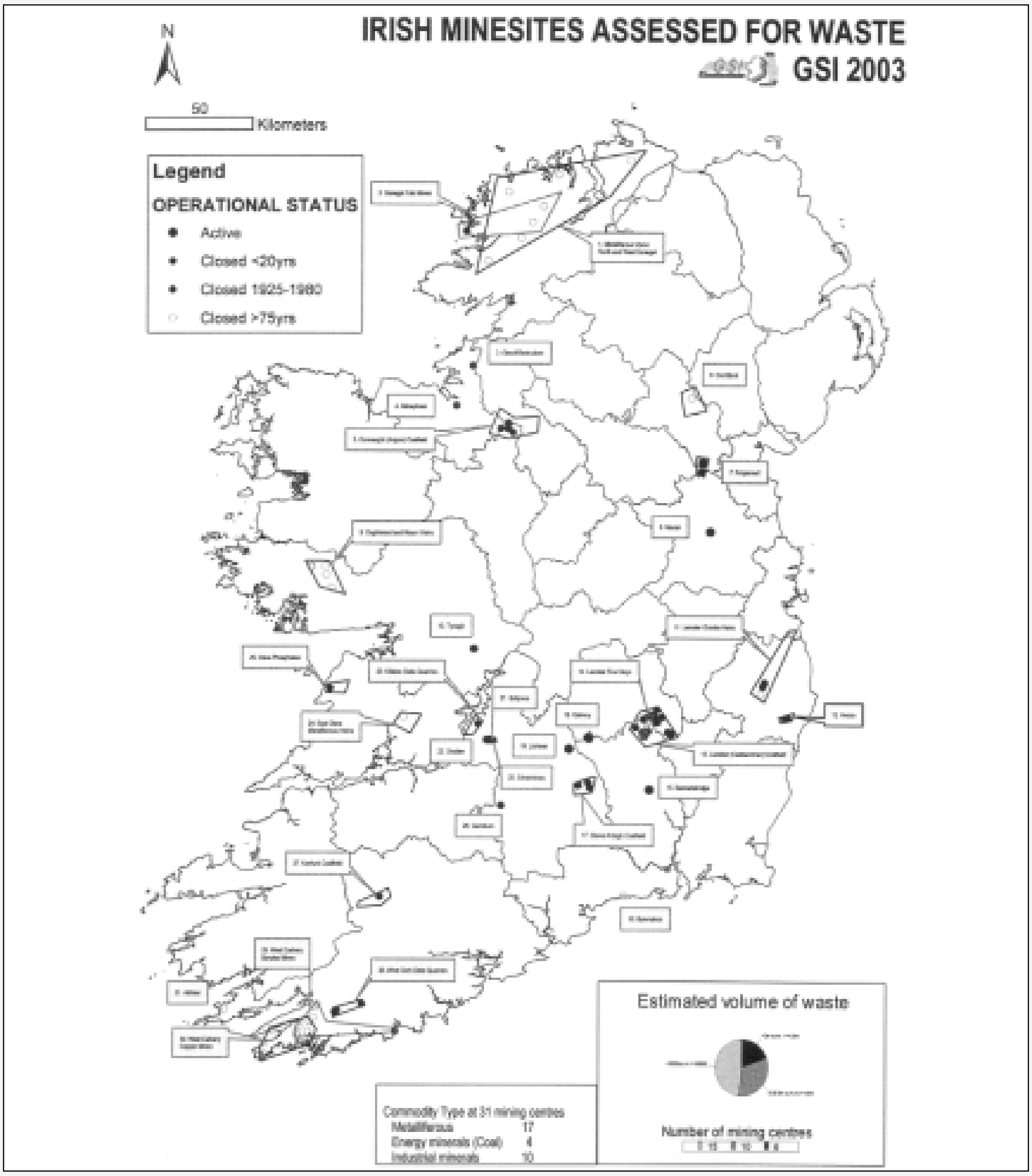
SUMMARY

The Geological Survey of Ireland (GSI) has been documenting waste at some 30 mines and mine districts across the country on an intermittent basis over the last three years. A database of sites was established initially in

response to a request by BRGM of France acting on behalf of the European Commission's DG XI (Environment). This database is the Irish contribution to the study "Management of Mining, Quarrying and Ore-Processing Waste in the European Union" which is currently aiding the formulation of an EU Directive on the management of waste from the extractive industries. Additional information on minesite flora, fauna and waste chemistry was gathered by GSI staff in 2002-2003, and a photographic archive was established. Tentative steps were also taken to rank sites in terms of the potential hazard they may present to the surrounding environment.

DESCRIPTION OF DATABASE

A selection of 31 mine locations was made in response to a four-page questionnaire received during 1999; each is either a single operation, or a group of related mines (See map). The commodities exploited at the chosen sites are varied: *Base metals, Energy minerals (coal), and Industrial minerals and rocks (gypsum, dolomite, talc, barytes, fire clay, slate)*. The survey did not extend to the aggregate or monumental stone industry. Information which is available in the resulting database consists of:



a) Site location details and type of mining and processing carried out
b) Types of waste produced, pollution incidents reported and current site use
c) Environmental setting of the site, groundwater information and environmental impact of the wastes; relevant bibliography
d) Current legislation for mining and mine wastes, and specific practices regarding waste management at each site.

FURTHER INVESTIGATIONS

Though well-received at EU level, the database was felt to be worthy of further independent consolidation. The following areas were focussed upon in subsequent investigations:

- Verification of volumes of waste and waste chemistry
- Better understanding of local hydrological regimes, leachate runoff and erosional features
- Degree of natural regrowth or ecological recuperation, and the success of artificial rehabilitative measures
- Documentary updates of sites accompanied by sketches and photographs.

Extended visits to many sites were made, from which the following results emerge:

Spoil heaps – size and stability: Four basic shapes were found to be prevalent at sites: cone, truncated cone, wedge, and arc fan. Tips were observed to be in a stable state, with exceptions at two former coal mines.

Spoil heaps – runoff: Channelling of tip slopes was observed to vary according to waste granulometry. A table of scores for predicted suspended and dissolved solids in runoff was made, as was a porosity and permeability chart for the tip-drift-bedrock continuum. Mechanical excavations were observed to have a deleterious effect at some tips.

Hydrochemistry: EC and pH readings were taken at 22 points in 15 minesites. A majority of values were neutral to slightly alkaline. Of concern is the acidity of coal mine waters from the Arigna field. Of the EC values measured, only the Tynagh site had a value above Irish limits for surface water.

Vegetation: Many sites show at least partial natural revegetation, and a few total. Several artificial programmes have been extremely successful. Lesser vegetation types are well represented at most sites, but tree growth is restricted. This is especially acute at abandoned coalmine tips.

Soils: The destruction of original soil profiles would appear not to have been total during mining activities; alternatively, new profiles have developed efficiently through natural or artificial means.

Scenic and remediation considerations: A number of larger, more recent operations - particularly in the coalfields - could benefit from landscaping where mine closure was not accompanied by restorative measures. At smaller sites, a balance between clean-up and conservation would seem appropriate.

The Competitivness of Nations

O9 Keynote

THE COMPETITIVENESS OF NATIONS

Phillip C F Crowson,
CEPMPL, University of Dundee

The focus of the mineral policies of the developed countries over the past decade has seemingly been on the environmental and social aspects of the industry. The senior managers of mining companies have rather uneasily combined concern over such matters with a continuing emphasis on the need to cut immediate costs, sometimes to the point of schizophrenia.

Governments and companies are in thrall to a wide variety of pressure groups and short term considerations that are likely to inhibit genuine competitiveness. Moreover, some of the more important variables that determine competitiveness are completely outside their control. Both governments and mining companies have to operate competitively within a varying range of constraints.

The paper examines the main forces influencing global competitiveness in the mining industry, not from the viewpoint of individual companies but of host countries.

They should not become involved in the operating decisions of mining companies, but they can powerfully influence the conditions within which those decisions are made. Governments and companies are both inevitably swayed by the prevailing political and economic fashions. Today's orthodoxy all too often becomes tomorrow's heresy, and vice versa. Yet there is a wide range of 'timeless' pre-conditions for developing and, more important sustaining, a vibrant minerals sector that are set out in the paper. It argues that many governments' priorities need readjusting if they are to meet those pre-conditions fully.

O10

THE GLOBAL MINERAL RESOURCE ASSESSMENT PROJECT: A COOPERATIVE INTERNATIONAL PROJECT TO ASSESS THE WORLD'S UNDISCOVERED NONFUEL MINERAL RESOURCES

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***U.S. Geological Survey, Virginia**

All nations continually face decisions involving the supply and utilization of raw materials, substitution of one resource for another, competing land uses, and the environmental consequences of resource development. In today's global economy, a nation's economic security depends on access to adequate mineral resource supplies from a variety of domestic and international sources. Global use of mineral resources will continue to increase for the foreseeable future because of the continuing increase in global population, and the desire and efforts to improve living standards worldwide.

In response to the growing need for information on the global mineral-resource base, the U.S. Geological Survey (USGS) is leading a cooperative international project, the Global Mineral Resource Assessment Project (GMRAP), to assess the world's undiscovered nonfuel mineral resources. The critical objective of GMRAP is to outline the principal areas in the world that have potential for selected undiscovered mineral resources, and to estimate the probable amounts of those mineral resources to a depth of one kilometer below the earth's surface. GMRAP also has a research component, whose objectives are to improve and test methods of assessing undiscovered mineral resources of the terrestrial earth.

Today, more than 70 chemical elements and dozens of minerals are mined and produced from more than 100 different deposit types and geologic environments. GMRAP will begin by assessing a selected subset of commodities and their most significant deposit types for world minerals supply. This restricted focus is designed to make the assessment effort manageable and to allow assessment products to be produced in a timely fashion. GMRAP initially will undertake global assessments of eight commodities, including copper (porphyry copper and sediment-hosted copper deposits), platinum-group metals, lead, zinc, nickel, gold, potash (potassium), and phosphate (phosphorous).

A quantitative form of resource assessment will be applied in GMRAP to express explicitly the degree of uncertainty associated with assessments, and to allow economic analysis that can translate geologic-based results into a format useable in decision-support systems and cost/benefit analysis. Quantitative assessment results are essential for effective evaluation of the consequences of alternative resource-related decisions. The USGS has developed a 3-part quantitative mineral resource assessment to meet these goals. Three-part assessments consist of: 1) delineating areas according to the types of deposits permitted by the geology; 2) estimating the amount of resources contained in the undiscovered deposits using appropriate ore characteristics and metal contents defined by worldwide grade and tonnage models, and 3) estimating the number of undiscovered deposits of each type for each delineated area (Singer, D.A., 1993, *Basic concepts in three-part* *quantitative assessments of undiscovered mineral resources:* Nonrenewable Resources, v. 2, no. 2, p. 69-81). The 3-part quantitative assessment protocol results in internally consistent quantitative estimates of undiscovered mineral resources. The results can be evaluated using economic filters, cash flow models, and other tools for application to economic, environmental, and policy analysis.

GMRAP is being conducted on a regional, multi-national basis with the cooperative participation of interested national and international geologic, mineral resource, and other institutions. The USGS role includes: coordination of the global assessment effort; facilitating and conducting workshops and working group meetings; and leading quantitative probabilistic estimation of undiscovered nonfuel mineral deposits. In conjunction with international cooperators, USGS will publish assessment products in digital, web-based, and, when appropriate, paper formats. International cooperators are assisting in compiling existing geologic maps and related information at appropriate regional scales (~1:1,000,000 or smaller). Emphasis is on establishing regional consistency in geologic interpretation and on extending geologic units permissive for undiscovered mineral deposits beneath un-perspective cover sequences. Cooperators will also provide current information on the location, sizes, and geologic types of known mineral deposits and occurrences, assist in development of regional tectonic and metallogenic models, and help gather information about regional mineral exploration history. In addition, cooperators will review results of the quantitative mineral resource estimates for delineated permissive tracts, and participate in analysis of assessment results with regards to regional and global resource, land-use, and environmental issues.

The first priority of GMRAP was formalizing relations with cooperators from countries and/or multinational organizations in seven assessment regions (map at http://minerals.usgs.gov/news/v1n2/1gmrap.html). Reports for each region containing overviews of geology, recent exploration, known mines and mineral resources, past and current production, and supply-demand relations will be completed in 2003. By the end of 2005 GMRAP will have completed compilation of geologic maps, known mineral deposits databases, and exploration history databases for each region. Global assessments for undiscovered copper, platinum-group metals, lead, zinc, nickel, gold, potash, and phosphate, along with regional metallogenic-tectonic syntheses, will be completed by 2008. Assessment results will be published as they are completed in digital, web-based, and paper formats, as appropriate.

GMRAP will provide a consistent, comprehensive level of information and analysis of global non-fuel mineral-resources based on the most up-to-date data available. The results will provide all nations a regional and global context for viewing their mineral-resource base; help plan new mineral exploration and sustainable resource development; and aid regional resource, land-use, and environmental planning.

O11

MINERAL EXPLORATION IN EUROPE: ACTIVITIES, ADVANTAGES AND PROBLEMS

Duncan Large
Independant Consultant

Digital Geological Information

O12 Keynote

A VISION FOR GEOSCIENCE INFORMATION? A PERSPECTIVE FROM THE BRITISH GEOLOGICAL SURVEY

Ian Jackson
British Geological Survey

In early 2002 BGS agreed a corporate Information Strategy. That Strategy contained a vision of where BGS wanted to be in 5 years time. It described the developments in information management, delivery, technology and skills that the Survey wanted to pursue. It also detailed the context within which BGS had to operate and, critically, the European and UK policy and legislation that would provide both opportunities and constraints for an organisation which, of necessity, must recover approximately 50% of its $55 million annual budget from commercial earnings. This presentation will examine the vision that BGS established and review progress against each element of that vision, concluding with a discussion of the issues and problems that have arisen.

O13

DIGITAL GEOSCIENCE INFORMATION FOR NEWFOUNDLAND AND LABRADOR - A NODE ON THE CANADIAN GEOSCIENCE KNOWLEDGE NETWORK

Larry Nolan* and John Broome
***Geological Survey of Newfoundland and Labrador**

Dramatic changes in digital information and communications technology over the past decade are completely transforming the way in which geological surveys throughout the world manage and disseminate their geoscience knowledge. In response to these changes and client needs, the Geological Survey of Newfoundland and Labrador in partnership with the other Canadian provinces and territories, and the Geological Survey of Canada, designed the Canadian Geoscience Knowledge Network (CGKN; http://cgkn.net).

Since 1998, Canadian geological surveys have been collaborating on the development of CGKN. The objective of the CGKN is to link the geoscience knowledge holdings of the 12 federal, provincial, and territorial geological surveys and to support access to these data in consistent and interoperable form through on-line services. The CGKN will become the Internet portal for Canadian government geoscience data and the geoscience node of the Canadian Geospatial Data Infrastructure (http://geoconnections.org). Open standards and a distributed network architecture are being used to permit participants to benefit from the cost savings of collaborative development with minimal impact on local operational requirements.

The CGKN portal currently permits discovery of Canadian geoscience data using an on-line geoscience data catalogue. Additional services are being developed both by the CGKN and individually by participants, like the Geological Survey of Newfoundland and Labrador. These services will enable our clients to view, evaluate and obtain consistent and standardized geoscience data, maps and publications. Each participating agency

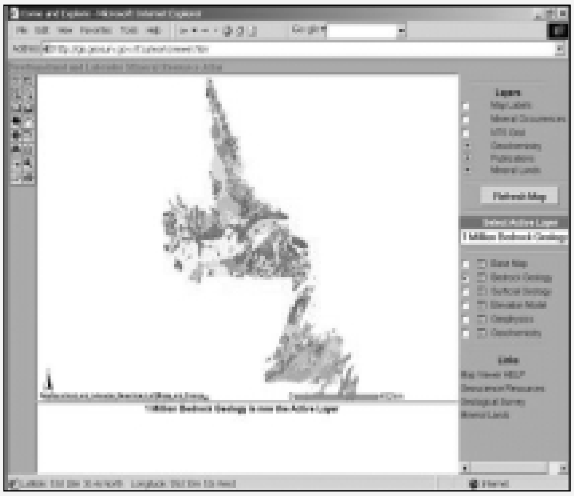

Figure 1. Geological Survey of newfoundland and Labrador web site

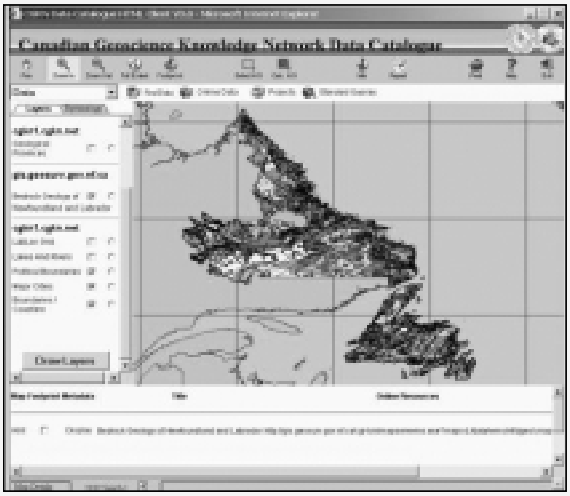

Figure 2. Canadian Geoscience Knowledge Netwirk web site

continues to develop their online presence at their own pace using tools and software they already have. Using international standards including the Open GIS Consortium (OGC) web mapping standard and the Federal Geographic Data Committee (FGDC) metadata standard they connect to the CGKN for data discovery and display. An example is shown in Figure 1, Newfoundland and Labrador 1:1 000 000 bedrock geology is displayed on the Government of Newfoundland and Labrador web site and in Figure 2 the same data is displayed on the CGKN web site. Although the web sites use different projections and different software to display the map they are both requesting the same map service from the Newfoundland and Labrador site.

O14

MINING THE DATA AT THE GSI - DIGITAL DEVELOPMENTS

Koen Verbruggen*, Archie Donovan and Mary Carter

***Information Management, Geological Survey of Ireland**

This paper presents a summary of initiatives at the Geological Survey of Ireland (GSI) to organise and provide data in digital format, including development of a Document Management System (DMS), ongoing work on a new Corporate Database and web mapping. Particular attention is paid to mineral related databases, which constitute some of the largest, most comprehensive and commonly accessed datasets.

GSI was founded in 1845, initially to geologically map the country and evaluate its potential mineral resources. The GSI underwent considerable development in the 1970's on the back of a developing base metal exploration industry and mining industry and this history has resulted in significant mineral related databases. More recently this data has been worked on as part of an initiative called the Earth Resource Information Warehouse (ERIW), the aim of which is to collate, catalogue and have readily available, all of GSI'' data in suitable formats for internal and external customers, making the best use of proven IT technology. Much of this work has been part funded by the Information Society, a government initiative administered by the Department of the Taoiseach.

The GSI DMS project involved the indexing of all of GSI's principal datasets, the scanning of 450,000 pages, including large scale maps, and development and population of a database which stores this information and imagery (amounting to 1.4Tb). These databanks are now available on all GSI desktops through a web browser, and to customers via our new Customer Centre.

The ongoing corporate database project (Centrally Organised Network of Records – CONOR), is providing new data-models, a compilation of ISO standard Metadata on all GSI datasets, a populated Oracle database and access via Cold Fusion screens. The contractor on this project is the British Geological Survey.

Web Mapping is being developed as part of the CONOR project, utilising ESRI ArcIMS© software and providing GIS maps on both internal and external web servers. This allows on-line querying and report generation on digital maps produced within the organisation on all datasets and the printing of images from those maps.

Planned further developments include the online delivery of web mapping and large image files and the web hosting of principal GSI datasets.

The net result of developments to date is a greater awareness of the variety and extent of GSI datasets, both internally and externally, easier access to GSI data for customers and faster, cheaper and more efficient delivery of that data to clients.

O15

CONFLICT OR CONSENSUS? DIGITAL INFORMATION AND TOOLS TO ASSIST IN MANAGEMENT OF MINERAL RESOURCES IN ENGLAND

Andrew Bloodworth*, Ellie Steadman and Jo Mankelow
***British Geological Survey, Keyworth**

Despite the importance of minerals to the economy of England, the environmental impact of their extraction has become a major concern to the public, planners and politicians. Debate on the subject can be both emotive and ill-informed. The British Geological Survey is developing a web GIS and associated decision-support tools to provide a more effective framework for constructive dialogue and policy development in the area of minerals extraction land-use management.

The GIS and associated tools assist in the identification of more sustainable options for mineral supply by improving access to the information base on minerals and their land-use context. The GIS is based on integration of a wide range of data concerned with mineral supply, demand and environmental constraints. This will enable all stakeholders to assess and analyse issues on a local, regional and / or national scale. BGS is also using this GIS as the basis for the development of a semi-automated tool to predict the environmental sensitivity of future mineral extraction. This can be used by planners in the Strategic Environmental Assessment (SEA) of regional plans for sustainable aggregate extraction.

O16

DEVELOPING A SYSTEM FOR ON-LINE MINERAL CLAIM STAKING

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P.Geo, Director, Mineral Lands Division, Department of Mines and Energy, Government of Newfoundland and Labrador

The Government of Newfoundland and Labrador undertook a review of its Mineral Policy in the mid 1970s. Among other things, this initiative resulted in a major revision in the legislation dealing with mineral land tenure in the province. Two new pieces of legislation to emerge were the Mineral Holding Impost Act and the Mineral Act.

The Mineral Act provides for the administration and regulation of mineral land tenure for exploration and development of areas of the province where the rights to minerals are vested in the Crown. The Mineral Act was premised on the free miner principle and was patterned after comparable legislation from the other Canadian jurisdictions. The designers of the Mineral Act were able to adopt the best and the most effective provisions in this new legislation.

The Mineral Act, from its inception in 1976, contained provision for map staking of mineral claims. The map staking provision was made operative in Labrador in 1983. It was felt that ground staking was an impediment to exploration in Labrador because of its vast area and lack of transportation infrastructure. The Voisey's Bay discovery in Labrador resulted in the largest staking rush in Canadian history. Approximately 250,000 claims were recorded in 10 months from November '94 to August '95; this was more than the total claims staked in the previous 10 years.

The map staking system worked extremely well. There were no overlapping claims or grievances filed in connection with any of this staking. As a result, the government discontinued ground staking and adopted map staking in the entire province in September 1995.

The map staking system uses the 10,000m UTM grid to define mineral claim boundaries. Each 100 ha UTM grid squire is divided into four 25ha claims. This method of defining mineral claims lends itself to computerisation.

The Department of Mines and Energy has partnered with XWave to redevelop the Mineral Rights Database (MRD) application. The MRD was developed in the late 1980s and is a Clipper application. The new MIRIAD (**Mi**neral **Ri**ghts **Ad**ministration) System will facilitate the on-line staking of mineral claims, maintenance of licenses and the updating of mineral claim maps in the most effective manner possible, thereby improving client service and freeing valuable staff time from administrative tasks and map updating. The MIRIAD System will position the department to remain competitive with other jurisdictions in the administration of mineral land tenure.

The MIRIAD System will require the development of two new applications (1) an internal License Maintenance Module and (2) a public Mineral Rights On-line Staking Module, both of which will interface with a Geographic Information System (GIS). Thirdly, the project will also include modifications to the web-based Mineral Rights Inquiry Module, currently deployed to the World Wide Web.

The On-line Map Staking Module will allow users to apply for map-staked licenses over the Internet using a web browser. This module will facilitate the complete staking operation including account registration, digital drawing of the area to be claimed, verification and validation of the staked area, final submission of the request, and processing of the credit card payment.

The License Maintenance Module will be designed to replace the functionality of the existing Clipper application, and will tightly integrate with the department's GIS system.

The Mineral Rights Inquiry Module was reviewed to identify potential changes relating to the re-development of the Mineral Rights Database.

The system architecture will be designed to facilitate:

- Interoperability of key system components;
- Secure architecture design;
- Scalability to handle increased web traffic; and
- Integration with the common platform for GIS operations currently being developed by the department for future GIS applications.

The License Maintenance Module will reside on local workstations and will be available solely to department staff via a government LAN/WAN connection. The On-line Staking and Inquiry Modules will be available to the Internet and may be accessed by the general public using a standard web browser.

All three modules will connect to a central ORACLE database platform, allowing information to flow freely between modules as updates are made to the database. It is proposed that the Mineral Rights Inquiry and On-line Staking Modules, which will be available on the Internet, will have limited access to the database to increase the overall security of the system.

The MIRIAD system is currently at the testing stage. It is expected that development and testing of the new system will be completed by mid-October 2003.

The MIRIAD system will allow the mineral exploration client group to stake claims in Newfoundland and Labrador 24 hours a day, 7 days a week via the Internet. The on-line staking procedure is extremely user-friendly, and is simpler than the current paper application. The MIRIAD System will immediately confirm that mineral rights have been secured to the area of interest when an on-line staking transaction is completed.

Developments in Mineral Potential Mapping

O17 KEYNOTE

RECENT ADVANCES IN MINERAL PROSPECTIVITY MAPPING AND ANALYSIS

Gary L. Raines

U.S. Geological Survey

Current efforts by geological surveys around the world to define standards for data content and format for geologic maps provide a critical foundation for GIS-based predictive spatial modelling. The products of spatial modelling provide objective, quantitative statements of our understanding of where undiscovered mineral resources are likely to occur. Spatial models can now be used as controls in spatial-temporal modelling of how the mining industry will explore for new deposits. Taken together these three areas of research, standards for digital data, spatial modelling, and spatial-temporal modelling, provide a framework for mineral-resource decision making by the mining industry and government agencies. The newest and least understood of these three areas of research is spatial-temporal modelling of exploration activity. Cellular automata provide an approach to simulation of exploration activity in space and time. Cellular automata (CA) are defined by an array of cells, which evolve by a simple transition rule, the automaton. Spatial-temporal information about mineral-related activity and spatial models of undiscovered resources provide a basis to calibrate a CA. A CA implemented for Idaho and Montana using a modified annealed voting rule simulates mineral-related activity with spatial and temporal resolution of 1.6 km2 and 1 year based on activity from 1989 to 1998. The calibrated CA reproduces the 1989-1998-exploration activity with an agreement of 94%. Using the calibrated CA in a Monte Carlo simulation projecting from 1998 to 2010, the calculated probability of mineral activity predicts activity consistent with expectations and provides a measure of level of activity useful in mineral-resource decisions.

O18

A GEOCHEMICAL SURVEY OF WESTERN NORTHERN IRELAND

Miller O'Prey* and Dee M. A. Flight
***Geological Survey of Northern Ireland**

Between 1994 and 1999 the British Geological Survey's Analytical and Regional Geochemistry Group, in collaboration with the Geological Survey of Northern Ireland, carried out a Geochemical Survey of the western half of Northern Ireland. The survey was jointly funded by the Department of Environment for Northern Ireland, the Department for Enterprise, Trade and Investment and the British Geological Survey.

Topography and land-use are varied, ranging from low-lying pasture in Co. Fermanagh to upland rough grazing in the Sperrin Mountains. Large tracts of coniferous forestry plantation are also present. Rainfall within the region is relatively high, up to 1700 mm/annum.

The survey utilised methods developed by the ongoing G-BASE (Geochemical Baseline Survey of the Environment) programme in Great Britain. Baseline chemical data were obtained for 33 elements in stream sediments and on 42 parameters in stream waters along with a locational and observational database containing information such as heavy mineral occurrences and land use at sample sites. In total 2908 drainage sites were visited, representing a sampling density of 1 sample per 2.15 km2. Wherever possible a complete suite of samples comprising filtered and unfiltered stream waters, stream sediment (-150 mm) and heavy mineral concentrates were collected. TOC was only determined on 50% of samples. The data has numerous applications but this presentation will concentrate on the application to mineral exploration.

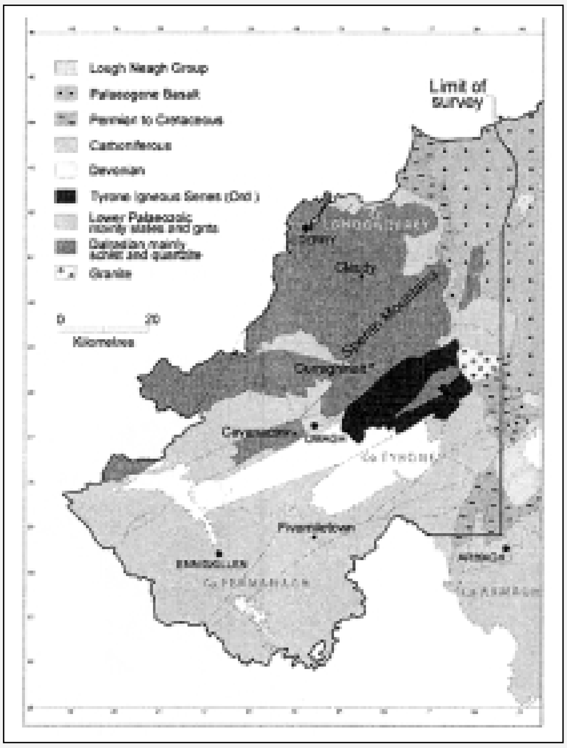
The solid geology of the survey area is diverse. Co. Fermanagh and south Co. Tyrone are mainly underlain by Carboniferous and Devonian sedimentary rocks, while in the north of the area older metasedimentary rocks of the Dalradian Supergroup predominate. Palaeogene basaltic lavas occur in the north-east and a variety of igneous rocks outcrop in east Co. Tyrone. The Middle-Upper Dalradian rocks of the UK and Ireland have been the focus of mineral exploration over the past 30 years and numerous base and precious metal discoveries have been made. The two most important Au prospects within the survey area are located at Curraghinalt and Cavanacaw. The Lower Carboniferous is also considered prospective for 'Irish-style' Zn-Pb mineralization. In addition to peat, the survey area is extensively covered by Quaternary superficial deposits, including glacial and fluvioglacial deposits.

The data show very strong, geologically controlled features and the Dalradian, Devonian, Carboniferous and Tertiary terrains can be readily distinguished on the basis of their respective geochemical signatures.

The responses to known mineralization demonstrate the sensitivity and efficiency of the techniques employed and there are a number of metal anomalies, which may indicate the presence of undiscovered mineralization. Significant As anomalies occur over Upper Dalradian lithologies of the central and eastern Sperrins as well as in west Co. Tyrone and are all supported by the presence of gold grains in panned concentrates. Additional As anomalies are located over parts of the Tyrone Igneous Series and as an arcuate zone to the north of Claudy. A coincident As, Ba, Cd, Pb, Zn anomaly over the Middle Dalradian occurs in west Tyrone. Other potentially significant anomalies include elevated Pb and Zn values over the Lower Carboniferous Limestone, east of Fivemiletown and close to the border in south-east Co. Fermanagh.

Following completion of the regional survey, a follow-up survey was conducted over a broadly anomalous area of Middle-Upper Dalradian lithologies in west Co. Tyrone. An additional 136 stream sediments and panned concentrates were sampled as before, but samples were also submitted for Au analyses. Two well-defined targets underlain by the Middle Dalradian were identified. The most promising area displays highly anomalous Au, elevated As and abundant panned Au grains. Carbonate-rich units provide a second target with Au and As anomalies associated with panned Au and sulphides. These targets were then the subject of a semi-regional soil survey with 902 B-horizon samples collected and analysed by total and enzyme leach methods. The results of this survey produced four anomalous areas including an area with multi-element anomalies trending southwest-northeast associated with Ba-Pb-Zn vein mineralization and igneous activity in the Middle Dalradian.

In 2002 all stream sediment samples from the regional survey were resubmitted for Au and PGE (Pt, Pd and Rh) analysis. Initial interpretation shows that the Au analysis produced a better-defined anomaly pattern than the gold grains in panned concentrates. Although highly anomalous values are distributed across the survey area, two anomalous regions stand out, south-west and north-east of Omagh. The PGM data highlights the Palaeogene basalts, but of potentially more economic interest is a highly anomalous area south of Claudy.



Simplified geological map of western Northern Ireland showing named towns and prospects

O19

AGGREGATE POTENTIAL MAPPING: MODELLING PROTOCOLS IN USE IN IRELAND

Gerry Stanley, Vincent Gallagher, Grainne Grehan and Phelim Lally
Geological Survey of Ireland

The supply of aggregate is essential for the construction sector, especially in the context of the National Development Plan (NDP) and the National Spatial Strategy. The National Development Plan will see a €53 billion investment in the country's infrastructure. Of this €9.2 billion is earmarked for construction and upgrading of roads, €9.1billion has been assigned to house construction and just over 1 billion has been assigned to other construction projects – all of which will require substantial quantities of aggregates. Current estimates of aggregate production from the country's 500+ quarries amount to some 100 million tonnes per annum. This is likely to remain at this level for the remainder of the NDP (until 2006). At the current rates of production between 4 and 6 new quarries or pits with an annual production of in excess of 1m tonnes will be required each year over the lifetime of the plan to replace exhausted operations.

New quarries and pits require new land - land that is currently being used for another activity or for which there may be a competing future use. The competition for land and the decisions to which use land is put is the realm of the Local Planning Authority. It is imperative that these important decisions are based on as much information about aggregate resources as possible. This is why Aggregate Potential Mapping (APM) is so vital to the process.

APM makes innovative use of data that already exists across a number of organizations, including the Local Authority and the Geological Survey of Ireland (GSI) while providing the information to the Planning Authority in language that is clear to Planners

The APM Programme of the GSI is carried out in cooperation with Local Authorities. To date schemes have been or are being carried out for Counties Donegal, Meath and Wicklow and we are having discussions with a number of other counties.

APM schemes are interpretations of geological and other data. Any scheme must therefore be as objective as possible and be based on a transparent process that is open to contest and is defensible. The GSI protocol attempts to meet these ideals by combining available data with the experience of its personnel and that of the Local Authority. As an exercise in data interpretation an APM scheme may be subject to revision as new data becomes available.

The GSI protocol divides the process in two. One stream is for granular aggregates (sand and gravel deposits) and the other is for crushed rock aggregates. The former are normally worked in pits while the latter are worked in quarries.

The process for each stream is essentially one of reclassification of geological data, elimination of areas from further consideration for various reasons, e.g., urban development and scoring of various attributes of significance for the aggregate sector. The scores assigned to the various attributes are then combined to produce a total score, which allows classification of the area into one of five categories or designations. A descriptor associated with each category portrays the potential for aggregates to be obtained from particular areas on the map.

Table 1 outlines the APM protocol for granular aggregates while Table 2 provides the same information for crushed rock aggregates. The details of the system will be outlined during the presentation.

However, we do not always have full information and a reliability map can be constructed to take account of this. A reliability map provides information on how much data was available for the interpretation. Where no data is available for a given attribute, the median value is assigned to the unit The number of scores for which there is no information is added – the higher this number the lower the reliability of the score for the unit. The two maps can then be compared.

The protocols are being applied to the APM systems currently underway in Counties Meath and Wicklow. The protocol will be open to revision as experience is gained with its implementation.

Table 1. APM Protocol for Granular Aggregates

Step 1: Reclassify
Reclassify Quaternary geology map to show: a. Boulder clay (till) b. Sand and gravel c. Silt or clay d. Rock e. Peat f. Water-bodies
Step 2: Eliminate
Eliminate areas overlain by: a. Lakes > 1ha and major rivers b. Urban centres c. Heritage and scientific sites
Step 3: Score
Assign scores to the following: a. Area of polygon b. Thickness of the body within the polygon c. Grading curve d. Deleterious substances e. Percentage waste f. Previous or current operations g. Proximity to market
Step 4: Combine the scores
Divide the scores into the following categories with equal weight for each within each category: a. Group 1 – quality of the deposit (area, thickness and grading curve) b. Group 2 – operational factors (no. of operations and proximity to market) c. Group 3 – negative factors (percentage waste and deleterious substances)
Step 5: Designate
Based upon the score achieved, categorise each polygon as follows: a. Deposit with very high potential b. Deposit with high potential c. Deposit with moderate potential d. Deposit with low potential e. Deposit with very low potential

Table 2: APM Protocols for Crushed Rock Aggregates

Step 1: Reclassify
Reclassify bedrock geology map to show: Dolerite/gabbro; Greywacke; Hornfels; Sandstone (includes psammite); Andesite; Diorite; Limestone; Quartzite; Basalt; Dolomite; Rhyolite/felsite; Chert; Granite (includes granite gneiss); Siltstone; Gneiss; Marble; Schist; Shale (includes phyllite); Slate; and Clays
Step 2: Eliminate
Eliminate areas overlain by: a. Overburden > 10m thick (not sand and gravel) b. Peat areas > 10ha c. Lakes > 1ha and major rivers d. Urban centres e. Heritage and scientific sites
Step 3: Score
Assign scores to the following: a. Area of polygon b. Overburden thickness within the polygon c. Los Angeles abrasion test d. Deleterious substances e. Previous or current operations f. Proximity to market g. Rock type suitability
Step 4: Combine the scores
Divide the scores into the following categories with equal weight for each within each category: a. Group 1 – quality of the deposit (area, overburden thickness, LA abrasion and rock suitability) b. Group 2 – operational factors (no. of operations and proximity to market) c. Group 3 – negative factors (deleterious substances)
Step 5: Designate
Based upon the score achieved, categorise each polygon as follows: a. Deposit with very high potential b. Deposit with high potential c. Deposit with moderate potential d. Deposit with low potential e. Deposit with very low potential

Exploration Opportunities

O20

SUPPLY AND DEMAND OF STRATEGIC MINERALS: TOO MANY EGGS IN TOO FEW BASKETS

Kevin Bonel* and Greg Chapman

***British Geological Survey**

O21

GEOLOGY AND MINERAL RESOURCES OF THE FENNOSCANDIAN SHIELD ? WITH AN EMPHASIS ON FINLAND

Elias Ekdahl

Finnish Industry Investment Ltd.

The Fennoscandian Shield, including the Caledonian domain, is undoubtedly one of the most prospective and under explored terrains within the European Union. Late Archaean and Early Proterozoic bedrock covers more than 1 million km2 and is comparable, in size, with the Slave Craton. Extensive geological, geophysical and geochemical data coverage, well-developed infrastructure and progressive mining legislation provide an excellent basis for mineral exploration and new discoveries. Finland occupies the central part of the Fennoscandian Shield terrain and also gives many type occurrences related to the geotectonic and metallogenic evolution of the crust.

The Archaean craton, is characterised by northerly trending greenstone belts surrounded by extensive granitoids and gneisses. The greenstones are related to the intracratonic rifting, which produced voluminous tholeiitic, komatiitic and intermediate to felsic volcanics. The earliest magmatic and metamorphic event seems to have taken place at around 2.84 Ga although there are dates of up to 3.5 Ga in Northern Finland. Epithermal Ag-Zn-Pb occurrence (Taivaljärvi) hosted by felsic pyroclastics represents the oldest mineralization type. Cumulates of komatiitic lava flows host Ni deposits as Tainiovaara and Arola in Finland and Kivijärvi in Russia. Algoma-type, banded iron formations, like Huhus in Finland and Kostamuksha in Russia, are hosted by Archaean volcanics and greenstone sediment belts. Recent investment in gold exploration in the Archaean greenstone belts of Eastern and Northern Finland and NW Russia has led to the discovery of a number of new occurrences. Shear zones and crustal scale hydrothermal processes control Au mineralization in the late stage of deformation. Crustal thickening, gradual cratonization and the intrusion of granitoids and porphyries led to the formation of some Mo-Cu-Au deposits. The formation of the 2.6 Ga old carbonatite at Siilinjärvi testifies to a rather thick crust by end Archaean.

The earliest Proterozoic magmatism at around 2.4 Ga formed a belt of layered mafic intrusive complexes throughout the whole Shield. The world class Kemi Cr mine and several PGE deposits in Finland and Russia represent one of the largest PGE reserves in the world. Thinning and rifting of the Archaean crust, 2.2 – 2.0 Ga ago, resulted in the evolution of continental sedimentary basins and periodic magmatism. SEDEX type, massive sulphide deposits and metalliferous black shales occur in the basins. A magmatic period 2.04 Ga gave rise to several Fe-Ti-V deposits as well as the Keivitsa Ni-Cu-PGE deposit in Northern Finland. Intracratonic rifting, the origin of Pechenga Ni belt in the Kola Peninsula and the Outokumpu, proto-ore, related to the oceanic crust at 1.97 Ga, indicated continental break-up and opening of pre-Svecofennian sea in the west.

The main stage (1.88 Ga) of the Svecofennian orogeny comprises of successive series of bimodal submarine volcanism hosting Vihanti, Pyhäsalmi, Skellefte and Bergslagen massive sulphide deposits. The geotectonic and metallogenic evolution continued in Sweden and Finland with mafic and ultramafic intrusions with Ni-Cu deposits and late orogenic felsic magmatism with porphyry type Cu-Mo-Au-W mineralization and epigenetic Au-As occurrences. Nowadays several multiphase Au bearing deposits or assemblages in Northern Sweden and Finland has been interpreted as FeOx-Cu-Au type (Kiiruna, Aitik, Kolari, Kuusamo).

Amalgated terranes were later intruded by microcline granites and complex pegmatites with interesting Li-Be-Sn-Nb-Ta deposits in Western Finland. Anorogenic rapakivi granites at 1.65 – 1.54 Ga host some minor Sn-Be-W occurrences. The Caledonian orogeny (0.45 Ga) is reflected in the origin of Kola alkaline province (Kovdor, Sokli) and diamondferous Terski and Kaavi kimberlite provinces in Russia and in Finland.

The Fennoscandian Shield hosts the major mineral potential of EU. There is still a lot of room for new economic discoveries and sustainable mining industry. Presently, the global mining sector is more and more consolidated and this leaves a gap between the mega companies and the junior explorers. The junior sector and mining financing structures are almost totally undeveloped in Scandinavia. The Fennoscandian Mining Fund is under development. The state owned Finnish Industry Investment Ltd., has a key role in this progress. The mining fund should be in place by 2004 and will be focused on mine developments of metallic ores and industrial minerals. At this time around 30 domestic and international exploration and mining companies are operating in Finland. The present activity is concentrated in gold and platinum group metals, base metals, diamonds and industrial minerals. Exploration investments in Finland were around 40 M in 2002 and have been increasing while the global trend has been decreasing.

Recent Developments in Ireland

O22

THE DISCOVERY AND GEOLOGY OF THE R ZONE AT THE GALMOY MINE, CO. KILKENNY.

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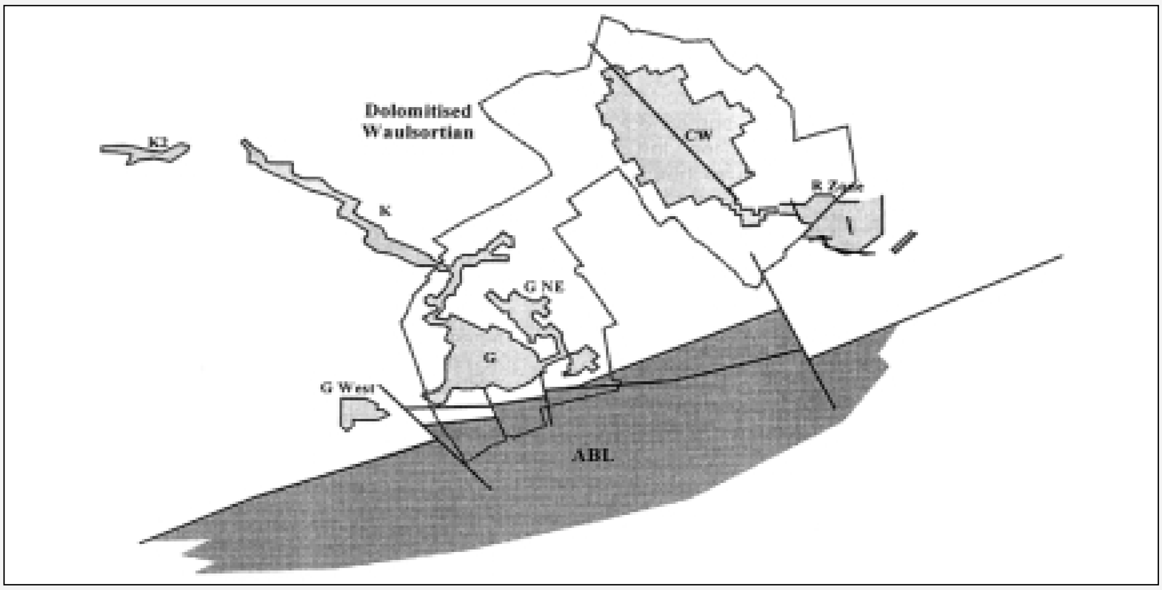
***ARCON Exploration Plc.**

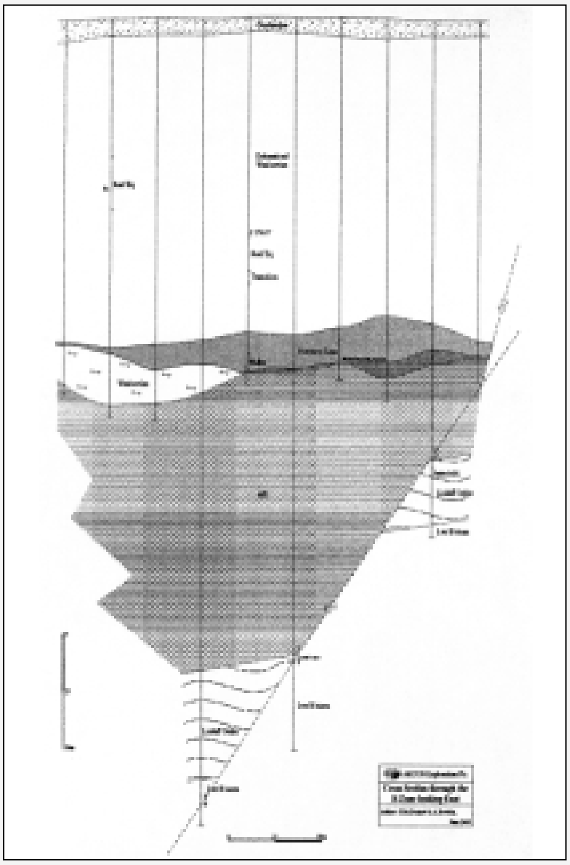
The R (Rathreagh) Zone is a recently discovered body of zinc/lead sulphide mineralization adjacent to the CW Orebody of the Galmoy Mine. The zone is of significantly higher grade than the other major orebodies at Galmoy, namely the CW and G Orebodies The Galmoy zinc/lead deposits are located c. 110km southwest of Dublin in north Co. Kilkenny within a belt of southeastward dipping Lower Carboniferous age limestones and dolomites. They were discovered in 1986 by drilling on Induced Polarisation (IP) anomalies. Most of the mineralization is hosted within the brecciated base of the (dolomitised) Waulsortian Limestone Formation. The source of the mineralising



fluids is the G Fault, which is a large, east-west striking, normal fault with c. 200m downthrow to the north. The G Orebody is clearly related to the G Fault whilst the other orebodies have been fed via a northwest striking, plumbing system. The G Fault is a member of a major southwest-northeast striking en echelon normal fault system that links Galmoy with Lisheen to the southwest and the Rapla Prospect, 6km to the northeast.

A gravity survey carried out in 2001 to cover the area between Rapla and Galmoy with the aim of delineating the structures that link those areas detected a significant gravity high c.350m east- southeast of the CW South Zone of the Galmoy Mine. Although the area of the gravity high had been covered by IP and Resistivity surveying and by airborne TEM surveying with no anomalous readings, from its geological location it was clearly an area of high potential.

The gravity high was drill-tested in September 2002 with the first hole intersecting 10.7m of mainly massive sulphides grading 19.5% Zn, 3.7% Pb and 28g/t Ag. Many of the subsequent holes. intersected even higher grade with the best hole intersecting 31.3m at 31.8% Zn, 9.4% Pb and 73g/t Ag. Delineation drilling is not yet complete but the present indicated resource at 4.5% Zn cut-off is 2,279,000 tonnes at 19.0% Zn, 7.2% Pb, 7.8% Fe and 66g/t Ag. However, most of the tonnage, c. 1,500,000 tonnes, and most of the metal, c.85%, occurs in a lens of massive sulphides grading in excess of 24% Zn.The massive sulphides replace the basal Waulsortian and the uppermost ABL and the lens lies adjacent to and on the northern down-thrown side of a small segmented normal fault with throw of c. 25m. This small fault is thought to be a steeper branch of a lower angle normal fault with throw of c. 100m that has been detected at depth. The deeper fault is probably linked to the G Fault system. On average the lens lies at c. 139m depth and mainly dips gently to the west-northwest. However, the dip is steeper in the eastern side of the body where the structural



block containing the zone appears to be thrust over another block of Waulsortian. Although only the reverse movement can be observed, it is thought that this northeast striking fault may have a significant strike slip component. To the north of the massive sulphide lens the mineralization thins and is similar in style to the breccia-hosted mineralization elsewhere at Galmoy. The only major difference being that the base of dolomitisation clearly controls the mineralization, rather than the base of Waulsortian, as a unit of undolomitised Waulsortian occurs beneath the breccia mineralization.

O23

THE GEOLOGY, ALTERATION AND MINERALIZATION OF THE PALLAS GREEN PROSPECT, CO. LIMERICK.

Dave Blaney
BRG Ltd.

The Pallas Green prospect consists of a block of thirteen contiguous prospecting licences, located between Limerick City and Tipperary town in the southwestern quadrant of the Irish Midlands, Lower Carboniferous Orefield (Fig 1). The property is held jointly by Minco Ireland Ltd. and Noranda Exploration Ireland Ltd. It is located along a regional scale, structural lineament, orientated WNW and known as the Limerick trend. This feature can be discerned from regional geophysics and is considered to be related to basement faults controlling the southwestern margins of the Silvermines and Slieve Barnagh Inliers.Geology of the block is dominated by Lower Carboniferous Limestones and extrusive volcanics. Strata dips gently to the south at between 10^{o} to 25^{o} towards the axis of the ENE-WSW orientated Limerick Syncline. Structure is dominated by five major northeast-southwest trending normal faults that can be traced from the Lower Palaeozoic/ORS Slieve Phelim/Silvermines inlier to the northeast. The Pallas Green alteration trend occurs within this block. It is defined by extensive alteration of both the Courceyan limestones and the overlying Chadian basaltic volcanics. The alteration has a west-northwest orientation and a strike length of at least 25km. It was first noted as zones of low magnetic susceptibility within the volcanics. Subsequent mapping plus lithogeochemical and petrographic studies have delineated a 3km to 5km wide corridor of dolomitisation of

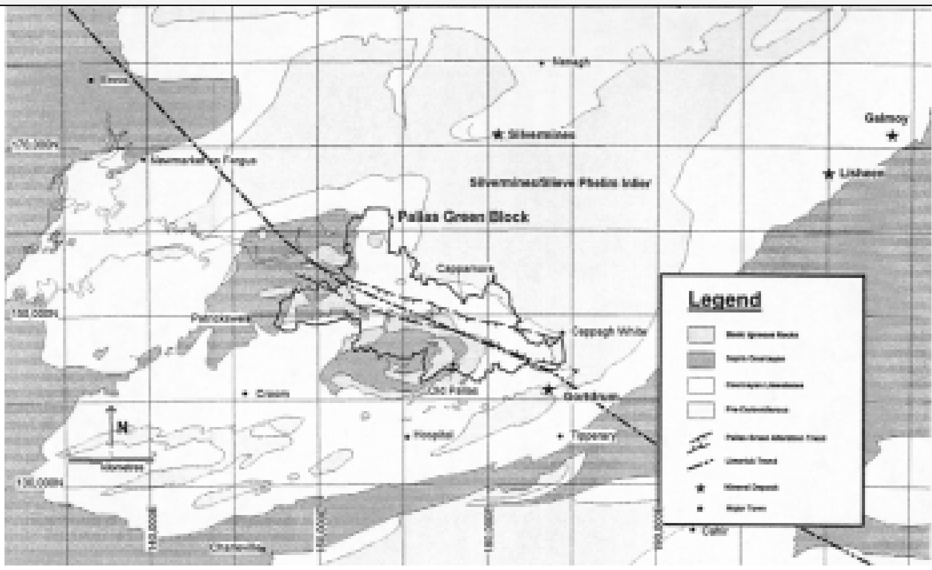


Figure 1. Regional locational map

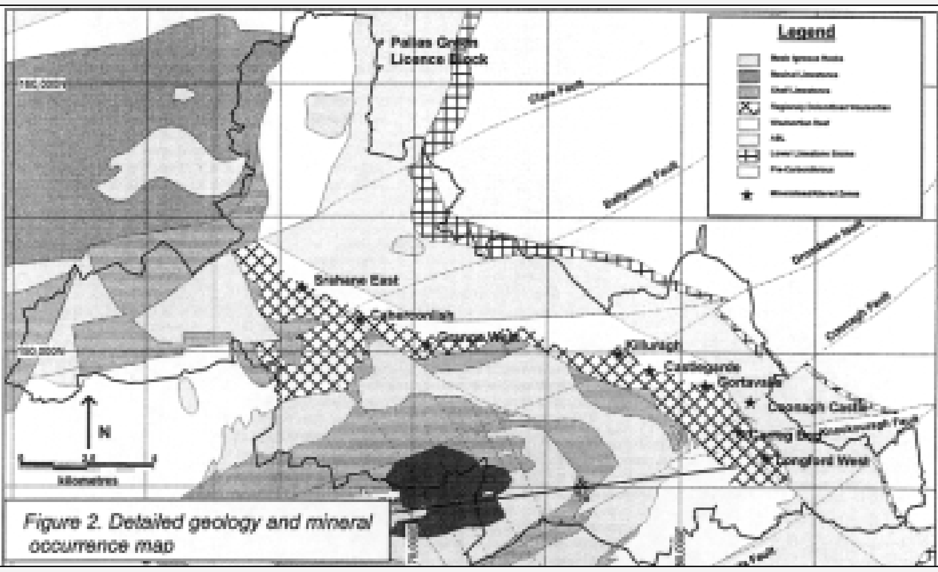


Figure 2. Detailed geology and mineral occurrence map

the Waulsortian reef with chloritisation and more minor sodium and potassium alteration crosscutting the Lower Volcanic succession.

Drilling by the Minco-Noranda joint venture, along the northern margin of the Pallas Green alteration trend, has discovered six new zones of massive sulphide mineralization and alteration (Fig. 2)

At Castlegarde, two discrete zones of basal Waulsortian reef hosted, massive ,sulphide mineralization were discovered in June 2000. The northern lens is a northwest striking, 50m to 100m wide, zone of massive pyrite/marcasite, sphalerite and galena with a strike length of approximately 200m. The mineralization is located at or just above the important Waulsortian reef/ABL contact, at depths of 146m to 160m. This mineralization is distal to the feeder zone and is considered as analogous to the K zone at Galmoy or the Cooleen zone at Silvermines. The southern zone has to date been intersected by only one drillhole at a depth of 295m. Step-out drilling from the Castlegarde mineralization has intersected black matrix style breccia alteration, containing disseminated sphalerite, galena and pyrite, at or close to the base of the Waulsortian reef. At Caherconlish, on the western quadrant of the Pallas Green alteration trend, significant thicknesses of Silvermines style, pyrite rich, base of Waulsortian reef hosted breccias have been discovered. The mineralization tends to have a low grade, pyrite-rich, upper zone and a zinc/lead rich basal zone. The Pallas Green alteration trend is comparable to the Rathdowney trend that hosts the Lisheen and Galmoy deposits. The widespread mineralization and alteration is evidence that an extensive and powerful hydrothermal system operated in the area, localised by the basement structure associated with the Limerick trend. Castlegarde and Caherconlish mineralization and alteration demonstrate that this hydrothermal system was capable of driving large scale mineralising events that could deposit ore-grade mineralization.

In stark contrast to the Rathdowney trend, the majority of the Pallas Green trend has yet to be explored. The Pallas Green licence block is considered to hold enormous potential to host a world-class deposit.

O24

AN ECONOMIC COST BENEFIT ANALYSIS OF THE RESOURCE AND ENVIRONMENTAL SURVEY OF IRELAND

Craig Bullock* and Peter Clinch
***Environmental Institute, University College Dublin**

In 2000/2001 the Environmental Institute at UCD undertook a cost-benefit analysis, of a proposed national geochemical and airborne geophysical survey of Ireland, on behalf of the Geological Survey of Ireland. This cost-benefit analysis represents one of only a few studies where attempts have been made to quantify the benefits of geological data or geological surveys.

As the cost element of the cost-benefit analysis is represented by the bill for undertaking the survey itself, the analysis concentrated on the estimating the benefits of enhanced information on the nation’s geology. There is a wide range of potential benefits spanning mineral exploration, health related issues, water quality, land use, and the pressing issues of environmental management and infrastructure development. A number of these individual benefits are substantial, while others are more modest but together perform an important contribution to our understanding of the environment.

The benefits can be categorised in terms of practical policy benefits as well as public and private benefits. Policy benefits include improvements in cost-effectiveness. They also have the further important benefit of improving the country’s capacity to satisfy various European policy directives in the areas of environment and health.

Private benefits occur when beneficiaries are identifiable, i.e. as individuals or private companies. Public benefits, on the other hand, contribute to quality of life and are distributed more widely through the population. Many public benefits are non-monetary in character including benefits in the areas of environment or health. Nevertheless, it is in principle possible to quantify many of these benefits in monetary terms for the purposes of a cost-benefit analysis. In some cases, the lack of national environmental information or previous economic quantification means that international comparisons are necessary. The range of benefits may also have to be expressed between a minimum and maximum. An aspect of the latter is the decision as to whether to include value of life estimates in the analysis, which greatly increase the potential benefits where, for example, radon emissions are concerned.

The benefits can be further categorised as direct, i.e. where they flow directly from the national survey or, indirect, where the survey contributes to a beneficial outcome. The main direct benefit is in the mainstream geological area of mineral exploration. Here, the survey could contribute to an expansion of private exploration activity. If this exploration were to result in the discovery of a single major mineral find, this in itself could justify the investment in the survey.

Indirect benefits would follow where the new survey information contributes to a particular goal once combined with other data. One such example would be a better understanding of the process of acidification and how to combat it so as to meet our obligations under European and international policy agreements. Improved geological information is only one factor in the design of measures to mitigate acidification, but the huge scale and potential cost of the problem means that the additional information is no less valuable for that.

Other benefits are extremely difficult to quantify. However, because many people or places can be affected, the benefits can be very large indeed, particularly where there is an impact on human health. Here, there is the prospect of major benefits by using the information to avoid the costs associated with, for example, groundwater pollution, radon exposure or exposure to toxic metals.

In total, the mid-range estimate of benefits for the survey was put at £131 million, a figure that far exceeds the cost of undertaking the survey. However, there is an additional intangible benefit in that, as a public undertaking, the information would be readily available to everybody, including to future generations. The full benefits will therefore only emerge in the course of time. For instance, the recent anxiety caused by the prospect of foot and mouth disease led to a need for information on where carcasses could be safely buried in the event of a serious outbreak. The prior existence of such information lowers the cost and increases the effectiveness of our ability to deal with such incidents.

O25
THE LONGFORD-DOWN MASSIF – A NEW GOLD PROVINCE IN THE APPALACHIAN-CALEDONIAN OROGEN

Michael H. Smith*, David Furlong and James Sweeney
***Conroy Diamonds and Gold Plc**

INTRODUCTION

The Longford – Down Massif is a major geological feature stretching from Co. Longford in the Republic of Ireland to Co. Down in Northern Ireland. (Figure 1: The Longford – Down Massif: Regional Geology). It is an inlier of Ordovician and Silurian aged rocks and can be correlated with similar strata in the Southern Uplands of Scotland and the Dunnage Zone of Newfoundland. (Stone et al., 1995). The rocks strike predominantly northeast – southwest and are divided into tracts by strike – slip faults. Of particular significance is the fault zone defining the boundary between the Ordovician and Silurian, the Orlock Bridge Fault. This is a major structural feature that has an inferred lateral displacement in excess of 400 kilometres (Anderson and Oliver, 1986). The pattern of movement of this fault during geological time may have had a major influence on mineral deposition. Within the Longford – Down Massif, numerous minor deposits of lead, zinc, iron and antimony have been worked in the past (Morris, 1984). Gold was initially discovered in old antimony workings in the townlands of Tullybuck and Lisglassan in County Monaghan in 1957 (Morris at al., 1986). Further discoveries of gold mineralization have recently been demonstrated by Conroy Diamonds and Gold Plc in an area some 20 kilometres by 3 kilometres in extent in Counties Armagh and Monaghan; the Armagh - Monaghan Gold Belt, (Smith, 2001) and elsewhere in the Longford - Down Massif at Slieve Glah in County Cavan. (Figure 1.)The Armagh – Monaghan Gold Belt lies along the major northeast – southwest trending strike – slip feature known as the Orlock Bridge Fault. The gold belt is underlain by andesitic composition greywackes mainly of Ordovician age and is divided into fault blocks by faults trending approximately north – south. (Steed and Morris, 1997) The association of the Armagh – Monaghan Gold Belt with the intersection between the Orlock Bridge Fault and a major north – south linear feature is seen as an important factor in mineralisation development. Russell, 1979, proposed this linear feature as a "geofracture" named R3. Within the Armagh – Monaghan Gold Belt gold appears to be associated with:

- Sulphides – arsenopyrite, arsenical pyrite and pyrite.

Hydraulic fracturing and quartz – feldspar and quartz – carbonate veins mostly penetrating sub – parallel to the foliation. A probable magmatic source from which is derived at least part of the mineralising fluids. This is indicated by geochemical studies (Steed and Morris 1997).

THE APPALACHIAN – CALEDONIAN OROGEN

The Longford – Down Massif forms part of the Caledonian Terrane of northwest Europe. This complex extends from Scandinavia (the Scandinavian miogeosyncline) and Greenland (the East Greenland miogeosyncline) and includes most of Scotland and the northern part of Ireland. Prior to the Mesozoic opening of the present Atlantic Ocean, the Caledonian Orogen of Greenland and Western Europe was continuous with the Appalachian Orogen of North America. Newfoundland lies at the north – east termination on the Appalachian Orogen (Williams, 1979), Longford – Down lies near the south – west termination of the Caledonian Orogen. The two major orogens form a major orogenic belt more than 7,500 kilometres long.

The Appalachian Orogen of Newfoundland is regarded as a "two sided symmetric system" (Williams, 1964). Pre – Cambrian continental platforms (Humber and Avalon zones or terranes of Williams 1964, Williams and Hatcher, 1983) are separated by a younger Palaeozoic mobile belt – the Gander and Dunnage Zones or terranes – which together form the Central Mobile Belt.

A similar symmetry exists in N.W. Europe, with the Longford – Down Massif and the Southern Uplands of Scotland forming part of the enclosed Palaeozoic mobile belt. This mobile belt records the formation, development and destruction of the earlier Palaeozoic Ocean, originally called the "Proto – Atlantic Ocean" (Wilson, 1966) and now referred to as the "Iapetus Ocean" (Harland and Gayer, 1972, Evans and Kerr, 2001).

This 7,500 kilometre long orogenic belt is mirrored in North America by the younger Western Cordillera.

Throughout the Caledonian – Appalachian Orogen, mineralization has been demonstrated. The work of various geological surveys has summarised gold and base metal mineralization, e.g. the British Geological Survey in Scotland (Stone et al.,

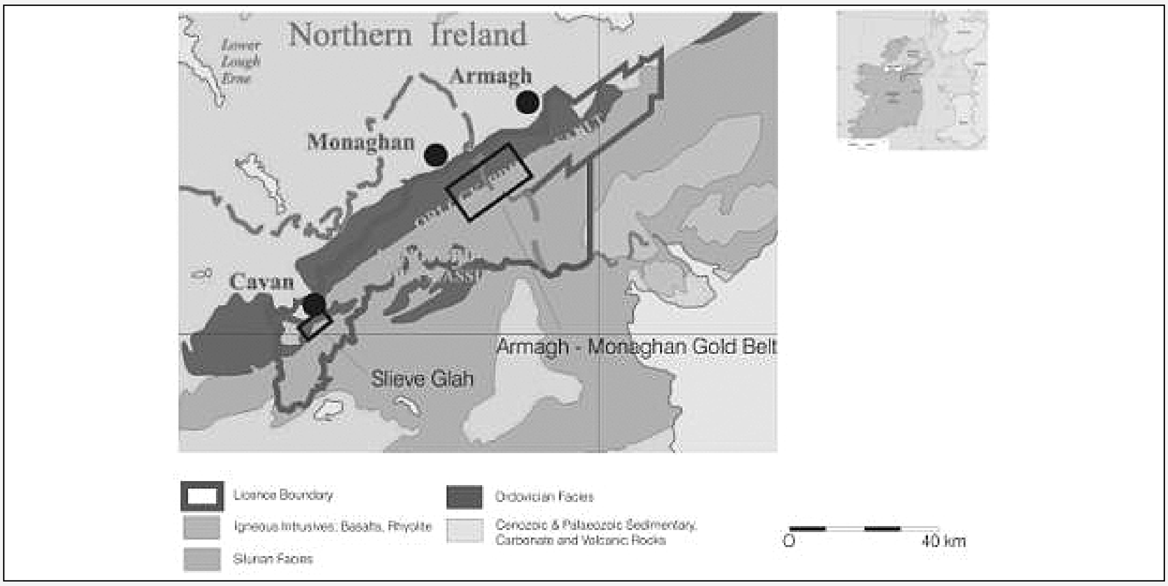


Figure 1. The Lonford-Down Massif: Regional Geology.

1995) and the Geological Survey of Newfoundland (Evans, 1996). In Ireland, mineralization in the Longford – Down Massif has been summarised by the Geological Survey of Ireland (Morris, 1984). Verbruggen and Colman, 2001, have also described gold mineralization in Britain and Ireland. This literature indicates that the Appalachian – Caledonian Orogen is a mineral prospecting play on a global scale.

Conroy Diamonds and Gold Plc's contribution has been to demonstrate the extent of gold anomalies and deposits in the Armagh - Monaghan Gold Belt and around the Slieve Glah area, in the Longford – Down Massif. The Slieve Glah area may represent a dilation zone, developed some 40m km to the south west of the Armagh – Monaghan Gold Belt, where a significant strike swing occurs on the Orlock Bridge Fault.

GENETIC MODEL

The elements of a genetic model for mineralization in the Armagh – Monaghan Gold Belt are proposed as follows:

- Structural Elements
    - o The Orlock Bridge Fault
    - o The "R3" Geofracture / Lineament
- Geology and Models for Terrane Origin;
- Source
    - o Igneous Intrusives
        - Minor;
        - Thermal Alteration;
        - Granodiorite;
        - Postulated Granodiorite
    - o Formation Water
    - o Permian Red Beds as a leached source of elements.
- Dynamic Elements
    - o Groundwater and Leaching;
    - o Gold deposition events vs. base metal deposition events;
    - o Structural Development
        - Fault and Shear Development
        - Block Exhumation

Structural control is of major importance – on both the large scale and small scale, and the Appalachian – Caledonian Orogen model for terrane origin is seen as critical in placing the Longford – Down Massif situation in a global context. Mineralising fluids appear to result from interaction between igneous intrusive sourced waters and formation waters within the sediment pile. This is indicated by geochemical studies (Steed and Morris, 1997).

CONCLUSION

The Appalachian – Caledonian Orogen is a major crustal feature created by the destruction of a Palaeozoic Ocean in a subducting environment and the reworking of its sediments into the terrane elements we see today. Mineralization is present throughout the orogen with particular hotspots in Newfoundland and Scandinavia. The Longford - Down Massif has yielded a few small base metal mines and, until the present round of exploration, one gold occurrence. The work of Conroy Diamonds and Gold Plc has shown the extent of gold deposits and anomalies and hence the potential for further gold discoveries within the Longford - Down Massif.

The Appalachian – Caledonian Orogen is a Palaeozoic feature occupying the eastern USA and NW Europe. The younger Western Cordilleran Orogen in western USA is also a large scale orogenic feature stretching from California to Alaska and hosts major mineral deposits and provinces, e.g. the Mother Lode of California, the Carlin Trend of Nevada. This orogen, like the Appalachian – Caledonian orogen, is also the product of a major subduction zone and prospect models developed in the Western Cordillera are probably partially valid in the Appalachian – Caledonian region. Those who seek Carlin Trend look-alikes should perhaps consider the older but highly prospective rocks of the Appalachian – Caledonian Orogen.

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O26

THE LISHEEN ZINC / LEAD MINE - AN UPDATE

Leo Fusciardi

Lisheen Mines Partnership

The Lisheen Mine is located 10km northeast of the town of Thurles, County Tipperary, Ireland. The mine is operated by the Lisheen Mine Partnership, a joint venture between Ivernia West Inc. and Anglo American Plc. The mine has been in operation since September 1999, and approximately 320 people are employed in mining, mineral processing, geological, engineering, financial and administrative roles. The mine has produced 1.187 million tonnes of zinc concentrates and 0.197 million tonnes of lead concentrates to the end of 2002.

The ore comprises massive lodes of sphalerite, galena and pyrite, hosted at or close to the contact between an argillaceous limestone unit, termed the ABL and a clean pervasively dolomitized unit know as the Waulsortian. Both are of Lower Carboniferous age. Extraction takes place from two essentially sub-horizontal and tabular orebodies, located at a nominal depth of 180m below surface.

The broad geometry of the orebody favours the use of three separate mining methods; Room and Pillar in areas where the ore ranges up to 7 m thick; a variant of this, Drift and Fill in areas of consistent thickness of between 7 and 12 m, and Long Hole Stoping in areas where the ore ranges from 7 to 25m thick. Mined out voids will be backfilled with cemented tails to enable pillar recovery.

The mining cycle involves face preparation, geological assessment, drilling, charging, blasting and mucking. Ore is trucked to a central underground crusher and is conveyed to a surface stockpile via an access decline. Backfilling with cemented tailings is planned to enable recovery of primary pillars.

Mineral processing involves the following stages: communition; flotation of the galena and sphalerite; thickening and filtering. Concentrates are trucked from site to customised port facilities at the Port of Cork for shipping to smelters in Europe and North America. Tailings from the process plant are stored in a 78 hectare Tailings Management Facility.

The mine operates to the highest safety, health and environmental standards. Key environmental issues such as noise, water discharge and vibration are monitored under an Integrated Pollution Control Licence. Water management commences underground where specially constructed sub-horizontal wells are drilled over the footprint of the orebody to extract clean water from the aquifer in advance of mining. This water is processed separately from water that has been in contact with the workings, the latter requiring processing in the two Water Treatment Plants on site and the former requiring treatment in conditioning ponds prior to discharge.

O27

COMBINING GEOPHYSICAL DATA FROM AIRBORNE SURVEYS, IRELAND

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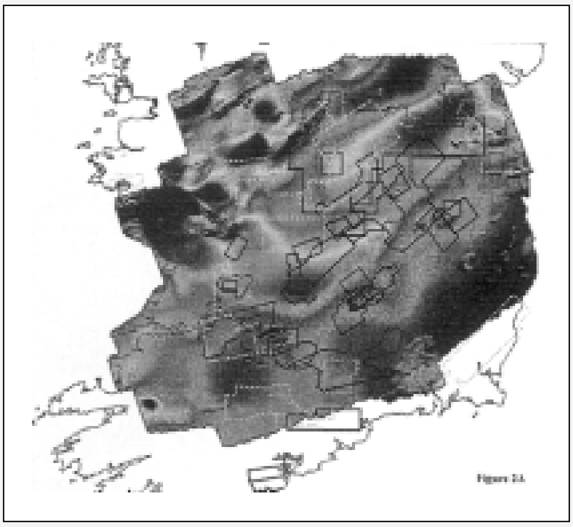
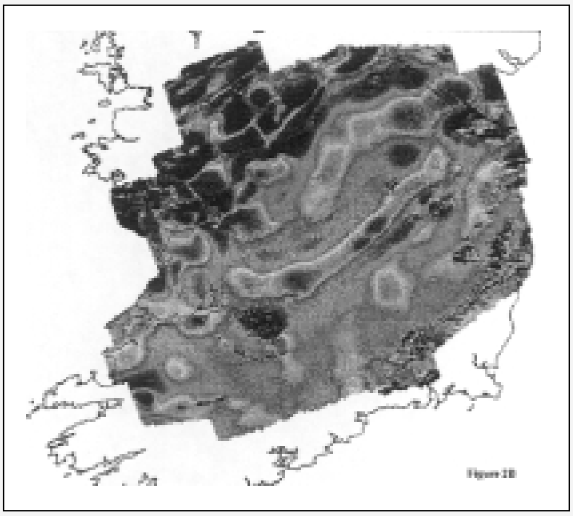
In 2001, the Irish government, as part of their Open Skies policy, began releasing CDs containing all information recorded during airborne geophysical surveys, flown as part of mineral exploration programs. Figure 1 is a generalized geological map of Ireland showing the outlines of airborne surveys flown to date for which digital data have been released (light green) or will be released in the next few years (yellow, dashed). Note the concentration of surveys flown near existing lead-zinc deposits/mines situated within the Carboniferous basins

Figure 1





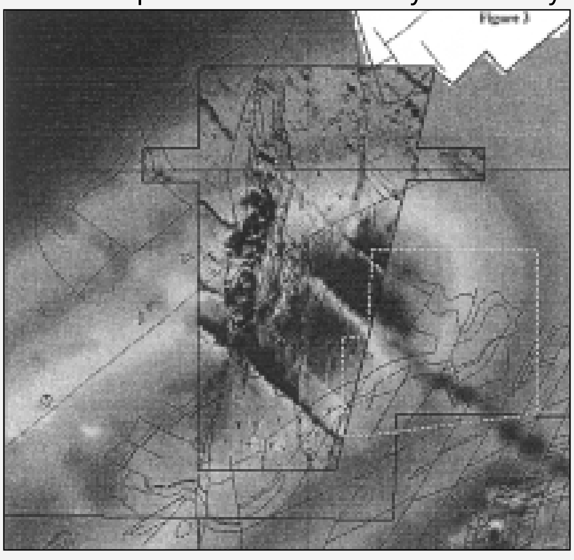
(blue & grey colours on Fig. 1) of Central Ireland. The large amount of overlap between several adjacent surveys presents an opportunity to co-register and merge the data into larger contiguous blocks.

The logical staging point for this merging project is magnetic data from a large-scale, relatively low-resolution survey, if it exists, to which data from smaller, more detailed surveys can be referenced and incorporated. An aeromagnetic survey, commissioned by the Geological Survey of Ireland, was flown in several phases during 1979 to 1980 - at 200 m altitude and 1 to 2 km line spacing. The survey was designed to include most of the large Devonian-Carboniferous sub-basins of Central Ireland, but also extends well into Silurian, Ordovician and older rocks near the basin margins. During 2000, the various phases of survey were combined into a levelled and seamless, larger block. These results form the basis of this study, and will be referred to as the "regional data".

This regional data provides a considerable amount of structural bedrock information, and is particularly useful in delineating large-scale, even basin-wide, features. The magnetic character of basement rocks near the basin boundaries and the changes in this character in the transition zone can provide valuable information regarding the basin geometry, and can lead to a better understanding of the character of the pre-Carboniferous basement geology, even in regions well into the basin. A myriad of digital processing techniques can be applied to enhance the structural geological content in these data. Figure 2 shows A) a total magnetic field image generated from the regional data (magnetic highs in red ranging to magnetic lows in blue) together with the outlines of currently released (dark blue) and forthcoming (yellow, dashed) airborne survey data, and B) a residual magnetic image following extraction of long-wavelength, features (> 50 km) from the same data. The residual tends to emphasize localized features - particularly note the enhancement in the magnetic low areas in the SE - and helps delineate several subtle features that can be traced across the basin in the NE-SW (central area) and E-W (southern area) directions.

The rationale for merging magnetic data from various surveys is to generate images, for interpretation, of the most detailed magnetic information currently available - that is, to replace lower resolution data with higher resolution data in those areas where available. Experience has shown that it is best to merge magnetic data of similar resolutions (that is, overlapping detailed surveys) into larger contiguous blocks, before substituting these data into the regional. This helps diminish discontinuities along mutual survey boundaries.

Merged magnetic data from regional and detailed surveys tends to facilitate their mutual interpretation - once identified, features that are sharply defined in detailed data blocks can often be traced by their subtle expression for some distance within the adjacent regional data. Figure 3 shows an example of total field magnetic data from the BHP (1996) Carrickmacross survey (see NE corner of regional data, Figure 2A), merged into the regional data for this area, with detailed geological boundaries in black. Note that two NW-SE oriented late dykes can be easily identified as cutting across the detailed data and the regional. Several (smaller?) sub-parallel dykes show much weaker expression and can only be faintly traced within the regional data to either side of the detailed survey area.



The digital data from detailed airborne surveys represent a major contribution to the geoscience knowledge base available for Ireland. Forthcoming data from similar surveys will significantly extend existing detailed coverage; several of these may be particularly helpful for co-levelling existing, isolated surveys.

O28
TARA MINES – LEADING ZINC MINE IN EUROPE

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Tara Mines Limited

Tara Mines Limited, which is owned in its entirety by Outokumpu, operates in Navan, Ireland and is the largest underground zinc mine in Europe. With the production of 55 million tonnes to date and ore reserves of 25 million tonnes confirm Navan to be a world-class orebody. Tara Mines holds all the prospecting licenses for the area around the existing operations. Exploration work has been successful over past the decade. The current strategic plan envisages an additional 10 million tonnes of ore to be mined out and an extension of the mine-life, up to the year 2015, at the rate of 2.8 mtpa. During the past few years several major events have occurred in Tara Mines history:

- The SouthWest Extension Project was launched to exploit the discovered southwest extension of the orebody. The new #5 ore handling system was built for a capacity of 1,000 tph.
- After the collapse of zinc prices mine operations were suspended in November 2001. Improvement program to recover an operational health at the operations was launched in March 2002.
- Finally Bula acquisition occurred in July 2002. The Rennicks and Bennett (Glencar) acquisition opened a new potential area for exploration near the

existing underground facilities belonging to Tara Mines.

Production was restarted in September 2002. SWEX ore handling system was commissioned in July 2003. Production in Nevinstown (Bula) is expected to start in September 2003.

Over a fairly short period of time, 2000-2004, well over €100 million will be spent in these mining projects and acquisitions to enhance the entire mining asset. Step by step the mine operations will be back in full production, generating wealth to its interest groups: owners, customers, employees, suppliers and the community.

The current production target is 2.6 mtpa ore milled and 200.000 tpa of zinc metal in concentrate. The future production target, from the year 2005 onwards, is 2.8 mtpa and 240.000 tpa zinc metal in concentrates. Outokumpu owns two major zinc smelters in Europe. Tara will have a vital and an important role for Outokumpu and for the European zinc business, as a reliable, high quality and high volume zinc concentrate supplier.

Mineral Exploration

O28 Keynote

LESSONS FROM VOISEY'S BAY FOR THE EXPLORATION GEOLOGIST

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University of Toronto

Anorthosite-Granite-Ferrodiorite-Troctolite igneous suites have long been recognised as a specific style of magmatism, mostly occurring during the Proterozoic, but, because of their lack of rocks rich in ferro-magnesian minerals, the intermediate nature of much of plagioclase (An40-60) and olivine (Fo40-60), and general paucity in Ni- and Cu-bearing sulphides, they were not regarded as prospective for magmatic sulphide deposits. This changed abruptly as the potential of the Diamond Fields discoveries at Voisey's Bay became apparent during exploration over the first 6 months of 1995. Subsequent exploration, and concurrent research on the deposits showed (see papers in Lithos, volume 47, January 1999, and in Economic Geology, volume 95, June/July 2000) that the deposits occur in a dyke linking a lower chamber with an upper chamber that was originally about 1 km vertically above it, and also along the line of entry of the dyke into the upper chamber. The lower chamber occurs within a Proterozoic, mixed pelitic/psammitic, sulphide and graphite bearing gneiss (Tasiuyak gneiss). Inclusions of reacted gneiss in troctolites that fill both chambers and the connecting dyke indicate that considerable amounts of SiO2, Na2O and H2O were extracted from the inclusions by the enclosing troctolitic magma. Trace element and Nd, Pb and Sr isotopes indicate that the Voisey's Bay magma became slightly contaminated within U-depleted lower to middle crust, and subsequently interacted with minor amounts (8-13%) of local Tasiuyak gneiss. In contrast, the adjacent, similar but 16-20 Ma younger Mushua intrusion interacted with much more (15-35%) U-depleted crust. The different degrees of interaction may be due to the channels taken by ascending magma becoming progressively heated by successive batches of magma. It is likely that the later Mushua magma, which has given rise to only minor amounts of Ni- and Cu-poor sulphides, may have reached sulphide saturation early, and have become depleted in chalcophile metals before rising far in the crust. Despite the Voisey's Bay magma reaching the level of the lower magma chamber undepleted in Ni, the Ni contents of olivine in different phases of this magma indicate that initially so much sulphide segregated from it that these sulphides contained relatively little Ni (< 1.5wt%). It is only because successive waves of fresh magma passed through the system and picked up the early sulphides, upgrading their Ni contents to 3.5-4 wt% Ni, that the deposits are of economic interest.

The Voisey's Bay discovery was a major stimulant to exploration within the area. Much of this focused on sulphides hosted by the anorthosites of the area. While these sulphides are largely contained within norites and gabbro segregations within the anorthosite complexes, the mafic rocks themselves are much more fractionated than the troctolites at Voisey's Bay, and the sulphides are both small in quantity and low in Ni tenor. It is significant that the only significant (but as yet uneconomic) concentration of sulphides discovered within the area outside of the Voisey's Bay footprint is the Pants lake deposit 80 km south of Voisey's Bay. Here some of the same Voisey's Bay ingredients, relatively unfractionated troctolites (Fo60-75), enclosing Tasiuyak gneiss, and reacted inclusions of gneiss in association with the sulphides, are also present. Other ingredients, magma conduits and evidence of successive pulses of magma, have not been found to date.

An exploration geologist should therefore (1) not ignore anorthosite complexes but should concentrate on the most mafic portions, (2) should favour environments where the country rocks are sulphide-rich, (3) pay attention to parts of an intrusion that are rich in inclusions of these country rocks, (4) take samples and study the geology for evidence that more than one wave of magma has been involved and (5) above all, should not expect sulphides to be distributed uniformly over the floor of an intrusion, but should look for possible magma conduits, and concentrate drilling where these might exist.

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PLATINUM-GROUP-ELEMENT DEPOSITS : CONCEPTS, CONTROVERSIES AND THEIR RELEVANCE TO EXPLORATION STRATEGY

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INTRODUCTION

Two major sulphide ore-deposit types associated with mafic and ultramafic igneous suites collectively provide much of the world's Ni and Co, and virtually all of the world's platinum-group elements (PGE). This presentation is intended to provide a general review of PGE deposit types and their settings, with emphasis upon those in which the PGE are the primary product. It will explore the diverse and often ingenious genetic models presented for such deposits, and assess their relevance to exploration for these increasingly important commodities. It is based largely upon the voluminous scientific literature upon such deposits, and sources too numerous to reference individually. The most recent "state-of-the-art" compendium on PGE mineralization is the magnificent effort edited by Louis J. Cabri (2002), which contains extensive references to earlier work and ideas. This is highly recommended to anyone interested in the subject!

CLASSES OF PGE DEPOSITS

Massive and semi-massive sulphide deposits, associated with mafic to ultramafic intrusive and extrusive rocks, are typically dominated by Ni and Co, with variable amounts of Cu. Many, but not all, also contain significant PGE, which occur either dispersed in Ni-dominated ores, or as discrete PGE-rich segregations, most commonly associated with Cu-enrichment. Well-known examples of such deposits are the huge resources of the Sudbury region (Canada) and the Noril'sk district (Russia), both of which make significant contributions to global supply. Noril'sk is of particular importance because some of its massive and disseminated ores have exceptionally high total PGE (up to 4 g/t), whereas values in the 1-2 g/t range are more typical of such environments. The presence of significant Ni and Cu is, however, no guarantee of PGE enrichment; the Voisey's Bay magmatic sulphide deposit in Labrador generally contains << 0.5 g/t PGE, despite its attractive Ni grades.

The world's largest reserves of PGE are associated with a rather different type of magmatic setting, and are disproportionately concentrated in southern Africa. These deposits consist of minor amounts of disseminated sulphides (and various other PGE phases), which are concentrated in stratiform zones ("reefs") of exceptional continuity, within layered mafic-ultramafic intrusions. In such deposits, PGE are the primary commodity, and Ni and Cu form the by products. Typical "ores" have total PGE contents ranging from about 5 g/t to almost 20 g/t. The Bushveld Complex, which is probably the world's largest layered intrusion, contains almost 80% of the world's reserves, and the Great Dyke of Zimbabwe (also a layered intrusion, despite its name) contains a vast resource, albeit largely sub economic. The Stillwater Intrusion of Montana, which has many similarities to the Bushveld Complex, contains the largest North American PGE reserves in several high-grade deposits, but these pale in comparison to those of southern Africa. These PGE-bearing intrusions range in age from 2.7 Ga (Stillwater) to 2.5 Ga (Great Dyke) and 2.0 Ga (Bushveld); thus, the Late Archean and Early Proterozoic eras make a disproportionate contribution to the global PGE inventory.

Many other layered mafic-ultramafic intrusions around the world contain PGE enrichment and local mineralization, and continue to be areas of keen and active exploration, but few actually produce metals. Interesting Au-rich PGE deposits associated with "reefs" in closed-system layered intrusions (e.g., the Skaergaard Complex of Greenland) may represent a separate subclass. Another North American PGE producer, the Lac des Iles deposit, in northern Ontario (Canada), is a Pd-rich zone associated with a mafic intrusion that lacks well-developed layering, but rather is characterized by "chaotic" geology, magmatic breccias, and widespread development of hydrous phases. Although still broadly associated with mafic intrusive rocks, it is different in character to deposits hosted by layered intrusions. Similar deposits under active exploration in Ontario have been labelled "contact-type PGE deposits". In terms of contained PGE, all these other subclasses are minor compared to the huge reef-type deposits.

MODELS FOR PGE MINERALIZATION ASSOCIATED WITH Ni-Cu SULPHIDE DEPOSITS

Massive and semi-massive sulphide deposits dominated by Ni-Cu-Co are widely accepted as resulting from the segregation of immiscible sulphide liquids from mafic magmas in suprasolidus (i.e., largely liquid-state) conditions. The sulphide liquids strip base metals and PGE from the magmas. PGE contents of such sulphide liquids are largely limited by the relative amounts of silicate magma that are "processed" by the sulphide liquids. As magmatic PGE concentrations are generally low (< 10 ppb each of Pt and Pd), and sulphide/silicate partition coefficients are very high (103 to 105), there is commonly a mass-balance problem, i.e., the reservoir of PGE is inadequate, unless large quantities of magma are processed. The Noril'sk deposits, which are the most PGE-enriched of this class, evidently represent an extremely dynamic environment in which these conditions were apparently met. The formation of even small amounts of sulphide liquid during the ascent of mafic magmas can strip them of available PGE, but will have minimal effects upon their base metal contents. PGE-depleted magmatic sulphide deposits, such as Voisey's Bay, may result from such prior effects, coupled with relatively low magma : sulphide liquid ratios at later stages.

Crystallizing sulphide liquids behave in a manner similar to a crystallizing magma, i.e., they undergo fractional crystallization. The precipitation of high-temperature Fe-Ni-Co sulphides will cause enrichment or depletion of metals in the remaining sulphide liquid. In general, Cu, Pd and Rh are enriched in the residual liquid, whereas Ni and Pt behave more neutrally. Fe and other PGE (e.g., Ir, Os, Ru) are removed from the sulphide liquid. This fractionation process can generate late-stage metal-enriched residual sulphide liquids, which are very mobile. Migration of such late-stage liquids results in discrete Cu and PGE-enriched "transgressive" ores, which are extremely important at Noril'sk and Sudbury. In the latter example, this material has percolated downward into footwall rocks. These concepts are in general widely accepted, although some researchers believe that magmatic and externally-derived volatiles may also contribute to the late-stage mobility of PGE in such environments.

MODELS FOR PGE-ONLY DEPOSITS

The genesis of PGE deposits associated with large layered intrusions and other deposits characterized by small amounts of highly PGE-enriched sulphides is a much more controversial topic, and there is little concensus on details and mechanisms. Although this is a source of frustration for many, the divergent ideas and controversies undoubtedly make such deposits persistently attractive to researchers. There are also at least 100 discrete PGE-bearing mineral phases, some of which are known only from single localities, and many of which are familiar to only a few researchers. It is thus no wonder that the geology and genesis of such deposits forms a dense and confusing topic!

For many years, reef-type PGE deposits were viewed as products of wholly magmatic processes, and explained by models that broadly resemble those described above for base-metal-dominated magmatic sulphide deposits. However, it has long been recognized that some characteristics of PGE deposits present problems in this context. The very high sulphide PGE contents (up to 300 g/t) and the high PGE/base-metal ratios demand the processing of immense quantities of silicate magma by relatively tiny amounts of sulphide liquid. Some PGE deposits, notably parts of the Bushveld Complex, also present severe mass-balance problems in that their total amount of contained PGE implies volumes of magma that cannot be accommodated within the physical boundaries of the host intrusion. It has been suggested that anomalously PGE-enriched parental magmas are required for the formation of such deposits, but the evidence for such initial magmas remains fragmentary at best. Once formed, PGE-enriched sulphides must then be accumulated by some process in an amazingly regular fashion to form thin layers traceable for hundreds of kilometres. The reasons behind the association of (some) PGE reefs with chromitite horizons have also been a subject of petrological debate for many years. Magmatic models involving the mixing of two sulphur-undersaturated magma "pulses" to generate a sulphur-saturated hybrid composition have proved the most enduring. The sudden exsolution of sulphide liquids in a turbulent mixing environment, followed by their settling through the magma column provides an explanation for the very large magma: sulphide ratios that are required, but it does not fully resolve all of the mass-balance problems. The basic concepts behind such mixing models have also been questioned recently on thermochemical grounds.

A series of alternative models for such deposits propose that PGE and base-metals were actually extracted from the underlying cumulate pile, rather than from the supernatant magma. These ideas invoke upward transport of metals originally contained in trace sulphide phases, by residual magmas, or by Cl-rich magmatic fluids, or by some combination thereof. The localization and concentration of metals is then attributed to the interaction between this "enrichment front" and physical or chemical discontinuities within the intrusion. In a broad sense, these proposals are analogous to the technique of chromatographic separation. The remarkable continuity of PGE reefs, and the remarkable consistency of metal ratios and grades within them present significant problems for such models. However, there is no doubt that hydrothermal and subsolidus processes have affected many of the magmatic rocks associated with PGE deposits. Discordant, pipe-like, mineralization also provides some evidence for mobility of PGE and an "epigenetic" style of mineralization, at least on a small scale, but it is not clear which processes — hydrothermal or magmatic — are actually responsible. Other researchers have straddled the fence, and suggest the formation of PGE deposits by a combination of magmatic and hydrothermal processes. It has also been suggested that PGE can be extracted from magmas as "atomic metal clusters" or precipitate directly as various mineral species, thereby removing the need for sulphide liquids entirely.

SUMMARY

Although the debate concerning the origins of PGE deposits is fascinating, it is in many ways peripheral to the exploration process, as it is centred upon academic arguments and specialized techniques. However, several of these disparate models do have implications for regional-scale targeting, and perhaps also for the definition of suitable pathfinders and indicators. I personally find the "alternative" models interesting and clever, but ultimately unconvincing — magmatic models, despite their problems, seem to be more consistent with the settings and characteristics of such deposits, and the premises of such models are more readily applied in exploration.

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O31
NEGATIVE PATHFINDERS IN GOLD EXPLORATION

Joe Breen
Moydow Ltd.

The Author makes the case that large gold deposits display virulent plumbophobia. Present day mining dynasties who want to stay around for a while should note that the decline and fall of the Roman Empire (Almost on a par with the Barrick / Newmont / Anglo triumvirate in their day) corresponds with the substitution of gold taps by lead pipe. Plumbing the depths of history the ineluctable conclusion is: Avoid lead to stay out of the red.

O32
GOLD IN NORTHERN IRELAND

Kent Ausburn
Tournigan Gold Corporation

Tournigan Gold Corporation (Tournigan) became active in Northern Ireland in late 2002 and currently controls 1395 sq. km. in north and northwest Northern Ireland and 620 sq. km. in County Donegal, Republic of Ireland. Tournigan began phase 1 exploration in May 2003 on the Tyrone license block (optioned from Strongbow Resources, Inc.) located in County Tyrone northeast of Omagh in the Sperrin Mountains. Phase 1 completion is scheduled in late August to early September 2003. Phase 2 exploration will likely be initiated immediately upon completion of phase 1.

Half of the Strongbow Tyrone Licenses and all of the new Northern Ireland and County Donegal prospecting licenses cover Neo-Proterozoic Mid to Upper Dalradian metasedimentary stratigraphy. The southeastern-half of the area covered by the Tyrone licenses overlies approximately half of the exposed Ordovician Tyrone Igneous Complex. Widespread precious metal and base metal occurrences are documented on the Tyrone licenses. Occurrences of mesothermal high-grade gold quartz-sulphide veins are known throughout the Dalradian stratigraphy, including the approximately 17 gram/tonne 255,000-ounce gold resource at Curraghinalt and the gold resource reported at Cavanacaw southwest of Omagh. Probable submarine sedimentary exhalative ("sedex") silver-lead-zinc mineralization with an anomalous gold-copper association is documented in Dalradian stratigraphy in the Glenlark area. Numerous occurrences of porphyry copper-gold, volcanic massive sulphide (VMS) copper-lead-zinc-gold-silver, possible submarine epithermal, or "exhalative" gold, and localised PGE mineralization occur throughout the Ordovician Tyrone Igneous Complex. Widespread alluvial gold occurrences have been documented in the Dalradian from regional stream sediment surveys conducted by the Northern Ireland Geologic Survey throughout areas covered by Tournigan's Northern Ireland licenses and from results of various stream sediment surveys on the Republic of Ireland licenses reported by the Geological Survey of Ireland. Northeast of Omagh in County Tyrone Proterozoic Dalradian metasedimentary rocks occur northwest of and are in thrust fault contact with younger Ordovician meta-igneous rocks of the Tyrone Igneous Complex along the northeast-striking, northwest-dipping Omagh Thrust Fault. The Omagh Thrust is correlated regionally with the Highland Boundary Fault in Scotland and locally is considered the suture zone between accreted Ordovician island-arc igneous terrane and Proterozoic Dalradian continental crustal terrane, likely representing the approximate locus of a paleo-subduction zone. The Sperrin Mountains are the remnant roots of the ancient Ordovician to Devonian orogens associated with closure of the Paleo-Atlantic (Iapatus) Ocean. The widespread and varied styles of precious metal and base metal mineralization localised along this metamorphic orogenic belt are typical of collisional tectonic regimes associated with ocean-continent subduction and arc-continent collision. Therefore, the Sperrin Mountains - Omagh area is considered a metamorphic, orogenic-belt related metallogenic province. In particular the high grade mesothermal quartz-sulphide gold veins at Curraghinalt and Cavanacaw are examples of a style of quartz-vein hosted gold mineralization classified as Orogenic Lode Gold Deposits (Groves, et al., 2003). Formation of orogenic lode gold deposits is considered an integral process of the development of subduction-related accretionary or collisional terranes in which the host-rock sequences were formed in arcs, back arcs, accretionary prisms, and autochthonous passive margins incorporated in later collisional tectonics, precisely the tectonic Environments represented in the Sperrin Mountains - Omagh region.

The 2003 Tournigan exploration program has focused on the high grade orogenic quartz-sulphide gold veins at Curraghinalt and the anomalous-association (modified?) gold-silver-zinc-lead sedex occurrences at Glenlark. The 255,000 ounce gold resource at Curraghinalt consists of approximately 468,097 tonnes @ 16.96 gram/tonne gold in several discrete veins and ore shoots localized in a block roughly 1000-m. along strike, 250-m. across strike, and 150-m. down dip. Gold mineralization comprising the resource is open in all directions. The presently defined resource and adjacent gold occurrences were discovered and developed by previous workers with 2,800 m. trenching, 18,000 m. diamond drilling, and 700 m. underground development. Prospect sampling and deep overburden - shallow soil geochemical surveys have partially delineated an approximately 8km X 0.5-1km west-northwest trending corridor ("Curraghinalt Trend") of medium to high grade rock and soil gold anomalies extending approximately 4.5km. northwest of Curraghinalt to Golan Burn and 2.5km. southeast of Curraghinalt to Alwories Burn. Tournigan's 2003 exploration at Curraghinalt has consisted of detailed mapping and structural analysis focused on underground rock-vein exposures and drill data, shallow-soil geochemical and VLF geophysics surveys along the Curraghinalt trend, and targeted trenching and test diamond drilling southeast of the Curraghinalt resource area. Detailed structural analysis has generated an increased understanding of vein system genesis, geometry, and structural controls, allowing relatively high-confidence projections of ore-shoots down-rake and along strike. Shallow soil geochemical and VLF geophysical surveys have filled in blank areas and increased resolution of the geochemical and geophysical signature of the Curraghinalt trend. Diamond drilling southeast of the Curraghinalt resource is testing the down-rake extension of the southeastern-most ore shoot in the resource block and the size and tenor of a possible significant new ore shoot 100- to 200-m southeast of the resource block. Results are pending. Seven diamond drill holes totalling approximately 730 meters were completed on the "modified" (overprinted?) sedex target this year at Glenlark. Gold and lead-zinc geochemical and IP geophysical anomalies were targeted. Final results are pending but preliminary "grooved" core sample assays and geochemical analyses are similar to results reported from test drilling conducted at Glenlark by previous workers.

Tournigan believes that 1 million-plus and possibly up to 2 million mineable ounces of gold are likely to occur in and around the current Curraghinalt resource block, and that the Curraghinalt Trend has the potential to host an additional 1 to 2 million ounces gold. Several other significant occurrences of medium to high grade Curraghinalt-style gold mineralization are documented and of interest at other locations on the Tyrone licenses, specifically the Glenmacoffer area. These occurrences may represent new undiscovered vein systems similar to those in the Curraghinalt trend.

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O33

THE MINERAL INDUSTRY IN NEWFOUNDLAND AND LABRADOR, AN OVERVIEW

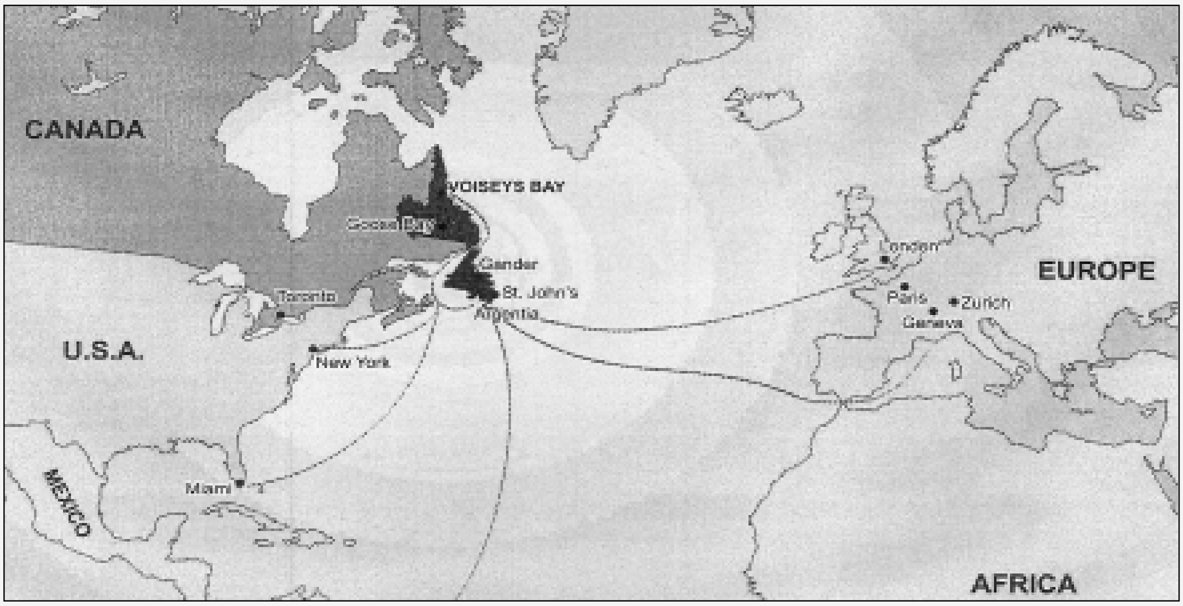
Gerry O'Connell
Newfoundland and Labrador Chamber of Mineral Resources Inc.

NEWFOUNDLAND AND LABRADOR

Newfoundland and Labrador is Canada's most easterly province. It has an area of over 400,000 sq km, six times the size of the Irish Republic, and extends from latitude 47 to 60 degrees north.

The province has rocks that range in age from Archaean to Carboniferous and has a diversity of prospective environments and mineral deposit types to match. Newfoundland and Labrador produces iron ore, gold and industrial minerals with an annual value of about US$600 million. This will increase substantially when the Voisey's Bay nickel deposit reaches production in 2005. As well, Aur Resources, owner of the Duck Pond polymetallic VMS-type deposit in central Newfoundland has signaled its intention to begin to bring the deposit to production in 2003. Additional gold and industrial mineral deposits are at the feasibility study stage.

The fact that the world-class Voisey's Bay nickel deposit was first spotted from a helicopter indicates the degree to which the province is under explored. In recent years a strong local base of skilled junior exploration companies has arisen and there has been a revival of the prospecting tradition. These groups are constantly making new mineral discoveries and have partnered with many of the world's major mining firms. Currently exploration is concentrated on finding magmatic nickel and IOCG deposits in Labrador and VMS, redbed copper and gold deposits on the island of Newfoundland. Newfoundland is one of the "hot spots" for gold exploration in Canada in 2003. Canadian gold producers Barrick Gold Corporation, Agnico-Eagle Mines Limited,



Goldcorp, and Richmont Mines, as well as numerous juniors have joined the hunt.

Mining is an area of provincial jurisdiction in Canada. As Newfoundland and Labrador's economy is heavily dependant on resources, public opinion and government policy are highly supportive of the industry. Mineral properties can easily be acquired by map staking and it will soon be possible to stake on the Internet. The obligations of claimholders are very reasonable and clearly stated in regulations. The province's Department of Mines and Energy makes available a wide array of geoscientific information through its highly respected Geological Survey, maintains a reference library of all mineral exploration reports and archives exploration drill cores at several sites. A government incentive program provides matching grants of up to $50,000 per project for advanced exploration, while services and skilled workers are readily available for exploration and development at very competitive rates. Newfoundland and Labrador is one of the most prospective, mining-friendly and competitive jurisdictions for mineral exploration and development available today.

O34

POTENTIAL FOR GOLD AND VMS DEPOSITS IN THE PRECAMBRIAN OF WEST AND SOUTH GREENLAND

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Geological Survey of Denmark and Greenland (GEUS)

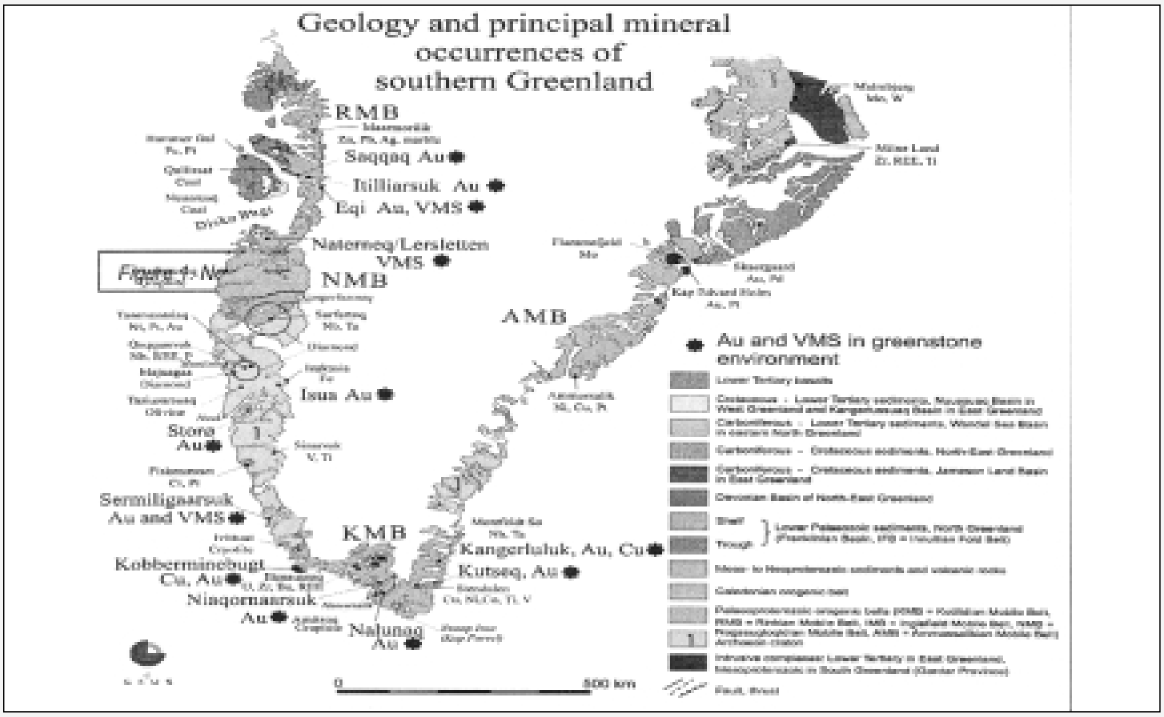
Focus here is on gold and VMS occurrences and their formation in Archaean greenstone belts and in Palaeoproterozoic mobile belts of West and South Greenland. The Archaean greenstones contain gold in different settings: a) mesothermal gold with extensive ankeritisation and sericitization; b) gold leached from mafic and ultramafic rocks and precipitated in shear zones; c) gold related to important tectonic terrain boundaries; and d) gold related to volcanic massive sulphide (VMS). Archaean VMS deposits are all minor in size. Four regions with gold bearing Archaean greenstone belts are listed below.

ISUA, WEST GREENLAND

In the southern part of this greenstone belt two significant gold occurrences occur in a sequence of banded amphibolite, calc-silicate minerals, chert and carbonate. The mineralization occurs in quartz-carbonate veins with the gold having been extracted from mafic and ultramafic rocks.

STORØ, WEST GREENLAND

Gold mineralization on the island of Storø occurs in the Mid to Late Archaean supra-crustals near an important tectonic



boundary, which is a major ductile shear zone with numerous, sheeted pegmatites. Gold mineralization occurs in the contact between amphibolite and the underlying quartz-aluminous schists, scattered iron formation and associated with arsenopyrite-rich rocks.

SERMILIGAARSUK, SOUTH-WEST GREENLAND

Gold in the Sermiligarssuk greenstone belt occurs in disseminated pyrite in quartz-ankerite lenses and in pyrite associated with massive arsenopyrite aggregates. Gold is suggested introduced during the formation of stratiform exhalites with massive-sulphide and chert (VMS). Regional metamorphism, recrystallization, shearing and intensive carbonate alteration along the shear zones led to the liberation and accumulation of gold.

DISKO BUGT REGION, WEST GREENLAND

Gold mineralization at Eqi is hosted in an age given c. 2.8 Ga greenstone belt. Intensive hydrothermal activity resulted in extensive carbonatization and sericitization. Primary enrichment of gold took place during the pervasive hydrothermal alteration. The gold is mainly located in carbonate-altered rocks and remobilised into quartz veins (up to 60 g/t). Interesting gold occurrences are also known in supracrustal successions from Itilliarsuk and Saqqaq. VMS occurrences are common in the greenstones of the Disko Bugt region. Isotopic studies of the Disko Bugt region show that VMS from felsic metavolcanites yield an errorchron age around 2.8 Ga. Epigenetic gold mineralization, hosted in shear and fault zones, is linked to the metamorphic peak around 1.9 Ga.

Gold in three Palaeoproterozoic mobile belts listed here is related to either intrusive granitoids or to shear zones.

NAGSSUGTOQUIDIAN AND RINKIAN MOBILE BELTS, WEST GREENLAND

The mineral potential of greenstones within the Nagssugtoquidian mobile belt is only known in outline with sporadic gold occurrences in amphibolites and shear zones. The largest known VMS occurrence is located in mafic volcanic rocks at Naternaq. In the Rinkian mobile belt a thick turbidite sequence hold a potential for gold deposits.

KETILIDIAN MOBILE BELT, SOUTH GREENLAND

Gold in the subduction environment of the Ketilidian mobile belt occurs in a zone bordering the southern part of a major granite batholith (1.85-1.80 Ga). Interesting gold prospects are Nalunaq, Niaqornaarsuk, Kutseq and Kangerluluk. The initial gold mineralisation was genetically related to metalliferous fluids associated with the emplacement of late intrusive stages of the Julianehåb Batholith (1.8-1.77 Ga) and by the regional deformation and metamorphism (1.792-1.785 Ga).
In conclusion, several parts of the Precambrian of West and South Greenland are interesting targets for gold such as the intrusion-related gold in the Ketilidian where gold will be exploited in near future. The VMS potential of the Precambrian of Greenland is small.

O35

GOLD RECOVERY AT A SAND AND GRAVEL PLANT IN THE SEGRE RIVER AREA (BALAGUER, NE Spain)

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INTRODUCTION
The Segre River rises in the central Pyrenees and is the main tributary of the Ebro River. The drainage area is principally made up of Stephanien acidic volcanic rocks, Ordovician to Silurian metasedimentary rocks and late-Hercynian granites. Late-Hercynian lodes of gold ore deposits and Caradocian paleoplacers have also been detected.
Exploration carried out in the Segre River in 1994 show that the terrace and the flood plain present a very low content in gold and heavy minerals. Table 1.

(* terraces).

Grade (g /m3)	Drainage basin. Main gravel input Maximum input of gold and heavy minerals	Transfer area. Moderate gravel input Moderate input and output of heavy minerals	Depositio-nal area. Main gravel output Maximum output of gold and heavy minerals
Segre river	<0.1 – 0.001*	0.01	0.2 – 0.09*
Noguera Pallaresa river	>0.1		
N.Ribag-orzana river	<0.01	0.001 – 0.0	0.001 05
Esera/ Cinca rivers	<0.01		
Ebro river		0.001	0.12 beach sands 1.38 black sands

Table 1. Gold content average in the Segre - Ebro Rivers

Nevertheless, sand and gravel plants located along the river enable the viable production of these minerals. Table 2
GOLD AND HEAVY MINERALS RECOVERY.
Sand and gravel plants are industrial processes for obtaining materials for concrete and asphalt paving and for others public works.
The gold and most of the heavy minerals are concentrated in the lowest sands fractions during sieving and washing of the sand and gravels.
The Sorigue sand and gravel plant operates over a Pleistocene terrace of the Segre River. Its operation consists of the sand and gravel extraction of four levels of 5 meters of thickness.

(*) gold content by aqua regia leaching and AA analysis

	River bed		Terrace	
Sand and gravels plants	g/t	€./t	g/t	€./t
Organya	0.001*	0,01	-	-
Coll de Nargo	0.032 *	0.32	0.0033	0.033
Pons	0.003 *	0.3	-	-
Vallfogona de Balaguer	0.058 *	0.58	0.025	0.25
Termens	0.11	.1	-	-
Vilanova de la Barca	-	-	0.026	0.26
Corbins	0.015	0.15		
Alcoletge	0.086	0.86		

Table 2. Gold content near sand and gravel plants in the Segre river.

The gold and most of the heavy minerals are concentrated in the lowest sands fractions during primary sieving and secondary sieving and washing of the sand and gravels. An artificial gold and heavy mineral enrichment process has been produced:

PRIMARY CONCENTRATION IN DRY SIEVING TREATMENT
0 - 40 mm sand and gravel fraction:
150 to 200% in terrace levels 1 and 2
200 to 250% in terrace levels 3 and 4

SECONDARY CONCENTRATION IN SIEVING AND WASHING TREATMENT
0 - 5 mm sand fraction
300 to 350% in terrace levels 1 and 2
250 to 300% in terrace levels 3 and 4
Altogether a factor of enrichment of 5 has taken place. Could sand and gravel plants be regarded as artificial placer deposits?
Carpets with riffles in the first stage and gravimetric concentrator (Knelson KC-XD48) in the second stage were employed after secondary concentration and before the cyclone separation in the industrial process.
Two materials were obtained after the gravimetric concentration process:
Very rich black sand concentrate in gold, zircon, ilmenite, rutile, magnetite, monacite, scheelite, cassiterite, iron and sulphides.
A very clean sand fraction (0 – 5 mm) without pathological materials such as sulphides, iron and radioactive minerals.
The secondary concentration of gold and heavy minerals coming from black sands is processed in a benefit plant. The black sands once sieved in two fractions, the gold is separated of heavy minerals by means of a Wilfley shaking table.
By means of this process it is obtained: a rich gold concentrated and a series of magnetics, paramagnetics and diamagnetics minerals.

GOLD AND HEAVY MINERALS POTENTIAL AREAS (TABLE 3).

Inferred gold reserves in the Segre River system	12.52 t	125.2 M€
Inferred heavy mineral reserves in the Segre River system	5,620.5 t	1.3 M€
Hypothetical gold resources in the Iberian Peninsula	940.0 t	9,400.0 M€
Hypothetical gold resources in the European Union	3,475.0 t	34,750.0 M€

Table 3. Reserves and resources of gold in sand and gravels

EUROPEAN UNION EXPLORATION CRITERIA.
Geology (lithologic and metalogenic):
- Metamorphic (turbidite) - Granite - Acidic volcanic and sandstone materials in Drainage basins.
- Low content in calcareous rock (less than 20%)
- Gold content exceeding 0.02 g/t in sand and gravel terraces and flood plain

Regional economy
- High demand for public works and building (GDP - Inhabitants)
- Sand and gravel production areas (>500,000 t/year)
- Near demand areas (≈ 100 Km)

Sand and gravel plant criteria
- Washed and sieving 0-5 mm to 0-7 mm fraction at the sand and gravel plant
- Gold content exceeding 0.1 g/t in 0-7 mm to 0-5 mm fraction
- Slurry 0/7 mm to 0/5 mm fraction between 1.7 to 1.9 water/solid using Gravimetric concentrators

CONCLUSION.

The sand and gravel plants are a potential resource in gold and heavy minerals for the European Union.

Acknowledgements: we are indebted to the CDTI Spanish National Program for Science and Technology.

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THE HISTORY OF GOLD EXPLORATION IN THE BOTWOOD BASIN OF CENTRAL NEWFOUNDLAND

Brian Dalton* and Roland Butler

***Altius Minerals Corporation**

The Botwood Basin of central Newfoundland gained prominence over the past few years as a new and exciting gold exploration area in Canada. The current gold exploration play in the region was developed over a period of several years by geologists at Altius Minerals Corporation, based on their local knowledge of the region. Even though the first geologist to visit the Botwood Basin more than 100 years ago suggested that the region had potential for gold deposits, it was not until 1986 that the first gold occurrence was officially documented. More than 100 gold occurrences and an antimony deposit were discovered following the release of large areas from long-term mineral concessions in the mid-1980's but, with the decline of "flow-through" funding, few prospects were explored in detail, and the district-scale potential was not recognised.

Altius began work in the area in the mid-1990's and was rewarded progressively with several important geological discoveries that will be discussed in this talk. To outline, Altius' work has considerably enhanced the understanding of the regional geology and structure, and also of permissible (and observed) mineralization styles. The geological architecture of the region has been shown to be quite analogous to Nevada's Carlin Trend. It consists of Ordovician marine sediments that have been thrust over Siluro-Devonian terrestrial to shallow marine (commonly calcareous) sediments. Two styles of gold mineralization have becomes the focus of Altius' exploration; i.e. low-sulphidation epithermal mineralization and sediment-hosted mineralization ("Carlin-type"). Both styles of mineralization have been clearly observed and in each case observations support an age of the mineralization that is later than the thrusting event.

Broad interest in the area seems to have been ignited when bonanza-grade drill intercepts were reported by Altius Minerals and its funding joint venture partner Sudbury Contact Mines / Agnico-Eagle Mines from the Moosehead property in the western Botwood Basin. This interest further expanded when it was announced that Barrick Gold Corporation was joining Altius through an exploration and development funding agreement, to target Carlin-type gold deposits in the eastern Botwood Basin on a land package comparable in size to the Carlin Trend in Nevada. A staking rush ensued in surrounding areas and more than 20,000 claims covering 5,000 square kilometers were staked. Today there are more than 20 companies active in the Botwood Basin including Altius.

Diamond drilling highlights at the Moosehead Property in the western Botwood Basin by Altius and Sudbury Contact Mines / Agnico-Eagle Mines include 14.07 g/t gold over 16.84 metres, which included a quartz vein that assayed a spectacular 1154.35 g/t over 0.18 metres. Altius and Barrick are active in the eastern Botwood Basin and have discovered three broad target regions that exhibit alteration and mineralization features consistent with Carlin-type gold deposit models.

Positive results achieved to date are still of an early stage nature, however, much additional investment is warranted and planned within the Botwood Basin. Further developing new ideas and combining them with persistent grassroots exploration has been reinforced within Altius as a strategy for success.

O37

GRASS-ROOTS EXPLORATION IN AN UNDER-EXPLORED DIVERSE GEOLOGICAL ENVIRONMENT EMPLOYING WORLD CLASS MINERAL DEPOSIT MODELS: NEWFOUNDLAND EXAMPLES

Mike Basha
Cornerstone Capital Resources Inc

The Island of Newfoundland forms the northernmost extent of the Appalachian Orogen, preserving a geological cross-section that records the formation and eventual destruction of the late Precambrian to early Paleozoic Iapetus Ocean. Four broad tectonostratigraphic subdivisions of the Island, based on stratigraphic and structural contrasts, demonstrate the varied and protracted tectonic evolution of the Appalachian Orogen. These tectonostratigraphic subdivisions provide an excellent framework for explorationists to apply generic mineral deposit models at the regional to district scale. Cornerstone Capital Resources is a Newfoundland-based mineral exploration company with a diversified portfolio of over 25 regional and district scale mineral exploration projects on the Island of Newfoundland and in Labrador. Eight of these projects are now funded through joint ventures and are being systematically explored using "working" mineral deposit models. The application of these deposit models provide guidelines by which Cornerstone can develop project-specific exploration strategies but their application is also designed to be flexible enough to incorporate new data and be modified as each project develops.

Cornerstone and its partners are exploring for a variety of mineral deposit types including Orogenic Gold, Intrusion-Related Gold, Epithermal Gold, Volcanogenic Massive Sulphides (VMS) and Sediment-Hosted Stratiform Copper (SSC). The Cape Ray, True Grit, Grey River and Redcliff Projects provide examples of the diversified mineral deposit types for which Cornerstone and its partners are exploring.

The Cape Ray Gold Project, the subject of a joint venture with Thundermin Resources, located in southwestern Newfoundland covers a distance of 100 km along a major Late Silurian to Early Devonian crustal scale high angle reverse fault zone representing the suture between composite Laurentian and Gondwanan terranes. There, lode gold mineralization is spatially associated with the fault zone and hosted by graphitic schists, pyritic iron-rich sediments and pre-mineral, syn-tectonic intrusives. The mineralization is interpreted to be related to hydrothermal activity associated with the end product of terrane collision and related metamorphism and magmatism. Along the Cape Ray Fault the style of mineralization, host rock lithologies and tectonic setting/history resemble many Archaean and younger "Orogenic" gold deposits.

The True Grit Project, located in south central Newfoundland and the subject of a joint venture with Moydow Mines, is targeting Orogenic Gold deposits. There, a 2.6 by 0.8 km Au-As-Sb in soil anomaly has resulted in the discovery of a broad zone of low-grade gold mineralization hosted by weakly altered arsenopyrite-bearing metamorphosed distal turbidites. Drill intersections of 0.5 g/t Au over 42.7 m have been returned. Local high-grade arsenopyrite-bearing quartz veins which, assay up to 16g/t Au over 1.0 m from saw-cut channel samples, are also present.

The Grey River project located on the south coast of Newfoundland is targeting Intrusion-Related Gold deposits. Both the True Grit and Grey River project areas are associated with the Hermitage Flexure, a sinuous Z-shaped flexure defined by a really extensive late orogenic to post orogenic granitoids and metasedimentary rocks. The granitoid intrusives, related to a major thermal pulse following the final closure of Iapetus during the Late Silurian, dominantly comprise extensive multi-phase, reduced (low magnetic susceptibility) K-feldspar megacrystic biotite granodiorite and granite and locally two-mica granites. The area is also characterised by a regional elevated Au-As-Sb-W-Bi geochemical association consistent with regions elsewhere in the world that host Intrusion Related or Orogenic Gold deposits, such as the Tintina Belt of Alaska-Yukon.

The Redcliff Project located on the Bonavista Peninsula in eastern Newfoundland is targeting Sediment Hosted Stratiform (SSC) Copper deposits in Neoproterozoic rocks of the Avalon Zone. These rocks record a complex and protracted evolution of magmatic arcs and marine to terrestrial basins along the ancient Gondwanan plate margin and are synchronous with the Pan-African Orogeny. The final accretion of this Neoproterozoic terrane to the Palaeozoic Appalachian Orogeny occurred during the Siluro-Devonian. Recent discoveries by Cornerstone of extensive copper (chalcocite) mineralization hosted by reduced grey beds in primarily red-bed sequences that overlie copper-bearing mafic volcanics indicate many similarities to other SSC deposits worldwide.

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THE REID PROPERTY – A GOLD PORPHYRY IN NEWFOUNDLAND

Peter Dimmell
Linear Resources Inc.

INTRODUCTION

The Reid property was acquired from Datan Resources, a prospecting syndicate, in September 2002. The property comprises 541 claims totaling 13,525 ha and is located on NTS 2 D / 5, to the north of the Northwest Gander River and west of the Baie d'Espoir Highway in central Newfoundland (Figure 1).

The property was staked to cover a number of altered (silicified / sericitized) float boulders carrying arsenopyrite and pyrite with gold values up to 4 g/t, discovered by prospector Cyril Reid, in late July 2002. The mineralized quartz porphyry and overlying altered / mineralized mafics and ultramafics, appear to be localized in a fault bounded area of approximately 400 m by 400 m, lying along the northern contact of the Coy Pond ultramafic complex with the host Spruce Brook metasedimentary units. Mineralization consists of arsenopyrite and pyrite as disseminations and fracture fillings in altered (silicified, chloritized, iron carbonatized) mafics, ultramafics and quartz porphyries. No previous gold exploration is documented.

EXPLORATION WORK

Linear has carried out gridding, geochemistry (B horizon soils), geophysics (VLF-EM, magnetics and IP), trenching and diamond drilling (6 holes - 911 m in Jan. / Feb. 2003).

The soil geochemistry indicates a gold in soil anomaly with values up to 1.5 g/t Au and associated As values to > 2200 ppm. The

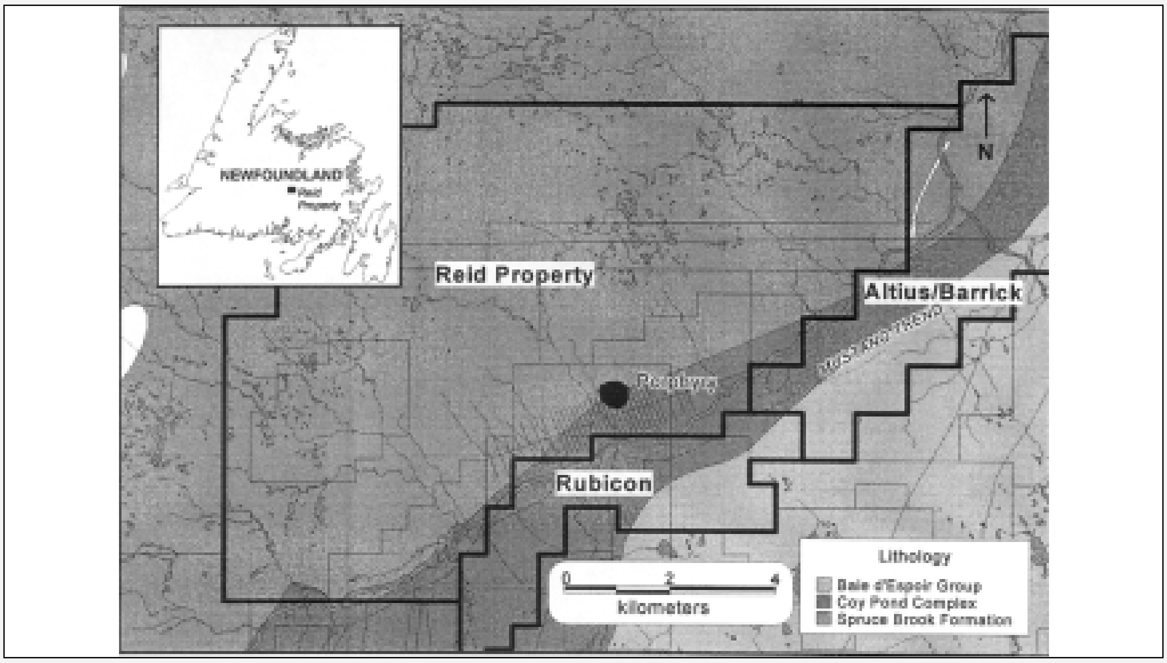

Figure 1. Reid Property Location Map with Geology and claim holdings

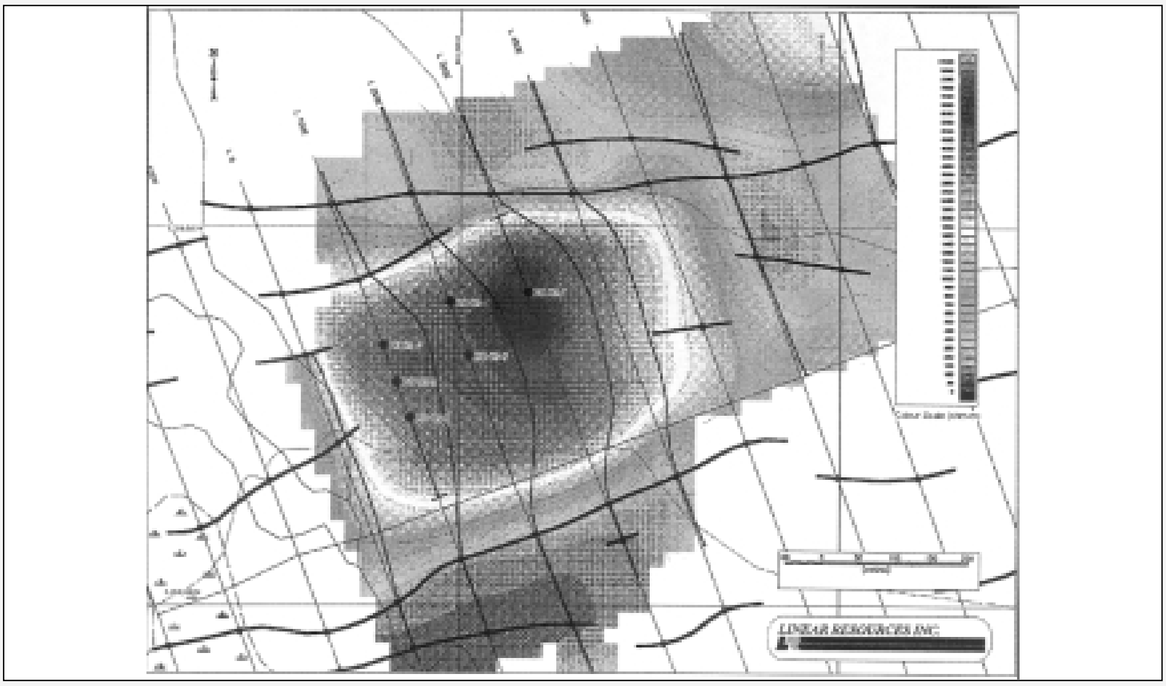

Figure 2 Reid property – IP Apparent Resistivity and Drill hole Locations

anomalous As / Au in soil area is coincident with a magnetic low which reflects alteration in the mafic and ultramafic units overlying the porphyry. Induced polarization defines an area of high chargeability and high resistivity associated with the magnetic low and soil geochemistry, flanked by strong conductive zones (as shown by VLF-EM anomalies) and strong chargeability / low resistivity IP zones, to the north and south.

GEOLOGICAL SETTING

The property lies within the Dunnage tectonostratigraphic zone. The Dunnage marks the vestiges of the proto Atlantic Ocean, Iaepetus, and is commonly referred to as the central mobile belt. The rocks in the belt host numerous base metal deposits such as Buchans and Duck Pond-Tally Pond and many newly discovered gold occurrences including those of the "Botwood Basin". The Reid property lies at the southern end of the "Mustang Trend" in the Botwood Basin, under evaluation for "Carlin Trend" gold by Altius – Barrick. The contact between the ultramafic Coy Pond complex (Cambrian to Ordovician) and the metasedimentary Spruce Brook formation (mid Ordovician) passes through the claim group. No outcrop, except for that exposed in the trenching, has been noted in the area of the quartz porphyry mineralization. An altered (sericitized, silicified), mineralized zone, assaying 2.1 g/t over 2.3 m, located in trench 1, is a mafic intrusive (gabbro ?). The mafic to ultramafic subcrop/outcrop, located in the northern portion of the IP anomaly and the magnetic low, is non magnetic and altered with iron carbonate and silicification prevalent. Outcrops of black shale with extensive quartz veining are noted in the southwest portion of the group and as float along the river.

MINERALIZATION

Mineralization is pyrite and arsenopyrite, with minor chalcopyrite and pyrrhotite in altered (silicified, sericitized, chloritized, and iron carbonatized) mafic and ultramafic units and quartz porphyry. The sulphides occur as disseminations, fracture fillings and coarse masses with euhedral cubic pyrite noted. The arsenopyrite is mainly disseminated, acicular and needle-like in form but also occurs as blocky crystals and as massive fracture fillings. Quartz veining is ubiquitous occurring as white to chalcedonic veining, with associated silicification. Metasedimentary units (siltstones and carbonaceous shales) of the Spruce Brook

Formation, to the north of the quartz porphyry are weakly altered (bleached) in places. Sulphide content is minor.

Four of the drill holes (BO-03-2,3,5,6) intersected significant quartz porphyry, while holes 1 and 4 had only narrow porphyry dikes in mainly variably altered mafic volcanics or intrusives. DDH B0-03-5 intersected carbonaceous sedimentary units in contact with the mafic volcanics to the north of the porphyry body. All of the drill holes gave significant gold values with wide zones of mineralization and gold values in the three vertical holes that intersected the porphyry. The mineralization in the massive to brecciated quartz porphyry, consists of disseminated acicular arsenopyrite and fracture filling pyrite and arsenopyrite. The wider zones of gold values are listed below:

BO-03-2		81.2	102.7	21.5 m	1.1 g/t
BO-03-3		78.8	98.8	20 m	1.6 g/t
	incl.	82.3	93.4	10.6 m	2.2 g/t
	and	116.1	152.2	36.1 m	0.96 g/t
BO-03-6		51.5	92.9	41.4 m	1.1 g/t

CONCLUSIONS

A new gold mineralized, porphyry system has been defined. The body is a near horizontal, altered/mineralized quartz porphyry, approximately 100m thick and dimensions of at least 300 by 300m, with associated, near vertical mineralized shear structures extending to the surface, through the overlying mafic volcanics and intrusives. More work is required to evaluate this new zone of mineralization.

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NEW BRUNSWICK OPPORTUNITIES: GOLD AND BASE-METAL POTENTIAL

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This presentation will highlight the geological setting and potential for gold and base-metal mineralization in New Brunswick. Arguably, the most exciting recent development is the recognition of an intrusion-related gold district in southwestern part of the Province. This area, which has been periodically active since the late 1800's, hosts various styles of gold mineralization. The most significant discoveries to date are the Clarence Stream deposits, which are characterized by an assemblage similar to the Tintina Belt (Alaska/Yukon). Similar environments are present elsewhere in the Province, but remain unexplored.

Northern New Brunswick is home to the world famous Bathurst Mining Camp (BMC), which has a history of 12 mining operations (one currently active) and hosts 45 deposits, including the super-giant Brunswick #12 mine. Current reserves and past production in the BMC total over 500 million tons of massive sulphide with an average grade of 11% combined Cu-Pb-Zn. Although in decline recently, exploration has been relatively steady since the 1950's, with 3 new deposits and 17 new occurrences discovered in the 1990's. In 2002, Noranda Exploration Ltd., the largest player in the BMC, closed its local exploration office in response to budget cuts, leaving a number of unfinished exploration initiatives and much of its land position available for option. Noranda's huge dataset was acquired

by the Province and will enter the public domain in Sept. 2004. Preliminary examination of these data, in conjunction with Provincial data, suggests that part of the BMC, previously believed to be barren, may be underlain by the ore-bearing Brunswick horizon.
New Brunswick has respectable tax, exploration, and value-added incentive programs, a comprehensive on-line provincial geoscience database, and an established mining infrastructure. These are complemented by an experienced workforce of professional geoscientists, prospectors, consultants, and support industries.

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