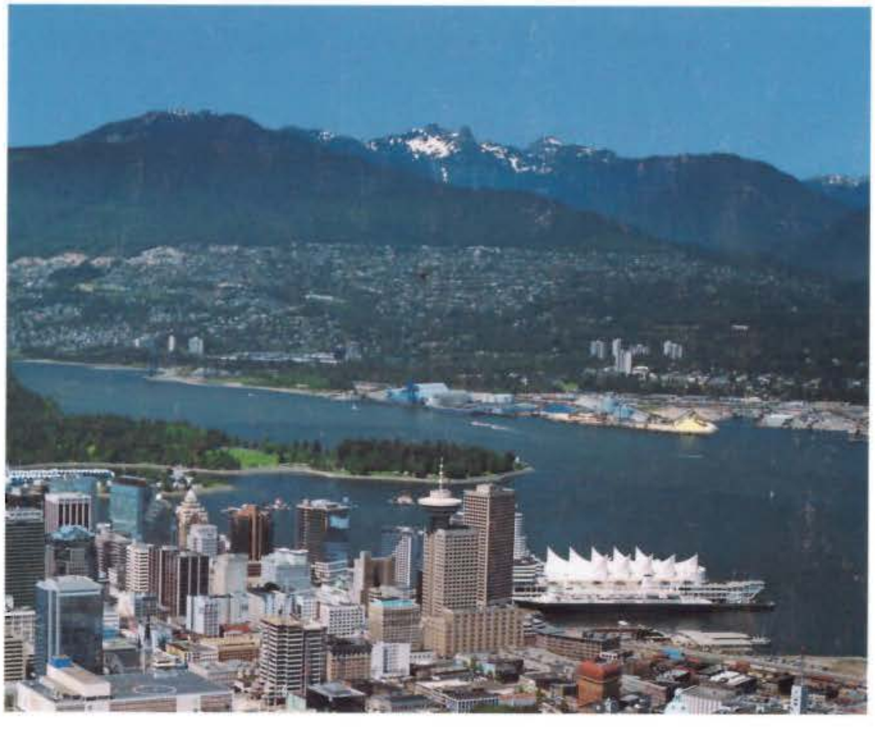
19th International Geochemical Exploration Symposium

Exploration
Geochemistry
into the 21st Century

The Association of Exploration Geochemists

SYMPOSIUM PROGRAM AND ABSTRACTS VOLUME



Vancouver, British Columbia, Canada

April 10-16, 1999

Hotel Vancouver

THE ASSOCIATION OF EXPLORATION GEOCHEMISTS

P.O. Box 26099, Robertson Rd.
Nepean, Ontario, K2H 9R0, Canada

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Symposium Program and Abstracts Volume

Edited by W.K.Fletcher and I.L.Elliott

Hotel Vancouver
Vancouver,B.C.,Canada
April 10th to 16th 1999

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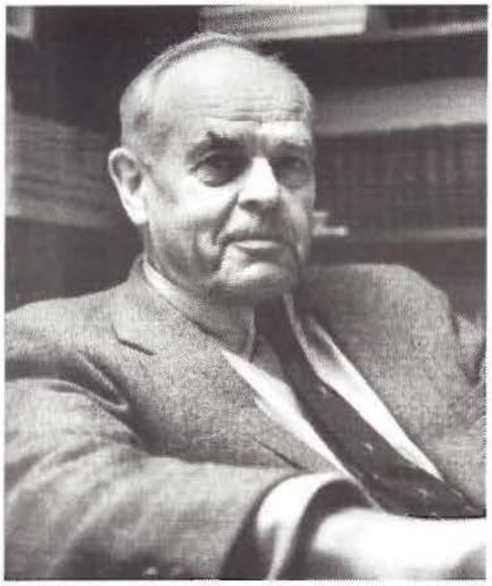
This Symposium is dedicated to the memory of Harry Verney Warren (1904-1998)



OC, OBC, D.Sc., D.Phil., FRSC, FGSA

Founding Member of the AEG, and Pioneer in Geochemistry, Biogeochemistry and Environmental Geochemistry

In March of last year, Professor Harry Warren passed away after a long, varied and richly productive career, based here in Vancouver at the University of British Columbia (UBC). He was one of the greats of geochemistry with an exceptionally fertile and innovative mind. He was constantly investigating new methods of geochemical exploration and seeking new applications for geochemical studies. He touched and influenced many lives through his enthusiasm and inspiration to legions of students, colleagues and professionals.

In his early years he excelled in several sports, notably rugby, cricket, grass hockey and track events. As a sprinter he held track records for the 100, 220 and 440-yard events at UBC, and went on to be a member of the Canadian track team in the 1928 Amsterdam Olympics. The same year he equalled the world record in the 100-yard dash on grass at a meeting in Dublin. At that time he was a Rhodes Scholar at Oxford (1926-1929), completing his doctoral dissertation on lead and zinc deposits of south-western Europe. Following a period of postdoctoral research at Caltech he joined faculty of the Department of Geology and Geography at UBC in 1932 where he was based until his retirement 41 years later when he was nearly 70. During his retirement he remained as active as ever for the next 20 years as an honorary, then emeritus professor, continuing to inspire by what others have described as his "boundless energy" and "unbridled enthusiasm".

Amongst his many accolades, Harry Warren became renowned as the Father of Biogeochemistry. Many of his 197 publications describe the results of a vast array of tests on the relationships between plant chemistry and mineral deposits, conducted at numerous sites across Canada and elsewhere. In addition to his many discoveries of metal enrichments in trees and shrubs (e.g. extraordinary enrichment of As in Douglas-fir), his fertile mind led to a range of rather exotic tests, such as the analysis of bee pollen and trout livers to assist in locating mineral-rich areas, and the use of dogs in the bush to sniff out sulphide-rich boulders. These studies have been the inspiration for others to continue to build on the foundation of observations and information that he laid, using the fundamental advances in low cost multi-element analytical technology that have emerged in recent years.

His profound interest in the distribution of trace elements in all natural materials was not directed purely at mineral exploration, but also at the relationship between trace element concentrations and health. He was a pioneer in environmental geochemistry and was a founding member of the Society for Environmental Geology and Health. In 1973 his efforts and achievements in this area resulted in his installation as an honorary member of the Royal College of General Practitioners in the UK. In his later years he became increasingly interested in medicinal plants and their properties, focusing on plants used in native Indian remedies. Harry Warren was, indeed, a pioneer in environmental geochemistry, since as far back as 1954 he published the first of 37 papers on the relationship between geology and human health. In that same paper he promoted the idea of major surveys to examine relationships between trace element content of soils and rocks and uptake by foodstuffs.

Harry Warren received many honours throughout his life, including the Order of British Columbia and the Order of Canada. On January 20 of this year he was inducted into the Canadian Mining Hall of Fame.

In 1997 I visited him in hospital at a time when it was a considerable effort for him to speak. His response to some new developments that I had recounted was "never a dull moment". These were his last words to me, and they really epitomize the full and adventurous life of this remarkable man who, in addition to his great influence on the development of biogeochemistry, environmental geochemistry and geochemical exploration in general, has made his permanent mark on history.

Colin E. Dunn
Emeritus Scientist, Geological Survey of Canada;
Consultant Geochemist, Nepean, Ontario.

Message from the President of The Association of Exploration Geochemists

Chairman, AEG Members, and Distinguished Guests: It is an honor and a privilege to welcome you to this Symposium.

The Association of Exploration Geochemists is proud to sponsor the 19th International Geochemical Exploration Symposium – "Exploration Geochemistry into the 21st Century". The first AEG sponsored IGES was actually the third IGES and held January 1972 in Toronto. There were approximately 700 delegates from 26 countries. The initial IGES was held April 1968 in Ottawa, organized by Robert Boyle and sponsored by the National Advisory Committee on Research in the Geological Sciences. The second IGES was held April 1969 in Golden Colorado. John Hansuld, Harold Bloom, and Frank Canney organized this IGES and it attracted 483 delegates from 16 countries. Since then an IGES has been held approximately every two years and is one of the major voices for the Association, the others being the Journal and the Newsletter. Two of these early organizers, Robert Boyle and John Hansuld, will be honored Thursday night with the Gold and Past President medals, respectively, of the Association.

The purpose of the Association of Exploration Geochemists is:

- to form a united and representative group of persons specializing in the field of exploration geochemistry;
- to advance the science of geochemistry, especially as it relates to exploration and associated research;
- to foster the common scientific interests of exploration geochemists;
- to facilitate the acquisition of professional knowledge and information relevant to exploration geochemistry and to promote the interchange thereof among its members;
- to encourage research and development of geochemical exploration methods;
- to advance the status of the profession of exploration geochemistry;
- and, to promote and maintain high standards of training and ethics among its members

The International Geochemical Exploration Symposia have been of significant benefit to the Association in the achievement of these goals.

This, the 19th IGES, should prove to be one of the year's more significant international geochemical gatherings. During the week we will honor three of our own: Harry Warren, Robert Boyle, and John Hansuld. With the broadening of exploration opportunities throughout the world, Association members, are providing the scientific and technical leadership and training to deal with today's challenges. Members not only provide expertise with respect to mineral discovery but also leadership in identifying, mitigating, and reducing the environmental impact of both old and new mining developments.

Geochemists throughout the world must continue to play a role in the advancement of the Geosciences, increasing the public awareness as to the value of the Earth Sciences, and promoting of scientific awareness and education. Each of us is responsible to maintain high professional standards throughout our careers. I challenge each of you to continue in the fine tradition of the AEG and to advance the application of geochemistry and, in this process, help AEG provide a solid forum from which to exchange ideas and communicate advancements.

On behalf of the AEG, I would like to express our appreciation and thanks to those on the Symposium organizing committee. They have given much of their time and energies over the last year to making this a successful event.

Enjoy the Symposium and the offerings of our host city - Vancouver.

Erick F. Weiland
President - The Association of Exploration Geochemists

Message from the Chairman IGES Organising Committee

Welcome to Vancouver, and the 19th International Geochemical Exploration Symposium. This is the last international meeting in the 20th Century for geoscientists with an interest in applied geochemistry. The last 50 years has seen the science of Applied Geochemistry in mineral exploration begin with the systematic application of weak chemical extractions based upon colorimetric analysis, proceed through the introduction of instrumental analysis for base and precious metals, then the generation of multi-element analysis and subsequent computer assisted data interpretation. Primary and secondary element dispersion processes in rocks and in the near surface environments were studied and are considered to be reasonably well understood.

We are entering the 21st Century, and many of the areas currently being explored are covered by overburden or barren rock. The analytical techniques being suggested for use in these covered areas are similar to those first used by the early geochemists like Harry Warren, to whose memory this Symposium is dedicated. However, the possible dispersion processes that could give rise to interpretable elemental patterns are not at all understood. In effect, the geochemical community is back to where it started. This is the challenge of the 21st Century: how to detect economic concentrations of minerals in difficult environments.

The Technical Committee of the IGES was blessed with the difficult task of selecting 50 oral presentations from over 150 submitted abstracts. The quality and diversity of this technical program reflects the challenges of the 21st Century. We sincerely hope you enjoy the program, and the opportunities to meet with your colleagues in our beautiful city.

Barry W. Smee
Chairman, 19th IGES

Acknowledgements

Grateful acknowledgement is made by The Association of Exploration Geochemists to the members of the Organising Committee and their respective employers for the use of their time and facilities,to those organizations who made financial and in-kind contributions and to all those individuals who gave so freely of their time and assistance.

List of Sponsors

The Association of Exploration of Geochemists thanks the following organizations for their support of the 19th International Geochemical Exploration Symposium.

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Symposium Program

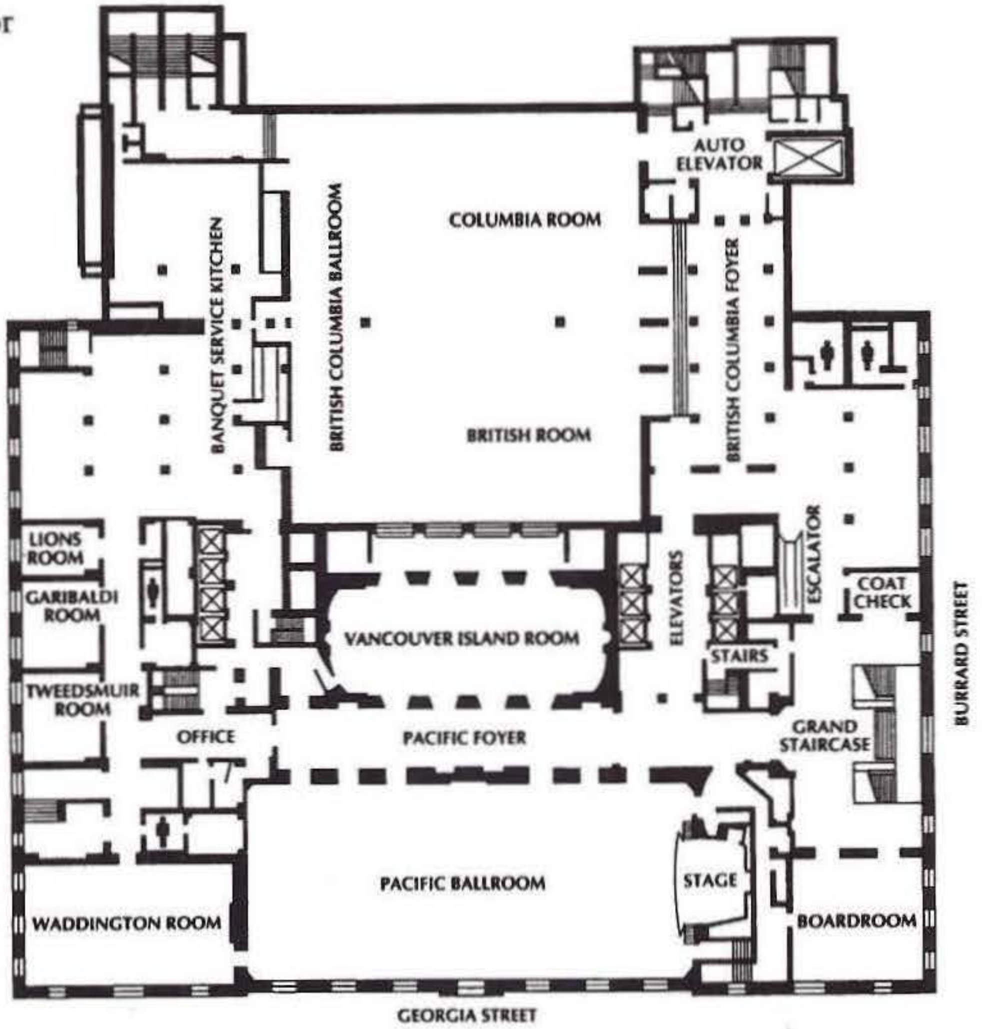
Saturday, April 10		Sunday, April 11		Monday, April 12	Tuesday, April 13	Thursday, April 15	Friday, April 16	Saturday, April 1
Short Course 1 8:15 - 5:00 Waddington Room Drift Prospecting Glacial Terrain	Short Course 2 8:30 - 5:30 Board Room Geo-Analysis with emphasis on Selective Extractions	Short Course 3 8:00 - 6:00 Board Room Diamond Exploration Methods	Short Course 4 8:30 - 5:00 Waddington Room Quality Control in Mineral Exploration	9:00 - 10:00 Columbia Room Opening Ceremonies Keynote Address	8:45 - 10:00 Columbia Room Session 3 Exploration for Buried Deposits II	8:45 - 10:00 Columbia Room Session 5 Advances in Drainage Geochemistry	8:45 - 12:05 Columbia Room Session 7 Presentation and Interpretation of Geochemical Data	Field Trips Depart
				Coffee	Coffee	Coffee	Coffee	
				10:25 - 12:05 Session 1 Exploration in Tropical Terrain	10:25 - 12:05 Session 3	10:25 - 12:05 Session 5	10:25 - 12:05 Session 7	
Lunch	Lunch	Lunch	Lunch	Lunch Complimentary	Lunch	Lunch Ticket	Lunch	
Waddington Room Drift Prospecting in Glacial Terrain	Board Room Geo-Analysis with Emphasis on Selective Extractions	Board Room Diamond Exploration Methods	Waddington Room Quality Control in Mineral Exploration	1:30 - 2:45 Session 2 Exploration for Buried Deposits I	1:30 - 2:45 Session 4 Lithogeochemistry	1:30 - 2:45 Session 6 Exploration in Glaciated Terrain	1:30 - 2:45 Session 8 Environmental Geochemistry	
				Coffee	Coffee	Coffee	Coffee	
				3:15 - 4:55 Session 2	3:15 - 4:30 Session 4	3:15 - 4:30 Session 6	3:15 - 4:30 Session 8	

Symposium Registration, Poster Sessions and Social Events

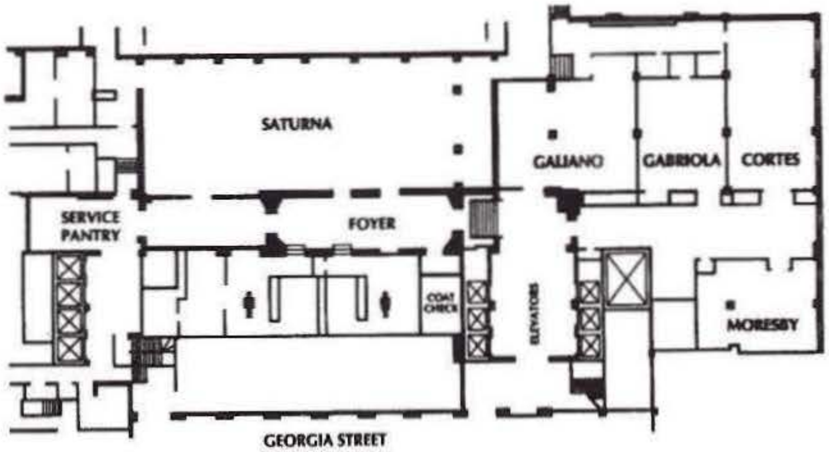
Saturday, April 10	Sunday, April 11	Monday, April 12	Tuesday, April 13	Wednesday, April 14	Thursday, April 15	Friday, April 16
SYMPOSIUM REGISTRATION						
8:00am - noon	7:00pm - 9:00pm	8:00am - 5:00pm	8:00am - 5:00pm	no registration	8:00am - 5:00pm	8:00am - noon
		Poster Session A and Exhibits			Poster Session B and Exhibits	
		British Room 9:00am - 6:00pm Advances in Drainage Geochemistry Exploration in Glaciated Terrain Presentation and Interpretation of Geochemical Data Environmental Geochemistry		Mid-Symposium Break Meet Friends and Enjoy the local scenery	British Room 9:00am - 6:00pm Exploration in Tropical Terrain Exploration for Buried Deposits Lithogeochemistry	
Social Events						
	Welcoming Reception 6:00pm British Room Complimentary	Lunch 12:00 - 1:30 Saturna Room Complimentary	Annual General Meeting 6:00pm Association of Exploration Geochemists Columbia Room		Lunch 12:00 - 1:30 Pacific Ballroom $40Can / $28US Banquet 6:00pm Pacific Ballroom $85Can / $60US	

Hotel Vancouver

Conference Floor



Discovery Floor



General Information

Annual General Meeting

The 1999 Annual General Meeting of The Association of Exploration Geochemists will be held at 6:00pm on Tuesday, April 13th in the Columbia Room.
Members and Fellows are urged to attend to participate in planning the future of AEG.

Optional Tours - See the registration staff for further details.

SUNDAY, APRIL 11, 1999

VW1	CANCELLED

WEDNESDAY, APRIL 14, 1999

VW2	CANCELLED
VW3	CANCELLED
VW4	Victoria Excursion (7:30am - 7:30pm approx. 12hrs)
VW5	CANCELLED

Field Trips - April 17 - 20, 1999

FT1	Applied Geochemical Methods - Okanagan (Depart 8:00am Hotel Vancouver) Leaders: Peter Bobrowsky and Stephen Cook from BC Geological Survey and Mike Cathro, BC Mines Branch.
FT2	CANCELLED
FT3	Nevada Applied Geochemical Methods Field Trip (Departs Vancouver for Airport at 5:15am)

All participants must pre-arrange passports, visas, birth certificates and customs entry papers as required for their respective countries of origin in order to clear US customs at the Vancouver International Airport.
Note for ALL FIELD TRIPS: Access to sites will be dependent upon weather conditions. Participants should be prepared for short hikes in a variety of weather conditions; bring appropriate clothing and footwear.

These field trips are intended to complement short course and technical session themes by providing applied demonstration of methods and interpretation

Check with registration staff for changes.

Social Program

Welcome Reception - British Room (7:00pm - 9:00pm) Sunday, April 11, 1999

A special welcome to Vancouver is arranged featuring entertainment and a variety of foods from the Pacific Northwest. This event offers delegates and accompanying persons the chance to relax and mingle with friends and colleagues, an evening long to be remembered.

Symposium Banquet - Pacific Ballroom Thursday, April 15, 1999 • $85 CDN / $60 US

Be sure not to miss this exciting event showcasing the finest in Westcoast cuisine and entertainment.

Exhibit Information

The conference exhibition will be located in the British Room of the Hotel Vancouver. We encourage all delegates to visit the exhibits and aquaint themselves with the latest developments in the field.

EXHIBIT HOURS

Sunday, April 11	7:00pm - 9:00pm (Opening Reception)
Monday, April 12	9:00am - 6:00pm
Tuesday, April 13	9:00am - 6:00pm
Thursday, April 15	9:00am - 6:00pm
Friday, April 16	9:00am - 6:00pm

Oral Presentations

Technical Program
Monday, April 12th
British Columbia Room

9:00am OPENING CEREMONIES AND GUEST ADDRESS

Barry W. Smee Chairman, 19th IGES Organising Committee
will introduce
Colin Dunn, A Tribute to Harry Warren
Erick F. Weiland, President, The Association of Exploration Geochemists
Bruce K. McKnight, Executive Director, B.C. and Yukon Chamber of Mines.

GUEST ADDRESS

Dr. David W. Strangway
B.A., M.A., Ph.D., P.Eng.,D.Sc., LL.D., D.Litt.S., F.R.A.S., F.R.S.C., O.C.
President and CEO, Canada Foundation for Innovation
Canada - An Innovative Society?

10:00am ***Coffee Break***

SESSION 1 • EXPLORATION IN TROPICAL TERRAIN
Chairmen: David Garnett, Bequerel Laboratories Inc, Menai, NSW, Australia
Marcondes Lima da Costa, Universidade Federal do Para. Belem, Brasil

10:25am THE RELATIONSHIP BETWEEN TRANSPORTED OVERBURDEN AND DISPERSION FROM BURIED GOLD DEPOSITS - CASE HISTORIES FROM THE YILGARN CRATON OF WESTERN AUSTRALIA.
R.R.Anand, M.Dell, J.Madden, S.Varga, R.Ward, J.E.Wildman and A.Williamson.
L.E.M.E. - C.S.I.R.O., Wembley, Western Australia.

10:50am SYSTEMATIC REGIONAL REGOLITH AND REGOLITH GEOCHEMICAL MAPPING IN WESTERN AUSTRALIA: APPLICATION TO EXPLORATION IN POORLY EXPOSED TERRAIN.
Paul A. Morris. Geochemistry Section, Geological Survey of Western Australia. East Perth, Western Australia, Australia.

11:15am MINERALOGICAL AND GEOCHEMICAL ANALYSIS OF CATHEDRAL TERMITARIA APPLIED TO GOLD EXPLORATION IN THE ROANDJI ALLUVIAL GOLD FIELDS,BANDAS GREENSTONE BELT, CENTRAL AFRICAN REPUBLIC.
M.A.Bernier[1], M.W.Milner[2] and T.G.Myles[3]
[1] Asquith Resources Inc.Toronto,Canada.,[2] M.W.M. Consultant,[3] Faculty of Forestry,University of Toronto.

11:40am MIGRATION PROCESSES OF SOLUBLE AND COLLOIDAL GOLD IN A MINERALISED CATCHMENT OF AMAZONIA
Ph. Freyssinet[1], B. Romand[1], C. Greffie[1], C. Crouzet[1] and J.S. Disnar[2]
[1] B.R.G.M., BP6009, 45060 Orléans, France.
[2] C.N.R.S., UMR6531, 45067 Orléans, France.

12:05pm ***Lunch Break: Complimentary, Saturna Room***

POSTERS

Posters related to Sessions 1 to 4 will be presented in the British Room on Thursday 15th and Friday 16th of April between 9:00am and 6:00pm.

Technical Program
Monday, April 12th
British Columbia Room

SESSION 2 • EXPLORATION FOR BURIED DEPOSITS I

Chairmen: J.Alan Coope, Consultant, Tucson, AZ., USA
William B.Coker, BHP Minerals Discovery Technology, Golden, CO., USA

1:30pm THE GOORNONG SOUTH GOLD DEPOSIT AND ITS IMPLICATIONS FOR EXPLORATION BENEATH COVER IN CENTRAL VICTORIA, AUSTRALIA.
K.M.Scott[1], and B. van Riel[2]
[1] L.E,M.E. - C.S.I.R.O., North Ryde, New South Wales, Australia
[2] Perseverance Mining Corporation, Fosterville, Victoria, Australia.

1:55pm THE NATURE AND DISTRIBUTION OF REGOLITH CARBONATES IN S.E. AUSTRALIA AND THEIR POTENTIAL AS A SAMPLING MEDIUM IN GEOCHEMICAL EXPLORATION.
K.G.M.McQueen, S.M.Hill and K.Foster.
L.E.M.E. Faculty of Applied Science, University of Canberra, A.C.T., Australia.

2:20pm THE APPLICABILITY OF PARTIAL EXTRACTIONS TO MINERAL EXPLORATION IN AREAS OF TRANSPORTED OVERBURDEN
D.M.Seneshen[1], R.A.Alcock[2] Ian Nichol[3]
[1] Western Mining Corporation, Englewood, Colorado, U.S.A.
[2] Canadian Mining Industry Research Organisation(CAMIRO), Toronto, Ontario, Canada.
[3] Professor Emeritus, Queen's University, Kingston, Ontario Canada.

2:45pm *Coffee Break*

3:15pm USE OF PARTIAL EXTRACTION FOR EXPLORATION IN AREAS OF TRANSPORTED COVER,YILGARN CRATON, WESTERN AUSTRALIA
D.J.Gray,J.E.Wildman and G.D.Longman.
L.E.M.E. - C.S.I.R.O. Wembley ,Western Australia.

3:40pm GEOCHEMICAL PATTERNS FROM VARIOUS EXTRACTION METHODS IN RESIDUAL AND TRANSPORTED REGOLITH IN THE COBAR REGION, NEW SOUTH WALES, AUSTRALIA.
X.C.Shen, D.R.Cohen and A.C.Dunlop.
School of Geology, University of New South Wales, Sydney, Australia.

4:05pm SELECTIVE LEACH GEOCHEMICAL PATTERNS OVER OUTCROPPING AND CONCEALED GOLD MINERLALISATION IN THE RATATOTOK DISTRICT, NORTH SULUWESI, INDONESIA.
Todd Wakefield, Newmont Minahasa Raya, Elko, Nevada, U.S.A.

4:30pm FIELD DATA IN SUPPORT OF AN ELECTROCHEMICAL TRANSPORT MECHANISM IN THE FORMATION OF SELECTIVE LEACH GEOCHEMICAL ANOMALIES.
S.M.Hamilton[1], A.F.Bajc[1], and M.B.McClenaghan[2]
[1] Ontario Geological Survey, [2] Geological Survey of Canada

POSTERS

Posters related to Sessions 1 to 4 will be presented in the British Room on Thursday 15th and Friday 16th of April between 9:00am and 6:00pm.

Technical Program
Tuesday, April 13th
British Columbia Room

SESSION 3 • EXPLORATION FOR BURIED DEPOSITS II

Chairmen: Peter Bradshaw, First Point Minerals Corporation,Vancouver,Canada.
Paul Taufen, Western Mining Corporation, Englewood, CO., USA.

8:45am NEW CONCEPTS,NEW TECHNOLOGY AND NEW STRATEGY IN MINERAL EXPLORATION.
Xie Xuejing, Institute of Geophysical and Geochemical Exploration, Langfang. Hebei, China.

9:10am NEW AG-CU DISCOVERY USING MERCURY VAPOR SOIL GAS DATA, COBRIZOS, SAN CRISTOBAL, SOUTHERN BOLIVIA.
Catrin Ellis Jones[1], Patty Rehn[2] and Warren Rehn[2]
[1]A.S.C. Bolivia LDC, La Paz, Bolivia, [2]Quicksilver Systems, Bend, Oregon, USA

9:35am GEOCHEMICAL EXPLORATION FOR CONCEALED DEPOSITS IN ALLUVIAL TERRAINS, ANHUI, EASTERN CHINA.
Cheng Zhizhong[1], Wang Xeuqiu[1],Liu Dawen,[1] and Zhou Quanxing.[2]
[1] Institute of Geophysical and Geochemical Exploration,Langfang,Hebei,China
[2] Anhui Bureau of Geology, Hefei, Anhui, China.

10:00am *Coffee Break*

10:25am SOIL GAS GEOCHEMICAL ORIENTATION STUDIES FOR MINERAL EXPLORATION THROUGH DEEP EXOTIC OVERBURDEN.
R.Patrick Highsmith[1,4] L.Graham Closs[2], Jeffrey A.Jaacks[1] and Ronald R Klusman[3]
[1] BHP World Minerals, Golden,Colorado,USA
[2] Colorado School of Mines,Department of Geology and Geological Engineering, Golden, Colorado,USA
[3] Colorado School of Mines, Department of Chemistry and Geochemistry, Golden, Colorado, USA.
[4] currently Chemex Labs Ltd.,Reno, Nevada, USA.

10:50am THE SPENCE PORPHYRY COPPER DEPOSIT: A COMPARISON OF EXPLORATION TECHNIQUES APPLIED.
Siegfried O. Weidner, Rio Algom Exploration Ltd, Vancouver, Canada.

11:15am PROSPECTION BENEATH COLLUVIAL-ALLUVIAL COVER AT QUASAR AND HARMONY IN THE CENTRAL PART OF WESTERN AUSTRALIA: THE VALUE OF INTERFACE SAMPLING.
I.D.M. Robertson, L.E.M.E. C.S.I.R.O., Wembley, Western Australia.

11:40am SURFACE WATER GEOCHEMISTRY: A METHOD TO DETECT BLIND MINERALISATION IN AREAS OF THICK OVERBURDEN.
Robert G.Jackson, Newmont Gold Company, Carlin, Nevada, USA.

12:05pm *Lunch Break*

POSTERS

Posters related to Sessions 1 to 4 will be presented in the British Room on Thursday 15th and Friday 16th of April between 9:00am and 6:00pm.

Technical Program
Tuesday, April 13th
British Columbia Room

SESSION 4 • LITHOGEOCHEMISTRY

Chairman: Ian Nichol, Queens University, Kingston, Ontario, Canada.
Graham Closs, Colorado School of Mines, CO, USA

1:30pm QUANTITATIVE ANALYSIS OF HYDROTHERMAL ALTERATION: APPLICATIONS IN MINERAL EXPLORATION.
Hans E. Madeisky, HEMAC Exploration Ltd. Vancouver, Canada.

1:55pm ELEMENT RATIOS IN NICKEL SULPHIDE EXPLORATION: VECTORING TOWARDS ORE ENVIRONMENTS.
Nigel W. Brand, WMC Leinster Nickel Operations, Leinster, Western Australia.

2:20pm BACKGROUND GEOCHEMICAL NOISE REMOVAL IN THE ALDRIDGE AND PRITCHARD FORMATIONS, BRITISH COLUMBIA, MONTANA AND IDAHO: RECOGNITION OF SUBTLE ALTERATION ABOUT SEDIMENT HOSTED MASSIVE SULPHIDE DEPOSITS.
Clifford R. Stanley, Acadia University, Wolfville, Nova Scotia, Canada.

2:45pm *Coffee Break*

3:15pm HYDROTHERMAL WALLROCK ALTERATION AS AN EXPLORATION TOOL FOR SLATE BELT HOSTED GOLD MINERALISATION.
Frank P Bierlien, Dennis C. Arne and Stafford McKnight.
Minerals Industry Research Institute, University of Ballarat, Victoria, Australia.

3:40pm THE USE OF LITHOGEOCHEMISTRY AS A GUIDE TO EXPLORATION AT THE EL INDIO GOLD - COPPER MINE, NORTH CENTRAL CHILE.
A.C.Tessier[1], D.R.Heberlein[2], S. Cordova[2] and X. Prieto[2]
[1] Consulting Geologist, Kingston, Ontario, Canada.
[2] Barrick Chile Ltda., Coquimbo, Chile[2]

4:05pm LITHOGEOCHEMICAL CONSTRAINTS ON HYDROTHERMAL ALTERATION AND MINERALISATION AT THE BIG BELL MESOTHERMAL GOLD DEPOSIT, YILGARN CRATON, W.AUSTRALIA.
Clifford R.Stanley[1] and Nigel W. Radford[2]
[1] Department of Geology, Acadia University, Wolfville, Nova Scotia, Canada.
[2] Normandy Mining Ltd, West Perth, Western Austalia.

POSTERS

Posters related to Sessions 1 to 4 will be presented in the British Room on Thursday 15th and Friday 16th of April between 9:00am and 6:00pm.

Technical Program
Thursday, April 15th
British Columbia Room

SESSION 5 • ADVANCES IN DRAINAGE GEOCHEMISTRY

Chairmen: Jane Plant, British Geological Survey, Keyworth, Notts, UK
Philippe Freyssinet, B.R.G.M., Orleans, France.

8:45am ACCUMULATION OF MINERALS AND GOLD BY MOSS MATS.
S.J.Sibbick[1], W.Jackaman[2] and K. Laurus[1]
[1] Norecol, Dames and Moore, Vancouver, BC.
[2] British Columbia Geological Survey, Victoria, BC, Canada

9:10am DISTRIBUTION AND DISPERSION OF MOLYBDENUM IN LAKE SEDIMENTS ADJACENT TO PORPHYRY MOLYBDENUM DEPOSITS CENTRAL BRITISH COLUMBIA.
Stephen J. Cook, British Columbia Geological Survey, Victoria, BC, Canada

9:35am REGIONAL MULTIELEMENT DRAINAGE GEOCHEMISTRY IN THE HIMALAYAN MOUNTAINS, NORTHERN PAKISTAN.
Richard H. Mazzucchelli[1] and Rohan Halfpenny[2]
[1] Searchtech Pty. Ltd, Perth, Western Australia
[2] Minorco Services BV, Budapest,Hungary

10:00am *Coffee Break*

10:25am INVESTIGATION OF THE EFFECTS OF WATERSHED DISTURBANCE ON HEAVY MINERAL - GEOCHEMICAL SIGNATURES IN TROPICAL STREAMS: IMPLICATIONS FOR MINERAL EXPLORATION SURVEYS
W.K. Fletcher[1] and Joanes Muda[2]
[1] Earth and Ocean Sciences, University of British Columbia, Vancouver, B.C., Canada
[2] Geological Survey Malasia, Kota Kinabalu, Sabah, Malasia

10:50am GOLD DISPERSION IN STREAM SEDIMENTS UNDER SEMI ARID CONDITIONS, NORTH EAST OF BRAZIL.
Germano Melo Jr.[1] and W.K.Fletcher[2]
[1] Geology Dept.Federal University at Rio Grande do Norte State, Natal, RN, Brazil.
[2] Earth and Ocean Sciences, University of British Columbia, Vancouver, Canada

11:15am A COMPARISON OF VEGETATION AND STREAM SEDIMENT GEOCHEMISTRY IN NORTH EASTERN NEW SOUTH WALES, AUSTRALIA
D.R.Cohen[1], C.M.Silva-Santisteban[1], N.F.Rutherford[2], D.L.Garnett[3] and H.M.Waldron[3]
[1] School of Geology, University of New South Wales, Sydney, Australia
[2] Rutherford Mineral Resource Consultants, Coogee, NSW, Australia.
[3] Bequerel Laboratories Pty, Menai, NSW, Australia.

11:40am COMPARISON OF GEOCHEMICAL PATTERNS IN TILL AND LAKE SEDIMENT SURVEYS, CENTRAL NEWFOUNDLAND.
M.J.Batterson, P.H.Davenport, D.G.E.Liverman and L.W.Nolan.
Newfoundland Department of Mines and Energy, St. Johnís,Canada.

12:05pm *Lunch Break: Ticketed, Pacific Ballroom*

POSTERS

Posters related to Sessions 5 to 8 will be presented in the British Room on Monday 12th and Tuesday 13th of April between 9:00am and 6:00pm.

Technical Program
Thursday, April 15th
British Columbia Room

SESSION 6 • EXPLORATION IN GLACIATED TERRAIN

Chairmen: C.F.Gleeson, Gleeson and Associates, Iroquois, Ontario, Canada.
C.E.Dunn, Geological Survey of Canada(Emeritus), Ottawa, Canada.

1:30pm A QUATERNARY GEOLOGICAL ANALYSIS OF TILL GEOCHEMISTRY IN LABRADOR AND EASTERN QUEBEC, CANADA.
Rodney A.Klassen, Geological Survey of Canada, Ottawa, Ontario, Canada.

1:55pm RESOLVING THE EFFECTS OF DILUTION BY EXOTIC DEBRIS ON THE GEOCHEMICAL SIGNATURE OF TILLS OVERLYING THE MACQUOID GREENSTONE BELT, NUNAVUT, CANADA.
Penny Henderson, Terrain Sciences Division, G.S.C. Ottawa, Ontario, Canada.

2:20pm THE APPLICATION OF TILL GEOCHEMISTRY TO MINERAL EXPLORATION IN NORTHERN SASKATCHEWAN, CANADA.
J.E.Campbell[1], D.H.Quirt[1] and M.J.Millard[2]
[1] Saskatchewan Research Council, Saskatoon, Saskatchewan, Canada.
[2] #101-1001, West Broadway, Vancouver, BC, Canada.

2:45pm *Coffee Break*

3:15pm GOLD DISTRIBUTION IN GLACIAL SEDIMENTS AND SOILS AT BOSTON PROPERTY, NWT, CANADA.
Kathryn A. Laurus[1] and W.K.Fletcher[2]
[1] 206 - 3212 Blueberry Drive, Whistler, BC, Canada.
[2] University of British Columbia, Vancouver, BC, Canada.

3:40pm THE INFLUENCE OF GLACIAL FLOW REVERSALS ON GEOCHEMICAL DISPERSAL IN THE CENTRAL CANADIAN CORDILLERA.
Victor M. Levson[1], Andrew Stumpf[2] and Bruce Broster[2]
[1] British Columbia Geological Survey, Victoria, BC, Canada.
[2] Dept. of Geology, University of New Brunswick, Fredericton, NB, Canada.

4:05pm DRIFT PROSPECTING IN THE VICINITY OF THE RESTIGOUCHE VMS DEPOSIT, BATHURST MINING CAMP: AN EXTECH II CASE STUDY.
Michael A. Parkhill[1] and André Doiron[2]
New Brunswick Dept. of Natural Resources and Energy, Bathurst, NB, Canada

SYMPOSIUM BANQUET

The Symposium Banquet will be held in the Pacific Ballroom beginning at 6:00pm. Guests will be able to enjoy the finest in Westcoast dining and entertainment.In a brief ceremony The Association of Exploration Geochemists will present its Gold and Past President medals to Robert Boyle and John Hansuld.

POSTERS

Posters related to Sessions 5 to 8 will be presented in the British Room on Monday 12th and Tuesday 13th of April between 9:00am and 6:00pm.

Technical Program
Friday, April 16th
British Columbia Room

SESSION 7 • PRESENTATION AND INTERPRETATION OF GEOCHEMICAL DATA

Chairmen: Robert G. Garrett, Geological Survey of Canada, Ottawa, Canada.
Owen Lavin, Newmont Exploration Ltd., Englewood, CO., USA.

8:45am MULTI-MEDIA COMPARISON OF GEOCHEMICAL DATA FOR MINERAL EXPLORATION: PART I-VARIATIONS DUE TO PRECISION, ANALYTICAL METHOD AND SIZE FRACTION
J.R.Harris[1], L.Wilkinson[1] and M.Bernier[2]
[1] Geological Survey of Canada, Ottawa, Ontario, Canada.
[2] Asquith Resources Ltd, Toronto, Ontario, Canada.

9:10am INTERPRETATION AND PRESENTATION OF QUALITY ASSURANCE - QUALITY CONTROL DUPLICATES.
Scott D. Long, Mineral Resources Development, San Mateo, California, USA.

9:35am APPLIED EXPLORATION GEOCHEMISTRY: CAMPO MORADO PRECIOUS METAL BEARING VOLCANOGENIC MASSIVE SULPHIDE BEARING DISTRICT, GUERRERO, MEXICO.
Mark Rebagliati, Farallon Resources Ltd, Vancouver, Canada.

10:00am *Coffee Break*

10:25am THE DIFERENTIATION OF SAMPLE MEDIA TYPES AND MINERALISATION FROM MULTI-ELEMENT GEOCHEMISTRY USING MULTI-VARIATE METHODS AND DIGITAL TOPOGRAPHY.
E.C.Grunsky[1], B.W.Smee[2] and L.D.Andriashek[1]
[1] Alberta Geological Survey, Edmonton, Alberta, Canada.[1]
[2] Smee and Associates Consulting, Sooke, BC, Canada.[2]

10:50am GOLD EXPLORATION USING KNOWLEDGE BASED PROSPECTIVITY ANALYSIS OF MULTIVARIATE DATA.
A.G.Gunn and K.E.Rollin.
British Geological Survey, Keyworth, Nottingham, UK.

11:15am AN UNSUPERVISED NEURAL NETWORK APPROACH TO THE ANALYSIS OF MULTI-ELEMENT STREAM SEDIMENT DATA, NORTHEASTERN NEW SOUTH WALES, AUSTRALIA.
A.P.Clare[1] and D.R.Cohen[2]
[1] Neural Mining Solutions, Sydney, New South Wales, Australia.
[2] School of Geology,University of New South Wales. Sydney, Australia.

11:40am REGIONAL GEOCHEMICAL GOLD ANOMALY SORTING AND EVALUATION IN INNER MONGOLIA, CHINA.
Changyi Shi and Jinhua Zhang.
Institute of Geophysical and Geochemical Exploration, Langfang, China.

12:05pm *Lunch Break*

POSTERS

Posters related to Sessions 5 to 8 will be presented in the British Room on Monday 12th and Tuesday 13th of April between 9:00am and 6:00pm.

Technical Program
Friday, April 16th
British Columbia Room

SESSION 8 • ENVIRONMENTAL GEOCHEMISTRY

Chairmen: Gwendy E. M. Hall, Geological Survey of Canada, Ottawa, Canada.
Steve Day, Steffen, Robertson and Kirsten, Vancouver, B.C., Canada.

1:30pm POTENTIAL NATURAL GEOCHEMICAL HAZARDS IN CANADA.
R.N.W.DiLabio, B.W.Charbonneau, R.G.Garrett, I.M.Kettles, R.A.Klassen,
M.B.McClenaghan, A.Plouffe and P.E.Rasmussen
Geological Survey of Canada, Ottawa, Ontario, Canada.

1:55pm THE ASSESSMENT OF SOIL HEAVY METAL CONTAMINATION AROUND AN ANCIENT MINING DISTRICT: NATURAL BACKGROUND OR AN ANTHROPOGENIC ANOMALY?
Anne Korre and Sevket Durucan.
T.H.Huxley School of Environment,Earth Sciences and Engineering,
Imperial College of Science Technology and Medicine, London, UK.

2:20pm GEOCHEMICAL EVOLUTION OF WATER QUALITY IN A MINE PIT LAKE AND POTENTIAL OPTIONS FOR IN-SITU CONTROLS.
J.Barta[1], R.J.Bowell[2], M.Gingrich[1], W.Marsanares[1], and J.Seher[3]
[1] Getchell Gold Company, Golconda, Nevada, USA.
[2] Steffen,Robertson and Kirsten(UK) Ltd, Cardiff, Wales
[3] Sierra Environmental Monitoring,Reno, Nevada, USA.

2:45pm *Coffee Break*

3:15pm ENVIRONMENTAL IMPACT FROM OLD MINING SITES ON THE MEXICAN ALTIPLANO: ARSENIC AND HEAVY METALS, A COMPARISON.
J. Castro-Larragoitia[1], U.Kramar[2], F. Vierra-D.[1] and M. Hernandés-P[1]
[1] Fac.Ciencias de la Tierra, UANL, Linares, NL, Mexico.
[2] Institut für Petrographie und Geochemie, Universitat Karlsruhr, Germany.

3:40pm MERCURY IN HUMUS,B-HORIZON AND GLACIAL SEDIMENTS IN THE VICINITY OF TWO PAST PRODUCING MERCURY MINES, BRITISH COLUMBIA, CANADA.
Alain Plouffe
Geological Survey of Canada, Ottawa, Ontario,Canada.

4:05pm WASTE ROCK PILE CHARACTERISATION,HETEROGENEITY AND GEOCHEMICAL ANOMALIES IN THE HILLSBORO MINING DISTRICT, SIERRA COUNTY, NEW MEXICO.
Erick A. Munroe[1] and Virginia T. McLemore[2]
[1] Dept. of Earth and Environmental Sciences, New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA.
[2] New Mexico Bureau of Mines and Mineral Resources, Socorro, NM, USA.

CLOSING REMARKS
B.W. Smee, Chairman, Organising Committee, 19th IGES
Erick Weiland, President, The Association of Exploration Geochemists

POSTERS

Posters related to Sessions 5 to 8 will be presented in the British Room on Monday 12th and Tuesday 13th of April between 9:00am and 6:00pm.

Poster Session A

Monday, April 12th
Tuesday, April 13th
9:00am - 6:00pm
British Room

Advances in Drainage Geochemistry

Exploration in Glaciated Terrain

Presentation and Interpretation of Geochemical Data

Environmental Geochemistry

Poster Session A
Monday, April 12th & Tuesday, April 13th
British Room • 9:00am - 6:00pm

ADVANCES IN DRAINAGE GEOCHEMISTRY

A1 CONTAMINATION FROM FORESTRY ACTIVITIES : IMPLICATIONS FOR STREAM SEDIMENT EXPLORATION PROGRAMMES.
T.C.Christie and W.K.Fletcher.
Earth and Ocean Science, University of British Columbia, Vancouver, B.C.,Canada.

A2 GEOCHEMICAL PATTERNS IN SEDIMENTS FROM A GLACIAL STREAM IN THE KARAKORUM MOUNTAINS, PAKISTAN.
A.C.Dunlop, I.A.Malik and D.R.Cohen.
School of Geology, University of New South Wales, Sydney, Australia.

A3 THE EXPLORATION SIGNIFICANCE OF RARE EARTH ELEMENT ANOMALIES IN LAKE SEDIMENTS: CASE STUDIES FROM HIGH DENSITY GEOCHEMICAL SURVEYS OVER THE WINSTON LAKE CU-ZN AND HEMLO GOLD DEPOSITS.
Richard Dyer, Ontario Geological Survey, Sudbury, Ontario, Canada.

A4 COST EFFECTIVE PROTOCOLS FOR THE COLLECTION, FILTRATION AND PRESERVATION OF WATER SAMPLES COLLECTED IN HYDROGEOCHEMICAL SURVEYS.
Gwendy E.M.Hall, Geological Survey of Canada, Ottawa, Ontario, Canada

A5 EXPLORATION FOR SKARN HOSTED MINERALISATION IN NORTHWESTERN NEW BRUNSWICK: REGIONAL AND DEPOSIT SCALE GEOCHEMICAL SURVEYS.
Michael A. Parkhill[1], Peter W.B.Friske[2], Toon Pronk[3] and Marni Lynne Dickson[4].
[1] New Brunswick Department of Natural Resources and Energy, Bathurst, NB, Canada.
[2] Geological Survey of Canada, Ottawa, Ontario, Canada.
[3] New Brunswick Department of Natural Resources and Energy, Fredericton, NB, Canada
[4] University of New Brunswick, Department of Geology, Fredericton, NB, Canada.

A6 AN INTEGRATED GEOCHEMICAL AND AEROMAGNETIC INVESTIGATION OVER A GOLD PROSPECT SOUTH GREENLAND: A CASE STUDY.
Henrik Stendal[1] and Laila Grahl-Maddsen[2]
[1] Geological Institute, University of Copenhagen, Copenhagen, Denmark.
[2] Havenevej 21, Lundeborg, DK-5874 Hesselager, Denmark.

EXPLORATION IN GLACIATED TERRAIN

A7 EXPLORATION FOR GOLD AND MASSIVE SULPHIDE DEPOSITS IN SOUTH CENTRAL BRITISH COLUMBIA USING INTEGRATED TILL SAMPLING AND SURFICIAL MAPPING.
A.Dixon-Warren, P.Bobrowsky and R.Lett.
B.C. Ministry of Energy and Mines, Victoria, British Columbia, Canada.

A8 APPLICATION OF COMPOSITE BOULDER LITHOGEOCHEMISTRY TO MINERAL EXPLORATION
Steven Earle[1] and Jim Murphy[2]
[1] Grasswood Geoscience Ltd., Nanaimo, BC, Canada
[2] Uranerz Exploration and Mining Ltd., Saskatoon, Saskatchewan, Canada

A9 MODELLING DOWN-ICE MOVEMENT OF ECONOMIC MINERAL INDICATORS IN QUATERNARY GEOCHEMICAL DATA USING A G.I.S.
J.R.Harris, L.Wilkinson and G.F.Bonham-Carter.
Geological Survey of Canada, Ottawa, Ontario, Canada.

A10 A COMPARISON OF REGIONAL GEOCHEMICAL SURVEYS OF TILL AND LAKE SEDIMENT, LABRADOR, CANADA.
R.A.Klassen, A.N.Rencz and A. Moore.
Geological Survey of Canada, Ottawa, Ontario, Canada.

A11 TILL PROVENANCE STUDIES IN THE MELIADINE TREND, RANKIN INLET AREA, NUNAVUT: IMPLICATIONS FOR GOLD EXPLORATION.
Isabelle McMartin, Geological Survey of Canada, Ottawa, Ontario, Canada.

A12 MINERALOGY AND GEOCHEMISTRY OF THE PEDDIE KIMBERLITE PIPE AND OVERLYING GLACIAL SEDIMENTS, NEW LISKEARD, ONTARIO, CANADA.
M.B. McClenaghan and B.A. Kjarsgaard
Geological Survey of Canada, Ottawa, Ontario, Canada

A13 UTILIZING TRACE ELEMENT AND WHOLE ROCK TILL GEOCHEMISTRY IN EXPLORATION FOR POLYMETALLIC MINERAL OCCURRENCES IN THE SOUTHERN INTERIOR OF BRITISH COLUMBIA.
Roger C. Paulen[1], Peter T. Bobrowsky[2] and Ray Lett[2].
[1] School of Earth and Ocean Sciences, University of Victoria, Victoria, BC, Canada.
[2]Geological Survey Branch, BC Ministry of Energy and Mines,Victoria, BC, Canada.

PRESENTATION AND INTERPRETATION OF GEOCHEMICAL DATA

A14 DISPLAYING STREAM SEDIMENT DATA AS WORM MAPS.
R.N.Carver, WMC Exploration Division, Belmont,Western Australia, Australia.

A15 INTEGRATED PRESENTATION AND INTERPRETATION OF GEOCHEMICAL DATA AND MULTIDISCIPLINARY INFORMATION: REGIONAL AND LOCAL SCALE APPROACHES.
H.Andrew Daniels[1], Tracy Minton,[2] and Greg. M. Hollyer[3]
[1] Minorco Services B.V., Budapest, Hungary.
[2] Geosoft Europe Ltd, Wallingford, Oxfordshire, UK.
[3] Geosoft Inc., Toronto, Ontario, Canada.

A16 DIGITAL GEOCHEMICAL ATLASES OF NEWFOUNDLAND AND LABRADOR.
P.H.Davenport[1], P.W.B.Friske[2], J.W.McConnell[1] and L.W.Nolan[1].
[1]Newfoundland Department of Mines and Energy, St. John's, NF, Canada.
[2]Geological Survey of Canada, Ottawa, Ontario, Canada.

A17 A COMPARISON OF MULTIMEDIA GEOCHEMICAL DATA USING G.I.S. TECHNOLOGY: IMPLICATIONS FOR MINERAL EXPLORATION.
J.R.Harris[1], A.N.Rencz[1], R.Klassen[1] and M.Bernier[2].
[1] Geological Survey of Canada, Ottawa, Ontario, Canada.
[2] Asquith Resources Inc., Toronto, Ontario, Canada.

A18 MULTIDIMENSIONAL STATISTICAL TECHNIQUE FOR DETECTION OF LOW CONTRAST GEOCHEMICAL ANOMALIES.
Mir Karger[1] and Sergey Sandomirsky[2]
[1] NPO Ecolandshaft, JSC, Moscow, Russia.
[2] Physical Optics Corp, Torrance, California, USA.

A19 PROSPECTING AND ECOLOGICAL STANDARDISATION OF BIOGEOCHEMICAL FIELDS.
A.L.Kovalevskii, Geological Institute, Siberian Branch, Russian Academy of Sciences, Ulan-Ude, Russia.

A20 PERSPECTIVITIES OF THE BIOGEOCHEMICAL EXPLORATION AND PROSPECTING FOR PRECIOUS METALS DEPOSITS.
A.L.Kovalevskii, Geological Institute, Siberian Branch, Russian Academy of Sciences, Ulan-Ude, Russia.

A21 ADVANCES IN G.I.S. TO EXAMINE AND INTEGRATE PUBLIC DOMAIN EXPLORATION GEOCHEMICAL DATA: THE EXAMPLE OF S.W.ENGLAND.
Charles J. Moon, Geology Department, University of Leicester, England.

A22 TECHNIQUE OF GEOCHEMICAL EXPLORATION AND RESOURCE APPRAISAL OF GOLD DEPOSITS IN KAMCHATKA.
Yu. N. Nikolaev and A.V.Apletalin.
MSU, Faculty of Geology, Moscow, Russia.

A23 G.I.S. PRESENTATION AND INTERPRETATION OF EPITHERMAL GOLD EXPLORATION DATA.
J.Carlos Sicoli Seoane,[1,2].
[1] Instituto de Geosciencias, Unicamp, Campinas, Sao Paulo, Brazil.
[2] Docegeo-CVRD, Santa Luzia, Minas Gerais, Brazil.

A24 GOLD ANOMALOUS CATCHMENT BASINS : A G.I.S. PRIORITISATION MODEL CONSIDERING DRAINAGE SINUOSITY.
J Carlos Sicoli-Seoane[1,2] and Ardemirio de Barros Silva[1].
[1] Instituto de Geosciencias, Unicamp, Campinas, Sao Paulo, Brazil.
[2] Docegeo-CVRD, Santa Luzia, Minas Gerais, Brazil.

A25 TOWARD A GEOCHEMICAL ATLAS OF WEST AND SOUTH GREENLAND : COMPILATION AND PRESENTATION OF RESULTS OBTAINED OVER A 20 YEAR PERIOD.
Agnete Steenfelt, Geological Survey of Denmark and Greenland, Copenhagen, Denmark.

A26 GOLD DISCOVERIES IN CHINA SINCE 1980.
Wang Xueqiu. (Presented by Cheng ZhiZhong)
Institute of Geophysical and Geochemical Exploration. Langfang, Hebei, China.

A27 SEARCHING FOR KIMBERLITE: EVALUATION OF TILL GEOCHEMISTRY IN THE LAC DE GRAS REGION, NORTHWEST TERRITORIES, USING G.I.S. SPATIAL ANALYSIS TOOLS.
L.Wilkinson[1], J.Harris[2] and B. Kjarsgaard[2].
[1 2] Geological Survey of Canada, Ottawa, Ontario, Canada.

ENVIRONMENTAL GEOCHEMISTRY

A28 ENVIRONMENTAL CONTAMINATION OF TOXIC ELEMENTS AROUND AN ABANDONNED Au ñ Ag MINE IN KOREA.
Joo Sung Ahn and Hyo-Taek Chon.
Seoul National University, Seoul, Korea.

A29 PHYTOMINING
C.W.M.Anderson[1], R.R.Brooks[1], A.Chiarucci[2], M.Leblanc[3], B.H.Robinson[4], R.Simcock[5] and R.B.Stewart[1]
[1]Massey University, Palmerston North, New Zealand. [2]Universita di Siena, Siena, Italy.
[3]Universite de Montpellier,Montpellier, France. [4]Horticultural and Food Research Institute,
Palmerston North, New Zealand. [5]Landcare Research,Massey University,Palmerston North,NZ.

A30 GEOCHEMICAL STUDY OF WASTES FROM A MERCURY MINE IN ASTURIAS, (NORTHERN SPAIN).
C.Baldo[1], J.Loredo[2], J.L.Rodrigues-Gallego[2] and J.Garcia-Iglesias[2]
[1] Facultad de Minas, Universidad National de la Rioja, Argentina.
[2] Escuela de Minas, Universidad de Oviedo, Espana.

A31 SURFICIAL GEOCHEMISTRY RELATED TO PAST MINING IN THE COOK CITY, MT, AREA AND ITS ENVIRONMENTAL IMPACT DOWNSTREAM IN YELLOWSTONE NATIONAL PARK.
Maurice A. Chaffee and William R. Miller.
U.S.Geological Survey, Federal Center, Denver, Colorado, USA

A32 HEAVY METAL CONTAMINATION IN THE VICINITY OF SOME BASE METAL MINES IN KOREA.
Hyo-Taek Chon1, Joo Sung Ahn1 and Myung Chae Jung2.
1 Seoul National University, Seoul, Korea. 2 Semyung University, Jecheon, Choongbuk, Korea.

A33 GEOCHEMICAL MAPPING IN GEORGIA: A TOOL FOR ENVIRONMENTAL STUDIES., GEOLOGIC MAPPING AND MINERAL EXPLORATION.
Mark D. Cocker.
Georgia Geologic Survey, Atlanta, Georgia, USA.

A34 DISTRIBUTION AND BEHAVIOUR OF SELECTED ELEMENTS IN SOIL OVER A HISTORICAL MINING SITE AT SV. JAKOB, CROATIA.
Goran Durn[1], Marta Covic[1], Uros Barudzija[1], Ksenija Namjesnik-Dejanovic[1], Slobodan Miko[2], Ladislav Palinkas[3]
[1] Faculty of Mining,Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia.
[2] Institute of Geology,Zagreb, Croatia. [3] Faculty of Natural Sciences,University of Zagreb,Croatia.

A35 STATE OF THE ART AND ENVIRONMENTAL HAZARD FROM MINING POLLUTION IN SOUTHERN IGLESIENTE (S.W.SARDINIA,ITALY.)
M.Gasparrini[1], M.Boni[1], S.Costabile[2] and B.De Vivo[2]
[1] Dipartimento di Scienze della Terra, Napoli, Italy.
[2] Dipartimento di Geofisica e Vulcanologia, Napoli, Italy

A36 AN EVALUATION OF THE ROLE OF ENVIROGEOCHEMISTRY IN PROPERTY AND CORPORATE TRANSACTIONS ASSOCIATED WITH THE MINERALS INDUSTRY IN ENGLAND AND WALES,UK.
Julian Kwoleck, 14 Sussex Square,Brighton,England.

A37 NATURAL ACID ROCK DRAINAGE IN THE GATAGA DISTRICT, B.C.; ENVIRONMENTAL AND MINERAL EXPLORATION IMPLICATIONS.
Ray Lett and Wayne Jackaman
B.C. Ministry of Energy and Mines, Victoria, B.C., Canada.

A38 DETAILED GEOCHEMICAL MAPPING (1: 25,000) IN PB-ZN MINING AND SMELTING REGION OF UPPER SILESIA,POLAND.
Josef Lis and Anna Pasieczna.
Polish Geological Institute, Dept. of Environmental Geology, Warsaw, Poland.

A39 TOPSOIL GEOCHEMISTRY AS A CONSEQUENCE OF ACID RAIN DEPOSITION AT AN ABRUPT CLIMATE BOUNDARY, THE CASE OF NATIONAL PARKîRISNJAKî,CROATIA
Slobodan Miko[1], Zoran Peh[1], Zeljko Kastmuller[1], Dragan Bukovec[2] and Oleg Antonic[3]
[1] Institute of Geology,Zagreb,Croatia. [2] Croatian Natural History Museum, Zagreb, Croatia.
[3] Institute Rudjer Boskovic, Zagreb, Croatia.

A40 EVALUATION OF GEOCHEMICAL POLLUTION OF THE ENVIRONMENT IN GOLD DISTRICTS OF KAMCHATKA.
Yu.N.Nikolaev[1], T.V. Shestakova[1], A.V.Apletalin[1], M.I.Zaltsman[1], D.A.Morozova[1] and E.G.Sidorov[2].
M.S.U.,Faculty of Geology, Moscow, Russia.

A41 REGIONAL GEOCHEMICAL MAPPING IN COPPER MINING AND SMELTING REGION OF LEGNICA PROVINCE (LOWER SILESIA ñ S.W. POLAND).
Anna Pasieczna and Josef Lis.
Polish Geological Institute, Dept. of Environmental Geology, Warsaw, Poland.

A42 MAGNETIC SUSCEPTIBILITY OF STREAM SEDIMENTS AS A MARKER OF ANTHROPOGENIC POLLUTION.
E.Petrovsky[1], A.Kapicka[1], V.Hoffmann[2], N. Jordanova[1], and M.Knab[2]
[1] Geophysical Institute, ASCR, Prague, Czech Republic.
[2] Inst. Geol. Paleontol.,University Teubingen, Teubingen, Germany.

A43 REMEDIATION OF ACID-SULPHATE RUNOFF USING A MODIFIED CONSTRUCTED WETLAND TECHNOLOGY: FIELD DEMONSTRATION FROM A COAL STORAGE PILE.
R.C.Thomas[1,2], C.S.Romanek[1,2], D.P.Coughlin[1] and D.E.Crowe[3]
[1] Department of Geology, University of Georgia, Aiken, South Carolina.
[2] Savannah River Ecology Laboratory, University of Georgia, Aiken, S.C.
[3] Department of Geology, University of Georgia, Athens, Georgia.

A44 PROBLEM OF TIME DEPENDENT TRANSFORMATIONS OF METAL SPECIATION IN SURFICIAL GEOCHEMICAL ENVIRONMENT.
Irena Twardowska[1], Joanna Kyziol[1], and Antonius F. Kettrup[2]
[1] Polish Academy of Sciences, Institute of Environmental Engineering, Zabrze, Poland.
[2] GSF-Institute of Ecological Chemistry, Oberschleissheim, Germany.

Poster Session B

Thursday, April 15th
Friday, April 16th
9:00am - 6:00pm
British Room

Exploration in Tropical Terrain

Exploration for Buried Deposits

Lithogeochemistry

Poster Session B
Thursday, April 15th & Friday, April 16th
British Room • 9:00am - 6:00pm

EXPLORATION IN TROPICAL TERRAIN

B1 EXPLORATION FOR P.G.E. IN THE ARABIAN SHIELD
Ahmad Al-Saleh[1], Jomaah Al-Alawi[1] and Michael Fleet[2]
[1] Geology Department, King Saud University, Riyadh, Saudi Arabia.
[2] Department of Earth Sciences, University of Western Ontario, London,Ontario,Canada.

B2 MINERALOGY AND GEOCHEMISTRY OF GOLD BEARING GOSSANS AND LATERITES FROM THE IGARAPÉ, BAHIA AND AGUAS CLARAS DEPOSITS, CARAJAS, BRAZIL
Romulo Simões Angélica[1], Marcondes Lima da Costa[1] and Herbert Pöllman[2]
[1] Centro de Geosciencias, Universidade Federal do Pará, Belém, Para, Brazil.
[2] Institute für Geologische Wissenschaft, Halle University, Halle, Germany.

B3 DRAINAGE AND COMPOSITE SURFACE LAG SAMPLING: AN EFFECTIVE DRAINAGE RECONNAISSANCE TOOL FOR GOLD IN LATERITIC TERRAINS IN NORTHERN COTE DíIVOIRE AND SOUTHERN BURKINA FASO.
R.N.Carver[1], M.F.Ouedraogo[2] and S.Diarra[3]
[1] WMC Exploration, Belmont, Western Australia, Australia.
[2] Resolute Limited, Ouagadougou, Burkina Faso.
[3] Resolute Limited, Korhogo,Cote Dí Ivoire.

B4 THE GEOCHEMICAL ASSOCIATION Au-As-B-W-(Cu)-Sn IN LATOSOL, COLLUVIUM, LATERITIC IRON CRUST AND GOSSAN IN CARAJAS, BRAZIL: ITS IMPORTANCE FOR IDENTIFICATION OF PRIMARY ORE.
Marcondes Lima da Costa[1], Romulo Simões Angélica[1] and Newton Cunha da Costa[2].
[1] Centro de Geosciencias, Universidade Federal do Pará, Belém, Pará, Brazil.
[2] Museo Paraense Emilio Goeldi, Belem, Pará, Brazil.

B5 REGOLITH MAPS AND MINERAL EXPLORATION.
Michael A. Craig.
(CRC.LEME), Australian Geological Survey Organisation, Canberra, Australia.

B6 SULPHIDE OXIDATION AND GOLD BEARING GOSSAN FORMATION AT SAO BARTOLOMEU, CENTRAL BRAZIL.
Sonia Maria Barros de Oliviera[1] and Nelson Marinho de Oliviera*
[1] Instituto de GeosciÍncias de Universidade de Sao Paulo, Sao Paulo, Brazil.
* In Memoriam.

B7 GENETIC RELATIONSHIP BETWEEN LATERITIC DURICRUST AND SOILS IN THE AMAZON REGION.
A.M.C.Horbe[1] and M.L. da Costa[2]
[1] Departamento de GeociÍncias, Universidade do Amazonas, Manaus, Brazil.
[2] Centro de Geosciências, Universidade Federal do Pará, Belém, Brazil.

B8 GEOCHEMICAL EXPLORATION FOR CARLIN TYPE GOLD DEPOSITS IN KARST TERRAIN, NORTHWESTERN GUANGXI, CHINA.
Liu Dawen[1], Wang Xueqiu[1], Zhou Yongfeng[2] and Cheng Zhizhong[1]
[1] Institute of Geophysical and Geochemical Exploration, Langfang, Hebei, China.
[2] Guangxi Bureau of Geology and Mineral Resources, Nanning, Guangxi, China.

B9 THE LAOWANCHANG "RED SOIL" REGOLITH HOSTED GOLD DEPOSIT,
GUIZHOU PROVINCE, CHINA.
K.G. McQueen[1], Jianquan Mao[2] and Taihe Zhou[1]
[1] CRC.LEME, Faculty of Applied Science, University of Canberra, ACY, Australia.
[2] Guizhou University of Technology, Caijiaguan, Guiyang City, Guizhou,China.

B10 BIOLOGICAL CONSTRAINTS ON MOUND BUILDING TERMITES IN GEOCHEMICAL
EXPLORATION: THE ROANDJI EXPERIENCE, CENTRAL AFRICAN REPUBLIC.
T.G. Myles[1], M.W.Milner[2] and M.A. Bernier[3]
[1] Faculty of Forestry, Earth Sciences Centre, University of Toronto, Toronto,Ont.,Canada.
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[3] Asquith Resources Inc. Toronto, Ontario, Canada.

B11 REGOLITH GEOCHEMICAL EXPLORATION USING ACID INSOLUBLE RESIDUES AS A SAMPLING
MEDIUM FOR GOLD AND BASE METAL DEPOSITS IN THE COBAR REGION,
NEW SOUTH WALES, AUSTRALIA.
Aung Pwa[1], K.G.McQueen[2], K.M.Scott[3] and J.C. van Moort[1]
[1] School of Earth Sciences, University of Tasmania, Hobart, Tasmania, Australia.
[2] CRC.LEME., Faculty of Science, University of Canberra, Canberra, ACT, Australia.
[3] CRC.LEME., CSIRO Exploration and Mining, North Ryde, N.S.W., Australia.

B12 BIOGEOCHEMISTRY OF THE BALLARAT EAST GOLDFIELD.
Jackie Stott[1,2], Dennis Arne[1] and Helen Waldron[3] (Presented by Frank P. Bierlein[1])
[1] Minerals Industry Research Institute, University of Ballarat, Victoria, Australia.
[2] Posgold Ltd., Tennant Creek, Northern Territory, Australia.
[3] Bequerel Laboratories, Menai, New South Wales, Australia.

B13 LATERITIC WEATHERING EFFECTS OVER BRAZILIAN PHOSPHATIC ORES:
CATALAO I AND JUQUIA, BRAZIL
M.C.M.Toledo[1], V.C.Ferrari[1], C.N.Santos[1], A.Alcover Neto[2], Ph. de Parseval[3], F. Fontan[3], C.C.Ribiero[4]
[1] Universidade de Sao Paulo,Brazil. [2] C.N.P.Q., Brazil.
[3] Université Paul Sabatier, France. [4] Ultrafértil, Brazil.

EXPLORATION FOR BURIED DEPOSITS

B14 EXPLORATION FOR BURIED DEPOSITS USING PARTIAL EXTRACTIONS:
THE NEVADA FIELD TRIP RESULTS.
S.B.Ballantyne[1] and D.G.Vanderkley[2]
[1] Consulting Geologist, Vancouver, BC, Canada.
[2] Cominco Ltd, Vancouver, BC, Canada.

B15 THE APPLICATION ON SHALLOW OVERBURDEN DRILLING TO EXPLORATION IN LATERITIC
ENVIRONMENTS: AN EXAMPLE FROM THE AGOUDU-MANGA GOLD PROJECT, BANDAS
GREENSTONE BELT, CENTRAL AFRICAN REPUBLIC.
M-A. Bernier[1] and M.W.Milner[2]
[1] Asquith Resources Inc. Toronto, Ontario, Canada.
[2] M.W.M. Consultant, Toronto, Ontario, Canada.

B16 EXPLORING AUSTRALIAN SEDIMENTARY BASINS FOR CONCEALED ORE DEPOSITS: THE CRC
LEME BASINS PROJECT.
P. de Caritat[1], D.Gibson[1], M.Killick[3], N.Lavitt[1,2], E.Papp[1,4] and E.Tonui[1,2].
Cooperative Research Centre for Landscape Evolution and Mineral Exploration and
[1] Australian Geological Survey Organisation, Canberra, ACT, Australia.
[2] University of Canberra, Canberra, ACT, Australia.
[3] CSIRO Exploration and Mining, Wembley, WA, Australia.
[4] Australian National University,Canberra, ACT, Australia.

B17 OXIDATION ANOMALIES - A PHENOMENON ASSOCIATED WITH DEEPLY BURIED REDUCED BODIES.
J. Robert Clark, Enzyme-ACTLABS, LLC, Arvada, Colorado, USA.

B18 COINCIDENT ENZYME LEACH℠ AND TELLURICS ANOMALIES ASSOCIATED WITH GAS RESEVOIRS AT 4500 METERS DEPTH, ROBERTSON COUNTY, TEXAS.
J.Robert Clark[1] and Reed Tompkins[2]
[1] Enzyme-ACTLABS,LLC, Arvada, Colorado,USA. [2] Pulse Resources, Spring, Texas, USA

B19 BRYOGEOCHEMICAL ORE PROSPECTING AT A BURIED TERRAIN IN YAKUTIA
G.P. Lapaev, Oktjabryska 10-55, Pereslavl-Zalessky, 152140 Russia.

B20 APPLICATION OF GROUND AND SURFACE WATER GEOCHEMISTRY IN MINERAL EXPLORATION IN THE BATHURST MINING CAMP, NEW BRUNSWICK, CANADA.
Matthew Leybourne, Dan Boyle and Wayne Goodfellow.
Geological Survey of Canada, Ottawa, Ontario, Canada.

B21 RELATIONSHIP BETWEEN MOBILE METAL ION (MMI) AND CONVENTIONAL (TOTAL DIGESTION) GEOCHEMISTRY.
A.W.Mann, R.D.Birrell and A.T.Mann.
Geochemistry Research Centre,Technology Park, Bentley, Western Australia, Australia.

B22 A NEW WEAK LEACH FOR GOLD EXPLORATION IN ARID ENVIRONMENTS.
S.C. Smith[1] and M.C. Newton III[2]
[1] Minerals Exploration and Environmental Geochemistry, Reno, Nevada, USA.
[2] Tectonex, Reno, Nevada, USA.

B23 MERCURY AS A RELIABLE INDICATOR OF CONCEALED MINERALISATION OR CONCEALED STRUCTURE ?.
Wei Jinsheng[1] and Xie Xuejing[2]
[1] Yongli Company of Ningbo China, Ningbo, Zhejiang, China.
[2] Institute of Geophysical and Geochemical Exploration, Langfang, Hebei, China.

LITHOGEOCHEMISTRY

B24 BEHAVIOUR OF RARE EARTH ELEMENTS DURING HYDROTHERMAL ALTERATION OF META TURBIDITES ASSOCIATED WITH MESOTHERMAL GOLD MINERALISATION IN CENTRAL VICTORIA, AUSTRALIA.
Frank P.Bierlien[1], Helen M. Waldron[2] and Dennis C. Arne[1]
1 Minerals Industry Reasearch Institute, University of Ballarat, Victoria, Australia
2 Bequerel Laboratories, Menai, New South Wales, Australia.

B25 THE OCCURRENCE OF GOLD AT THE GETCHELL MINE, NEVADA, USA.
R.J.Bowell[1], M.Gingrich[2] and W.F.Perkins[3]
[1] Steffen, Robertson and Kirsten (UK) Ltd., Cardiff, Wales, UK.
[2] Getchell Gold Corporation, Getchell Mine, Golconda, Nevada, USA.
[3] Institute of Earth Studies, University College of Wales, Aberystwyth,Wales, UK.

B26 APPLICATION OF LITHOGEOCHEMICAL METHODS IN EXPLORATION FOR BLIND PORPHYRY COPPER MINERALISATION.
S.V.Grigorian[1], A.Farsinia[2] and S.Kousari[1].
[1] "VNIZARUBEZHGEOLOGIA" Moscow, Russia.
[2] National Iranian Copper Consolidated Company, Tehran, Iran.

B27 RESOURCE APPRAISAL OF PORPHYRY COPPER MINERALISATION IN THE SUNGUN REGION (IRAN) BY REGIONAL LITHOGEOCHEMICAL PROSPECTING METHODS.
C.V.Grigorian, A.A.Matiev and Gh. Rahimipour.
Moscow State University, Faculty of Geology, Moscow Russia.

B28 ANALYSIS OF LITHOGEOCHEMICAL DATA OVER THE SWAYZE GREENSTONE BELT USING A GEOGRAPHIC INFORMATION SYSTEM (GIS).
J.R.Harris[1], L.Wilkinson[1], E.Grunsky[2], K.Heather[3], S.Fumerton[4] and J.Ayer[5]
[1] Geological Survey of Canada. [2] Government of Alberta. [3]Barrick Resources.
[4] Consultant. [5] Ontario Geological Survey.

B29 FE/TI RATIOS FROM PARTIAL EXTRACTION ICP ANALYSES AS INDICATORS OF HYDROTHERMAL ALTERATION IN GREENSTONE-HOSTED GOLD DEPOSITS.
Hans E. Madeisky and Ariadna Chernavska.
HEMAC Exploration, Vancouver, British Columbia, Canada.

B30 ALTERATION INDICES FOR EXPLORING GREENSTONE HOSTED GOLD DEPOSITS : AN EXAMPLE FROM THE GIANT MINE, YELLOWKNIFE, NWT, CANADA.
Hans E. Madeisky and Ariadna Chernavska.
HEMAC Exploration, Vancouver, British Columbia, Canada.

B31 GEOCHEMISTRY OF HOST ROCKS, VEINS, REPLACEMENTS AND JASPEROIDS IN THE HILLSBORO DISTRICT, SIERRA COUNTY, NEW MEXICO, USA.
Virginia T. McLemore[1] and Erik A. Munroe[2]
[1] New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, USA.
[2] Dept. of Earth and Environmental Sciences, New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA.

B32 THE CHARACTERISATION OF AURIFEROUS QUARTZ USING ION BEAM TECHNIQUES (PIXE/PIGME).
D.W.Russell and J.C. van Moort.
School of Earth Sciences, University of Tasmania, Hobart, Tasmania, Australia.

B33 CHARACTERISATION OF RESIDUAL AND TRANSPORTED REGOLITH PROFILES USING THE PIMA II.
X.C.Shen, A.C.Dunlop and D.R.Cohen.
School of Geology, University of New South Wales, Sydney, NSW, Austalia

B34 PHYSICAL AND LITHOLOGIC CONTROLS ON HYDROTHERMAL ALTERATION IN THE BAKER PATTON FELSIC VOLCANIC COMPLEX, FLIN FLON, MANITOBA, CANADA.
Clifford R. Stanley[1], and Robert A. Duncan[2]
[1] Department of Geology, Acadia University, Wolfville, Nova Scotia, Canada.
[2] Mineral Deposit Research Unit,University of British Columbia, Vancouver, Canada.

B35 MINERAL CONTROLS ON COMPOSITIONAL DIVERSITY IN FRESH AND HYDROTHERMALLY ALTERED ROCKS HOSTING THE SUMMITVILLE HIGH SULPHIDATION EPITHERMAL GOLD DEPOSIT,COLORADO,USA.
Clifford R. Stanley[1], Mark F. Coolbaugh[2] and John E. Gray[3]
[1] Department of Geology, Acadia University, Wolfville, Nova Scotia, Canada
[2] Department of Geological Sciences, Mackay School of Mines, Reno, Nevada, USA.
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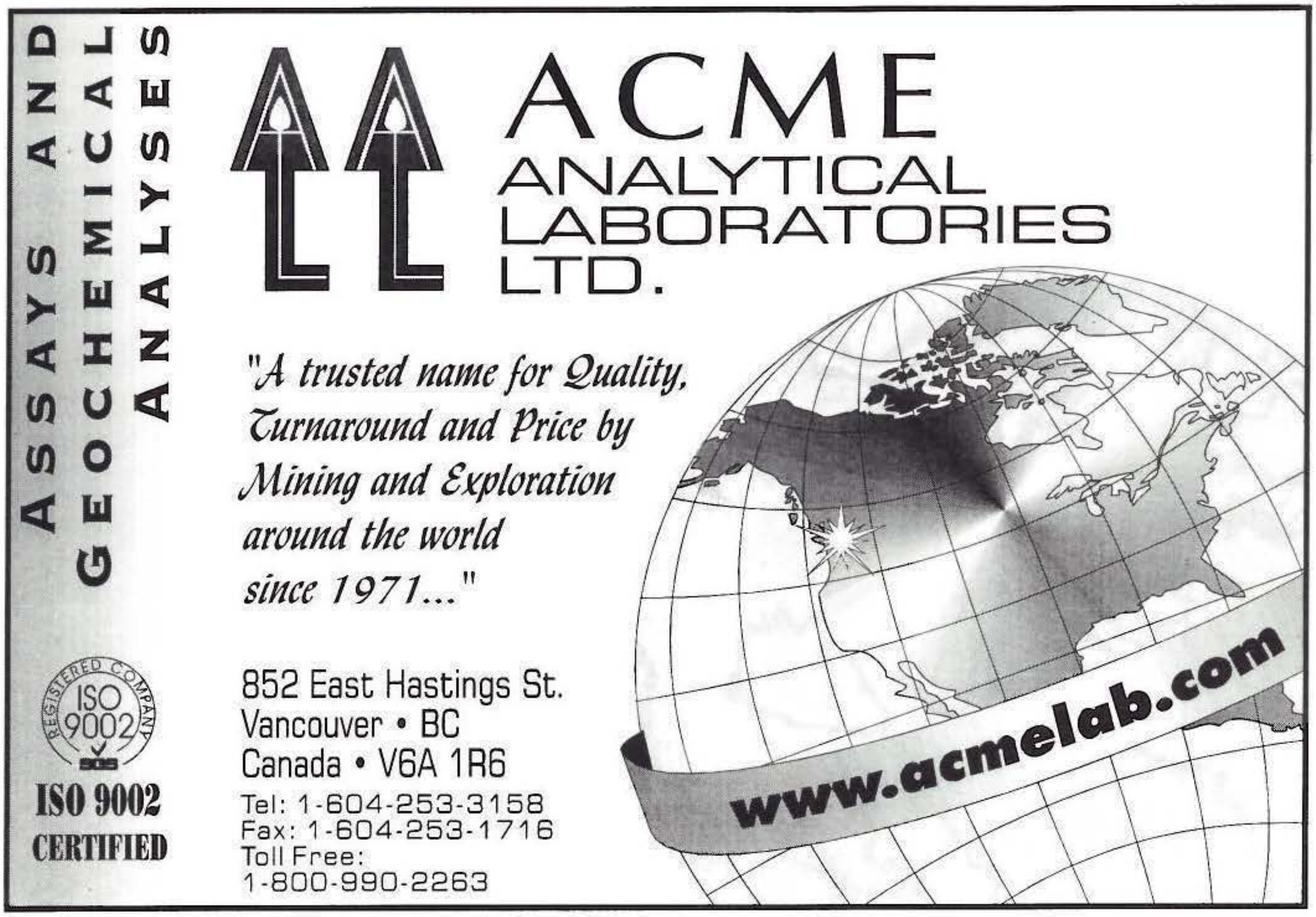

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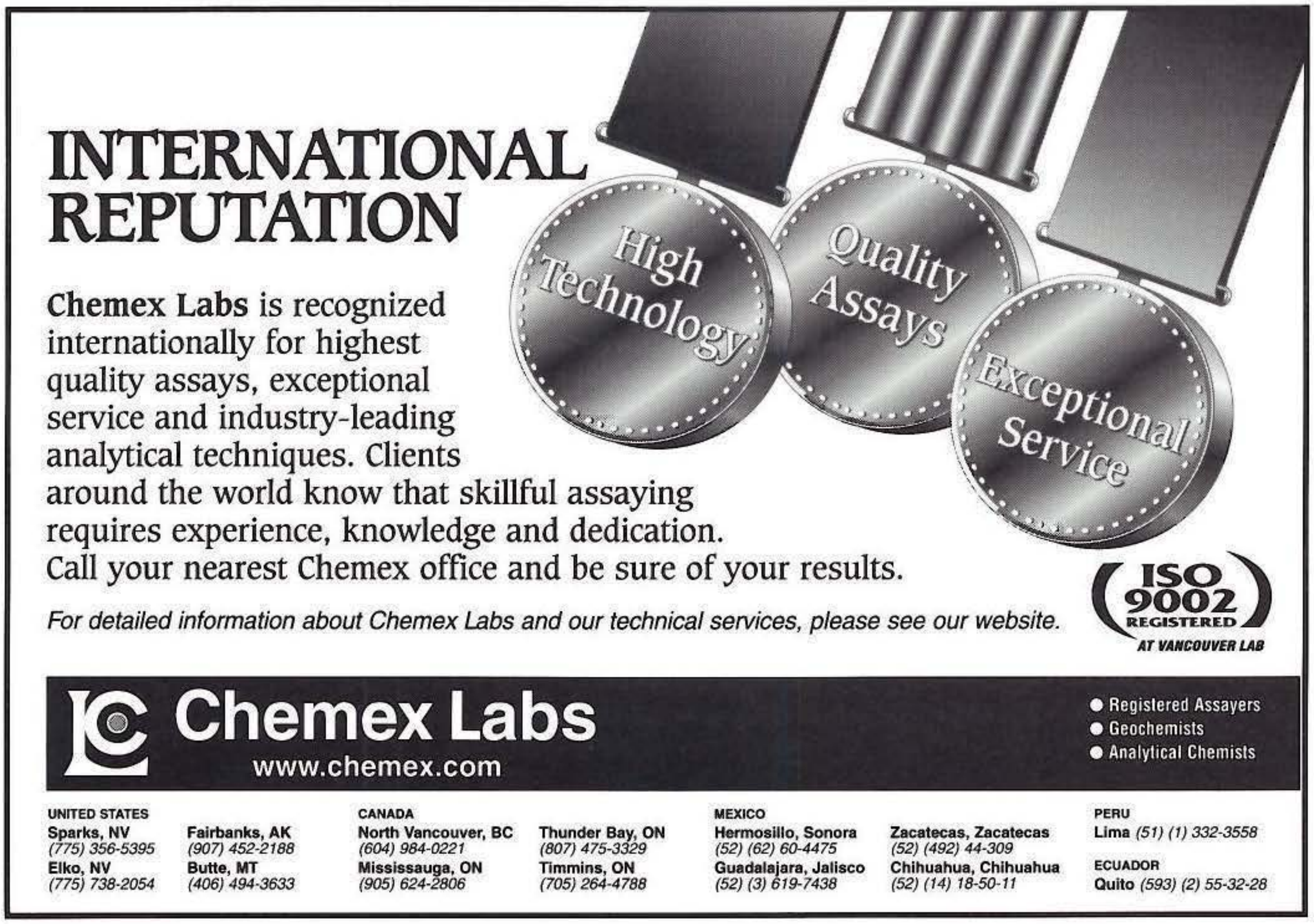

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Abstracts

Oral Presentations

Monday, April 12th
Tuesday, April 13th
Thursday, April 15th
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In alphabetical order by first author's name.

THE RELATIONSHIP BETWEEN TRANSPORTED OVERBURDEN AND DISPERSION FROM BURIED GOLD DEPOSITS - CASE HISTORIES FROM THE YILGARN CRATON OF WESTERN AUSTRALIA

R.R. Anand, M. Dell, J. Madden, S. Varga, R. Ward,
J.E. Wildman and A. Williamson

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Sedimentary cover is common on the Yilgarn, Australia's main Au producing region, and ranges in age from Permian to Recent and in thickness from a few centimetres to many tens of metres. Six orientation districts, Mt. Gibson (S, Deep South deposits), Lawlers (Genesis), Bronzewing, Mt McClure (Calista), Kanowna Belle (Kanowna Belle, Kanowna) and Ora Banda (Matt Dam), representing a range of regolith and geomorphic settings, were studied. Each of these has substantial areas of transported overburden concealing prospective bedrock sequences. The sediments include marine, colluvial, alluvial, estuarine and aeolian types and several may be present in the sequence at a given site. They overlie complete or truncated lateritic profiles. The overburden varies in character according to region, topography and age, with each variant potentially presenting different problems and opportunities to exploration. Within each of these districts, detailed multi-disciplinary studies were undertaken at one or more sites, including regolith-landform mapping, stratigraphy, petrography and, chemical and mineralogical compositions of the transported and residual regolith. This was coupled with investigations of geochemical dispersion of Au and ore-related elements from buried mineralisation in a range of sample media. This paper summarises the results and exploration approaches in these areas of transported overburden.

There are three principal sedimentary units. From the youngest these are: Association A (sandy silty and gravelly sandy clay units), Association B (sandy clays) and Association C (palaeochannel clays and sands). They appear to behave differently to any expression of concealed Au mineralisation. Where present together, Association A (post-Miocene in age) and B (Eocene-Miocene?) overlie Association C (Eocene). The lower horizons of Association A consist dominantly of detrital pisoliths and nodules, which may overlie either ferruginous lateritic residuum (S, Bronzewing, Calista) or mottled clays and saprolite (Deep South, Genesis, Kanowna Belle, Kanowna, Matt Dam). Commonly, the proportion of ferruginous lateritic debris decreases upwards, which is interpreted as a consequence of general erosion of lateritic profiles, inverting the stratigraphy of the regolith. Surface units of the sediments are characterised by late-stage silicification and calcification associated with the formation of red-brown hardpans and calcrete respectively. Association B consists of a weakly cemented, red, massive, structureless, sandy clays (e.g., Kanowna Belle). In places, they have *in situ* mottles and ferruginous granules. Association C consists of thick sequences of palaeochannel clays (e.g., Bronzewing, Kanowna) and sands that have been overprinted by the development of ferruginous megamottles and pisoliths. Soils developed in colluvium and alluvium have poor horizon-differentiation and are acid at the S, Deep South, Genesis, Bronzewing and Calista deposits but are calcareous at Kanowna Belle, Kanowna and Matt Dam. Of the eight case histories, six show surface expression of concealed Au mineralisation in soils and near-surface sediments and the geochemical responses in the other two are confined to within 2-4 metres of the unconformity between the sediments and saprolite, in both the sediments and residuum. At the S and Deep South deposits, sampling of soil and red-brown hardpan horizons (Association A) was effective in detecting Au mineralisation concealed by 2-15 m of sediments. At Deep South, the Au anomaly is 200 x 50 m wide at an average of 345 ppb. Selective sampling indicated an intimate association between newly formed minerals (Mn and Fe oxides and nodular and tubular carbonates) and Au. Similarly, Genesis deposit, covered by 5-7 m thick sediments (Association A), displayed low but anomalous, secondary dispersion haloes (80 x 120 m) of Au, As, Sb and Bi (associated with Fe oxides) in the red-brown hardpan horizon. Manganese oxides from the hardpan horizon have scavenged rare earth elements but did not have any noteworthy affinity with Au.

At Kanowna Belle and Matt Dam, analysis of calcareous soils and hematite-goethite-rich ferruginous granules formed from sediments delineated concealed mineralisation covered by 3-15 m of sediments (Association A and B). Besides Au, ferruginous granules and mottles gave broader and stronger As, W and Sb anomalies. At Matt Dam, the strongest Au anomaly is in the <75 µm soil fraction directly above the mineralisation. In the Kanowna palaeochannel deposits (Association C), anomalous concentrations of Au occur in goethite-hematite-rich megamottles and calcareous soils directly overlying the buried mineralisation.

There is no surface expression of buried mineralisation in soils and near-surface sediments at the Bronzewing and Calista deposits, covered by 15-30 m of sediments (Association A and C). However, there are anomalous concentrations of Au (>100 ppb) with Cu and As in the basal part of the sediments and at the colluvium-residuum interface for at least 150 m across the strike of mineralisation at Calista and Bronzewing. Size fractionation of the basal sediments of Association A that occurs within a 2-4 metres of the residuum-colluvium interface, indicates that Au is concentrated in the >2 mm fraction and depleted in the <75 µm fraction, relative to the bulk sample. It is inferred that enrichment in the coarse fraction is due to mechanical dispersion of lateritic detritus. The palaeosurface now represented by the unconformity has sufficient gradient to allow colluvial migration of mineralised lateritic nodules downslope. Hydromorphic dispersion would be expected to enrich the fine fraction. Thus, dispersion into basal sediments is probably due to both mechanical and chemical mechanisms, during and after deposition, including bioturbation. There is no evidence for any geochemical dispersion in authigenic mottles and pisoliths extracted from the palaeochannel sediments (Association C) overlying mineralisation. Various partial extraction techniques gave little or no useful additional data.

It is concluded that the geochemical response to mineralisation in transported overburden is determined by the characteristics, thickness and source of sediments, their subsequent modification by weathering and the nature of the groundwater regimes. Thus, mapping of sediments and correct identification of their characteristics and the depth of the unconformity are essential. Exploration approaches will be discussed.

GEOCHEMICAL EVOLUTION OF WATER QUALITY IN A MINE PIT LAKE AND POTENTIAL OPTIONS FOR IN-SITU CONTROLS

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The geochemistry of an established pit lake in a former operating open pit (Summer Camp Pit, SCP) at the Getchell mine in north west Nevada has been studied through review of historical data and recent testwork and modeling. Metal levels are low in the mildly acidic to alkaline pit lake, but arsenic, sulfur and Total Dissolved Solids (TDS) are relatively significant.

Although sulfide oxidation and sulfate dissolution processes are active in wall rock - water reactions, they exert only a small control on pit lake chemistry. The major control on pit lake chemistry is the inflow from the dewatering of the Getchell underground mine which contributes high alkalinity, arsenic and sulfate. Alkalinity is almost entirely supplied by carbonate species leached from mineral-water reactions in the limestone bedrock. Sulfur dominates the anion budget of the pit lake with concentrations up to 900 mg/l predominately as sulfate. Speciation of sulfur are almost entirely as free sulfate or as Ca-Mg sulfate with minor Fe-sulfate minerals, free sulfide and metal-sulfide species. The overall effect on the pit lake is to transform lake macrochemistry from Ca-Mg-HCO_3 to Ca-Mg-SO_4.

Sulfur geochemistry in the pit lake is complicated and involves not just mineral-water interactions but also the influence of biota. Evidence exists to suggest that bacterial cycling of sulfur is naturally occurring in SCP lake at the present time, despite the low organic carbon estimates. Induced biological control of the high sulfate waters may be a possible solution to the lowering of sulfate, but is limited by the availability of nutrients. Enhanced biological activity runs the risk of increasing arsenic mobilization through by-reactions to sulfate reduction, such as methylation. Alternatives to biological control could include encouraging mineral precipitation through ion exchange or co-precipitation with iron or barium.

The field data demonstrates that acid generation processes are active at the present time in the pit lake. However the overall chemistry of the pit lake remains alkaline or neutral indicating that available alkalinity is able to adequately buffer any acid produced preventing increased leaching of metals and sulfate from the wallrock.

COMPARISON OF GEOCHEMICAL PATTERNS IN TILL ANDLAKE SEDIMENT SURVEYS, CENTRAL NEWFOUNDLAND

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The whole of Newfoundland has been covered by systematic lake-sediment geochemical surveys at an average sampling density of 1 site per 6 km^2, and over 10,000 km^2 of the central mineral belt of Newfoundland has been covered by systematic till geochemical surveys at an average sampling density of 1 site per 4 km^2. These coverages allow regional geochemical patterns to be compared between the two sample media for several elements in an area of strong geochemical relief and high mineral potential.

The lake-sediment geochemical surveys were conducted by the Geological Survey of Newfoundland and Labrador between 1973 and 1995 using National Geochemical Reconnaissance Program protocols of sampling and analysis, and the data are internally consistent. The till geochemical surveys were conducted by the Geological Survey of Newfoundland and Labrador and the Geological Survey of Canada between 1978 and 1998. In all cases the < 0.063mm fraction of till (from below the B soil horizon, where available) was used for geochemical analysis, although there was some variation in analytical methods between individual surveys. Comparison of the results from these different methods on a sample sub-set indicates that for most elements it is feasible to level the geochemical data between them, and provided the necessary algorithms to accomplish this.

Regional trends in each of the two media are co-registered by aggregating the site data from each to a common 2 km square grid. For each element Spearman rank correlations are calculated to quantify the degree of overall similarity between the two media. Areas where the two media show different spatial patterns are readily highlighted by ratioing the normalized grid values for each element. The initial grid values and ratioed grids values are further smoothed and gridded to a smaller cell size to prepare interpolated surfaces for visual presentation as raster images.

MINERALOGICAL AND GEOCHEMICAL ANALYSIS OF CATHEDRAL TERMITARIA APPLIED TO GOLD EXPLORATION IN THE ROANDJI ALLUVIAL GOLD FIELDS, BANDAS GREENSTONE BELT, CENTRAL AFRICAN REPUBLIC

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Termitaria are routinely used in exploration methodology in lateritic environments because they provide rapid, relatively inexpensive, highly effective means of exploring masked formations and structures. The success of the technique depends on the ability of termites (Macrotermes and possibly Odontotermes) to burrow to and excavate rock and mineral particles at or near the oxidation front. The construction of mounds above ground and the recognition of mound residuals allows sampling for geochemistry, mineralogy and petrology of material otherwise available only through drilling.

This presentation documents the results of a survey involving 5661 termitaria sites in a "high priority" target covering 64 km² on the Roandji gold permit, south-central Central African Republic (CAR). The termitaria survey, is part of a multimedia, high density, mineralogical and geochemical survey involving more than 11,000 samples. The comprehensive survey was designed to locate one or more bedrock sources for a series of highly auriferous streams and rivers, which drain the "high priority " area of this part of the Roandji gold fields. The alluvial deposits, mined extensively from 1928 to 1951 as part of the first mechanised gold mining operation in former French Equatorial Africa, yielded an estimated 1.5 tonnes of gold and continue to support sporadic mining by local artisanal miners.

The 64 km² survey area includes a valley and ridge terrain formed on banded iron formation and an adjacent low plateau developed on granitic rocks. The bedrock is Archean in age and belongs to the Bandas greenstone belt, a 12,000 km² band of classic Archean greenstone-granite terrain, and one of two recently recognised greenstone belts in the CAR. The survey area is masked by indurated colluvial deposits and lateritic duricrust which occurs both as surficial and buried horizons up to several meters thick. This duricrust has hindered mineral exploration, beyond the valley floors, for the past 70 years.

The unusual density of the termitaria (probably twice the sample density of 90/km²) and the even distribution of the termites in the area combined with their favourable genetic and compositional characteristics make for an ideal sampling medium. Sampling methodology, modified from previous work, included (1) a tighter sampling interval (up to 10 metres along 100 metre lines) to obtain maximum efficient sample density, and (2) the collection of a bulk, unscreened 20-litre sample for heavy mineral separation and analysis, in addition to a standard 500 ml geochemical sample.

The sampling program was carried out over a three-month period using three field crews. The bulk samples were collected from 10 cm-deep channels excavated over a minimum distance of 2 m from the top of the mound, and often included sampling of the adjacent detrital fan. The processing of the 20 liter samples was performed on a daily basis by eight teams of up to 10 panners using conical gold bateas. The procedure involved washing the samples to a bulk concentrate and subsequent refining by a key panner using a black flat bottom pan, to obtain a final concentrates for gold particle counts. The maximum processing rate reached was 40 samples per day.

Mineralogical processing, mainly for gold, and geochemical analysis of the field duplicates has provided a measure of accuracy at the sample processing stage (an estimate of the ability of the panners to extract and count all gold particles), and an estimate of sample site variability for the geochemical samples. A comparison of analytical methodologies for gold in the geochemical samples and an estimate of the size distribution of the gold particles is also provided for by the repeat analysis of selected suites by combined fire assay and gravimetric analysis.

The high density of sampling of termitaria has allowed for the first systematic analysis and imaging of the primary gold potential of the Roandji alluvial zone. The mineralogical results of the 5661 sample survey have led to the identification of a northwest trending linear anomaly 5.4 km long and from 250 to 500 metre wide, defined on gold grain abundance, in an otherwise blind upland area. The number of gold particles in 20-litre samples taken within this zone ranges from 17 (75th percentile) to a maximum of 751. A mineralogical study of selected mineral and gold grains by means of SEM-EDS shows an assemblage comprised of hematite/specularite rutile and associated hydrous iron oxide minerals and zircon. Gold, in the anomalous zone, occurs as coarse grained euhedral particles, essentially pristine, lacking in wear, aside from the work done on the grains by termites, and limited corrosion and rounding characteristic of colluvial and lateritic environments. The grain size of recovered gold varies from about 10 µm to 3.5 mm (length), with the majority of the particles having a width of less than 250 µm.

The nature of the primary mineralization is unknown but quartz inclusions imply some of the coarse gold is in vein form, but gypsum/anhydrite as well as iron oxide pseudomorphs after sulphides on gold grains, implies a high sulphur environment such as sulphide facies iron formation. The coarse grained nature of the gold may be in part metamorphic in origin. Wires and crystal forms are not common. The zone of high gold particle abundance has a corresponding anomalous Au signature (52 ppb (75th percentile) to >1000 ppb), a strong As signature (40 ppb (75th percentile), and a weak Cu and V association, mapped for initial 1850 termitaria samples assayed.

The prominent termitaria gold grain anomaly straddles the major divide at an anomalous offset of the divide, symmetrically between two proud ridges, and crosses secondary divides there. The tend is parallel to the structural grain and appears to represent structurally incompetent members of the iron formation, with implications both for flow of material into fold cores and hydrothermal effects in the axial zone of the fold.

A program of manual overburden trenching and rotary air blast drilling to explore both masking duricrust overburden and underlying saprolite follows.

HYDROTHERMAL WALLROCK ALTERATION AS AN EXPLORATION TOOL FOR SLATE BELT-HOSTED GOLD MINERALIZATION

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Turbidite-hosted mesothermal gold deposits, such as those found in central Victoria, Australia, were long believed to be characterised by a lack of significant wallrock alteration, due in part to the apparent absence of a diagnostic alteration halo. However, visible wallrock alteration in meta-turbidites may often appear to be absent or only weakly developed simply because the host rock composition did not allow for the extensive development of distinct alteration assemblages, such as those which are recognised within extensive alteration haloes in reactive ultramafic host rocks around Archaean lode gold deposits in, for example, Canada and Western Australia.

The Lower Paleozoic meta-sedimentary and meta-volcanic sequence of the western Lachlan Fold Belt in central Victoria, Australia, hosts a large number of late orogenic gold deposits and has long been recognised as one of the world's major slate belt gold provinces. Most deposits are associated with quartz reefs in brittle thrust faults cutting tightly folded turbidite sequences (e.g., Bendigo, Ballarat), although deposits hosted by ductile shear zones (e.g., Stawell) and associated with disseminated sulfides and quartz stockworks (e.g., Fosterville) are also found. Fluid inclusion studies indicate that the moderately saline ore fluids (10wt% $NaCl_{eq}$) contained variable amounts of CO_2, CH_4 and N_2 (Changkakoti et al., 1996), and that the deposits were formed at temperatures similar to those estimated for peak metamorphism (Offler et al., 1998).

Until recently, the perceived lack of wallrock alteration around turbidite-hosted gold deposits generally discouraged comprehensive studies on the significance and extent of wallrock alteration in gold deposits in Victoria. Consequently, both the origin and relative timing of gold mineralisation in many turbidite-hosted deposits have been the subject to some controversy. Likewise, the nature of turbidite-hosted gold mineralization (i.e., size, structure, distribution, ore grades) poses an immense challenge to exploration and the delineation of drilling targets. Nevertheless, the study of mineralogical and chemical changes within turbidites associated with gold mineralization can provide invaluable information regarding ore genesis and represents a potentially powerful exploration tool.

Integrated petrological and geochemical examination of meta-sedimentary assemblages associated with mesothermal lode gold mineralization in five major centers of past and present production (Ballarat, Percydale, Tarnagulla, Maldon, Fosterville) in central Victoria, Australia, reveal that hydrothermal alteration in the hosting Cambro-Ordovician turbidites is much more pronounced and extensive than has long been thought. Characteristically, the auriferous reef structures are surrounded by up to several tens of meters-wide bleached zones, while sericitization, carbonatization and the development of carbonate spots, and pyrite and arsenopyrite porphyroblasts are the most obvious features of alteration (Bierlein et al., 1997; 1998). Quantitative XRD analysis illustrates that these marked bleached haloes are due to the breakdown of metamorphic chlorite, replacement of albitized plagioclase clasts by white mica, extensive carbonatization, and, to a lesser extent, kaolinization. A distinct negative correlation between metamorphic chlorite and hydrothermal carbonate phases provides a reliable mineralogical alteration index useful to exploration.

SEM analysis of carbonate porphyroblasts within alteration haloes indicates that they are Fe- and Mg-rich carbonates, consistent with the interpretation that carbonatization has fixed Fe and Mg liberated by the destruction of metamorphic chlorite. Petrographic examination of carbonate porphyroblasts indicates that these extensively developed 'spots' both pre- and post-date cleavage development in the host sequence, and this agrees with megascopic structural evidence for a late syn- to post-tectonic timing for the emplacement of most central Victorian gold deposits.

Whole-rock traverses illustrate the development of systematic chemical changes which generally occur within 10 to 100 metres from the auriferous structures and involve enrichment in CO_2, K_2O, H_2O, S, As, and Au as quartz reefs are approached, whereas SiO_2 and Na_2O are commonly depleted. However, major elements such as K_2O and Na_2O vary dramatically as a function of lithology and thus are not reliable indicators of alteration in isolation. Instead, the ratio $K_2O + CO_2 / K_2O + CO_2 + Na_2O + Al_2O_3$ provides a more suitable means of defining alteration in rocks of varying lithologies. Rock density measurements and preliminary mass balance calculations indicate chemical exchanges occurred at constant bulk rock volume.

Where metamorphosed in the contact aureoles of granite plutons, CO_2 values from host rocks within alteration haloes are greatly reduced. In addition, carbonate species that characterize wallrock alteration in the vicinity of central Victorian gold deposits have been replaced by calc-silicate assemblages consisting of diopside-hornblende-anorthite-apatite-sphene. However, trace element haloes similar to those typical of deposits outside contact aureoles are largely preserved in contact-metamorphosed host rocks. Thus, all wallrock alteration studies support the interpretation, based on geochronological investigations (Arne et al., 1998; Foster et al., 1998), that most central Victorian gold deposits preceded the emplacement of granite plutons in the western Lachlan Fold Belt.

Although the siliclastic nature of slate belt sequences may render the development, and identification, of *visible* alteration envelopes around slate belt-hosted mesothermal lode gold systems difficult, the development of tens of meter-wide haloes involving extensive mineralogical and geochemical modifications within the wallrocks clearly points to hydrothermal alteration in a regime of high fluid/rock ratios and under disequilibrium conditions. Recognition of these modifications thus can provide a very effective tool to exploration for slate belt-hosted gold mineralization.

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ELEMENT RATIOS IN NICKEL SULPHIDE EXPLORATION: VECTORING TOWARDS ORE ENVIRONMENTS

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Elements ratios in geochemical exploration can aid in distinguishing mineralised from unmineralised geological complexes, predict deposit types, and assist in estimating and evaluating dispersion of ore indicator elements. Exploration at Kambalda Nickel Operations, Western Australia, has focussed on developing a reliable robust geochemical method that can vector towards nickel sulphide mineralisation. One such method utilises element ratios which are faithful to and compatible with the genetic geological exploration model for komatiite-associated massive nickel sulphide deposits. A particularly successful element ratio is expressed as [(Ni/Cr) x (Cu/Zn)].

The [(Ni/Cr) x (Cu/Zn)] ratio is effective in vectoring towards channellized komatiitic environments. This paper presents key examples that demonstrates the power of the Ni/Cr) x (Cu/Zn)] ratio in fresh meta-komatiite rock and its intensely weathered equivalent through to the surface materials. The effect of different analytical techniques on the ratio, enhancing contrast(?), and exploration implications will be discussed.

Komatiite-associated nickel sulphides are low in Cr compared to unmineralised komatiite flows. Low Cr values persist down-plunge from Ni sulphide mineralisation in what is interpreted to be a channellized komatiite flow. Mineralised basal komatiites flows are enriched in Ni compared to unmineralised flows. Thus, utilising a Ni:Cr ratio, potential mineralised flows (high Ni, low Cr) can be distinguished from unmineralised flows (low Ni, high Cr) with Ni:Cr ratio values >1. This Ni:Cr signature can be traced down-plunge, on the basal komatiite flow, for >15 km and upsection through the komatiitic stratigraphy. In addition, this signature is, in part, preserved through the weathered komatiite and into surface material and has successfully identified new Ni sulphide occurrences and highlighted significant areas of exploration interest.

Sulphide-bearing sedimentary horizons, of variable thicknesses, occur at the base and within the komatiitic section. These meta-sedimentary rocks typically have three times the Zn concentration (1500 ppm) to that of Cu (500 ppm). Nickel sulphides however, have a greater concentration of Cu than Zn. Thus, the utilisation of a Cu:Zn ratio can assist in discriminating Ni sulphides from non-Ni sulphides and lithological signatures with values typically >1.

Combining the Ni:Cr and Cu:Zn ratios has the effect of reducing the influence of particular lithologies (eg, sulphidic meta-sedimentary rocks) and aids in the delineation of Ni sulphide mineralisation. Multiplying the two ratios together enhances the contrast of element ratios related to mineralisation and subdues the effect of lithologies. Utilisation of the [(Ni/Cr) x (Cu/Zn)] ratio increases contrast between background and mineralisation, and thus the ability to vector towards basal komatiite channellized environments through the distinctive behaviour of Ni, Cr, Cu and Zn. Interpretation of the ratio in fresh rock and weathered rock environments has led to: (1) targeting potential Ni sulphide mineralisation in surface, weathered and fresh rock environments; (2) distinguishing mineralised from unmineralised meta-komatiite lithologies; (3) vectoring towards mineralised positions; (4) indicating the plunge direction of a mineralised environment; and (5) evaluating large base metal data bases. However, the utilisation of such ratio values alone should not be considered definitive. They must be viewed with their original absolute element values and known lithologies.

THE APPLICATION OF TILL GEOCHEMISTRY TO MINERAL EXPLORATION IN NORTHERN SASKATCHEWAN, CANADA

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Two studies in northeastern Saskatchewan, from the Peter Lake Domain and the eastern Athabasca Sandstone Basin, illustrate the use of major and trace elemental analyses for till composition and provenance. The results of these studies have implications for mineral exploration in these areas. Different approaches are taken depending on the objective of the study, the geological conditions, type of sample media, survey type, and the mineral commodity sought.

Although the economic potential of the Peter Lake Domain is recognized, mineral exploration is limited primarily due to the lack of bedrock exposure (generally < 5%) and to a poor understanding of the regional geology. A preliminary Quaternary geological study was undertaken at a reconnaissance scale to characterize the till deposit(s), and to determine if the till composition would provide some insight into the local bedrock geology. The major surficial deposit in the northeast and southwest region of the Domain is ground moraine composed of silty-sand till. Ice contact deposits (sand and gravel) and hummocky moraine (sandy till) are prevalent in the central and northern portion of the Domain. Regional ice flow direction is sub-parallel to the dominant regional bedrock structures at circa 210 to 230°.

Fractionation and textural analyses indicate that the <63 µm fraction is the optimum sample fraction for geochemical interpretation. Principal Component Factor Analysis (PCA) and Correspondence Factor Analysis (CFA) of the major and trace element geochemical data reveal elemental groupings reflecting contributions from different mineral groups. Three main groups were identified; feldspar-rich, silica-rich, and ferromagnesian-rich. A trend related to alteration/weathering (clay minerals) was also observed. When the probable bedrock sources for the tills are superimposed on the CFA factor plot best illustrating the elemental/mineral groups, two features can be seen. Firstly, several lithological units can be differentiated on the basis of their mineral signatures. Secondly, a weathering/alteration trend can be identified with the samples falling on tie-lines between LOI and their respective unweathered lithologies. Therefore, the till geochemistry of the <63 µm fraction generally reveals elemental associations reflective of the source rocks. Pebble lithologies and the mineralogy of the heavy mineral concentrates (HMC) of selected samples support this finding. The work to date suggests that the silty-sand till is locally derived, and that the geochemical characteristics of this till are useful in mineral exploration to provide insight into the unexposed bedrock geology as well as to identify areas of possible base and precious metal mineralization.

The second study involves a test hole in the eastern portion of the Athabasca Sandstone Basin, west of Wollaston Lake. In this region, bedrock outcrop exposure is less than 1%, and the thickness of the drift cover is variable, often in excess of 30 m. Since core recovery of the glacial sediments was poor (~27%) due to their sandy nature, only limited conclusions can be drawn. Nonetheless, the information collected in this study is considered valuable in light of the paucity of stratigraphic information concerning the Quaternary geology and the properties of these sediments in the Athabasca Basin. Major and trace element geochemistry of the fine fraction (<63µm), clay mineralogy, pebble lithology, and HMC mineralogy were determined to assist with the litho-stratigraphic logging of the drillcore, and to detect the presence of any evidence from known uranium mineralization present up-ice.

Three till units were identified in the drillhole, based primarily on visual examination of colour, texture, oxidation, compaction, and structure of the tills, and supported by subtle patterns in the geochemical, mineralogical, and lithologic data. Textural and geochemical features of the fine fraction confirm the presence of multiple tills and provide additional compositional characteristics important to uranium exploration. A positive correlation between clay content and metal concentrations is suggested, and content variations in both appear to correspond to the stratigraphic breaks. HMC mineralogy and pebble lithology data are less conclusive. In this drillcore, the most useful geochemical elements are Fe_3O_2(t), Na_2O, Ba, Ce, V, Sr, and Cr. The clay mineralogy also proved informative.

Geochemistry of the <63 ☞m fraction, the HMF mineralogy and pebble lithology indicate that a significant crystalline basement component is present in varying amounts in all of the tills, although the exposed sandstone/basement contact is approximately 60 km up-ice of the drillhole (~35 km to nearest exposed basement) . The proportion of basement-derived material in the till increases with depth, with the lowermost till lying immediately on the sandstone bedrock surface containing the greatest proportion of basement-derived material.

Normative kaolinite proportion decreases with depth while the normative illite and chlorite proportions increase with depth. The MgO/Al_2O_3 and K_2O/Al_2O_3 ratios mimic the normative chlorite and illite curves, respectively. These clay mineral trends appear to reflect the increase in the basement component in the till with depth. However, it is possible at least in part, that the chlorite and illite could be derived from the uranium mineralization-related sandstone alteration halo sub-cropping approximately 225 m northeast of the drillhole. The highest uranium value (6.2 ppm) in the <63 ☞m fraction occurs in the uppermost cored till unit at a depth of 10.3 m. This sample also contained elevated values of Pb and Zn, but not of other elements typically considered to be related to unconformity-type uranium deposits. The source of this uranium is unknown. Further work is needed to better resolve these questions.

This investigation identifies several impediments for uranium exploration in the eastern Athabasca Basin which involve surficial deposits, such as the commonly used surface boulder lithogeochemistry. First, the presence of thick overburden consisting of multiple till units strongly suggests that the chances of the surface till containing locally-derived material, and thus an expression of possible underlying mineralization, is minimal. The practise of basal till sampling using overburden drilling would also not be useful as the lowermost till appears to contain a significant component of distally-derived material. The basement component of the fine fraction geochemistry and clay mineralogy overprints the indicators of unconformity-type uranium mineralization/alteration that may be present in locally-derived sandstone material.

ENVIRONMENTAL IMPACT FROM OLD MINING SITES ON THE MEXICAN ALTIPLANO: ARSENIC AND HEAVY METALS IN STREAM SEDIMENTS - A COMPARISON

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Intensive mining activities have been carried out during the last three hundred years in North-Central Mexico. For this period, the last seventy years have contributed to about eighty percent of the waste production, mainly due to mineral processing by flotation and cyanide leaching. Evidence of this are huge tailing heaps which are often unsecured and represent environmental hot-spots.

In this work, two deposits in geographical similar locations but with different types of mineralization and element relations were investigated. Both are located at the middle of the Mexican Atiplano between 1500 and 2000m a.s.l., in an area with typical semi-arid climate. No perennial rivers are present at either location and the completely unsecured tailing piles are adjacent to the banks of local seasonal creeks which evaporate and ooze in the centre of closed valleys several kilometers away from each mining district.

The behaviour of arsenic and several heavy elements which are released in high amounts from the tailings was investigated. Material from these tailings is transferred into the creeks by periodic heavy rains and distributed over the entire downstream area and the surrounding soils. The distribution of the toxic elements along the creeks and their relations within the different compartments was investigated. Extraction procedures were applied to investigate element mobility and their potential to be remobilized by rains and to be transferred into the groundwater or to be spread over agricultural land by flooding.

With this focus the mining districts Concepción del Oro/ Zacatecas and the Santa María de la Paz/ San Luis Potosi were investigated. The first one is a Cu-Au Skarn deposit with disseminated Cu-Au mineralization in the outer zones of a granodioritic stock. The mining activities reached their peak in the second third of this century. In Concepcion del Oro, the dominating mineral dressing process was cyanide leaching whereas in La Paz, a typical Ag-Pb-Zn-vein mineralization with an associated Cu-Au-Skarn, ore dressing by flotation is preferred. The works on the vein zone of La Paz were stopped 1992 but the ones on the skarn zone are still ongoing.

The mineralogical compositions of the tailings and the stream sediments were characterized by X-ray diffraction (XRD) and the heavy metal contents were determined by energy dispersive X-ray fluorescence (EDXRF). The metal contents of the different grain size fractions (>200µm; <200>63µm; <63µm) from the tailing piles were also determined. Sequential extraction procedures followed by analysis with ICP/MS and FAAS were carried out on selected samples in order to estimate the potential effects on the local environment. Characteristic for both mineral deposits is a high arsenic content that is enriched in the tailing heaps up to 3000 mg As/kg in La Paz and up to 700 mg As/kg in Concepción del Oro. The As content of the <63µm fraction in tailing material from La Paz can reach up to 5% As.

Because of the high calcite content of the host rocks, the tailing material from La Paz is carbonate dominated, whereas the tailings of Concepcion are quartz, feldspar and silicates dominated, with minor carbonate. Mineralogy and the ferric-iron content of the tailing material are parameters controlling the different behavior of the elements of environmental concern at both sites.

In the high energy segment of the stream, the arsenic contents of sediments from La Paz decrease with increasing distance from the tailings. In the lower energy segment the arsenic content increases again up to 2% at about 10 km from the heaps. The shift of the element ratios As:Zn:Pb in favor of As, together with high concentrations of Fe and immobile Pb, indicates that transport by fine particulates as well as solution and coprecipitation with Fe-oxides, enriched by oozing and evaporation, are the most important mechanism for the environmental dispersion of toxic elements from the tailings.

At Concepcion del Oro, overbank sediments for a distance of more than 12 km from the dumps visibly contain considerable amounts of tailing materials with element concentrations of up to 4500 mg/kg Cu, 1000 mg/kg Zn, 800 mg/kg As and 300 mg/kg Pb. Due to the relatively steep and narrow valley morphology the runoff waters from the Concepcion area are dominated by high energy transport for the first 10 km. Sedimentation at the overbanks mainly takes place at subsiding waterlevels. At greater distances, morphology changes to low energy environment and solution transport, sedimentation of the fines, secondary enrichment by oozing, coprecipitation and evaporation dominate.

The role of primary and secondary mineralogy on release, mobilization or fixation of the elements will be discussed. In both cases organic matter is negligible. The results of this work will help to determine the main contamination paths for materials released by old mine sites in semiarid climate, and how far these toxic elements can be remobilized by natural processes.

GEOCHEMICAL EXPLORATION FOR CONCEALED DEPOSITS IN ALLUVIAL TERRAINS, ANHUI, EASTERN CHINA

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Anhui province in eastern China is located in the Circum-Pacific Rim. Porphyry copper deposits have been discovered near the Yangtz river in the province. However, the alluvium which covers most of the region prevents a complete evaluation of the mineralization potential by geology and conventional geochemistry. Two new geochemical methods - collection of nanoscale metals in earthgas (NAMEG) and leaching of mobile forms of metals in overburden (MOMEO) have been used to investigate the possibility to delineate new targets favorable for large concealed deposits. The studies show that water-extractable metals can give prominent expression to concealed mineralization in this alluvial terrain.

The MOMEO and NAMEG methods were used to delineate regional anomalies and to reduce the target size step by step in northern Anhui. First of all, a wide-spaced MOMEO and NAMEG sampling was carried out in an area of over 80 000 km^2 at density of one sample per 400 km^2 in order to rapidly get an overview of the potential for large deposits. A large anomaly of water-extractable Cu was delineated around the known copper deposits near the Yangtz river and Au anomalies were delineated in an un-explored covered area. The largest Au anomaly was selected as a regional survey at low-density sampling(1 sample per 25 km^2) in order to reduce the size of target. The anomaly was reduced to an area of approximately 300 km^2. Four concentration centers were delineated by the follow-up survey within the area.

AN UNSUPERVISED NEURAL NETWORK APPROACH TO THE ANALYSIS OF MULTI-ELEMENT STREAM SEDIMENT DATA, NORTHEASTERN NSW, AUSTRALIA

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Identification of complex patterns of correlation between variables and associations among samples or reduction of the dimensionality of geochemical data, through conventional parametric statistical procedures such as factor analysis or cluster analysis, may be biased or obscured by multivariate outliers and non-normal variable distributions. Such procedures may require substantial pre-processing of data prior to modeling.

An alternative approach is the use of unsupervised neural networks to organise multivariate data into a set of unique classes without *a priori* knowledge or the need for pre-processing. Patterns in n-dimensional space may be transformed to lower dimensional space that is topologically ordered and easily visualised. Modified forms of the standard unsupervised Kohonen self-organising map approach, permit clustering procedures that are non-linear, non-parametric and rapid. The number of clusters, into which samples are allocated on the basis of their multielement signature, is determined by the unsupervised neural network and is directly dependent upon the original input data distribution. The neural network ceasing the grouping of data once the rate of change in clustering had passed below a minimum threshold.

An unsupervised neural network clustering has been performed on stream sediment geochemical data, derived from 1677 sub-catchment within a 30,000 km^2 block in the northeast region of NSW. The raw data was converted to a raster form with a cell size of 0.16 km^2 equivalent to the smallest recorded catchment area (the average catchment area being 16 km^2). Fourteen high density data clouds (common patterns or clusters) and one much smaller composite anomalous group (representing the outliers) were obtained, with convergence occurring once the neural network had achieved the optimal number of iterations for clustering the 33 dimensional data set. Element associations within the clusters could be related to a feldspar suite (Na, K, Ba, Sr, Rb, Pb and Eu), the siderophiles and metals that strongly adsorbed to Fe-oxides (Fe, Co, Cr, Cu and Ni), a base metal mineralisation suite (Cu, Pb, Zn) and various combinations of metals associated with heavy minerals (REE, Nb, Ta, Th, Hf and Zr). These clusters are closely related to sub-catchment geology, although many of the outliers were related to sub-catchments containing known mineralisation. Element and sample (catchment) clusters were similar to those obtained by more conventional multivariate statistical methods.

A COMPARISON OF VEGETATION AND STREAM SEDIMENT GEOCHEMISTRY IN NORTHEASTERN NEW SOUTH WALES, AUSTRALIA

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Despite the demonstrated effectiveness of biogeochemistry in prospect-scale geochemical exploration or environmental surveys, the application of biogeochemistry in regional reconnaissance surveys and its use as an alternative or supplement to stream sediments has only been evaluated in a limited number of cases.

In this study, the geochemical response of stream sediments and adjacent vegetation samples with variations in lithology and the presence of mineralisation, from 920 sub-catchments within a 14,000 km^2 block of the northeastern region of New South Wales, have been compared. The area contains a range of lithologies, including metasedimentary rocks, ultramafic intrusives, pre-orogenic and post-orogenic granites of a Devonian-Permian accretionary complex and clastic sedimentary rocks of the Mesozoic Clarence-Moreton Basin. Stratiform and vein-hosted Au, Sb and base metal deposits, granite-related Sn-W-Mo-Au-base metals mineralisation and alluvial Au and Sn deposits occur within the area. Sampling was designed to confine each sub-catchment to a single lithological group (mafic-ultramafic, acid intrusive, volcanic, metasediment or alluvium). Leaves or phyllodes of over 20 genera (dominantly *Casuarina, Eucalyptus, Acacia, Callistemon* and *Melaleuca*) and the <250 µm fraction of the stream sediments were analysed by INAA.

There are around 2800 taxa of vascular flora in the region, with some uncommon species having less than five individuals recorded. The variation in climate and altitude within the region has given rise to complex phytogenetic patterns with some plants genera showing wide distribution (such as *Casuarina)* and others exhibiting highly restricted distributions.

The uptake of most trace elements varied between genera, with *Callistemon* displaying the highest median As and La contents and *Casuarina displaying* the highest Co contents. The stream sediment and vegetation geochemistry reflect both hydromorphic and mechanical dispersion within the region. The vegetation appears to be influenced to a greater extent by hydromorphic dispersion, as indicated by differences in the ratio of Cr concentrations between leaves and sediments collected from sub-catchments draining serpentinites and basalts.

Although most known mineral deposits in the region produced anomalies in one or other of the media, there was poor to insignificant correlation between the trace element concentrations of the vegetation and stream sediments on a site-by-site basis. A number of Au targets were only detected on the basis of the biogeochemistry and others were only reflected in the stream sediment geochemistry. Most of the known As mineralisation produced a response in both media. In general, vegetation displayed more extensive and consistent dispersion trains away from mineralisation than did the stream sediments. In many instance, trace element anomalies in vegetation extend further downstream than stream sediments. Differences in the response of the two sampling media suggests their joint use in exploration or environmental surveys should be considered, to maximise the probability of detecting mineralization in northeast NSW. Further orientation work to establish the optimum genera or species and the potential effects of seasonal variations on geochemical contrast, however, is essential before implementation of future biogeochemical exploration surveys in the region.

DISTRIBUTION AND DISPERSION OF MOLYBDENUM IN LAKE SEDIMENTS ADJACENT TO PORPHYRY MOLYBDENUM DEPOSITS, CENTRAL BRITISH COLUMBIA

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Lake sediment geochemistry is an effective tool to delineate regional geochemical patterns and anomalous metal concentrations related to mineral deposits in the Nechako Plateau region of central British Columbia, where mineral exploration has historically been limited by extensive drift cover and poor bedrock exposure. This study investigates geochemical controls on sediment metal distributions for three lakes and groups of lakes adjacent to sub-economic porphyry Mo prospects in the Endako region. These, Tatin Lake, Hanson Lake and the Counts Lakes, occur within Middle Jurassic felsic intrusives of the Francois Lake plutonic suite, a northwest-trending belt of predominantly quartz monzonite composition which hosts the Endako deposit and other porphyry Mo prospects. Objectives of the study are to determine: i) the extent to which lake sediment geochemistry reflects the presence of adjacent porphyry Mo prospects; ii) distribution patterns of Mo and other elements in lake sediments, and iii) the effectiveness of lake sediments as a regional Mo exploration medium.

Tatin Lake (max. depth: 19 m) is a large (4-5 km long) lake with three sub-basins. Temperature/oxygen profiles indicate that bottom waters are anoxic below depths of 15-17 m and that a wide range of limnological regimes are present, from eutrophic to oligotrophic. Quartz-molybdenite stockwork mineralization of the Ken porphyry Mo-Cu prospect occurs on the northwest side of the lake. The water column of Hanson Lake (max. depth: 7 m) is thermally unstratified, with sub-oxic to anoxic conditions occurring locally below 4-5 m depth in the single basin. Two mineral prospects occur nearby: the Hanson Lake Mo-Cu showing, a molybdenite-pyrite-chalcopyrite stockwork about 2.5 km south of the lake, and the Han and associated properties, which correspond to an extensive area of anomalous Zn-Pb-Cu soil geochemistry to the north and northwest. The Counts lakes are a group of small, mostly eutrophic, lakes and ponds in Counts Lakes valley south of Nithi Mountain. Five of these, informally named Nithi A-E here (range of depths: 1-10 m), are located downslope of known Mo prospects on Nithi Mountain.

Lake sediment samples were obtained at 145 sites using a Hornbrook-type torpedo sampler from an inflatable boat or canoe. Twenty dissolved oxygen and temperature profiles were conducted, at from one to five sites on each lake, to investigate water column stratification. Sediment samples were dried, disaggregated and pulverized in entirety to approximately -150 mesh in a ceramic ring mill. One subsample was analyzed for Mo, Zn, Cu, As, Fe and 25 additional elements, plus loss on ignition, by inductively coupled plasma-atomic emission spectrometry (ICP-AES) following aqua regia digestion. A second subsample was analyzed for Au, As, Sb and other elements by instrumental neutron activation analysis (INAA).

Sediments at Tatin, Hanson and the Counts Lakes contain elevated median Mo concentrations of 8 ppm (max: 23 ppm), 7 ppm (max: 55 ppm) and 42 ppm (max: 165 ppm), respectively relative to regional background of about 1-2 ppm Mo. Mo distribution patterns are influenced by proximity to mineralization, basin morphology and by limnological variations, as well as by the high organic matter content of centre-basin sediments. In each case, the lateral distribution of these patterns in lake sediments reflect the locations of adjacent quartz-molybdenite veins and their dispersed remnants in till and soil. They are interpreted to be of hydromorphic origin, with Mo likely transported to lake basins in sub-surface ground water and, to a lesser extent, stream water prior to complexing by profundal organic sediments. The most complex Mo geochemical patterns occur in Tatin Lake, where there is considerable between-basin variation in Mo content. Most of the highest Mo concentrations here are in the west end of the lake, in near-shore shallow-water organic sediments (12-14 ppm) near the Ken occurrence and in profundal sediments of the westerly-most sub-basin (up to 14 ppm). There is a close association between Mo and LOI distributions, and distribution of Mo is roughly inverse to that of Fe and Mn. Mo is relatively normally distributed in Hanson lake sediment, and elevated concentrations (11-18 ppm) are closely associated with centre-lake profundal sediments. In the smaller Counts lakes, sediment geochemical patterns are strongly influenced by proximity to the Nithi Mountain Mo prospects. The highest Mo concentrations, up to 165 ppm, are in the westernmost ponds immediately downslope of known mineralization. Even relatively low Mo values here are considerably greater than those present in most Nechako Plateau lakes. Differences between background Mo concentrations and those of the Counts lakes are even more pronounced when only profundal centre-lake or centre-basin sites are considered. Centre-basin results from Tatin Lake (12 ppm, 7-10 ppm, 23 ppm), Hanson Lake (11-12 ppm) and the Counts lakes (Nithi A-49 ppm; Nithi B-160 ppm; Nithi C-60 ppm; Nithi D-33 ppm, 38 ppm, 56 ppm, 54 ppm; Nithi E-83 ppm) exceed regional background by 3-80x. These results are more comparable to those of centre-lake sediments obtained during regional helicopter-borne surveys than are median Mo values for entire lakes, which may be skewed downward by the typically-lower metal contents of near-shore clastic-rich sediments.

Elevated lake sediment Mo concentrations of 12 ppm or greater in centre-basin sediments reflect, in these cases, the presence of adjacent porphyry-style Mo mineralization. Centre-lake sediments do not always contain however the highest Mo concentrations near areas of Mo mineralization, due in part to the range of limnological environments which may exist among separate sub-basins of a lake and, on a smaller scale, to the presence of near-shore Mo zoning patterns of hydromorphic origin which may occur downslope and down drainage of oxidizing mineralization. The presence of near-shore, as well as centre-lake, Mo anomalies have important implications for the implementation of lake sediment geochemical surveys. Centre-lake sampling of each lake and sub-basin is recommended for regional surveys. In the case of more detailed follow-up surveys, near-shore sediments along lake margins should also be sampled, particularly at base of slope and adjacent to drainage inflows, as general directions toward buried mineralization may be inferred from the orientation of lateral zoning patterns.

POTENTIAL NATURAL GEOCHEMICAL HAZARDS IN CANADA

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In virtually every geologic terrane in Canada, areas where sediments and water contain naturally elevated trace element levels have been identified during geochemical surveys and during bedrock and surficial mapping projects. These areas range in size from a few hectares to several thousand square kilometres and they include areas of wilderness, parkland, and farmland. Their geologic sources are usually simple to understand, but their potential effects on humans, the food web, and wildlife are less well understood. This is because most environmental scientists and even most geoscientists are unaware of their existence and because "Entry Assessments" and "Exposure Assessments" have not been conducted. This creates a large research gap that will only be filled by multidisciplinary teams investigating metal movement from the geosphere to the biosphere.

Several elements on the Canadian Environmental Protection Act (CEPA) Priority Substances List are naturally occurring. It has taken a great deal of effort to have this recognized and stated in CEPA documents and in the Toxic Substances Management Policy. Many of these elements occur in these naturally metal-rich areas at levels above national sediment and water quality guidelines. This has important implications for the minerals industry: high natural background areas are more complex to explore geochemically; establishing a pre-mining geochemical baseline or operating a mine/mill are more difficult in the face of sediment and water quality guidelines that are unattainable; and distinguishing natural from anthropogenic loadings on the environment or designing a closure plan is difficult when high natural levels are not credible and mining/smelting has already been under way for decades. Issues like these create a second research gap.

We view the geoscientist's role in this field as consisting of: documenting every new natural geochemical "hazard"; filling the research gaps; and communicating inside and outside of our normal science and business groups. Several potential geochemical hazards are described in the Geological Hazards Atlas (in press), which will make information on hazards more accessible to a wide audience.

Areas and materials in Canada having naturally elevated trace element levels will be described in this presentation. They include: the Buchans area, NF; parts of the South Mountain Batholith, NS; parts of the Meguma Terrane, NS; the Salmon River Valley, NS; parts of the Eastern Townships, QC; the Grenville Metasedimentary Belt, ON; the Lockport Formation, ON; some Muskoka Lakes, ON; the Rove Formation, ON; some Prairie soils, MB and SK; and the Pinchi Fault, BC.

* protect the mining industry from spurious charges of pollution by documenting natural areas of metal enrichment.

- discussed Canadian soil quality guidelines.
- release mechanisms (natural) for metals from soils - wind - fire - landslides - dust storms etc...

INVESTIGATION OF THE EFFECTS OF WATERSHED DISTURBANCE ON HEAVY MINERAL-GEOCHEMICAL SIGNATURES IN TROPICAL STREAMS: IMPLICATIONS FOR MINERAL EXPLORATION SURVEYS

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Stream sediment geochemical surveys are well-suited to mineral exploration in tropical rain forests. However, there is evidence that watershed disturbance can increase sediment loads and thereby dilute or even eliminate geochemical anomalies that, under natural conditions, result from the preferential concentration of heavy minerals by streams. To investigate this and other factors influencing background and threshold values in rainforest streams, sediments have been collected from disturbed and undisturbed watersheds on the Kuamut Formation in the Danum Valley, Sabah, Malaysia.

In the laboratory a <2mm portion was wet screened to obtain the abundance of the 0.424-2 mm, 0.212-0.424 mm, 0.053-0.212 mm and –0.053 mm size fractions, and the magnetic 0.053-0.212 mm fraction. Another portion was wet sieved to obtain the –0.212 mm fraction for analysis by ICP-ES after a total decomposition using HF-HCl-HNO$_3$. Mineralogy of the sediments and heavy mineral concentrates was determined by X-ray diffraction.

Results show that although average concentrations of many elements are significantly higher in sediments from unlogged versus logged watersheds, the differences do not simple relate to the effects of logging. Correlation coefficients for the complete data set show two main trends: (i) concentrations of Ca-Mg-Ti-Co-Cr-Sr-V increase with increasing abundance of magnetite; and (ii) K-Ba correlate with abundance of fine (< 0.053 mm) sediment. However, a scatterplot of Ti vs K (as geochemical surrogates for magnetite vs fines) shows much more complex relations than indicated by the

Kay Fletcher

overall correlations. Most importantly, the Ti-K correlations can be negative or positive depending on which drainage basin the sediments are from. Furthermore, trends in concentration of many trace elements follow the Ti-K trends within individual drainage basins.

Insofar as all the streams are on a single geological unit, the presence of distinct linear trends in the scatterplots implies that the composition of the sediments is being systematically modified in a variety of ways. The association between magnetite-Ca-Mg-Ti-Co-Cr-Sr-V (and negative correlation with K-Ba) is best developed in the two largest streams and most likely results from fluvial processes that concentrate heavy minerals and eliminate fines from the streambed. Conversely, field observations suggest that a trend for Ti-K, together with many other elements, to be positively correlated at low concentrations of Ti depends on whether the sediment source is dominated by bedrock or by regolith supplied from recent mass wasting events.

In a traditional approach to interpretation of geochemical data, sediments would be classified by their bedrock source, and background and threshold values determined for each geological unit. Here, however, background is also controlled by the nature of the sediment source and by sedimentological processes that concentrate heavy minerals. The effects of the latter can be recognized by the high magnetite (or Ti) content of the sediments. Alternatively, variations in trace elements concentrations related to heavy mineral content can be estimated using magnetite (or Ti) and fines (or K) as independent variables in multiple regression analysis. Use of this relation tends, however, to hide the more subtle geochemical variations related to the sediment source. These effects are best recognized and interpreted in X-Y-Z scatterplots where Z is the trace element of interest, and X and Y, in this case K and Ti, are estimators of source and process effects, respectively.

- K is correlated with texture, K is good surrogate for content of fines in a sample (by total digestion)
- high fines = dilution - could be landslide?

MIGRATION PROCESSES OF SOLUBLE AND COLLOIDAL GOLD IN A MINERALIZED CATCHMENT OF AMAZONIA

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Hydrochemical monitoring of the Yaou catchment in French Guiana was carried out so as to model the processes of gold dispersion in Amazonia. The 25 ha catchment is entirely covered by a rainforest laterite profile and about 10% of the area contains gold mineralization. The measurement system, installed during a complete hydrological cycle, allowed the runoff waters to be sampled at the basin outlet and the soil pore waters and groundwaters to be sampled in the mineralized weathering profile.

Gold analysis was carried out on solutions filtered at 0.1 and 0.45 µm and on suspended matter of the runoff waters in order to determine the amounts of dissolved and colloidal gold in the different reservoirs of the catchment. The gold concentrations in all the solutions were found to be mainly due to the presence of colloids between 0.1 and 0.45 µm in size. Moreover, the flux of colloidal gold was found to be independent of the suspended matter load, which proves that the gold colloids are not exported as suspended matter onto mineral or organic particles. At the basin outlet, the proportions of dissolved and colloidal gold are estimated at 30 and 70%, respectively.

The gold concentration in the soil pore water above the deposit is between 10 and 20 ppt in the humiferous horizon at 0.5 m depth and falls to less than 10 ppt in the B horizon at 1 m depth (Fig. 1). This corroborates the gold morphology observations, which reveal intense gold corrosion in the humiferous horizon and secondary gold reprecipitation in the B horizon. The groundwater draining the deposit contains about 15 ppt colloidal gold (between 0.1 and 0.45 µm), with a maximum of 60 ppt the oxidation front in the sulphide mineralization at 25 m depth (Fig. 1).

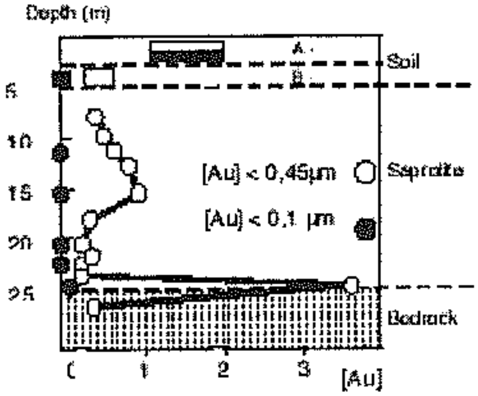

Figure 1 : Distribution of gold concentrations for solution filtered at 0.1 and 0.45 µm in the soil and in the groundwater within the mineralized saprolite.

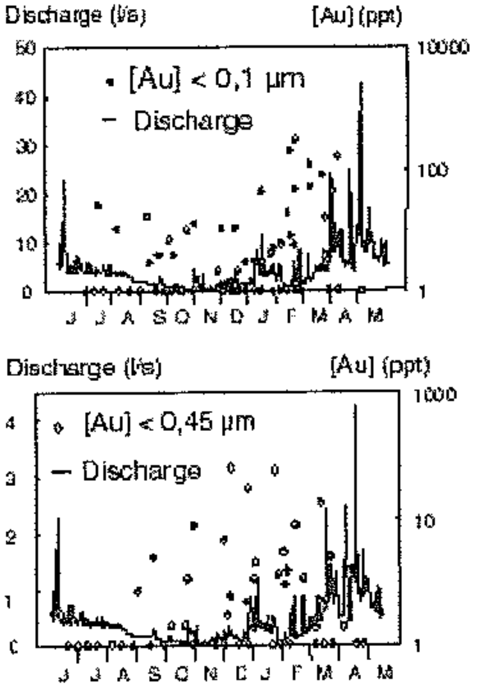

Figure 2 : Variations of discharge and gold concentrations (solutions filtered at 0.1 and 0.45 µm) at the bassin outlet during one year of monitoring.

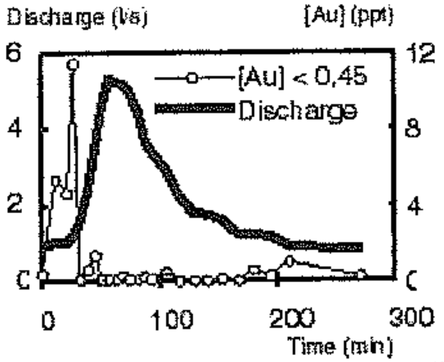

Figure 3 : Variations of gold concentrations during a peak discharge events.

The average gold concentration at the basin outlet over the year was about 50 ppt, but showed marked seasonal variations, with the highest concentrations occurring at the beginning of the wet season (Fig. 2). This means that the soil pore waters must be relatively concentrated after the dry season and then leached by surficial runoff. Similarly, gold concentration was seen to rise sharply for a few minutes during peak discharge events in response to the arrival of surficial runoff having leached the ground litter (Fig. 3).

The flux of gold transported to the basin outlet is estimated at 0.24 g/ha/y. This is the resultant of the contribution of gold liberated at the oxidation front of the mineralization and that leached from the soils. Chemical tracers used to assess the contribution of the different basin reservoirs to the gold flux showed that a major part of the gold transported out of the basin is supplied by shallow runoff in the soil, and a minor part is supplied by groundwater draining the saprolite.

USE OF PARTIAL EXTRACTION FOR EXPLORATION IN AREAS OF TRANSPORTED COVER, YILGARN CRATON, WESTERN AUSTRALIA

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Many new extraction techniques are claimed to be effective in the location of buried or otherwise hidden mineralization. If effective, these would offer an inexpensive method for exploring areas of transported overburden. This study examined the chemistry of these extractions and their usefulness on the Yilgarn Craton, particularly in areas of extensive transported overburden. Seven contrasting sites have been tested, grouped geographically as follows:

(i)*Northern* (northern Yilgarn and margins) - Harmony, Fender and Bronzewing;
(ii)*Central* (close to and north of the Menzies line) - Curara and Safari;
(iii)*Kalgoorlie region* (south of the Menzies line in the eastern Yilgarn) - Steinway and Apollo.

Soils were sampled along traverses, air dried, sieved to < 2 mm, and extracted with various reagents. *Sequential selective extractions* are used to dissolve specific minerals: (i) pH 5 acetate reagent extracts carbonate and surface adsorbed elements; (ii) 0.1 M hydroxylamine dissolves separate phase Mn oxides with Co and, partially, Ba and Ni; (iii) 0.25 M hydroxylamine dissolves 'amorphous' Fe oxides, with Ag, Be, Cu, Pb, REE, and, partially, Ba, Cd, Co, Mn, U and Zn.

A *HCl reagent* uses 4 M HCl (15°C for 4 hours), with an oxidizing agent, to give an "enhanced" Au digest. Except for Au, this reagent dissolves similar elemental concentrations to that of the sum of the sequential extractions, with minor exceptions for Co, Ce, Ba and Fe. An *iodide extraction* is a weak extraction (0.1 M KI, pH 7.4) developed to test soluble soil Au.

Mobile metal ion analysis (MMI; ® Wamtech Pty Ltd.) consists of two separate techniques. The first, an acid extraction for Cd, Cu, Pb, Zn, gives similar comparative results to selective and HCl extractions. The carbonate-rich Kalgoorlie soils give much lower MMI responses, probably because high carbonate neutralizes the reagent. The second method is an alkaline extraction for Ag, Au, Co, Ni and Pd, with virtually identical Au results to the iodide and enhanced HCl extractions. In carbonate-rich soils, these extractants dissolve 70 - 80% of the total Au, with significantly lower proportions extracted in the northern sites, probably because of occlusion of Au. MMI is also very effective at dissolving Ag and therefore does not give any additional exploration information for Au or Ag than can not be obtained using total or standard (*e.g.*, cyanide or *aqua regia*) analyses.

Enzyme Leach utilizes a reaction between glucose oxidase and dextrose to produce low concentrations of hydrogen peroxide to leach amorphous Mn oxides. The proportion of Mn extracted by Enzyme Leach varies considerably between sites, from about 20% at Bronzewing to < 0.5% at Steinway. Although a wide range of elements were analysed, many elements, namely Cs, Ga, Fe, Hf, La, Nb, Pb, REE, Sc, Sn, Th, Ti and Zr, show very close correlations. This may be due to a highly specific interaction between these elements in particular soil phase(s) or an analytical interference from Fe. This should be checked before these elements are routinely used.

At the **Harmony** site there is 0.5 - 3 m of colluvium over mineralized ferruginous saprolite, and there has been sufficient mechanical or biological mixing to bring some Au to the surface where colluvium is thin. There is up to 15 ppb Au in soils over mineralization, and MMI and HCl digests both give useful results. However, these reagents dissolve most of the accessible Au, and total Au gives equivalent results. No other elements appear to give useful exploration data. Enzyme Leach I and Cu weakly correlate with mineralization in one of the two traverses, and MMI Ni on the other. However, the poor repeatability, absence of any clear reason for I, Cu and Ni correlating with mineralization, and lack of success at other sites, suggest these correlations are not significant. **Fender** has 2 - 8 m of sand and silty clay over mineralization. Total and extractable Au in the soils peak over mineralization on one Au-rich traverse, probably due to the thin cover. No other elements (total or extractable) correlate with mineralization. Aside from Au, all 3 traverses (one of which is over Au-depleted saprolite) give similar results, despite the major variation in the magnitude of mineralization. There is a false positive anomaly (Ag+Cd+Cu+Pb+Zn+W) for the eastern-most sample of the Au-poor traverse. Mineralization at **Bronzewing** is covered by 5 - 25 m of colluvium and alluvium, with no significant Au anomaly at surface. Enzyme leach Cu correlates (weakly) with mineralization, though this could be coincidental. The chemical signal is stronger in soils in a nearby ephemeral drainage channel than over mineralization (*i.e.*, a false positive), possibly related to Mn.

At **Curara** active drainage systems in the area have high concentrations of Mn oxides (≤ 500 ppm Mn) and amorphous Fe (≤ 600 ppm Fe), with anomalous responses for a wide range of elements. In 2 of the 8 traverses tested, the drainage overlies the buried mineralization, giving a good correlation of element concentration with buried mineralization, which is apparently coincidental. The **Safari** traverse has 4 - 6 m sandy calcareous cover over Au-rich saprolite. Total and extractable Au in the soils (by most methods) peak over mineralization, probably because the cover is thin. Tungsten also appears correlated with mineralization, though not as closely as Au. No other elements correlate with the position of mineralization. Distributions of Ce, Co, Cu, Ni, Pb and Zn appear to be weakly correlated with that of extractable Mn or Fe, for some extractions.

Mineralization at **Steinway** is overlain by 5 m of leached saprolite and 25 m of palaeochannel sediments. Despite this, total Au peaks at 155 ppb, approximately 100 m E of mineralization. Unlike all other soils, this sample shows relative solubility differences in the order MMI > Iodide > 4 M HCl. Thus, for example, HCl dissolves only 11% of the total Au in this soil sample, but 73 ± 18% of the total Au for other samples in the traverse. This lesser Au solubility suggests the Au is primary and physically transported. Total and extractable Ag also show a well-defined peak, though 80 m to the W of the main Au peak. Total and HCl extractable W also overlie mineralization. This suggests that the Au, Ag and W anomalies are probably due to physical transport of Au-bearing detritus, possibly from outcropping mineralization approximately 1 km south of Steinway (Lintern and Gray, 1995a). Transported lateritic gravels containing Au grains occur beneath the calcareous top-soils. The **Apollo** site has 5 - 10 m transported cover over 10 - 30 m variably leached saprolite and saprock. Gold concentrations show no correlation with buried mineralization. There is a major anomaly in highly soluble Zn (550 ppm) directly overlying mineralization. A second Ag+Cd+Cu+W anomaly was observed for the western-most soil, again with moderate to high solubilities. These anomalies could be explained by elemental dispersion from weathering sulphides north of the traverse, with precipitation associated with or within the pervasive soil calcite.

The extraction methods are highly site-specific, possibly due to the nature of the soil matrix, (such as carbonates, Mn oxides or 'amorphous' Fe oxides) landscape position, and presence of present-day drainage channels. The groundwater conditions vary considerably from fresh and neutral in the northern sites, to highly saline and acid in the Kalgoorlie area, with major consequences for element transport. Another factor that can vary significantly in arid environments is the amount of organic material. The depth of transported cover appears particularly significant, with sites with greater than 10 m transported material not showing any Au anomaly at surface associated with the mineralization. Generally, partial extractions showed either false positive anomalies, or little ability to show buried mineralization, except where totals would work anyway. Although these methods may give better signal-to-noise ratios, or make subtle anomalies more obvious, they do not appear to offer any major advantages for Au exploration in areas of transported overburden on the Yilgarn.

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THE DIFFERENTIATION OF SAMPLE MEDIA TYPES AND MINERALIZATION FROM MULTI-ELEMENT GEOCHEMISTRY USING MULTIVARIATE METHODS AND DIGITAL TOPOGRAPHY

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Multi-element geochemical data can be effectively interpreted through the application of multivariate statistical techniques, imaging methods and integration with digital topographic information. These techniques have been applied to a suite of 1,665 soil samples collected in a sampling program from the central Sumatra area of Indonesia. The selected samples were analyzed for Au, Cu, Pb, Zn, As, Sb, Ba, Ca, Cd, Co, Cr, Fe, Ga, K, La, Li, Mg, Mn, Nb, Ni, Sc, Sr, Ti, V, Y, and Zr using aqua regia digestion followed by ICP-ES determination.

Plan maps of individual elements proved difficult to interpret with several elements displaying bimodal populations. The spatial patterns of individual elements appeared to be discontinuous and raised suspicion that the bimodal population reflected differences in sample media rather than features related to lithology or mineralization.

Statistical methods were employed to evaluate the hypothesis of differences in sample media types. Principal components analysis identified several distinct element associations and populations. The application of cluster analysis techniques confirmed two distinct populations of sample media and the use of fractal methods displayed two spatially distinct populations of samples.

The application of principal components resulted in three significant multi-element associations and spatial patterns:

- a pattern reflecting sample media types (saprolite and volcanic ash) occurring as two geochemical populations,
- a pattern associated with saprolitic soils reflecting elevated Cu concentrations hosted by mafic volcanic rocks, and
- a precious metal signature associated with the saprolitic soils possibly reflecting local epithermal processes

The scores of each principal component were interpolated, imaged and plotted as plan maps. The primary pattern of apparent sample media types (first principal component) was difficult to interpret in plan view and did not appear to reflect any lithological or known mineralization trends. A pattern of Cu and associated mafic volcanic rocks (second principal component) is coincident with the regional northwest trending lithological patterns in the area. A precious metal signature (third principal component) appears to be localized and does not have any apparent regional lithological association but may reflect smaller scale epithermal processes.

A digital elevation model with a resolution of 10 meters was integrated with the results of the principal components analysis. The two populations of samples that occur within the first principal component show very distinct spatial characteristics. The population of samples, interpreted to be volcanic ash, occurs along hill tops slopes and drainage channels and overly the saprolitic soil profile.

The zone of elevated Cu enrichment associated with mafic volcanics trends northwesterly along the western slopes and is coincident with the regional stratigraphy. Both the Cu signature associated with mafic volcanics and the precious metal signature are associated with the saprolitic soils.

The spatial patterns of the two populations (saprolite and ash) were evaluated using fractal methods. Both populations are spatially distinct and can be inferred to reflect different processes.

This results of this study indicate that given a suitable multi-element set of data, the application of multivariate techniques, fractal analysis and integration with digital topography provides significantly more information than can be determined by evaluating single elements and standard plan view maps. The application of these techniques also provides a more effective way of visualizing and interpreting multi-element geochemical data.

GOLD EXPLORATION USING KNOWLEDGE-BASED PROSPECTIVITY ANALYSIS OF MULTIVARIATE DATA

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Multidataset analysis using GIS procedures, underpinned by soundly-based deposit models, provides a firm foundation for planning mineral exploration programmes. However, the quantity and diversity of information relevant to exploration demands systems which maximise their utility through the application of quantitative, consistent and objective techniques. To meet this need BGS has developed a knowledge-based system (XMAP) for mineral prospectivity mapping based on various data types: point, vector, polygon, grid and event. The package combines data populations of various types each with its own weight, style and zone of influence in relation to the occurrence pixel. Boolean and fuzzy logic data models are used to integrate the quantified spatial relationships into a single prospectivity map showing the distribution of relative favourability for the occurrence of a mineral deposit. The system allows incorporation of any number of selection criteria each weighted according to user preference or the significance inferred from the deposit model.

The first stage of the analysis involves definition of key exploration criteria derived from empirical observations and deposit models. Available digital spatial datasets are assessed in relation to these criteria. Capture of new pertinent geoscience data and the reassessment of existing derived data may also be undertaken at this stage. Further data manipulation is carried out to maximise the utility of the information relevant to specific deposit types. For geochemical data this may involve simple filtering above selected thresholds or calculation of elemental ratios. The generation of new event datasets may also be useful. For example, the points of intersection of various lineations windowed to particular azimuths may reflect important controls on the distribution of certain types of gold deposits. Additional functionality is also available to meet the needs of specific models. This includes routines which can derive structural data from the geological map. For example, a curvature routine to identify fold axes is used in mapping the prospectivity for slate-belt type gold deposits in certain terranes.

XMAP has been used to map the potential for mesothermal lode gold mineralisation in the Neoproterozoic Dalradian terrane of the Grampian Highlands of Scotland. Selection criteria were derived from published models and from detailed assessment of the locational controls on known lode gold occurrences. The following key regional features were taken into account: tectonic setting, regional structure, regional geochemistry, stratigraphy, lithology, buried intrusions and their contacts. Parameters which provide information on these features were extracted from regional and local-scale datasets held on relational databases at BGS. The parameters of greatest utility included: geology (lithology, age); geochemistry (trace element distributions in stream sediments, especially As, Sb and Bi); geophysics (lineations from regional aeromagnetic and gravity surveys, positive residual polar magnetic anomalies, Bouguer gravity anomalies); remote-sensing (lineations from satellite images and topographic maps); and mineral occurrence data (metalliferous mineralisation in bedrock, incidence of gold grains in heavy mineral concentrates). The distribution of selected parameters used in the analysis are shown in Figure 1 for the south Loch Tay area of the Dalradian belt. The corresponding derived prospectivity distribution is shown in grey tones on the same figure.

XMAP is a versatile and powerful tool for the identification and ranking of prospective targets and for the estimation of mineral potential. The quality of the derived prospectivity maps is dependent on the reliability of mineral deposit models and the availability of relevant, high quality data. As our understanding of metallogenesis improves and more digital datasets become available, so more reliable exploration criteria can be defined and the system can be applied with greater confidence to a range of deposit types. In this way expensive field exploration programmes can be focused more effectively leading to cost reductions for industry.

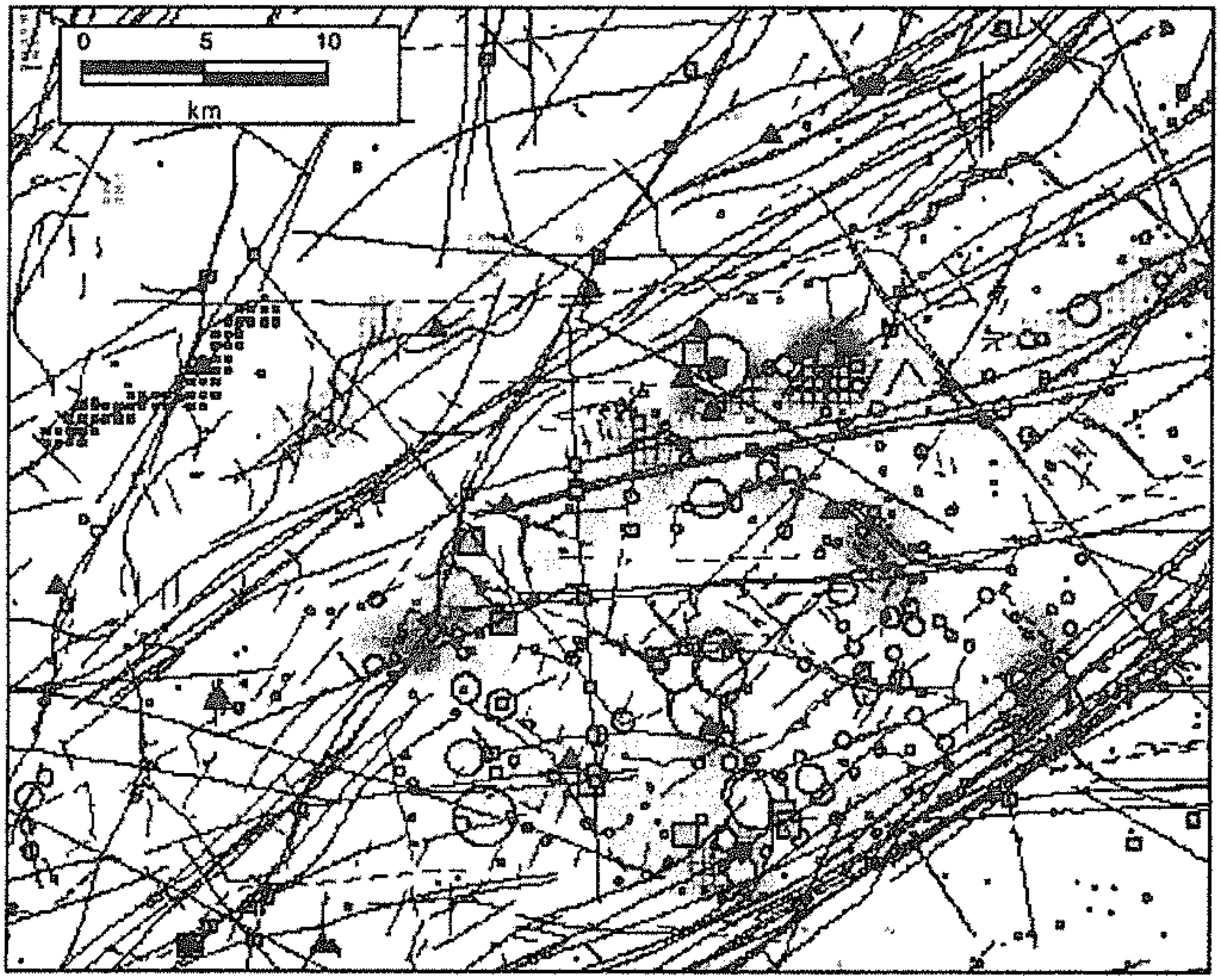

Figure 1: The south Loch Tay area of the Dalradian terrane showing multiple exploration datasets and derived gold prospectivity. Explanation: prospectivity for lode gold deposits shown grey, the darker the tone the greater the prospectivity. Heavy black lines, faults; other lines, aeromagnetic, gravity and Landsat TM lineations; large squares, gold in bedrock; intermediate squares, gold in concentrate; small squares, intersections of north-trending faults and east-west aeromagnetic lineations; triangles, base-metal occurances in bedrock; proportional circles, arsenic concentration in stream sediments; inverted triangles, antimony >3 ppm in stream sediments; coarse grey stipple, residual total magnetic intensity >30 nT; coarse black stipple, Bouguer gravity gradient >5 mGal km^{-1}.

FIELD DATA IN SUPPORT OF AN ELECTROCHEMICAL TRANSPORT MECHANISM IN THE FORMATION OF SELECTIVE LEACH GEOCHEMICAL ANOMALIES

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In recent years, there has been growing interest in geochemical exploration methods capable of detecting mineralisation concealed by thick overburden. Selective leach analytical procedures have produced promising though mixed results. Both the morphology and elemental assemblages of anomalies have been shown to be difficult to predict and to reproduce from one deposit to another. One of the principal hindrances to the interpretation of selective leach geochemical anomalies in thick overburden is that there is no widely accepted mechanism for their formation. In particular, the young age (10 Ka) and excessive thicknesses of many North American glacial deposits requires that a very fast geochemical transport process operates in these environments. A recent electrochemical model developed by the Ontario Geological Survey accounts for many of the phenomena reported for selective leach anomalies and predicts a number of others. A brief overview of the model will be presented and recent field data that corroborates it will be discussed. The field data include two and three-dimensional redox and SP data from two gold deposits in Northern Ontario and corresponding surficial geochemical results. The data show remarkable correlation with theory as predicted by the model.

MULTI-MEDIA COMPARISON OF GEOCHEMICAL DATA FOR MINERAL EXPLORATION: PART 1 - VARIATIONS DUE TO PRECISION, ANALYTICAL METHOD AND SIZE FRACTION

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In any exploration program employing geochemical data use of stringent quality control procedures in the data collection and analytical process is paramount. Without proper control measures the results obtained from analysis cannot be considered fully reliable. A lack of quality control can translate into a waste of time and money as false anomalies due to improper data collection and laboratory analysis techniques may arise. Secondly, variation in results may arise from different analytical methods and digestion methods used in the laboratory. Thirdly, different results may be obtained over the same area, from separate geochemical surveys conducted over time, even when the same analytical methods have been used. Variations in results can also be expected depending on the size fraction of the particular geochemical media analysed.

This study has four primary objectives:

1. to analyse a Quaternary geochemical dataset with respect to precision and accuracy using simple statistical, spatial, graphical and visualization techniques within a GIS
2. to study the effects of different analytical methods, using the same geochemical dataset, with respect to the statistical and spatial delineation of geochemical anomalies
3. to study the statistical and spatial variations, with respect to the delineation of geochemical anomalies, using two different geochemical datasets collected 10 years apart over the same geographic area

4. to study the differences, with respect to delineation of geochemical anomalies, between different till size fractions (clay vs. clay-silt)

A Quaternary geochemical dataset collected by the Geological Survey of Ontario over the Swayze Greenstone Belt, southwest of Timmins, Ontario, is used to address the first objective. The geochemical data were sampled from till (C-horizon), soil (B-horizon) and humus. Exploration interest in the area focuses on base metals and Au, therefore, Cu, Zn, Pb, Ni, Au and As are analysed with respect to variations in analytical precision and accuracy using a series of split duplicates and reference standards. Two till geochemical datasets (GSC Open Files 2578 and 3205), collected in the Northwest Territories by the Geological Survey of Canada, were used for objectives two, three and four. Exploration interest in this area is focused on diamonds, therefore common pathfinder elements such as Ba, Cr and Ni are studied.

A GIS (Arc/Info) is used in concert with PC-based database and statistical analysis software to analyse (both statistically and spatially) and visualize the data.

Quality control measures applied to the dataset reveal that Cu, Zn, Pb, Ni and As are statistically and spatially well behaved and form a reliable dataset for exploration use. However, results of precision studies applied to the Au indicate that this element is not well behaved due primarily to the nugget or Au sparsity effect. Spatial plots of Au anomalies based on split duplicate populations reveal striking differences that should be accounted for before rigorous use in the exploration process.

Different analytical methods will result in different results on an element-to-element basis. Analysis of Ba indicates that a statistically significant difference exits between INAA, XRF and ES analyses. Different surveys of the same geographic area also are statistically different, depending on the specific element chosen for analysis. However when the data is normalized to take account of lithologic variations, relative differences are suppressed and the same anomalies, with respect to geographic locations, exist between each analytical method as well as different surveys.

RESOLVING THE EFFECTS OF DILUTION BY EXOTIC DEBRIS ON THE GEOCHEMICAL SIGNATURE OF TILLS OVERLYING THE MACQUOID GREENSTONE BELT, NUNAVUT, CANADA

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Since the 1970's, studies of surficial deposits in northern Canada by the Geological Survey of Canada have focused on establishing a Quaternary geological basis for mineral exploration by drift prospecting, using an approach which combines both surficial geology mapping and till sampling at the regional and detailed scale (Shilts 1971, 1973, 1977; Ridler and Shilts, 1974; Aylsworth and Shilts, 1989; DiLabio, 1979; Klassen, 1995). Results of compositional analyses of till collected during these studies have been used to interpret ice flow history and glacial dispersal trends within an area extending from latitude 58°N to 66°N, and longitude 97°W to Hudson Bay. On this regional scale, a dispersal train of distinctive red erratics derived from known bedrock sources, the Proterozoic Dubawnt Supergroup, has been defined (Kaszycki and Shilts, 1980). Because rocks of the Dubawnt Supergroup are more easily eroded than other Shield lithologies, the dispersal train extends over 200 km southeasterly from the bedrock source to Hudson Bay, parallel to the major ice flow direction. Dubawnt-rich tills bury several Archean greenstone belts within the area and depress the geochemical signature derived from the local bedrock with relatively geochemically-inert exotic debris. This paper will focus on methods for estimating these dilution effects and for revealing the local bedrock geochemical signature in Dubawnt-rich till overlying the MacQuoid greenstone belt, an area of potential mineralization.

As part of a regional surficial geology mapping and till sampling project conducted in the MacQuoid greenstone belt in 1998, seven composite till samples were collected along a transect oriented parallel to the dominant ice flow direction (140°) and within the

Dubawnt dispersal train (Klassen, 1995). Samples of the local bedrock were also collected at each site, where possible. From northwest to southeast, the transect sites overlie arkosic sandstone (Dubawnt Supergroup) (sites 1-3) and felsic volcanics (site 4 and 7), granitoid intrusive rocks (site 5), and mafic intrusive rocks (site 6) of the MacQuoid greenstone belt. In addition, two composite samples overlying Archean granitoid rocks were collected down-ice from volcaniclastic rocks within the Dubawnt Supergroup.

Using this suite of samples, three methods of estimating the dilution effects of Dubawnt debris were assessed:

1. Size partitioning - geochemical, mineralogical and, where appropriate, lithological analysis of various size fractions of both till and crushed bedrock samples (i.e. <0.002mm, 0.002-0.063mm, 0.063-0.125mm, 0.125-0.250mm, 0.250-2mm, 2-4mm).
2. Chemical partitioning – the application of various leaches prior to geochemical analyses (<0.063 and <2mm fraction) to determine the residence sites of elements.
3. Normative calculations – comparison of till geochemistry with lithogeochemistry. Theoretically, till is derived from local bedrock sources and deviation from the theoretical composition (Lestinen et al, 1996) can be an indication of dilution effects by exotic debris.

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Notes:

- best contrast in <0.002 µm fraction
- next best is <0.063 µm fraction
- partition diagrams generated for several size fractions.

SOIL GAS GEOCHEMICAL ORIENTATION STUDIES FOR MINERAL EXPLORATION THROUGH DEEP EXOTIC OVERBURDEN

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Exploration in the twenty-first century will be forced into areas blanketed with thick alluvium, glacial deposits, or volcanic flows. Soil gas geochemistry offers an opportunity to inexpensively prospect through that cover. As early as the 1950's the scientists of the former Soviet Union wrote of anomalous emissions of helium, argon, carbon dioxide, mercury, and other gases over various types of mineral deposits. Western scientists followed with their adaptations of the methods for detecting soil gases. The governing principle in this type of soil gas geochemistry is the process of oxidizing sulfide minerals. Oxidizing sulfide minerals generate acids that may react with the wallrocks of mineral deposits. Significant amounts of oxygen are consumed by this process, and large amounts of carbon dioxide may be generated. Since the average concentration of oxygen in the atmosphere is 21.0%, the technology exists to detect very subtle changes in the concentrations of oxygen in the soil air. The average atmospheric concentration of carbon dioxide is 0.036%, also well within the sensitivity of modern, portable instrumentation.

This study includes two geochemical orientation studies designed to characterize the carbon dioxide and oxygen soil gas responses over different types of mineral deposits, buried by different types of overburden, in different climates. The soil gas response over each 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 volcanogenic massive sulfide deposit in Wisconsin. The width and contrast of the anomalies observed at Crandon is superior to the soil geochemical response along the same traverses. Narrow anomalies in carbon dioxide and oxygen also occur over the Ruby Star copper-skarn deposit in Arizona. The anomalies are structurally controlled and appear to mark the edges of the copper mineralization.

A large, massive sulfide deposit, such as the Crandon deposit, is an excellent location to test soil gas geochemistry. At least two other soil gas studies have been conducted at Crandon. The Crandon deposit has published ore reserves of approximately 65 million tonnes grading 5.8% zinc and 1.4% copper. The deposit sub-outcrops beneath 20 to 60 meters of glacial deposits. The Ruby Star deposit is a structurally disrupted, porphyry copper skarn deposit. There is a drill-indicated resource of approximately 100 million tons containing nearly 1.0% copper. The mineralization is broken into large blocks suspended within a Tertiary conglomerate. Total depth of Tertiary conglomerate and Quaternary alluvium varies from 100 to 450 meters across the study area.

The precision of the soil gas data is relatively poor, and sample site variability is high. Repeated traverses, however, tend to generate very similar patterns. Repeated traverses that do not match well with the originals can be correlated with precipitation events or barometric pressure fluctuations. Base stations, therefore, are important aspects of quality control in soil gas surveys. The base station permits careful monitoring of background soil gas conditions and meteorologically induced fluctuations. Data collected at each sample site also includes temperature and barometric pressure. The meteorological data combined with the base station measurements are the ultimate determinants of data quality.

Carbon dioxide and oxygen reflected the Crandon mineralization on each traverse. On one traverse, the concentration of carbon dioxide in the soil gas reached approximately 3%, and oxygen levels were depleted by approximately 2.5% against a background depletion of 0.8%. Narrow soil anomalies in copper and zinc also occurred on that line, but the anomalies were barely distinguishable from background. The soil gas patterns were correlative between closely spaced lines, but the anomalies were often of different magnitudes. The soil gas anomalies at Crandon were broader and higher contrast than the soil anomalies, but the size and magnitude of the anomalies are not predictable.

The carbon dioxide and oxygen anomalies at Ruby Star were of modest magnitudes, carbon dioxide values in the soil gas approached 0.9 % with oxygen values depleted by 0.7%. However, the background values were much more subdued than at Crandon; the average background value for carbon dioxide and oxygen was 0.2 %. The soil gas anomalies were consistently higher contrast than the soil anomalies, but they did not necessarily define the surface projection of the mineralization. Soil gas anomalies at Ruby Star were often indicators of faults or the margins of mineralized bodies.

This soil gas technique is very effective at identifying deeply buried mineralization. In spite of different background levels of soil gas in different climates, clearly discernible patterns result from closely spaced sampling. Information about the presence of sulfide minerals and alteration along faults can be obtained from a soil gas survey. Weather conditions, however, must be given careful consideration when designing and conducting soil gas surveys. Precipitation and dramatic changes in barometric pressure can either enhance or subdue soil gas responses.

This study presents two additional successful trials of soil gas geochemistry as an exploration tool. In the past, successful trials in orientation surveys have failed to spawn large-scale application of the method in mineral exploration. High costs and impractical field methods were the likely culprits in preventing widespread use of soil gas geochemistry. The 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 overburden.

SURFACE WATER GEOCHEMISTRY: A METHOD TO DETECT BLIND MINERALIZATION IN AREAS OF THICK OVERBURDEN

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There is growing evidence for some natural process by which trace elements are mobilized in oxidizing bedrock, transported vertically to the earth's surface, and adsorbed on to mineral grains and humus in the soil. Assuming this is the case, it is also likely that some proportion of these mobile ions would enter the aqueous phase and could be detected by water analysis.

As part of a multi-media study, surface water was collected from 4 areas of known gold and base metal mineralization in NE Ontario, a region of extensive thick deposits of till, glacialfluvial sand, and glaciolacustrine clay. The areas studied include the Shoot Gold Zone in Taylor Township, several sub-economic gold zones in Hislop Township, the Holt-McDermott and Worvest Gold Deposits in Holloway Township, and the Patton base metal mineralization in Stimson Township.

Sample sites consisted of springs, small flowing streams, and either stagnant pools or excavated sumps in bogs. The pH and conductivity of the water was measured in-situ. The water samples were filtered to <0.45 um and acidified as necessary using ultrapure acids. The water was then analyzed for 58 elements by ICP-MS; for As, Sb, Se, and Hg by hydride generation/ICP-MS; Ca, Mg, Na, and K by ICP-ES; Cl and SO4 by ion chromatography; and alkalinity by titration.

The study results suggest that the collection and analysis of surface water samples would be an effective first pass approach to identifying blind exploration targets at the property scale. Multi-element anomalies were obtained over or down-drainage of all deposit areas studied. Element associations differed for the various deposits. Those elements which were observed to be anomalous include a chalcophile suite (Cu, Pb, Zn, Cd, As, Sb, Mo, Ga), a lithophile suite (Sn, W, Rb, U, Li, Sr, Ba), major anions (SO4, Br, Cl, I), and major cations (Ca, Mg, Na, K). Some of the areas were also characterized by natural acidity in the 3.5-5.5 range. Water pH only appeared to exhibit some control over the levels of the major cations and Pb, Zn, Cd, and Mo. However, anomalous residual concentrations above the background trend still occurred in the vicinity of mineralization.

The water anomalies were restricted in areal extent. The maximum down-drainage dispersion distance observed was in the order of 200-250 m. Consequently, the medium is more appropriate for property scale exploration. The recommended sample density is 50-100 m along all available drainage pathways.

NEW AG-CU DISCOVERY USING MERCURY VAPOR SOIL GAS DATA, COBRIZOS, SAN CRISTÓBAL, SOUTHERN BOLIVIA

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Mercury vapor anomalies in soil gas were drilled in the Cobrizos district, in the province of Sud Lipez, southwestern Bolivia. The results of drilling to date indicate approximately 10,600,000 tonnes of resource with 118 g/T Ag with Cu, and minor Zn and Pb. The prospect lies on the northern margin of the San Cristóbal volcanic massif. The hosts to the epithermal mineralization at Cobrizos are regional (Altiplano) continental basin sediments.

Cobrizos is located 80 km south of the southern Altiplano town of Uyuni, and 12 km north of San Cristóbal. The property contains an historic copper mine with minor production exploited first by Spanish colonizers. Exposure and historic exploitation is restricted to an area no greater than 300m by 500m, which is locally covered by tailings. The host rocks at Cobrizos are comprised of a series of dark-red to purple-red mature, dune-bedded sandstones and poorly indurated siltstones and shales of the Tertiary Potoco Formation. The central portion of the historic mine area forms a low (<20 m high), topographic elongate dome (100m by 200m) surrounded by alluvium of the Salar de Uyuni basin. Sub-horizontal, banded, and locally weakly silicified travertines overlie the red-beds. The travertines drape and dip quaquaversally around the dome, attaining a maximum preserved thickness of seven meters. This preservation indicates the youthfulness of the hydrothermal system. North of the dome, very young, green massive sandstones which contain angular fragments of silicified travertine (and mammalian fossils) indicate faulting, along approximately E-W strikes, and sedimentary reworking contemporaneous with hydrothermal activity.

Mineralization, observed at the surface and in drift and crosscut workings, occurs as veins, sheets, and disseminated native copper and copper carbonates and sulfates within the coarse competent sandstones, and as sheets, mantos, and veins within the Potoco shales. Silver mineralization is generally encountered at depth, and where sampled by drilling, consists primarily of native silver, chalcanthite and secondary argentite.

Mercury vapor in soil gas was sampled using buried mercury collectors (Quicksilver Systems design) consisting of a silver strip, a 2-part plastic mesh device which suspends the silver strip in the burial hole and a permeable cover, which reduces soil contact with the silver strip. 787 collector strips were placed in the field June 26 through June 30, 1996, and retrieved August 10 and 11, 1996 for an average exposure period of 45 days. Samples were placed on a 100-meter by 100-meter grid extending from the historic mining district in the southwestern portion of the grid to the north and east over a total area of 6.24 square km. Over the main district, stations were located on a 50 meter grid to ensure that the known mineralized area was well represented in the data set.

Mercury vapor analyses were performed in the laboratory. Mercury vapor is devolved from the collector strips by heating to 500°C in a Thermolyne tube furnace. The released mercury vapor is carried in a stream of air to a Jerome 511 Gold Film Mercury Vapor Analyzer for analysis.

The anomalous values, ≥5 ng (nanograms) Hg, represent about 11% of the data (76 sample sites of 723 total). The anomalous population has a mean value of 40.5 ng. The anomalous threshold value of 5 ng is 5 times the background mean of 0.98. A plot of mercury vapor values at Cobrizos shows a strong anomalous pattern over the exposed mineral district with a halo of anomalous values to the north and south and to a lesser degree to the west. Maximum dimensions of the anomalous area around the main district are about 900 by 250 meters. Northeast of the main district anomaly is a slightly more subdued linear anomaly, beginning 300 meters east of the northern limit of the main anomaly and continuing for about 2 kilometers to the northeast (N30E).

Exploration of the area surrounding the old copper mine at Cobrizos was conducted by testing the mercury vapor anomalies with seventeen drill holes. The results of drilling indicate an excellent correlation between ore mineralization and the mercury vapor anomalies. The combined silver ore (true) thickness is approximately 96 meters although the thickness varies greatly along strike. The two principal host sedimentary sequences are separated by a variable thickness (approximately <20m.) of essentially barren redbeds. A series of post-mineral faults disrupt the mineralized zones. The mineralized zones are clearly represented by areas of anomalous Hg vapor values, whereas the truncation of the ore bodies are identified by the corresponding absence of anomalous Hg vapor. Two additional targets, identified by anomalous mercury vapor values, remain untested by drilling.

The mercury vapor results show a strong anomalous pattern over the exposed mineral district, extending to the south and to the NNE, offset by EW or N55W buried faults. Drilling, targeted on these anomalies, has been highly successful in locating mineralization. Mercury vapor soil gas geochemistry has proved to be an ideal exploration method in this environment, particularly in the large areas of extensive overburden.

A QUATERNARY GEOLOGICAL ANALYSES OF TILL GEOCHEMISTRY IN LABRADOR AND EASTERN QUEBEC, CANADA

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In western Labrador, bedrock composition, glacial history, and subglacial processes associated with transport and deposition are reflected in regional scale (100's of km) surveys of till geochemistry. Compositional contrasts between igneous and metamorphic bedrock of the Canadian Shield and softer, little-metamorphosed bedrock of the Labrador Trough facilitate modeling glacial dispersal trains through lithological and geochemical analyses. Compared to till derived from Shield terrain, Labrador Trough till is finer-grained and is depleted in chromium and enriched in zinc, iron, and manganese. For elements such as iron and manganese, geochemical contrasts between 'Shield' and 'Trough' terrains can differ by as much as an order of magnitude. The study area is situated near one or more dispersal centres of the Labradorean Sector of the Laurentide Ice Sheet and has been subjected to a complex ice flow history, defined by striations and by transport pathways inferred from the distribution of indicator erratics that define glacial dispersal trains extending 50- >100 km outward in all directions from the Labrador Trough. Three glacial events characterized by different ice flow directions control drift composition, although their significance as controls on drift composition varies regionally. The last event is not always the principal control. In some areas the effects of multiple ice flow events and incorporation of 'recycled' glacial detritus are evident in till composition, whereas in others evidence for only one transporting event can be recognized, despite striation evidence indicating multiple ice flow directions.

Glacial effects and transport distances differ among elements, depending in part on their mineral association, the physical and chemical properties of the minerals hosting the trace metals, and on geochemical contrasts between bedrock terrains crossed by the ice. Glacial dispersal trains are evident in the exponential form of compositional profiles along ice flow paths, and by close linkages between lithological and geochemical properties of till. Trains can be mapped up to tens to hundreds of kilometres down-ice from their source terrains. The distance of glacial dispersal depends on the element chosen for analysis and its mineral and lithological associations, the size fraction used for geochemical analysis, and geochemical contrasts between source and background, among other factors. Where trace metals occur in lithic fragments resistant to glacial comminution, ongoing milling of coarse detritus can lengthen the dispersal distance determined through geochemical analyses of finer fractions. The effects of glacial 'masking' of underlying bedrock are dependent on the element analysed. For example, in Shield terrain adjacent to the Labrador Trough, chromium in bedrock is masked up to twenty kilometres down-ice from the Trough margin. In contrast, zinc concentrations in till closely reflect those of bedrock despite the high proportion of glacially transported debris in finer fractions. The work illustrates how the application of Quaternary geological principles, knowledge of glacial process, and glacial dispersal models can be applied to the interpretation of regional geochemical surveys of till.

THE ASSESSMENT OF SOIL HEAVY METAL CONTAMINATION AROUND AN ANCIENT MINING DISTRICT: NATURAL BACKGROUND OR AN ANTHROPOGENIC ANOMALY?

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Physical degradation of the soil is one of the main environmental issues as land contamination by heavy metals or organic products is increasing not only at urban sites but also in some rural areas. The importance of natural and man-made inputs of chemical elements in the surface environment in relation to the health of plants, animals and man is known and accepted. Researchers in the late 1980s and into the 1990s have been trying to address the fluxes of toxic elements in soil, water, dust and air together with their pathways to the target organism (Thornton, 1993).

Toxic elements rarely occur alone and their associations and interactions with one another and with other components of the environment are known to influence their availability to organisms and their ultimate toxicity. In recent years, advances in computer hardware and software intensified the application of quantitative analysis techniques that would otherwise be extremely tiresome and time consuming. Research into the analysis of soil chemistry information has utilised statistical analysis tools to assist the selection of optimum soil sampling patterns, to estimate measurement uncertainty due to sampling and chemical analysis and to assist in assessing the risk of soil contamination (Fergusson 1992, Goovaerts et al. 1997). Soil contamination research in the past has, in most cases, been quantitative in terms of levels of pollutants sampled and measured, however, the analysis of contamination has been limited to a descriptive evaluation of the sources of soil pollution (Davies and Ballinger, 1990; Li and Thornton, 1993). Therefore, the fundamental research question to be addressed in this field is the quantification of the extent of pollution, not just in levels of pollutants but also in terms of their geographic spread; the relationship between the pollutants that very often coexist; and the determination of the sources of pollutants.

One issue of major importance in soil contamination studies is to distinguish the natural background from anthropogenic anomalies. So far, this has been done by using different sample types such as different horizons of the soil profile or by comparing, statistically, rock and stream sediments, and soil analysis results (Selinus and Esbensen, 1995). However, these techniques are expensive and time consuming processes requiring vast amounts of data both from soil and baseline studies. Furthermore, these methods do not clearly associate specific sources with pollutants, and the estimation method allows only a qualitative interpretation of the results that cannot be applied in cases were baseline data is not available. Experience in contaminated land assessment and remediation has shown that both the industry and the regulatory authorities would require a comprehensive methodology for the quantitative assessment of soil quality and its spatial extent. The authors have developed a methodology which combines contemporary statistics, multivariate statistics and geostatistics with modern spatial data analysis techniques and geographic information systems (GIS) to meet these requirements, even for sites with complex background and poorly recorded history (Korre, 1997).

The methodology developed is illustrated using soil chemical analysis data from Lavrio old mine site, one of the oldest examples of mining activity in Europe. The mines are situated at the south-eastern part of the Attiki peninsula, about 60 km from Athens in Greece. The silver bearing structures around Lavrio were known and exploited for more than 25 centuries. As a result, the area around the ancient mines and processing plants is polluted with high heavy metal loads. The methodology developed enabled the authors to distinguish the naturally occurring high heavy metal loads from the human induced pollution in the area.

GOLD DISTRIBUTION IN GLACIAL SEDIMENTS AND SOILS AT BOSTON PROPERTY, NWT, CANADA

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Geochemical exploration for gold in the Slave Structural Province, NWT, Canada is hampered by Quaternary sediments and a lack of information on the effects of glacial dispersion and periglacial conditions. This study investigates distribution of gold in these surficial materials on the Boston Property in the southeastern portion of the Hope Bay Greenstone Belt, 650 km northeast of Yellowknife, NWT.

The principal surficial materials are till with a cover of post-glacial marine sediments infilling depressions. In areas of shallow cover, frost boils mix weathered bedrock with drift and bring bedrock fragments to the surface. Samples were collected from till and from soil profiles on lines across the mineralized zone. The -212 and –53 μm fractions were separated by wet sieving and heavy mineral concentrates (HMCs) prepared. Gold was determined by fire assay-atomic absorption spectroscopy (FA-AAS) or, for low concentrations, by an aqua-regia-column preconcentration-ICP procedure.

There are two types of gold anomalies: (i) glacial anomalies in the regional till; and (ii) anomalies developed by ongoing frost boil action and colluvial processes. Anomalies are absent where marine sediments are present. Gold values in the regional till range from 15 to 1030 ppb in -106+53 μm HMCs and from 10 to 65 ppb in the -53 μm fraction which contains ~60% of the total gold content. Anomalous values extend at least 2 km down-ice from the gold mineralization. In cross section the younger gold anomaly is mushroom-shaped, up to ~100 m wide at the surface, and drapes over a ridge of mineralized bedrock. The anomaly in near-surface horizons is 10-50 m broader than the anomaly in the underlying horizons. Maximum gold values (>5000 ppb) are found in areas of weathered bedrock and where frost boils include abundant fragments of mineralized bedrock.

For reconnaissance scale exploration, frost boils in the regional till can be sampled on a 500x40 m grid with lines perpendicular to the ice flow direction. The -53 µm fraction should be analyzed for gold with a detection of 1 ppb or lower. At the property scale, with much higher gold values, it is feasible to analyze the -212 µm fraction from near-surface samples collected at a 10-20 m spacing along grid lines 100 m apart.

THE INFLUENCE OF GLACIAL FLOW REVERSALS ON GEOCHEMICAL DISPERSAL IN THE CENTRAL CANADIAN CORDILLERA

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Major ice flow reversals have recently been recognized in the northern Interior Plateau region of the Canadian Cordillera and the influence of these flow reversals on geochemical dispersal is believed to be considerable. Success for exploration programs attempting to locate the up-ice source of mineralized erratics or geochemical anomalies in till in this region, requires a thorough understanding of the ice-flow history. Although much of this region is dominated by very well developed drumlins and flutings that reflect a generally eastward ice flow direction (e.g. Tipper, 1971; Plouffe, 1996), new evidence has shown that a significant westward flow also effected the area during the Late Wisconsinan glaciation (Levson and Stumpf, 1998; Levson et al., 1998, Stumpf et al., in prep). Westerly ice flow extended across an area reaching at least as far north and northeast as the Skeena and Omineca mountains and as far southeast as François and Ootsa lakes. In many areas this westerly flow was independent of large topographic barriers as indicated by flows across major mountain ranges such as the Babine, Hazelton and Coast mountains. Westerly ice flow appears to have occurred at the last glacial maximum when ice centers over the Hazelton and Coast mountains migrated eastward into the Interior Plateau. The full extent and timing of this event and its effects on dispersal are currently being investigated (Stumpf et al., in prep., a).

Evidence for westerly flow is most readily found in the western part of the region and diminishes eastward reflecting the eastward migration of ice divides and probably also later shifts back to the west. Areas in the east part of the region, therefore, were under the influence of westerly flowing ice for a relatively short period of time. Consequently, the effects of westward flow on geochemical dispersal are expected to increase westward and diminish eastward. This pattern is complicated by local topographic effects that also appear to have had an influence on dispersal. For example, in major valleys such as the Babine Lake valley, late glacial ice flow was largely effected by the valley topography (Stumpf et al., 1997) and the dominant direction of till geochemical dispersal is down-valley (southeasterly), in spite of the fact that there is evidence in the Babine valley for late stage, westerly flow across the valley trend.

Westerly ice-flow locally extended to the end of the last glaciation, especially in Coast Mountain valleys (e.g. Skeena valley) and in interior, east draining valleys (e.g. Morice valley), which have large passes opening westward to the Pacific Ocean. However, late glacial ice-flow, back to the east from the Coast Mountains, did occur in valleys with high or relatively restricted mountain passes. However, since evidence for westward flow is preserved in many valleys at unprotected, low elevation sites, the erosional effects of the later, topographically-controlled flows must have been minimal. These observations suggest that the maximum buildup of interior ice extended late into the last glaciation and that a topographically controlled, late-glacial, ice-flow phase was short-lived in this part of the Interior Plateau.

Since shifting ice divides can result in 180 degree changes in ice flow direction and complex glacial dispersal patterns (Stumpf et al., in prep., b), explorationists should not base paleoflow interpretations on striae or flutes developed on surfaces that do not show good stoss and lee forms. In contrast, effort should be placed on deciphering paleo-ice flow from directional features such as roche-moutonnée, drumlinoids and rat-tails. Some locations within this region show both eastward and westward flow directions, even on outcrops that occur in close proximity, and therefore a clear understanding of the temporal relationships of multiple flow events is required. Since the data that can be gathered from any one outcrop are often ambiguous, it is necessary to collect regional data before making inferences regarding the dominant glacial dispersal direction. For example, maximum-phase ice flow data may be obtained from high elevation sites outside of the influence of late-stage valley or cirque glaciers. Particular emphasis needs to be placed on factors that influence transport direction, a poor understanding of which is one reason for unsuccessful drift prospecting programs in this region. In some cases, where limited data are available, we recommend that sampling strategies initially be designed to evaluate the dominant dispersal direction before intensive 'up-ice' surveys are conducted.

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INTERPRETATION AND PRESENTATION OF QUALITY-ASSURANCE QUALITY-CONTROL DUPLICATES

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Most projects have some duplicate analytical data to monitor the quality of the database. These consist of assays of second sub-samples taken at points in the process of collecting, preparing, and assaying samples. A population of same-pulp duplicate results can be used to estimate the variance contributed by the pulp sub-sampling plus assaying procedures. A population of duplicate samples collected in the field, such as separate splits of reverse-circulation drill chips, can be used to estimate the sum of variances of the sample collection, sample preparation, and assaying processes. Between these two points, duplicates of coarse reject material, such as output from a jaw or rolls crusher, are often evaluated, particularly in projects which have matured to a pre-feasibility level.

Sometimes pulp samples are assayed at a second laboratory; these are usually referred to as assay checks or check assays. Check assays, along with inserted standard reference materials, are important verifications of the accuracy of the results in the database. However, it is more difficult to obtain estimates of *precision* (as opposed to *accuracy*) if a different laboratory is used, because of the presence of systematic errors (bias) between laboratories. If the same laboratory is used, systematic errors stemming from differences in laboratory accuracy are avoided. The data are consequently easier to interpret, since evaluations of accuracy and precision are done separately. For this reason, one should submit some pulps to a second (check) laboratory as a check on accuracy, while some other pulps, and all other types of duplicates should be submitted to the laboratory performing the original assay.

An all-too-common mistake is to introduce a selection bias when selecting duplicates: samples are selected for re-assay on the basis of their original assay result. Selection bias occurs because each result has a sub-sampling plus measurement error attached to it. In a sufficiently large population, the positive and negative errors exactly cancel out. By selecting a sub-population which includes only the high results (or only the low results) one preferentially selects a sub-population containing positive (or negative) errors. If precision is very good, the effect is negligible. Where precision is poor, the effect can be very large. In one extreme case, a "coarse-gold" project had established a protocol whereby they used one assay-ton fire assay results to select samples which exceeded a high cutoff (around the 95th percentile) for re-assay using a screen fire assay procedure. The second set of results averaged 15 percent lower than the original results.

In some situations, introducing a selection bias is relatively unimportant. For example, all the samples in a soil grid which have anomalous (high) values may be routinely re-assayed to verify that they are indeed anomalous. This may slightly reduce the number of anomalies, but the fact that average grade of the anomalous population drops on re-assay is of little or no import, and is usually not even examined.

Sometimes the selection bias is introduced during the process of interpreting the results. This can happen when one groups the data into "grade ranges" based on the original result. The person who does this usually finds that the lower grade ranges have an average original result lower than the re-assay result, whereas for the higher grade ranges the original results average higher than the re-assay results. They have demonstrated the regression towards the mean that comes with selection bias, not necessarily any problem with assay techniques. If they had chosen to use the re-assay set of results to select the grade ranges, they still would have found the lower grade ranges (now constructed from the re-assay results) have averages lower than the original results, and for the high grade ranges, the average of the re-assay results is lower than the original results: a paradox produced by selection bias.

A kind of selection bias also exists when one performs a linear regression fit to data where the selection of the independent variable is essentially arbitrary. Where precision is good, no noticeable effect is seen by swapping variables. But where precision is poor, the regression fits are quite different.

In most data sets, one must deal with outliers. These are pairs of results where one of the members of the pair is a large Type I error, that is, an error whose size has nothing to do with sub-sampling or measurement errors. Clerical errors and sample mix-ups are Type I errors. These need to be identified and removed before making linear fits, comparing means, and so on. This is usually done visually from scatter plots of the data. Is the visual selection unbiased? An effective way of avoiding bias is to use the visual selection to establish a criterion for rejecting pairs, based on the ratio of the pair variance to the variance of pairs having similar pair means. One must restrict the comparison to pairs having a similar grade because precision is usually a function of grade; this is the basis of Thompson-Howarth charts of precision *versus* grade. In those charts, the problem of outliers is avoided by selecting median values from groups of duplicate pairs of similar grade; the approach works, but tends to overly smooth the data, eliminating detail which may be important. More detail is retained if, after identifying and discarding outliers, with the data sorted by pair means, a moving window of standard deviations of pair differences is calculated. These can be converted to relative standard deviations by dividing by a moving window of average grade, then plotted against the average grade, to obtain a plot that has the approximate shape of $y = 1/x + c$. This is like a Thompson-Howarth chart, but it retains more of the character of the underlying data.

One often needs to compare duplicate results under different conditions, such as different preparation protocols. Comparing scatter plots is visually challenging. Instead, cumulative frequency plots of relative differences (one measure of precision) can allow different populations of duplicate data to be compared on one graph. This approach is valid as long as the grade distributions of the populations are the same.

QUANTITATIVE ANALYSIS OF HYDROTHERMAL ALTERATION: APPLICATIONS IN MINERAL EXPLORATION

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Lithogeochemical exploration, like every other geochemical method, depends on recognizing element concentrations and distribution patterns which are significantly different from the local background in order to identify prospective exploration targets. The difference between interpreting major element lithogeochemical surveys, and conventional soil and silt surveys, is that the latter generally focus on metals which are more or less absent in unaltered rocks. It is a comparatively simple matter to determine what the local background in these metals is, and then identify the anomalies. However, determining what the local background in major element compositions of unaltered rocks is, and what effect hydrothermal alteration associated with an ore-forming event had on these, is an entirely different matter. If host rocks were homogenous prior to alteration, then the effect of hydrothermal alteration can be measured by subtracting the unaltered from the altered host rock compositions. But such cases are rare, and generally one must be prepared to deal with variable, and sometimes extremely variable, unaltered host rock compositions.

In order to separate the background variations in the geochemistry of unaltered rocks from the variations superimposed by later hydrothermal alteration, a new method of analyzing whole-rock geochemical data has been developed. It is an adaptation of a petrologic modeling technique originally designed to study mass transfer processes in igneous systems. The fractionation models used by that technique have been adapted for use in lithogeochemical exploration. Linear co-variation diagrams model the variations in the geochemistry of unaltered rocks, which are controlled by the bulk stoichiometry of the rock-forming process and/or mineral assemblage. The residuals to these linear co-variation models are used to characterize and quantify the effects of subsequent hydrothermal alteration. By removing the background geochemical variations, this approach significantly improves the anomaly contrast. It becomes possible to screen out false anomalies produced by empirical alteration indices, and to examine the relationships between metal deposition and specific alteration facies and intensities in an ore-forming system. By quantifying hydrothermal alteration, this method can identify lithogeochemical vectors which point to the core of a hydrothermal system, and, if it exits, to mineralization.

This method has been applied to deposits hosted in a variety of terranes, with metamorphic grades ranging from greenschist to upper amphibolite. Deposit types include volcanic- and sediment-hosted massive sulphide, volcanic-hosted epithermal gold, mesothermal vein, carbonate-hosted (Carlin-type) gold, porphyry copper-gold, and Archean shear zone-hosted gold deposits. It is gradually becoming an accepted method in mineral exploration, not only as a direct method of examining prospective target areas, but also for geological and metasomatic mapping where intensive alteration, metamorphism, or deep weathering mask the true identity of the rocks being mapped, thereby reducing the risk of host rocks for potential economic mineralization being mis-mapped or overlooked.

REGIONAL MULTI-ELEMENT DRAINAGE GEOCHEMISTRY IN THE HIMALAYAN MOUNTAINS, NORTHERN PAKISTAN

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A regional drainage reconnaissance survey was initiated in the Himalayan region of northern Pakistan in 1992, as part of an Australian aid programme (Sweatman et al, 1995) and later extended by teams from the Pakistan Mineral Development Authority and the Sarhad Development Authority (SDA). During the course of this programme drainage sediments were sampled over an area of some 100,000 square kilometres in northern Pakistan and both the <200 µm (-80#) fraction and panned concentrates analysed by the SDA Mineral Testing Laboratory in Peshawar for the following elements (with the detection limits in ppm shown in parentheses): Au (0.05), Cu (5), Pb (5), Zn (5), Ag (0.5), Co (5), Bi (10), and Ni (5). In 1997, Minorco Services BV entered into exploration agreements with the Pakistan authorities, the terms of which included the re-analysis of the accumulated samples for a more comprehensive multi-element suite and to lower detection limits where appropriate. Accordingly some 4300 panned concentrate samples were analysed for Au, Pd and Pt to a 1 ppb detection limit and a similar number of <200 µm samples were analysed for Au (to 1 ppb) and a further 31 major and trace elements by Ultra Trace Laboratories in Perth, Western Australia. The results are interpreted in terms of the geology and mineralisation in the area and observations made with regard to the sampling techniques applicable in regional drainage surveys in mountainous terrain.

The area is characterised by extreme topographic relief, extending from the Karakoram Mountain Range, which includes peak elevations over 8000m, to the Indus River valley, which ranges upwards from elevations of about 800m in the project area. Although the area has a semi-arid climate, much of the higher ground has permanent snow-cover and active glaciers, the melt-waters from which source an extensive drainage system flowing in a southwesterly direction to the Arabian Sea.

The geology of the area covered by the survey can be divided into three main tectonic crustal units separated by major thrust faults with an overall concave north east-west trend. From north to south, these are:

- the Eurasian Plate, including metamorphosed sediments of Palaeozoic-Cretaceous age, and deep level granitoid intrusions;
- the Kohistan Arc, a Cretaceous-Tertiary island and continental arc of tholeiitic to calc-alkaline volcanics and sediments, intruded by various igneous bodies including the Kohistan Batholith and the major layered Chilas Complex mafic-ultramafic assemblage; and

- the Indian Plate, which comprises late Precambrian to early Palaeozoic schists, marbles and gneisses and Cambrian granitic rocks.

The major structures separating these units, the Northern Suture Zone (NSZ) and the Main Mantle Thrust (MMT) are zones of shearing up to 4 km wide which incorporate oceanic ophiolitic volcanics and alpine serpentinite intrusion. Collectively, these environments are regarded as having potential for a wide range of precious metal, base metal and non-metallic mineral deposits.

The dispersion patterns for a number of elements closely reflect aspects of the regional geology. The Eurasian and Indian Plates are both characterised by high background values for Ba, Pb, Sn, Tl and the ratios K/Na and Rb/Sr. In addition, As is strongly enriched in the Eurasian Plate, while the Indian Plate has high background Se concentrations. The Kohistan Arc is highlighted by elevated values for Co, Cu, Fe, Mn and V. A series of elongate patterns of enrichment for Cr, Ni and the ratio Mg/Ca delineate the NSZ and the MMT. These relationships are well summarised by the results of Factor Analysis, the first two factors derived clearly relating to the three regional geological units and the structures which separate them respectively.

Initially, samples were collected to represent catchments of 10 to 50 sq. km in area, but lack of access dictated that larger catchments were sampled in some cases, while subsequent detailed follow-up has led to an extreme variation in the areas of catchments represented in the database, ranging from 0.2 to over 1500 sq. km. Statistical studies have demonstrated that background abundances for many elements are strongly affected by variations in catchment area. Barium, Co, Cu, Mo, Ni and Zn concentrations decrease with increasing catchment size, which is the normal pattern of downstream dilution. Arsenic, Au, Cr, Nb, Pd, Pt, Sb, Sn, V and W show the reverse tendency - i.e. enrichment in larger catchments. This behaviour is typical for elements which are dispersed in heavy mineral phases and is magnified by the sampling of trap-sites, which are loci for the hydraulic concentration of heavy minerals. For some elements, the observed distributions may represent patterns of concentration of metals derived from bedrock sources which have been completely eroded as a result of extreme tectonic uplift. For example, Au concentrations in panned concentrates up to 480 ppm in major drainage channels are correlated with other detrital elements such as Pt and Pd, rather than pathfinders normally associated with primary gold deposits. A correction for downstream dilution and concentration effects can be applied in interpretation by using variable threshold levels based on catchment area. However, in future surveys of this type, alternative sampling techniques should be employed to delineate regular downstream dispersion patterns which can be more readily traced to actively eroding bedrock mineralisation. A brief orientation study at Dommel Nissar in the North West Frontier Province has confirmed that high contrast anomalies for Au and Cu associated with skarn Cu-Au mineralisation can be detected by analysing the <75 µm (-200#) fraction from low energy sediments, without the need to sample trap-sites.

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THE NATURE AND DISTRIBUTION OF REGOLITH CARBONATES IN SE AUSTRALIA AND THEIR POTENTIAL AS A SAMPLING MEDIUM IN GEOCHEMICAL EXPLORATION

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A variety of secondary carbonate-rich materials are developed in the regolith of the southern part of the Australian continent. It is now recognised that some of these regolith carbonates can be used very effectively as a geochemical sampling medium for gold exploration and this has led to a carbonate sampling "feeding frenzy" in Western and South Australia (e.g. Lintern and Butt 1993; 1997). To date there has been only limited application of this technique to other areas of southern Australia, such as the semi-arid areas of New South Wales and Victoria, where carbonate types and their landscape settings are perhaps more complex.

Throughout southern Australia, regolith carbonates occur in association with coastal calcarenite dune complexes and further inland with a wide range of geological and landscape settings. Their regional distribution is largely controlled by a fundamental relationship between:

(1) the degree of leaching of carbonates, which is mainly proportional to the amount of rainfall, but also to landscape setting and factors such as groundwater pH; and

(2) the availability of carbonate and appropriate cations, mostly derived from bedrock weathering (particularly of primary carbonates, and mafic lithologies), reworking of older regolith carbonate accumulations, aeolian accessions, rainfall chemistry surface runoff, bioclasts and other biological concentrations.

Rainfall chemistry appears to be an important control on regolith carbonate distribution. Areas with widespread pedogenic carbonates occur south of the Menzies Line in Western Australia and its equivalent across South Australia and New South Wales. This boundary, at approximately 30° S latitude, marks the northern extent of calcium- and magnesium-rich winter rains derived from the Indian and Southern Oceans.

Regolith carbonates in southeastern Australia can be broadly subdivided into a number of facies based on morphology. These include:

Nodular carbonate facies and coated grains consisting of weak to strongly indurated carbonate-rich bodies exceeding 2 mm in diameter. They commonly occur above or cemented within hardpans and are composed of calcite with some dolomite in the lower parts of the facies.

Carbonate rhizoliths which are elongate accumulations of mostly calcite with root-like morphologies and orientation, up to several centimetres in diameter and rarely with internal structure.

Carbonate hardpan facies made up of hard, impervious layers of indurated carbonate which occur in a variety of settings. Their internal morphology is usually complex, incorporating coalesced nodules, coated grains and other carbonate indurated fragments.

Boulder carbonate facies with boulder and cobble sized blocks of carbonate indurated regolith, usually within a matrix of powder carbonate or nodular carbonate facies.

Powder carbonate facies composed of fine-grained, structureless, unconsolidated to weakly consolidated carbonate material, usually dolomite or magnesium-rich calcite, typically found in the lower parts of profiles.

Tabular massive carbonate facies composed of lensoidal carbonate accumulations commonly forming mounds or domes within thick alluvial sequences. The main carbonate mineral is typically dolomite, however calcite-rich varieties also occur.

Septarium magnesite accumulations which generally occur in association with mafic and ultramafic bedrock and more rarely above low-Mg rocks.

Particular facies types characterise either pedogenic or groundwater formation. Pedogenic carbonates mostly consist of nodular and rhizolithic facies within the top 1-2 m of the regolith. They may overlie laminated, massive and silty carbonate facies. Groundwater carbonates are mainly massive and tabular facies formed in the phreatic zone, particularly within deep alluvial sequences, such as along palaeovalley systems. Studies of profiles and regolith-landform toposequences indicate that the regolith carbonate facies vary both vertically within a profile and latterally across the landscape. Textural observations indicate that some carbonate deposition is displacive but that much of it is replacive. There appears to have been more than one stage of deposition in some pedogenic carbonates.

Pedogenic carbonates have been successfully used as a sampling medium for gold exploration in the Yilgarn and Gawler cratons. In these areas the association of gold with pedogenic carbonate is thought to be due to the cycling of gold from depth to the surface by vegetation, mobilisation of the gold as organo-complexes and reprecipitation with carbonate under evaporative conditions (Lintern and Butt, 1997). Preliminary results from studies in New South Wales indicate that with a proper understanding of origins, facies and landscape settings, regolith carbonates may also be a valuable sampling medium in this region. Analysis of a range of carbonates from the Broken Hill and Cobar regions has indicated a strong affinity between Au and Ca. However, carbonates with high Mg contents, contain much less Au, possibly reflecting greater mobility, and leaching of Au in saline groundwater. As a result, the nodular, Ca-dominated, pedogenic carbonates are generally a good sampling medium for gold. Further to this however, the lateral dispersion of carbonate solutions through the regolith towards the axis of valley systems may account for "false anomalies" in many situations.

Unlike Western Australia where most of the gold deposits are of the "gold only" type, in many parts of eastern Australia gold is commonly associated with polymetallic base metal mineralisation (e.g. in the Broken Hill and Cobar regions) or with porphyry-style Cu-Au deposits (e.g. in the Parkes-Narromine region). In these settings concentration of gold in regolith carbonates may mean that gold will prove to be a useful pathfinder element for base metal deposits, particularly in areas with moderate cover.

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GOLD DISPERSION IN STREAM SEDIMENTS UNDER SEMI-ARID CONDITIONS, NORTHEAST OF BRAZIL

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A stream sediment orientation survey was carried out for gold mineralization in the semi-arid (~500 mm annual average precipitation) northeast of Brazil. Eleven stations were sampled in duplicate along a 3000m stream. The stream is ~1.5m wide by 0.8m deep at the upper station and 6.0m x 0.5m at the lower station. Estimated overall stream gradient is 5%. Mineralization at the headwaters occurs as centimeter- to meter-thick gold-sulfide-bearing quartz veins located in a NNE-SSW shear zone hosted by biotite-garnet schists.

Sampling was carried out in summer when the stream was dry. Sediment was dry-sieved on site to collect two 12 L (17 to 22 kg) of –2000 μm material composited from 3 to 5 high energy sites at each station. In the laboratory, the 22 samples were dry sieved to obtain the –2000+500μm, -500+180μm, -180+106μm, -106+63μm and -63μm fractions. All fractions <500μm were analyzed for Au (fire assay-AAS), As (hydride generation-AAS), Hg (cold vapor-AAS) and 30 other elements (aqua regia-ICP). Cursory evaluation clearly indicates that for most elements sampling and analytical variability are negligible compared to between-station variability.

Except for sporadic, isolated values above the 5 ppb detection limit, Au was not detected in fractions coarser than 63μm. However, the -63μm fraction shows a typical downstream dispersion pattern, with a decrease of Au values from 40-55 ppb to <5ppb over a distance of ~1.3 km. Erratic high and low values are superimposed on this trend. Anomalous downstream dispersion patterns are observed for As, Cu, Pb, Zn, Co and Cd in all size fractions analyzed. These are less erratic than for gold and extend ~3 km downstream to the limit of the study.

Sediment size fraction data show that distribution of gold is closely related to sediment texture with gold concentrations decreasing as the abundance of –63μm material increases. This relation is observed between adjoining stations but, insofar as abundance of the -63 μm increases down the stream, has probably also magnified the anomaly in the headwaters while diluting it further downstream. We attribute the relation between gold and sediment texture, which is not shown by any of the base metals, to gold behaving as a heavy mineral that is concentrated on the streambed by washing away of fine sediments, or diluted by their deposition.

It is interesting to note that in the wet tropics, where there is a deeply weathered regolith and frequent transport of sediment eliminates fines from the streambed, anomalous dispersion trains for gold and other heavy minerals usually extend further downstream than the dispersion trains for associated base metals. Based on the results reported here, it seems possible that in arid regions the more limited development of deeply weathered regolith and the less effective removal of fines from the stream bed can hinder development of long dispersion trains for gold. In such situations the importance of pan concentrates and pathfinder elements may be increased.

SYSTEMATIC REGIONAL REGOLITH AND REGOLITH GEOCHEMICAL MAPPING IN WESTERN AUSTRALIA: APPLICATION TO EXPLORATION IN POORLY EXPOSED TERRAINS

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Unconsolidated surface material derived from the protracted weathering of bedrock (regolith) covers up to 95% of some 1:250 000 scale map sheets in Western Australia, up to a depth of 100 m. Although effectively blanketing bedrock and related mineralization, regolith itself can be used as an exploration tool, if the relationship of regolith to parent bedrock is understood. An increased knowledge of this relationship has led to the development of a variety of exploration techniques suited to regolith-dominated terrains, resulting in the discovery of several world-class mineral deposits. However, regional-scale, grass roots exploration has been hampered by lack of information about the distribution and composition of regolith. In order to address these issues, the Geological Survey of Western Australia (GSWA) embarked upon a program of regional-scale regolith mapping and regolith geochemistry in 1994. This program is based on helicopter-supported collection of regolith samples and information about regolith and surrounding geology from sites at a nominal density of one sample per 16 km^2 over selected 1:250 000 scale map sheets. To date, the program has resulted in the publication of twelve sets of maps and explanatory notes, accounting for an area of approximately 192 000 km^2 and in excess of 12 000 samples. The present production rate is four map sheets per year.

Integral to understanding regolith chemistry is some knowledge about the distribution of regolith. Standard information about regolith and surrounding geology recorded at each sample site are combined with Landsat TM and aerial photography to produce a regolith distribution map. The GSWA regolith classification scheme involves a tripartite division of regolith according to its position in an idealised landform profile, qualified by optional suffixes indicative of composition, and parent rock type. The robustness of this regolith-landform classification scheme has been proven over map sheets spanning a wide range of lithological, climatic and physiographical associations.

This diversity of associations has required sampling of several media, including stream sediments, sheetwash, sandplain, soil, and lake sediments. The 2 mm – 0.45 mm (i.e. coarse sand) fraction of each sample is analysed for up to 50 components using a total, ICP-dominated approach, for a variety of major element oxides and trace elements - the fine fraction has been excluded to avoid dilution by eolian material. Analytical data are shown as a series of spot concentration maps plotted against a background of simplified geology. These data indicate that in the mature and usually subdued landscape of Western Australia, bedrock is the prime control on regolith chemistry at the sample density of one per 16 km^2, due to the in situ development of regolith. However, the influence of transported regolith is also reflected in the chemistry.

Integration of regolith chemistry and distribution with other datasets is important in understanding how regolith can help in mineral exploration. In a 1900 km^2 area on the northern margin of the Archaean Yilgarn Craton, the combination of regolith chemistry and airborne magnetics suggests a more limited extent for Archaean granitoid rocks than previously mapped, and a correspondingly more extensive area of Proterozoic high-level intrusive and extrusive mafic igneous rocks. The latter have disseminated sulfides in hand specimen, and overlying regolith has elevated Cr, Sc, V and platinum group element (PGE) abundances.

In a younger part of the same intracratonic, dominantly sedimentary sequence, regolith overlying dolerite sills in one part of the stratigraphy has elevated Au, PGE, Cr, Mg and Ni abundances relative to mafic intrusive rocks elsewhere in the stratigraphy. Current tectonic modelling suggests that some of these high-level intrusive rocks may be related to igneous activity coincident with basin extension. In the same sedimentary sequence, areas of potential sedimentary exhalative mineralisation (SEDEX) have been identified by statistical treatment of regolith chemical data. Such a statistical approach allows direct comparison of trace elements regardless of absolute concentrations.

For many map sheets covered by the GSWA regolith program, traditional bedrock-oriented approaches to mineral exploration are inappropriate due to the extensive and thick regolith overburden. Regolith can be used as a surrogate for bedrock if it is collected at a uniform sample density, and its chemistry is interpreted along with other data, principally a map showing the distribution of regolith. Further integration with bedrock mapping and airborne geophysics results in a powerful approach to exploration in poorly-exposed terrains. Although this approach has aided in identifying the extent of important rock units under the regolith cover, as well as areas of anomalous metal concentrations, its long term value is in the provision of background element concentration data against which anomalous values can be identified and assessed.

WASTE ROCK PILE CHARACTERIZATION, HETEROGENEITY AND GEOCHEMICAL ANOMALIES IN THE HILLSBORO MINING DISTRICT, SIERRA COUNTY, NEW MEXICO

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Mine waste rock piles are anthropogenically created landforms in present and past mining areas that are derived from open pit and underground mining methods. In addition to diverse mineral and chemical heterogeneities, the waste rock piles contain heterogeneous grain sizes. There are 100,000s of waste rock piles in New Mexico of varying size and composition. One of the controversial problems facing scientists today is how to sample these waste rock piles quickly and economically in order to adequately assess environmental hazards. A sampling strategy was administered on four waste rock piles from four different types of mineral deposits in the Hillsboro mining district to characterize the piles geochemically in an economically feasible manner.

The Hillsboro mining district lies in the Animas Mountains, eastern Black Range, New Mexico and has been mined approximately the last 120 years mainly for gold, silver, and copper. Lesser amounts of lead, zinc, manganese, and vanadinite have also been mined. Four types of deposits are found in the district: Laramide vein, placer gold, porphyry-copper, and carbonate-hosted replacement deposits. Underground mining was the main mode of extraction until 1982 when open pit mining for copper began at Copper Flat. During the period 1877-1982 an estimated 270,000 ounces of gold, from lode and

placer gold, 78,000 ounces of silver, 24,000 pounds of lead, and 24 million pounds of copper were produced from the district.

The district lies in a semi-arid region of southwestern New Mexico and receives less than 250 mm of annual precipitation, mostly in the form of severe, intermittent, short duration rainfall events during the summer months. Much of this type of precipitation tends to runoff and is unattenuated by the ground. The remainder of the precipitation comes in the winter and early spring as light rain and snow which slowly percolates into the ground with the onset of warmer temperatures.

Physical parameters of the waste rock piles sampled, such as grain size distribution, terrain, and the physical dimensions are important components for the geochemical characterization of each site. Knowledge of these parameters provides insight into overall metal concentrations of the waste rock piles in addition to the potential for wind and water erosion. Each of the waste rock piles sampled in the Hillsboro mining district are found at different elevations, have different exposure to weather, and have different locations relative to ephemeral streams. Physical aspects of the waste rock piles are in Table 1. Grain size distribution data for each of the four waste rock piles is in Table 2.

TABLE 1. Physical aspects of waste rock piles. Volume was calculated by Delunay Triangulation method.

Waste Rock Pile	Elevation (meters) above s.l.	Width (meters)	Length (meters)	Average Height (meters)	Maximum Height (meters)	Average Slope angle	Approxv olume cubic (m)
Site A	1628	32.0	46.0	6.6	7.3	26.0	2969.5
Site B	1792	20.0	120.0	7.4	14.0	23.0	11582.0
Site C	1743	22.0	39.0	2.0	2.3	14.0	475.9
Site D	1664	6.0	33.0	1.8	2.5	18.0	52.8
Site E	1658	32.0	35.0	5.5	6.2	20.0	2267.1

TABLE 2. Grain size distribution of four waste rock piles displayed in total weight percent.

Grain Size	Site A Total Wt. %	Site B Total Wt. %	Site C Total Wt. %	Site D Total Wt. %
whole	100.0	100.0	100.0	100.0
> 2 mm	57.7	75.4	74.6	51.4
< 2 mm	42.3	24.6	25.4	48.6
2-1 mm	7.0	6.5	5.8	9.1
1-0.5 mm	9.7	6.2	5.4	11.3
0.5-0.25 mm	10.5	4.3	3.6	9.7
0.25-0.125 mm	7.1	2.7	2.9	4.6
0.125-0.063 mm	4.2	1.9	3.1	5.6
<0.063 mm	3.8	3.0	4.6	5.3

Chemical analyses by Flame Atomic Absorption Spectrometry (FAAS) and X-ray Fluorescence Spectroscopy (XRF) of six size fractions (2-1 mm, 1-0.5 mm, 0.5-0.25 mm, 0.25-0.125 mm, 0.125-0.063 mm, and < 0.063 mm) indicated the less than 0.25 mm grain size typically contained the highest metal concentration. Chemical analyses for each of the waste rock piles are shown in Table 3. XRF analysis was unable to determine lead and zinc concentrations in Site C due to interferences created by those elements. For the same reason, lead and zinc values for Site D were also unable to be determined by XRF because of the high percentage (approximately 10%) of manganese present.

TABLE 3. FAAS and XRF chemical analyses of six size fractions on four waste rock piles.

Waste Rock Pile	Particle Size	Cu (ppm) FAAS / XRF	Pb (ppm) FAAS / XRF	Zn (ppm) FAAS / XRF
Site A	2-1 mm	130 / 80	20 / 20	120 / 71
	1-0.5 mm	130 / 87	20 / 21	75 / 77
	0.5-0.25 mm	160 / 96	20 / 23	115 / 87
	0.25-0.125 mm	140 / 102	20 / 25	145 / 110
	0.125-0.063 mm	150 / 100	20 / 24	90 / 101
	< 0.063 mm	160 / 110	20 / 21	150 / 97
Site B	2-1 mm	1140 / 860	80 / 73	450 / 462
	1-0.5 mm	1080 / 920	80 / 81	400 / 411
	0.5-0.25 mm	900 / 790	80 / 94	380 / 392
	0.25-0.125 mm	910 / 820	110 / 124	410 / 458
	0.125-0.063 mm	780 / 810	120 / 160	440 / 464
	< 0.063 mm	760 / 760	180 / 218	440 / 477
Site C	2-1 mm	130 / 98	42450 / ---	70210 / ---
	1-0.5 mm	160 / 186	72250 / ---	88780 / ---
	0.5-0.25 mm	190 / 286	75710 / ---	95100 / ---
	0.25-0.125 mm	220 / 365	73640 / ---	99170 / ---
	0.125-0.063 mm	240 / 308	51010 / ---	64780 / ---
	< 0.063 mm	250 / 294	28140 / —	43470 / ---
Site D	2-1 mm	120 / ---	1500 / ---	1710 / ---
	1-0.5 mm	130 / ---	1700 / —	1910 / ---
	0.5-0.25 mm	110 / ---	1840 / ---	1950 / —
	0.25-0.125 mm	120 / ---	1770 / ---	1900 / ---
	0.125-0.063 mm	120 / ---	1800 / ---	1810 / ---
	< 0.063 mm	90 / ---	1470 / ---	1520 / —

In addition to each of the grain size fractions, chemical heterogeneity can be found within an entire waste rock pile. As an example, 45 samples were analyzed by XRF for each of the sample sites on the grid of the Laramide vein waste rock pile (Site B). Groupings of data display relatively high concentrations of metals while other sample groupings show low concentrations. Copper values range from 460-2700 ppm, lead from 73-730 ppm, zinc from 120-1400, and arsenic from 4-76 ppm.

In order to receive the highest metal concentrations and to insure equal treatment of each mineralogically varying waste rock pile, the less than 0.25 mm stainless steel sieve was chosen for sampling. Four waste rock piles were sampled using grids of different sizes and shapes, which conformed to their respective dimensions. Three sampling densities (15, 30, and 45) were taken within grids created for each of the waste rock piles. An elongate/oval sampling grid was used for the placer gold waste rock pile (Site A). A pseudo-trapezoidal grid was used for the Laramide vein waste rock pile (Site B). A crescent-moon shape grid was used for the carbonate-hosted Pb-Zn waste rock pile (Site C). A rectangular grid was made for the carbonate-hosted manganese waste rock pile (Site D). From this study it was found that, mine waste rock piles can be adequately chemically characterized by homogenizing samples collected from a grid containing 15-30 sample cells.

DRIFT PROSPECTING IN THE VICINITY OF THE RESTIGOUCHE VMS DEPOSIT, BATHURST MINING CAMP: AN EXTECH-II CASE STUDY

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The Restigouche VMS deposits are located in northern New Brunswick where eastward ice movement was followed by northeastward flowing ice. The main Restigouche deposit is down-ice from a hill, where a gossan cap was protected from glacial erosion. The C4-C5 zone is on a hill that was exposed to intense glacial erosion, accounting for the absence of a gossan cap and the high percentage of till clasts transported from Silurian-Devonian rock units up-ice. Thin sandy/clayey basal till covers much of the area, although a borrow pit is located in till 5 m thick. Locally, preglacial weathered bedrock is present, commonly overlain by basal till. A felsic breccia, outcropping and intersected in drill holes, has an associated transported gossan/cemented till that also overlies fresh till. The transported gossan/cemented till may have been transported as an ice-thrusted sheet, is highly anomalous in base-metals (Co 770 ppm, Ni 3300 ppm and Zn 6300 ppm) and may be associated with mafic dykes.

Geochemical analyses on the 63μm size fraction of basal till samples from a 250 m grid survey (126 sites) and 102 sites on a 25 m grid around and down-ice from the main Restigouche deposit revealed highly anomalous Cu, Pb, Zn, and Sn values in till within 1-2 km east-northeast of the deposit. Fifty-three till samples were collected on 250 m centres, around and down-ice from the Restigouche C4-C5 zone to close off an anomaly 1 km north of the main deposit. Anomalous values in basal till from the south end of the detailed grid are dispersed down-ice toward 070☜, from the deposit and contain maximum concentrations of Cu (1400 ppm), Pb (30000 ppm), Zn (1600 ppm), Au (506 ppb), As (1600 ppm), Sb (77 ppm), Ag (36 ppm), and Sn (28 ppm). These high values appear to be related to the gossan that caps the Restigouche deposit because there is a short geochemical dispersal train away from this deposit. At the C4-C5 zone fresh sulphides are exposed and therefore glacial dispersal of base metals is more evident than at the main Restigouche deposit. A large Zn anomaly (750-6300 ppm over an area of 1 x 1.5 km) is centred on the C4-C5 zone and extends down-ice (glacial dispersal) for approximately 2 km including the northern part of the detailed grid, and downslope in the up-ice direction (hydromorphic dispersion). In contrast the Zn anomaly around the main Restigouche deposit is smaller in size (approximately 300 m) and concentration (300-400 ppm except in samples directly over the deposit). Cu, Pb, and Sn have similar patterns.

MERCURY IN HUMUS, B-HORIZON, AND GLACIAL SEDIMENTS IN THE VICINITY OF TWO PAST PRODUCING MERCURY MINES, BRITISH COLUMBIA, CANADA

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As part of the Metals in the Environment initiative of the Geological Survey of Canada, it was proposed to complete a sampling program of the humus, B-horizon and glacial sediments in the vicinity of the only two mercury mines that have been active in Canada: Bralorne Takla and Pinchi. Both of these mines are located along the Pinchi Fault, a major structural break which separates Paleozoic to Triassic Cache Creek Group sedimentary rocks from Mesozoic Takla Group volcanic rocks in the Interior of British Columbia. The ore bodies at both mines are epithermal in origin, and consist of cinnabar mineralization dominantly present in Cache Creek Group limestone, but also found sporadically in carbonatized serpentine. Both mines were active in the 1940's and Pinchi Mine reopened for a brief period in the early 1970's. A reconnaissance sampling program was completed at the Bralorne Takla Mine in 1997 and two transects were sampled during the 1998 field season in the Pinchi Mine region. The objectives of this project are to determine if there is an anthropogenic signature detectable around these mine sites, to establish criteria that could be used to distinguish between natural and anthropogenic metal enrichments, and to identify the forms and phases where metals are bound. Knowing the phases in which metals are held could indicate if metals from either source, natural or anthropogenic, could be remobilized and potentially become bioavailable.

Humus geochemistry can reflect atmospheric metal fallout derived from a smelter, with metal concentrations progressively decreasing downwind from the point source (e.g. Henderson et al., 1998). Humus was sampled around both mercury mines to determine if such a spatial distribution of metal concentrations does suggest the presence of an anthropogenic signature. However, the presence of high metal concentrations in humus could be related to a combination of high metal concentrations in the underlying bedrock and glacial sediments of the Pinchi Fault region (Plouffe, 1995; 1998) plus the mining activities during which metals were released to the environment. More detailed testing such as the use of a scanning electron microscope (SEM) to view the microscopic form of metals, and detailed sequential leaching analyses will be conducted on selected samples to differentiate between natural and anthropogenic metal enrichment. These tests will also be conducted on the B-horizon and underlying glacial sediment samples to evaluate metal phases in weathering profiles.

In the Pinchi Mine region, debris enriched in mercury has been transported by glaciers over a distance of 12 km as measured in the clay-sized fraction of till, and over a distance exceeding 24 km, based on analysis of heavy mineral concentrates (Plouffe, 1998). Mercury in till is present in the form of sand-sized cinnabar grains which reflect detrital glacial transport (Plouffe, 1997). Consequently, glacial dispersal of sediments enriched in mercury might have influenced metal concentrations in humus. Geochemical results of the 1998 survey were not available at the time this abstract was prepared, but will be presented for the first time at this conference.

Following the reconnaissance sampling conducted in the Bralorne Takla Mine region, the spatial distribution of mercury concentrations in humus does not show a clear "bulls-eye" pattern centered on the mine but rather several sporadic high mercury levels in humus. At some of these sites, the underlying B-horizon and glacial sediments are also enriched in mercury. The source of the high metal concentrations in humus is still unclear and will be deciphered using SEM and sequential leaching analyses.

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APPLIED EXPLORATION GEOCHEMISTRY: CAMPO MORADO PRECIOUS-METAL-BEARING VOLCANOGENIC MASSIVE SULPHIDE DISTRICT, GUERRERO, MEXICO

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The seven Campo Morado district precious-metal-bearing, volcanogenic massive sulfide deposits occur in a lower Cretaceous, bimodal, calc-alkaline volcanic sequence within a major northerly trending belt in the Guerrero Terrane of northeastern Guerrero, Mexico. During upper Cretaceous to Early Tertiary greenschist-facies regional metamorphism, the rocks were deformed strongly into a northeast-verging fold-and-thrust belt. Most deposits occur in the upper part of a sequence of felsic flows and heterolithic volcanoclastic rocks or the contact with overlying chert and argillite-sandstone. Unlike the other deposits, the La Suriana deposit massive sulphides are developed at the top of a felsic sequence overlain by andesitic fragmental rocks.

A 4,000 km^2 stream sediment geochemical survey revealed that the historic Reforma and La Suriana VMS deposits lay within a north trending 5 x 25 km zone encompassing numerous Au, Ag, Cu, Pb, Zn, As and Sb anomalies. Many anomalies could not be explained by the presence of known deposits or prospect occurrences. Following initial 1:20,000 scale geological mapping, a 73 km^2 area, centred over the most prospective strata within the zone of anomalous stream sediments, was covered by a 29,221 sample 25 x 100 m soil grid. Campo Morado is within a peritropical zone of excessive planation where lateritic soil profiles may develop, but due to the elevation, steep topography and rapid denudation of soil, lateritic profiles are absent. Deep weathering does occur in many rock units. Clay and iron oxide minerals are present for several tens of metres of depth in sediments and hydrothermally altered volcanic rocks. B horizon soils are characterized by blocky textured features, yellow-buff color and distinct illuviation of clay minerals. Clay coatings of rock fragments clearly indicate incomplete weathering of parent materials. A suite of eight elements comprising Au, Ag, Cu, Pb, Zn, As, Sb and Hg are found in elevated concentrations in the VMS deposits and associated hydrothermally altered felsic volcanic rocks of the Campo Morado and Suriana Formations. These elements generated a plethora of soil anomalies of varying intensities. To establish exploration priorities an empirical filtering process was developed. Including all samples the median value for zinc, the dominant metal in the VMS deposits, was arbitrarily set as the base. After dropping all units the median value for each of the other seven associated metals was divided into the median zinc value to produce a factor which when applied to each respective metal concentration produced a median concentration numerically equal to that of zinc. This process, giving an equal weighting for each of the eight metals, allowed the factored values to be simply added to produce an anomaly intensity rating for each soil sample. The factored eight-metal plot identified a 4.5 km long northeast trending cluster of high intensity anomalies. Subsequent exploration drilling guided by geophysics, alteration vectoring and soil geochemistry, resulted in the discovery of three blind polymetallic VMS deposits. Soil geochemistry did not directly identify the location of these deposits, but did closely track the elevated metal content of the generally recessive, surface leached, altered felsic volcanic units that host the deposits. Formational anomalies, and those caused by non targeted deposit types or alteration assemblages were effectively filtered out by virtue of their low ranking. As effective as the filtering method proved to be, careful scrutiny of each element is essential. For example, at the La Suriana deposit, high Ba concentrations in soils distinguish it from the deposits hosted by the Campo Morado Formation which lack Ba enriched hangingwall alteration. On a district scale, soil geochemistry aided in distinguishing two distinct volcanic assemblages; soils from the southern Suriana Formation volcanic assemblage contain higher concentrations of Cr, Co, Ga, Sc, Sr, V, Al, Ca, Fe and Mg relative to the northern Campo Morado Formation derived soils.

PROSPECTING BENEATH COLLUVIAL-ALLUVIAL COVER AT QUASAR AND HARMONY IN THE CENTRAL PART OF WESTERN AUSTRALIA: THE VALUE OF INTERFACE SAMPLING

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Depositional plains overlying the Archaean, at Mt Magnet, and the early Proterozoic, west of Peak Hill, contain heterogeneous, multiphase, exotic sediments, unrelated to the underlying rocks. These sediments conceal complete or truncated, deeply weathered and leached regolith, developed on metamorphosed, folded and faulted basement. Palaeochannels, incised into the basement, are infilled with argillaceous sediments that have also been deeply weathered and mottled. These are overlain by a dark brown colluvium-alluvium, derived from erosion of a lateritic regolith. There has been precipitation of silica in the upper part of this colluvium since deposition, to form red-brown hardpans. At Mt Magnet, the colluvium has a high background Au content (approximately 50 ppb) due to significant mineralisation in its source area. This masks any possible subtle anomalies from post-depositional hydromorphic dispersion from underlying, blind resources. Close-spaced drilling at these sites allowed various sampling media, from lag and soil to bedrock, to be compared.

At Quasar, Au mineralisation is hosted in Archaean ultramafic rocks, very near their contact with felsic rocks. The deeply weathered basement has been eroded to saprolite, a 6 m deep palaeovalley has been incised immediately to the south-east of the mine site and filled with kaolinite and smectite clays, all subsequently weathered. The whole area has been covered by a 4-8 m thick blanket of colluvium-alluvium of lateritic nodules, quartz and lithorelics of ferruginous saprolite in a silty clay matrix. The upper part has been hardpanised. The resultant surface is extremely flat and is covered by red-brown, stony soil and polymictic, ferruginous lag.

Geochemical dispersion is minimal in the stripped saprolite. Although element abundances and anomaly/background contrasts are high, anomalies in the top-of-basement are very small in area. Single point anomalies for Au, Pb and Bi indicate the general rather than the precise position of mineralisation. Use of top-of-basement sampling on a 100 x 50 m drill grid was barely adequate for detection of a target such as Quasar. In comparison, samples of the saprolite-colluvium interface have multipoint anomalies in Au, Pb and Bi that are significantly larger than those of the top-of-basement, although of lower contrast, but they targeted the mineralisation accurately.

None of the pathfinder elements (Pb, Bi and possibly Zn) are an unequivocal guide to mineralisation, even in the interface. Target sizes were improved and spurious anomalies reduced by using an additive multi-element index with threshold abundances subtracted, i.e., 100(Bi-1) + 2(Pb-10) + 2.2(Zn-30). This accurately targeted the mineralisation within the pit. Gold concentrations should be used, together with this, to rank anomalies. The composition of the lag reflects its immediate source, the uppermost layer of the colluvium-alluvium. There are no correlations between the compositions of the lag and the upper to middle units of the colluvium-alluvium or between the latter and the weathered basement, only between the unconformity sample and the basement. The weathered basement rocks (felsite or mafic-ultramafic) may be distinguished from the covering sediments (colluvium or palaeochannel clay) by characteristically greater Cr/Fe ratios.

At Harmony, Au mineralisation occurs in Lower Proterozoic mafic-ultramafic metavolcanics, very close to their contact with metasediments (wackestones). The Au deposit lies at the crest of a palaeo-ridge of ferruginous saprolite. The weathered basement was incised in the south by a 30 m deep palaeovalley and lateritic duricrust has developed on the valley flanks. The palaeovalley has been infilled with minor sands and thick, kaolinitic-smectitic clays that have also been weathered, mottled and, near their upper surface, converted to lateritic duricrust. The whole has since been covered by a silty to gritty colluvium-alluvium that varies from 10-18 m thick over the palaeovalley and from 0.5-3.0 m thick over the mineralisation. The resultant present surface is very flat and is covered by red-brown soil and strewn with polymictic, ferruginous lag.

Intensive drilling allowed construction of a detailed regolith model for 6 km^2 around the mineralisation. This was used to guide sampling of the drill cuttings, targeting i) the ferruginous component of the uppermost metre of the basement (lateritic duricrust, ferruginous saprolite and mottles washed from mottled saprolite) and ii) the unconformity between basement and cover (a metre sample of mixed basement and cover). These adjacent sampling media (top-of-basement and unconformity) were compared. Gold, in the top-of-basement, forms a large anomaly southwest of the pit, largely associated with the sporadically-developed lateritic duricrust. However, there is little anomalous Au within the pit. Tungsten only marks the south end of the mineralisation with a single point anomaly. Drilling at 150 m centres seemed barely adequate to locate the Harmony mineralisation, as dispersion of W is negligible in the saprolite. Gold was largely dispersed in the lateritic duricrust, which is mostly developed outside the mine area. Both elements indicate the general area but do not accurately target the mineralisation.

In comparison, interface sampling at similar drill centres revealed significant multipoint anomalies in Au (200-2000 ppb) and W (5-20 ppm), both of which targeted the mineralisation. Although Au also indicates dispersion in the lateritic duricrust to the east, W targeted the mineralisation very accurately and also showed mechanical dispersion trains, away from mineralisation, off the crest and down the palaeo-slope to the north and south. Only where the colluvium is locally very thin (0.5 m), may a weak, sporadic Au geochemical signal be detected in soil (10-15 ppb in a background of 2-6 ppb) directly over mineralisation.

The problems confronting exploration at these two remarkably similar colluvium-covered sites are typical of many newly-discovered mineralized districts on the Yilgarn Craton and its margins. Probing for regolith stratigraphy and for buried erosional surfaces and their palaeotopography are essential aspects of exploring areas of transported overburden and in deciding which unit to sample. Once the regolith stratigraphy is established, routine but accurate logging and well-directed sampling of drill cuttings lead to efficient exploration and data interpretation. A sample collected a metre too high could be in transported overburden, giving misleading results, whereas sampling too deep could include only saprolite, possibly devoid of Au and pathfinder elements, due to small anomaly sizes and/or leaching. Use of the interface sample on eroded lateritic terrain, which has been subsequently buried by exogenous cover, makes use of a number of possible media and dispersion opportunities. These are i) remnants of the base of any lateritic residuum with its extended geochemical halo, ii) any remnants of mechanically dispersed ferruginous lag or palaeosol that developed on the erosion surface prior to sedimentation and had not been swept away subsequently, and iii) any hydromorphic dispersion zone developed by seepage along the unconformity. Thus, the interface sample maximised the potential for mechanical and hydromorphic dispersion, gave a more certain result, and is a good medium in areas of buried, truncated, deeply weathered profiles.

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THE GOORNONG SOUTH GOLD DEPOSIT AND ITS IMPLICATIONS FOR EXPLORATION BENEATH COVER IN CENTRAL VICTORIA, AUSTRALIA.

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The Goornong South Gold Deposit is blind, generally occurring below more than 5 m of transported overburden. It is located 4 km north of the Fosterville mineralisation and 25 km east of the major gold producing district of Bendigo. Mineralisation is structurally controlled along a north-south fault and is hosted by Ordovician turbidites in the Ballarat Trough of Central Victoria. The economic mineralisation occurs over a strike length of 1.3 km within the 40 m deep oxidised zone. Subcropping gossanous material and float are found at the northern and southern ends of the deposit.

The mineralisation was found following a soil geochemical survey and a limited drilling programme to test some old prospecting pits. Although results from that programme were disappointing, a subsequent programme of drilling to obtain bedrock samples for geochemistry revealed the main mineralisation along strike from the earlier tested area. A preliminary resource, calculated from 75 drill holes (and open-ended in all directions) currently stands at 779,000 tonnes @1.34 g/t Au.

The regolith history of the region is complex, involving several cycles of weathering, erosion and deposition through the Tertiary and Quaternary. During the early Tertiary, the auriferous White Hills Gravel was deposited. Subsequent weathering resulted in dominantly north-flowing streams which eroded both the earlier gravels and Ordovician bedrock, leading to deposition of gravels and sands of the Calivil Formation, to produce the deep leads of the area. These Tertiary sediments are effected by ferruginisation and/or silicification. Basalts covered large areas of Central Victoria about 5 m years ago, but are not retained in the Goornong South area where more recent alluvium related to present-day streams and aeolian deposition occupies the current wide valleys. At Goornong South, the cover is mainly recent alluvium of variable thickness, which overlies either saprolitic bedrock or Tertiary gravels. Pedogenic carbonate is developed in the soils formed in the recent alluvium.

Gold mineralisation at Goornong South is characterised by the absence of potential pathfinder elements except for As (and perhaps Sb). During the complex weathering of the Tertiary and Quaternary, As and Au have been dispersed within the residual regolith to produce haloes defined by cut offs of 100 ppm and 50 ppb respectively. Dispersion also occurs into the overlying transported material where slightly lower levels of these elements are present in the soil developed in overburden above mineralisation. Detailed study of the soils shows that the coarse (+2mm) fraction contains ferruginous pisoliths and is richer in Fe, Mn, As, Sb, Co, Cr, Pb and W than the finer (-63 micron) fraction. The fine fraction generally contains higher Au, Ce, La, Na and Hf. Arsenic >100ppm in the coarse fraction of the soil defines an anomaly twice the size of that in bedrock whereas Au in this fraction gives a similarly-sized anomaly to that in bedrock. However the Au anomaly defined using the fine fraction of the soil is nearly four times as large as that derived by bedrock geochemistry. Calcrete found in the top metre of the soil profile does not appear to significantly concentrate Au.

Although Au in the fine fraction of the soil gives the largest anomaly, because of the ease of collecting the coarse ferruginous fraction of the soils, that material is suggested as a good cost-effective sampling medium for areas of significant cover in Central Victoria.

THE APPLICABILITY OF PARTIAL EXTRACTIONS TO MINERAL EXPLORATION IN AREAS OF TRANSPORTED OVERBURDEN

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The presentation reviews the results of an investigation into the role of partial extraction analyses of near-surface samples as unique indicators of concealed mineralization. Partial extraction analyses (e.g. enzyme leach) are thought to be superior to conventional analytical procedures (e.g. aqua regia) for detecting mineralization under transported overburden (Clark, 1995; Mann et al., 1995). Their ability to detect mineralization under such overburden relies on assumptions that (1) sulphide mineralization can oxidize under transported overburden to release elements to groundwater, and (2) elements can migrate to surface in aqueous or gaseous media to become fixed in and on organic and inorganic substrates. Partial extraction techniques selectively dissolve elements held in specific forms in soils, and the spatial distribution of these elements should reflect buried mineralization. Elements held in more resistant substrates unrelated to mineralization are not extracted, and this lowers background noise considerably such that anomalies spatially related to mineralization can be identified.

The study focused on determining whether partial extractions are applicable to mineral exploration by testing extractions of variable strength over (1) copper mineralization covered by 100 to 150 m of Upper Miocene alluvial gravels in Chile, and (2) various types of base metal mineralization covered by 2 to 40 m of Quaternary glacial drift (e.g. till, glaciolacustrine and glaciofluvial sediments) in Canada. Seven orientation surveys were carried out to determine which sample media, extractions, and elements reflect buried mineralization on a consistent basis, and to establish that anomalies spatially associated with mineralization are genuine, and not simply artifacts of flawed analysis or sample processing, changing terrain conditions, or anthropogenic activity.

The main conclusion of the study is that strong and intermediate strength extractions (i.e. 30 to 100% of total element concentration extracted) outperform weak extractions (i.e. <5% of total element concentration extracted) in shallow (<5 m) transported overburden, and the opposite is true for deep (>5 m) transported overburden. Elements that are anomalous over mineralization covered by shallow glacial overburden are held in sulphides and their decomposition products (i.e. Fe-oxides), and these source minerals are present in sufficient abundance to produce anomalies that can be identified by both strong and intermediate extractions. A strong extraction of A- or B-horizon soils provides the best expression of mineralization under shallow glacial overburden. Weak extractions of B-horizon soils offer more pathfinder elements for locating mineralization, but anomaly patterns are inevitably more erratic and difficult to interpret because of the sensitivity of such extractions to natural variations in the weathered zone.

In the case of deep glacial drift and alluvial gravels, elements that are anomalous over and adjacent to base metal mineralization are, for the most part, held in water-soluble forms in B-horizon soils. In many cases, the anomalies can only be identified by weak extractions because the water-soluble minerals, which bind elements indicative of mineralization, are of insufficient abundance to be recognized by stronger extractions. The use of weak extractions requires that more time and care be devoted to sample processing and analysis, and the high spatial variability associated with such extractions further requires that samples be collected at short intervals. To offset the cost of collecting and analyzing more samples, it is suggested that samples be "pre-screened" with less expensive pH and conductivity determinations (Smee, 1983). Areas of low pH and erratic soil conductivity should be followed-up with a weak extraction (e.g. water) to test for base metal anomalies directly over mineralization, and also for erratic base cation (e.g. Ca) and halogen (e.g. Br) anomalies over and adjacent to mineralization.

Variability in partial extraction data can be increased by flawed analysis or sample processing, changing terrain conditions which effect soil composition and texture, and anthropogenic activity (Seneshen et al., 1995; Seneshen, 1997). These factors influence weak extractions in particular, and they must be accounted for prior to meaningful interpretation of anomaly patterns.

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GEOCHEMICAL PATTERNS FROM VARIOUS EXTRACTION METHODS IN RESIDUAL AND TRANSPORTED REGOLITH IN THE COBAR REGION, NSW, AUSTRALIA

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In deeply weathered regions where thick regolith contains a significant transported component, geochemical exploration using the total trace element contents of surface samples has commonly proven to be ineffective. Recent studies in the Cobar region have shown that various selective extractions are capable of detecting elevated metal contents in residual saprolite through thin veneers (<2 m) of transported regolith. In this study, the ability of such extractions to detect subtle metal dispersion patterns through deeper transported overburden has been examined.

In the study area, the deep weathering profile developed over Cobar Supergroup metasedimentary rocks and Girilambone Group phyllites has been partially stripped and covered by up to 40 m of transported regolith within present and palaeo-drainage regimes. The transported material consists of massive quartz-kaolinitic silts with ferruginous and quartz gravels. Sporadic ferricretes occur within the middle to upper parts of the channels. Calcrete occurs as thin, discontinuous crusts within the top of the regolith and near the interface between saprolite and fresh bedrock. Three selective geochemical extractions (weak hydroxylamine•HCl, Enzyme Leach and aqua regia) and a total extraction were applied to surface and regolith profile samples collected from RC drilling traverses over a series of targets previously defined by auger and RAB drilling programs.

Metal patterns display three distinct geochemical associations. Elevated Zn-Mn ± (Au,Cu,Pb) concentrations in the lower saprolite, are coincident with extensive Zn-Cu anomalies in Chesney Formation siltstones. Total Zn levels are usually depleted in the upper part of the saprolite. Trace element patterns for the three selective extractions indicate weak but widespread Zn anomalies near-surface and at the interface between the residual and transported regolith. Dispersion of Zn from saprolite containing up to 900 ppm total Zn into the lower 10 m of the overlying, bleached, transported silts and quartz gravels was detected. Although total Zn values are subdued, the Zn contents of the three selective extraction increase progressively to the base of the partially oxidised silts and gravels (in association with increasing Mn and Fe). The greatest extent of vertical dispersion is observed in the Enzyme Leach-extractable Zn.

In near-surface samples, anomalous Zn, Mn ± Cu values for the selective extractions generally follow the total contents of those metals (especially for Enzyme Leach). This feature appears linked to recent soil development, with some disturbance of patterns by erosion or sheetwash deposition. Total and selective extractions Zn values in the upper section of the transported regolith did not reflect the position of the underlying Zn sources. In carbonate-rich samples, lower amounts of metals were released by hydroxylamine•HCl and Enzyme Leach compared with carbonate-poor samples.

The As-Sb±Au association is mainly observed in the residual regolith, along the faulted contact between the Chesney Formation siltstones and Girilambone phyllites. Arsenic is depleted in the upper part of the saprolite but both total and selective extraction As and As/Fe values increase with depth. Sporadic Fe, As and Sb anomalies in near-surface transported cover were observed for the three selective extractions. High selective to total ratios for Fe, As and Sb extend from the residual into the transported regolith, despite a substantial decrease in total abundances. Enzyme Leach patterns for surface samples show a weak but distinct As feature that coincides, in part, with the RC sample As-Sb anomaly.

The As-Sb-Pb-Fe association is developed in the interbedded gravels and silts in the palaeo-drainage channels. Persistent anomalies in the total As, Sb and Pb concentrations are correlated with high Fe values (due to maghemite and hematite-rich pisolites), but no primary As-Sb-Pb source has been detected in the underlying saprolite. A feature of the selective extractions of these refractory lag gravels is the release of higher As and Pb than other regolith materials in the area. Increased total As/Fe and Pb/Fe are sporadically associated with the lower gravel units and at the contact between the transported silts and saprolite. Where there is development of goethitic rims on pisolites and ferruginous gravel matrices, there is also enhancement in the aqua regia, hyroxylamine•HCl and (to a lesser extent) Enzyme Leach-extractable As-Pb-Sb±Cu±Zn concentrations. The distribution of such ferruginous materials is, however, patchy. Localised high As/Fe ratios suggest limited mobilisation and reprecipitation of As and probably Pb.

The total and selectively extractable metal associations can be related to various stages in the mineralogical and geochemical evolution of the regolith. Some geochemical dispersion patterns appear derived from a variably truncated and leached saprolite profile, dominated by quartz-sericite(illite)-kaolinite with localized hematite along joints and fractures. The stripping of the upper parts of the saprolite has directly contributed metals to the overlying transported silts and gravels. The spatial character of element patterns, particularly in the transported overburden, indicate a continued redistribution of previous dispersion patterns during the present weathering cycle. For the targets and regolith profiles examined, there is little evidence from the selective extraction geochemical patterns to suggest direct transient dispersion of metals, from primary or oxidizing sulphide sources, through regolith containing a significant transported component.

REGIONAL GEOCHEMICAL GOLD ANOMALY SORTING AND EVALUATION IN INNER MONGOLIA, CHINA

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1:200,000 stream sediment surveys have been carried out in the Daqingshan-Wulashan region located at the north edge of Huabei platform in the central part of Inner Mongolia, China. Regional gold geochemical data from stream sediment surveys (about 1 sample/4km^2) in this region were processed by a newly developed data processing program - Sub-Area Median Contrast Filter (SAMCF). SAMCF is a computerized system of data processing, anomaly recognition and anomaly mapping for regional geochemical data. This is developed on the basis of conventional filtering methods and unconventional statistical Exploratory Data Analysis (EDA) techniques. The geochemical background surface is regarded as a continuous changing curved surface by SAMCF. A sub-area is taken to simulate the spatial variation of the geochemical background field. A small window acts for local anomaly or noise and a large window acts for local background. Different anomaly thresholds are taken in the different geochemical sub-areas. The EDA technique is used to calculate the positive and negative anomaly thresholds, and the anomalies are delineated using contrast values. It is shown that SAMCF can give satisfactory results in terms of its ability to recognize anomalies related to known mineralization in the survey area. Of particular interest is the preservation of strong anomalies, enhancement of subtle anomalies, and the discovery of some new anomalies.

Comparing the regional Au anomalies delineated by SAMCF and by conventional method, the distribution patterns of Au anomalies after SAMCF are more distinctly and clearly revealed. The intensity and area of some conventional Au anomalies have been enlarged after SAMCF. Some new strong and highly significant Au anomalies, which have a very small area or do not appear in the conventional anomalies map, have also been discovered. The Honghaocun regional Au anomaly is obviously enhanced after processing by SAMCF. Also detailed follow-up surveys have found new economic gold orebodies within the Honghaocun Au anomaly.

ACCUMULATION OF GOLD AND HEAVY MINERALS BY MOSS-MATS

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Sediment derived from moss-mats has been employed as a sample medium throughout British Columbia, both by the provincial Regional Geochemical Survey (RGS) and by mineral exploration companies. RGS programs conducted on Vancouver Island utilized moss mat sediments exclusively. Moss-mats, collected from the active stream channel, have proven to be a highly effective sampling media. Acting as a natural riffle, they accumulate sediment by trapping particulate matter entrained in the streamflow, making them particularly effective in stream environments where fine-grained streambed sediment is absent. Geochemical orientation studies have suggested that moss-mats preferentially concentrate heavy minerals relative to conventional stream sediments. This process has been used to explain higher, more reproducible gold concentrations found within moss-mat sediment relative to stream sediment. As a test of this hypothesis, an orientation survey was conducted on streams hosting both moss-mats and stream sediments, which drain known mineral occurrences.

Samples were collected at five locations in British Columbia representing a variety of biogeoclimatic regimes and mineral deposit types. Moss-mat samples were collected from competent boulders or logs within the active stream channel. Stream sediments were collected from sites containing abundant fine-grained material and located within two metres of the moss-mat sample site. One to two kilogram samples of each sample type were collected. The samples were wet sieved to obtain representative size fractions, which were separated into light, and heavy mineral fractions. The heavy mineral fraction was further separated into magnetic and non-magnetic fractions. Non-magnetic heavy mineral fractions and light mineral fractions were analyzed at a commercial laboratory by INAA for 34 elements. The results of this study illustrate some of the processes which occur during the transport of sediment in a stream and the process by which moss-mats accumulate sediment. Heavy mineral accumulation in moss-mats is dependent upon the specific density of the grains and fluctuations in stream flow velocity. The effectiveness of moss-mat as a sampling medium for gold and other heavy mineral associated elements is evaluated.

BACKGROUND GEOCHEMICAL NOISE REMOVAL IN THE ALDRIDGE AND PRITCHARD FORMATIONS, BRITISH COLUMBIA, MONTANA AND IDAHO: RECOGNITION OF SUBTLE ALTERATION ABOUT SEDIMENT HOSTED MASSIVE SULPHIDE DEPOSITS

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Subtle hydrothermal alteration haloes have recently been recognized about some sediment hosted massive sulphide (SHMS) deposits. Muscovite and chlorite alteration haloes exist about the Sullivan Pb-Zn deposit, British Columbia, and Fe-carbonate alteration haloes exist about the Tom and Jason Pb-Zn deposits, Yukon. Unfortunately, not all SHMS deposits exhibit these more obvious alteration haloes, and if more subtle ones do exist where none have been recognized, these haloes are probably masked by the mineralogical (and thus lithogeochemical) variability of the host rocks. Host rock variability about SHMS deposits can be substantially large, especially when the host sediments are coarser grained, due to differential quartz and feldspar sorting processes. Dilution by carbonate, Fe-sulphides, and biogenic and detrital (non-hydrothermal) silica also produces variations with similar scales. Clearly, these primary compositional variations make detection of the effects of subtle hydrothermal alteration associated with SHMS deposits difficult, if not impossible.

The substantial 'fresh' host rock compositional variability in the Aldridge and Pritchard Formations, Purcell / Belt Basin, British Columbia, Montana and Idaho (> 25 wt. % SiO_2 variation and > 15 wt. % Al_2O_3 variation) is undoubted caused by differential sorting of quartz and feldspar during turbidite deposition. Consequently, it represents a significant impediment to lithogeochemical anomaly recognition. Unfortunately, the absence of a 'conserved element' in these sediments prohibits use of numerical procedures capable of modeling and removing this compositional variability (*e.g.* - Pearce element ratio - PER - analysis).

Consequently, a more complicated approach that does not require a 'conserved element' assumption, generalized element ratio analysis (GER), has been used to accurately model the background compositional variability observed in the Aldridge and Pritchard Formations. The GER approach employs the same type of x/z versus y/z molar element ratio diagrams as PER analysis, except the denominator element(s) are not conserved. The GER diagrams are specific projections of the multi-element geochemical space occupied by these rocks that have optimal properties. The projection collapses the observed multi-element background lithogeochemical variability to a manageable dimensionality, and thus facilitates investigation of the effects of additional geochemical process (*e.g.* - hydrothermal alteration) that may have affected the rocks.

Design of GER diagrams utilizes petrologic constraints consistent with the essential mineralogy of the rocks (quartz, plagioclase, potassium feldspar, muscovite, biotite, pyrrhotite, and calcite or dolomite), coupled with a matrix methodology, to determine the linear combinations of numerator and common denominator elements that make up the axes of the GER diagram. Three different background compositional variability models (three GER diagrams) have been successfully designed using these matrix methods for the Aldridge and Pritchard Formations. The resulting GER diagrams collapse the 10 dimensional geochemical space (Si, Al, Fe, Mg, Ca, Na, K, OH, CO_2 and S), containing the 8 dimensional object describing the possible compositions of rocks containing mixtures of the essential mineral suite (the polyhedron with vertices that are the compositions of the nine essential end-member minerals), into two dimensional GER sub-spaces (the plots). In these sub-spaces, the possible compositions of all rocks composed of mixtures of the essential mineral suite plot on unique, specific chords. Thus, the GER projections produce one dimensional background compositional variation models on two dimensional plots, leaving one additional dimension available on each plot for monitoring the effects (presence) of other geochemical processes (alteration minerals).

The three models developed for the Aldridge and Pritchard Formations successfully predict the range of possible compositions that hydrothermally unaltered sediments exhibit across a 150 km N-S by 100 km E-W area and through approximately 5 km of stratigraphy, despite the effects of metamorphism (chlorite, biotite and garnet grades). Thus, the very substantial regional background compositional variations observed in the Aldridge and Pritchard Formations do not impose impediments to the recognition of subtle hydrothermal alteration effects. Lithogeochemical variations not attributable to the presence of these essential minerals are obvious when examined using these models (they do not plot on the background chords on the MER diagrams), and the locations of anomalous samples on the diagrams give clues as to why they are anomalous. Thus, samples that underwent small amounts of hydrothermal alteration, containing either additional alteration minerals or anomalous amounts of the essential minerals, can be detected. This allows recognition of subtle and historically overlooked alteration effects associated with sediment hosted massive sulphide mineralization (*e.g.* - the Sullivan Pb-Zn deposit). As a result, these models may be used to detect, classify and quantify the effects of hydrothermal alteration, and therefore represent a sensitive exploration parameter for SHMS deposits in the Aldridge and Pritchard Formations.

LITHOGEOCHEMICAL CONSTRAINTS ON HYDROTHERMAL ALTERATION AND MINERALIZATION AT THE BIG BELL MESOTHERMAL GOLD DEPOSIT, YILGARN CRATON, WESTERN AUSTRALIA

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The Big Bell mesothermal Au deposit, Murchison Province, Yilgarn Craton, is hosted by a sequence of Archean volcanic rocks metamorphosed to middle amphibolite grade. A variety of lithologies exist in the deposit area, including amphibolite, garnet amphibolite, biotite schist, cordierite schist, feldspar schist, altered (muscovite) schist, intermediate (quartzo-feldspathic) schist, felsic volcanic and porphyry. Ore (23.1 M metric tons @ 2.86 grams per tonne produced; 6 M metric tons @ 3.1 grams per tonne reserves) is hosted by altered, feldspar and, to a lesser extent, biotite schist that exhibit a strong foliation orientated NNE-SSW along the axis of the enclosing greenstone belt.

Whole rock lithogeochemical data have been used to determine the original composition of the host rocks to the deposit. Zr/Ti ratios reveal that all lithologies except intermediate schist, felsic volcanic and porphyry were originally basalts that were variably hydrothermally altered. These non-basaltic lithologies are the only ones commonly exhibiting sharp contacts with other rocks in the district, whereas the basaltic lithologies commonly exhibit gradational contacts with other basaltic rocks.

Subsequent Pearce element ratio analysis has revealed that the least altered basaltic rocks (amphibolites and garnet amphibolites) exhibit compositional variations consistent with fractionation of olivine, plagioclase and clinopyroxene in a 7:10:8 molar ratio. Furthermore, the bulk composition of the plagioclase involved in fractionation is $X_{AN} = 0.75$, and the bulk Fe/(Fe+Mg) ratio of the fractionating olivine and clinopyroxene was approximately 3/7.

These fractionation parameters are consistent with common basalt fractionation processes.

Hydrothermally altered rocks (cordierite, biotite, feldspar and altered schists) exhibit compositional variations consistent with original quartz, sericite and pyrite alteration. Metasomatic element additions (K, S, H) and losses (Ca, Na, Mg) deduced from Pearce element ratio analysis have allowed identification of balanced chemical reactions describing the hydrothermal alteration. Subsequent metamorphism has converted this precursor hydrothermal alteration assemblage into a suite of successor metamorphic mineral assemblages, and this has hindered recognition of these metamorphic rocks as altered basalts.

Finally, the paucity of quartz veins, absence of significant macroscopic evidence for shearing across the Big Bell gold-bearing 'foliation' zone, and the strong association between gold and pyrite all suggest that mineralization at Big Bell probably resulted from chemical trapping during hydrothermal alteration. The Fe+2 liberated and H+ consumed by the hydrothermal alteration (hydrolysis) reactions that produced muscovite and quartz probably triggered the precipitation of pyrite, and thus Au, from Au-bisulphide complex by the reaction : $Au(HS)_2^- + Fe^{+2} \Rightarrow FeS_2 + Au + 2\ H^+ + e^-$. As a result, the Big Bell mesothermal Au deposit exhibits a strong genetic affinity with banded iron formation gold deposits, rather than shear-hosted gold vein deposits.

THE USE OF LITHOGEOCHEMISTRY AS A GUIDE TO EXPLORATION AT THE EL INDIO GOLD-COPPER MINE, NORTH-CENTRAL CHILE.

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More than 10,000m of NQ diamond drill core were relogged and approximately 1,000 core samples were collected along two sections and one level of the underground workings at the El Indio mine. Samples were analyzed for major oxides, Ba, Sr, Nb, Zr and Y by pressed pellet XRF; and Ag, Cu, Pb, Zn, Mo, Bi, and As by ICP following a multi-acid total digestion. Gold analyses were done by AAS following an aqua regia digestion. Data was processed using the mass change method of MacLean (1990), Barrett (1991, 1993) and others.

Al_2O_3, TiO_2 and Zr proved to be the most immobile elements in the alteration environment. TiO_2 vs. Zr in visually least altered rocks were used to define igneous fractionation trends. Altered rocks were taken to fall on a line through the origin and the original composition on the fractionation line, with points plotting above the fractionation trend line representing samples which have undergone a net mass loss, and those falling below, a net mass gain. A Mass Factor (M.F.) was then defined by dividing the ratio of immobile components in the precursor rock by the ratio in the altered rock. The original component concentration of an altered rock was then determined by multiplying the Mass Factor by the concentration in the altered sample (i.e. Rc=M.F.*Pc, where Pc is the concentration in the altered rock). The value Rc – Pc, the mass gain or loss of a component, was then plotted on maps to define alteration zones.

The data showed that geochemical changes could be detected up to 100m away from the known veins, approximately 7 times farther than the extent of visually recognizable alteration. Components with the widest anomalous signatures (50 to 100m) include SiO_2, Al_2O_3 and K_2O (mass gain); and CaO and Na_2O (mass loss). Components with more narrow signatures (20 to 50m from the vein) include Fe_2O_3 and Y (mass gain), and MgO (mass loss). Au, As, Cu and Pb show uniform mass gains within 5 to 10m of the veins. Ba and Nb show different responses depending on the sulphide content of the veins. Ba shows broad mass loss envelopes adjacent to sulphide-rich veins and mass gains adjacent to sulphide poor veins. Nb shows tight mass gain envelopes over sulphide-rich veins and tight mass loss adjacent to sulphide-poor veins.

In summary, lithogeochemical data not only substantially increases the size of the exploration target, but allows an estimate of the distance to the target, the identification of anomalies independently of the original rock type, and an indication of whether the target is low or high sulphide type of vein.

SELECTIVE LEACH GEOCHEMICAL PATTERNS OVER OUTCROPPING AND CONCEALED GOLD MINERALIZATION IN THE RATATOTOK DISTRICT, NORTH SULAWESI, INDONESIA

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A geochemical orientation survey was carried out in January, 1998 in the Ratatotok district of North Sulawesi, Indonesia to determine the effectiveness of selective leach (mobile ion) soil geochemistry in prospecting for concealed gold mineralization within the district. Soil samples were collected from three prospects in the district and submitted for mobile metal ion (MMI) and enzyme leach (EL) analysis. Of the prospects sampled — all within 3 km of Newmont's Mesel Mine (7.8 Mt grading 7.3 g/t Au (1.8 Moz)) — only one had been drilled at the time of the orientation survey and was known to contain gold mineralization ('blind' mineralization beneath 50 meters of post-mineral volcanic rocks). The other two prospects, drilled in mid 1998 after the orientation survey was completed, are now known to contain outcropping, not concealed, gold mineralization.

Patterns of MMI and EL elements show the location of concealed gold mineralization, however similar element patterns occur over outcropping gold mineralization and areas which have been sterilized. Results from field duplicate pairs and background samples are, for some elements, highly variable. Also, element concentration is clearly affected by parent soil lithology contrary to selective leach design. Although an anomalous pattern was detected above concealed mineralization, anomalies generated from selective leach soil geochemistry within the Ratatotok district are not necessarily diagnostic of concealed mineralization. Selective leach soil geochemistry is an effective prospecting tool for concealed gold mineralization in the Ratatotok district, however the resulting anomalies, as is true with all geochemical anomalies, must be interpreted in their geologic context to learn their true significance.

This paper describes the patterns observed in the MMI and EL analytical results over three prospects in the Ratatotok district. Of particular importance, patterns related to mineralization type (unmineralized vs. outcropping vs. buried) and geologic setting are compared. It is hoped that these observations, together with observations from workers in different geologic and mineralization settings, will lead to a better understanding of selective leach soil geochemical response to concealed mineral deposits.

THE SPENCE PORPHYRY COPPER DEPOSIT: A COMPARISON OF EXPLORATION TECHNIQUES APPLIED

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The Spence porphyry copper deposit was discovered in June 1996 during a reconnaissance reverse circulation drilling program on Rio Algom's 100% owned NORA claims. The deposit is located in northern Chile, 60 kilometres southwest of the Chuquicamata copper deposit and 120 kilometres northeast of the port city of Antofagasta. The deposit is at an elevation of 1,700 metres above sea level and is traversed by the main highway to Chuquicamata as well as the Antofagasta-Bolivia railway. The deposit is completely covered by recent gravels that average 80 metres in thickness. Based on 94,5649 meters of drilling in 341 holes, the in-pit resource is estimated at 306 million tonnes grading 1.1% copper.

Regional exploration by Rio Algom for porphyry copper mineralization in northern Chile began in 1992 and concentrated on well defined north-south trending porphyry copper belts which are host to most major copper porphyry deposit in Chile. A rigorous exploration approach is based on the acquisition of gravel covered areas selected on the basis of indications of porphyry type mineralization including nearby alteration and/or mineralization, structural lineaments or intrusive trends. Areas selected are tested by widespaced drill holes.

At Spence, the 10th hole drilled during the testing of broad gravel covered flats cut weakly leached and copper enriched felsic intrusive. Following this drill discovery and concurrent with delineation drilling a geophysical program consisting of induced polarization (IP), resistivity, ground magnetics, transient electromagnetic (TEM) and a high-sensitivity aeromagnetic surveys as well as a geochemical program consisting of enzyme leach was undertaken to evaluate the applicability of these various techniques in gravel covered pampas.

The deposit is hosted by Paleocene-Eocene age porphyritic quartz monzonite/granodiorite stocks and dykes that intrude Upper Jurassic/Lower Cretaceous andesitic volcanics and volcaniclastics. Alteration is typical for a porphyry deposit and consists of an early K-metasomatic alteration overprinted by a phyllic alteration. The deposit has been extensively weathered and enriched by supergene events. It consists of a copper-barren, argillic Leach Cap, a Copper Oxide Zone, and a copper enriched Supergene Zone that overlies and extends outward from the copper bearing Hypogene Zone. The mineralogy of the deposit is relatively simple and consists of atacamite and brochantite in the Oxide Zone; chalcocite, covellite and pyrite in the Supergene Zone; and chalcopyrite, pyrite, bornite, molybdenite and tennantite in the Hypogene Zone.

The ground magnetic survey consisted of 81 line kilometers with a line spacing of 500m. Overall magnetic relief is low. The survey is characterised by two broad anomalies southwest and northeast of the deposit caused by mafic volcanics and intrusives. The ground survey delineated major structures. A dipole-dipole array with electrode spacing of 300m was used for an IP survey of 48 line km. Results show a strong, oblong 4km by 1km polarizable zone caused by the pyritic quartz-sericite alteration zone of the deposit. A TEM survey was cut short as no depth penetration could be obtained due to a conductive clay layer within the upper parts of the gravel cover. A high sensitivity aeromagnetic survey identified major regional structures and overburden thicknesses, but not the deposit.

Geochemical test surveys over the Spence mineralization consisted of the Enzyme Leach analytical method. Several "apparent-possible" anomalies were identified in areas of major structures and thinner gravel cover.

Results of the exploration techniques studied, cost and time expenditures involved, indicate that reconnaissance drilling is the most effective approach. Only the IP survey gave a distinct and unmistakeable anomaly which could be classified as a classic response to a porphyry deposit.

NEW CONCEPTS, NEW TECHNOLOGY AND NEW STRATEGY IN MINERAL EXPLORATION

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The great uncertainty and risk encountered in mineral exploration are briefly reviewed. Reduction of the risk depends on the development of new concepts, new technology and new strategy in mineral exploration. New concepts oriented by the author and his co-workers since 1980's are stated.

The new concepts developed are: (1) For the reduction of the risk in mineral exploration, the study of direct information generated from mineralization itself will be emphasized; (2) Geochemical methods are the main methods to obtain direct information and will take the lead in future exploration provided that their discrimination power can be improved to the sub-ppt or ppt range; (3) Geochemical methods will become a strategic method in mineral exploration only if the hierarchy of broad and nested geochemical patterns are studied by geochemical mapping; (4) Search for giant ore deposits has become the focus of activity of the mining industry. The main indication to differentiate giant ore deposits with ordinary ones is their huge metal endowment; (5) The greatest chance to find new giant ore deposits will be in concealed terrain and deep-penetration geochemical methods that should be developed to detect the deep-seated minerlization; (6) Super-critical fluid generated from earth interior might evolve earth-gas and nanoscale metals at reduced temperature and pressure, and bring information of concealed mineralization to the earth surface.

Based on these new concepts, new deep-penetration geochemical technology, both tactical and strategic which could discover nanoscale metals brought up from depth by earth-gas has been developed and new exploration strategy has been worked out using super-low density or extremely low density sampling techniques to cover very large region in a short time, in order to discover the geochemical blocks with huge metal endowment by the delineation of very broad geochemical patterns. Method of progressive focusing of the target areas has been developed by tracing the nested hierarchy of geochemical patterns and integrated methods will be used to pinpoint the concealed large to giant ore deposits. This strategy could greatly reduce the uncertainty and risk of mineral exploration.

Abstracts

Poster Session A

Monday, April 12th
Tuesday, April 13th

In alphabetical order by first author's name.

ENVIRONMENTAL CONTAMINATION OF TOXIC ELEMENTS AROUND AN ABANDONED Au-Ag MINE IN KOREA

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Kubong Au-Ag mine, one of the largest Au mines in Korea, produced 4,500 tons of crude ore a month. However, the mine ceased operation in 1970 due to shortage of ore reserves and worse economic condition, and has been abandoned since then. Environmental geochemical survey for the mine and other former Au-mining areas in Korea was done in 1996, and revealed that contamination by toxic element was the severest in this area. The main sources were tailings and effluent which had been discharged directly into nearby stream and agricultural areas without treatment or control. Tailings samples contained As, Cd, Pb and Zn up to 5,000 mg/kg, 54 mg/kg, 2,800 mg/kg and 1,560 mg/kg, respectively. Through a sequential extraction of tailings, heavy metals were found to be mainly associated with sulfide gangue minerals, and mobility of these metals would be enhanced by the natural oxidation. Nearby agricultural fields are used predominantly for rice production which is the main diet crop in Korea. Thus, the pathways and contamination level of As and heavy metals in the agricultural environment was assessed as a detailed survey in 1997, and proper reclamation procedures considered.

For the detailed survey, paddy soils, rice crops, stream sediments and waters from tailings effluent, stream and shallow wells were sampled inthe directly contaminated area and a control area. Mean concentrations of As, Cd and Pb in paddy soil samples collected from the contaminated site were 59.4 mg/kg, 1.4 mg/kg and 67 mg/kg, respectively, and their concentrations were significantly correlated with each other. Rice grains contained as much as 0.55 mg/kg of As and 3.1 mg/kg of Cd. Considering the pollution criteria for Cd of 1.0 mg/kg in rice grain, some of the samples are unsuitable for human diet.

Element concentrations in stream sediments sampled downstream from the abandoned mine reached As 4,400 mg/kg, Cd 32.8 mg/kg, Pb 2,000 mg/kg and Zn 1,000 mg/kg, indicating that the stream was contaminated directly by tailings input. The elevated concentrations of As and heavy metals in sediment were found about 4 km downstream from the tailings. It is thought that the stream conditions have been impaired over a greater distance. Tailings effluents contained 1,890 μg/l of As and 25 μg/l of Cd, showing that As and Cd in tailings as well as sediment can be easily mobilized into the stream and irrigation water. Concentrations of heavy metals in water samples from the stream and shallow wells were relatively low due to rain on the day before sampling. However, fairly high concentrations of As, with up to 78 μg/l and 56 μg/l in streams and wells, respectively, show high releases of As in the study area.

Given the distribution of As and Cd in the paddy field, the contents in soils and rice crops were elevated along the path of the stream around the mine. It is suggested that the stream used for irrigation water is the most likely source of the contamination in paddy soils and rice crops. this was confirmed by the increased amounts of exchangeable forms of heavy metals in paddy soils, compared with those of tailings and stream sediments. Two core samples taken (ca. 7 and 10 m depth) in the tailings profile showed that concentrations of heavy metals in subsurface were higher than those in surface, and there is a possibility of heavy metal contamination in groundwater.

For the reclamation of the study area, containment of tailings will be needed to control the main pollution source, and the polluted sediments should be dredged. To lower the contamination level in agricultural field, paddy soil should be mixed with unpolluted soil and be deeply plowed. A model for containment and how to treat the dredged sediment have to be assessed in a further study.

PHYTOMINING

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The proposed new technique of phytomining involves growing a crop of a hyper-accumulating plant species, harvesting the biomass and buring it to produce a bio-ore for sale.

The first experiments were carried out in California using the Ni-hyperaccumulator *Streptanthus polygaloides*. It was proposed that a yield of 100 kg/ha of sulphur-free Ni could be produced. In later experiments we have used the same technique to test the phytomining potential of the Italian Nihyperaccumulator *Alyssum bertolonii* and the South African *Berkheya coddii*.

We have also been able to induce plants to hyperaccumulate Au by adding ammonium thiocyanate to the substrate. Up to 57 μg/g Au (dry mass) could be accumulated by Indian mustard (*Brassica juncea*).

Unusual hyperaccumulation (>500 μg/g dry mass) of toxic Tl has been determined in *Iberis intermedia* (Brassicaceae) from southern France. This species contained up to 3070 μg/g (0.31%) Tl in the wholeplant dry matter. This unusually high accumulation of Tl has significance for animal and human health, phytoremediation of contaminated soils, and phytoming for Tl. It has been calculated that a net return of $US1200/ha (twice the return from a crop of wheat) would be possible with a biomass yield of 10 t/ha containing 0.08% Tl in dry matter. The break-even point (net yield of $US500/ha) would require 170 μg/g (0.017%) Tl in dry matter.

For phytomining for Ni, the effect of different fertiliser treatments was established in situ in Tuscany and showed that the biomass of the Nihyperaccumulator *Alyssum bertolonii* could be increased by a factor of three without significant loss of the Ni concentration in the plant. Analogous experiments have been carried out by use of the South African Ni-hyperaccumulator *Berkheya coddii*. A biomass yield of over 20 t/ha can readily be achieved though the nickel concentration is not as high as in *A. bertolonii*.

Because of world prices for heavy metals, it is unlikely that phytomining will ever become possible for the cheaper metals such as Cu, Pb and Zn despite there being plants that will hyperaccumulate these elements. For metals such as Co and Ni, yields can be increased by use of complexing agents such as EDTA, results of such experiments are described.

GEOCHEMICAL STUDY OF WASTES FROM A MERCURY MINE IN ASTURIAS (NORTHERN SPAIN)

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In terms of wastes it is known that mining is a local but very important issue. Characterisation of wastes from mercury mining is of particular interest in relation to the contribution of metals to the environment because of the great toxicity of some heavy metals and their compounds.

Mercury is not highly mobile under most environmental conditions, however its association with suspended solids and colloidal matter in aquatic systems is possible. Thus, its attachment and transport on fine particles is a supportable hypothesis for mercury mobility. Also important is the presence of arsenic minerals. In the case under study the arsenic minerals are regular and As-rich pyrite, which are readily soluble in the environment with arsenic complex anions being the most common mobile forms. However, in As migration is greatly limited by strong sorption by clays, hydroxides and organic matter.

Mercury mining in Asturias (north-western Spain), where mines were active until 1974, was an important regional industry that developed over many years and was carried out without adequate pollution control over waste disposal. No corrective actions have been applied during the abandonment stage and the mining works remain in the form of old industrial installations with significant quantities of mining wastes exposed to weathering of metalic sulphides so that a natural lixiviation of metals occurs.

In the area of "El Terronal", 5 km northern Mieres, a large volume of mercury mine wastes evaluated at some 170,000 m^3, are stocked in a topographic depression formed by the bottom of a tributary valley of the Caudal river, which is being rehabilitated for salmonids. Furthermore, these wastes varying over a wide range of grain sizes, are disposed in an area of humid and temperate climate that favour the formation of leachates. Rainfall infiltrates through the waste piles producing acidic conditions in the waste piles, where heavy metals are easily mobilised and dispersion of toxic metals in soils and waters occurs in a domain very close to populated areas where crops and grazing are present.

Chemical analysis of representative samples from these mining wastes in the different zones of the piles shows total mercury concentrations ranging from 1 to 1,500 $mg.Kg^{-1}$. Total arsenic concentration ranges from 20 to 72,000 $mg.Kg^{-1}$. A multielement data set produced by multielement analytical techniques, in conjunction with methods of multivariate analysis, has been applied to characterise geochemically the stocked materials and to evaluate their importance as contamination source.

DISPLAYING STREAM SEDIMENT DATA AS WORM MAPS

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One of the common methods for displaying the results of stream sediment surveys is to create "worm" maps by colouring the drainage according to its assayed metal content. An alternative form of this data presentation uses only one colour but varies the thickness of the stream vectors according to increasing metal content. Historically this was accomplished with pen or pencils but with the arrival of CAD packages the process can now be accomplished on a computer. This however only represents a change of technology and the process essentially remains unchanged having to be repeated for each of the elements that may need to be displayed. The process is very time consuming for large suites of elements which are commonly run on drainage reconnaissance samples and makes fine tuning of the legends difficult as significant re-working is required.

The process outlined below creates a series of line vectors representing the streams, efficiently stores and manages these data and provides a basis for rapidly assigning different colours and widths to these vectors in the form a DXF or other digital ASCII vector file format. This is accomplished using basic digitising software or by way of on screen digitising from images using a software package such as Surfer. The ASCII digitising files are loaded into a data base package (Paradox) which facilitates:

- The general management of the data.
- The assigning of the colour and which variables to the vectors according to assay values via relational data base queries.
- The basic like programming language packaged with the database is then used to write the vector files.

The coloured stream vectors are then displayed with Surfer, Geosoft, Arcview or any other mapping package.

The process only requires basic software packages and as such can be accomplished without the resources of a cartography department or expensive GIS software packages. It is however also compatible with that approach. The examples provide use only Surfer and Paradox/Object-PAL but the same outcome could be achieved with any commercial digitising package and database product. Copies of source code used t import the digitising data into the database and to write DXF files are available on request.

SURFICIAL GEOCHEMISTRY RELATED TO PAST MINING IN THE COOKE CITY, MT, AREA AND ITS ENVIRONMENTAL IMPACT DOWNSTREAM IN YELLOWSTONE NATIONAL PARK

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Documenting the effects of past mining on the environment provides useful information for building models for future mitigation studies as well as for planning for new mine development. This case study describes the effects of intermittent surface and underground mining for base and precious metals between the 1870's and 1953 in the New World mining district, near Cooke City, MT, just northeast of Yellowstone National Park. Geologically, the area is mostly composed of intermediate-composition Tertiary volcanic rocks. Precambrian gneisses, Paleozoic clastic and carbonate rocks, and Tertiary intrusive rocks are present locally. Of the elements determined, those found to be enriched during Tertiary mineralization, which deposited the significant ore deposits of the district, include Ag, As, Au, Bi, Cu, Fe, Hg, Mo, Pb, S, Sb, Se, Te, Tl, W, and Zn. Exposures of mineralized rock, as well as mine dumps and a large mill tailings pile from the 1950's, remain in the upper catchment area of Soda Butte Creek, a stream originating in the area of the mining district and flowing into the Park. In June, 1950, a flash flood in the Cooke City area carried a part of the tailings pile, which is located along the side of Soda Butte Creek, downstream about 18-19 miles (29-30 km), into Yellowstone National Park. Small deposits of these flood-plain tailings can still be found in a few localities within the Soda Butte Creek drainage basin.

Samples of water and stream sediment were collected to characterize the downstream chemical effects of past mining and the flash flood. The water samples, which were collected during low flow, in September 1996, provide data describing the geochemical character of the water at that time. In contrast, data for the sediment samples document cumulative past migrations of elements. Of the 69 variables measured in the water samples, only Mo and SO_4 show anomalies that are probably related to the mineralized area. The weak anomaly for SO_4 extends from the area of past mining downstream in Soda Butte Creek to its junction with the Lamar River, a distance of about 20 miles (about 32 km). The similarly weak anomaly for Mo may extend as much as 12 miles (19 km) downstream. The water analyses show that at the time of sampling, there was no significant movement into the park of any of the other elements determined that are associated with the mineralization (Ag, As, Au, Bi, Cu, Fe, Pb, Sb, Se, Tl, W, and Zn).

The stream-sediment samples were analyzed for 53 variables. The effects of past mining are best characterized by the distributions of weakly anomalous concentrations of As and Au, which extend from the mineralized area downstream to the junction of the Lamar River, where sediment from background areas dilutes the chemistry of transported, mineral-rich sediments to background levels. Anomalous Cu, Fe, S, Te, and Zn are found to distances of 10-19 miles (16-30 km) downstream. Except for their possible presence in flood-plain tailings material, element anomalies for Ag, Bi, Hg, Mo, Pb, Sb, Se, Tl, and W in stream sediments do not extend more that about 1 mile (1.6 km) below the immediate area of past mining above Cooke City.

With the exceptions of Bi and Mo, the flood-plain tailings contain anomalous concentrations of all of the ore-related elements found in the ore dumps and the original mill tailings pile. Thus, trace-element chemistry can be used to positively identify suspected mill tailings material along the Soda Butte Creek flood plain.

For the water and stream-sediment samples collected below the area of past mining, the concentrations of most of the ore-related elements determined for this study are only weakly anomalous relative to background concentrations. Many of these same ore-related elements are also associated with geothermal features in other parts of Yellowstone National Park, commonly in much higher concentrations than those found in Soda Butte Creek.

HEAVY METAL CONTAMINATION IN THE VICINITY OF SOME BASE-METAL MINES IN KOREA

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Base-metal mining can be an important source of trace elements in the environment owing to various mining activities including processing and transportation of ores, disposal of tailings, and waste water around mines. The elevated levels of heavy metals discharged from mine waste materials can be found in the nearby streams, agricultural soils and food crops, and eventually, they may pose a potential health risk to residents in the vicinity of mines. In this study, five typical base-metal mines, the Sambo Pb-Zn-barite, the Shinyemi Pb-Zn-Fe, the Geodo Cu-Fe, the Shiheung Cu-Pb-Zn and the Dalsung Cu-W, were selected. The results of heavy metal contamination in those areas are discussed and compared between sites.

Agricultural soil, stream sediment and stream water around each mine were severely contaminated by heavy metals that comprised the ore mineralogy. Although the degree and extent of contamination varied with each mine, the dispersion pattern of metals was mainly controlled by the feature of geography, prevailing wind and the distance from the mine. The main pollution sources are tailings and mine waste materials abandoned without proper cover systems, and metals have been continuously released by wind or drainage from the sources. In order to assess the level of heavy metal contamination, the concept of pollution index was applied. Because soil contamination involves not a single but a number of elements, it is convenient to treat and interpret multi-element data simultaneously. The elements included in this pollution index are Cd, Cu, Pb and Zn.

Most of chemical forms of metals identified by sequential extraction scheme were non-residual fractions, such as exchangeable, Fe-Mn oxides or organic matter bound forms. These non-residual forms of metals are susceptible to the change of ambient conditions of the nearby environment and have a high potential of bioavailability. In general, Cd and Zn have a higher fraction in exchangeable form than other elements and present the highest mobility in soils or sediments.

Analysis of metals in plants from the study areas indicates that leafy vegetables, especially tobacco, tend to accumulate higher metal concentrations than grain or fruit crops. In the Sambo mining area, significant levels of metals were found in rice grain which can lead to a large amount of metal intake by residents. Relatively high contents in plants were found under oxidizing conditions rather than reducing environments and Cd and Zn, in particular, were most easily taken up by plants.

Heavy metal contamination will continue in the areas mentioned above as long as the tailings, contaminated soils and sediments as sources of contamination are left without reclamation. It is strongly recommended that an environmental guideline for reclamation in the vicinity of mining areas should be set and the environmental impacts of past and present mining activities must be monitored continuously. Finally, co-work with other disciplines such as medical geology or environmental toxicology is needed to investigate the adverse health effects to the residents or animals in the study areas.

CONTAMINATION FROM FORESTRY ACTIVIES: IMPLICATIONS FOR STREAM SEDIMENT EXPLORATION PROGRAMMES

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Although it is well established that background geochemical patterns in stream sediments generally depend on drainage basin geology, little is known of the effects of watershed disturbance on such patterns. Here we report on the effects of forestry activities on sediment geochemistry on the Interior Plateau of British Columbia.

Stream sediment samples were collected from six small streams in 1996, before logging, and in 1997 after clear-cutting. Samples were sieved to –212 µm and analyzed by multi-element ICP after both a strong acid and a total decomposition. Field and analytical duplicates, and samples from unlogged control sites were used to estimate variations not associated with logging activities.

Results show that prior to logging each stream had a distinct multi-element geochemical signature related to drainage basin geology. There was no overall effect of logging on these signatures within or downstream of the cut-blocks - probably because unlogged buffer zones along the stream channels prevented the development of new sediment sources. Logging roads did, however, cause local changes of sediment geochemistry in two ways:

1. Abrasion of zinc from galvanized culverts results in zinc anomalies, with concentrations >200 ppm. These anomalies can extend several hundred metres downstream and persist for at least five years after installation of culverts.

2. Construction of stream crossings and roadside ditches creates new sources of sediment supply to the streams. Although of local origin, the newly exposed and eroding surficial deposits contain more fine-grained material and have multi-element geochemical signatures that differ significantly from the mature fluvial sediments found in the stream channels before logging. Input of the new material results in geochemical anomalies that can extend several hundred metres downstream from the source. In this study Ni, Mg and Co were found to have the largest concentration differences between sediment sources and sediments, and hence to give the longest anomalous dispersion trains.

The effects of logging roads on sediment geochemistry thus relate to creation of new sources of local sediment as well as to introduction of exotic materials into the stream. No geochemical response could be attributed to the clear-cut forest block. Such changes might develop eventually if soil erosion increases or if changes to the groundwater regime modify input of dissolved elements to the stream channel.

GEOCHEMICAL MAPPING IN GEORGIA: A TOOL FOR ENVIRONMENTAL STUDIES, GEOLOGIC MAPPING AND MINERAL EXPLORATION

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Stream sediment and stream geochemical mapping is a valuable tool in the southeastern United States, because extensive weathering and thick vegetation commonly inhibit geologic mapping. Geochemical mapping in Georgia has been used to define: 1) the background geochemistry of major river basins for river basin management planning, 2) geochemical patterns that are related to regional and local geologic units and structures, 3) geochemical anomalies related to known or previously unidentified mineralization, and 4) geochemical anomalies related to anthropogenic sources. Mapping is based primarily on stream sediment and stream geochemical data collected during the late 1970's as part of the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) Program. The northern seventy percent of the state was sampled on an average density of one per 17 km^2. Data were mapped and analyzed with the aid of a Geographic Information System (GIS), and spatially related to rock units on the digital state geologic map. The remaining thirty percent of the state was recently sampled on a density of approximately one per 100 km^2 by the Georgia Geologic Survey. Samples are being analyzed through the U.S. Geological Survey, and those data are not presently available.

River basin management plans require baseline geochemical studies with which to evaluate present and future water quality data. The NURE data provide a large and detailed picture of a river basin's geochemistry. Most geochemical data in Georgia can be related to natural geological sources. A small number of generally isolated geochemical anomalies cannot be related to a natural source and appear to be related to an anthropogenic source.

Regional geochemical patterns, which generally extend northeast through Georgia, are emphasized by color contour maps generated by the GIS. The regional geology is the dominant influence on the geochemistry. Paleozoic carbonate and clastic sedimentary rocks are found in the Ridge and Valley and Cumberland Plateau provinces in northwest Georgia. Precambrian and Paleozoic metasedimentary, metavolcanic, metaplutonic and plutonic rocks are found in the Blue Ridge and Piedmont provinces to the south and east. These crystalline rocks consist of four major tectono-stratigraphic terranes. Cretaceous through Holocene clastic and carbonate rocks in the Coastal Plain cover the southern sixty percent of the state. Differences in pH, conductivity, and alkalinity of stream water can be related to differences in rock chemistry, porosity and permeability of the rocks and organic matter in the streams. Anomalously higher concentrations of most metals in the NURE database can be related to either the regional geology or to more localized geology such as individual rock units or structural trends. Regional multi-element geochemical patterns may be used to characterize rock units of similar origin but were affected by different degrees of metamorphism. The Carolina terrane, which consists mainly of metavolcanic and metavolcaniclastic rocks, is characterized by relatively high pH, conductivity, alkalinity, aluminum, iron, manganese, scandium, sodium, titanium, and vanadium. Isolated chromium anomalies are related to known ultramafic rocks or are along strike and may indicate the presence of unmapped ultramafic rocks.

Many regional and more localized multi-element metal anomalies can be related to known mineralization, but some have an unknown source. Coincident rare-earth element, uranium, thorium and titanium anomalies define five heavy mineral belts that are related to Paleozoic metasedimentary rocks (metamorphosed paleoplacer deposits?) and Cretaceous to Eocene fluvial to shallow marine clastic sediments in the Coastal Plain. Base metal anomalies coincident with Lower Paleozoic carbonates in the Ridge and Valley province suggest Mississippi Valley-type mineralization. Isolated base-metal anomalies in the Carolina terrane are related to known ore deposits. Multi-element metal anomalies without an identified source should be confirmed and evaluated for potentially economic mineralization.

INTEGRATED PRESENTATION AND INTERPRETATION OF GEOCHEMICAL DATA AND MULTIDISCIPLINARY INFORMATION: REGIONAL- AND LOCAL-SCALE APPROACHES

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From large-scale reconnaissance programmes that cover countries or continents to local programmes on a single exploration property, today's explorationists have unprecedented access to multielement geochemical data and large volumes of multidisciplinary information from geological, geophysical and other sources. The challenge in this "data- and information- rich" environment is to strategically remove poor-quality assay data and use the remaining statistically meaningful data for integration with other information. In this paper, we describe presentation and interpretation techniques that can help address this challenge at both regional and local scales.

In regional programmes, the goal is to initiate exploration in an often unfamiliar country or region and recommend areas for detailed investigation. Data volumes are large with as many as 40,000 samples assayed for up to 48 elements -- and often stored in different digital formats. Quality control is a problem since historical data often have different sources, survey types and analytical techniques. Here, histogram and scatter analysis presentations are effective for identifying problems (such as background shifts reflecting data from different laboratories) at an early stage.

Following initial quality control, there are a variety of plotting and interpretation alternatives. A traditional approach is to transform data to a logarithmic scale and create proportionally sized symbol plots. In addition, there are new methods, such as interactive manipulation of colour symbol plots, to emphasize trends in elemental data. Another approach is to grid the data using geostatistical algorithms – special processing routines that emphasise coherent patterns while maintaining the spatial integrity of individual samples. Advanced map products such as ternary maps and integrated geophysical, geological and satellite presentations are important aids for selecting prospective areas.

In local projects, the purpose is to acquire and interpret relatively low-cost geochemical data to find ore bodies. Usually, the field explorationist receives assay results on a continuing basis from the laboratory. Quality control focuses on validating digital results using known standards or duplicate samples and statistics. In addition, onscreen presentation techniques can help to systematically isolate problems.

After validating data quality, the next step is to interpret assay results and direct the ongoing field programme. Box-and-whisker plots and symbol plots facilitate rapid statistical evaluation and mapping of geology. In addition, joint interpretations with integrated geological and geophysical information assist in selecting targets and decreasing drilling risk.

In summary, this paper provides a roadmap of integrated presentation and interpretation methods for regional and local projects. For the explorationist, the significance is an up-to-date cross-section of techniques to help navigate the large volumes of data and multidisciplinary information available in today's mine-finding environment.

DIGITAL GEOCHEMICAL ATLASES OF NEWFOUNDLAND AND LABRADOR

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Printed geochemical atlases are now available for many countries, typically presenting broad overviews of regional geochemical patterns based on generalized interpolations. For mineral exploration and other site-specific local studies geochemical concentrations at each sample site are needed, and are usually obtained from much larger-scale maps. Using the capabilities of inexpensive desk-top data viewers and geographic information systems, digital atlases of Newfoundland and Labrador (over 37,000 sample sites from a combined area 400,000 km^2) have been prepared that permit the display of geochemical data at all levels of resolution from broad overviews to element values at individual sample sites.

For broad overviews, colour raster images for each element have been created, both with and without shading to enhance geochemical relief. Isopleths (line contours) have been created for those elements where the signal-to-noise ratio exceeded 70%, judged from the ratio of overall variance to sample-site variance based on site duplicates. Contours are at five percentile increments, labeled in concentration units, and are derived from the same interpolated surfaces as the raster images. They are useful at intermediate scales, and for overlaying on raster images or colour thematic maps such as bedrock or surficial geology. For highest resolution, a point file contains the complete geochemical and field data for each site, from which the viewer can display symbol maps in a wide variety of formats. Separate sets of images, contours and point files have been prepared for the lake and the stream data. In addition to the geochemical data, several other relevant coverages are provided; topography, bedrock and surficial geology (from 1:500,000 or 1:1,000,000 scale maps), mineral occurrences, and images of regional aeromagnetic data.

Each atlas is available on CD-ROM and the data are formatted for use with popular commercial desktop GIS such as Arcview and Mapinfo. A data viewer that can read the Arcview shapefile format is also included. The data have been organized to make display and manipulation as simple as possible, and the data are documented through a set of help files that can be opened with the viewer. Not only do these atlases provide unprecedented insight into the extensive regional geochemical database, they are also far cheaper to produce (and purchase) than printed atlases.

EXPLORATION FOR GOLD AND MASSIVE SULPHIDE DEPOSITS IN SOUTH CENTRAL BRITISH COLUMBIA USING INTEGRATED TILL SAMPLING AND SURFICIAL MAPPING

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Massive sulphide and gold deposits are comparatively small exploration targets and can be especially difficult to detect when bedrock is covered by glacially transported material. Drift prospecting is most effective for finding concealed mineralization when the nature and source of the glacial deposit is known. This paper describes the results of a drift prospecting survey integrating surficial mapping and a lithological study with till geochemistry over an area of nearly 1500 km^2 in south central British Columbia. This area is underlain by Devono-Mississippian age volcanic and metasedimentary rocks of the Eagle Bay Assemblage and Mesozoic granitic intrusives of the Baldy Batholith. The volcanic rocks host massive sulphide-gold mineral occurrences including the Samatosum and Homestake deposits. Local Quaternary stratigraphy, paleo-ice flow directions and till provenance were determined from surficial mapping combined with geochemical exploration methods to locate additional gold and base metal mineralization in bedrock.

Terrain mapping revealed that the dominant surficial sediment is till. A single basal till occurs within the survey area, differing in texture and composition depending on the source bedrock. Ablation till, colluvium, glaciofluvial sediments, glaciolacustrine deposits and fluvial sequences were also noted in the area. Ice flow indicators such as glacial striae and landforms revealed that ice moved from the north or northwest to the south or southeast, coinciding with regional trends. Data collected from till fabrics and till clast and matrix dispersal patterns further strengthen this interpretation.

Till dispersal patterns indicate that the glacial sediment was locally derived. Spatial plots of the select lithological components of the till revealed isolated concentrations of clasts over or near bedrock sources. The till matrix component displayed similar trends with highly anomalous geochemical values of individual elements proximal to known source areas. Where dispersal trains are detected, clast plumes extend up to 5 km in length whereas the geochemical dispersal trains can be observed up to 10 km.

During the till geochemical survey basal till was preferentially sampled at an average density of 1 sample/ 3.8 km^2. The -63 micron size fraction of the basal till was analysed for gold by neutron activation and for arsenic, silver, copper, cadmium, lead and zinc by aqua regia digestion-inductively coupled plasma emission spectroscopy. Gold, silver, copper, cadmium, lead and zinc were selected because they are key ore indicator elements. Arsenic concentrations are also examined, as it is an important pathfinder for gold. Most elements exhibit low to moderate concentrations randomly dispersed across the survey area with high values occurring as isolated concentrations or forming ribbon-shaped plumes trending parallel to ice flow. Key elements commonly record maximum concentrations in till not readily associated with known mineral occurrences.

The highest gold value in till detected by the survey was found to reflect a dispersal train originating from an auriferous quartz vein in granodiorite of the Baldy Batholith. This anomaly suggests that auriferous quartz veins, similar to the Alaskan Fort Knox deposit, may be an alternative source of mineralization to massive sulphides.

GEOCHEMICAL PATTERNS IN SEDIMENTS FROM A GLACIAL STREAM IN THE KARAKORAM MOUNTAINS, PAKISTAN

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A geochemical drainage survey, covering 80,00 km^2 of northern Pakistan and incorporating the analysis of pan concentrates and -180 μm sediments, has identified a large number of catchments with anomalous Au and base metals. A subsequent detailed investigation of the Sumayar valley (a tributary of the Hunza River) has been undertaken to characterise the combined effects of heavy mineral fractionation and sediment dilution on anomaly detection in this regime.

Sumayar rises 1800 m from the Hunza Valley (2500 m elevation) to the Silkiang Glacier that extends a further 7 km upstream. Outside the narrow valley floor relief is extreme, with local peaks exceeding 7000 m. Streams are fed by seasonal snow and glacier melt and flows exhibit pronounced diurnal variations. Glacial valley floors are modified by incision associated with continuing rapid uplift of the Karakoram Mountains. As well as glacial processes, valley slopes are sculptured by ephemeral rock falls, avalanches and mudflows. Sumayar is situated near the margin of the Eurasian Plate and the Kohistan Arc that is marked by the ophiolititic melange of the Shyok Suture Zone. The upper and lower reaches of the Sumayar Valley occur in Hunza Schist (metapelites, carbonates and mafic volcanics) with the middle section cut by the tourmaline-bearing Sumayar leucogranitic pluton.

Sumayar is a vigorously flowing, boulder-bedded stream, generally less than 10 m wide and 1 m deep. Irregular bars develop at changes in channel orientation and below large obstructions. The stream gradient varies from 3.4° below the Silkiang Glacier to 9.6° below the Sumayar Pluton and decreases to 5.7° towards the Hunza R. Pan concentrates, 125-180 μm and -125 μm sediment from twelve paired boulder trap sites were analysed for a wide range of elements by INAA and XRF. The site pairing typically represented the head and tail of elongate bars, but clear-cut high and low energy regimes could not be easily discerned on the basis of stream and bar morphology, grain size distribution or heavy mineral composition.

Elevated Au values in the pan concentrates (5 -30 ppm) are common in Sumayar, accompanied by high As concentrations in both sediment (40-200 ppm) and pan concentrates (680-2,200 ppm). High Au values below the Silkiang Glacier coincide with higher proportions of heavy minerals (particularly the magnetic fraction), and high $[M]_{+125\mu m}/[M]_{-125\mu m}$ ratios for Fe, Ti, As and Cr. These samples are from a section of stream where high lateral moraines protect sediment that are partly derived from the Shyok Suture ultramafics (Cr, Fe, Ni and probable Au±As sources) from dilution by material derived from the adjacent Hunza Schist metasediments. This would allow winnowing of heavy minerals (chromite, magnetite, gold, ilmenite and arsenopyrite) from the moraine and glacier by the stream.

Beyond the limit of the lateral moraine, subdued Au, Cr, Ni and As values and a higher proportion of non-magnetic minerals occur in the pan concentrates. This coincides with several large talus fans and avalanche paths. Material from the valley slopes directly above the lateral moraines is funneled into the stream within this zone and appears to dilute geochemical signatures derived from and above the Silkiang Glacier.

In the steeper section of the valley, where the glacial landform is being incised, pan concentrates show irregular highs and lows in Au, Cr, Ni, Fe and Ti levels. Local hydraulic effects are complicated by additional contributions of Sn, W and As to the stream from the vicinity of the Sumayar Pluton. These features can be interpreted as the result of downcutting by the stream through Au, Cr, Ni, Fe and Ti-bearing glacial and fluvioglacial materials with variably amounts of dilution by locally derived material. Some samples display depletion of Cr, Au, Fe and Ti but enrichment of Sn, W and Li. In the lower gradient zone above the Hunza R., the association of elevated Au, W (>1000 ppm), Cr, As and Sn in pan concentrates is consistent with reduced capacity of the stream to transport heavy minerals such as Au and scheelite in response to the lower gradient.

In general, the pan concentrates and -125 µm sediments are less influenced by site characteristics and sampling errors that the 125-180 µm fraction. Tin, Fe, Sn, Cu, Ni, Ca, Sr, and Ba provide the strongest reflection of variations in steam hydraulics, whereas U, Zn, Cr, V, Ti, Pb, Nb and Ta are more dominantly affected by down-stream geological variations. The patterns for Au are obscured by sample representativity problems; ANOVA indicating down-stream variations in the pan concentrates and -125 µm fraction are not significant compared with the combination of differences in site energy plus sampling and analytical errors. However, the correlation between Au and elements that are also subject to hydraulic fractionation, but for which site related variation is less significant (e.g. Cr, Zn, As, Fe and Ti), suggest the Au patterns are real and that the variations in other elements could be employed in the setting of Au thresholds for follow-up surveys.

Although mechanical dispersion processes dominate in such terrains, oxidation rims on a proportion of arsenopyrite, bornite and chalcopyrite grains indicate a hydromorphic dispersion component is also present. The very low values for Au in the -125 µm fraction, however, suggest that hydromorphic dispersion is not important for Au.

In environments typified by Sumayar, processes of selective trapping of heavy minerals in gravels, dilution from local talus fans, reworking of previous glacial and fluvioglacial debris and variations in catchment geomorphology, must be taken into account in the design and interpretation of data for follow-up geochemical surveys. In such regimes, the use of large composite pan concentrate samples of sand matrix from boulder traps may be appropriate to minimise inhomogeneity related to local dilution processes.

DISTRIBUTION AND BEHAVIOR OF SELECTED ELEMENTS IN SOIL OVER A HISTORICAL Pb-Ag MINING SITE AT SV. JAKOB, CROATIA

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Geochemical patterns of certain elements (Pb, Zn, Cd and Hg) in soils from the floodplain of the river Sava and some tributaries that drain Mt. Medvednica NW of Zagreb, Croatia, indicate that the sources of pollution were not only the Pb-Hg-Ba mining region, situated along the upper course of the river Sava in neighbouring Slovenia, but also local historical mining sites located on Mt. Medvednica.

As a target of this study was an old 17th century lead mine (galena with 485 ppm of Ag) situated near the chapel of St. Jacob Croatian Sv. Jakob) on the crest of Mt. Medvednica (830m a.s.l.). The mineralization which consists of galena, sphalerite, pyrite and quartz occurs as irregular veins within Triassic dolomites. A total of 110 brown forest topsoil (0-25 cm) soil samples was collected on dense regular grid covering an area of approximately 1.5 km^2. Ten samples were selected for detailed chemical and mineralogical analysis.

Trace metal values were obtained from aqua regia extracts, while their residence sites in soils were identified by sequential extraction performed with the aid of a modified combination of procedures proposed by Tessier et al., (1979) and Hall et al., (1996). The following phases were defined by the reagents used: exchangeable, carbonate, iron and manganese oxide, organic-sulphidic and residual. The concentrations of trace metals in the resulting solutions were determined by atomic adsorption spectroscopy and

inductively-coupled plasma spectrometry. Total mercury was determined by flameless AAS mercury detector (AGP-1) from solid samples after heating at 700°C and pre-concentration with a gold wire (detection limit = 10 ngg^{-1}).

The aqua regia extractable Pb values varied from 9 to 18000 μgg^{-1}, Zn 12-9000 μgg^{-1}, Cd from <0.1 to 180 μgg^{-1}, and total Hg from 10 ngg^{-1} 1800 ngg^{-1}. The distribution of these elements in soil indicates their inherited and undisturbed geochemical relationship to the mineralization. The importance of each of the phases for the trace metals obtained by sequential extraction in soil samples with high total contents is:

a) Pb carbonate > Fe and Mn oxide> organic-sulphide> exchangeable = residual
b) Zn organic-sulphide> Fe and Mn oxide> residual> carbonate> exchangeable
c) Cd Fe and Mn oxide>carbonate=organic-sulphide> exchangeable>residual

Mineralogy of the soils is dominated by quartz, mica, goethite, kaolinite and plagioclase, cerrusite was identified by XRD only in one sample and no primary sulphide minerals (galena) were found.

The flooding of the river Sava (the last major flood occurred in 1964) is the major source of soil pollution in the floodplain area south of Zagreb. However, this study shows that violent mudflows, that occur after rainstorms and flood northwestern parts of the city, from streams that drain the areas of historical mining sites also present a probable source of pollution.

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THE EXPLORATION SIGNIFICANCE OF RARE EARTH ELEMENT ANOMALIES IN LAKE SEDIMENT AND WATER: CASE STUDIES FROM HIGH DENSITY GEOCHEMICAL SURVEYS OVER THE WINSTON LAKE CU-ZN AND THE HEMLO AU DEPOSITS

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Fieldwork for high-density lake sediment and water geochemical surveys over the Schreiber-Terrace Bay and Hemlo greenstone belts resulted in the collection and analysis of over 2800 samples. Results of the surveys show the presence of over 40 multi-element anomalous areas. Anomalous elements include: Au, Cu, Zn, Pb, Ni, Mo and rare-earth elements (REEs). Significant REE anomalies in lake sediment and water are spatially associated with the Winston Lake Cu-Zn deposit and the Hemlo area Au deposits. Previous researchers have found significant REE enrichment within the altered volcanic stratigraphy of the Winston Lake orebody. This enrichment is contemporaneous with regional metamorphism that is possibly associated with the emplacement of the Crossman Lake batholith. This alteration assemblage (biotite-chlorite-REE) post-dates VMS mineralization. The lack of a REE signature within the lake sediments in the vicinity of the Zenith deposit (considered a rafted piece of the Winston Deposit) located approximately one km to the east, is consistent with this theory. The REE bearing minerals have been found as inclusions within biotite grains. Since biotite altered rocks are readily weathered, this may explain the transport of REE bearing minerals into the local catchment basins. In the Hemlo area, a relationship between gold mineralization and REE enriched calc-silicate alteration of bedrock has been demonstrated by previous workers. Therefore, of exploration significance in the study areas (and possibly elsewhere) is the use of REE enriched lake sediments and/or waters as a possible indication of pervasive hydrothermal alteration of bedrock. This may warrant a re-interpretation of existing lake sediment geochemical datasets, particularly those which cover greenstone belts and granite-greenstone contacts.

APPLICATION OF COMPOSITE BOULDER LITHOGEOCHEMISTRY TO MINERAL EXPLORATION

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In glaciated areas with consistent drift cover there are many choices regarding sampling media for geochemical exploration surveys. These include drainage sediments or water, vegetation, organic or mineral soil, the fine-grained components of the drift itself, and the rock fragments within the drift. All of these materials have been directly or indirectly affected by glacial transportation, and most have been subjected to modification by secondary processes. The rock fragments within the drift (including boulders) are transported, but in most cases they are little affected by secondary processes.

Over the past 12 years lithogeochemical surveys based on sampling boulders in the drift have been widely used in exploration for unconformity-type uranium deposits within the Athabasca Basin of Saskatchewan, and within the Thelon Basin of the Northwest Territories. Tens of thousands of samples have been collected by many different exploration companies, and well-defined anomalies have been outlined in areas of known mineralization. Composite boulder sampling has also been successfully tested and applied in several areas of porphyry-style mineralization within the Interior Plateau of British Columbia.

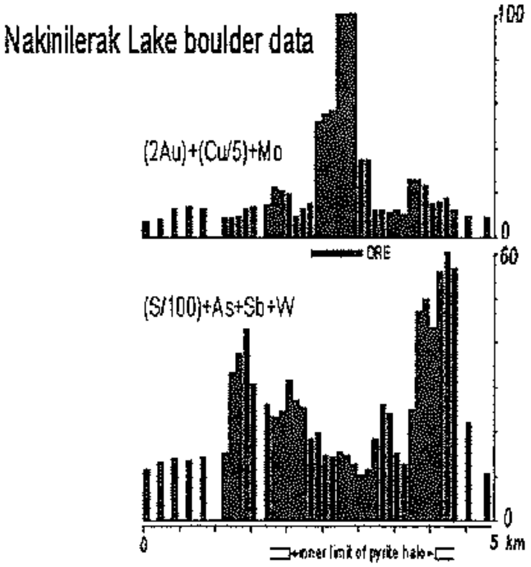
Composite boulder samples are collected by taking chips from the most angular of the relatively large boulders observed in the vicinity of a sample site. Lithology and visible alteration are not used as criteria in selecting the boulders to sample, except that boulders with lithologies which are clearly exotic to the study area are excluded. In most cases between 10 and 15 individual boulders are sampled at each site. At any sample site some of the boulders are likely to have been transported for thousands, if not for tens of thousands of metres, but others may have been transported for only hundreds of metres - or less. By sampling at least 10 boulders at each site there is a high probability of including some boulders of relatively local origin. Data are presented showing that where there is a significant geochemical contrast between background and anomalous rock, and where the background is relatively consistent, anomalies will be evident even if as few as 25% of the boulders sampled have alteration or trace-element enrichment.

Studies carried out in areas with bedrock information available from drilling have shown relatively little down-ice displacement of composite boulder sample anomalies. In many cases, the up-ice end of a boulder anomaly is situated only a few hundred metres down-ice from the bedrock source, even in areas with tens of metres of till cover.

The primary advantage of composite boulder sampling over other geochemical techniques used in glaciated areas is that the sample material is derived directly from bedrock. Because glacial boulders have not been significantly affected by secondary processes, both trace element enrichment and hydrothermal alteration patterns can be studied. Furthermore, alternative analytical techniques, such as reflectance spectral identification of alteration minerals, can be applied. Alteration information can be used to assess the geological character of the anomalous zone, and since alteration halos are commonly much larger than trace element halos, boulder sampling can be used to detect larger targets than other methods.

Results of composite boulder sampling programs are presented and described from surveys carried out in areas with known mineral deposits, both in Saskatchewan and British Columbia. These include the McArthur River and Dawn Lake unconformity-type uranium deposits in Saskatchewan, and the Mt. Milligan and Nakinilerak Lake porphyry gold-copper deposits, and the Getty South porphyry copper deposit, all in British Columbia. A summary of data from Nakinilerak Lake is shown below.

Composite boulder lithogeochemistry is a technique which should be applicable to exploration for many different deposit types. The criteria for its successful application include the consistent distribution of ice-transported drift (along with an understanding of the glacial history), the existence of extensive geochemical or alteration halos in the deposit type being sought (in the order of hundreds of metres or larger), and a relatively consistent geochemical background.



STATE OF THE ART AND ENVIRONMENTAL HAZARD FROM MINING POLLUTION IN SOUTHERN IGLESIENTE (SW SARDINIA, ITALY)

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In two recent papers (De Vivo et al., 1997, in press a) multielement geochemical maps of the island of Sardinia have been compiled using 26,335 stream sediment samples. These were collected from 1972 to 1985 by Ente Minerario Sardo (EMSa) to carry out geochemical exploration for the mining industry. From these samples multielement geochemical maps (51 elements) have been produced covering about 12,000 km2 with a nominal density of 1 sample per 0.5 km2. In another paper, based on the same samples, geochemical risk maps of the island have been drawn (De Vivo et al., in press b) for potentially dangerous elements.

Subsequently, we have concentrated our work on the mining district of Iglesiente-Sulcis, southwestern Sardinia, where base metal ores have been actively exploited up to recently. We have conducted stream sediment sampling in the whole district. Here we present results for the southern Iglesiente area (about 150 km2) where the biggest mines in the district occur. These have produced a few hundred million tons of Zn-Pb-Ag and Ba ores (Bechstädt & Boni, 1994). There are also variable concentrations of other potentially dangerous associated elements e.g., Cd, Ge, As, Cu, Mo, Hg and Sb. In addition, variable contents of elements derived from human and industrial activity have also been recorded in several areas of the Iglesiente district.

Our sampling has been carried out with a density of 3 samples per km^2. Of the 332 samples used in construction of the geochemical maps. 249 were sampled by us and analyzed for 35 elements by commercial laboratories in North America. A further 83 samples, derived from former campaigns of EMSa and analyzed only for 11 elements, have been integrated into some of the maps.

Cartography was obtained by mapping the various elements with GIS program (Grassland), applying interpolation with the inverse distance weighted method. To classify the different concentrations, the various percentages of the elements have been calculated. They are represented as 10 distinct intervals, ranging from 5 to 99% including a maximum value. For the compilation of the geochemical risk maps, the distribution of regional elements has been reclassified using as thresholds the known intervention criteria for agricultural, residential/recreational and commercial/industrial land use.

The main concentrations of heavy elements closely follow the carbonate lithologies, where most of the ore deposits (MVT and Sedex) are hosted.

Fairly high contents of Ag, Ba, Cd. Cu, Pb, Sb, Zn and As coincide with the distribution of stream sediments along the southernmost carbonate ridge of Mount Onixeddu-Mount Barega-Mount Arcau. The prevalence of Ba, Ag and Pb in this area is in accord with the barite and argentiferous galena ores exploited in the Mount Onixeddu and Barega mines.

Along the streams draining the central carbonate ridge, forming the southern flank of the Iglesias syncline, high concentrations of the metallic elements are widespread. However, Ba and Sr, due to the scarcity of barite ores, are generally of minor importance in this area. In the western part of the aforementioned ridge (around the San Giovanni mine) Pb, Ag and Zn-Cd predominate. On the eastern side, Fe as well as As, Sb and Cu, all of them associated with pyrite, are extremely abundant. This is clearly related to the massive sulfides formerly exploited in the Seddas Moddizzis, Genna Luas and Campo Pisano mines.

The northern flank of the Iglesias syncline, extending in the west up to the Masua mine, had many other orebodies with associated treatment plants, tailings and dumps. Typical are the intensely exploited areas of Nebida, Mount Scorra, Mount Agruxiau and Monteponi. Especially the areas around the latter are characterized by impressive red dumps ("Fanghi Rossi"=Red Muds), made up of the residues of the treatment of Zn-oxides ores. Here Zn-Cd exceeds Pb-Ag although the Zn-Cd-Pb-Fe-Ag association is quite common in the stream sediments sampled along the whole northern flank. This points to a higher percentage of sphalerite ores; Ba is ubiquitous. However, the streams draining the Red Muds around the Monteponi mine also contain high concentrations of As, Sb, Bi, Cu, Mn and W.

Another two very polluted areas, not underlain by carbonates, are the swampy river mouth of Rio Sa Masa, near Gonnesa, and the Corsi reservoir south of Iglesias. However, the Rio Sa Masa drains not only the main mining sites of the Iglesias syncline, but also the small industrial area of the town of Iglesias and a few villages. A similar situation exists for the drainage area of the Corsi artificial lake. This could explain the additional presence of high concentrations of Sn, Bi and Co that are not common in the local ores.

The geochemical risk maps have been compiled only for those potentially dangerous elements whose concentration has passed the minimum threshold of intervention criteria for any use of the territory. This was the case for 9 elements: Ag, As, Ba, Cd, Cu, Mo, Pb, Sb and Zn. Among those, geochemical pollution is very serious for Ba, Cd, Pb and Zn, which are the main elements contained in the stratabound orebodies, and for As, which is contained in pyrite from massive sulfides. These five elements show a broad distribution, far from their source areas, that precludes any possible use of the territory. The situation is better for Ag, Sb, and Cu, which are also less abundant in the host rocks and are mainly contained in sulfosalts related to minor veins. Their concentrations, though remarkably high, are limited to the immediate surroundings of the veins and dumps.

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COST-EFFECTIVE PROTOCOLS FOR THE COLLECTION, FILTRATION AND PRESERVATION OF WATER SAMPLES COLLECTED IN HYDROGEOCHEMICAL SURVEYS

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The usefulness of water, both surface and ground, as a sample medium in mineral exploration is currently being demonstrated by the release of hydrogeochemical survey data in digital map form by, amongst others, Geological Surveys such as those of Finland, Britain, Canada, the US and Germany. In addition to guiding exploration activities, these data are now finding application by those in Government Environmental Departments, not only to highlight geographical areas of concern but to set criteria levels (safety limits) for element concentrations with respect to aquatic life, irrigation, livestock watering and drinking water. The number of samples collected in a geochemical survey, typically well into the thousands, and the different bedrock and surficial geology covered combine to provide a broad database from which to make sound estimates of natural concentration ranges. One drawback to the acceptance of these data by Environmental Agencies is that the methods of collection employed do not adhere to the strict guidelines recommended by the US Environmental Protection Agency. For example, collection vessels are not made of Teflon and are not usually subjected to the rigorous cleaning recommended by the EPA; 'clean-room' clothing is not worn by field personnel. The cost of adhering to such protocols would be prohibitive and hence the number of samples collected would be much smaller, an outcome which is apparent when the databases held by Geological and Environmental Agencies are compared.

The objective of the work described in this talk was to recommend the most cost-effective and efficient procedures by which to sample (i.e. bottle type), filter (0.45 □m) and preserve surface waters for the accurate determination of "dissolved" Al, Ag, As, Cd, Co, Cr, Cu, Hg, Fe, Mn, Mo, Ni, Pb, Sb, Se, Tl and Zn for both exploration and environmental objectives. The bottles studied comprise: Teflon (*FEP*, Nalge #1600); high density polyethylene (*HDPE*, Nalge #2007); polyethylene terephthalate copolyester (*PETG*, Nalge #2019); polypropylene (*PP*, Nalge #2006); and precleaned HDPE^P ('Superfund-Analyzed' to meet or exceed EPA specifications). Three cleaning methods were investigated: a modified EPA Method 1638; one promoted by the State of Virginia based on washing with HNO_3; and a third, that of simply rinsing each bottle with deionised water three times prior to filling. The majority of the 12-0.45µm and 2-5µm filters tested (of syringe, in-line and vacuum type) were from two leading manufacturers, Gelman and Millipore. These filters were investigated not only for their levels of contamination but also for their propensity to retain elements which are present as colloids which should pass through a 0.45µm pore size. Four samples of different matrix - Ottawa, Rideau and Gatineau Rivers and a spiked water sample - were used to test the preservation of the 16 analytes (i.e. all except Hg) in a medium of 0.4% HNO_3 for one month. Preservation of Hg was tested in three reagent media: 0.5% BrCl; 2% HCl; and 0.04% $K_2Cr_2O_7$.

By far the 'dirtiest' bottle studied is the most expensive, Teflon (ca $Cdn28), which remained unacceptable in its Cr and Ni contamination after rigorous cleaning. The least expensive bottle (ca $Cdn 0.90), made of HDPE, shows the best characteristics and is highly recommended. It could be used without rigorous cleaning (only rinsing with deionised water) if batches are checked, but a rinse with weak HNO_3 (5%) is probably advisable. HDPE bottles purchased 'precleaned' are an unnecessary expense (ca $Cdn 2.30) as they are inferior to their uncleaned counterparts. The approach practised by some laboratories - to add a charge of concentrated (≥8M) HNO_3 reagent to the bottle hours or days before water collection - is not acceptable. This strategy causes much higher levels of contamination for all bottles than is the case when acidifying during or after sample collection. Cleaning does not remove 'available' elements as prolonged contact with HNO_3 leaches out significant quantities.

The evaluation of filter systems concluded that optimum performance, in terms of contamination and ease of use, was achieved with the ion chromatography Acrodisc syringe filter with Supor membrane from Gelman, and the Sterivex syringe filter capsule with Durapore membrane from Millipore. However, the Durapore membrane was superior to the Supor brand in its significantly lower retention of colloidal species which should pass a 0.45 µm filter size. These findings and others will be discussed in this presentation.

MODELING DOWN-ICE MOVEMENT OF ECONOMIC MINERAL INDICATORS IN QUATERNARY GEOCHEMICAL DATA USING A GIS

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Glacial cover, which can obscure mineralization and/or disperse indicator minerals and pathfinder elements down-ice, complicates mineral exploration in Canada. Sampling of indicator minerals from till and soil is used routinely in mineral exploration although difficulties often arise when tracing these minerals up-ice to a potential source. Tracing anomalous concentrations of a given geochemical element up-ice to a potential economic source is also a complex procedure fraught with many problems. Proper interpretation requires knowledge of glacial directions, topography, bedrock lithology, glacial stratigraphy and surficial conditions. Interpretation is also complicated by the differences in chemical behaviour of elements in the surficial environment.

The objective of this paper is to model the effects of glacial dispersion, in Quaternary geochemical data using search algorithms programmed within a GIS. Two search strategies are employed; one dealing with a nearest-point analysis and the other with a down-ice search analysis.

Two Quaternary till geochemical datasets are used to demonstrate these modeling methods; one from the Northwest Territories consisting of approximately 300 samples and the other from the Swayze Greenstone Belt, Ontario consisting of approximately 800 till and soil samples. The focus in the Northwest Territories is on predicting the location of kimberlite pipes up-ice from several indicator mineral dispersal trains. In the Swayze area, focus is on the up-ice prediction of gold and base metal mineralization.

The nearest point analysis involves calculating the distance and azimuth from a known mineral prospect (e.g. gold deposit, kimberlite pipe) to the nearest till geochemical sample and then examining the results for possible associations between distance and azimuth with element concentrations. The down-ice search algorithm involves searching down-ice from known mineral prospects using a user specified search geometry (in most cases a wedge) and calculation of first-order statistics (e.g. mean, median, standard deviation). A Monte Carlo simulation is then employed which involves searching down-ice from a series of randomly selected points. The statistical distributions for each pathfinder element based on the points representing known mineralization and the random points are compared. If the indicator concentrations are significantly higher down-ice from the known mineralization than from the random points, then a down-ice search is conducted from each grid cell in the geochemical map under consideration. If the element concentration down ice from a given grid-cell has a concentration equal to or higher than the distribution calculated from the known mineralization, that grid-cell is flagged as a potential mineralization source. A final map showing potential mineralized source zones is then produced. These source zone anomaly maps are compared to regular interpolated geochemical maps, with respect to predicting known basemetal prospects and kimberlite pipes, using the *weights of evidence* GIS modeling technique.

The first pass of the down-ice search algorithm is run using a simple wedge-shaped geometry, using a wedge length that is determined from orientation surveys or by the variogram parameter. No account of other factors which may effect local dispersion such as topography, surficial cover and element mobilities are considered. In the second pass, these other factors are accounted for using regression analysis, to determine how far down-ice a particular element would be expected to be dispersed, in a given geographic locale.

Results from the nearest point analysis for the Swayze dataset show that Cu and Zn concentration is inversely proportional to distance from a basemetal prospect and that concentrations are greater in a southerly direction, down-ice from basemetal prospects. The same results were achieved for the Northwest territories dataset for Cr, Ba and Ni, all of which are pathfinder elements for kimberlites. However, directions of anisotropy were more variable for this dataset, reflecting multiple glacial movement directions.

Results of the down-ice search algorithm for the Swayze dataset indicates that southerly and easterly directions are most important for Cu while southeasterly and southwesterly directions are most important for Zn. NE directions are dominant for Ba and Ni and NW for Cr in the Northwest Territories dataset.

Weights of evidence analysis indicates that the up-ice Cu and Zn anomaly maps derived from the search analysis are better predictors of known basemetal prospects than the Cu and Zn maps derived from normal interpolation methods, in the Swayze area. The up-ice anomaly maps for Ba, Ni and Cr were also found to be better predictors of known kimberlites. More important for exploration are the areas on these up-ice anomaly maps that are not associated with known mineral prospects or kimberlites , as these zones may represent new sources of mineralization or undiscovered kimberlite pipes.

A COMPARISON OF MULTI-MEDIA GEOCHEMICAL DATA USING GIS TECHNOLOGY: IMPLICATIONS FOR MINERAL EXPLORATION

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Geochemical data collected from different media form an important part of most mineral exploration programs. These media which include till, vegetation, waters, rock each have their own properties and hence interpretative value. For each media a variety of tools have been developed to interpret the results; however there is not a great deal of information that compares the information content from two or more media from the same area. Cook et al (1995) compare results from several hundred till and lake sediments for an area in British Columbia. Generally they indicate that the two media are complimentary but there is only limited discussion as to differences between the information content. In part this results from the obvious spatial disparity between media, for example vegetation samples and lake sediments.

The objective of this paper is to compare and contrast geochemical data collected from different media using a variety of statistical and spatial analysis procedures. A number of geochemical databases are used to meet the objectives of this paper. An extensive and detailed geochemical database comprising lithogeochemical, lake sediment, till and soil data, has been assembled over the Swayze Greenstone Belt in Northern Ontario, Canada. The lithogeochemical database comprises a number of individual datasets collected over the past 20 years by the Geological Survey of Canada (GSC), Ontario Geological Survey (OGS) and exploration companies (Falconbridge). The lake sediment geochemical data were collected by the GSC as part of the national geochemical reconnaissance program while the till and soil and humus geochemical were collected by the OGS during regional surveys of the Swayze Greenstone Belt. Other surveys will include a more regional and pervasive study of lake sediment and till samples in Labrador (Friske et al. 1996; Klassen et al 1997).

The focus of analysis is on regional base metal and Au exploration so the elements of interest comprise pathfinders such as Cu, Zn, Pb, Ni, Au and As. These elements are characterized by different mobilities and solubilities in the surficial environment as well as different preferences for substituting in the lattice structures of sulphide and silicate mineral structures. These general differences will have an effect on the statistical and spatial behaviour of each trace element.

Each dataset is analysed separately and in combination to assist in regional base metal and gold exploration. The ARC/INFO geographic information system (GIS) in concert with geostatistical and chemical analysis packages, have been employed to manipulate, integrate and compare the different geochemical data.

The spatial behaviour of each dataset is investigated using variograms. Data anisotropy, due to glacial transport and regional stratigraphy is identified and modeled. The lithogeochemical and quaternary geochemical point data have been interpolated to continuous surface maps using kriging and inverse distance weighted algorithms. The lake geochemical data are presented as element concentrations using catchment areas (drainage basins) as a natural zone of influence.

Anomalous populations are identified using a variety of methods including identifying breakpoints on probability plots, plotting log area vs. log concentration as suggested by Cheng et al, 1994 and using *the weights of evidence* technique (Bonham-Carter, 1994). The geochemical anomalies are then screened with respect to various factors, including:

- background lithologic and surficial variations
- alteration (hydrothermal)
- scavenging by Fe and Mn oxides
- scavenging by organic matter
- pH /solubility effects

A variety of techniques are used to screen or filter the anomalies including multiple regression and a variety of map analysis techniques (Boolean overlay and co-occurrence analysis). The remaining anomalies, thought to more likely represent mineralization are then compared to the known basemetal and Au occurrences to assess which dataset best predicts the known occurrences.

The different geochemical datasets are compared on a point-to-point, point-to-grid and grid-to-grid basis. The Quaternary media were sampled at the same point facilitating a direct comparison between trace element concentration in humus, soil and till using correlation and regression analysis. The Quaternary data are then compared to other media (rock, lake-sediment) using nearest point techniques. Both distance and direction (reflecting glacial dispersion and orientation of regional stratigraphy) are accounted for as the nearest point search algorithm records distance and direction as crucial attributes. Thus similarity between samples from different media can then be analysed with respect to distance and direction. The Quaternary data is then compared at each sample point to gridded (interpolated) values from the rock and lake sediment data. Finally all the data are compared on a grid-to-grid basis using interpolated values. In general, correlation between the different datasets is weak with the exception of Zn and Cu in till and soil. This is not totally unexpected given many factors affect the distribution of metals in the surficial environment, including:

- unique properties of element (e.g.: affinities, mobilities)
- glaciation effects
- nature of parent material
- different chemical weathering environments
- general nature of each media (i.e. humus and rock are more site-specific media)
- different size fraction of Quaternary media
- different analytical techniques

A number of zones of high potential for gold and base metals have been identified based on the analysis of the geochemical dataset. Many of these zones correlate with areas of known mineralization; however, a number of zones of high favourability are not associated with known mineral occurrences or deposits. These latter zones define new targets for mineral exploration.

MULTIDIMENSIONAL STATISTICAL TECHNIQUE FOR DETECTION OF LOW CONTRAST GEOCHEMICAL ANOMALIES

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Presently, mineral deposits, which occurred on the surface are almost completely exhausted. Therefore, mineral prospecting and exploration in the last decade has concentrated on discovering buried and concealed mineral deposits. One of the pertinent features of these deposits is that on the surface they have low contrast geochemical anomalies. That is, for each element, the differences between anomalous and background concentrations are statistically insignificant.

In this presentation we propose an advanced technology for detection multicomponent geochemical anomalies using methods of multidimensional statistics and multidimensional heuristic methods. This technology is based on three components: a measure of contrast of an anomaly, selection of a background sample, and reducing dimension of the feature space, as well as a conventionally used log-normal model of a background distribution.

1. The key element of this technology is an index of contrast of multicomponent anomalies, which we denote "τ". Index τ is a normalized distance ρ^2 between any observation and a center of a background population, which is measured by the Makhalanobis metrics in a feature space of logarithms of concentrations.

2. The next important component is a two-step procedure of a background sample selection. The goal of this procedure is to create a sample for estimation of the parameters of a local background – vector of means and correlation matrix. We make preliminary extraction of a background sample out of a whole data population utilizing tremendous capability of a human eye for selective perception. For this purpose we use linear and non-linear 2D projections of data set. The second step is a final purification of the background sample from outlying observations using statistical tests.

3. The third important component is selection of a set of guide elements that are most significant with respect to contrast of an anomaly. We assume that set of elements to be most significant that provides the maximum unbiased estimation of the distance ρ^2 between a background and abnormal observations.

The distinguishing merits of this technology are as follows:

(i) In the frame of the statistical model of a geochemical background mentioned above, the index τ statistic is the most powerful criterion for testing a hypothesis to determine if an observation is abnormal or not.

(ii) If a given observation belongs to a background population, then the corresponding value of τ is normally distributed with a zero mean and a unit variance. In opposite case $\tau \gg 0$. That's why we are able to interpret the index τ like a well acquainted 1D index of the contrast of anomaly, which is usually measured in standard deviations of a background distribution. The only difference is that negative values of τ reflect the closeness of an observation to the center of the background population.

(iii) Due to the features (i) and (ii) maps of the index τ can be rigorously interpreted in terms of statistical inferences.

(iv) If there is correlation between chemical elements in a background population, the index τ, acquired through the most significant elements, enhances the contrast of geochemical anomalies more than either the method of selective leaching of metals or any other method of geochemical data processing. If there is no significant correlation, the index τ provides anomalies at least with the same contrast as any other method.

The benefits of the proposed technique, particularly feature (iv), have been proven in all cases of its application in geochemical prospecting of several concealed and buried mineral deposits.

Kimberlite pipes in the Mirninskoye ore field (Yakutiya, Russia) penetrate through Cambrian carbonate formations and are covered with Quaternary overburden. Conventional multiplicative anomalies are low contrast and do not show noticeable spatial links with known kimberlite pipes. However, the high contrast τ anomalies, calculated with 15 chemical elements, demonstrate strong spatial correlation with some of the known kimberlite pipes and were used as a guide for discovery new orebodies.

A *rare metal tin-beryllium* deposit and the Pechenga *Cu-Ni* deposit (Kola Peninsula, Russia) are buried under moraine deposits. Thickness of moraine deposits is 20-40 m in the first case and 10-20 m in the second. A superficial exploration of this type of mineral deposits utilizes a method of acetate-buffer extraction of metals out of *humus* horizon of soil. This method is capable of trapping very weak geochemical haloes that are superposed on moraine deposits. The results of this method were compared with the τ parameter, which was calculated using conventional data from geochemical sampling of the illuvial horizon of soil. Concentrations of 18 chemical elements were utilized in these calculations. Various conventionally used multiplicative and additive indices were also calculated. A statistical analysis of acquired results was conducted. In this competition between various methods of geochemical exploration index τ became an indisputable leader. Only τ anomalies are comparable with the assays of acetate-buffer extracts.

Similar results were acquired for Massive sulfide deposits on the Southern slope of the Great Caucasus (Azerbaijan) as well as for non-ferrous mineral deposits at Rudny Altai Mountains (Russia and Kazakhstan), etc.

The benefits of the proposed technology are extremely high, when it is applied to relatively large-scale mineral exploration (from 1:10,000 to 1:50,000) for buried or concealed mineral deposits. It also creates a metrology for comparison of the efficiency of different methods of exploration.

A COMPARISON OF REGIONAL GEOCHEMICAL SURVEYS OF TILL AND LAKE SEDIMENT, LABRADOR, CANADA

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Geochemical analyses results for till (2438 samples) and lake sediments (>12 000 samples), obtained as part of regional surveys in support of mineral exploration in central Labrador, Canada (52° -57° N, 57°- 69° W), were compared to determine differences and similarities between sample media, and between geochemical maps derived from them. Geochemical data for both media have been used in support of mineral exploration and, more recently, the determination of 'background' for environmental geochemistry. Traditionally, geochemical surveys based on different sample media have been qualitatively compared by visual examination of maps. This study attempts to quantify and map similarities and differences between surveys through the use of trace metal ratios which emphasize comparative differences. The ratio method provides a straight-forward and robust approach to comparison of different datasets.

Because the two sample media were collected at different densities and locations, the first challenge was to develop a basis for comparing the media using geochemical ratios. Three methods were evaluated:

1) Gridding, where both data sets are resolved to a common grid (2 Km) by averaging all data for each media within each cell; 2) Point-to-Point, where each till sample was compared to its 'nearest neighbour' lake sediment sample up to a specified 'maximum' separation distance; 3) Hybrid, where till data for each site were compared to the gridded (2 Km) model of lake sediment geochemistry. From X-Y plots and examination of correlation coefficients, for each media, linear correlations are evident between 'raw' data and gridded values. The Gridding technique smoothes 'anomaly' definition, but better defines regional trends than Point-to-Point comparisons. The Hybrid method, however, was chosen for ratio

calculations because data for each till sample site were retained, and the basis for constructing a gridded model of lake sediment geochemistry was strong, given the regional scale of investigation (100's of km) relative to sample density (average 1/13 km2), and to the near-uniform distribution of lake sediment samples.

In the initial comparison, the primary research question addressed was: 'to what degree do the two media reflect geology ?' . In glaciated terrain, till is the surgical sediment type that bears the closest compositional relation to bedrock, representing the composition of bedrock eroded by ice along the path of ice flow, modified by the physical processes associated with glacial transport and deposition. Because till is the most widespread surficial sediment, the inorganic mineral component of lake sediment is largely derived from till in its catchment area, although further modified by the physical processes of surface erosion and lake sedimentation. Consistent with that, till and lake sediment geochemistry both show comparable associations with bedrock geology. For example, copper concentrations in both media are greatest in mafic volcanic terrain of the eastern Labrador Trough, and least in areas of peralkaline volcanic rock.

Unlike till ('unweathered' C horizon), lake sediment geochemistry is also affected by physical, chemical, and biological processes active in both the surficial and lake environments during postglacial time, including addition of terrestrial and aquatic organic material and secondary chemical precipitates. Depending on those processes and their effects on geochemistry, the glacial geological signal can be either partially or fully masked. Where the effects are minimal, metal ratio maps are expected to show minimal site-to-site variation. The elements copper (Cu), zinc (Zn), nickel (Ni), arsenic (As), manganese (Mn), and lanthanum (La) were chosen for study. Copper and nickel were chosen because of their application to mineral exploration; zinc and arsenic because of their affinity for organic material; manganese because of its mobility in the surficial environment, and lanthanum because of its apparent immobility in the surficial weathering environment. The elements chosen have different mineral associations, and are affected to different degrees by secondary weathering and biological activity. Hence, each has a different interpretive value in comparing sample media and metal ratios.

Ratio maps reveal three salient features: 1) local areas of significant difference between media, referred to as 'ratio anomalies'; 2) systematic regional variations in ratio values both within and between major bedrock geological units; and 3) differences in ratio patterns among elements. The systematic differences among ratio maps are attributed to the physical, chemical, and biological factors differentially affecting lake sediment geochemistry, including: 1) grain size and mineralogy of surficial deposits in the drainage basin, and their effects on clastic sedimentation rates in lakes; 2) partitioning of trace metals between primary mineral grains, secondary chemical precipitates, and organic components; 3) climatic and vegetation differences, an interpretation supported by regional differences in the organic matter content of lake sediments and pH; and 4) physiographic differences and their relation to runoff, rates of erosion, and lake sedimentation. From this study, factors other than bedrock are important to the interpretation of regional lake sediment geochemistry, and the two media portray different background variations in trace metals.

PROSPECTING AND ECOLOGICAL STANDARDIZATION OF BIOGEOCHEMICAL FIELDS

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The actual biogeochemical data can and should be used for prospecting and decisions of ecological problems. Our experience of such approach has shown, that the investigated biogeochemical fields demand special standardization, proceeding from practical prospecting or ecological problems.

We have accepted geological concept "the ore body" at prospecting standardization as the basic criterion. This concept is simultaneously economic, since the mining of ore bodies should produce a profit, justifying an expense on its forecasting, prospecting and investigation. We accept the border content of an examined ore elements (OE) as practical criterion of "the ore body". The first problem of the prospecting biogeochemical data standardization is definition of the (OE) content in the standard nonbarrier bioobject, which corresponds to border content in the ore body. The possibility of such standardization is real only in conditions, when the straight dependence with a value of the linear correlation coefficient - r 0,8. between the OE contents in the channel samples from the bottom of ditches and in the nonbarrier bioobject of a plant is observed. At such value of r between the compared components interdependence takes place at a level r2, i.e. 0,64 (64%), approximately - two thirds.

The values of r exceeded 0,90, i.e. the examined interdependences were at a level 80% in the majority of our biogeochemical fields standardization cases. By the present time, the high values of r 0,90 were established for gold (Kovalevskii, 1973-1991), beryllium (Kovalevskii, Kovalevskaya, 1979), molybdenum (Kovalevskii, 1974-1991; Kovalevskii, 1987), silver (Kovalevskii, 1991-1997) by us. The high values of r at comparison of the OE contents in the nonbarrier bioobjects and in channel samples from the bottom of ditches were observed by many other researchers (Grabovskaya, 1963-1971; Barskii, Radchenko, 1977; Radchenko, 1977-1983; Dunn, 1986-1995; et al.). Model of silver-bearing and silver-ore mineralization in the Gil'bera zone of deep fault in which was established the ring structure by the size 16È16 km, is a combination of linear silver-bearing stockworks (LSS) with separated veined silver ore bodies (VSOB) and local silver-bearing zones (LSZ), located out of LSS limits. The last were discovered and contoured by thickenings of the supposed ore biogeochemical anomalies (SOBA) of Ag with concentrations 70-3000 ppm in the rotten wood of pine (Pinus silvestris) stump ash or 7-300 ppm in the ash of pine suberized cones from forest litter. These 11 thickenings of approximately isometric form have sizes 100-300È150-400 m and include from 9 up to 51 SOBA Ag. Total quantity of SOBA Ag in the south part of investigated region to the present time exceeds 200. The quantity of such thickenings in the whole ring structure is expected to be some hundreds.

The main problem of biogeochemical data standardization is revealing of LSS in high anomaly biogeochemical field of Ag, study of their complicated internal structure and revealing VSOB connected with rich, common and poor ores. All the 6 standardization levels of a complex lithogeochemical field discussed can be received with the help of plants. Standardizing for them is a concentration curve in the system: "Ag in channel samples from ditches - Ag in the standard nonbarrier bioobject". By the similar way, it is necessary to make ecological standardization of biogeochemical fields. Basic lines of the physiologically active chemical elements (PACE) contents should be here the upper limit of deficit contents - ULDC and the limit of permissible concentration - LPC, contouring the areas with PACE optimum contents. It can be divided at least into 3 gradations: the low, the middle and the upper optimum at a wide range of an optimum. The negative biogeochemical fields at such standardization will correspond to territories with a low, middle and high level of deficit. Positive fields - will correspond to low, middle and high investigated PACE surplus. The fractional gradations on the deficit and surplus areas should be done by quantitative physiological reactions of living organisms. Thus "the quartile method" can be convenient. The distinctions of 25% are accepted in it. The main levels are 50% and additional - lethal of wreck, degeneration of organisms or absence of viable posterity. It is necessary to allocate at least three intervals in the lethal diapason. For example: 1%, 10% and 50% of lethal outcome. The estimation of physiological action PACE quantitative criteria is a rather difficult affair, since they should be based on long-term researches of large sets of investigated plants or animals species. In medicine, for example, the "unit" of morbidity or mortality is used their quantity on 100000 persons. Children, teenagers, adults, elderly, men or females and time of the research are always taken into consideration in medical investigations. These criteria should be calculated on the basis of integration of being available actual data for large natural regions (tundra, coniferous forests, wide-leafs forests, partially wooded steppe, chernozem steppe, deserts, mountains, etc.), countries and continents. First of all it is necessary to use legislatively authorized ULDC and LPC meanings in the different countries. The analysis of these data shows, that the available information has unilateral purposefulness. LPC are established for a plenty PACE, their combinations and objects of biosphere (air, drinking water, foods, food rations, drinks, soils, etc.). The general number of substances, normalized by LPC, is measured nowadays by thousands. The considerably less attention is given to ULDC, though deficit biogeochemical provinces and localities cover commonly much larger territories and have considerably greater practical importance, than surplus ones. As a whole, the major microelements form deficit provinces on approximately following areas: I - 60-70%; Se - 30-40%; Fe - 20-30% on the Globe for the humans and agricultural animals. These values can vary in significant limits in various countries and for various living organisms. For example, I- and Se-deficit territories can cover the whole countries and large provinces with population of many millions humans. Biogeochemical maps with allocation of various deficit, optimum and surplus levels should be completed for them in the first turn.

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PERSPECTIVITIES OF THE BIOGEOCHEMICAL EXPLORATION AND PROSPECTING FOR PRECIOUS METALS DEPOSITS

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At the present time, precious metals (PM) deposits have the priority in prospecting and investigations in many countries. There is a tendency of transition from mining of rather easy revealed, mainly poor deposits in river valleys to richer, but hardly revealed, mainly veined deposits of Au, Ag, Pt, Pd. The majority of PM deposits and their ore bodies are small in sizes and consequently hardly revealed, though they form sometimes extensive ore fields and provinces. Numerous Au and Pt deposits had been mined or are mining in river valleys in many known PM fields and provinces when deposits in native rocks are not numerous or even absent. This phenomenon, characteristic for basic Au-mining regions of Russia: Yakutia and North-East, may be explained by difficulties in revealing and contouring of numerous small and very small Au-ore bodies and deposits. The situation is much worse with prospecting for proper Ag-ore veined bodies and deposits than with Au in the USSR and in Russia. They were not objects of prospecting works in the majority of regions. The revealing of new large Au-bearing regions and provinces at the present time is incredible. Therefore the revealing of new mining objects of Au and Pt should be connected mainly with detailed prospecting of hardly revealed veined ore bodies and deposits in known Au-bearing regions with numerous deposits in river valleys with "unknown" sources in native rocks. The main role, in our opinion, in revealing and investigations of these sources can belong to modern nonbarrier biogeochemical exploration (NBE) and prospecting (NBP) of Au in many favourable cases.

Our experience of biogeochemical prospecting for PM and integration of the numerous publications (Kovalevskii, 1973-1997 in Russian; Kovalevskii, 1978-1997 and many others) show, that there are some types of deposits and ore occurrences of various ore elements including several PM in the majority of PM ore fields and especially in PM ore regions. For example, since 1950-th low perspective ore occurrences of fluorite, gold, silver, lead, asbestos, mica were known in investigated Gil'bera zone of deep fault and in its vicinities on the area about 300 sq.km. 5 new and 6 supposed perspective Ag ore occurrences of three types including with Au, and some geochemical types of unevaluated platinoids mineralization: Pt; Pt+Ir; Pt+Os; Pt+Au; Pt+Os+Au; Au+Rh+Pt+Os and others were here revealed by our research works. Various PM mineralization form here mainly monoelement (~on 90%) local mineralized zones (LMZ) 0,2-2 m width, their thickenings, which correspond to complex mineralized zones (CMZ) 5-50 m width, including 2-6 LMZ. These CMZ enter in complex PM stockworks (CPMS) 100-300È150-400 m size. Being 100-400 m away from each other, they form linear, arc and ring structures. The regular combinations of LMZ, CMZ and CPMS form original fractal structures in the region. There is a basis to approve, that similar ore-bearing fractal structures are typical, in many ore regions and units, though they were not studied from this point of view.

One of the main theoretical bases of biogeochemical exploration and prospecting for PM is their unexpected high availability to plants, thanks to their aggressive root excretions. They have acid reaction and various solvents, including nitric and hydrochloric acids, i.e. the aqua regia, which dissolve Au and Pt well. After this, root excretions include the complex of organic-mineral chelate compounds, which dissolve Pt and Pd better than aqua regia. By our data, Ag has the greatest availability to plants. Its plant-rock coefficient (PRC) is equal 10-30 at the background contents of Ag in rocks for the rotten wood of pine (Pinus silvestris) stumps. PRC of Pt and Pd have appeared close to 1,0 as well as of the most other chemical elements, instead of to the minimum values, equal 0,0n-0,00n, which were expected in agreement with the numerous publications. By our data, PRC for Au is equal 0,1-0,5, average ~0,2 in various regions of East Siberia. The values of PRC for all PM decrease with the increase of their grain sizes in the root-inhabited zone. The significant advantages of the biogeochemistry over soil-geochemical investigations are caused by the many times decrease of LMZ ore elements contents in the top horizons of soils 0,1-0,5 m when biogeochemical anomalies have "stable" contrast till maximum root depth, usually 1-5 m and sometimes 10-20 m, i.e. it is explained by much more depth of biogeochemical information comparing with soil-geochemical one. Their following peculiarities should be taken into account in using developed and recommended by us technologies of the NBE and the NBP for PM.

Silver

Ag in Gil'bera zone is the most PM investigated element. Despite 4-divisible special explorations for Ag from 1970 to 1985, only 5 LMZ with concentrations of Ag from 100 up to 2000 ppm were here revealed by the "Buryatgeology". By our works of 1984-1998 it was revealed more than 200 supposed ore biogeochemical anomalies (SOBA) with concentrations of Ag from 70 up to 3000 ppm on a background 0,7 ppm in the wood of pine rotten stumps. 22 veined silver-ore bodies (VSOB) with the contents of silver from 20 up to 6000 ppm were revealed at opening by ditches of 24 SOBA (reliability of biogeochemistry - 92%). Thus NBE and NBP of Ag in Gil'bera zone with its several known LMZ have allowed to increase prognostic resources of Ag approximately 40 times
(Kovalevskii A.L., 1991-1998).

Gold

Biogeochemical investigations for Au were conducted in many countries. They have proved high efficiency in comparison with soil-geochemical ones in many cases. By our research it was established, that economic, recently automated scintillation emission spectral analysis - SESA (Kovalevskii, Prokopchuk, 1978-1997; Kovalevskii, Prokopchuk, 1980-1997) for the analysis of plants ash samples by weight 0,5-1 g was rather suitable. It was established that plenty of species and parts of plants, growing in various suitable landscapes are high-informative for NBE and NBP for Au to total contents and to mineral forms (Kovalevskii, 1973-1997; Kovalevskii, Kovalevskaya, 1989) of Au, determined by SESA.

Platinum and other platinoids

By our researches in the investigated Gil'bera zone of deep fault it was established, that LMZ of Pt and Pd have buried lithogeochemical haloes. They were missed by soil-geochemical sampling, but well revealed by biogeochemical one. The nonbarrier, quantitatively-informative bioobjects in relation to high concentrations of the platinoids total forms have appeared, as well as in relation to Ag and Au old suberized parts of woody plants: cones of a pine and fur-tree from forest litter and external layers of various tree species bark. By the data of foreign researches, branches of some tree and bush species, are nonbarier to platinoids. The economic and high-productive SESA is suitable for the analyses of suberized ashed bioobjects of plants (Kovalevskii, Prokopchuk, 1992-1997: Kovalevskii, Prokopchuk, 1993-1997).

AN EVALUATION OF THE ROLE OF ENVIROGEOCHEMISTRY IN PROPERTY AND CORPORATE TRANSACTIONS ASSOCIATED WITH THE MINERALS INDUSTRY IN ENGLAND AND WALES, UK

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Corporate and personal liability frequently arise in commercial property transactions connected with the minerals industry due to an estimated 100,000 to 200,000 hectares of contaminated land in the UK arising from natural and anthropogenic sources. Examples of major contaminants and their related industries or land use are outlined, together with commentary on factors affecting the presence of contaminants and their mobility.

The essential stages of the property transaction are discussed together with the geochemical investigative methods available, as well as the "Transaction Approach" including (i) gathering environmental information under the Environmental Information Regulations 1992 to locate and identify contamination; (ii) the effect of property transfer on environmental liabilities and the limits of "caveat emptor"; (iii) preliminary enquiries and searches, and (iv) environmental surveys. Aspects of locating and identifying contaminated land associated with the redevelopment of land for commercial and industrial uses and its valuation, are considered.

This paper also considers the assessment and management of environmental risk, and the function of insurance in relation to land contaminated by the minerals industry after the Statutory Guidance for contaminated land becomes effective. In particular the unique migration of organic and inorganic ground-water contaminants is discussed including coal measure contamination.

The future role and significance of envirogeochemistry in conveying land affected by the minerals industry is appraised in relation to the Environment Act 1995 provisions for contaminated land, and the author presents his views on compulsory geochemical searches and investigations for property and corporate transactions.

NATURAL ACID ROCK DRAINAGE IN THE GATAGA DISTRICT, BC, ENVIRONMENTAL AND MINERAL EXPLORATION IMPLICATIONS.

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In many parts of British Columbia acid stream water, gossans and iron oxide stream precipitates are indicators for acid rock drainage (ARD). Acid water is generated by the oxidation and solution of pyrite and pyrrhotite as ground water moves through fractured, sulphide-bearing bedrock or mined sulphide waste rock. Impressive secondary iron oxide deposits found in the Gataga District of north-eastern B.C. often contain large concentrations of zinc, cadmium, arsenic, cobalt, molybdenum, nickel, lead and other heavy metals scavenged by the iron hydroxides from the mineralized spring water. These metals reflect natural acid rock drainage from either sedex-type Pb-Zn-Ag-Ba sulphide deposits (e.g. Driftpile Creek) or metal-rich carbonaceous, pyritic shales. High zinc and silver background levels in soils and spring deposits due to the weathering of metal-rich shale can hinder exploration for shale-hosted Pb-Zn-Ag-Ba deposits by masking the geochemical expression of concealed base-metal sulphides. In addition, elevated concentrations of lead, cadmium and arsenic found in the acid rock drainage may be toxic. The degree to which these metals impact on the surface environment may be important for planning any future exploration and mining opportunities. The object of detailed geochemical studies in the Gataga District has been to identify geochemical pathfinder elements for sedex Pb-Zn-Ag-Ba deposits and to assess the impact of toxic heavy metals in ground and surface water.

Spring water, spring sediments and soil samples were collected around the Driftpile and Bear Pb-Zn-Ag-sulphide-barite deposits and from a background area (Red Gossan) where detailed exploration activities have identified only minor traces of base-metal sulphides. These mineral occurrences are located in a folded sequence of Ordovician to lower Devonian basinal-facies clastic rocks filling the north-west trending Kechika Trough. Spring deposits found in the Kechika Trough can be characterised by (i) small iron oxide mounds where laminated limonite or jarosite layers surround the spring; (ii) surface crusts of iron oxide associated with inactive springs; (iii) thick, white precipitate (barite, aluminium hydroxide) coating sediment in streams; or (iv) laminated calcium carbonate mounds. In addition to pH and sulphate, spring and stream water samples were analysed for cobalt, nickel, lead, zinc, arsenic, cadmium, aluminium, thallium, zinc and 60 other elements by inductively coupled plasma mass spectrometry (ICPMS). Soil and spring deposit samples were analysed for molybdenum, copper, lead, zinc, silver, mercury and 60 other elements by a combination of neutron activation (INAA) and aqua regia digestion-inductively coupled plasma emission spectroscopy (ICPES). The partitioning of elements in selected spring deposit samples was also studied by sequential extraction analysis using 0.25M hydroxylamine hydrochloride (amorphous iron-manganese oxides), 1M hydroxylaimine hydrochloride (crystalline iron oxides) and finally by hydrofluoric-nitric-perchloric acid digestion. Metal concentrations in the extracts were determined by ICPES.

Spring waters from the Bear and Driftpile areas were found to be more acidic and have higher median lead, barium, aluminium and thallium levels than those draining the background Red Gossan area. However, the more alkaline Red Gossan springs have higher median sulphate, cobalt, nickel, calcium, manganese, zinc, arsenic and uranium concentrations compared to the Bear and Driftpile waters. One acid spring (pH = 4.3) sampled near the Bear barite-lead-zinc sulphide horizon, contained 390 ppb lead, 2.5 ppb thallium and 100 ppb aluminium. East of the Driftpile deposit, acid ground water contained up to 7.3 ppb lead and 2.3 ppb thallium. Lead levels in the Red Gossan spring waters are less than 1 ppb, but cadmium values reach 100 ppb and arsenic 21 ppb. Spring deposits from the Bear and Driftpile areas also have elevated lead, barium, mercury and bromine whereas the Red Gossan spring deposits have higher zinc, cobalt, nickel, arsenic and cadmium. B-horizon soils have high lead, silver and mercury over the buried massive sulphide at the Bear occurrence. Sequential extraction analysis reveals that zinc, cadmium, cobalt and manganese are mainly concentrated in the amorphous iron oxide fraction (released by 0.25M hydroxylamine hydrochloride) whereas lead, arsenic, silver and barium are bound in the more crystalline iron oxide fraction and residual fractions of the spring deposits samples.

Elevated lead, thallium, aluminium and barium levels in spring water are indicators of oxidation and mobilization of weathering sulphides (e.g. ARD) from concealed massive sulphides in the Gataga District. A white coating on the stream bed below acid springs is a useful visual prospecting guide to mineralized ground water. Although lead concentrations in some acid spring waters exceed national drinking water and aquatic life guidelines, these levels decrease rapidly in adjacent streams to less than 1 ppb through dilution and neutralisation. Lead, silver and mercury in soil and spring deposits are the most reliable geochemical pathfinders for lead-zinc-silver massive sulphides, although bromine and thallium can also be useful indicators. The most geochemically impressive zinc, cobalt, nickel, arsenic and cadmium-rich iron oxide spring deposits are associated with neutral ground water and reflect drainage from metal-rich pyritic shale rather than from massive sulphides. Sequential extraction analysis shows that lead and arsenic are incorporated into the most crystalline oxide and resistant silicate mineral phases of the spring deposits. The metals will only be released as suspended particles into stream water by subsequent long term weathering and erosion of the spring deposits. Bound to suspended oxide particles, lead and arsenic are geochemically more stable and consequently much less toxic than if dissolved in the surface water. Metal adsorption combined with neutralization of acid water by calcareous rocks is likely to minimize the impact of natural acid rock drainage on the environment.

DETAILED GEOCHEMICAL MAPPING (1:25,000) IN PB-ZN MINING AND SMELTING REGION OF UPPER SILESIA, POLAND

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As a geochemical anomaly on regional scale, Upper Silesia has an exceptional position in the geochemical image of Poland. Due to its characteristic assemblage of elements (Pb-Zn-Cd), this anomaly is strongly marked in surficial environments, i.e. soils, water sediments and surface waters as a result of natural and anthropogenic factors. Outcropping ore-bearing dolomites and the occurrence of zinc-lead deposits are the main natural factors contributing to the origin of this anomaly. Dolomites and the ore deposits are the reason that a geochemical aureole develops in the surficial environments; these natural processes are overlapped by anthropogenic factors connected with extraction and treatment of ores and smelting industry as well. In order to recognise the character and the extent of the anomaly on a detailed way, the first sheet (Sawków) of the Detailed Geochemical Map of Upper Silesia, to the scale of 1:25,000, was mapped. Results of this survey may be utilised in town and country planning as well as applied for assessment of the degree of pollution affecting soils under cultivation, etc.

The geochemical survey covered an area of 82 km^2; a sampling grid was based on regular 250x250 m pattern (16 points in 1 km^2). Sampling points totalled 1393 (from the topsoil 0.0-0.2m and 0.8-1.0 m).

After leaching the samples with aqua regia Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn were determined by ICP-AES and Hg by CV-AAS. Distribution of elements in soils are presented on mono-element's maps. The maps were produced using SURFER with the method of inverse distance and presented using the isolines on the base map.

Lithology appears as a factor which has an effect on concentrations of aluminium, barium, calcium, cobalt, chromium, iron, magnesium, nickel, strontium. titanium and vanadium. Elements such as cadmium, zinc, lead, silver, arsenic, copper, mercury, manganese and sulphur are closely connected with the zinc-lead ore-bearing formation and the mining and smelting activities. The data obtained from spatial element location in the topsoil and subsoil indicate, that in the most examined area the superficial soil layer is contaminated with cadmium, lead, zinc and sulphur. Going more deeply, the contaminated area tends to be limited to the historical and contemporary mining zones. The most intensive anomalies related to the ore-bearing formation outcrops occupy greater areas in the subsoil.

Factors recommended by the Institute of Soil Science and Plant Cultivation Puawy, Poland) were applied to assess the degree of pollution of cultivated soils in surveyed area. They are used to classify soils among classes 0 through V. Class 0 is assigned to unpolluted soils with heavy metals contents within the limits of their natural background. Soil classes 0–III can be utilised by agriculture. Classes IV and V are assigned as polluted soils that should be excluded from agricultural use. Degree of pollution of soils with metals (mostly with cadmium, lead and zinc, and to a lesser degree with arsenic and copper) is very high in the Sawków area. Polluted soils – those corresponding to classes III and upper - due to excessive pollution with lead – occupy as much as 49.4% of the map sheet area.

A list of permissible concentrations of heavy metals, recommended by the Institute of Hygiene in Rhr (Germany) was applied to assess the suitability of soils for agriculture and gardening and for the town and country planning needs (playing grounds for children, sport fields, allotment gardens, industrial plants).

MINERALOGY AND GEOCHEMISTRY OF THE PEDDIE KIMBERLITE PIPE AND OVERLYING GLACIAL SEDIMENTS, NEW LISKEARD, ONTARIO, CANADA

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The Peddie kimberlite is located in Bucke Township, 8 km south of the town of New Liskeard and 5 km north of Cobalt. It was discovered in 1995 and is in the southern region of the Kirkland Lake-Timiskaming kimberlite fields. The New Liskeard area was glaciated during the Wisconsinan, during which time bedrock was eroded and striated and silty sand till and overlying fine-grained glaciolacustrine sediments were deposited over most of the area. In 1997, the Geological Survey of Canada excavated several trenches into the kimberlite for the purpose of collecting samples to document the kimberlite's mineralogical and geochemical signature. The kimberlite is covered by 2 to 3 m of till and glaciolacustrine silt and clay. Detailed sampling was undertaken in the trenches dug above the kimberlite. Additional trenches were excavated adjacent (south) of the kimberlite; these contained kimberlite boulders of variable size (centimeter to meter scale) within till. Both kimberlite and till samples were collected from these trenches. In addition, till samples were collected up to 5 km south of the kimberlite from hand-dug pits to examine glacial dispersal patterns.

The kimberlite is classified as a hypabyssal facies phlogopite macrocrystic monticellite kimberlite. A high precision U-Pb perovskite radiometric age determination of 153.6 Ma indicates the kimberlite is of Late Jurassic age. This is consistent with this kimberlite intruding a Proterozoic age Nipissing quartz diabase sill, and containing Ordovician limestone xenoliths. The Peddie kimberlite contains quite unusual 'eggs' (10 - 20 cm in size) consisting of >90% olivine (which are not mantle dunite xenoliths) and the kimberlite also contains a very unusually high volume of large olivine grains that give it a distinct mineralogical signature. The upper surface of the kimberlite has undergone varying degrees of weathering, leaving most of the upper surface friable and soft. A small portion of the upper surface, however, is unweathered, hard kimberlite and displays what may be the first reported striated kimberlite surface. Striae on the kimberlite and other bedrock in the area indicate that ice flowed towards 200° and 180°.

Bulk (10-kg) samples of weathered and fresh kimberlite and till were processed using a combination of shaking table and heavy liquids to recover a heavy mineral fraction for picking kimberlite indicator minerals and pebbles for lithological examination. The weathered kimberlite and till required no preparation prior to processing, however, the fresh kimberlite had to be mechanically crushed to <2.0 mm. Indicator minerals were picked from three size fractions of the non-ferromagnetic heavy mineral fraction of samples: 1) 0.25 to 0.5 mm, 2) 0.5 to 1.0 mm and 3) 1.0 to 2.0 mm. Olivine is the most abundant indicator mineral in both weathered and fresh kimberlite followed, in decreasing abundance, by ilmenite, pyrope, chromite, and Cr-diopside. Indicator minerals are most abundant in the 0.25 to 0.5 mm fraction of kimberlite and till. Geochemical results from electron microprobe analysis of the indicator mineral grains from the kimberlite and till will be presented along with till geochemical results.

TILL PROVENANCE STUDIES IN THE MELIADINE TREND, RANKIN INLET AREA, NUNAVUT: IMPLICATIONS FOR GOLD EXPLORATION

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Regional surficial mapping and glacial transport studies have been undertaken in the Rankin Inlet area by the Geological Survey of Canada as part of the Western Churchill NATMAP Program. Exploration by industry for both shear zone and iron-formation-hosted gold deposits is continuing along a 65 km long linear aeromagnetic anomaly, the Meliadine Trend (Miller et al., 1995). This work was initiated to provide a better surficial geology framework for mineral exploration in an area of thick drift, and to supply a baseline for environmental assessments in case of future development. Preliminary data and interpretations, arising from field work undertaken in 1997 and 1998, are presented here.

Within the study area, the dominant surficial sediment is till, deposited by a regional southeastward trending ice flow event (131° to 147°). Above 50 m a.s.l, till has been weakly reworked by wave and current action of the Tyrrell Sea, and only the tops of the landforms are developed into marine terraces. Along the coast (< 50 m a.s.l), glacial landforms are intensively reworked into beaches, terraces and spits, and till, where preserved, is generally thinner and wave-washed. Four major continuous beaded eskers traverse the area within broad valleys largely occupied by lakes. In the vicinity of these eskers (<4 km), ice flow indicators are found oblique to the esker direction suggesting that laterally restricted zones of convergent ice flow occurred along glacial conduits near the ice margin (Kaszycki and DiLabio, 1986; Shilts, 1984). Locally, this may have implications for glacial transport directions and drift prospecting in the Meliadine Trend.

Regionally, over 200 till samples were collected at an average spacing of 4 km and analysed for geochemical and lithological composition. In the vicinity of selected gold deposits, 80 more samples were collected for mineralogical and size partitioning studies to provide models of gold dispersal and determine the analytical scheme for the regional samples. Results show that till provenance studies based on pebble lithologies are essential to interpret geochemical trends and anomalies. In the Meliadine Trend, the bulk of the till has been transported less than 10 km from its source. Till composition is primarily related to locally derived up-ice lithologies (up to 88% greenstone belt clasts) and less to thickness, landform and degree of marine reworking. In some areas, the incorporation of metal-poor local debris (granites) can suppress gold and its pathfinders' dispersal trends. Iron formation clasts are difficult to trace in the pebble fraction and do not appear to be a good indicator lithology for modelling glacial dispersal. There is a close relationship between As and Au concentrations in the fine fraction of till, reflecting the known association of gold with arsenopyrite (Armitage et al., 1993). Although the bulk of the Au resides within the silt size fraction, and within the HMC fraction of till, any significant (higher than detection limit) gold levels in the pulverized pebble fraction indicates a close proximity to mineralization.

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TOPSOIL GEOCHEMISTRY AS A CONSEQUENCE OF ACID RAIN DEPOSITION AT AN ABRUPT CLIMATE BOUNDARY, THE CASE OF NATIONAL PARK "RISNJAK", CROATIA

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The area within the boundaries of the Risnjak national park has been a target for environmental studies undertaken by both earth and forestry scientists whose studies show a considerable anthropogenic impact/damage caused by acid rain deposition. The park lies in the karst region of western Croatia approximately 30 km from the port and industrial city of Rijeka. The bedrock is composed of Mesozoic limestone and dolomite within which a coarse-grained sedimentary rock and sandstone molasse type Paleozoic complex is situated. The boundary between these complexes is characterized by numerous sedimentary (early diagenetic type) barite deposits which were mined in the near past. This region is characterized by one of the sharpest climatic boundaries in this part of Europe, changing suddenly from a Mediterranean climate into a cold continental climate type, followed by a marked vegetation change. The topsoil consists of mainly brown soils on limestone and dolomite with a humus accumulation horizon of variable thickness.

The geochemical data used in this work were obtained from 80 sites on a regular grid (each site consists of 5 topsoil subsamples) during a low sampling density regional geochemical mapping program (1 site per 25km^2) and a high density national park geochemical sampling program (1 site per 1 km^2). Twenty five elements were analyzed in the fine soil sample fraction (-63μm) by ICP-AES after total dissolution in a mixture of concentrated mineral acids (HF, HCl, HNO_3, $HClO_4$) and partial extraction with 1 M CH_3COONa buffered at pH=5. The later was used to evaluate airborne contamination.

The proportions of elements extracted by CH_3COONa, as percentage of the total content of the analyzed elements Al, Ba, Ca, Co, Cr, Cu, Fe, Mg, Mn, Ni, Pb, Sr, Ti, V and Zn varies considerably and are different for each individual element. The content of elements obtained by 1M CH_3COONa extraction was usually bellow 5 % of the total content. In the case of lead from soils in the NP "Risnjak" area this percentage was as high as 50% while contamination by other elements obtained by this extraction was not detected clearly. The total lead concentrations detected at elevations higher than 1000 m a.s.l. were higher than 80 ppm (maximum concentration 139 ppm Pb) while the regional average for the region is 43 ppm.

The total data set was further processed through R-mode factor analysis in order to establish different geochemical associations among the elements and to detect and identify possible anomalies of elements that could be associated with airborne contamination. A six factor model accounted for 75 % of the total variance. The group of elements Pb, Zn, Ni, Co, Mn, Cd, V and P has a strong positive correlation with Factor 2, with loadings higher than 0.7. This whole group of elements is interpreted as to be associated with airborne contamination associated with acid rain deposition. Factor scores computed for this association of elements plotted on a map show high positive scores distributed at the climate boundary that passes through the Risnjak national park. Along this regional climate barrier deposition of airborne contaminants from both regional (NE Italy) and local (Rijeka, oil refineries and oil fired power plants) fossil fuel consumption sources evidently occurs.

Although single element maps do not distinctly indicate airborne contamination of the topsoil by most elements (with the exemption of lead), it was possible with the aid of factor analysis integrated and processed through GIS (as a multi-disciplinary tool) to clearly identify areas influenced by airborne pollution.

ADVANCES IN GIS TO RE-EXAMINE AND INTEGRATE PUBLIC DOMAIN EXPLORATION GEOCHEMICAL DATA: THE EXAMPLE OF SW ENGLAND

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GIS is routinely used to aid in the interpretation of new geochemical surveys. However it also has a role in capturing and re-interpreting existing data, much of which has been discarded or underused, as the data are only available in paper form.

In SW England data from a wide variety of formats and age were integrated with the aim of formalising the location of significant anomalies, both of exploration and environmental interest. A major criterion in identifying anomalies was their occurrence in more than one survey. GIS is ideal in this regard as different surveys can be represented in different layers and overlaid using either raster or vector methods. Surveys ranged from regional high precision data available in digital form to colorimetric thesis data only recorded as patterns.

One major advantage of using GIS is that digital elevation models (DEM) are now routinely available. DEMs can be used to place stream sediments in their catchment context. Soil samples can be represented as points or contoured and up slope cut-offs identified. In addition draped geochemical data can be rotated and viewed from various angles to aid interpretation. DEMs also allow the identification of geomorphological features, for example it is possible to test the association of Au geochemical anomalies with valley features that may represent remnants of Permo-Triassic sediments. Geomorphological controls on placer formation, such as Tertiary terraces, can be identified and correlated with cassiterite (Sn) anomalies.

GIS also allows the integration of geochemical data with digital geology, vein occurrences and SPOT/Landsat. Predictive models of element concentration can be generated and tested. An example in SW England is the identification of natural and anthropogenic As anomalies. In particular the recognition of doughnut As anomalies around the granites (probably formed during their intrusion) can recognised as regional anomalies and subtracted from the original data to highlight point source vein anomalies and those related to smelting.

TECHNIQUE OF GEOCHEMICAL EXPLORATIONS AND RESOURCE APPRAISAL OF GOLD DEPOSITS IN KAMCHATKA

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Conditions for geochemical exploration of endogenic gold in Kamchatka are specific: they relate to small amount of sulphides in gold-bearing ore minerals and the wide occurrence of volcanic ash hindering formation of lithochemical anomalies at the ground surface. The technique investigated include:

- Dividing territory into districts on the basis of conditions of realisation of geochemical exploration;
- Specifying the environment of sampling and rational sequence of works;
- Methods of detecting geochemical anomalies;
- Definition of their belonging to economic types of deposits;
- Methods of quantitative estimation of gold resources based on geochemical data.

Dividing territory into districts (DTD). Information about occurrence and thickness of volcanic ashes forms the basis of DTD. According to the conditions for geochemical exploration, the territory of Kamchatka is subdivided into regions:

- *open* (ash absent or up to 0.5 m thick) - 32 % of the total area
- *half-closed* (ash 0.5-1.5 m thick) - 54 % of total area;
- *closed* (seaside lowlands and intermountain depression) - 14 % of total area.

Rational sequence of geochemical works. Geochemical exploration is divided into three stages:

1. *Regional exploration.* Are effective on all of Kamchatka (excepting the closed regions) when sampling alluvium of middle streams with a density of 1 sample on 1-100 km^2 for detecting of ore regions and evaluation of their resources.

2. *Geochemical explorations on territories selected for geological detailed investigation.* In the half-closed regions of Central and Southern Kamchatka, with widespread development of ash, stream sediments surveys sampling alluvium of small-sized streams with a density from 4 to 10-20 of samples/1 km^2 are most expedient. In open regions of Northern Kamchatka and Koriak Mountain it is recommended to carry out sampling on secondary residual haloes of distribution in alluvium – deluvium with a density of 10-20 samples/km^2. On territories, where there is a possibility of finding gold deposits with increased amount of sulphides successful exploration can use applied biogeochemical prospecting with a density of 4-10 samples/km^2.

3. *Detail geochemical exploration.* In the half-closed regions of peninsula, where the thickness of ashes is more than 1-1.5 m, lithochemical exploration with sampling of the surface horizon is ineffective. Instead it is recommended to:

- increase sample depth up to 1-1.5 m (with sampling from buried eluvium-deluvium);
- exploration and investigation of primary haloes of metals;
- biogeochemical exploration using grass and thorn vegetation;
- ion-potentiometric exploration of K^+, Na^+, Ca^{2+}, $NH4^+$, I^-, Cl^- and other ions (depth till 60-70 m).

Geochemical classification. Gold deposits of Kamchatka fall under the category of gold-silver formation and are subdivided into 5 mineral-economic types. The main elements - indicators are:

- Au, Ag, As - for purely gold deposits (<1 % sulphides);
- Au, Te, Ag, Mo, As, Sb - for gold – tellurium deposits (<1 % sulphides);
- Au, Se, Ag, As, Cu - for gold –selenium deposits (<1 % sulphides);
- Au, Ag, Pb, As, Se, Hg, Mn - for gold -silver deposits (1-3 % sulphides);
- Au, Ag, Pb, Cu, Zn, As, Hg, Se, Mo, Bi - for gold –galena-sphalerite deposits (3-20 % sulphides).

Criteria for classification of detected ore objects according to parameters of their geochemical anomalies are also ratios: Au/Ag, Se/Te and AsSb/PbZn.

Detection and evaluation of geochemical anomalies. The concentration of gold are the basis for detecting gold objects in regional works and in prospecting of territories. In practice it found that in the conditions of Kamchatka regions and sites with gold are distinguished in isogrades of 3 mgr/ton, ore deposits - 10 mgr/ton, and indications of rich ores is the presence of gold contents of >100 mgr/ton in streams and secondary haloes.

Quantitative methods of resources estimation. These are carried out:

- *in regional works* - by calculation of the total productivity of gold in streams sediment distribution haloes $\sum P_i'$on estimated territory through consideration of the coefficient of proportionality k ' < > 1 and definition of the number of deposits of various size classes by the method of iteration (A.A.Matveev, 1994).

- *in geochemical surveys within ore regions* - by direct calculations of total areal productivities and evaluation of gold resources (in tons) according to the theory of proportionality between the amount of metal in an ore body and its hypergene anomaly (A.Solovov, 1985): $P_{sh} = kP_p$, where P_p and P_{sh} are areal productivities (m^2%) of endogene mineralization and its secondary haloes, k – coefficient of residual productivity (in conditions of Kamchatka k < 1). In streams sediment prospecting the counts of areal productivities are carried out by formula:

$$P = (1/40 \cdot k' \cdot k) \cdot [(C'_{an} - C'_{background}) \cdot S_{an}],$$

where C'_{an} - the average anomaly concentration of ore element within area S_{an}, k'- coefficient of proportionality between the average concentration in alluvium and eluvium-deluvium (in conditions of Kamchatka k'>1).

- *in local geochemical investigations* - according to endogenic geochemical zonality and construction of geological-geochemical models of deposits leading to quantitative criteria for evaluation of erosion level of mineralization, its distribution with depth, and also for detection of hidden ore bodies on the flanks and at deep horizons.

EVALUATION OF GEOCHEMICAL POLLUTION OF THE ENVIRONMENT IN GOLD DISTRICTS OF KAMCHATKA

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Development of gold deposits of Kamchatka is of utmost importance for economics of the region and looks particularly complicated from the environment damage prospective. Such damage will be inevitable, taking into account current gold mining and recovery technologies. The results of 1991-1997 ecological - geochemical studies allow us to evaluate environmental conditions in main gold bearing districts of Kamchatka and environmental impact of exploration works.

Natural geochemical pollution is determined by parameters and characteristics of anomalies, which form in soils, vegetation, river bed sediments and water as a result of rocks and ores weathering, hypergene migration of chemical elements and their accumulation on geochemical barriers. Gold deposits of Kamchatka, which are main sources of natural pollution in ore districts, are divided into two groups:

- low-sulphidation deposits (<1%), where As, Se, Te, Sb and Ag are harmful accessories (gold, gold-selenide, gold-telluride, gold-argentite);
- deposits with higher sulphur content (3-5%, rarely up to 20%) and wide range of harmful and toxic elements: Pb, Cu, Zn, Cd, Bi, Mn, Mo, As, Hg, Sb, Se (gold-galena-sphalerite, gold-copper, gold-sulphide).

The latter form mostly contrast litho- and biogeochemical anomalies, and also extensive litho- and geochemical dispersion haloes (table).

Pollution Characteristics	Deposit type *gold low-sulphidation*	*gold moderate-sulphidation*
Soils		
Main polluting elements	As, Pb, Zn, Hg	As, Pb, Zn, Cu, Bi, Ag, Sb, Hg.
Contaminated area	1-3 km^2	5-20 км^2
Level of contamination	Low (bulk - 2-15 MPC; mobile forms - 2-5 MPC	Medium (bulk concentrations - 3-20 MPC; mobile forms - 2-5 MPC
Vegetation		
Main polluting elements	As, Mo, Zn, Mn, Ni, Se, Ag	Pb, Zn, Cu, Ag, Cd, Co, Ni, Sn, Cd, Mo
Contaminated area	1-3 km^2	6-30 km^2
Level of contamination	2-10 C_b	5-150 C_b
Bottomset beds		
Main polluting elements	As, Se, Pb, Hg, Ag, Mn	Pb, Hg, Ag, Zn, Cu, As, Se, Mo
Length of streams	1-5 km	2-10 km
Level of contamination	Low (2-10 C_b)	Medium (5-50 C_b)
Surface waters		
Main polluting elements	Zn, Mo, Cu, Sr, Pb, B, As	Cu, Zn, Pb, Cd, Ag, Hg, As
Length of streams	-	1-3 km
Level of contamination	Absent	2-40 MPC

Technogenic geochemical pollution. In the explored deposits, main sources of environmental pollution are waste dumps from trenches and edits, ground and drain waters.

Waste dumps from superficial (surface) workings occupy an area from1' to 3-5sq.km, within which areas soil and vegetation are destroyed of significantly disturbed. In waste dumps of trenches, which intersect gold mineralisation, main polluting elements are As, Pb, Sb, Zn, Mn, Hg.

Waste dumps of edits of the deposits under study are the strongest sources of local environmental pollution:

- on the deposits with high sulphur content concentrations of Pb, As, Se and S exceed Maximum Permissible Concentration (MPC) by 50-100 times, Zn, Cu, Sb, Hb - by 5-10 times
- on low-sulphidation gold deposits in the waste dumps of exploration edits concentrations of As 30-60 times exceeds MPC, whereas Se, Sr, Pb, Zn, Mo, Cu, Mn 2-8 times exceed MPC

Based on balanced calculations, it was stated that at pH=3-4 Ag, Pb, Cu, Zn, As, Se, Mo, S are being leached from waste dumps; at pH=7-8: Ag, Cr, Cu, As, Mo.

Geochemical barriers, which stop transport of chemical elements from waste dumps and their migration, form if on the surface of mineralised zones we see:

- kaoline clays, which form as a result of weathering of metasomatically altered rocks. Kaoline clays sorb As and Mo
- carbonate films, which tie up insoluble forms of Pb, An and Cu;
- hydroxides of iron and manganese, which sorb Pb, Co and Ag;

Pollution from edits waste dumps spreads on to adjacent river basins (Area=1000-3000 sq.m). Main soil polluting elements are As, Se, Pb, main vegetation polluting elements - Mo, Ag, As, Se, Ni, As, Cu, Zn, Co, Sr. Pollution of river bed deposits from edits waste dumps includes As, Pb and Ag 10 times exceeds background values and spreads out for a distance of up to 1km.

Main pollution of natural water systems comes from waters originated in mine workings and drainage from under edits' waste dumps. Waters from mine workings on the high-sulphidation deposits contain Zn 600 times higher than MPC, Pb – 5 - 10 times, Se, Cd, hg, Cu – 2-3 times higher than MPC; for low-sulphidation deposits Zn concentration reach as high as 13 times MPC, As – 2-10 times MPC, Cu – 7 times MPC. Technogenic impact from geologic exploration leads to changes in chemical composition and decrease in pH of river water (down to 3-4), immediately below edits' waste dumps. SO_4^{2-} content increases to 100 milligram per litre, content of ore-related elements increases sharply: Zn - up to 40 times MPC, Cd, Se, Hg, Cu - 2-5 times MPC, Pb, Ag, As - 2-5 times higher than background values.

Conclusions:

1. Natural geochemical pollution in gold bearing districts of Kamchatka is significantly higher than technogenic pollution.

2. Intensity of technogenic pollution from waste dumps and surface mine workings increases in the following order (from least to most pollution): gold-selenide -> gold-argentite -> gold-galena-sphalerite ores. Only the latter create a real danger of excessive soil, vegetation and surface waters' pollution.

3. Intensity of technogenic geochemical migration of the main gold ore components in the gold-bearing districts decreases where we have higher carbonate content in rocks; and also where we find weathering profiles with kaolinite formation.

EXPLORATION FOR SKARN HOSTED MINERALIZATION IN NORTHWESTERN NEW BRUNSWICK: REGIONAL- AND DEPOSIT-SCALE GEOCHEMICAL SURVEYS

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The Restigouche Project comprises multiparameter airborne geophysical and National Geochemical Reconnaissance (NGR) stream sediment surveys which were carried out on five 1:50 000 NTS sheets in northwestern New Brunswick. A total of 1080 stream sediment and water samples were collected. Two multi-element stream sediment anomalies (with one or more of Cu, As, Sb, Pb, Zn) and an unexplained area of anomalous Ni, Co, ±Cu, ±Cr have been followed up with detailed stream sediment sampling, as well as basal till and humus samples on the intervening plateaus. Different grain-size fractions were analyzed using a comprehensive multi-element INAA/ICP/AAS package, and various sample preparation techniques.

Detailed geochemical surveys (basal till, humus, stream sediment, and balsam fir twigs) were conducted around known base-metal skarn occurrences in the McKenzie Gulch (Legacy deposit 400,000 mT @ 1.70% Cu and 0.3 oz/T Ag) and Popelogan (Cu, Mo, W, Zn) areas. These occurrences are spatially associated with Siluro-Devonian felsic stocks, dykes and sills which intrude calcareous to clastic sedimentary rocks of the Upper Ordovician to Lower Silurian Matapédia Group and the Lower Silurian Upsalquitch and LaVieille formations. Till samples at, and down-ice from, the Legacy deposit are anomalous in Au, Cu, Ag, Mo, Sb, and As. Also noted is a strong correlation between till clast type and the underlying bedrock type. There is some minor (minimum of 2 km) east-northeast transport of clasts from the Upper Ordovician Grog Brook Group. Glacial dispersal of 040☜ and 060☜ is confirmed by striae, clast fabrics, distribution of pebble erratics, and patterns of till geochemistry. These till geochemical and lithological signatures can be used effectively to pinpoint areas underlain by felsic intrusions and related mineralization in this and other areas of northwestern New Brunswick, where there is little or no outcrop. The highest Cu values in the balsam fir and humus samples also occur within 500 m of the Legacy deposit. Correlation of geochemical response between balsam fir twigs and basal till samples is inconsistent and needs to be investigated further.

REGIONAL GEOCHEMICAL MAPPING IN COPPER MINING AND SMELTING REGION OF LEGNICA PROVINCE (LOWER SILESIA - SW POLAND)

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Legnica Province is one of the most industrialized regions of Poland. The aim of this study was a determination of chemistry of soils and estimation of their pollution rate due to anthropopression. A geochemical soil survey was conducted in the Legnica Province in 1996. The survey was arranged in a 1x1 km grid pattern while the field work in regions of particular interest (with copper smelting industry and copper mining) followed a more detailed grid pattern of 500x500 m. The hand penetrometer was used as a field tool for collecting 1000-g soil samples from a depth of 0.0-0.2 m. Samples were leached with aqua regia; then ICP-AES, determinations were made of concentrations of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Ni, P, Pb, S, Sc, Sr, V and Zn. As and Hg concentrations were measured using the CV-AAS method. Element determinations were made on 5677 samples and totalled 139,175. Monoelemental geochemical maps were prepared with the use of SURFER for Windows programme and triangulation method.

The geochemical survey of soils in the Legnica Province area reveals that elements such as aluminium, cobalt, cadmium, magnesium, nickel, scandium, strontium, titanium and vanadium are connected, first of all, with the structure of geological substratum. The southern part of Legnica Province lies in the Sudety Mts. and their foreland. A considerable part of the geological structure of the eastern part of the survey area is underlain by metamorphic rocks belonging to the old-Palaeozoic structure of the Kaczawskie Mts. In the western dominant lithologies are terrigenous sediments of the Permian, Triassic and Cretaceous of the North Sudetic Depression. Apart from material of Scandinavian origin, a large part of the glacial sediments within the foreland area are derived by material coming from the Sudetes. Geochemical background of such different substratums is clearly reflected by the distribution of elements mentioned above.

A group of elements with arsenic, iron, phosphorus, lead, sulphur, vanadium and yttrium has increased concentrations due to processes of migration. This effect takes place in organic soils (peaty soils, peats) and leads to the origin of distinct, sometimes very intense, geochemical anomalies. Their origin, however, is natural and does not result from the presence in the substratum of ore mineralization or rocks enriched in the elements mentioned.

Mining, ore treatment and smelting of copper ore are the main sources of anthropogenic pollution. Other local sources of soil pollution are towns with associated industry, transport system, and local emissions of dust and gases from burning of coal by family households and local heating plants. Geochemical anomalies connected with the copper industry occupy vast areas with elevated copper and lead concentrations in the environs of copper smelters. Increased contents of other elements such as silver, arsenic, zinc, cobalt and nickel occur within copper-lead anomalies; however, their areas of occurrence are confined to the limits of the industrial plants only.

UTILIZING TRACE ELEMENT AND WHOLE ROCK TILL GEOCHEMISTRY IN EXPLORATION FOR POLYMETALLIC MINERAL OCCURRENCES IN THE SOUTHERN INTERIOR OF BRITISH COLUMBIA

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The bedrock geology in the Kootenay, Slide Mountain and Quesnel terranes has high potential for new discoveries of polymetallic mineral deposits, but typically, such targets are mantled by unconsolidated sediments of varying complexity and thickness. In such an area drift prospecting techniques must be used by relying on the recognition of subtle geochemical anomalies which are related to clastic dispersal of mineral grains and the provenance of the sampled media. The intent of the survey was to outline and identify the shape, extent and bedrock source of geochemical dispersal trains that have been recently discovered in the eastern Bonaparte Plateau and Adams Plateau areas.

Regional till sampling by the British Columbia Geological Survey Branch has lead to the discovery of new auriferous and massive sulphide occurrences and has further defined several areas with high potential for additional polymetallic mineral deposits. Bedrock mineralization was reflected by anomalous geochemical plumes in lodgement till. Such anomalous areas often have characteristic geochemical dispersal plumes consisting of specific pathfinder elements. These trace metal geochemical plumes are primarily controlled by glacial (physical) transport, drift thickness, depositional environments and topography, the latter of which can also alter dispersal trains by hydromorphic distribution. Whole rock analysis of till defines areas locally up-ice that exhibit contrasting chemistry indicative of bedrock contacts and lithological changes. This is particularly important where lack of bedrock exposure inhibits observation of lithological and chemical changes of the subcrop.

Recent work in 1998 focused on the tracing of geochemical anomalies outlined in the 1996 and 1997 till sampling surveys with respect to relative abundance of indicator elements. Boulder tracing in the areas where high geochemical anomalies have been reported resulted in the discovery of additional mineralized bedrock occurrences and defined zones where mineralized bedrock is believed to subcrop under the glacial drift. This paper presents the results of case studies that can be applied to the southern interior region and presents the results of recent discoveries from the till geochemistry surveys of 1996 and 1997. Empirical results from the 1998 sampling program are also presented.

MAGNETIC SUSCEPTIBILITY OF STREAM SEDIMENTS AS A MARKER OF ANTHROPOGENIC POLLUTION

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Measurements of low frequency magnetic susceptibility have been carried out along some 40 km of the upper part of the Moldau river in South Bohemia (Czech Republic). The study area represents an environmentally "clean" region with small local contamination sources, such as paperworks, public boilers, campsites, a town and its sewage plant. Magnetic susceptibility was measured on stream sediments, open-air grassland and litter under the coniferous forest (or stands of spruce). Moreover, magnetic susceptibility of the parent rocks was measured, where available, in order to account for the "background" lithogenic signal. Parent rocks are presented mainly by orthogneisses and rarely by granitoids. Both are metamorphic rocks and show very low susceptibility due to prevailing diamagnetic minerals (as plagioclases) and almost missing ferrimagnetic ones. Thus, any enrichment with respect to the background level is readily detected and can be attributed to anthropogenic origin. Our results show that stream sediments give the best "picture" of the local contamination sources, always indicated by significant magnetic susceptibility increase. This enhancement can be observed within a short distance from the source (cca 1 km), further on the values fall down to base level, which steadily increases due to down-stream accumulation of both natural and anthropogenic particles. However, increased susceptibility near the contamination sources is observed not only for stream sediments, but also for grass and forest litter, which suggests that it is due to both waste-water discharge in the river and atmospheric dust deposition.

Calculated average values and scatter of the susceptibility data show that the highest standard deviation is obtained on the contaminated sites, and this effect is again best expressed for the stream sediments and less for grass surfaces. Almost uniform values are measured in "clean" areas. The reason for this observation is most probably a point-like character of the source inputs in the river, where distribution of pollution is controlled by the water flow dynamics, so that wide variations of particle concentration can be found depending on the local conditions. On the other hand, the atmospheric pollution is more evenly distributed, mostly controlled by the prevailing wind direction. Therefore, the deposition to the surface does not vary so much over a small area.

Our results suggest that magnetic susceptibility measurements of stream sediments in an area with isolated pollution sources and with negligible (or well distinguishable) lithogenic contribution is a powerful tool for detecting artificial anthropogenic contamination.

GIS PRESENTATION AND INTERPRETATION OF EPITHERMAL GOLD EXPLORATION DATA

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The integration and analysis at different scales of the great diversity of data suitable for the exploration of commodities associated with epithermal systems, such as multielementary geochemistry in various media, geophysics, regional and detailed geological mapping, structural compartmentation, and remote sensing, is no easy task. Validation, choosing among different types of data, and keeping models updated through the addition of new data are usually the crux of modeling such deposits. In fact, it is notorious that even big and successful players in the mining industry have relied on single elements or on a couple of the elements, to base exploration decisions, even though multi-element analysis was carried out. Digital cartography systems or commercial graphical software are a partial solution, but are not really adequate for compilations, analysis or modeling.

Modern geographic information systems (GIS) are a more practical solution for large datasets of different sources and formats, relating information from different sources, streamlining data capture, integration, projection and registration, and allowing the comprehension of phenomena at various scales through data structuring and modeling.

Multi-element geochemistry of two sieve fractions (above and below 80#) of 750 stream sediment samples, plus color count for gold in pan concentrates collected nearby the stream sediment stations, were captured from lab result spreadsheets and associated by their corresponding sample number to sample site location obtained from GPS. Topo sheets in 1:50.000 scale were digitized in CAD to provide a base map and edited in the GIS to become seamless; catchment basins were delimited and each basin was assigned its corresponding sample. Geology maps and photo-interpretation of structures were also digitized and georreferenced in the GIS.

Displaying and querying tasks are easily achieved with very little training of the exploration team, as the resulting database and information layers are readily accessible. Daily chores such as insuring that sampled basins are of similar areal extent, and anomaly selection for detailed work through prioritization of areas become much simpler tasks. Visualisation of anomalous trends aided by pathfinder elements, variations in distribution of metals in the different size fractions, and other more subtle relations are easy to spot. The real advantage, of course, lies in the modeling allowed by GIS. Modeling for simultaneous anomalies of volatile pathfinders to investigate buried orebodies, prioritizing anomalies by their proximity to certain structures or lithological boundaries, or even weighting gold values based on sinuosity of the streams are all possible.

GOLD-ANOMALOUS CATCHMENT BASINS: A GIS PRIORITIZATION MODEL CONSIDERING DRAINAGE SINUOSITY

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Gold values in sediments of anomalous catchment basins are a function of several geological factors, including average composition of underlying rocks, chemical controls, such as dispersion patterns and scavenging of metal ions by oxides, and hopefully by the effects of anomalous processes of mineralization. The influence of all these factors, in turn, is a reflex of the "sampling" conducted by the drainage in accumulating the sediment. Drainages with lower gradients, more sinuous paths, or both, are more likely to yield higher gold grades, as they promote less dispersion.

To test this affirmation, 52 gold bearing basins (above the detection level of 3 ppb, in the <80# sieve fraction), out of 196 sampled basins situated completely in rhyolites of the Eo-Ordovician Castro Basin (Parana State, southern Brazil), were modeled in GIS regarding total length of drainages, distance and slope from uppermost to lowermost stream portions. The table of attributes for the basins was edited to include fields for these data. Sinuosity and slope indexes were calculated by dividing total length by distance and the difference in altitude by the distance respectively. The results were reclassified in three ranges for sinuosity and slope (low, medium and high). To each of those ranges tentative values of 1, 1.3 and 1.6 were assigned. Gold values for each basin were thus weighted by classes of sinuosity and drainage slope, originating a modified gold anomaly map.

Some basins otherwise not considered first priority are emphasized, while basins which were originally considered anomalous, but overlie monotonous terrain, are downplayed. It is expected that the resulting map reflects more accurately the geological factors in general, and, as all basins are situated on a single rock type, anomalies related to mineralization.

TOWARDS A GEOCHEMICAL ATLAS OF WEST AND SOUTH GREENLAND: COMPILATION AND PRESENTATION OF RESULTS OBTAINED OVER A 20 YEAR PERIOD

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When geochemical exploration was begun by the Geological Survey of Greenland about 25 years ago, it was not envisaged that the results could contribute to geochemical maps covering large parts of the ice free margin of Greenland; and when the idea of producing geochemical maps or atlases spread some 10 years later the use of old exploration data was not recommended. However, because of the expense of collecting samples in Greenland, there was no choice: the only way to produce a geochemical atlas was to use existing data and samples.

Mountainous topography and thin or absent overburden made stream sediment the preferred sample medium in geochemical exploration surveys. Initially, these were aimed at local exploration for specific metals, but gradually, increasingly large areas were covered and samples were analysed by multi-element techniques as these became available. In 1989 it was decided to aim for complete coverage of large parts of Greenland, and the need arose for calibrating the analytical data from the individual surveys. Internal standards were introduced and many collections of early samples were reanalysed by contemporary multi-element methods in order to build up consistent data sets. As a result, a large contiguous area in West and South Greenland has now been completed to the new standards and data have been compiled for a geochemical atlas of the Precambrian part of West and South Greenland between latitudes 59º and 70º N.

The compilation was a complicated task because samples had been analysed in different ways, and minor or major bias was shown to exist between analytical data produced by various methods and various laboratories, or between results acquired from the same laboratory at different times. It has become obvious that most elements are important for geological interpretation, hence an effort has been made to include as many elements in the final dataset for the entire region as possible. Thus, there were 108 individual datasets, each comprising 9 to 12 element determinations, that were examined and calibrated against each other before they were entered into the database used for producing element distribution maps.

At present, the atlas comprises maps of 10 major and 31 trace elements, together with gamma-radiation, at sample sites. Element distributions are shown as dot maps or as contoured grid maps produced by kriging. The atlas of maps will be accompanied by a geological interpretation and comments on their applicability to environmental research and management.

Geologically, the maps demonstrate the contrast between the three Palaeoproterozoic orogens flanking or involving the central block of Archaean basement, and they emphasise the mineral potential of South Greenland. The niobium distribution outline districts of alkaline magmatism, including kimberlite formations.

The compilation exercise for the atlas has demonstrated the value of careful monitoring of analytical data and the importance of an efficient sample archive. Development over the past 20 years suggests that the samples and the data will be used again in the future for purposes as yet unforeseen.

AN INTEGRATED GEOCHEMICAL AND AEROMAGNETIC INVESTIGATION OVER A GOLD PROSPECT, SOUTH GREENLAND – A CASE STUDY

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The gold prospect on the Niaqornarssuk peninsula in South Greenland has been investigated by various means. This paper aims to interpret the significance of the geochemical studies, the total intensity of the aeromagnetic survey and the geology in relation to a gold mineralisation. The investigation comprises an area of c. 600 km^2, where 455 bedrock and bedrock chip samples are collected together with 140 heavy mineral concentrates (HMC) and 125 stream sediments from high-energy seasonal streams. In addition, 382 HMC samples from the top of scree cones were sampled. The airborne geophysical survey had a line spacing of 500 m with a sensor altitude of c. 300 m draped.

The geological setting of the area is dominated by the Julianehåb batholith, which forms the central part of the Palaeoproterozoic Ketilidian orogen (1,8 Ga). The gold mineralisation is related to second order structures (shear and quartz veins) crosscutting amphibolites and to hydrothermal altered granitoids with traces of Fe-sulphides. The gold prospect is part of a row of gold-mineralised sites in a northeast-striking zone along the southern rim of the Julianehåb batholith (Stendal, 1995; Stendal and Schønwandt, 1997).

- More than 100 ppb gold of the bedrock samples were yielded in 64 samples. The gold is correlated with Bi and to some extent to Na due to albitization of the hydrothermal altered granitoids. Gold has a strong negative correlation to K.

- The HMC samples from the high-energy seasonal streams have element contents comparable to the HMC scree cone samples. Typical cluster element associations are Au-W and Bi-Cu-Au. The peak gold anomaly is 42 ppm.

- The cluster element associations for the stream sediments are As-Cu-Zn and Pb-Au-Na-W. The maximum gold content is 0.7 ppm gold.

- The total magnetic intensity has ENE-WSW striking structures parallel to the shear zones in the area. The rock geochemistry, however, reveals a gold anomalous trend striking nearly N-S.

The geophysical data showed that the gold mineralised area is related to low magnetic areas, but the structure of the gold mineralisation could not be followed. The variation of the single elements and the element associations within the drainage samples and the HMC scree cone samples reflects the local geology, the extension of hydrothermal alteration zones and the gold mineralisation. The rock geochemistry resulted in a hitherto unknown N-S gold-bearing structure.

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REMEDIATION OF ACID-SULFATE RUNOFF USING A MODIFIED CONSTRUCTED-WETLAND TECHNOLOGY: FIELD DEMONSTRATION FROM A COAL STORAGE PILE

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Metal-contaminated acid-sulfate water is commonly generated when meteoric waters interact with sulfide minerals disseminated in exposed mine tailings and coal piles. Constructed-wetlands have been used often to remediate sites impacted by these waters, although large tracts of land are normally required for this remedial strategy to be effective. To reduce the land area required for constructed-wetlands, an anaerobic cell was added to a field-scale wetland system located at the Savannah River DOE Site near Aiken, South Carolina (SRS).

There are three coal-storage piles associated with electric power plants at the SRS. Acid-sulfate runoff from these coal piles (2% SO_4^{2-}, pH = 2-3, contaminated primarily with Fe, Al, and Mn but also Cr, Co, Ni, Cu, As, Zn and U) is comparable in chemistry to mine tailings leachate. Surface runoff from the coal-storage piles is retained in seepage basins to minimize the discharge of suspended coal fines to National Pollution Discharge Elimination System (NPDES) outfalls.

In our field experiment, acid-sulfate water is pumped from a nearby SRS seepage basin through an isolated anaerobic cell containing composted stable waste, spent brewery grains, Kricket Krap® and granular limestone. The composite substrate has an acid-neutralizing potential of 10 to 30‰ (by weight) $CaCO_3$ equivalents and a range of C:N ratios (11.4 to 34.4) conducive for the growth of sulfate-reducing bacteria. The composition of the substrate was determined from anaerobic culture experiments and bench-scale column studies, utilizing locally available materials. The purpose of the anaerobic cell is to raise the pH and remove metals through the action of sulfate reducing bacteria. Water exiting the anaerobic cell passes through two open polishing tanks that contain indigenous wetland plants to remove excess H_2S and raise the pO_2 of the water for eventual discharge into the environment.

Preliminary results from the anaerobic cell indicate that 90% of the iron and 98% of the aluminum is removed from the basin water as oxyhydroxides, sulfides and carbonates. The latter two of these solids are formed either directly or indirectly as a result of biomediated sulfate reduction reactions that occur in the anaerobic cell. Trace element concentrations (Ni, Co, As, Cr, Zn) are also reduced to an equivalent extent, however the nature of the removal remains unresolved (e.g., precipitation or coprecipitation as a sulfide, oxyhydroxide, or carbonate; or organic complexation through cation exchange).

Although the Mn concentration of the seepage basin water (<5 ppm) is comparatively low for acid mine drainage (AMD), Mn remains an enigma for the anaerobic cell and constructed treatment wetlands in general. Preliminary results from the anaerobic cell indicate that Mn concentrations remain largely unchanged; in fact, Mn occasionally increases, possibly due to limestone dissolution in the substrate.

Advantages of using the anaerobic cell in constructed-wetlands include: 1) the ability to remediate low pH (<3) AMD passively, 2) the utilization of bacteria that produce alkalinity in addition to that derived from limestone dissolution, 3) a reduction in treatment byproducts (e.g. sludges) that must be periodically managed in other systems, and 4) a reduction in the area required for wetlands to be used as an effective remediation technology.

PROBLEM OF TIME-DEPENDENT TRANSFORMATIONS OF METAL SPECIATION IN SURFICIAL GEOCHEMICAL ENVIRONMENT

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Sequential extraction schemes for trace metal speciation and determination of "pools" of consecutively increasing binding strength, along with identification of phases primarily responsible for element scavenging and binding mechanisms, has for some time been recognized as a very useful tool both in exploration and environmental geochemistry. Among a multitude of extraction schemes, classical method of Tessier et al. modified by Kersten and Forstner, and that of Hall et al. are the most widely applied ones. The extensive studies proved these methods to be both reliable and precise.

The phases of high capacity to adsorb trace metals in a relatively mobile, easily leachable form are of particular interest for exploration geochemistry. These phases are generally considered to include, besides amorphous Fe oxyhydroxide and Mn oxides, also easily leachable "soluble organic" component of humus (leach step II). "Insoluble organic" matter is enriched in organic/sulfidic fraction (leach step IV) of the highest binding strength and hence has low potential for remobilization, besides the last in sequence immobile residual fraction (leach step V). This leach scheme, along with the aforementioned reproducibility should enable differentiation of the mechanisms of element transport and accumulation. Selective extraction of metals scavenged in the surficial environment by "soluble organic" fraction has been reported to be successful for such elements as Zn, Cu, Pb, Co and Ni. However, this leach appeared to fail for humus, soil and sediment samples for Au, where the recovery of this element bound in "soluble organic" phase appeared to be very low, from 12 to 25 % for different matters. This failure was assumed to be caused by Au readsorption in batch system. To avoid this, a dynamic flow-through leach system was suggested.[3]

Results of a sorption study carried out on peat samples, which are almost pure organic matter, using both batch and flow-through systems for binding Cr, Cu, Zn and Cd, display different patterns of element transport and accumulation in organic media for each metal. The results of sequential extraction carried out for three various peat matters showed high qualitative and quantitative reproducibility. At the same time, significant differences in the metal scavenging between short-term batch and long-term dynamic (flow-through) process were observed. These differences affect both sorption capacity and binding strength of metals attributed to the different forms of binding in "soluble" and "insoluble organic" fractions. The elements most susceptible to time-dependent transformations of the binding capacity and fraction structure appeared to be Cd, and to a lesser extent Zn. These metals show ability to expand their sorption capacity mainly due to a high increase of enrichment in the "insoluble organic" fraction. This well explains weak competitive effect of these elements in batch sorption process in spite of their strong geochemical similarities. The observed transformations of metal ions fractionation, directed to formation of more strongly bound complexes in time show that the process of element binding onto organic matter is more complex and comprises the reactions with different kinetics. In these transformations, chemisorption of a stronger type that occurs over a longer time should be involved. This sorption behavior undermines the opinion about the rapid kinetics of the process. The "insoluble organic" fraction shows invariably high enrichment of all studied metal ions in the dynamic process. The mechanism of the enrichment seems to be diverse for different metal ions. It occurs either independently, which results in high increase of the total sorption capacity (Cd, Zn) or simultaneously with the decrease of a metal enrichment in "soluble organic" fraction. In particular, reduction of fractions associated with chelating complex formation with humic and fulvic acids, as well as of electrostatically bound metal ions in peat suggests the transformations of binding mechanisms onto organic matter from the weaker to the stronger binding ones (e.g. Zn, Cd, Cr).

These observations show, that the distinguishing of hydromorphic or chemical dispersion from mechanical dispersion of the element on the basis of its quantitation in "soluble organic" fraction may be misleading. They may also explain low recoveries of hydromorphically/chemically dispersed Au supposed to be bound in "soluble organic" fraction.

The identification of mechanisms of metal binding onto organic matter and the phenomenon of their time-dependent transformations is currently subject to studies being conducted in two collaborating research institutes in Poland and Germany.

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GOLD DISCOVERIES IN CHINA SINCE 1980

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China is a large under-explored metallogenic terrain. Taking the recent discoveries of ore deposits for an example, 817 ore deposits have been discovered during the period 1981-1995 according to the report by the Ministry of Geology and Mineral Resources of China. Geochemical methods have played an important role in these new discoveries. Statistics by the Ministry of Geology and Mineral Resources shows 579 new deposits which have been discovered by geochemical methods, 153 by geophysical methods, 85 by multidisciplinary methods (Fig. 1).

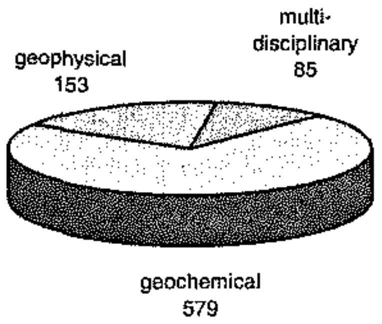

Fig. 1 Discoveries of 817 new deposits in China during the period 1981-1995. 579 new deposits have been discovered by geochemical methods.

There are 539 gold deposits discovered among 579 new discoveries by geochemical methods. Figure 2 shows the number of gold deposits discovered by geochemical methods from 1970-1995.

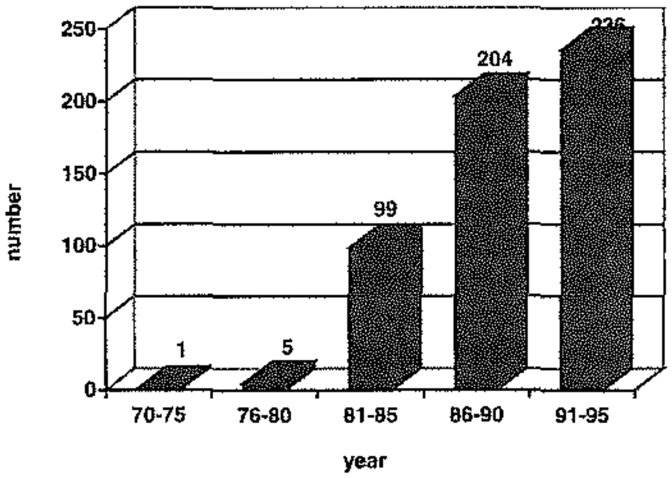

Fig. 2 Number of gold deposits discovered by geochemical methods according to 5-
year duration from 1970 to1995.

The most exciting of them is the discoveries of two world-class gold camps (Each one contains gold reserves of over 500 tones). One occurs in the greenstone belt located at Xiaoqinling on the boundary of Henan and Shanxi provinces. Another occurs in carbonate terrains of southern China which has become the second largest Carlin-type gold camp in the world. Several case histories from different geographical and geological settings are described in detail in this presentation.

The reasons of success in gold discoveries in China since 1980s, other than the theoretical considerations and methods used for gold exploration described in Xie and Wang (1991), are that: (1) Geochemical methods inherited the trend of direct prospecting methods, by which the prospector searched for ore outcrops and ore alteration with the naked eye, yet has extended the ability to discover direct evidence from parts of hundreds recognized by the naked eye to parts of billions, and even to parts per trillion by analytical methods. This made it practical to find "micro ore outcrops" which were not observable with the naked eye even in outcropping or sub-outcropping terrains; (2) Holistic geochemical approaches have been used to cover as large a region as possible in a short time to display a huge mass of information for gold exploration, like China's Regional Geochemistry - National Reconnaissance Project. This enables us to delineate hierarchical nested geochemical patterns from local, regional, provincial, to national. The huge mass of direct information and broader geochemical patterns can reduce uncertainty and risk in mineral exploration for large ore deposits or world-class ore camps.

SEARCHING FOR KIMBERLITE - EVALUATION OF TILL GEOCHEMISTRY IN THE LAC DE GRAS REGION, NORTHWEST TERRITORIES USING GIS SPATIAL ANALYSIS TOOLS

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The Slave Province, bound approximately by 62-69 degrees N latitude and 104-116 degrees W longitude, has been the focus of intense diamond exploration since 1991. Diamond exploration is hampered in the Slave Province by thick, extensive till cover necessitating the use of expensive traditional exploration methods (heavy mineral studies). GIS analytical techniques have been used to identify kimberlite pathfinder elements, till chemistry clay fraction anomalies and to determine and quantify their possible spatial relationships to known kimberlite pipe occurrences using the "weights of evidence" technique, in the Lac de Gras area of the Northwest Territories. This study is unique in that geochemical anomalies in the clay fraction of till are studied with respect to known kimberlites as opposed to coarser fractions.

Major and trace element concentrations of kimberlite (15 analyses) were compared to Archean host rock lithologies (64 analyses) resulting in the identification of 16 potential kimberlite pathfinder elements: Al_2O_3, K_2O, Na_2O and Pb which are lower in kimberlites than regional background and CaO, Ba, Co, Cr, Fe_2O_3, La, MgO, MnO, Ni, Sb and Sr which are higher in kimberlites than regional background. Poor precision resulted in the elimination of Sb, Pb, La and Sr from further consideration.

Surficial geology of the Lac de Gras region is dominated by a single thin (<2 m) to very thick (30 m) till unit and ice flow indicators suggest an early SE ice flow direction followed W and NW flow directions, with dominant ice flow, in terms of glacial transport and definition, to the NW. Semi-variograms were calculated for log-transformed kimberlite pathfinder element concentrations, to determine the maximum distance and direction of correlation between samples. Anisotropy directions varied from NE-SW for the majority of pathfinder elements, to NW for Na, Al and Cr, to E-W for Co, with distances at which the data becomes un-correlated varying from 10 km to 27 km. The preferred direction of anisotropy was used interpolate the data using kriging with a spherical model. Anomalous concentrations, identified from natural breakpoints in the probability plot for each element, and were used to create binary anomaly, or predictor maps.

In the clay fraction data (177 samples), Cr, Ba, Fe, K and Mg, and to a lesser extent Ni and Mn all showed an enrichment in the coarser-grained surficial unit T3 (hummocky till, 5-20 m thick). The bedrock units these surficial units overlie are not however, significantly higher or lower in any of the pathfinder elements, suggesting a kimberlite-rich source for this surficial material, likely local since the till is concentrated in the area of known kimberlite occurrences. Correlation of the thicker T3 unit with the known kimberlites is very weak and may suggest an up-ice source for the kimberlite-rich material in till unit T3. However, it is more likely, given the correlation of Ni and Ba with the known kimberlites (see below) and the concentration of this unit over the kimberlite areas, that the scale of surficial mapping is insufficient.

An attempt was made to account for factors that may contribute to false anomalies due to Fe and Mn scavenging. Firstly, the role of Fe and Mn scavenging in concentrating kimberlite pathfinder elements was tested by calculating the correlation between Mn and Fe and kimberlite pathfinder element. Concentrations of Ba, Cr, Ni, Al, Mg, K and Co are affected to varying degrees, however, the high correlation between kimberlite pathfinder elements, with Fe and Mn may also represent primary mineralogical relationships. Secondly, binary anomaly maps were constructed for Fe and Mn and subtracted from binary anomaly maps of the kimberlite pathfinder elements, thus screening out areas where Fe and Mn co-occur with pathfinder element anomalies.

In the "weights of evidence" method, the locations of known kimberlite pipes (44 in this case), each of which is assigned an area of 250 m^2 in this case, are used to assess the degree of spatial association between known kimberlites and each binary predictor map. Results indicate that Ni, Ba, Cr and to a lesser extent, K and Na are the only pathfinder elements in the clay sized fraction of till that showed a significant spatial relationship with known kimberlites. Screening for scavenging effects due to Fe results in Cr, Ni and Ba anomalies which are slightly better predictors of known kimberlites.

Ni, relatively immobile, is likely held within primary, clay-sized serpentine, while Ba could likewise be held within primary, clay-size phyllosilicates, or mobilized in solution from chemically weathered Ba-carbonates or barite in kimberlites. Correlation of Ba and Ni clay fraction till anomalies with known kimberlites did not significantly increase with the removal of Fe and Mn scavenging effects, supporting a primary mineralogical relationship between Fe and Mn and Ba and Ni. Anomalies, of kimberlite pathfinder elements related to older ice-flow directions, are spatially correlated with known kimberlite occurrences suggesting that the dominant ice-flow direction of NW-SE did not disrupt earlier mineralogical distribution patterns in the till.

High Cr and Fe correlation, coupled with low Cr mobility suggests Cr and Fe are both contained within the same, primary, clay-sized mineral. However, correlation of Cr anomalies in the clay fraction of the till with known kimberlites increased substantially with removal of Fe and Mn scavenging, suggesting scavenging is significant in controlling it's concentration in the clay fraction. Cr is anisotropic in a NW-SE direction (as determined from variogram analysis), and may indicate that it's apparent mobility due to secondary weathering processes is related to this later change in ice flow direction.

The lack of correlation between kimberlite pathfinder elements which are characterized by significantly lower concentrations than regional background (e.g. negative anomalies) and anisotropic in the NW-SE direction (Na and Al) or NE-SW direction (K) is likely a result of swamping of kimberlite concentrations by naturally higher background values.

Fe, Mg, and Mn anomalies, anisotropic in a NE-SW direction, were not found to be spatially related to the known kimberlite pipes. Variable ice-flow directions may have resulted in the dilution of key minerals in certain directions and resulted in anomalies not directly over the source rocks themselves. All three are enriched in the T3 till unit and their lack of correlation with the known kimberlite pipes may reflect a mineralogical partitioning of source material within the till during the various glacial events.

Abstracts

Poster Session B

Thursday, April 15th
Friday, April 16th

In alphabetical order by
first author's name.

EXPLORATION FOR PGE IN THE ARABIAN SHIELD

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The Arabian Shield which occupies most of the western half of the Arabian peninsula has been the target of extensive exploration activity for the past three decades. So far no platinum occurrences have been documented, and the relatively high PGE values reported for certain areas are associated with uneconomic chromite and Cu-Ni deposits. A program was launched two years ago with the aim of identifying possible PGE mineralization in selected parts of the shield. Primary targets for investigation belong to three major groups of mafic/ultramafic complexes:

1) typical layered complexes (e.g. Jabal Shai, Jilani, Wadi Kamal)
2) sub-volcanic intrusions (e.g. Hummah, Jifarah)
3) ophiolite segments (e.g. Halaban, Hail)

A surprising result was the extremely low background values for PGE in the soils of the layered complexes compared with those from the sub-volcanic intrusions; for example, stream sediments in the Hummah Hills consistently display values for Pt ranging from 0.5 to 3.0 ppb, whereas the soils (and most rock samples) in the Jilani and Jabal Shai layered complexes typically contain less than 0.1 ppb of both Pt and Pd.

Chromite lenses associated with the Halaban Ophiolite were found to contain a maximum of 4.4 ppb platinum, and the geochemical signature of the copper occurrences within the Hail melange indicate an affinity to nearby granitoids.

The most interesting discovery by far was made in the vicinity of a small (2 km across) body of gabbro and pyroxenite in the SW shield where pronounced soil anomalies (60-75 ppb combined Pt & Pd) exist along the outer margins of the intrusion. The rocks are mainly foliated ortho-amphibolites, and it is not yet certain whether they represent a sheared and hydrated part of the igneous body or not; more follow-up work is currently being undertaken to discern the exact origin of these anomalies.

MINERALOGY AND GEOCHEMISTRY OF GOLD-BEARING GOSSANS AND LATERITES FROM THE IGARAPÉ BAHIA AND ÁGUAS CLARAS DEPOSITS, CARAJÁS, BRAZIL.

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The Igarapé Bahia mine and the Águas Claras prospect are examples of supergene gold mineralization in gossans and laterites. They are located in the Carajás mining district, Pará state, Northern Brazil. These areas belong to Vale do Rio Doce Company and all the exploration programs were conducted by DOCEGEO.

The two areas exhibit similar primary geology, with gold-bearing sulphide zones associated with breccia/shear zones and intense hydrothermal alteration, related to Archaean to Proterozoic metavolcano-sedimentary sequences. The supergene products are divided in two main groups: The gossan system and the lateritic system with evidences of superimposition of the latter on the former.

Profiles were studied after surface and subsurface sampling. The following horizons and zones were described, from base to top: (1) in the gossan system: primary sulphide zone, secondary sulphide zone and a thick oxidation zone; (2) in the laterite system: a saprolite, a brecciated lateritic iron crust, a dismantled iron crust or stone-lines and latosols. The lateritic iron crust developed over the pre-existing gossans, resulting in a complete obliteration of the primary textures and structures and promoting a new remobilization of gold and other elements. The complete structure can be observed today in the Igarapé Bahia area while at Águas Claras the gossans are truncated and exposed.

The mineralogical composition of gossans and laterites is mainly represented by hematite, and variable amounts of goethite, Al-goethite, maghemite, gibbsite, kaolinite and quartz. Hematite predominates in the gossans and goethite becomes progressively enriched toward the laterites. In the deepest parts of the gossans the following minerals were identified: malachite, cuprite and native copper, mainly associated with hematite, besides azurite, chrysocolla and quartz; the Águas Claras area presents a broader paragenesis in the primary sulphide zone, that includes: chalcopyrite, pyrite, arsenopyrite, cobaltite, quartz, magnetite, wolframite and dravite. Primary gold occur as minute particles finely disseminated in the sulphides and with different compositions in the Au-Ag alloy. In the Águas Claras area it occurs associated with a wide range of Bi-, Ag- and Pb-tellurides, besides native bismuth. Dravite and wolframite also occur as important accessory minerals, both in the primary and secondary environment. In the gossans they occur as centimetric cumulates, acting as important guides for gossans identification.

Major element geochemistry of the profiles is mainly characterized by very high iron contents in the gossans, that progressively diminish toward the latosols. On the other hand, the contents of Si, Al, Ti and LOI increase toward the top of the profiles. Calcium, Mg, Na and K are completely depleted in the gossans and laterites. Geochemical associations of trace elements are variable for the two areas and reflect mainly the chemical and mineralogical variations from the primary zones. In the supergene mineralized bodies (gossans + iron crust) the following geochemical signatures were characterized: Au, Cu and Mo, for the Igarapé Bahia area; and Au, Cu, As, B, W, Sn and Bi, for the Águas Claras area.

From the various horizons and zones of the profiles, different gold particles were separated and analysed by SEM-EDS. Strong variations were described in terms of morphology and chemical compositions in the Au-Ag alloy. The studied grains were divided in two groups: (1) Primary particles associated with primary sulphides; and (2) secondary or supergene particles, associated with gossans, laterites and latosols. These were further divided in two groups: (2.1) residuals particles, generally more 30 μm mean diameter and exhibiting a primary core with Ag-depleted rims; and (2.2) authigenic or neoformed particles, which are extremely fine (< 5 μm) and of very high fineness, and frequently associated with the coarser and residual grains.

The results obtained allowed us to interpret the supergene evolution of the area in four main phases, each one associated with or related to a major period of gold remobilization:

Phase I - Gossan formation: related to the development of gossan bodies in tropical climatic conditions which ranged from semi-arid to seasonally humid (savannas), considered to be prior to Lower Tertiary. During this phase, gold was remobilized from lower primary zones through thiosulphates complexes and reprecipitated in the upper oxidized zones associated with iron oxy-hydroxides.

Phase II - Mature Lateritization: related to the broad lateritic weathering processes that took place in the whole Amazon region during Early Tertiary times. Mature lateritic profiles were formed above the gossans and their wall-rócks, with the development of a brecciated lateritic iron crust that includes gossans fragments. The gossan system was obviously opened during this phase resulting in physical and chemical dispersion of gold. The role of organic matter related to biological activity was very important in the chemical remobilization of gold.

Phase III - Post-Mature lateritization: related to all weathering processes that took place in the region after the establishment of the lateritic profiles during the transition Upper Oligocene-Middle Miocene. The main supergene products of this phase are the upper latosols of the Igarapé Bahia area. After the weathering of gold-bearing lateritic crusts, this element is once again remobilized following the same chemical mechanisms of phase II, but under increasing biological activity. This resulted in an intensive physical dispersion, broadening of geochemical haloes and weakening of gold signals. This new lateritic cycle was less intensive as compared to the previous one. It took place in the transition to more arid conditions during the Plio-Pleistocene, resulting in an intense denudation of the landscape with erosion, truncation and exposure of the Águas Claras gossans. Widespread gold-bearing colluvium (in the Águas Claras area) and Placer deposits are important supergene products regionally related to this phase.

All the weathering processes that took place after the establishment of the landscape in the end of phase III are considered in this work as phase IV. These are related to prevailing humid conditions that become dominant after the end of Pleistocene and during the Holocene, giving rise to new latosols, stone-lines, colluvium and alluvium.

EXPLORATION FOR BURIED DEPOSITS USING PARTIAL EXTRACTIONS: NEVADA FIELD TRIP RESULTS

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In support of the theme "Geochemical Exploration into the 21st Century" an orientation soil survey was conducted at the Ivanhoe Property as part of the IGES "Nevada Applied Geochemical Methods Field Trip". New data from the sponsoring operators and collaborating analytical laboratories will be presented for discussion and the further interpretation of geochemical exploration for buried deposits.

The sampling and support for the 181 sample survey was co-sponsored by the AEG, Great Basin Gold Ltd. and Cornucopia Resources, the 75% and 25% respectively partners in the Ivanhoe joint venture.

The Ivanhoe Mining District is located at the northwestern end of the Carlin Trend and is situated 72 km north of Battle Mountain, Nevada. Approximately 3 million ounces of gold mineral inventory has been outlined by nearly 900 near surface historic drill holes located mainly in the Hollister Resource and pit areas. Recent drilling by Great Basin Gold Inc. has confirmed high grade gold and silver intercepts in veins and feeder systems hosted in basement Paleozoic Valmy Formation which underlies the historically known Miocne volcanic hosted epithermal gold resource. Both low and high sulphication epithermal deposit features are recognized in the unoxidized deeper levels of the Ivanhoe geothermal and epithermal environment. Recent exploration has identified similar styles of gold-silver epithermal mineralization found in the Midas Mining District located to the northwest of Ivanhoe.

Seven soil survey lines were established over a 9.54 km controlled grid. A sample interval of 60.9 metres was used along the lines, which varied from 1.5 to 1.89 km in length. The soil is composed of eluvial, colluvial and valley drywash material. Outcrop is common. All sampling was conducted by S.B. Ballantyne using a mattock and stainless steel trowel. A 20 cm deep trench was dug and one sample collected for MMI analysis at the depth. Two B-horizon soils were also collected at the sample site.

Activation Laboratories prepared and split a sample suite of B-horizon soils for their Enzyme Leach Analysis with the other split portion supplied to Chemex Labs for their conventional Aqua-Regia leach and cold Hydroxylamine selective leach packages, both using MS-ICP finish. The second B-horizon soil was prepared and analyzed using Cyanide leach procedures by ACME Laboritories. The 20 cm deep soil material was prepared and analyzed by XRAL Laboratories. SGS Canada Inc., using their Moble metal Ion technology.

Each of the aforementioned laboratories gratuitously prepared, determined and supported the interpretation of these new results. The goal is to advance the use of applied geochemical methods to delineate blind or buried gold and silver mineralization in the Ivanhoe Mining District. Field and blind duplicate sampling and a random sample number scheme were used in the sample collection phase while the laboratories used their own reference and quality control methods during analyses.

The selective leach methodology and the expanded low level detection limits provided by ICP-MS equipment has provided new multi-element soil results. This can assist in the precious metal target selection assessment of the newly discovered complex sulphosalt, selenide, telluride, sulphide and electrum bearing epithermal ore grade material found at depth at Ivanhoe.

THE APPLICATION OF SHALLOW OVERBURDEN DRILLING TO EXPLORATION IN LATERITIC ENVIRONMENTS: AN EXAMPLE FROM THE AGOUDOU-MANGA GOLD PROJECT, BANDAS GREENSTONE BELT, CENTRAL AFRICAN REPUBLIC

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The Agoudou-Manga area, in south-central Central African Republic (CAR), is host to a narrow (20-60 cm), 250 m long vein-hosted gold occurrence set in felsic intrusive. The geology in the vicinity of the showing includes oxide-facies banded iron formation; diorite-trondjcmite intrusives; mafic metavolcanics; sedimentary quartzites and quartz-mica schists. The rocks belong to the Bandas greenstone belt, one of two recently recognised Archean greenstone belts in the CAR. Following the identification of the occurrence in 1996, a comprehensive exploration program was undertaken in a 15 km² area centred on the showing in an attempt to search and map the extensions of the vein as well as identify new primary vein/stock work gold mineralisation. This program was comprised of localized overburden trenching and geochemical sampling, line cutting, ground geophysics, surficial mapping, and diamond-drilling. It also included a phase of systematic shallow overburden sampling and analysis, achieved through 4,009 portable percussion drill holes and 716 rotary air blast (RAB) drill holes. This presentation documents the results of the overburden drilling program and discusses the merits and technical limitations of the two methodologies used.

The bulk of the overburden drilling program was conducted over a 12 month period using two portable gas-operated Pionjar percussion drills equipped with specially designed 1 m-length split-spoon samplers. The Pionjar drilling was performed systematically at 25 m and 50 m spacing on 100 and 200 m spaced grid lines, to a maximum depth of 3 metres. The 3 m drilling depth was selected following an orientation survey which determined both the effective penetration depth with respect to the anticipated drill coverage per day (minimum 5 holes/drill/day), and the effective variation in overburden stratigraphy and composition. The drills were operated in tandem on each survey lines and were manned by two geologists and a crew of four labourers per drill. The 1 metre long core sections recovered were logged and then sampled for geochemical analysis (500 ml sample) and for gold particle abundance determinations (2 litre sample). The technique allowed for the detailed logging and sampling of alluvial and colluvial deposits and associated paleotopography, up to the maximum drilling depth of 12 metres, and to a maximum of 10 metres for silt-rich latosols and bedrock saprolite sequences. It permitted the mapping of a detailed overburden stratigraphy for the area and resulted in the identification of a widespread and previously unrecognized surficial colluvium unit capping the normal laterite sequence. The systematic sampling and analysis also allowed for the production of a geochemical image of the area based on averaged Au assays over 3 m. It resulted in the identification of a 1.1 km long 100-250 ppb range Au anomaly associated with the Agoudou-Manga showing, the northern 700 m section of which is underlain by banded iron formation. Limitations were low penetration rate and difficult recovery in cohesive and dry laterite and saprolite, inadequacy to bore through lateritic duricrust, and insufficient core volume for meaningful analysis of gold particle abundance trends. Several modifications were also required to the coring unit and hydraulic lift procedure to prevent thread failure on the unit during retrieval from the hole.

The RAB drilling was performed using a Smith-Capital Micro-HR pneumatic percussion drill mounted alongside an Ingersoll-Rand compressor on the back of an articulated 5 ton Timberjack skidder. The customised drill was designed for off-road operation over moderate to steep terrain and under wet field conditions. The RAB drilling technique was principally used as a follow-up procedure to test anomalous gold values obtained from the Pionjar drilling. The principal advantages of the RAB drilling technique were its ability to supple large volume samples (up to 25 litres) for mineralogical processing and both gold particle abundance determinations and gold morphological and gangue mineralogy, its high penetration rate to the maximum drilling depth of up to 15 m, its relative ease at boring through lateritic duricrust, and its low operational manpower requirements. The principal limitations of the technique are the destruction of the original overburden textural features essential to the detailed logging of stratigraphy and identification of geological contacts, and the progressive increase in contamination of sample by overlying overburden dislodged during the collision of air-blown debris with drill hole walls. Part of the latter problem was overcome by averaging gold assays and gold particle counts over the entire length of the drill hole and comparing site to site averages to determine meaningful trends. Other limitations included the significant drop in return of air-blown debris from moist or saturated overburden layers, the heavy maintenance requirements for the equipment, and its high fuel consumption rate (150-200 litre/10 hour shift).

BEHAVIOR OF RARE EARTH ELEMENTS DURING HYDROTHERMAL ALTERATION OF META-TURBIDITES ASSOCIATED WITH MESOTHERMAL GOLD MINERALIZATION IN CENTRAL VICTORIA, AUSTRALIA

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It has been recognized that the study of mineralogical and chemical changes within turbidites associated with gold mineralization can provide invaluable information regarding ore genesis and represents a potentially powerful exploration tool by significantly increasing the magnitude of the exploration target. To this end, a number of detailed petrological and geochemical investigations of wallrock alteration associated with turbidite-hosted gold deposits have been carried out in central Victoria in the last few years. These studies demonstrate that wallrock alteration is much more pervasive and extensive than previously thought (e.g., Bierlein et al., 1998).

The relative mobility of so-called 'immobile' elements such as rare earth elements (REE) and high-field-strength elements (HFSE) in hydrothermal systems is influenced by a number of factors which include fluid-rock interaction, pH, Eh, fO_2, changes in temperature and pressure, and fractionation processes during alteration. Thus, these elements are useful in understanding the processes that lead to the genesis of a given ore deposit, as they can provide constraints on the nature, source and composition of ore-forming hydrothermal fluids, when used in conjunction with petrographical information, fluid inclusion data, and isotopic signatures. However, the geochemical behavior of REE during water-rock interaction is still not well understood and detailed applied studies are lacking.

Alteration traverses across and away from auriferous structures in six centers of past/present gold production in central Victoria (Ballarat West, Ballarat East, Fiddlers Reef, Fosterville, Maldon, Tarnagulla) sampled during previous studies provided an ideal opportunity to investigate possible systematic variations in REE distributions in hydrothermally altered meta-sedimentary rocks.

The presence of broad petrological and chemical alteration haloes and the positive correlation between size of a given central Victorian gold deposit and width of the alteration envelope (aside from ancillary factors such as porosity and permeability of the sediments, etc.) implies that a) pervasive fluid circulation must have occurred on a considerable scale, b) fluid movement at the site of ore deposition was by no means restricted to narrow conduits alone, c) ore-forming fluids interacted with large volumes of host rock, and d) non-equilibrium conditions existed between the fluids and the wallrocks. On the other hand, REE and HSFE concentrations in most of the samples suggest these elements experienced little or no mobilisation throughout hydrothermal alteration. Most noticeably, systematic trends (i.e., from most altered to least altered samples) cannot be identified in any of the traverses. Aside from some variations in the total REE content, all samples display chondrite-normalised REE signatures very similar to Post-Archaean Average Shale (PAAS) with general REE enrichment relative to chondrite values, and particular enrichment in light REE (LREE). $(La/Yb)_n$ ranges from 7.11 to 11.93, they are moderately depleted in Eu (Eu/Eu* 0.48–0.69) and have relatively flat heavy REE (HREE) patterns with $(Tb/Yb)_n$ approximating 1.1.

Taylor and McLennan (1985) demonstrated that the REE distribution in a wide range of unaltered siliclastic sediments was very uniform, irrespective of their grain size, the occurrence of low-grade metamorphism, and variations in primary mineral assemblage. Thus, any departure from chondrite-normalised REE signatures very similar to PAAS in a hydrothermally altered sediment is likely to be attributed to the effects of alteration, since this process commonly involves very high fluid/rock ratios. As illustrated by Alderton et al. (1980), gains and losses of REE during alteration are controlled largely by 1) REE concentrations of the reacting minerals, 2) the relative stability of these minerals towards the fluid, 3) the availability of sites within the secondary minerals for accommodating REE released during alteration, 4) the REE concentration of the incoming fluid and 5) the ability of the fluid phase to remove REE from the system. Consequently, a correlation is expected to exist between precursor rock, alteration assemblage, physico-chemical properties of the ore-forming solution, fluid/rock ratios, and resulting REE pattern. In addressing these points, Alderton et al. (1980) demonstrated that no significant change of REE is likely to occur during sericitic alteration. This is because low concentrations of REE released during the breakdown of detrital feldspar and micas will re-precipitate and are fixed at constant inter-REE ratios by secondary sericite, while heavy minerals with much higher REE and HFSE concentrations do not tend to take part in the alteration process. Thus, the only noticeable change affects Eu in that sericitized siliclastic sediments are likely to develop a slightly increased negative Eu anomaly. Confirming this estimation, samples analyzed in this study yield Eu/Eu* ratios of 0.48–0.69, which are somewhat lower than the Eu/Eu* ratio for PAAS (0.7; Taylor and McLennan, 1985).

Fluid inclusion studies in a number of lode gold deposits in central Victoria suggest that the ore-bearing fluids were characterized by temperatures ranging from 18^0 to 31^0 C, variable C-O-H-N compositions, near-neutral pH values and generally low salinities of less than $10wt\%_{NaCl}$. Experimental studies have shown that REE mobility under these conditions is governed by complexing processes (with Cl^- and CO_3^{2-} as dominant complexing agents), but REE mobility is expected to remain low with no or very little intra-REE fractionation taking place, even in conditions involving relatively high fluid/rock ratios (w/r >100). The findings of the current study generally confirm these estimations.

Samples in traverses from Ballarat, where pervasive hydrothermal alteration appears to have involved significantly higher fluid/rock ratios than at Fosterville or Fiddlers Reef (as indicated by the higher degree of bleaching of wallrock, as well as the extent of petrographical and geochemical alteration in traverses), show some systematic LREE enrichment, while HREE are noticeably depleted relative to PAAS. These trends could be accounted for by high activities of K^+ in the hydrothermal fluids. Likewise, in samples from alteration traverses at Tarnagulla and Maldon, where the meta-sedimentary rocks have been affected to various degrees by contact metamorphism, HREE are noticeably depleted relative to PAAS. Effective fluid/rock ratios during metamorphism are generally less than 1 and short-lived contact metamorphism is thus not likely to have a significant effect on the overall REE concentration in a rock being metamorphosed. Nevertheless, at temperatures of 500^0 to 600^0 C REE concentrations in the fluids might be expected to be elevated because of the greater availability of complexing agents such as F^-, CO_3^{2-} and OH^-, and the predominance of these complexes would lead to the preferential removal of HREE.

The observed REE signatures, which suggest that REE and HFSE remained practically immobile throughout hydrothermal alteration, rule out high-temperature, strongly reducing or strongly acidic fluid compositions and further support the argument that REE remain relatively immobile during sericitisation and carbonatisation of siliclastic sediments, notwithstanding relatively high fluid-rock ratios.

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THE OCCURRENCE OF GOLD AT THE GETCHELL MINE, NEVADA

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The Getchell mine, owned by the Getchell Gold Company, is located in north-western Nevada along the east flank of the Osgood Mountains approximately 45 miles north-east of Winnemucca. Mining has occurred on the site in several intervals since 1934 and the recent operations have been active since the mid-eighties. Annual production in 1997 was around 180,000 ounces.

The geology of the Getchell property is typical of the Basin and Range of northern Nevada. The Osgood mountains comprise Palaeozoic sedimentary rocks which have been extensively thrust faulted. These were intruded by a granodiorite stock and related hypabyssal intrusives and underwent further faulting.

Emplacement of the stock generated a 3km wide metamorphic auerole represented by a garnet-rich skarn at the margin flanked by a wollastonite calc-silicate skarn, biotite-cordierite hornfels and andalusite hornfels.The lithologies occur in broadly east-west trending belts.

The major focus of gold-bearing mineralization are gold-bearing breccias which are associated with a N-S trending shear zone.

The paragenesis of the mineralised zones can be sub-divided into at least eight discrete hypogene assemblages and at least two supergene events. Broadly the mineralization changes from sulfide skarn mineralization through a quartz-pyrite association in ductile-brittle deformation through to replacement style sediment hosted micron gold mineralization. This later phase of mineralization is characterised by widespread occurrence of realgar and orpiment.

From mineralogical and geochemical studies at least three major modes of gold occurrence have been characterised in the Getchell ores;

In realgar-silica ores: Gold is largely associated with quartz as "invisible" gold. Accessory amounts occur associated with pyrite as "invisible" gold and as free grains. Some gold also occurs as "invisible" gold associated with carbonates and realgar. Within discrete structural zones associated with late stage mineralization in the Getchell mine are localized high gold grade ores characterized by high carbonate and sulfide contents and an abundance of free gold. Gold within these zones occurs largely as discrete native gold grains with accessory amounts associated with pyrite and quartz as "invisible gold".

In pyrite-rich ores: Gold is largely associated with pyrite as "invisible" gold. Accessory amounts of gold occurs as free native gold grains and encapsulated in quartz as "invisible" gold. A small portion also occurs associated with other sulfides such as pyrrhotite, arsenopyrite and base metal sulfides. Gold is present in arsenian pyrite, most likely concentrated in the outer rims of the grains. From work on auriferous arsenopyrite the gold is most likely present in solid solution, in metastable arsenian pyrite in the auric oxidation state. Native metal grains within arsenian pyrite are most likely result from exsolution after deposition and/or electrochemical precipitation onto the surfaces of As-rich pyrite

In oxide ores: Gold occurs largely as free gold and as encapsulated "invisible" gold in quartz.

The first mode appears to be the most common in material from the open pits and vein mineralization. The second appears to be associated with pyrite-rich replacement deposits in hornfels and mylonite. The third appears to be a rare occurrence largely restricted to reactivated breccias and their oxidized equivalents.

EXPLORING AUSTRALIAN SEDIMENTARY BASINS FOR CONCEALED ORE DEPOSITS: THE CRC-LEME BASINS PROGRAM

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The Australian continent has a unique geological and weathering history, presenting particular problems for Australian mineral exploration. CRC LEME was established in 1995 to aid the discovery of concealed world-class ore deposits through knowledge of the Australian landscape evolution. The Basins Program of CRC LEME is focused on understanding the processes of landscape evolution, weathering and dispersion of ore systems existing beneath and within sedimentary basin sequences. It is concerned with the study of the interaction of water and rock at various scales, and in diverse geological settings. Through mapping and geochemical analysis, the Basins Program aims to generate models of erosion, transport and sedimentation, of sediment diagenesis and weathering, and of dispersion of geochemical anomalies. Together, these are expected to yield improved exploration techniques in areas of shallow basin cover and extensive weathering. Various ongoing and proposed projects focus on a range of Australian basins.

DRAINAGE AND COMPOSITE SURFACE LAG SAMPLING – AN EFFECTIVE GEOCHEMICAL RECONNAISSANCE TOOL FOR GOLD IN LATERITIC TERRAINS IN NORTHERN COTE D'IVOIRE AND SOUTHERN BURKINA FASO.

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The gold prospective Birimian terrain between Korhogo (Cote d'Ivoire) and Banfora (Burkina Faso) is largely mantled with a lateritic regolith which is expressed as a dissected duricrust plateau. The plateau is at an altitude of 360m and the most incised major drainages such as the Leraba Bandama Blanc rivers are at about 290m altitude. Regolith in the area under discussion can be subdivided as follows:

- 30% duricrust plateaus - 350 - 370m altitude.
- 40% degraded lateritic plateau 320 - 350m altitude. This regolith unit is characterised by lateritic gravel soils and lower elevation duricrusts which have been formed either from the degradation and re-cementing of the higher elevation surface or the development of new duricrust following the erosion of the upper section of the older laterite profile.
- 20% outcrop/subcrop. This unit can be subdivided into two classes. The first are high elevation hills above 360m altitude and above the duricrust plateaus. These areas have thin skeletal

soils and unweathered outcrop. Secondly there are the weathered outcrops lower in the landscape that have been exposed following the erosion of the overlying lateritic mantle.

- 10% depositional areas which are confined to the rivers and major tributaries.

The climate is savanna with a rainy season between May and October. The precipitation ranges from 1166 mm in the north to 1414 mm in the south. The vegetation is savanna bushland in the north with a progressive increase in rainforest vegetation heading to the south. Much of the natural vegetation (30%) has been cleared for cropping and grazing.

At the reconnaissance exploration planning stage this presents us with an undulating landscape of gentle relief (30m over 90% of the area) with a well developed drainage network. The drainage is suitable for stream sampling but is not optimal. In areas of undissected plateaus it may be a few kilometres between streams. Additionally there is significant disturbance of the stream channels by rice cultivation particularly in the wetter southern part of the region. The region has a moderate population density, with small villages usually less than 2 km apart. These are connected by a network of natural bush roads and paths which are navigable by 4 wheel drive vehicle providing good access to most of the area. The solution to the less than adequate stream pattern is to supplement it with composite surface lags.

The sampling process involved stopping at 500 m intervals along the track and sweeping surface material into a plastic bucket. In sloping areas the sample was biased towards the most transported material available at the site. Every two km the composite sample was sieved producing a fine (-200 μm) and a coarse (-6+2 mm) fraction. It was the objective to obtain the same size fractions from the streams however the coarse fraction was only obtained at 50% of sites. In general the streams were sampled upstream from track crossings rather than at the junctions.

The coarse fraction was pulverised and then both size fractions assayed using an aqua regia digestion on a 15 g aliquot of sample. A package of 34 elements (ACME Ultratrace 1F) with low detection limits for Au (1ppb) and gold pathfinders (< .5ppm). This type of analytical package is required as elements of interest are at low concentrations in this weathering dominated environment.

A three person crew in a single vehicle was able to consistently cover 50-75 square km per day at a sample density of ½ square km making this an efficient reconnaissance technique in this terrain. From a technical point of view it effectively shows the areas of known mineralisation and has generated additional exploration targets.

This method is more efficient in time and financial terms than collecting large grid arrays of reconnaissance soil samples. The generated anomalies can be rapidly followed up using the same track network with conventional soil samples collected at 200 m intervals which allows the definition of areas for more detailed grid soil geochemistry.

OXIDATION ANOMALIES - A GEOCHEMICAL PHENOMENON ASSOCIATED WITH DEEPLY BURIED REDUCED BODIES

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Understanding the formation of "oxidation anomalies" and the patterns that they form is essential to successfully using Enzyme Leach^{SM} data in most exploration projects. The model that is described here is a partial explanation for geochemical features that have been found in hundreds of exploration projects. Oxidation anomalies, as detected with the Enzyme Leach^{SM}, appear to be produced by the very gradual oxidation of buried reduced bodies as they are unroofed by erosion. Any reduced body (an ore deposit, a barren body of disseminated pyrite, a buried geothermal system, a petroleum reservoir, a structurally isolated block of pyritic sediments, etc.) can produce one of these anomalies. Redox cells form over and around the top ends of reduced bodies in the subsurface. A reduced body in the subsurface is a source of electrons, and it will have a tendency to spontaneously give up electrons (oxidize) as it is slowly uncovered. Those electrons will follow the path of least resistance toward the nearest source of oxygen, the atmosphere. That flow of electrons will produce a "reduced chimney" between the reduced body and the atmosphere. As this chimney forms, oxidizing conditions will develop around the sides of the reduced body.

Oxidation anomalies are characterized by high contrast values for a suite of elements, the "oxidation suite," which can include Cl, Br, I, As, Sb, Mo, W, Re, Se, Te, V, U, and Th. Often, rare-earth elements and base metals will be anomalous in the same soil samples, but usually with less contrast. Evidence indicates that the oxidation suite migrates to the surface as halogen gases and volatile halide compounds. These elemental gases and compounds would tend to form under the acid/oxidizing conditions of the anode of an electrochemical cell, around the sides of the reduced body. Less commonly, enzyme-soluble Au and enzyme-soluble Hg will be found in the area of these anomalies. Metallic Au and Hg are not soluble in the Enzyme Leach. However, oxidized forms of Au and Hg are readily soluble. In some cases, the low-level Au and Hg anomalies appear to form as a result of the oxidation of these elements in the soil by the subtle flux of oxidizing gases passing through the soil. In other instances, the contrast of the Au or Hg anomaly is so great that it must have been formed by dispersion from a source in the subsurface. Low contrast base-metal anomalies coinciding with oxidation-suite anomalies may result from the gradual migration of cations away from the oxidizing poles of redox cells along electrochemical gradients. Alternatively, the base metals may migrate as methylated metals, which are volatile. The migration of trace amounts of these volatile compounds to the surface may be aided by a much larger flux of carbon dioxide gas generated in the area of the reduced body at depth.

Amorphous oxides in soils and sediments are an extremely efficient trap for cations, anions, and polar molecules. These amorphous oxides probably exist as mixtures of oxides and/or hydroxides of Fe, Mn, Al, and Si that occur in the coatings on mineral grains. Upon reaching the surface environment, components of this trace flux of volatiles can be trapped in these amorphous oxide coatings. The Enzyme Leach^{SM} employs an enzyme reaction to selectively dissolve amorphous manganese dioxide. This would collapse the physical structure of the mixture of amorphous oxides, allowing the leaching of various trace elements and compounds in the mixed oxide coatings (model proposed by David Cohen).

Oxidation anomalies typically form an asymmetrical or partial halo around the buried reduced body, and that body underlies part of the central low within that halo. The trace element suite in oxidation anomalies, although often enriched in many types of metal deposits, is not typically representative of the composition of the buried reduced body. For example, a very similar suite of elements forms halos around petroleum reservoirs as is found around porphyry copper deposits, epithermal gold deposits, buried geothermal systems, and barren pyritic bodies. Sometimes, the base metal or precious metal association in the halo is indicative of the composition of the source. Oxidation anomalies can form above reduced bodies that are covered by either overburden or barren rock. The depth of detection for oxidation anomalies is often too great for the mineralized body to be of economic interest. At this time, the greatest depth at which one of these reduced bodies has been detected is 4500 meters. In arid climates, anomaly-to-background ratios for the oxidation suite commonly range between 5:1 to 50:1, and sometimes anomaly contrast exceeds 100-times background. Oxidation anomalies tend to have more subdued contrasts in humid climates.

Because of the difference in the oxidation potential required to oxidize chloride, bromide, and iodide to elemental chlorine, bromine, and iodine, you would expect to see a differentiation pattern within oxidation halos. With larger deposits, such as porphyry systems and some petroleum reservoirs, these differentiation patterns are observed about one-third of the time. When a distinct separation of Enzyme Leach^{SM} Cl, Br, and I is observed, the peak Cl anomaly is closest to the boundary of the central low, and the peak iodine anomaly is farthest out on the margins of the halo.

COINCIDENT ENZYME LEACH^{SM} AND TELLURICS ANOMALIES ASSOCIATED WITH GAS RESERVOIRS AT 4500 METERS DEPTH, ROBERTSON COUNTY, TEXAS

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Gas reservoirs are currently being explored for in the Cotton Valley reef trend in Robertson County, Texas, at depths of 4400 to 4900 meters (14,600 to 16,000 feet). Exploration in the area has consisted of conducting three-dimensional seismic surveys to identify pinnacle reefs in the Cotton Valley formation. Due to the depth it is impossible to determine porosity from seismic data. Only about half of the reefs have porosity; and almost all the ones that have porosity produce natural gas. Once identified in seismic surveys, these reefs have been drilled to determine if they contain natural gas, at a cost of around $5,000,000 USD for each wildcat well. A technique has been needed to determine if hydrocarbons are present in these deep reefs as they are detected with the seismic surveys.

An Enzyme Leach^{SM} survey was conducted in conjunction with a Redox Cell Analysis^{SM} (RCA) tellurics survey over an area known to have productive reefs more than 4400 meters beneath the surface. An RCA survey will detect Troll Discharges©, electrical currents produced by redox cells in the subsurface. Since these reefs are relatively small compared to most hydrocarbon reservoirs, the scale of sampling was more typical of a mineral survey. Soil samples were collected on a square grid with 125 meter centers, and tellurics measurements were made at a grid spacing of 150 meters. The soil samples were dried at a temperature below 40° C, sieved to minus-60-mesh, and analyzed using the Enzyme Leach^{SM}. The data was plotted using, procedures designed to highlight subtle features within the data for each variable.

The Camp Cooley gas field was the first of these reservoirs over which an Enzyme LeachSM survey was conducted. The field originally contained 33 billion cubic feet (BCF) of natural gas, and had been depleted by more than 6 BCF at the time the survey was conducted. Troll Discharges• cease when a field approaches 20% depletion, and RCA was not able to detect a clear signal of these redox cell discharges over the Camp Cooley field. Enzyme LeachSM anomalies do not suddenly disappear as a reservoir is depleted, and anomaly patterns indicative of an oxidation halo were detected at the surface. Both Cl and Br produced crescent-shaped highs at the surface that bounded the reef in the subsurface on three sides. By itself, the iodine pattern was ambiguous, and it could only be interpreted in light of other trace element patterns. Of the other elements in the oxidation suite, As, Mo, and V produced anomaly patterns that bracketed the field. The V and Mo anomalies bounded the field on three sides, while As formed a more complete halo that outlined the reef in the subsurface. Uranium commonly forms halo anomalies at or near the surface around hydrocarbon reservoirs in the subsurface. Although the U values in the data are quite low, a halo pattern is present over the central part of the reef. Of the base metals, Cu and Pb produced the most useful patterns. Copper formed a nearly complete halo that outlined the reef in the subsurface, and a Pb halo rings the central part of the field. The central lows of all these trace element halos corresponds with the location of the reservoir 4500 meters below the surface. Nickel and Co are useful only in light of other trace element patterns. Both form partial halos around the reef with a weak apical high over the center of the reef.

Since the Camp Cooley field was too depleted to be used for an RCA test, the study was expanded into adjoining areas where drilling either had just been completed on other reefs or was underway. An RCA survey detected Troll Discharges© over a reef that was going to be a productive reservoir. Enzyme Leach^{SM} anomaly patterns very similar to those over the Camp Cooley field were found in the same area. The area where these discharges were detected corresponded very closely with the central low of an oxidation halo defined with the Enzyme Leach^{SM} survey. Therefore, it appears that the same process is producing both the geochemical anomalies and the tellurics anomalies.

The suite of trace elements in Enzyme Leach^{SM} anomalies associated with these gas reservoirs is much the same as would be associated with many buried mineral deposits. The major difference is that the magnitude of the commodity metal anomalies for a buried metal deposit would usually be substantially higher than the metal anomalies around these deep gas reservoirs. Therefore, it appears that the same type of process is responsible for the formation of oxidation halos in both environments.

Confidential research has shown that it is unlikely that a reduced mineral deposit will produce an oxidation halo anomaly when it is more than 2500 meters below the surface. That raises the question as to why a natural gas reservoir more than 4000 meters down can produce an oxidation halo at the surface. The most likely hypothesis relates to the observation that the Troll Discharges©, disappear when the reservoir is partially depleted. Because of the very high pressure in these gas reservoirs, they leak, producing a plume of methane that rises to the surface. This plume of leaking hydrocarbons is most likely responsible for the oxidation/reduction cells that form over these reservoirs. As the reservoir pressure is depleted, the leaking stops, and the oxidation/reduction cell dies. This in turn quenches the Troll Discharges©, that can be detected by RCA. Since Enzyme Leach^{SM} anomalies can remain in the soil for some time after an oxidation/reduction cell dies, the oxidation halos found at the surface persist long after the field goes into production.

RCA and Enzyme Leach^{SM} surveys provide complementary evidence of the presence of reduced bodies in the subsurface. By combining these two technologies, much of the financial risk in the exploration for these deep gas reservoirs can be eliminated at a very small fraction of the cost of drilling a 4500 meter wildcat well.

THE GEOCHEMICAL ASSOCIATION Au-As-B-W-(Cu)-Sn IN LATOSOL, COLLUVIUM, LATERITIC IRON CRUST AND GOSSAN IN CARAJÁS, BRAZIL: ITS IMPORTANCE FOR IDENTIFICATION OF PRIMARY ORE

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Carajás, in the south of Pará State (Amazon region) is the most important ore mineral province in Brazil. It produces iron, gold and manganese besides important copper and aluminum reserve. In contrast to lowland domain of the Amazon region, Carajás has a high plateau landscape, 600 to 900 m high, developed over old deep lateritic formations and largely covered by dense tropical rain forest. The present climate is hot and humid tropical with 1600-mm average annual precipitation and a mean annual temperature of 26°C. It presents a complex geological evolution made up of high-grade metamorphic terrain of Archean age and greenstone belt terrains, which are mineralized, as well as post-tectonic granites of 1.88 Ga. Over these rocks, thick laterites have developed, which are also of complex evolution. The lateritic terrains present themselves today as yellow to red latosols and colluvium on the slopes of the hill and plateaus, as well as thick iron and iron-aluminum crusts. Within laterite profiles locally one may find ore-rich gossans. The best gossans occurrences are located at Igarapé Bahia gold mine and Águas Claras gold deposit where different supergene materials on the surface were described, including: yellow to red latosols, lateritic iron crust, gossans and colluvium. Because Águas Clara is located on hill slopes, it has much more colluvium than Igarapé Bahia, and the colluvium dominates over latosols and lateritic crust.

In order to investigate the capacity of these materials as geological sampling media and as indicators of primary ore, a multielement geochemical survey was carried out. Seventy-four samples were collected and analyzed for 27 elements by AAS (Au, Cr, Cu, Mn, Ni, Pb and Zn), XRF (Cl, W), EOS (A, B, Be, Ga, Mo, Sc, Sn, Sr, V, Y, Zr and Bi), AA-HG (As, Hg, Se and Sb), ICP-AES (Te) and F (selective ion). Mineralogical determinations using XRD show that latosols are made up of kaolinite, quartz, hematite, gibbsite and some goethite, dravite, muscovite and wolframite. The lateritic crusts are mainly composed of hematite and some kaolinite and goethite but quartz, dravite, muscovite, wolframite and chromite are not frequent. The gossans display the mineralogy of lateritic crust but may contain gibbsite and maghemite too. The colluvium contains all the minerals found in the latosols, lateritic crust and gossans, mainly: hematite and quartz, with a little tourmaline but are relatively poor in kaolinite. This composition shows that these materials are the source areas of colluvium.

Of the analyzed trace elements only Ag, Be and Se are below detection limits. Compared to Earth's crust level As, Au, B, Cr, Cu, Ga, Mo, Pb, Se, Sn, V, W and Zr are more than three times concentrated, where As, Au, B, Mo, Sn and W are more than ten times. They show their highest values in the gossan and the lowest ones in the latosols. The colluvium come closer to gossans. Multivariate R-Mode Cluster Analyses performed in latosol, iron crust, and colluvium assigned two important geochemical associations: for latosols: 1) As-Cu-Mn-Pb-B-Au-W-F, and 2) Cr-V-Ga-Mo-Ni-Zn-Se-Sc-Hg-Sn-Cl-Y-Zr; for colluvium: 1) As-Y-Cu-Mn-Pb-Mo-Ni-Zr-Au-W-B-F and, 2) Cr-V-Sc-Ga-Se-Hg-Sn; for iron crust: 1) As-W-Au-B-F-Sn-(Hg-Zr), and 2) Cr-Mn-Ga-Mo-V-Cu-Ni-Zn-Sc-Pb. The first association comprises generally the most concentrated elements and may be interpret as a partly preserved association of primary ore. The second association involves elements related to laterite evolution. Although the latosols represent a product of long-term leached geological material, at Águas Claras they still preserve the geochemical signature and signal of the primary ore mineralization, and together with the colluvium they can be used as good sampling media. Because of the low sample quantity for gossans it was not possible to acquire its geochemical association by cluster analyses, but qualitative data analyses show that gossans also depict the primary ore signature and signal described by high content of their chemical elements. Most of these elements form their own mineral: Au as native gold, As as arsenopyrite, W as wolframite, B as dravite, Cu as chalcopyrite and Sn as cassiterite. Wolframite, gold and chalcopyrite may locally be at ore concentrations.

REGOLITH MAPS AND MINERAL EXPLORATION

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Regolith-landform mapping practices in Australia owe much to early agricultural and land management surveys mapping in its Northern Territory. There have been many other influences on regolith mapping in subsequent years. Regolith geochemistry research for exploration commenced in Western Australia in the 1970s. AGSO commenced regional and continental scale regolith mapping in the early 1980s. It currently directs much of its effort towards exploration-specific regolith-landform mapping through its work in CRC LEME. Considerable emphasis is now placed on the automation of regolith mapping, regolith field data manipulation, regolith database generation, database interrogation and digital map and data presentation. However, although many Australian geoscience agencies have changed to digital products in the last five or so years, most clients still require hard-copy products.

LEME, and by other agencies. Here and elsewhere, the maps are being produced in a variety of presentations, including regionally based regolith-landform maps, derivative thematic maps and regolith-based geochemical maps. These products can assist exploration companies to develop improved exploration strategies through a better understanding of regolith materials and their landform associations. Government geoscience agencies and exploration companies now regard these maps as an essential requirement for mineral exploration.

Regolith mapping in Australia is entering a new phase of development beyond basic mapping. Mapping ideas are constantly growing in sophistication and are now addressing the need for multi-dataset integration and analysis within a GIS environment to develop complex thematic maps. Landsat Thematic Mapper data, gamma ray spectrometrics, magnetics, geochemistry, geological datasets and digital elevation models (DEM) provide modulating data for map generation. Field-based observations provide calibration for remote data sets and strengthen mapping decisions. Current basic regional regolith maps show the potential of simple attribute data within the GIS environment, but greater power can be achieved by exploiting multi-data set interactions. The greatest advances in our understanding will occur through linking regolith models, mineralisation models, geology and geophysics with a preferred exploration model to derive thematic maps and this is a major objective of CRC LEME. Exploration company geologists are keen to see thematic regolith maps addressing specific exploration models that will meet their needs. Important thematic maps such as geochemical sampling strategy maps, or geochemical sampling media maps depend on basic regolith data. Robustness and greater value comes from incorporating a wide range of datasets into thematic products. However, it is almost impossible to create a single generic map (hardcopy or digital) to suit all possible combinations of datasets and client needs. Example thematic maps containing gold localities, regolith type, saprolite classes and related geology on a Total Magnetic intensity backdrop image show the positive advantage of this new approach.

Increasingly, thematic regolith map construction uses a larger number of data layers to derive a final theme. Innovatively processed Landsat Thematic Mapper scenes highlighting (for example) iron oxides, clays and silica often form valuable layers and assist during map generation or later forming backdrop images for final themes. Regolith polygons, highlighting iron-oxide dominant geochemical sampling media associated with greenstones, on a suitable backdrop image, creates a further theme enhancement. A further enhancement option is by draping complex theme over a detailed digital terrain model. For example, a sampling media theme draped over a DEM of an area that is prospective on the basis of regional geochemical results shows landscape relationships not otherwise easily seen. More effective maps can be created by merging complex geochemical themes with regolith polygon based themes. Hot linking graphic drill logs, photographs and element abundance tables in ArcView brings further value to digital maps. Although ESRI's ArcView software displays complex data sets very effectively, other competitors' products are rapidly improving capability. Individual hardcopies are easy to print at selected points during the multi-layer integration process. Increasingly, the limitations of printing the complex colour combinations arising from multi-data sets are being recognised. Digital maps are being promoted as a result.

The need to re-examine existing geochemical and regolith datasets will grow as exploration models evolve, as our understanding of the relevance of geomorphology and landscape evolution improves. The flexibility of digital map generation, the relative ease of database interrogation and construction of complex thematic maps will facilitate this re-examination. The results may well reduce the need for new, more extensive field programs and may help provide a much more cost effective focus in the short term. Further collaborative work with industry is a vital future direction to better develop exploration oriented and more specialised thematic regolith maps.

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SULPHIDE OXIDATION AND GOLD-BEARING GOSSAN FORMATION AT SÃO BARTOLOMEU, CENTRAL BRAZIL

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At São Bartolomeu, Central Brazil, primary mineralization consists of boudinaged sulphide-rich quartz veins hosted by a monotonous series of quartz-sericite-chlorite phyllites of the Proterozoic Canastra Group. Pyrite is the most abundant sulphide and occurs with galena, chalcopyrite, sphalerite and silver. Gold is present as fine-grained inclusions in pyrite and as free grains associated with quartz.

Chemical weathering of the gold-bearing sulphide-rich lodes has produced gossans containing goethite as the main neoformed mineral. The gangue minerals are residual sericite and quartz. Gossans present typical boxwork textures and a geochemical signature characterized by Pb>Zn>Cu>Ag>Au. Gold contents range between 0.1 and 29 ppm. Contents higher than the mean value of 2 ppm have been found in more than 20% of the 158 analysed samples. Values of this order of magnitude have never been registered in the fresh ore, which points to a significant enrichment in gold during the oxidation of sulphides.

Gold is present in gossans both as a residual primary mineral and as a neoformed secondary mineral. Primary gold particles are relatively small, ranging in size from 30 to 150 μm, and contain varied amounts of Ag. Fully unweathered grains are rarely preserved. When present, they generally exhibit xenomorphic shapes (ovoid, spherical, elongated) with regular outlines and striated surfaces. Discernible crystal faces exhibiting smooth surfaces and sharp edges are hardly found.

Most primary particles shows signs of chemical dissolution which vary markedly with the intensity of weathering. Grain surfaces become rough. Crystal faces can still be recognized but are rounded with blunt edges. Indented shapes with jagged rims and rounded lobate morphology are quite common. The crystal surfaces are covered by micrometric corrosion pits, creating a porous network that generally follows preferential directions related to crystalline features.

Secondary gold is very pure, occurring as minute flat pseudohexagonal crystals about 1μm in diameter. These crystals can be found as isolated particles but more commonly coalesce into polycrystalline aggregates of fused particles. Their shape and composition suggest *in situ* reprecipitation of secondary gold chemically refined by low-temperature fluids during the gossan formation.

In the São Bartolomeu region ore weathering led to the formation of a gossan where sulphides were replaced by goethite through strictly vertical processes. In this way, gold dissolved and migrated downward, precipitating beside preserved primary particles. This may be the reason for the absolute enrichment in gold observed in gossans today.

APPLICATION OF LITHOGEOCHEMICAL METHODS IN EXPLORATION FOR BLIND PORPHYRY COPPER MINERALIZATION

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Exploration of porphyry copper mineralization by their lithogeochemical (primary and secondary) halos were carried out in 1993-1997 within the Sungun area (North Iran) by the authors in collaboration with the Ahar Copper Consolidated Company. The Sungan area of porphyry copper mineralization occurs within the northern contact zone of a monzonite batholith. The known area of mineralization is located along the central part of this northern contact. Stream sediment sampling was the principal method of systematic middle-scale geochemical exploration. Soil sampling and bedrock sampling on the scale 1:10 000 were leading techniques during detailed geochemical exploration.

The following geochemical feature of some porphry copper deposits of former USSR (Aktogay and Aydarly in Kazakhstan and Tehkut in Armenia) and Bulgary (Asarel) have been used as criteria for assessment of geochemical anomalies:

1. The same elemental composition of primary halos of all studied deposits (copper, molybdenum, silver, lead, zinc, arsenic, antimony, etc.).
2. The same vertical zonality of primary halos of all studied deposits, which was used for the assessment of erosion level (using the multiplicative zonality index Pb x Zn / Cu x Mo).
3. The absence of distinct vertical zonality in zones with the dispersed porphyry copper mineralization.

Geochemical exploration in the Sungun porphyry copper ore field revealed several geochemical anomalies. Two of the anomalies, which were considered promising for blind mineralization on the basis of the above geochemical criteria, have been tested. The drilling of both anomalies revealed ore reserves of economic significance at depths from 50 to 400 m.

Recent exploration has confirmed the effectiveness of also using the above criteria to reject nonpromising anomalies from further consideration. On the basis of geochemical sampling results several geochemical anomalies were recognized as zones of dispersed mineralization. Two of them were tested by drilling which did not find mineralization at depth. Thus the negative evaluation based on the results of geochemical sampling was confirmed.

RESOURCE APPRAISAL OF PORPHYRY COPPER MINERALIZATION IN SUNGUN REGION (IRAN) BY REGIONAL LITHOGEOCHEMICAL PROSPECTING METHODS

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From 1648000 km^2 of territory of Iran more than 75 % occupy uncovered mountainous, well divided regions with favourable conditions for realisation of regional lithogeochemical prospecting (stream sediments sampling) and secondary halo lithogeochemical works. In Iran the geochemical explorations have long in use, but quantitative interpretation of geochemical haloes and resource estimation of detected ore deposits until the present time have not been carried out. In the present work for the first time for Iran, on the example of Sungun region was carried out resource appraisal of porphyry copper mineralization based on regional lithogeochemical surveying of two different scales. The basis of this work is theory and methods of the quantitative interpretation of regional stream sediment prospecting 'developed by A.P.Solovov (1980-1985).

The region of work is located Northwest of Iran, in 50 km from the boundary with Armenia, in northern part of province " East Azerbaijan ". The climate of region is arid and continental. The geological structure of Sungun region include Mesozoic stratified formations of limestone, conglomerate, marl, acidic to basic submarine volcanics which are broken through by intrusive and subvolcanic formations of younger age (monzonite, granite, aplite, gabbro, micromonzonite, trachyandesite, alkali syenite, nepheline syenite).

Sequence of data processing for resource estimation include:

- determination of background values and minimum-anomalous concentration of chemical elements;
- revealing of geochemical anomalies and construction of geochemical maps on the geological

base;
- definition of lithogeochemical streams sediment distribution parameters of main elements;
- geological- geochemical interpretation of results and evaluation of resources of main metals.

As a result of construction of geochemical maps on a geological base, in Sungun region were distinguished 4 copper mineralization field, to one of which (I), in centre of territory, is related the economic deposit of Sungun. The geochemical field of Sungun is polyelement and in association with copper and molybdenum here reveals anomalies of Pb, Zn and other polymetal elements. The structure of Sungun geochemical field has concentric zonality with a centre in the Sungun field, which is framed by less contrast anomalies of polymetals in association with Cu and Mo, that shows replacement of porphyry copper mineralization by copper- polymetalic mineralization.

Territory of Sungun region is characterised by mountainous weathered type of relief, in which the main role in construction of lithogeochemical stream sediment distribution belongs to solid phase. The forms of the graphics of productivity for Cu, Mo and other main elements show that in the streams form "real" lithogeochemical distribution haloes of metallic elements. In this case on interval of receipt of material from slopes, the calculated productivities P' are apparent and their interpretation needs determination of slope coefficient of alluvium α' and correction factor λ' necessary for determination of P'_{true}. Important role for Quantitative estimation of endogene mineralization by lithogeochemical stream sediment distribution of elements belongs to local coefficient of proportionality (k') and coefficient of residual productivity (k) (between productivities of stream sediment distribution haloes, Secondary hyperegene haloes and primary haloes of orebody), which are dependent on local landscape-geochemical conditions.

The evaluation of estimate resources of the main metals in Sungun region using regional geochemical data was carried out by two methods:

Variant I. Quantitative evaluations of estimated resources of copper and molybdenum was carried out by determination of true productivities in anomalous streams, using method of A.P.Solovov. The coefficient ($k' \cdot k$) comprises 0.54 for Cu and - 0,74 for Mo. The estimated depth of ore deposit H was evaluated by the coefficient of similarity for similar genetic types of ore deposits.

$$p'_{true} = \lambda' \cdot p'$$

$$Q = (\Sigma p'_{true} \cdot H)/(40 \cdot k' \cdot k) \text{ ton}$$

Variant II. Area of region was divided to square cells with areas of 3 x 3 km. Then concentrations of metals were averaged within each cells. Productivity of a cell with an area $\Delta S = 9$ km^2 will be:

$$\Delta P = (C'_{average} - C'_{background}).\Delta S \quad (M^2 \%),$$

and the estimated resources :

$$Q = (\Sigma \Delta p \cdot H)/(40 \cdot k' \cdot k) \text{ ton}$$

Quantitative estimation of Cu and Mo resources in Sungun region has carried out By using independent methods on the basis of different scale of regional lithogeochemical surveying. These quantitative estimations are close for two different methods and in good agreement with the results of detail exploration investigations on Sungun porphyry copper deposit (quantitative resource estimation testify to presence of a big deposit with resources Cu 10 mil.t. and Mo 220 thousand t. within the limits of Sungun field). The quantitative resources, established for the first time for Iran, and lithogeochemical parameters of streams sediment distribution in Sungun region can be used in similar geological and landscape-geochemical conditions for evaluation and quantitative estimation of porphyry copper mineralization in regional lithogeochemical prospecting.

ANALYSIS OF LITHOGEOCHEMICAL DATA OVER THE SWAYZE GREENSTONE BELT USING A GEOGRAPHIC INFORMATION SYSTEM (GIS)

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Geographical Information Systems (GIS) are being used with increasing frequency in mineral exploration programs. GIS are capable of storing, displaying and plotting georeferenced points, lines and polygon data. They also provide a wide range of spatial analysis tools with which to display, query, manipulate, visualize and analyse data. Geochemical data are particularly amenable for analysis by GIS as a wide range of spatial analysis tools are available to analyze and interpolate point data.

In January 1993 the Geological Survey of Canada in conjunction with the Ontario Geological Survey initiated a three year project involving the compilation and analysis of a wide range of digital data over the Swayze Greenstone Belt using GIS technology. As part of the geochemical compilation process a large lithogeochemical database was assembled which included proprietary (provided by Falconbridge Ltd.) and non-proprietary (provided by Ontario Geological Survey and Geological Survey of Canada) geochemical data. Wilkinson et al., 1998, have produced a detailed report on how this dataset was compiled and the problems encountered in the building of this database. They screened the database for a variety of problems including missing and unreliable data, and incomplete analyses. This paper is a companion paper to the one produced by Wilkinson et al., 1998 and reports on the analysis of this "cleaned" geochemical database with respect to mineral exploration within the Swayze Greenstone Belt of Northern Ontario using a GIS.

The specific goals of this paper are to, 1) develop and compare methodologies for detecting altered versus non-altered litho-geochemical samples creating two populations; one that can be used for lithological classification and the other for mineral exploration; 2) present GIS methods for visualizing geochemical data, identifying anomalous lithogeochemical populations (selected oxides and trace elements) from background and screening the anomalies with respect to lithological and mineralization/alteration effects; and, 3) evaluate the anomaly maps with respect to the known gold prospects using the Bayesian *weights of evidence* technique.

A GIS (Arc/Info) in concert with relational database (Microsoft Access) and statistical (S-PLUS and Statsgraphics) software is used in the analysis of the data. Several methods were used to differentiate altered samples from non-altered samples and the different methods were compared with respect to the number and spatial location of altered samples. The methods used to flag altered samples included: excessive LOI (> 8% for mafic rocks and > 4% for felsic rocks), excessive volatiles (CO_2 + H2O) > 3.8%, alteration index (H.I. > 49 and ACNK index > .72), atypical minerals based on normative mineral classification, index of typicality (or atypicality index) (Grunsky, et al., 1992) and identification of anomalous trends on 3D scatterplots.

The major oxide data, as well as selected trace elements useful for gold exploration (e.g.Cu, Zn), were then converted to continuous surface (contour) maps using kriging. The data were interpolated in four different groupings; altered samples, non-altered samples, all samples and all samples normalized to lithology (normalization is discussed in the next section). In addition, ratio images of altered over un-altered samples were produced for each major oxide element. These ratio maps can be considered as pseudo mass balance maps, which can provide information on depletion and enrichment of oxides as a result of alteration. The data were also normalized to take account of regional lithologic background thus enhancing anomalies related to alteration/mineralization effects.

Visual inspection of probability plots and the *weights of evidence* GIS mineral potential modeling technique were used to determine thresholds in the element concentrations. These thresholds are used to create binary anomaly ("predictor or evidence" maps) in which concentrations of above the determined threshold are considered anomalous.

The *weights of evidence* technique based on Bayesian probabilities (Bonham-Carter, 1994) is used to compare the anomalous geochemical data in the form of binary anomaly maps to the known gold occurrences. The anomaly maps based on the altered, non-altered, normalized, all samples and ratios are compared and contrasted with respect to the prediction of the known Au occurrences. Gold potential maps based on the major elements are produced to aid in regional exploration activities. The Au occurrences have been sub-divided into groups for comparison to the individual geochemical anomaly maps based on the following criteria: 1) whether the Au point represents a deposit or occurrence, and 2) Au occurrences or deposits with a grade >= 10.0 g/t. (e.g. significant vs less significance occurrences/deposits).

Out of a total of 3396 samples, 1788 have been flagged as altered representing approximately 53% of the total number of samples. Trends between the altered and un-altered samples include SiO_2 , K_2O and MgO which are significantly higher for altered samples while CaO, FeO and TiO_2 are significantly lower. SiO_2 , K_2O and MgO enrichment reflect silicification, potassic and chlorite alteration. The interpolated data reveal major differences between methods with respect to the delineation of alteration zones. Based on these analyses several key alteration zones have been identified that are worthy of exploration follow-up.

Weights of evidence analysis indicate that the normalized data are the best predictors of known Au prospects. Several well-known areas of Au mineralization have been identified for exploration follow-up. More importantly, a number of previously unknown areas of potential Au mineralization have been identified and await exploration follow-up.

GENETIC RELATIONSHIP BETWEEN LATERITIC DURICRUSTS AND SOILS IN THE AMAZONIAN REGION - BRAZIL

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The whole Amazonic region show yellow and red silty-clayey to clayey soils overburden iron-aluminum, aluminium and silicic-iron lateritic duricrust. From the base to the top the duricrust undergo an increase in its fragmentation with the development of metre-sized blocks of the duricrust passing from massive, to pisolithic and nodular millimetre-sized gravels upward disappearing in its top. At the same time the silty-clayey to clayey matrix present only in the fractures of the massive duricrust embedded the nodular gravels forming the soil in the surface.

Each kind of duricrust have its own signature that is partially preserved in the matrix. In the iron-aluminium duricrust the content of hematite and goethite are greater than kaolinite and gibbsite and in the matrix the contents are inverse. The aluminium duricrust have high contents of gibbsite but kaolinite predominated in the matrix. In the silicic-iron duricrust the contents of quartz and kaolinite increase to the matrix.

The major elements show an increase of SiO_2 and Al_2O_3 from the iron-aluminium and silic-iron duricrust to the soil as consequence of the great contents of neoformed and residual kaolinite. In the aluminium duricrust profile the Al_2O_3 diminish along the profile as a consequence of the transformations of gibbsite to kaolinite. Fe_2O_3 also diminish as consequence of the dissolution of hematite, only partially is maintained in the soil as goethite.

The multi trace elements showed an excellent continuity between the massive duricrust and the soil. V, Cr, Ni, Mn, Cu and ETR, mainly associated with hematite, with high contents in the iron-aluminium duricrust and the low in the aluminium duricrust reduced progressively from the duricrust to the soil as consequence of dissolution of hematite. In the soil only Zr, Y and B, associated to residual minerals as zircon and tourmaline, increase in contents. Therefore for the three kind of duricrust the trace elements present the same pattern.

These vertical progressive transformation of the duricrust structure in silty-clayey to clayey matrix observed in the Amazonian region is consequence of its weathering in humid tropical climate and the emergence of a rain forest in the Quaternary period. The chemical leaching destroy the structure of the duricrust by the dissolution of the hematite and/or gibbsite neoforming kaolinite and goethite. These new minerals and quartz are in equilibrium with the subsaturation water activity in the surface of the soil and with the organic acid produced by the florest. Gibbsite and hematite are present in the soil as residual minerals. The crescent content of quartz in the top of the profile indicated a podzolitization processes of the soil.

BRYOGEOCHEMICAL ORE PROSPECTING AT A BURIED TERRAIN IN YAKUTIA

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In Yakutia there is much experience of bryogeochemical ore prospecting in buried terrain. In the Kular gold-bearing region in the north of Yakutia, in connection with the exhaustion of placer gold reserves, bryogeochemical prospecting was carried out between 1980 and 1985 in the Omoloy depression and a coastal plain with a combined area of 11500 km^2. This report is concerned with the Ulakhan-Siss area that occupies 5900 km^2 within the basins of the Omoloy and Yana rivers. The area has the most abundant gold placers of the Kular region. The placers are located along the Ulakhan-Siss range where Permian and Triassic bedrock are locally altered by contact-metasomatism. The rest of the area (80% of the whole area) presents a coastal plain mantled with Cenozoic deposits of alluvial, aeolian and another origin. The whole of the area is underlain by thick permafrost.

8580 samples of thaw lake and stream mosses were collected from the area. Ashed mosses samples were analyzed for Au by GFAAS and for 35 another elements by arc-source emission spectrography. The background value of Au is about 2 ppb. Peak values of Au are usually several hundreds ppb and occasionally rise to >600 ppb (up to 970 ppb).

Results suggest that the bulk of gold anomalies, together with anomalies of indicator elements such as Pb, Tl, Zn, As, form two distinct geochemical zones 22-24 km wide. The first zone coincides with known Ulakhan-Siss gold-bearing zone for a distance of 65 km and runs a further 25 km north-east to the mouth of the Yana on covered terrain where the thickness of surficial deposits is more than 100 m. The second zone, delineated for the first time, in the north of the Ulakhan-Siss area is analogous to the first and extends for about 60 km.

A vast (~ 2200 km^2) geochemical structure with an oval shape was delineated in the west half of Ulakhan-Siss area. This structure contains almost continuous strong anomalies of As and Mo and numerous more local anomalies of Sn, W, Bi and other elements. In the south-east part of the structure cassiterite placers and some tin ore occurrences are known. Here also, a large zone of bryogeochemical anomalies for La, Ce, Y, Yb, Nb and Ti was defined. This zone stretches south-westward far beyond the boundary of Ulakhan-Siss area and reaches the Solur gold placer where reserves of silicomonazite (kularite) are known. This geochemical structure evidently conforms to a large-scale tin ore-bearing area that is promising for mineral exploration for buried cassiterite, silicomonazite and gold placers.

In conclusion, the bryogeochemical investigations in the Kular gold-bearing region have shown a good ability to outline mineralized belts and provinces with economic potential on terrains mantled with permafrost and unconsolidated deposits with a thickness up to 160 m and more.

APPLICATION OF GROUND AND SURFACE WATER HYDROGEOCHEMISTRY IN MINERAL EXPLORATION IN THE BATHURST MINING CAMP, NEW BRUNSWICK, CANADA

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A deposit-scale study of hydrochemical processes was conducted at the Halfmile Lake and Restigouche (Zn-Pb-Cu-Ag) massive sulphide deposits, Bathurst Mining Camp (BMC), New Brunswick, Canada as part of the Geological Survey of Canada's EXTECH II (EXploration TECHnology) program. The study (between 1994 and 1996) was undertaken in order to characterize the hydrogeochemical response of natural sulphide oxidation and to better understand the processes and pathways of metal dispersion away from sulphide mineralization. Both the Halfmile Lake and Restigouche deposits are hosted in a deformed sequence of Ordovician (465 Ma) felsic volcanic rocks with similar topography and climate. Groundwater flow is dominated by fracture-flow. The two deposits differ in that the Halfmile Lake deposit is steeply dipping with steep structures whereas the Restigouche deposit is closer to surface with a shallow dip. The Halfmile Lake and Restigouche deposits were undisturbed at the time of sampling, although the Restigouche deposit has subsequently been developed as an open-pit mine. Additional groundwaters were sampled from the undisturbed Stratmat Main Zone and Willett deposits, the presently producing Heath Steele and Brunswick #12 mines and the past-producing Wedge deposit.

Groundwaters were collected using flow-through bailer and straddle-packer systems. The straddle-packer system permits recovery of groundwaters from discrete depth intervals. In fractured rocks, straddle-packer recovered groundwater compositions are more depth-representative than bailer recovered groundwaters. At the Halfmile Lake deposit, groundwaters were collected at depths up to 760 m and are characterized by low total dissolved solids (TDS; < 230 mg/L) and compositions which range from Ca-HCO_3 to Na-HCO_3. In contrast, groundwaters at the Restigouche deposit are compositionally variable and range from low TDS (< 300 mg/L), shallow Ca-HCO_3- and Ca-SO_4-type groundwaters to higher TDS (up to 2660 mg/L) Na-HCO_3-Cl and Na-Cl groundwaters. Saline Na-Ca-Cl waters with up to 22,000 mg/L TDS occur in the deepest part of the Restigouche and Brunswick #12 deposits. Geochemical modeling and stable isotopic compositions indicate that shallow Ca-HCO_3 groundwaters are produced by modern meteoric recharge and the major solutes are controlled by dissolution of fracture and vein carbonate and by silicate hydrolysis. The Ca-SO_4 groundwaters reflect natural oxidation below the water table of sulphide minerals by modern recharge waters. Carbon isotopic compositions of dissolved inorganic carbon (DIC) range from -15 to -5‰ $^{13}C_{DIC}$ for most ground and surface waters. Mass balance modeling indicates that recharging groundwaters initially possess $^{13}C_{DIC}$ values of -18 to -20‰ due to equilibration with soil zone CO_2 and the $^{13}C_{DIC}$ evolves to heavier values due to dissolution of fracture zone carbonate minerals (-5 to -6‰ $^{13}C_{PDB}$).

Interaction between oxygenated recharge waters at the Restigouche and Stratmat Main Zone deposits has resulted in elevated levels of metals (e.g., up to 4000 µg/L Pb and 5300 µg/L Zn) in groundwaters with circumneutral pH. At low pH, sulphide-associated metals occur primarily as free ions but at pH above 7.5, carbonate and bicarbonate complexes are more important. Although neutral aqueous metal species are important at high pH, metal transport is generally restricted due to adsorption onto Fe-oxyhydroxides. Chloride-metal complexes are significant only for the saline groundwaters from the Restigouche deposit resulting in enhanced Zn and Fe solubility.

At the Stratmat Main Zone deposit, groundwaters were sampled in detail through the massive sulphides with a straddle-packer. Groundwaters display a rapid increase in TDS (200 to 1600 mg/L) with depth through the sulphide zone. The massive sulphides coincide with a large SP anomaly (-600 mV) compared to the host rocks. With increasing depth through the massive sulphide zone, base metal (Cu, Zn, Mo, Pb, Cd) and Fe contents increase (e.g. Fe increases from 40 to 2300 µg/L). The SP anomaly is interpreted to reflect the maintenance of an electrochemical cell driven by oxidation of massive sulphides at the base of the massive sulphide zone and reduction of dissolved oxygen at the top. Differential groundwater flow through the massive sulphides maintains the electrochemical cell by supplying dissolved oxygen and preserving a compositional gradient. The dominant anion in the groundwaters in the massive sulphide zone is SO_4 which indicates that the primary control over groundwater composition is sulphide oxidation. Geochemical profiles of Fe and base metals are consistent with sulphide mineral oxidation with increasing oxidation of Fe^{2+} to Fe^{3+} and precipitation of Fe(III)-oxyhydroxides towards the top of the sulphide zone. Base metals also decrease toward the top of the ore zone as a result of adsorption onto Fe-oxyhydroxidephases.

Surface waters collected from the Halfmile Lake and Restigouche deposit primarily represent groundwater discharge based on the compositional and stable isotopic similarities with shallow groundwaters. Geochemical and isotopic modeling indicates that the major solute compositions are controlled primarily by the underlying lithologies and dissolution of carbonate. Surface waters at the Restigouche and Halfmile Lake deposits are variably anomalous in Zn, Pb, Cu, SO_4, and Fe (up to 18 µg/L, 4.8 µg/L, 8.4 µg/L, 30 mg/L and 6970 µg/L, respectively). Stream water anomalies define dispersion plumes that extend downstream up to 4 km (Zn) from the Restigouche deposit but less than 1 km (SO_4, Zn) from the Halfmile Lake deposit. Lead isotope compositions of ground and surface waters proximal to the Restigouche deposit reflect sulphide (galena) sources although there is no correlation between Pb abundance and Pb isotopic ratio.

Metal anomalies in BMC waters are controlled by a number of factors including the degree of sulphide oxidation, water composition, depth to mineralization and the local hydrology. The hydrology is important because it controls the depth to which oxygenated waters are recharged as well as the discharge of groundwaters to the surface environment. These factors explain why the surface water anomalies at the Halfmile Lake deposit are more subdued than those at the Restigouche deposit. The dispersion distance (both downstream and in groundwaters) is controlled by water pH, adsorption onto precipitating Fe-oxyhydroxides and dilution by unmineralized waters.

The results to date have the following implications for hydrogeochemical mineral exploration in the Bathurst Mining Camp: 1) Surface waters are now an effective exploration tool because of recent advances in ICP-MS techniques which allow for rapid, routine, low-cost multi-element analyses at low detection limits; 2) base metal dispersion is generally restricted indicating that effective sampling should be carried out at a detailed scale (500 m intervals or less); 3) the local hydrology may determine whether a concealed target has a surficial expression; 4) groundwater geochemistry is most useful in defining nearby targets during the course of a drilling program; and 5) Pb isotope compositions indicate that Pb abundance in waters is a poor discriminator of mineralized sources.

GEOCHEMICAL EXPLORATION FOR CARLIN-TYPE GOLD DEPOSITS IN KARST TERRAIN, NORTHWESTERN GUANGXI, CHINA

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The karst terrain located on the boundary district of Guizhou, Guangxi and Yunnan province in southern China contains the second largest Carlin-type gold camp in the word. However, most of gold deposits discovered are located in Guizhou province and only small deposits hosted-in volcanic clastic rocks have been discovered in Guangxi province. No large Carlin-type gold deposits have been discovered in the past decade by follow-up detailed survey although significant gold anomalies have been delineated in calcareous siltstone and limestone by stream sediment surveys. The evaluation of these anomalies is particular needs new geochemical methods.

The method of the selective leaching of Mobile forms of Metals in Overburden (MOMEO) has been used to: (1) discriminate whether the anomalies are caused by concealed mineralization or by weathering enrichment; and, (2) delineate the target concentration centers if the anomalies are generated by concealed mineralization. Four exploration stages are conducted. First of all, a strategic reconnaissance survey using wide-spaced sampling at a density of one sample per 100-400 sq. km was conducted to quickly delineate broad geochemical patterns favorable for large gold deposits or camps. One hundred and fourteen samples from the bottom of soil horizon A were collected in an area of 15,000 km^2. The samples were subjected to MOMEO processing and then analyzed for Au, Ag, Cu, Zn, Pb, Fe and Mn by GF-AAS, and As, Sb and Hg by HG-AFS. The results indicate that water-extractable Au, As, Sb and Hg give significant indication of concealed gold deposits and a regional anomaly was delineated.

A regional survey was concentrated on the regional anomaly at a sampling density of 1 sample per 1-16 sq. km in a area 256 sq. km. The anomaly was reduced to an area of 24 km^2 where a follow-up detailed survey was carried out using a sampling density of 400m by 200m, and 100m by 50m. A few concentration centers with a total area of 8 km^2 were delineated. The trend of the concentration centers coincides with the faults and the anomalous patterns are very promising for concealed Carlin-type gold deposits.

ALTERATION INDICES FOR EXPLORING GREENSTONE-HOSTED GOLD DEPOSITS: AN EXAMPLE FROM THE GIANT MINE, YELLOWKNIFE, NWT, CANADA

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Whole-rock geochemical data from the Giant Mine are used to identify and quantify alteration facies, examine their relationship to gold deposition, and develop alteration indices for targeting new ore shoots in the Yellowknife camp. Giant is a typical shearzone-hosted gold deposit in an Archean greenstone terrane. Gold is found in quartz-sulphide veins and veinlets in a sericite-chlorite-carbonate gangue. Oreshoots have alteration haloes extending for several hundred feet into the wall-rocks. These haloes are zoned more or less symmetrical. The typical pattern from an oreshoot outward is sulphidation, silicification, dolomitization, potassium metasomatism, alkali depletion, and carbonation. The width of an alteration halo depends on a number of factors, the most important of which are the volume of fluid passing through and reacting with the rock during the life of the hydrothermal regime (i.e., the water-rock ratio), and the rock fabric and permeability. Alteration haloes around oreshoots can be recognized by elevated alteration index scores, and in each traverse across the Giant shearzone the highest scores coincide with the highest gold grades.

There is an obvious connection between intense hydrothermal alteration and elevated gold content but the degree of alteration is neither a measure nor a predictor of gold grade. All rocks containing gold are highly altered, but not all highly altered rocks contain gold. In each of eight traverses across the Giant shearzone, the highest gold grades are invariably found in the most altered rocks. But this is true regardless of whether that gold grade is 100 g/t or 0.01 g/t. Intense hydrothermal alteration is a necessary condition, but is not a sufficient condition for gold mineralization. And although there is little or no correlation between gold grade and alteration grade in individual samples, there is a strong correlation between these when gold grades and alteration grades, respectively, are averaged for each traverse across the shearzone. The reason for this is, rocks have a limited capacity for alteration, and once that limit has been reached they can no longer react with hydrothermal fluids. These fluids then pass through the altered rocks, reacting with their unaltered neighbours until they too reach their limit, and so on. Given the very low gold content of hydrothermal fluids, a very large amount of fluid must pass through a body of rock in order to deposit enough gold to form an oreshoot. Thus, the sections of the Giant shearzone containing oreshoots are more intensively altered and have broader alteration haloes than the barren sections. This can be exploited as an

exploration parameter. Alteration index scores can be used to define a permissive envelope for gold mineralization, and areas likely to contain oreshoots can be identified by a widening of that envelope.

FE/TI RATIOS FROM PARTIAL EXTRACTION ICP ANALYSES AS INDICATORS OF HYDROTHERMAL ALTERATION IN GREENSTONE-HOSTED GOLD DEPOSITS

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Conventional multi-element aqua regia ICP analyses were used to identify the alteration facies which hosts the gold mineralization at the Con Mine in Yellowknife, NWT. Geochemical profiles of a sampling traverse through a gold bearing shearzone illustrates the spatial relationships between gold mineralization and hydrothermal alkali depletion, sulphidation, and carbonation (as determined by whole-rock, S and CO_2 analyses), and the solubility (in aqua regia) of Ti and Fe bearing rock-forming minerals vs. Fe and Ti bearing alteration minerals. In unaltered greenstones Ti is present mainly in ilmenite, augite, and biotite which are soluble in aqua-regia, while in altered greenstones Ti is found in leucoxene, a mixture of titanite, anatase, brookite, and rutile, which are relatively insoluble in aqua regia. In contrast, in unaltered greenstones Fe is present in moderately soluble silicates, while in altered greenstones much of the Fe is present in highly soluble carbonates and sulphides. Geochemical profiles of Fe/Ti ratios exploit this inverse solubility of Ti and Fe minerals in fresh vs. altered rocks, smoothing the geochemical background of the unaltered rocks while emphasizing the zones of intense hydrothermal alteration that define the permissive environment for gold mineralization. And although there is no correlation between gold grade and intensity of hydrothermal alteration, intense alteration is a necessary condition for the presence of gold mineralization (whatever the grade), and therefore high Fe/Ti ratios define the permissive envelope for gold mineralization.

Ilmenite, as well as leucoxene, anatase, brookite, and rutile are reasonably stable in the weathering environment. Therefore, low Ti concentrations obtained by partial extraction ICP analyses may be useful in distinguishing between soils, saprolites or laterites derived from hydrothermally altered and those derived from unaltered greenstones.

RELATIONSHIPS BETWEEN MOBILE METAL ION (MMI) AND CONVENTIONAL (TOTAL DIGESTION) GEOCHEMISTRY

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Comparison of the geochemical signatures obtained from Mobile Metal Ion geochemistry and conventional (total digestion) geochemistry over known mineralization in a number of geological settings provides a useful and instructive basis for evaluating the geochemical processes operating.

Comparisons over gold mineralization will include deposits located in semi-arid, deeply weathered lateritized' terrain (Golden Web, Coolgardie, Western Australia), high rainfall, lateritized terrain (La Salle, Venezuela), arid, desert terrain (Tregony, Tanami Desert, Northern Australia), and carbonated, deeply weathered lateritic profiles (Davyhurst, Western Australia). Results for Au indicate a range of outcomes from contrast of equal intensity for the two techniques, to examples with higher contrast for the partial technique. In several cases the total digestion technique has produced displaced, false anomalies which are not evident on the partial digestion surveys.

One comparison over a Ni deposit in a carbonated lateritic environment (Nepean, Western Australia) shows a sharp, high intensity anomaly for MMI Ni (and Pb, Pd) located over mineralization. Surrounding this is a very broad, low order conventional (total digestion) anomaly.

For the base metals Zn, Cd, Pb, and Cu, geochemistry at three locations will be compared. At

Elura in Eastern Australia, the MMI geochemistry shows very high contrast for Zn, Cd, and Cu over the Northern Pods mineralized zone. Conventional geochemistry shows very subdued response. For Pb the differences in contrast between the two techniques are less obvious. At Panorama, in the Pilbara of Western Australia, an area of low, intermittent rainfall, and rugged relief, mineralized chert horizons exhibit strong surface MMI responses for Zn, Cd, and Cu. Again the conventional geochemistry response is limited to subdued anomalism for Pb. At San Nicolas, in Mexico, the metal response from a deeply buried system is evident from sampling of the caliche-containing surface gravels and subsequent MMI analysis. Response from conventional(total digestion) of the same samples is very limited and not diagnostic.

The range of outcomes for contrast differences between MMI analysis for various metals, and the equivalent conventional analysis over mineralization have led to the development of a three-stage model to describe the processes occurring in the solum. Mobile ions are continually produced in the soil profile as a result of ore body oxidation, and vertical migration. Conversion of unbound metal to a bound form in the soil zone and subsequent lateral transport can account for many of the observed resolution differences between the two analytical methods, and the differences in behaviour of different elements. The model is able to supply valuable information relating to application of the MMI and conventional analytical methods in mineral exploration. It also suggests that previous models for formation of geochemical anomalies related to buried mineralization, require modification to successfully interpret new observations and information.

GEOCHEMISTRY OF HOST ROCKS, VEINS, REPLACEMENTS, AND JASPEROIDS IN THE HILLSBORO DISTRICT, SIERRA COUNTY, NEW MEXICO USA

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New geochemical and geological data, combined with earlier studies, have provided a refinement of the evolution of the mineralization in the Hillsboro (Las Animas) district in central New Mexico. Laramide (polymetallic) vein, placer gold, carbonate-hosted Ag-Mn, Laramide skarn, and porphyry-copper deposits are found in this district. Past production has been predominantly from the Laramide veins, although minor production has occurred from the carbonate-hosted deposits. During the period 1877-1982 an estimated 270,000 troy ounces Au, from lode and placer deposits, 78,000 troy ounces Ag, 24 million pounds Cu, and 153,387 pounds Pb were produced from the district, mostly from the Laramide veins. The Copper Flat porphyry-copper deposit in the central part of the district was discovered in 1975. Quintana Minerals Corp. produced approximately 7 million pounds of Cu in March-June 1982, prior to closure of the open-pit mine. Alta Gold Co. is currently applying for mining permits to reopen the Copper Flat mine.

The geology of the Hillsboro district is dominated by Cretaceous andesite flows, breccias, and volcanoclastic rocks that were erupted from an andesite volcano. The Copper Flat quartz monzonite porphyry is 75.1±2.5 Ma (K-Ar; Hedlund, 1974) and intruded the vent of the volcano. The unmineralized Warm Springs quartz monzonite is south of the Copper Flat porphyry. A third altered, unmineralized quartz diorite crops out in the northern part of the district. These two intrusions most likely represent small, satellite stocks that intruded along fracture zones on the flanks of the volcano. Latite and quartz latite dikes intruded the andesite and Copper Flat porphyry and radiate outwards from the Copper Flat porphyry. Alteration of the igneous rocks consists of locally intense silicification and K-metasomatism. Jasperoids are common in the limestones.

The igneous rocks are part of a differentiated comagmatic suite. The andesites are metaluminous and alkaline; the quartz monzonites and latites are peraluminous and alkaline to subalkaline. The linear variation in Nb/Zr, Zr/TiO_2, V/ TiO_2, and various major elements suggests that the igneous rocks are comagmatic. The igneous rocks are classified as Within-Plate Granite (Pearce et al., 1984). These data are consistent with a subduction-related back-arc extension setting.

The Copper Flat porphyry-copper deposit consists of Cu, Au, Mo, and Ag disseminations and quartz veins in a breccia-pipe in the quartz monzonite stock (Dunn, 1984). Unlike the Santa Rita and Tyrone deposits, only a thin supergene enrichment zone occurs at the top of the Copper Flat porphyry; Copper Flat is predominantly a low-grade hypogene deposit. Much of the ore is concentrated within a breccia pipe that is 396 m long, 183 m wide, and has a vertical extent of almost 518 m (Dunn, 1982). Predominant minerals include pyrite, chalcocite, chalcopyrite, azurite, malachite, and cuprite. Fluid inclusion data indicates that the depositing fluids had temperatures of 320-360°C, contained 10-45 eq. wt.% NaCl, and were emplaced at depths of 1-2 km (Fowler, 1982). Mineable reserves were estimated in 1984 as 66 million metric tons of 0.42% Cu and 0.012% Mo (Dunn, 1984). Current reserves of the deposit are estimated as 66 million metric tons of ore containing 220.9 million kg Cu, 7,116 kg Au, 90,700 kg Ag, and 7.1 million kg Mo (Dillard, 1995). The gold grade is reported to be 0.14 ppm.

The Laramide veins are associated with latite and quartz latite dikes and consist of quartz, pyrite, clay, iron oxides, barite, malachite, chrysocolla, chalcopyrite, bornite, and galena. Chemical analyses range from 8-64,600 ppb Au, <0.2-590 ppm Ag, <5-4,958 ppm Bi, 40-57,337 ppm Cu, <1-475 ppm Mo, 57-8906 ppm Pb, and 138-17,026 ppm Zn. Fluid inclusion data indicates that the depositing fluids had temperatures of 179-359°C and contained 7.7-34.4 eq. wt.% NaCl (Norman et al., 1989).

The carbonate-hosted deposits consist of small replacement pods of Ag-Mn and Pb-Zn, small Pb-Zn skarns, and veins in Paleozoic limestones and dolomites, typically belonging to the El Paso Formation (Ordovician), Fusselman Dolomite (Silurian) and Lake Valley Limestone (Mississippian). These deposits are typically Ag-Mn or Pb-Zn dominant. Breccia fragments of jasperoid indicate that an early deposition of jasperoid preceded metals deposition. Chemical analyses range from <5-99 ppb Au, 1-<50 ppm Ag, 34-1047 ppm Bi, 131-173 ppm Cu, 2-140 ppm Mo, 30->10,000 ppm Pb, and 123->20,000 ppm Zn.

Large jasperoid bodies have replaced the limestones belonging to the El Paso Formation, Fusselman Dolomite and Lake Valley Limestone in the southern part of the district. Field relationships indicate that some of the jasperoids are probably Cretaceous in age. The jasperoids are heterogeneous in texture, color, and composition. They range from aphanitic to brecciated, locally vuggy and fine to medium grained. They consist primarily of quartz and iron and manganese oxides with local pyrite, fluorite, and calcite. The jasperoids contain 88.45-97.57% SiO_2, 0.23-3.07% Fe_2O_3, 1-39 ppm As, 60-305 ppm Ba, <2-49 ppm Cu, <2-50 ppm Pb, and 10-119 ppm Zn.

Many workers in the district have recognized district zoning. The Copper Flat porphyry-copper deposit forms the center. Propagating outward radially from the Copper Flat quartz monzonite are Laramide Au-Ag-Cu veins hosted by many of the latite dikes. Carbonate-hosted replacement deposits are found in the southern and northern parts of the district, distal from the center and contain Ag, Pb, and Mn with minor V, Mo, and Zn. Interpretation of published and unpublished geochemical data of veins in the district has shown a refinement of earlier interpretations of district zoning. Au, Ag, and Cu decrease in concentrations along the Empire vein away from the Copper Flat quartz monzonite. Au, Ag, and Cu decrease in concentrations away from the Warm Springs quartz monzonite along the Sherman vein. This suggests that the Warm Springs quartz monzonite may be a second source for mineralizing fluids. Collectively, the evidence suggests that the deposits found in the Hillsboro district were formed by large, convective hydrothermal systems related to the Copper Flat volcano and subsequent intrusion of the quartz monzonite and latite dikes.

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THE LAOWANCHANG "RED SOIL" REGOLITH-HOSTED GOLD DEPOSIT, GUIZHOU PROVINCE, CHINA

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The Laowanchang gold deposit is the largest of a number of unusual "red soil" gold deposits in the Fuyuan-Xinren goldfield, located in the karst dominated terrain of southwestern Guizhou Province, China. The deposit occurs approximately 180 km southwest of Guiyang in the large "Carlin-like" gold province of southwestern Guizhou, within the western part of the Yangzi tectonic block. The Fuyuan-Xinren goldfield occupies a belt about 80 km long and 20 km wide. More than thirty locations of Au-Hg-Sb geochemical anomalies have been found in the goldfield, and further exploration has confirmed more than ten "red soil" gold deposits.

The Laowanchang deposit occupies an area 2 km long and 1 km wide, within the eastern part of the Fuyuan-Xinren goldfield. It is located in a moderately hilly cone karst erosion area with a relative relief of some 300 m, where the Early Permian Maokou limestone is exposed. Karst features include depressions, caves, sinkholes, funnels and pinnacles. These karst features are partly buried by residual and transported regolith, including slope wash, silty clays and clayey silts, with some colluvial and transported clays, pebbles and fragments of locally derived tuffaceous mudstones, brecciated and silicified tuff, sandstones, and limestone breccias. This material is of probable Quaternary age and infills the karst topography, including major collapse depressions and valleys, to a depth of 5 to 20 m, locally up to more than 50 m.

Gold is hosted by infilling "red soils" clays, silts and sediments in some of the karst depressions, and on the northern slopes of the karst hills. There are five ore bodies, which are currently being mined in the Laowanchang deposit. The ore bodies are about 200 to 300 m long, 20 to 100 m wide and generally 5 to 20 m (locally up to >50 m) deep. The size and shapes of the ore bodies vary depending on the form of the underlying karst topography in the Maokuo limestone. The indicated resource of the deposit is some four million-tonnes with an average grade of approximately 5 grams per tonne (ie ca. 20 tonnes gold). The potential gold reserve should be larger since the bottom of the main ore body is still open, and lower grade gold ore has been found in the surrounding area.

The "red soil" material hosting the gold mainly consists of red, yellow, brown with minor grey and pallid silty clays, clayey silts and soils with fragments of tuffaceous mudstones, tuff breccia, sandstones, limestone, and some heavily oxidised ferruginous pebbles. Most of the coarser fragments are angular and unsorted, and appear to be derived from the Late Permian Dachang Formation, since remnant tuffaceous and breccia textures, commonly observed in the Dachang Formation, can still be recognised. The fragments have been heavily oxidised and weathered, and commonly display pseudomorphed breccia textures where previous breccia fragments have been replaced by quartz aggregates of radiating elongate crystals normally 0.1 x 0.7 cm in size. Detailed XRD analysis of the soils and clays from the ore bodies indicates that the "red soil" is mainly composed of quartz, kaolinite, illite, with lesser amounts of goethite, anatase and ± chlorite.

Field relationships, textures, compositional and geochemical characteristics of the "red soil" indicate that this material is essentially a karst infill of oxidised residuum from chemical weathering of the Maokuo limestones with a component of weathered fragments from surrounding and possibly originally overlying bedrock. Analysed REE, Y and Zr in the "red soil" show mostly between 4 and 7 times enrichment over average upper crustal values and significant enrichment over levels in the regional limestones and overlying Dachang Formation. The REE patterns are consistent with derivation from a predominantly limestone source with a much lesser component from the Dachang Formation.

Gold within the "red soil" is generally fine-grained and invisible to the naked eye, (typically in the 2.5-4 µm size range). It is associated with smectite and goethite. SEM observations have revealed that gold also occurs as irregular micro-nuggets (up to 60x20 µm). These grains are commonly intergrown with iron oxide/hydroxide phases and show irregular and delicate growth features.

Gold concentration within the "red soil" has clearly involved chemical mobility from a source during weathering processes. Possible sources of the gold include the Maokua limestones (<3 ppb Au) or the deeply weathered and now largely stripped Dachang Formation (45 ppb Au). Simple residual concentration *in situ* by a factor of up to 7 (as suggested by the enrichment values for the REE and Zr) would not be sufficient to produce the observed concentrations of gold in the deposit. This implies either some groundwater related concentration mechanism or the presence of underlying primary mineralisation. The high As content and elevated levels of Sb, Hg and W of the gold-bearing "red soil", together with the association of the "red soil" deposits with faults are consistent with the latter possibility. Most of the limestone-hosted "Carlin-like" primary gold deposits in the area are associated with faults and have high As and elevated Hg, Sb and W contents.

The high grade of the ores, the simple mining processes and the extremely low cost for gold recovery make the Laowanchang type regolith "red soil" gold deposits economically significant. Indications that the "red soil" gold deposits have been concentrated from pre-existing mineralisation in the underlying limestones has important implications for further exploration. Areas immediately around these deposits, particularly along faults, should be explored at depth for possible primary gold deposits.

BIOLOGICAL CONSTRAINTS ON MOUND-BUILDING TERMITES IN GEOCHEMICAL EXPLORATION: THE ROANDJI EXPERIENCE CENTRAL AFRICAN REPUBLIC

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Data collected peripheral to a mineralogical survey of 5661 cathedral termitaria from the Roandji goldfields, are examined in a study of the biological constraints on mound building termites and their impact on mineral exploration.

The topography of the 64 km^2 survey area is an upland supported by banded iron formation surrounded by a lowland underlain by acid intrusives and gneiss. The vegetation is scrub savanna controlled by fire; the climate is sub-humid tropical. The upland, which includes a major drainage divide cresting at 700 metes is dominated by sterile ferricrete (iron duricrust) and colluvial deposits derived from the dismantling of both sterile ferricrete and auriferous saprolite/bedrock.

This upland supports the highest density of termitaria observed in the region, about 200 mounds/km^2. Within this zone of greatest abundance there are sterile zones with no termitaria of *Macrotermes*. This contrast in the density could reflect impenetrable lithology such as chert, quartzite or possibly duricrust (or related soil structure), adjacent to more easily mined iron formation. Alternatively, metal toxicity within this ground, indicated by moderate values of copper, arsenic, and vanadium at Roandji, as well as high levels of gold and silver, prompt the question of geochemical-based faunal barrens within geochemically anomalous areas. Within the zone of greatest abundance, only approximately 15% of the mounds were observed to be active. This high level of moribundity may derive from metal poisoning within the mound itself. The activity of bacteria and fungi in the chimney linings and in the matrix of the mound plays a role in the modification and dissolution of high-silver electrum present in termitaria which may be reflected in colony longevity. Other toxins in tropical soils associated with gold mineralization include arsenic, mercury, and antimony which are sometimes ingredients in insecticides that may limit termite activity. Further, mercury vapour flux from fractured and/or zones of epithermal mineralization, as well as the radiogenic gas helium, sulphur dioxide and both organic and inorganic methane, are vented preferentially through the chimneys of termitaria which may both contribute to the toxicity of the mound and provide valuable data for mineral exploration.

Several specimens from Roandji cathedral termitaria have been identified only as *Macrotermes subhyalinus.* Mushroom-shaped, small and very indurate mounds have yielded *Cubitermes* (sp), a humivorous termite present in both alluvial lowlands and here on dry uplands, including zones barren of *Macrotermes.* These mounds were not sampled as part of this survey. Although mound geometry appears to have species specificity some components relate to the history of the colony and to climatic and weather controls. Rain drop erosion of towering forms, analogous to hoodoos, is important as is damage by insectivores. Termitaria vary in character from earthen galleries in trees, to rounded domes and conical towers. Prominent mounds are built both by some species of the genus *Macrotermes* but also some *Odontotermes.* The active mounds are sometimes metres high with prominent buttresses on the sides and multiple turrets at the top. At Roandji damage from exploration sampling and destruction from follow-up trenching, resulted in immediate reparation. However, if the royal cell is damaged the mound may die out. Inactive mounds or mounds in disrepair have subdued forms with round tops and concave slopes grading into regional soils. Although possibly distinguishable when active, the mounds of various genera, in disrepair are indistinguishable, which, considering potential differences in depth of mining by different mound-building species, has implications for exploration.

Granulometry of the termitaria matrix is complex. Maximum sizes at Roandji sometimes include pebbles; this reflects contamination of inactive termitaria by rodents burrowing into the subsoil. Lithology of grit-fraction includes secondary iron hydroxides of both the duricrust and underlying sulfides, primary iron oxides of the underlying iron formation and abundant coated but unweathered silicate fragments. These grains represent unoxidized lithic fragments from the weathering front with implications for geological mapping. Gold particles in the silt-sand size range, including particles as long as 7 mm. They are transported by termites externally (in mandible transport) as determined by surface markings, or as discrete lithic particles or as clay-rich aggregates. Smaller, sub-micron particles, may be also transported internally (gut transport), and contribute biochemically to the geochemical gold values of termitaria. Biochemical effects including bacterial dissolution of gold, particular the high-silver electrum varieties present in the abundant gold grains of Roandji termitaria.

Zoning of the mound occurs with respect materials of construction and the nature of the contained gold. The initial construction may be derived from duricrust and saprolite containing only silver-depleted gold. Late stage repairs to the mound surface during drought stress when predation induced repairs require groundwater and concomitant adsorptive materials in unoxidized ground. This has implications for follow-up sampling of active mounds near the end of the dry season, with "demand samples" from the watertable.

Termitaria represent a powerful geological tool, despite any biological constraints, in understanding and sampling masked, deeply weathered terrain.

REGOLITH GEOCHEMICAL EXPLORATION USING ACID INSOLUBLE RESIDUES AS A SAMPLING MEDIUM FOR GOLD AND BASE METAL DEPOSITS IN THE COBAR REGION, N.S.W., AUSTRALIA

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Acid insoluble residues of regolith samples after treatment with aqua regia (3HCl:1HNO$_3$) and subsequently with H$_2$SO$_4$ have been tested as a sampling medium for determining geochemical signatures around gold and base metal mineralisation at the McKinnons and Wagga Tank deposits, respectively, and in an area east of the CSA base metal deposit, in the Cobar region, N.S.W., Australia. The residues, composed of quartz, chalcedony and minor mica, are believed to retain elements related to mineralisation and associated wall rock alteration.

Gold and base metal deposits in the Cobar region occur within clastic sediments and volcaniclastics of the Early Devonian Cobar Basin. Common alteration styles are silicification and chloritisation with some carbonitisation and sericitisation. Within the regolith, clay mineral alteration is significant. Most mineralisation in the Cobar region is controlled by structure and competency contrast related to stratigraphy. Deposits occur along shear or fracture zones within siltstones, sandstones and volcaniclastics.

At both the McKinnons and Wagga Tank deposits the weathering profile is about 80-100 m thick. The regolith at McKinnons consists of a top 1 m of brown soil composed of quartz, illite with minor amount of kaolinite, muscovite and hematite/goethite and also containing ferruginous pisoliths. This layer is underlain by an upper horizon of white saprolite consisting of quartz, clay minerals (mainly illite) and muscovite, and a lower horizon of grey brown saprolite comprising quartz, clay (illite), muscovite, pyrite, goethite and hematite. In the Wagga Tank area, the weathering profile consists of soil overlying a residual ferruginous layer composed largely of maghemite underlain by a kaolinite-rich zone which passes into goethitic saprolite containing alunite-jarosite family minerals.

To establish remnant geochemical signatures associated with mineralisation, detailed studies were made of the element distributions in acid insoluble residues of regolith from the 15150N section at the McKinnons gold deposit, from rock and regolith along the 11100N section at the Wagga Tank base metal deposit and from a number of locations in the CSA area. The study examined a total of 272 samples, including 101 drill hole regolith samples from the McKinnons deposit, 111 drill hole samples of rock and regolith (inclusive of surface soil) from the Wagga Tank deposit, and 60 drill hole samples of regolith from the CSA mine east locality.

Mineralogical determinations by semi-quantitative X-ray diffraction (XRD) and scanning electron microscope (SEM) revealed that the residues are mainly composed of quartz and chalcedony (probably more than 90%) and a minor amount of mica. Samples were chemically analysed for 22 elements, including K, Fe, Ca, Ti, Mn, Cl, Ga, Rb, Sr, Zr, Y, Cu, Zn, Pb, Ni, As, V and Mo by proton induced X-ray emission (PIXE) and Al, Na, Mg and F by proton induced gamma ray emission (PIGME) using the 3MV van de Graaff accelerator at ANSTO, Lucas Heights, Sydney. Silver, Ba, Sb, Bi, W, Pb and Tl were determined by ICP-MS for 66 acid insoluble residue samples from 12 drill holes along 15150 m N section of the McKinnons deposit.

Distributions of the above elements in the acid insoluble residues of rock and regolith exhibit similar geochemical signatures at both the McKinnons and Wagga Tank deposits. There are two main groups of elements associated with gold and base metal mineralisation. The first group is related to mineralisation and includes Cu, Zn, Pb, Ni, As, Mo, Ag, Sb, Ba, Bi and W. The second group of elements is related to hydrothermal alteration, and includes K, Fe, Ca, Ti, Mn, Cl, Ga, Rb, Sr, Zr, Y, V, Al, Na, Mg, Tl and F. The elements of the former group are elevated and the alteration-related elements are generally depleted near and around the mineralisation. The depletion of some elements such as K, Al, Ca, Na, Rb and Sr is considered to be related to feldspar and mica destruction. At Wagga Tank deposit, large surfacial halos of Cu, Pb and As are recognised above the deposit.

Detailed distribution patterns particularly in the regolith (including surface soil) demonstrate that there is a significant geochemical zonality associated with the McKinnons and Wagga Tank deposits. PIXE data reveal that Cu, Pb, As are enriched whereas Zn and Ni are depleted above or in the upper level of the mineralisation. Silver, Sb, Bi, Ba and W by ICP-MS are also enriched at the upper level of the McKinnons ore zone but decrease at depth. Extensive geochemical halos of Cu, Pb and As in both deposits, and of Ag, Sb and Bi in the McKinnons deposit occur at the surface above the mineralisation.

The above geochemical signatures are observed in fresh rock, weathered rock (saprolite) and in surface soil. These signatures are considered to be mainly the result of primary geochemical dispersion and are retained within the regolith despite the weathering effect. The best indicators in the acid insoluble residues to define the gold-base metal mineralisation and associated hydrothermal alteration in all types of samples (fresh rock or regolith) are enrichment of Cu, Zn, Pb, Ni, As, Ag and Sb, and depletion of K, Fe, Ca, Na, Rb, Sr, Ga and Tl.

This method of using acid insoluble residues also has potential to distinguish between true and false anomalies. The regolith-hosted base metal anomalies to the east of the CSA mine, which are not associated with mineralisation, do not show any indication of hydrothermal alteration. These samples exhibit enrichment in K, Fe, Ca, Na, Rb, Sr and Ga in the acid insoluble residues.

THE CHARACTERISATION OF AURIFEROUS QUARTZ USING ION BEAM TECHNIQUES (PIXE/PIGME)

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The hydrothermal quartz veins of the Devonian Tasmania Reef (Beaconsfield, Tasmania, Australia) are zoned and consist of auriferous quartz with a central core of carbonate. Sulphides are distributed throughout the two to six metre wide reef, which has average grades ranging from 14g/t to 38g/t gold. The vast majority of the gold occurs as either small free grains (up to 1.8 mm) in quartz or tiny inclusions (less than 0.5 mm) in pyrite. Ordovician quartzose sandstones/conglomerates host the reef.

The process of hand picking visually pure quartz fragments, grinding them to a fine powder and then acid leaching the powders, provided pure quartz samples for analysis. In order to characterise the quartz of the vein systems in the Beaconsfield area, trace element distributions in 327 samples of vein quartz were determined by Proton Induced X-ray Emission (PIXE) and Proton Induced Gamma Ray Emission (PIGME). The bulk chemical composition of the samples was determined simultaneously for up to sixty elements by combined PIXE/PIGME analyses. These analyses from 400 mg of acid cleaned quartz powders, were compared with gold fire assays of one metre length diamond drill core splits. The repeated use of duplicate analyses as monitors and the rigorous mixing of the quartz powders, ensured that the analyses were representative of the bulk sample.

Initial inspection of the 327 samples suggested that only a few elements (Li, As, Ge, Al) had a strong positive correlation with gold mineralisation. The cause of the high Ge, Li and K content is probably capture of these elements during rapid growth of hydrothermal auriferous quartz. In the Tasmania Reef, such quartz is fractured, microcrystalline and contains free gold. The importance of Ge as an indicator for Au mineralisation was also stressed by van Moort et al., 1990.

After the initial data had been statistically analysed, a range of elements demonstrated a positive correlation with either reef quartz or barren quartz. These are listed in Table 1 below. These elements were determined on 400 mg spot samples of powdered, acid cleaned quartz using PIXE/PIGME techniques.

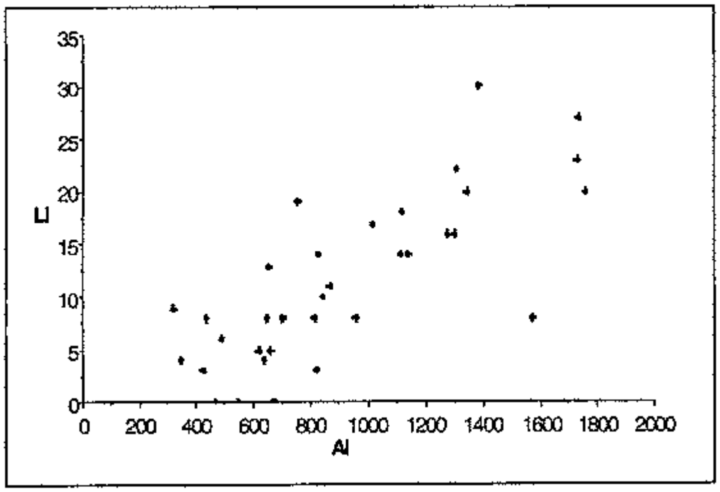
Table 1: Statistical Techniques Used

SIGNIFICANT ELEMENTS IN:-	SIGNIFICANT ELEMENTS IN:-
REEF QUARTZ	BARREN QUARTZ
Au (m,c,s)	K (m,s)
As (m,c,s)	Ti (m,s)
Ag (m,c,s)	Cl (m)
Li (m,c,s)	Na (m)
Ge (m,c,s)	S (m)
Mn (m,c)	Ni (m)
Al (m,c)	
Fe (m,c)	
Zr (c,s)	
Cr (m)	
F (s)	

Key: m=significant mean; c=significant cluster analysis; s=significant spearman correlation

A process of cluster analysis and a more detailed Spearman Ranking of the analyses, unearthed a wider range of elements and pairs of elements which have a significant positive correlation with mineralisation. Other highly significant correlations between one element and another element are those between Al/F, Al/Fe, Al/K, Al/Ti, Al/Li, As/Fe, Ge/Li and K/Rb. Different elemental ratios can be correlated with either auriferous or barren quartz, for instance, the correlation between Al and Li for auriferous quartz is plotted in Figure 1.

Figure 1: Correlation between Li and Al (in ppm), N=57, R_S=0.604



The K/Al ratios of samples supported the contention that there was an absence of micron-scale non-stoichiometric muscovite or orthoclase fragments, as confirmed by inspection using an electron microprobe. These processes provided confidence that the samples analysed in this study were pure quartz with ionic defects and/or substitutions.

A system of numerical data evaluation of the chemical analyses was developed to aid in the identification of auriferous quartz. These methods are based on significant statistical correlation by Spearman Rank analysis, between pairs of elements for the mineralised and non-mineralised populations. The identification of samples with little Li (i.e. <5ppm) or no Li were useful in removing the non-auriferous samples, allowing further analyses to be done on a restricted number of samples, hence reducing the cost. More sophisticated screening procedures were developed using combinations of Al-F-Ge-Li-Na-Rb-Ca-Cl and Al-Ti-K-Rb-Ge-Li-Na. These series of "screens" enabled the non-mineralised samples to be removed, retaining the majority of the mineralised population. Several successful screens were developed and one example follows: {mol(Al+F), mol(Ge+Li), mol(Na+Rb), mol(Ca+Cl)}. Successive applications of these pairs of elements separated auriferous quartz from barren quartz with a high degree of certainty.

This screening of PIXE/PIGME analyses of spot quartz powder samples was an efficient technique for the characterisation of quartz and the subsequent identification of auriferous reefs.

CHARACTERIZATION OF RESIDUAL AND TRANSPORTED REGOLITH PROFILES USING THE PIMA II

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In areas of thick regolith with a significant transported component, interpretation of trace element geochemical patterns is partly dependent on the differentiation of geochemical signatures associated with residual and transported materials. Differentiation may be problematic in terrains where there has been partial or complete stripping of the regolith profile down to the saprolite, the gross mineral composition of residual and transported regolith are similar and where subsurface sampling is conducted using drilling methods that do not preserve gross regolith fabrics. In characterising geochemical patterns in transported cover within thick regolith in the Cobar region, an investigation has been made of infrared spectrometry to measure subtle differences between hydrated mineral phase (principally phyllosilicate) characteristics and abundance in the transported and residual portion of the regolith.

The PIMA II is a field-portable infrared spectrometer, which can measure the short wave infrared (1300-2500 nm) reflectance spectra of geological materials, including soils and drill spoils. The PIMA II has a spectral sample interval of 2 or 4 nm and a spectral resolution of 7-10 nm. Little or no sample preparation is required and each measurement takes 30 to 60 seconds, depending on the mode selected.

The study area is located around 13 km north of Cobar in central New South Wales, Australia. Slates, siltstones and sandstones of the Devonian Cobar Supergroup host structurally controlled Cu mineralisation at the nearby CSA Mine. The Cobar Supergroup is unconformably bounded in the east by the Ordovician Girilambone Group phyllites. The deep weathering profile has been partially stripped. Up to 30 m of transported regolith (often in the form of channel fills) related to both present and palaeodrainages overlies saprolite and is dominated by fine grained quartz and kaolinite-dominant clays (with a significant aeolian component). PIMA spectra were recorded for the <63 μm fraction of 617 air dried profile samples, collected at 1 m intervals from 24 reverse circulation (RC) drill holes, on four traverses near the CSA Mine. Spectral data was supplemented by quantitative XRD and normative XRF mineralogy on selected samples. Modelling of PIMA data, to identify the mineralogical characteristics of samples was completed using existing compilations of near infrared mineral spectra.

Typical PIMA spectra display three major absorption bands around 1415, 1915 and 2210 nm and five weaker bands around 1398, 2165, 2355, 2385 and 2460 nm. The strength of these weaker bands depends on the abundance and/or the crystallinity of various minerals. The ~1415 and 2485 nm absorption bands, attributed to O-H stretching, occur in all OH-bearing minerals. The ~1915 nm band is due to combined H-O-H bending and O-H stretching, and the 2210, 2355 and 2385 nm bands to combined Al-O-H bending and O-H stretching. The fine structure of the near 2200-2300 nm band is diagnostic of a number of minerals. The weak 1398 nm band (due to O-H stretching and rarely present in the samples measured) and 2165 nm band (due to Al-O-H bending plus O-H stretching) forms two characteristic doublets of kaolinite and halloysite, with the sharper band at 1415 nm and 2210 nm respectively. Prominent 2355 and 2485 nm features are related to muscovite/illite, whereas the 2385 nm band indicates kaolinite.

To quantify downhole variation of absorption features and enhance the weaker absorption features, the hull quotient spectra were calculated and the resultant profiles stacked for each RC hole. Most stack plots displayed two distinct spectral types. Type I is observed in the upper part of the profiles (in the transported regolith) and is characterized by a sharp 1915 nm band, three very weak bands at 2355, 2385 and 2485 nm and the absence of the 1398 nm and 2165 nm bands. By contrast, type II spectra (in the saprolite) has a broader 1915 nm absorption feature, a pronounced 2355 nm band, a distinct 2485 nm absorption and either a prominent 2165 nm feature or inflection. The 1398 nm absorption is only present in spectra with a prominent 2165 nm band.

The spectra indicate a mineral assemblage of kaolinite + muscovite/illite ± halloysite ± montmorillonite for type I and muscovite/illite + kaolinite for type II. In most cases, type II spectra are dominated by muscovite or illite. This was confirmed by the quantitative XRD and normative XRF mineralogy, which indicated that the residual regolith contains more muscovite/illite than kaolinite. The transition from type I to type II occurs at depths ranging from 3 to 25 m below surface. Whereas the transition could be abrupt or gradual, the patterns away from the contact were very consistent. The higher kaolinite/muscovite ratio in the transported materials is attributed to erosion of kaolinite-rich materials from upper saprolite and deposition on a truncated weathering profile.

Three major geochemical associations in regolith from this area have been previously recognized in the RC drill samples -- a Zn-Mn±Au±Pb association, an As-Sb±Au Pb association and an As-Sb-Pb-Fe association. The PIMA spectra indicates the Zn-Mn±Au±Pb pattern is associated with the residual regolith. The ~1400 nm doublet of kaolinite is generally absent in the spectra related to this geochemical association and the ~2200 nm doublet only occurs in samples near the edge of the drainage, suggesting an overall low crystallinity of kaolinite. The As-Sb±Au association is also related to the residual regolith but the PIMA spectra differs from the previous association in the presence of kaolinite doublet at ~2200 nm and a prominent 2385 nm band, indicating a higher crystallinity of kaolinite. The As-Sb-Pb-Fe association is linked to the type I spectra from the transported regolith. The kaolinite, halloysite and montmorillonite associated with this pattern show no fine structures, indicating a poor crystallinity.

The use of PIMA techniques allow rapid, field-based recognition of regolith boundaries related to transported and residual material, not readily recognized by direct observation. Geochemical patterns related to dispersion from residual into overlaying transported material or from transported material into underlying saprolite, may be more readily discerned in similar truncated regolith.

A NEW WEAK LEACH FOR GOLD EXPLORATION IN ARID ENVIRONMENTS

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Lacking in the current arsenal of commercially available weak and selective leaches is one that has a high affinity for gold and at the same time efficiently captures a large suite of useful pathfinders. Many of the more familiar soil leaches are supposedly selective, reacting with, for instance, just amorphous manganese oxides, or just humic acids. Rather, to maximize sensitivity to the deepest deposits, it makes more sense to use all, not just one or a few, of the active soil constituents that would be likely traps for vertically migrating ions.

This new extraction method for soil samples targets ions that may have migrated from deep mineralized bedrock to the surface through thick overburden including alluvium, lacustrine sediments, and volcanics. Trace metals from buried deposits migrate vertically toward the surface, drawn for example by evapotranspiration, capillary action, concentration gradient, geobattery galvanics, vapors, and microbial activity, perhaps even as micro-particulates. At the surface the trace elements and other products of oxidation from mineral and ground water interaction, like CO_2, are incorporated into the soil matrix as carbonates, oxide precipitates of Fe, Mn, and Al, organic complexes, and as loosely bound ions on clays and silicates. Since the soil matrix includes one or all of these constituents, each of them can be considered as an active trap for mobile ions. Of particular interest to precious metals exploration, recent studies indicate a strong relationship between the formation of pedogenic carbonates and mobilized Au.

This new leach operates best in high pH (basic) solutions which draw many anions into solution that are unavailable to neutral or acidic leaches. It reduces the likelihood of attacking sulfides and silicates and the possibility of peptizing soil particles that can not be removed from solution by centrifugation. Unlike some other popular methods, it is partially buffered which tends to hold the pH in the basic range through all of the analyses and consequently holds the extraction efficiency constant. Because the reagents form strong complexes, readsorption prior to analysis is expected to be less of a problem than with other popular leaches.

Compared to other methods, the anomalies from this broad-spectrum leach are more robust and have exceptional contrast, especially for gold in arid and semi-arid environments. The benefits of this new leach will be demonstrated using examples from north central Nevada.

PHYSICAL AND LITHOLOGIC CONTROLS ON HYDROTHERMAL ALTERATION IN THE BAKER-PATTON FELSIC VOLCANIC COMPLEX, FLIN FLON, MANITOBA

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Geological mapping at 1:2000 scale in the Baker-Patton felsic volcanic complex, Flin Flon, Manitoba has identified three felsic units in the Sourdough Bay area. These consist of, from bottom to top : i) 300 m of hiatal-textured, quartz-phyric rhyolite tuffs, ii) 250 m of aphyric massive and flow-banded rhyolite with associated breccia and tuff facies suggesting an exogenous dome morphology, iii) and 500 m of plagioclase-phyric rhyodacite flows. Mineralization in the area consists of : a) the Baker-Patton Cu-stringer and semi-massive sulphide deposit (~50,000 tonnes, 1.0 % Cu) at the quartz-phyric rhyolite / aphyric rhyolite contact, b) the Cabin zone Zn-Cu massive sulphide deposit (~80,000 tonnes, 6.9 % Zn, 1.0 % Cu) at the aphyric rhyolite / rhyodacite contact, and c) the Pinebay Cu massive sulphide deposit (~1.34 M tonnes, 1.5 % Cu) approximately 200 m above the aphyric rhyolite / rhyodacite contact.

Hydrothermal alteration is strongly controlled by host rock characteristics. Pearce element ratio analysis of whole rock lithogeochemical concentrations has facilitated understanding of the metasomatic material transfers that produced the observed alteration. Within the rhyolite tuffs, pervasive and ubiquitous quartz-sericite-pyrite alteration occurs. This is associated with Na and Ca loss, and K and H addition during metasomatism. Subordinate patchy chloritization in this unit is restricted to steep, probable syn-volcanic fault zones, and is associated with Fe, Mg and H addition and K loss. Alteration in the aphyric rhyolites consists of chlorite stringers with subordinate sericite and pyrite. These are abundant along the same faults, producing a pseudo-fragmental texture. Metasomatic Fe, Mg and H addition and K loss occurred during this alteration. Within the less altered rhyodacite flows, disseminated ankerite-chlorite alteration of plagioclase phenocrysts predominates, except in a fault-controlled chloritic alteration pipe footwall to the Pinebay deposit. Ankerite-chlorite alteration is associated with Ca and Na loss and K addition during metasomatism. S addition (as pyrite) is restricted to rocks exhibiting a K/Al ratio of 1/3, corresponding to muscovite alteration. Fe is also added in this zone. Finally, no Si or Al metasomatic addition or loss is observed in any volcanic unit or alteration type.

Inferred bulk pore and fracture permeability of the host volcanic units controlled the nature of hydrothermal alteration in the Baker-Patton felsic volcanic complex. Sericite alteration in the rhyolite tuffs was produced by reaction under low fluid/rock ratio conditions caused by the high porosity of the unit. In contrast, chlorite alteration in the more massive rhyolite flows was produced where the same fluids were focused by fracture permeability into vertical fluid pathways, where high fluid/rock ratios occurred.

Volume changes associated with the various alteration reactions controlled the extent of alteration. Feldspar sericitization involves a ~5 % volume loss, perpetuating further alteration through the formation of additional open space and resulting in pervasive alteration. In contrast, feldspar and muscovite chloritization involves a ~100 % volume increase, and thus self-moderates itself due to available volume limitations, restricting chloritization to fractures. As a result, the primary permeability of the host units and the volume changes associated with the alteration reactions controlled both the nature and intensity of alteration within the Baker-Patton felsic volcanic complex.

MINERAL CONTROLS ON COMPOSITIONAL DIVERSITY IN FRESH AND HYDROTHERMALLY ALTERED ROCKS HOSTING THE SUMMITVILLE HIGH SULPHIDATION EPITHERMAL GOLD DEPOSIT, COLORADO

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The Summitville high sulphidation gold deposit is hosted by a quartz latite volcanic dome in the 22 Ma (Miocene) South Mountain Formation within the Summitville caldera of the San Juan Mountains, Colorado. Ore is dominantly Au with minor Ag, Cu and Pb in structurally controlled vuggy silica tabular bodies (fractures) and pipes (fracture intersections) surrounded sequentially by quartz-alunite, kaolinite, illite, montmorillonite, and propylitic (chlorite) alteration zones. After discovery of placer gold in 1870, underground mining produced 8,280 kg of gold from 272,000 metric tons (average recovered grade of 29 grams/metric ton) between 1873 and 1949. Between 1984 and 1992, Galactic Resources Inc. recovered 9,700 kg of gold from 9.25 M metric tons (average recovered grade of 1.75 grams/metric ton) from open-pit production. Reserves have been exhausted and the mine is presently undergoing substantial environmental remediation.

Host rock quartz latite flows contain 5-15 % phenocrysts (~75 % are <1 cm oligoclase-to-andesine plagioclase, 10-15 % are >2.5 cm sanidine, and 10-15 % are < 5 mm resorbed 'quartz eye' phenocrysts). Rare mafic phenocrysts (resorbed hornblende, biotite and clinopyroxene), and accessory magnetite / ilmenite, apatite, titanite and zircon in the groundmass also occur. Large compositional variation, even in fresh volcanic rocks (which exhibit a 58 to 70 wt. % SiO_2 range), probably resulted from sorting of the coarse phenocrysts within the quartz latite flows.

Pearce element ratio (PER) analysis of 298 lithogeochemical samples from benches between elevations of 3,565 and 3,695 m within the open pit reveals that : (1) quartz and feldspar fractionation (sub-equal in molar terms, or ~ 1 : 5 in volume terms) can explain the compositional variation observed in 'unaltered' quartz latite, and (2) the fractionating feldspar composition in 'unaltered' quartz latite is dominated by sub-equal amounts of albite and potassium feldspar, with subordinate anorthite. These fractionation parameters corroborate quartz latite petrographic observations, and allow petrologic model development that facilitates removal of significant background geochemical noise. This has allowed isolation and unambiguous examination of super-imposed hydrothermal alteration effects.

The vuggy silica, quartz-alunite, kaolinite, illite, montmorillonite and propylitic alteration zones can be lithogeochemically discriminated from the 'fresh' rocks using an Al/Zr *versus* (2Ca+Na+K)/Zr (molar) PER diagram. Fresh and propylitically altered ('unaltered') rocks plot along the feldspar control line (m = 1) on the PER diagram. In contrast, argillically altered rocks (from montmorillonite, illite and kaolinite altered zones) plot below these 'unaltered' rocks due to hydrolysis and alkali loss. Montmorillonite altered rocks exhibit (2Ca+Na+K)/Al molar ratios (the slope of a line through a data point and the origin of this diagram) between 0.7 and 0.4 (ideally 1/5). Montmorillonite alteration is incomplete and occurs predominantly in fracture envelopes. Thus, the (2Ca+Na+K)/Al molar ratios in montmorillonite altered rocks reflect a combination of both feldspar and montmorillonite control. In contrast, pervasive illite and kaolinite altered rocks exhibit (2Ca+Na+K)/Al molar ratios between 0.4 and 0.2 (ideally 3/11), and 0.2 to 0.0 (ideally 0), respectively, reflecting their dominant mineralogy.

Quartz-alunite altered rocks exhibit (2Ca+Na+K)/Al molar ratios of 0.25 to 0.35, corresponding to the (Na+K)/Al molar ratio (= 1/3) observed in (natro)alunite. These rocks plot above kaolinite altered rocks on the PER diagram, and thus record a change in the direction of displacement on the diagram due to further hydrothermal alteration. Vuggy silica altered rocks also exhibit (2Ca+Na+K)/Al molar ratios of approximately 1/3, except these rocks also exhibit significantly lower Al/Zr and (2Ca+Na+K)/Zr PER's. Acid sulphate leaching displaced these compositions toward the origin, in a third (different) direction on the PER diagram, because they underwent congruent dissolution of alunite, and thus lost Al, Na and K. Infrared absorption (PIMA) results and X-ray diffraction data (including Reitveld mode and composition optimization) confirm the inferred mineralogy of these hydrothermal alteration zones.

(2Ca+Na+K)/Al is a quantitative measure of hydrolysis (1 = fresh; 0 = complete hydrolysis) for the Summitville quartz latite rocks. Comparing this metric with the simple Zr-denominated PER's provides an understanding of the mineralogical controls and geochemical affinities of all elements. Na and Ca were lost during the formation of montmorillonite and illite; and K was added during illite formation (Fe and S addition were also added to form minor pyrite during illitization). K was subsequently lost during the formation of kaolinite, but was then added again, along with S, during the formation of alunite. K and SO_4 were then lost during acid leaching and the formation of the vuggy silica alteration zone. Finally, no significant Si or Al addition or loss took place during alteration. These major element additions and losses allow determination of the bulk balanced hydrolysis reactions for each alteration zone, and volume changes associated with these reactions are consistent with the pervasive (volume loss) or fracture controlled (volume gain) nature of the different alteration zones.

Many trace element abundances demonstrate strong correlations with specific alteration mineral assemblages. Associations include : Mn and chlorite, Tl and illite, Li and kaolinite, Sr and alunite, and Se and pyrite. Finally, a sporadically anomalous Au-Ag-As-Cu-Te-Bi element (mineralization) suite occurs in the vuggy silica zone. Addition of Pb and W and losses of Ba, Zn and Ni define geochemical haloes extending out into kaolinite altered rocks. All of the above geochemical patterns and compositional controls allow development of a multi-element geochemical / mineralogical zoning model for the Summitville deposit that may have exploration applications at other high sulphidation epithermal Au deposits.

BIOGEOCHEMISTRY OF THE BALLARAT EAST GOLDFIELD

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(Presented by F.P. Bierlein[1])

The Ballarat East gold deposit is hosted by Ordovician metaturbidites that have been tightly folded along north-south trending fold axes. Gold occurs in quartz "reefs" on the eastern limbs of faulted anticlines (leatherjacket structures) and subparallel to the axial surfaces of folds (Taylor, 1998). Gold mineralisation is accompanied by arsenopyrite and rare base metal sulphides, and is associated with a primary hydrothermal alteration halo extending 10's of metres out from the leatherjacket structures (Bierlein et al, 1997). This primary alteration halo is characterised by elevated CO_2, K, Au, As, Sb and S, and associated with sericitisation and carbonatisation to form a zone of visible bleaching. At surface the contrast between the altered and relatively fresh wallrock is enhanced by oxidation of sulphides to produce a zone of intense kaolinisation. The ore zones and associated primary alteration halo are exposed at surface along a continuous ridge, the Whitehorse Range, from which the rich alluvial deposits of the Ballarat field were presumably derived.

The gold deposits along the crest of the Whitehorse Range were extensively worked last century, and the area was revegetated during the 1930s with Monterey Pine (*P. radiata*). *P. Radiata* of different ages were sampled at 25 m intervals along two east-west traverses roughly perpendicular to the strike of the Ballarat East field. Sampling occurred during the winter of 1995 following heavy rains. Blackwood (*Acacia melanoxylon*) and Chinese scrub (*Cassinia aculeata*) were also sampled for comparative purposes. A third traverse through a belt of remnant eucalyptus (*E. obliqua, E. dives, and E. macrorhyncha*) was sampled to the south of the pine plantation in 1996. These samples were washed in de-ionised water. Sample material included either leaves or needles, the tips of twigs, and outer bark. The samples were dried, pulverised and analysed using instrumental neutron activation at Lucas Heights, NSW.

Results for Au and As for two of these traverses are summarised in Figure 1 using those data that provide the best anomaly definition. Complete data are given in Stott (1996). Also shown on these diagrams are the positions of the major ore zones as inferred from historical aerial photographs. Note that the positions of these main ore trends are approximate only, and include only those areas worked in the past. Au and As from *Cassinia* leaves and twigs, and *Eucalyptus* bark show a positive correlation with extensions of known mineralised trends, as do Ce, Cr, La, Sm and Th.

Repeat sampling to determine sampling variance has revealed probable contamination of *Eucalyptus* outer bark by dust. Sequential washing experiments indicate that the dust is difficult to remove from fibrous outer bark. Therefore, while application of biogeochemistry to the central Victorian Goldfields appears feasible, caution must be exercised in the interpretation of outer bark from some *Eucalyptus* species.

LATERITIC WEATHERING EFFECTS OVER PHOSPHATIC BRAZILIAN ORES: CATALÃO I AND JUQUIÁ (BRASIL)

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Carbonatitic massifs are responsible for 95% of Brazilian phosphatic ores actually mined, most of them related to residual lateritc mantle. Igneous origin and lateritization influence are the great differences from phosphatic ore from the other parts of the world, where they are mainly formed by sedimentary processes.
Lateritization over these apatite-rich igneous rocks increases P_2O_5 contents and promotes textural, morphological and mineralogical modifications, either in the whole ore as in individual grains, which are disadvantageous to industrial processes for ore concentration. After total dissolution of primary apatite, recycling of P leads to the formation of several generations of supergene phosphates, both apatitic and non apatitic, with a wide range of variation of textural, morphological and chemical features.

Catalão I and *Juquiá* are examples of Brazilian phosphatic ores, enriched by lateritization, each one having their own geological and mineralogical features; some aspects are common to both, other are quite different. This paper presents a textural, morphological and chemical characterization of the phosphatic ore and apatitic minerals from both massifs.

Apatite is mainly associated to carbonatitic rocks in both cases. At *Catalão*, carbonatite forms veins crossing earlier silicatic alkaline rocks, unlike *Juquiá*, where carbonatite is individualized in a 2km continuous body.

The P_2O_5 average contents in the fresh rock and in the lateritic ore are higher at *Juquiá*, where it reaches, in the weathered rock, 34% weight % P_2O_5, with 28% in average for the richer zones, and 16% for the whole ore. In this particular situation, enrichment industrial processes are not necessary, and the lateritic morphological and textural modifications does not represent a problem in ore utilization. *Juquiá* lateritic ore represents an extreme case of favourable conditions, with lithological homogeneity and P_2O_5 richness. The continuity of the carbonatitic body protects the lateritic mantle from Al participation in secondary phosphatogenesis: this does not occurs at *Catalão*.

At *Catalão*, the average contents reaches 9 weight % P_2O_5 in weathered rock, but, on unlike *Juquiá*, the chemical and morphological heterogeneity of phosphate phases, both primary and supergene, and the textural features of weathering origin, may lower the quality of the ore with respect to industrial processes of concentration and solubilization.

MERCURY AS A RELIABLE INDICATOR OF CONCEALED MINERALIZATION OR CONCEALED STRUCTURE

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For many years mercury has been used as a universal indicator in search of concealed mineralization of various kinds. Research profiles of mercury survey across known mineral deposits nearly always give positive response of anomalous mercury values. But tests run in unknown regions often give bewildering results. The author based on his more than 20 years' experience on mercury survey reached the conclusion that mercury is mainly originated from fracture or faulted zones, whether mineralized or barren. So mercury anomalies are only reliable indications of faults, fractures and mercury deposits not other kind of ores. The application of mercury survey could be extended more efficiently in all fields related to the study of structure, especially in the field of hydrologic and engineering geology.

A new mercury analyzer is designed and constructed which is of low-cost and easy operation. Compared with Zeeman mercury analyzer, the ability of our new analyzer to reduce the interference is tenfold improved.

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