25th International Applied
Geochemistry Symposium
22 - 26 August 2011
Rovaniemi FINLAND

Final Programme AND Abstracts

25th IAGS2011

Programme and Abstracts

25th International Applied Geochemistry Symposium 2011
22-26 August 2011 Rovaniemi, Finland

Pertti Sarala, V. Juhani Ojala and Marja-Leena Porsanger

Publisher: Vuorimiesyhdistys - Finnish Association of Mining and Metallurgical
Engineers, Serie B, Nro B92-1, Rovaniemi 2011

Sarala, P., Ojala, V.J. and Porsanger, M.-L. 2011. Programme and abstracts. The 25th International Applied Geochemistry Symposium 2011, 22-26 August 2011, Rovaniemi, Finland. Vuorimiesyhdistys - Finnish Association of Mining and Metallurgical Engineers, Serie B 92-1, 192 pages.

Layout: Irma Varrio

ISBN 978-952-9618-63-7 (printed)
ISBN 978-952-9618-64-4 (CD)
ISBN 978-952-9618-65-1 (PDF)
ISSN 0783-1331

This volume is available from:
Vuorimiesyhdistys ry.
Kaskilaaksontie 3 D 108
02360 ESPOO

Electronic version:
http://www.iags2011.fi or http://www.vuorimiesyhdistys.fi/julkaisut.php

Printed in:
Painatuskeskus Finland Oy, Rovaniemi

Contents

Preface

AAG's biennial International Applied Geochemistry Symposium (IAGS), the 25th in order, will be held in Rovaniemi, Finland in 2011. This is the second time when the AAG's meeting is organized in Finland. However, during 30 years period the development in field methods, sampling, analysis methods, interpretation and computer-aided data processing and modeling has been significant in every geochemical research fields.

The theme of the 25th IAGS 2011 meeting is 'Towards sustainable geochemical exploration, mining and the environment'. It describes the need of responsible and sustainable acts in finding new mineral resources and production of metals and other raw materials. It also tells the importance of environmental aspects in all steps from exploration to mining and activities after the mine closure. Of course, the responsibility is not only the task of mining sector but also the actors in industry, power production and supply, agriculture, and all others who are responsible for the maintenance of society. The theme of the symposium is something that concerns all of us. Taking care and management of whole process needs control, research, education and the development of new methodology. These are the things that the Applied Geochemists are considering.

It seems that the need of this symposium to be held in the Arctic Circle and at the home of Santa Claus in Rovaniemi, Finland has been considerably. More than 220 abstracts of oral and poster presentations for 19 sessions are respectable number and prove the activity and usefulness of applied geochemistry in a wide range of the scientific commune. In addition, six high quality keynote speeches ensure the quality of scientific impact. Seven pre-, mid- and post-field excursions and six workshops widen the opportunity to discussion and to change the knowledge. And as a balance to all scientific activity we have large repertoire of social functions which will give an impression of nature in northern Finland and the skills of people living there.

The organizers of the 25th IAGS are the Geology section of the Finnish Association of Mining and Metallurgical Engineers, the Geological Survey of Finland and the Institute of Geosciences at the University of Oulu in conjunction with the Rovaniemi-Lapland Congresses. The local organizing committee includes also representatives from the mining and exploration companies and geochemical laboratory. Also, a big number of sponsors have given their support for the symposium and the exhibitors have utilized the opportunity for marketing their products and services.

Behalf of the 25th IAGS organizing committee and the organizers we wish the rewarding symposium and the enjoyable stay in Rovaniemi and northern Finland!

Pertti Sarala, Juhani Ojala and Marja-Leena Porsanger

Organizers

The Finnish Association of Mining and Metallurgical Engineers is a non-profit organization that promotes, advances and supports science and engineering in the exploration, mining and minerals industries and facilitates the exchange of information and ideas to enhance the professional excellence of its members. To achieve its aims, the association organizes seminars, conferences, excursions and other formal and informal professional meetings and publishes newsletters, papers and books. Members are drawn from all sections of the minerals industry: private enterprise, government, research, education and the support sector, including consultancies, manufacturers and suppliers.

The Geological Survey of Finland (GTK) produces and disseminates geological information for use in promoting systematic, sustainable use of the national geological endowment. GTK studies and maps the Earth's crust, inventories mineral and ore resources, provides a national geological information service, performs contract services for external clients and participates actively in international projects. GTK operates under Finland's Ministry of Employment and the Economy. It was established in 1885.

The University of Oulu is an international scientific community known for its high standard of research and education that provides experts for demanding tasks at the national and international levels. The University promotes well-being and education in Northern Finland and is a significant player in the Finnish and European research based system of innovation and education.

The Department of Geology is part of the Faculty of Science and it provides education in three subjects: geology and mineralogy, surficial geology and geochemisty.

The Association of Applied Geochemists, founded in 1970, is an international organization specialising in applied geochemistry, the purpose of which is to:

- advance the science of geochemistry as it relates to exploration and the environment

- further the common interests of exploration geochemists

- facilitate the acquisition and distribution of scientific knowledge

- promote the exchange of information

- encourage research and development

- advance the status of the profession

- sponsor symposia, seminars and technical meetings

To achieve these goals, the Association of Applied Geochemists:

- published the Journal of Geochemical Exploration from 1972 until 2000, and currently publishes GEOCHEMISTRY: Exploration, Environment, Analysis starting in 2001

- publishes quarterly a newsletter, EXPLORE

- publishes in a digital bibliography of geochemically oriented papers, which is now available to AAG Members on the ASSOCIATION OF APPLIED GEOCHEMISTS web page

- holds biennial International Applied Geochemistry Symposia with associated field trips

- holds regional meetings of specialized interest and co-sponsor meetings with other scientific so-

Local Organizing Committee

Chairmen:
Pertti Sarala, PhD, Senior Scientist,
Geological Survey of Finland

Juhani Ojala, PhD, Chairman of the Division of Geology of Finnish Association of Mining and Metallurgical Engineers (Store Norske Gull As)

Members:
Vesa Peuraniemi, Professor of Surficial Geology,
University of Oulu

Eero Hanski, Professor of Geochemistry,
University of Oulu

Esko Korkiakoski, PhD, Division Manager,
Geological Survey of Finland

Peter Johansson, PhD, Division Manager,
Geological Survey of Finland

Heikki Niskavaara, Business Area Director,
Labtium Ltd.

Markku Kilpelä, Exploration Manager,
Agnico-Eagle Finland Ltd.

Marja-Leena Porsanger, Conference Coordinator,
Rovaniemi-Lapland Congresses

.

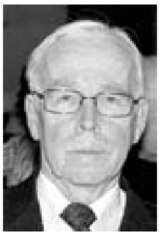
Scientific Committee

Dr. Robert Bowell
Dr. John Carranza
Prof. David Cohen
Dr. Colin Dunn
Dr. Pasi Eilu
Dr. Gwendy Hall
Dr. Steward Hamilton
Prof. Eero Hanski
Prof. Gunnar Jacks
Dr. Peter Johansson
Dr. Paivi Kauppila
Dr. Tommi Kauppila
Dr. Kirsti Korkka-Niemi
Dr. Nina Kortelainen
Prof. Raimo Lahtinen
Dr. Laura Lauri
Dr. Bruno Lemiere
Dr. Mel Lintern
Prof. Wolfgang Maier
Dr. Hannu Makkonen
Ms. Beth McClenaghan
Dr. Isabelle McMartin
Dr. Paul Morris
Dr. Jari Mäkinen
Dr. Tiina Nieminen
Dr. Maria Nikkarinen
Mr. Heikki Niskavaara
Dr. Vesa Nykänen
Dr. Juhani Ojala
Mr. Jarkko Okkonen
Prof. Vesa Peuraniemi
Ms. Raija Pietilä
Prof. Nigel Radford
Prof. Reijo Salminen
Prof. Veli-Pekka Salonen
Dr. Pertti Sarala
Dr. Olle Selinus
Dr. David B. Smith
Prof. Cliff Stanley
Dr. Timo Tarvainen
Dr. Brian Townley
Dr. Erkki Vanhanen

Keynote Speakers

David Blowes, Prof.,
University of Waterloo, Canada

David Blowes is a member of the Department of Earth and Environmental Sciences at the University of Waterloo, where he has held the Canada Research Chair in Groundwater Remediation since 2001. He also is a member of the Waterloo Institute for Groundwater Research. He has conducted research on the release and transport of dissolved metals from mine wastes, transport of dissolved metals in aquifers and remediation of groundwater contaminated by dissolved metals. His recent research projects focus on in situ remediation of contaminated groundwater using permeable reactive barriers, prediction of the long-term geochemical evolution and environmental impact of waste rock piles and the application of reactive transport models to assess the potential effectiveness of groundwater remediation strategies. He is the recipient of the Natural Sciences and Engineering Research Council Synergy award and served as the Geological Society of America Birdsall-Dreiss Distinguished Lecturer in 2006.



Reijo Salminen, Prof.
Geological Survey of Finland, Finland

Reijo Salminen is a Research Professor (emeritus) at the Geological Survey of Finland (GTK), Espoo. He has worked for GTK since 1972 being in charge of geochemical studies. He conducted the geochemical mapping program of Finland. He has been part time professor and external lecturer in geochemistry at Turku University. His speciality is in geochemical mapping, geochemistry in mineral exploration and environmental geology. He has been a regional co-ordinator for Europe in IUGS/IAGC Working Group on Global Geochemical Baselines. He has conducted large geochemical mapping projects in Europe, Russia and Africa. He is active in promoting geology as an important factor to policy and decision makers.

John Carranza, Dr. ITC of the University of Twente,
the Netherlands

Emmanuel John M. Carranza (born 08 October 1962) obtained a BSc degree in geology (Adamson University, Manila, Philippines) in 1983, a MSc degree (with distinction) in mineral exploration (International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, Netherlands) in 1994 and a PhD degree in GIS-based mineral potential mapping (Delft University of Technology, Delft, Netherlands) in 2002. He started his professional career in 1983 as a geologist in the Bureau of Mines and Geosciences of the Philippines where he was involved with geological mapping, stratigraphic studies, geological hazard mapping, evaluation of industrial rocks/minerals and geochemical exploration for gold. His work on exploration geochemistry led to recognition of a previously unknown mineralized area in a Quaternary volcanic terrane in Bicol Region of the Philippines. He received the 1998 ITC Research Award for his paper on catchment-basin analysis of stream sediment geochemical anomalies. In 2001-2003, he was a Researcher in the Earth Systems Analysis (ESA) department of ITC where he is involved with (a) research in developing geospatial data infrastructure for mineral resource management, (b) teaching at post-graduate level and (c) supervising MSc and PhD students. Since 2003 to the present, he is Assistant Professor in the ESA department of ITC with more-or-less similar teaching and research tasks as his preceding Researcher appointment. He has supervised and led to graduation 4 PhD students and at least 25 MSc students. He has been an external examiner for 4 PhD candidates. His research interests include GIS-based mineral potential mapping, geological/mineral remote sensing, spatial predictive modeling of geo-objects, and exploration/environmental geochemistry. He has published more than 45 papers in international peer-reviewed geoscience journals and more than 40 papers in international conference proceedings. He has written and published a book on Geochemical Anomaly and Mineral Prospectivity Mapping in GIS.

William W. Shilts, Prof.
Illinois State Geological Survey, USA

Dr. William W. Shilts is Executive Director of the Prairie Research Institute at the University of Illinois. The Institute houses five state scientific surveys addressing archeology, biology, geology, water, and technology, and employs over 800 scientists and technical support staff. A native of Hudson, Ohio and graduate of Western Reserve Academy, Dr. Shilts received his undergraduate degree in geology from DePauw University in Greencastle, Indiana, his Master of Science in geology from Miami University in Oxford, Ohio, and his Ph.D. in geology from Syracuse University in Syracuse, New York. From 1995 to 2008, Dr. Shilts was Chief of the Illinois State Geological Survey (ISGS). During that time he made detailed, three-dimensional geologic mapping a priority and strengthened efforts to create an energy program, ensuring that Illinois' abundant coal, oil, and biofuel resources can be utilized in an environmentally benign way. Prior to becoming ISGS Chief, Dr. Shilts worked for 30 years as a research scientist for the Geological Survey of Canada, leading studies in the fields of, exploration and environmental geochemistry, glacial sedimentology and stratigraphy, permafrost and patterned ground, atmospheric contaminants (mercury and acid rain) in lakes, and the impacts of historic and prehistoric earthquakes on lakes. He has supported and advised theses of more than 30 graduate students in the U.S. and Canada, and has been or is presently an adjunct professor at Carleton University (Ottawa), the University of Montreal, the University of Illinois, Illinois State University, and the University of Quebec at Montreal. He has been a member of the US National Committee of the International Geological Union and of the Board on Earth Sciences and Resources of the U.S. National Academy of Sciences. Dr. Shilts has been a proponent for providing clear explanations of earth science to the lay public and for the importance of utilizing earth science as an important component for assuring responsible economic development and environmental security in modern societies.

Michael Wiedenbeck, Dr.
GeoForschungsZentrum Potsdam, Germany

Michael Wiedenbeck currently heads the Secondary Ion Mass Spectrometry facility at the Helmholtz Centre Potsdam. He has a BSc (High honours) degree in Geology from the University of Michigan. He went on to obtain his Diploma in Crystallography and Isotope Geochemistry from the ETH-Zürich, where his research applied isotopic methods for dating the tectonic evolution of the Southern Alps in northern Italy. After completing his degree in Switzerland he moved to Australia for obtaining his Doctorate in Isotope Geochemistry from the Australian National University where he learned the art of zircon dating using the then emerging SIMS technique. After completing his PhD he held postdoc positions in Nancy (France), Ahmedabad (India) and Oak Ridge (USA). He then went on to hold the position of manager at the University of New Mexico / Sandia National Laboratory SIMS Facility for two years before moving to Germany in 1998. Michael has been a member of the Governing Council of the International Association of Geoanalysts since 2001 and has been the President of that society since 2006. In 2002 he hosted the inaugural meeting of the IAG's Materials Certification Committee in Potsdam, which led to the first geochemistry-specific sample certification protocol which is compliant with ISO guidelines. He has been active in this arena ever since, and has now been involved with the production of seven ISO-compliant certifications of bulk rock and isotope Reference Materials. Other professional interests include teaching Quality Assurance concepts for geochemical applications and developing new strategies for calibrating microanalytic measurement techniques. He is currently the chairperson of the Steering Committee of the soil science NanoSIMS Facility in Munich and is also a member of the IAEA's Technical Committee for the use of Reference Materials in light stable isotopes in Vienna. Michael has contributed to over 80 scientific publications and has been a member of the Editorial Board of Geostandards and Geoanalytical Research since 2004.

Ravi Anand, Adjunct Professor CSIRO and Curtin University of Technology, Western Australia

Ravi Anand is a Chief Research Scientist at CSIRO and an Adjunct Professor in regolith geology and geochemistry at Curtin University of Technology, Perth, Western Australia. In 1984, Ravi did his PhD on weathering processes at the University of Western Australia. He then became a postdoctoral fellow at the University of Western Australia. He joined CSIRO in 1987 as a Research Scientist in the Division of Mineralogy, carrying out research into methods of exploring for concealed mineral deposits in Australia's deeply weathered terrains. He has been a leader of industry-funded projects in since 1990. These projects have included multidisciplinary, multi-client projects through Australian Mineral Industries Research Association Limited (AMIRA) and projects with individual companies. He contributed to, and led, the teams which worked to understand regolith processes and landscape evolution, and sought to describe systematically what it was that they saw, placing those regolith materials into a consistent, process-related framework. He set up the procedures whereby exploration teams firstly learned the significance of the regolith materials, then learned how to recognize and record these in the field, and finally to understand the geochemical significance of these materials. The outcomes of his research have been major contributors to the discovery of many mineral deposits in deeply weathered terrains. He has successfully included a very active PhD and Honours student program in his research. He also conducted undergraduate, postgraduate and professional development courses in Australia, Africa, South America and Europe.

In Memoriam

Kalevi Kauranne

Prof. *Leevi Kalevi Kauranne* (24th July 1927-12th July 2011) was a distinguished Finnish geologist and in the frontier of the geochemical exploration. In the beginning of his career, during 1950s, the focus of his research was in developing till geochemical exploration, new innovative method in glaciated terrains. He started his geochemistry research by studying the mineral dispersion, geochemistry and composition of till in the Outokumpu area. In 1970, his doctoral thesis dealt with the problems concerning the durability of stone materials used in road construction.

At the Outokumpu mine, he started as a research assistant and finally worked as a mine geologist (1949-1950). In 1952, he got a position at the Geological Survey of Finland (GTK). After that he worked as a geologist and the head of the central laboratory in the National Board of Roads and Waterways (1960-1967), and an assistant professor at the Tampere Technical University. An important advance in his career happened in 1973, when he started to work as head of the new geochemistry department at GTK (1973-1978). Since then he was the research director (1978-1979) and finally general director (1980-1991) of GTK before retiring in 1991.

Prof. Kauranne worked in several countries: in 1954 and 1958 as geochemist in Norway, in 1963 representative of the United Nations in Togo and in 1983 representative of the Asian Bank on the Philippines. He was active in many international societies; a member of the Finnish Academy of Sciences, a member of the Board of International Geological Correlation Programme at UNESCO/IUGS, an honorary member of the Finnish Geological Engineering Society and the Estonian Geological Society, and an honorary doctor of Uppsala University. He had also many confidential posts in scientific societies in Finland.

Kauranne was an author of about 150 research papers and reports, and an editor of several scientific publications. He was one of the editors of a text-book on engineering geology and the handbook of exploration geochemistry; Regolith Exploration Geochemistry in Arctic and Temperate Terrains published by Elsevier. His papers and publications are still commonly cited in modern scientific papers.

Prof. Kauranne was awarded in 1991 by the Oskari Vilamo Foundation (engineering) and in 2011 by the Eero Mäkinen bronze medal to honor his contribution to the Finnish exploration and mining industry.

Sponsors

Platinum Sponsors

AGNICO-EAGLE
NEWMONT
SGS

Gold Sponsors

ALS Minerals
LABTIUM
Kevitsa Mining
A subsidiary of First Quantum Minerals Ltd
Store Norske
Pyhäsalmi Mine Oy
AcmeLabs™

Silver Sponsors

BOLIDEN
National Research FLAGSHIPS
Minerals Down Under
CSIRO
MAWSON

Other Sponsors

Rovaniemi
FEDERATION OF FINNISH LEARNED SOCIETIES

Programme at a glance

Sunday 21 August			
09:00 - 17:00	Workshops, Santa Claus Conference Centre, Santa's Hotel Santa Claus		
17:30 - 18:30	AAG Annual General Meeting, Santa Claus Conference Centre, Santa's Hotel Santa Claus		
19:00 - 21:00	Get-together Party, Restaurant Valdemari		

Monday 22 August			
08:00 - 18:00	Registration Desk and Speaker Service Centre open		
08:00 - 10:00	Welcome Coffee		
10:00 - 11:15	Conference Opening, Fellman Hall		
11:15 - 12:00	Keynote 1: Professor **Michael Wiedenbeck**, GeoForschungsZentrum Potsdam, Germany *Geochemical microanalysis: What can you really do with all this high-tech gear?*		
12:00 - 13:00	*Lunch, Posters and Exhibition*		
13:00 - 14:30	Parallel sessions		
	A1: Advances in analytical geochemistry Fellman Hall	B1: Applied biogeochemistry LS 2	C1: Continental-scale geochemical mapping LS 3
14:30 - 15:00	*Coffee/tea, Posters and Exhibition*		
15:00 - 16:30	Parallel sessions		
	A2: Advances in analytical geochemistry (cont.) Fellman Hall	B2: Applied biogeochemistry (cont.) LS 2	C2: Continental-scale geochemical mapping (cont.) LS 3
16:30 - 17:00	*Break, Posters and Exhibition*		
17:00 - 18:00	Parallel sessions		
	A3: Advances in exploration isotope geochemistry Fellman Hall	B3: Organic geochemistry LS 2	C3: Continental-scale geochemical mapping (cont.) LS 3
18:00 - 20:00	Welcome Reception, Conference venue		

Tuesday 23 August			
08:00 - 17:15	Registration Desk and Speaker Service Centre open		
09:00 - 09:45	Keynote 2: Professor **Ravi Anand**, CSIRO and Curtin University of Technology, Western Australia *Predictive geochemistry in areas of transported overburden* Fellman Hall		
10:00 - 11:30	Parallel sessions		
	A4: Geochemical exploration and mineral prospectivity in GIS Fellman Hall	B4: Predictive geochemistry in arid areas of transported overburden: mechanisms of anomaly formation LS 2	C4: New and old discoveries: Geochemical exploration case studies LS 3
11:30 - 12:00	*Coffee/tea, Posters and Exhibition*		
12:00 - 13:30	Parallel sessions		
	A5: Applied Aqueous Geochemistry Fellman Hall	B5: Predictive geochemistry in arid areas of transported overburden: mechanisms of anomaly formation (cont.) LS 2	C5: New and old discoveries: Geochemical exploration case studies (cont.) LS 3
13:30 - 14:30	*Lunch, Posters and Exhibition*		
14:30 - 15:15	Keynote 3: Dr. **John Carranza**, ITC of the University of Twente, The Netherlands *Analysis and mapping of stream sediment geochemical anomalies: should we logratio-transform the data?* Fellman Hall		
15:15 - 15:45	*Coffee/tea, Posters and Exhibition*		
15:45 - 17:15	Parallel sessions		
	A6: Applied Aqueous Geochemistry (cont.) Fellman Hall	B6: Special session: The 10th Finnish Geochemistry Day LS 2	C6: New and old discoveries: Geochemical exploration case studies (cont.) LS 3
19:00 - 19:45	Concert, Rovaniemi Church		
20:00 - 22:00	Rovaniemi City Reception, Rovaniemi City Hall		

Wednesday 24 August

9:00 - 17:00	Mid-Conference Excursions Optional Tours		
18:00 - 20:00	AAG Distinguished Lecturers' Night: Dr. **Scott Long**, AMEC, USA *Considerations for optimizing screen (metallics) gold fire assay* Dr. **Robert Bowell**, SRK Consulting, UK *The Role of Applied Geochemistry in the Mining Life Cycle* Santa Claus Conference Centre, Santa's Hotel Santa Claus		
20:00 - 22:00	Pub Night at Pub Hemmingways, Sponsored by SGS Mineral Services		

Thursday 25 August

08:00 - 17:45	Registration Desk and Speaker Service Centre open		
09:00 - 09:45	Keynote 4: Professor **Reijo Salminen**, Geological Survey of Finland *Geochemical mapping - past, present, future* Fellman Hall		
9:45 - 11:30	Special session: 'Forerunner of geochemical mapping and analysis methods' - honorary session for the 125th anniversary of the Geological Survey of Finland Fellman Hall		
11:30 - 12:00	*Coffee/tea, Posters and Exhibition*		
12:00 - 13:30	Parallel sessions		
	A7: Urban Geochemistry Fellman Hall	B7: Indicator minerals and trace elements in exploration in glaciated terrain LS 2	C7: Role of genetic models in exploration LS 3
13:30 - 14:30	*Lunch, Posters and Exhibition*		
14:30 - 15:15	Keynote 5: Professor **William W. Shilts**, Illinois State Geological Survey, USA *Geochemistry of Landscapes Covered by Glacially Crushed Debris* Fellman Hall		
15:15 - 15:45	*Coffee/tea, Posters and Exhibition*		
15:45 - 17:45	Parallel sessions		
	A8: Harmful metals and arsenic - geochemical anomalies and contaminated soil Fellman Hall	B8: Indicator minerals and trace elements in exploration in glaciated terrain (cont.) LS 2	C8: Partial/selective digestion geochemistry LS 3
20:00	Official Dinner, Sky Hotel		

Friday 26 August

08:00 - 15:30	Registration Desk and Speaker Service Centre open		
09:00 - 10:30	Parallel sessions		
	A9: Applied Aqueous Geochemistry Fellman Hall	B9: Geochemical research in mine districts and the environment after closure of mines LS 2	C9: Recent developments in lithogeochemical methods with exploration applications LS 3
10:30 - 11:00	*Coffee/tea, Posters and Exhibition*		
11:00 - 12:30	Parallel sessions		
	A10: Sampling and real-time analysis methods in geochemical studies Fellman Hall	B10: Geochemical research in mine districts and the environment after closure of mines (cont.) LS 2	C10: Recent developments in lithogeochemical methods with exploration applications (cont.) LS 3
12:30 - 13:30	*Lunch, Posters and Exhibition*		
13:30 - 14:15	Keynote 6: Professor **David Blowes**, University of Waterloo, Canada *Environmental Geochemistry of Sulfide Bearing Mine Wastes: Prediction and Remediation* Fellman Hall		
14:15 - 15:00	Conference Closing		

Monday 22 August

Registration and Welcome coffee

8:00 - 10:00 Main lobby

Conference Opening

10:00 - 11:15 Fellman Hall

Pertti Sarala, Chair of the Organizing Committee
Elias Ekdahl, Director General, Geological Survey of Finland
Paul Morris, President, The Association of Applied Geochemists
Esko Lotvonen, Regional Mayor, Regional Council of Lapland

Platinum Sponsors
Ingmar E. Haga, Vice-President, Europe, Agnico-Eagle Mines Ltd
Owen Lavin, Chief Geochemist, Newmont Mining Corporation
Hugh de Sousa, Director, Geological Services, SGS Minerals Services

Keynote Address

11:15 - 12:00 Fellman Hall

Key1 Geochemical Microanalysis: What can you really do with all this high-tech gear?
Michael Wiedenbeck
Secondary Ion Mass Spectrometry Laboratory, Helmholtz Centre Potsdam, Germany

Lunch, Posters, Exhibition

12:00 - 13:00 Restaurant Felli

PARALLEL SESSIONS

A1: Advances in analytical geochemistry

13:00 - 14:30 Fellman Hall Chairs: Heikki Niskavaara (Finland), Gwendy Hall (Canada), Brenda Caughlin (Canada)

A1.1 SEM-based Automated Mineralogy of Follow-up Stream Sediment Geochemistry: A QEMSCAN Pilot Study from Northern Pakistan
Liaqat Ali[1], Charles Moon[1], Ben Williamson[1], Gavyn Rollinson[1]
[1]Camborne School of Mines, University of Exeter, Penryn, Cornwall, UK, [2]National Centre for Excellence in Geology, University of Peshawar, Peshawar, Pakistan

A1.2 New measurements of selenium and sulfur concentration in country rocks of the Duluth Complex, Minnesota, USA, and implications for the formation of the Ni-Cu-PGE deposits
Matthias Queffurus, Sarah-Jane Barnes
Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada

A1.3 Light Element Analysis by Portable XRF in Geochemical Applications
Michelle Cameron, Esa Nummi
Bruker Elemental, Kennewick, WA, USA

A1.4 Nanoparticles of Re and precious metals in black shales: analytical determination and extraction
Galina Oleynikova[1], Elena Panova[1]
[1]All Russian Geological Institute, Saint-Petersburg, Russia, [2]Saint-Petersburg state university, Saint-Petersburg, Russia

B1: Applied biogeochemistry

13:00 - 14:30 LS 2 Chairs: Fyodor Kot (Israel), Kenneth McQueen (Australia)

B1.1 Application of Orientation Biogeochemical Exploration Method in the Vicinity of Ildong Fe-Pb-Zn Skarn Deposits in Korea
Suhyeon Jeon, Ji Young Park, Jongnam Kim, Hyo Taek Chon
Seoul National University, Department of Energy Resources Engineering, Seoul, Republic of Korea

B1.2 Orientation Biogeochemical Survey around Low-grade Uranium Deposits in Black Shale in Goesan District, Korea
Jongnam Kim[1], Kukhwan Kim[2], Youngjune You[2], Hyo Taek Chon[1]
[1]Seoul National University, Seoul, Republic of Korea, [2]Korea Resources Corporation, Seoul, Republic of Korea

B1.3 Nickel uptake by Cypress Pine (Callitris glaucophylla) in the Miandetta area, Australia: Testing the limits of biogeochemistry
Kenneth McQueen[1], Augustine Alorbi[1]
[1]University of Canberra, Canberra, ACT, Australia, [2]Australian National University, Canberra, ACT, Australia

B1.4 Biogeochemical expression of buried mineralisation through barren transported cover: Regolith Expression of Iron-Oxide Copper Gold (IOCG) Mineralisation in the southeastern Middleback Ranges area, South Australia
Byron Dietman[1], Steven Hill[1], Geoff Johnson[2], Charlotte Mitchell[1], Chad Hicks[1]
[1]University of Adelaide, Adelaide, SA, Australia, [2]OneSteel Limited, Dulwich, SA, Australia

C1: Continental-scale geochemical mapping

13:00 - 14:30 LS 3 Chairs: Patrice De Caritat (Australia), Reijo Salminen (Finland)

C1.1 A Geochemical Picture of a Metallogenic ProvinceUsing the Zinc Deposits of Alaska as an Example
Issai Goldberg[1], Grigory Abramson[1], Lev Natapov[1], Chris Haslam[1]
[1]Interesources Pty Ltd, Sydney, Australia, [2]Interesources Pty Ltd, Sydney, Australia, [3]Macquarie University, Sydney, Australia, [4]Exploration Strategy, Melbourne, Australia

C1.2 Inferring Bio-Availability of Nutrients from Overbank Sediment Sampling and MMI Analysis: Preliminary Findings from the National Geochemical Survey of Australia
Alan Mann[1], Patrice de Caritat[1], Pierrette Prince[1]
[1]Consultant, Perth, Australia, [2]Geoscience Australia, Canberra, Australia, [3]SGS, Toronto, Canada

C1.3 China Geochemical Baselines
Xueqiu Wang, Qin Zhang, Qinghua Chi, Shanfa Xu, Lanshi Nie, Bimin Zhang, Jian Zhou
Institute of Geophysical and Geochemical Exploration, Langfang, Hebei, China

C1.4 The quest for REE: known and new exploration targets in Greenland identified by regional stream sediment data
Agnete Steenfelt
GEUS, Copenhagen, Denmark

Coffee, Posters, Exhibition

14:30 - 15:00 Main lobby

A2: Advances in analytical geochemistry (cont.)

15:00 - 16:30 Fellman Hall Chairs: Heikki Niskavaara (Finland), Gwendy Hall (Canada), Brenda Caughlin (Canada)

A2.1 Predicting Elemental Concentrations of Glacial Till by VSWIR Reflectance Spectroscopy
Maarit Middleton[1], Paavo Närhi[1], Viljo Kuosmanen[2], Raimo Sutinen[1]
[1]Geological Survey of Finland, Rovaniemi, Finland, [2]Geological Survey of Finland, Espoo, Finland

A2.2 A new Approach to In-situ Density Determination of Drill Cores
Johanna Helena Susanna Dry, Jeremiah Pelo
Anglo American, Johannesburg, South Africa

A2.3 Characterization of Variance in Reference Materials: Isolating Analytical, Digestion, and Sub-Sampling Errors and Determining a Fundamental Sampling Constant
Cliff Stanley[1], Nelson O'Driscoll[1], Pritam Ranjan[2]
[1]Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada, [2]Dept. of Mathematics & Statistics, Acadia University, Wolfville, Nova Scotia, Canada

A2.4 Use of automated mineralogy for identification of multi-commodity indicator minerals
Hugh de Souza, Kim Gibbs, Chris Gunning, Sarah Prout
SGS Mineral Services, Lakefield, ON, Canada

B2: Applied biogeochemistry (cont.)

15:00 - 16:30 LS 2 Chairs: Fyodor Kot (Israel), Kenneth McQueen (Australia)

B2.1 Regolith carbonate geochemical and plant biogeochemical inter-relationships for the expression of deeply buried mineralisation at the Tunkillia gold prospect, central Gawler Craton, Australia
Benjamin G van der Hoek[1], S M Hill[1], Robert C Dart[1], B Van der Stelt[2]
[1]University of Adelaide, Adelaide, South Australia, Australia, [2]Minotaur Exploration Ltd., Adelaide, South Australia, Australia

B2.2 Metal mobilisation from soils and sediments by hydroxycarboxylic acids of natural origin
Zandra Arwidsson[1], Marie Ålund[2], Bert Allard[2], Stefan Karlsson[2]
[1]SAKAB AB, Kumla, Sweden, [2]Man-Technology-Environment Reserach Centre, Örebro University, Örebro, Sweden

B2.3 On Soil Boron-Organic Matter Association and Bioavailability
Fyodor Kot, Ronit Farran, Malik Kochva, Avi Shaviv
Technion-Israel Institute of Technology, Haifa, Israel

B2.4 Riparian Eucalypt Biogeochemistry for the expression of Groundwater Salinity Hazards in the Murray River, near Loxton, South Australia
Stephanie McLennan, Steven Hill
Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, South Australia, Australia

C2: Continental-scale geochemical mapping (cont.)

15:00 - 16:30 LS 3 Chairs: Patrice De Caritat (Australia), Reijo Salminen (Finland)

C2.1 The National Geochemical Survey of Australia: A New, Quasi-Continental Geochemical Atlas and Dataset to Support Mineral Exploration and Environmental Applications
Patrice de Caritat, Michelle Cooper
Geoscience Australia, Canberra, Australia

C2.2 Element Associations in Southern Labrador Lake Sediments - a Comparison of Two Regions and Two Sample Densities
Stephen Amor, John McConnell, Jerry Ricketts
Geochemistry, Geophysics and Terrain Sciences Section, Geological Survey of Newfoundland and Labrador, St. John's, NL, Canada

C2.3 Regional Biogeochemical Investigations in the Northeast Yilgarn Craton, Western Australia
Nathan Reid[1], Melvyn Lintern[1], Ryan Noble[1], Ravinder Anand[1], David Gray[1], Gordon Sutton[2], Richard Jarrett[2]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]CSIRO Mathematics, Informatics and Statistics, Urrbrae, South Australia, Australia

C2.4 Modelling lithology using groundwater, vegetation and laterite chemistry: results from the Yilgarn Craton, Western Australia
David Gray[1], Ryan Noble[1], Gordon Sutton[2], Nathan Reid[1], Melvyn Lintern[1], Terry Rankine[1], Richard Jarrett[2]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]CSIRO Mathematic, Informatics and Statistics, Urrbrae, South Australia, Australia

Break, Posters, Exhibition

16:30 - 17:00 Main lobby

A3: Advances in exploration isotope geochemistry

17:00 - 18:00 Fellman Hall Chairs: Eero Hanski (Finland), Laura S. Lauri (Finland)

A3.1 Copper and Iron isotopes in mine tailings and their relationship to weathering processes
Nathalie Perez Rodriguez, Peter Nason, Lena Alakangas, Björn Öhlander
Division of Geosciences, Luleå University of Technology, Luleå, Sweden

A3.2 Sulfur and lead isotope geochemistry of the carbonate-hosted Pb-Zn deposit of Jebel Ghozlane (Nappes zone, Northern Tunisia)
Nejib Jemmali[1,2], Fouad Souissi[1], Torsten W Vennemann[3], Emmanuel John M Carranza[4]
[1]Laboratoire des Matériaux Utiles, Sidi Thabet, Tunisia, [2]Laboratoire des Ressources Minérales et Environnement (LRME), Département de Géologie,, El Manar, Tunis, Tunisia, [3]Stable Isotope Lab., Inst. of Mineralogy and Geochemistry, University of Lausanne, Lausanne, Switzerland, [4]Dept. of Earth Systems Analysis, Faculty of Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands

A3.3 Wild mushrooms as an indicators of vertical migration of $^{137}\mathrm{Cs}$ in different types of forests at the Kivalo research area in Northern Finland
Jarkko Ylipieti, Kristina Rissanen
Radiation and Nuclear Safety Authority, Rovaniemi, Finland

B3: Organic geochemistry

17:00 - 18:00 LS 2 Chairs: Carlos Bandeira (Brazil), Aaron Stewart (Australia)

B3.1 Termite mound anomaly formation processes: Understanding termite induced surface metal flux
Aaron Stewart[1], Ravi Anand[1], Michael Verrall[1], Jamie Laird[2], Chris Ryan[3]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Australia, [2]University of Melbourne School of Physics, Melbourne, Australia, [3]University of Tasmania Centre of Excellence in Ore Deposits (CODES), Tasmania, Australia

B3.2 Validation of the Electrochemical Cell Model using observations of surficial hydrocarbon geochemical signatures relative to mineral exploration
Dale Sutherland
Activation Laboratories Ltd., Ancaster, Ontario, Canada

B3.3 History of geochemistry societies ALAGO and SBGq and their meaning for the Brazilian and Latin American scientific development
Carlos S. Bandeira de Mello
Cenpes/Petrobras, -, Brazil

C3: Continental-scale geochemical mapping (cont.)

17:00 - 18:00 LS 3 Chairs: Patrice De Caritat (Australia), Reijo Salminen (Finland)

C3.1 Distribution and mobility of Niobium in European soils
Andreas Scheib, Dee Flight
British Geological Survey, Keyworth, Nottingham, UK

C3.2 How Much Influence do Humans Exert on Regional Geochemical Patterns? - The Cyprus Case
David Cohen[1], Neil Rutherford[1], Eleni Morisseau[2], Andreas Zissimos[2]
[1]University of New South Wales, Sydney, NSW, Australia, [2]Geological Survey Department, Strovolos, Cyprus

Welcome Reception

18:00 - 20:00 Main lobby

Welcome words

Tuesday 23 August

Keynote Address

9:00 - 9:45 Fellman Hall

Key2 Predictive geochemistry in areas of transported overburden: mechanisms of anomaly formation
Ravi Anand
CSIRO Earth Science and Resources Engineering, Kensington, Australia

PARALLEL SESSIONS

A4: Geochemical exploration and mineral prospectivity in GIS

10:00 - 11:30 Fellman Hall Chairs: Vesa Nykänen (Finland), John Carranza (Netherlands)

A4.1 Using Trend surface modeling to identify the geochemical anomaly boundaries
Reza Ghavami-Riabi[1], Zohra Jangravi[1], E. Hajmolla ali[1]
[1]Shahrood Univ. of Technology, Shahrood, Semnan, Iran, [2]Kaniran Company, Tehran, Tehran, Iran

A4.2 Drill hole geochemistry at Wharekirauponga, Golden Cross and Ohakuri epithermal gold prospects, New Zealand
Anthony Christie[1], Richard Carver[2], Joel Thomas[1], Al McOnie[3]
[1]GNS Science, Lower Hutt, New Zealand, [2]GC Xplore, Perth, Australia, [3]Consulting Geologist, Katikati, New Zealand

A4.3 Multi-scale interactions of geological processes during mineralization: cascade dynamics model and multifractal simulation of geochemical landscapes
Lingqing Yao[1], Qiuming Cheng[1]
[1]China University of Geosciences, Wuhan, China, [2]York University, Toronto, Canada

A4.4 Modern spatial analysis methods for geochemical landscape/image processing and interpretation
Qiuming Cheng[1]
[1]York University, Toronto, Canada, [2]China University of Geosciences, Wuhan, China

B4: Predictive geochemistry in arid areas of transported overburden: mechanisms of anomaly formation

10.00 - 11:30 LS 2 Chairs: Mel Lintern (Australia), Nigel Radford (Australia), Brian Townley (Chile)

B4.1 Findings of nanoscale metal particles: direct evidence for deep-penetrating geochemistry
Xueqiu Wang, Rong Ye
Institute of Geophysical and Geochemical Exploration, Langfang, Hebei, China

B4.2 Landscape Geochemical Constraints on Vertical and Lateral Element Dispersion within an area of Deep Cover: an example from the Mundi Mundi Plains, Broken Hill, Australia
Charlotte Mitchell, S. M. Hill
University of Adelaide, Adelaide, SA, Australia

B4.3 Geochemical Exploration in the deep cover of the Olympic Dam IOCG Province, South Australia: context and examples from the lower parts of the Mesozoic sequence in the southwestern Eromanga Basin
Robert C Dart, S M Hill
University Of Adelaide, Adelaide, South Australia, Australia

B4.4 A landscape evolution approach to understanding the geochemical origins of regolith carbonates in the Eucla Basin, southern Australia
Ashlyn Kate Johnson[1], *S. M Hill*[1], *David Chittleborough*[1], *David Mitchell*[1]
[1]*Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, Adelaide, South Australia, Australia,* [2]*Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, Adelaide, South Australia, Australia,* [3]*School of Earth & Environmental Sciences, University of Adelaide, Adelaide, South Australia, Australia,* [4]*Iluka Resources Limited, Adelaide, South Australia, Australia*

C4: New and old discoveries: Geochemical exploration case studies

10:00 - 11:30 LS 3 Chairs: Pasi Eilu (Finland), Erkki Vanhanen (Finland), Krister Sundblad (Finland), Stephen Hore (Australia)

C4.1 Palaeo-redox Fronts Exposed within a Key Section at Four Mile West, South Australia
Stephen Hore[1], *Steven Hill*[2]
[1]*Geological Survey of South Australia (PIRSA), Adelaide, Australia,* [2]*Centre for Tectonics, Resources and Exploration (TRaX), School of Earth & Environmental Sciences, University of Adelaide, Adelaide, Australia*

C4.2 Application of Fractal Concentration-Area Model Based on Enrichment Factor to Delineate Geochemical Anomalies in Stream Sediment Surveys (Case study: Jebal-e-Barez 100,000 Sheet, Iran)
Ali Rafiee
Zanjan University, Zanjan, Iran

C4.3 Characterizing the Hydrocarbon Microseepage-induced Alteration Using Mineralogical, Geochemical and Spectrometric Methods: A Case Study in East Sichuan (China)
Yunpeng Wang, Hua Su, Xuan Ding
Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China

C4.4 Geochemical exploration for rare earths and gold in the Tana Belt, southern side of the Lapland Granulite Belt, Finland
Olli Sarapää, Pertti Sarala
Geological Survey of Finland, Rovaniemi, Finland

Coffee, Posters, Exhibition

11:30 - 12:00 Main lobby

A5: Applied Aqueous Geochemistry

12:00 - 13:30 Fellman Hall Chairs: Kirsti Korkka-Niemi (Finland), Raija Pietilä (Finland), Jarkko Okkonen (Finland)

A5.1 Hydrogeochemical baseline characterization and implications for exploration and environmental assessment of a porphyry molybdenum deposit, Malmbjerg, Greenland
Robert Bowell[1], *Andrew Barnes*[1], *Devin Sapsford*[2], *Daniel Thomas*[2], *Jesper Konfoed*[3]
[1]*SRK Consulting, Cardiff Wales, UK,* [2]*School of Engineering, Cardiff, Wales, UK,* [3]*Quadra FNX, Vancouver, Canada, Canada*

A5.2 Metal and sediment accumulation the in Lake Pyhäjärvi
Jari Mäkinen
Geological Survey of Finland, Kuopio, Finland

A5.3 The Application of Predictive Geochemical Modelling to Determine Backfill Cover Requirements at Turquoise Ridge Joint Venture, Nevada
Ruth Warrender[1], Rob Bowell[1], Amy Prestia[2], Andy Barnes[1], Wayne Mansanares[3], Mark Miller[3]
[1]SRK Consulting (UK) Ltd, Cardiff, UK, [2]SRK Consulting (US), Reno, USA, [3]Barrick Turquoise Ridge, Nevada, USA

A5.4 Concentration dynamics in a boreal catchment – trace elements, REEs and humic substances
Stefan Karlsson, Bert Allard, Viktor Sjöberg
Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden

B5: Predictive geochemistry in arid areas of transported overburden: mechanisms of anomaly formation (cont.)

12:00 - 13:30 LS 2 Chairs: Mel Lintern (Australia), Nigel Radford (Australia), Brian Townley (Chile)

B5.1 Using gum trees for Au exploration in the Eastern Goldfields (Western Australia)
Melvyn Lintern, Ravi Anand
CSIRO, Kensington, WA, Australia

B5.2 An integrated groundwater and regolith study of metal migration through cover at a Ni sulphide deposit, Western Australia
Ryan Noble[1], Melvyn Lintern[1], Ravinder Anand[1], David Gray[1], Nathan Reid[1], Brian Townley[2]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]Department of Earth Sciences, University of Chile, Santiago, Chile

B5.3 Geophysical, geological and indirect geochemical exploration of covered terrains in Northern Chile: from regional to local scale
Brian Townley[1], Diana Comte[3], Daniel Carrizo[2], Alvaro Puig[4], Gonzalo Yañez[4]
[1]Dept. of Geology, University of Chile, Santiago, Chile, [2]Mining Technology Center, University of Chile, Santiago, Chile, [3]Dept. of Geophysics, University of Chile, Santiago, Chile, [4]Codelco - Chile, Santiago, Chile

B5.4 Multifractal Methods for Identification of Weak Anomalies Caused by Buried Sources from Surface Geochemical Landscape in Covered Terrances
Qiuming Cheng[1]
[1]York University, Toronto, Canada, [2]China University of Geosciences, Wuhan, China

C5: New and old discoveries: Geochemical exploration case studies (cont.)

12:00 - 13:30 LS 3 Chairs: Pasi Eilu (Finland), Erkki Vanhanen (Finland), Krister Sundblad (Finland), Stephen Hore (Australia)

C5.1 Surface Geochemical Exploration at the Rompas Au-U Discovery, Ylitornio, Finland
Lars Dahlenborg, Erkki Vanhanen, Terry Lees, Michael Hudson
Mawson Resources Ltd, Vancouver, Canada

C5.2 Geochemistry, Petrology and Fluid Characteristics of Rapakivi-hosted Polymetallic Quartz Veins in the Sarvlaxviken area, southeastern Finland
Mira Valkama[1], Curt Broman[2], Krister Sundblad[1], Nigel J. Cook[3], Rune Nygård[4]
[1]Department of Geography and Geology, University of Turku, Turku, Finland, [2]Department of Geological Sciences, University of Stockholm, Stockholm, Sweden, [3]Centre for Tectonics, Resources and Exploration (TRaX), School of Earth and Environmental Sciences, University of Adelaide, Adelaide, Australia, [4]Ödemarksvägen 107, Broby, Finland

C5.3 Exploration potential in the appinitic rocks of the central Lapland granitoid complex, Finland
Laura S Lauri[1], Olli Sarapää[1], Thair Al Ani[2]
[1]Geological Survey of Finland, Rovaniemi, Finland, [2]Geological Survey of Finland, Espoo, Finland

C5.4 Regolith-landform mapping and exploration geochemistry in south Mali
A.P.J. Bristow[1], C.R.M. Butt[2]
[1]Peruvian Latin Resources SAC, Lima, Peru, [2]CSIRO Earth Science & Resource Engineering, Bentley, Australia

Lunch, Posters, Exhibition

13:30 - 14:30 Restaurant Felli

Keynote Address

14:30 - 15:15 Fellman Hall

Key3 Analysis and mapping of stream sediment geochemical anomalies: should we logratio-transform the data?
Emmanuel John M. Carranza
Department of Earth Systems Analysis, Faculty of Geo-Information Science and Earth Observation (ITC) University of Twente, Enschede, The Netherlands

Coffee, Posters, Exhibition

15:15 - 15:45 Main lobby

PARALLEL SESSIONS

A6: Applied Aqueous Geochemistry (cont.)

15:45 - 17:15 Fellman Hall Chairs: Raija Pietilä (Finland), Jarkko Okkonen (Finland)

A6.1 Speciation of trace metals in a contaminated stream at the Laver mine by using membrane filtration, ultrafiltration, DGT and transplanted aquatic moss
Björn Öhlander, Jerry Forsberg, Helene Österlund, Johan Ingri, Frauke Ecke, Lena Alakangas
Luleå University of Technology, Luleå, Sweden

A6.2 Carbon and Nitrogen Concentrations and Isotopic Composition in Sediments of Lakes Receiving Nitrogen Rich Mine Effluents
Sara Chlot, Anders Widerlund, Björn Öhlander
Div of Geosciences, Luleå University of Technology, Luleå, Sweden

A6.3 Solid Characterization of Nano-Sized Hydroxyapatite after the Exposure to an Aqueous Fluoride Solution
Vanessa A. S. Sternitzke[1], Ralf Kaegi[2], C. Annette Johnson[1]
[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Water Resources and Drinking Water, Duebendorf, Switzerland, [2]Eawag, Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Process Engineering, Duebendorf, Switzerland

A6.4 Hydrogeochemical assessment of surface water - groundwater interaction: model development
Dmytro Siergieiev, Angela Lundberg
Luleå University of Technology, Luleå, Sweden

B6: Special session: The 10th Finnish Geochemistry Day

15:45 - 17:15 LS 2 Chairs: Kirsti Korkka-Niemi (Finland), Pertti Sarala (Finland)

B6.1 Classification of waste from extractive industry as inert - the use of litogeochemical data to define inert rock types
Teemu Karlsson, Anna Tornivaara, Hannu Luodes, Soile Aatos, Maria Nikkarinen, Päivi Kauppila
Geological Survey of Finland, Kuopio, Finland

B6.2 Geochemical Baselines in the Pirkanmaa region, Finland
Tarja Hatakka, Timo Tarvainen, Jaana Jarva, Birgitta Backman, Mikael Eklund, Pekka Huhta, Niilo Kärkkäinen, Samrit Luoma
Geological Survey of Finland, Espoo, Finland

B6.3 Relationships between bedrock geochemistry and till geochemistry in the Redstone area, south cental British Columbia, Canada
Jaakko Hietava[1]
[1]University of Oulu, Oulu, Finland, [2]Outokumpu Chrome Oy, Kemi, Finland

B6.4 Factors that affect the occurrence of Cr(VI) in acidic mine waters
Auri Koivuhuhta[1], Marja Liisa Räisänen[2]
[1]University of Eastern Finland, Kuopio, Finland, [2]Centre for Economic Development, Transport and the Environment, Kajaani, Finland

B6.5 Quaternary geology, till geochemistry and heavy minerals at Suurikuusikko, Kittilä, northern Finland
Anne Peltoniemi-Taivalkoski[1], Pertti Sarala[2]
[1]-, Rovaniemi, Finland, [2]Geological Survey of Finland, Rovaniemi, Finland

B6.6 Pathways of metals from bedrock and soil into water and berries in the Sarvlaxviken area, SE Finland
Sari Myllymäki[1], Krister Sundblad[1], Kirsti Korkka-Niemi[2], Eila Varjo[1], Mira Valkama[1], Rainer Huopalahti[3]
[1]Department of Geography and Geology, University of Turku, Turku, Finland, [2]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland, [3]Department of Biochemistry and Food Chemistry, University of Turku, Turku, Finland

B6.7 Alteration styles and geochemical zonation at the Raitevarri Cu-Au occurrence, Karasjok, Norway
Jani Jäsberg[1], Pasi Eilu[2], V. Juhani Ojala[3]
[1]University of Turku, Turku, Finland, [2]Geological Survey of Finland, Espoo, Finland, [3]Store Norske Gull AS, Rovaniemi, Finland

B6.8 Till geochemistry and indicator minerals in the interpretation of the thick till sequence at Muhos, central western Finland
Juha-Pekka Lunkka, Vesa Peuraniemi, Tiina Nikarmaa
Department of Geosciences, University of Oulu, Oulu, Finland

C6: New and old discoveries: Geochemical exploration case studies (cont.)

15:45 - 17:15 LS 3 Chairs: Pasi Eilu (Finland), Erkki Vanhanen (Finland), Krister Sundblad (Finland), Stephen Hore (Australia)

C6.1 Soil geochemistry and magnetometry evidence for extensive and complex rapakivi-related mineralization in the Sarvlaxviken area, southeastern Finland
Krister Sundblad[1], Mira Valkama[1], Karoliina Penttinen[1], Rune Nygård[2]
[1]University of Turku, Turku, Finland, [2]Ödemarksvägen 107, Broby, Finland

C6.2 A multi-element geochemical approach to finding copper in the central African Copperbelt
Frank Santaguida[1], Doug Jack[2], Mattias Fackel[2], Hugh Carruthers[2], Godeffroid Kazardi[2], Alex Ferrar[2], Everisto Gocha[2]
[1]FQM Kevitsa Mining Oy, Sodankylä, Finland, [2]First Quantum Minerals Ltd., Ndola, Zambia

C6.3 Tourmaline- and sulfide-bearing, graphitic pelitic gneisses of the Paleoproterozoic Wollaston Group, northern Saskatchewan: new insights into understanding the carbon-sulfur-boron-uranium geochemical system with implications for U/C-type uranium deposits
Irvine R. Annesley[1,2], *Robert Millar*[2,3]
[1]JNR Resources Inc., Saskatoon, Saskatchewan, Canada, [2]Department Geological Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [3]Saskatchewan Research Council, Saskatoon, Saskatchewan, Canada

C6.4 The Frederick Project: Geochemical exploration for sediment-hosted base metals in covered terrain in the Bangemall Basin, Western Australia
Richard Mazzucchelli
Searchtech Pty Ltd, Kalamunda, WA, Australia

Concert

19:00 - 19:45 Rovaniemi Church

Rovaniemi City Reception

20:00 - 22:00 Rovaniemi City Hall, Hallituskatu 7
Hosted by *Mauri Gardin*, Mayor of Rovaniemi

Wednesday 24 August

AAG Distinguished Lecturers' Night

18:00 - 20:00	**Santa Claus Conference Centre, Santa's Hotel Santa Claus**
AAG1	Considerations for optimizing screen (metallics) gold fire assay *Scott Long* *AMEC, Mining & Metals: Mining Consulting Group (formely MRDI), USA*
AAG2	The Role of Applied Geochemistry in the Mining Life Cycle *Robert Bowell* *SRK Consulting, Cardiff, UK*

Pub Night

20:00 - 22:00 **Hemingways, Koskikatu 11**
Sponsored by SGS Minerals Services

Thursday 25 August

Keynote Address

9:00 - 9:45	**Fellman Hall**
Key4	Geochemical mapping; past, present, future *Reijo Salminen* *Geological Survey of Finland, Espoo, Finland*

Special session: 'Forerunner of geochemical mapping and analysis methods' - honorary session for the 125th anniversary of the Geological Survey of Finland

9:45 - 11:30	**Fellman Hall**	**Chairs: Risto Pietilä (Finland), Vesa Peuraniemi (Finland)**
SS1	The early stages of geochemical mapping in Finland *Kalevi Kauranne* *Espoo, Finland*	
SS2	Highlights of exploration geochemistry in Finland *Heikki Papunen* *Department of Geology, University of Turku, Turku, Finland*	
SS3	Regional geochemical surveys in Australia *C.R.M. Butt* *CSIRO Earth Science & Resource Engineering, Bentley, Australia*	
SS4	Mineral Exploration at Spitsbergen in the High Arctic *Rolf Tore Ottesen[1] and Morten Often[2]* *[1]Geological Survey of Norway, Trondheim, Norway, [2]Store Norske Gull AS, Longyearbyen, Norway*	

SS5 The use of dogs in prospecting
Jorma O. Valkama[1], V. Juhani Ojala[2]
[1]Geological Survey of Finland, Rovaniemi, Finland, [2]Store Norske Gull AS, Rovaniemi, Finland

Coffee, Posters, Exhibition

11:30 - 12:00 Main lobby

PARALLEL SESSIONS

A7: Urban Geochemistry

12:00 - 13:30 Fellman Hall Chairs: Amélie Paula Reis (Portugal), Andreas J. Scheib (United Kingdom)

A7.1 Soil arsenic risk map of Pirkkala municipality, Finland
Timo Tarvainen[1], Birgitta Backman[1], Samrit Luoma[1], Vesa Vanninen[2], Jaana Jarva[1], Tarja Hatakka[1]
[1]Geological Survey of Finland, Espoo, Finland, [2]Municipality of Pirkkala, Pirkkala, Finland

A7.2 National geochemical baseline database - Tapir
Jaana Jarva, Timo Tarvainen, Mikael Eklund
Geological Survey of Finland, Espoo, Finland

A7.3 Environmental assessment of Ni and Cd in topsoil and ground-level dust from urban playgrounds, public gardens and parks from Lisbon, Portugal
Amélia Reis[1], Carla Patinha[1], Eduardo Ferreira da Silva[1], Ana Dias[1], Sofia Bartolomeu[2], António Sousa[3], Anabela Cachada[4], Maria Batista[5], Cátia Prazeres[5], Rui Figueira[3], Cecília Sérgio[6], Rita Salgueiro[1], Orquidia Neves[3], Armando Duarte[4]
[1]GEOBIOTEC, University of Aveiro, Aveiro, Portugal, [2]Physics Department, University of Aveiro, Aveiro, Portugal, [3]CERENA-Technical Superior Institute, Lisbon, Portugal, [4]CESAM, University of Aveiro, Aveiro, Portugal, [5]LNEG, Lisbon, Portugal, [6]Jardin Botânico - MNHN, Lisbon, Portugal

A7.4 Geochemistry of kindergarten playground soils in Zagreb, Croatia
Slobodan Miko, Martina Šparica Miko, Ozren Hasan, Saša Mesić, Nikolina Ilijanić
Hrvatski geološki institut - Croatian geological survey, Zagreb, Croatia

B7: Indicator minerals and trace elements in exploration in glaciated terrain

12:00 - 13:30 LS 2 Chairs: Isabella McMartin (Canada), Beth McClenaghan (Canada), Norman Moles (United Kingdom)

B7.1 Exploration for Concealed Deposits using Porphyry Indicator Minerals (PIMs): Application of Apatite Texture and Chemistry
Farhad Bouzari[1], Craig J.R. Hart[1], Shaun Barker[1], Thomas Bissig[1]
[1]Mineral Deposit Research Unit, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, British Columbia, Canada, [2]Geoscience BC, Vancouver, British Columbia, Canada

B7.2 Glacial Dispersal of Indicator Minerals from the Izok Lake Zn-Cu-Pb-Ag VMS Deposit, Nunavut, Canada
Anna Hicken[1], Beth McClenaghan[2], Dan Layton-Matthews[1], Roger Paulen[2]
[1]Queen's University, Kingston, Ontario, Canada, [2]Geological Survey of Canada, Ottawa, Ontario, Canada

B7.3 Magnetite composition applied to drift prospecting methods for IOCG exploration in the Great Bear magmatic zone, Canada: results from the NICO Au-Co-Bi deposit
Isabelle McMartin[1], Louise Corriveau[1], Georges Beaudoin[2], Simon Jackson[1], Philippe Normandeau[3]
[1]Geological Survey of Canada, Ottawa, Ontario, Canada, [2]Department of Geology and Geological Engineering, Laval University, Quebec City, Quebec, Canada, [3]Department of Earth and Planetary Sciences, McGill University, Montreal, Quebec, Canada

B7.4 Microchemical characterization of placer gold: Application in exploring glaciated terrains for volcano-hydrothermal and orogenic gold mineralization
Norman Moles[1], Rob Chapman[2]
[1]University of Brighton, Brighton, UK, [2]University of Leeds, Leeds, UK

C7: Role of genetic models in exploration

12:00 - 13:30 LS 3 Chairs: Robert Bowell (United Kingdom), Keith Scott (Australia)

C7.1 Trace Element and Radiogenic Isotope Geochemistry of the ~1.1 Ga Midcontinent Rift of North America: Implications for the Discovery of Ni-Cu-PGE Deposits
Pete Hollings[1], Mark Smyk[1]
[1]Lakehead University, Thunder Bay, Ontario, Canada, [2]Ontario Geological Survey, Thunder Bay, Ontario, Canada

C7.2 Geology and Geochemistry of the Simpson Island Dyke, NWT, Canada
Thomas Mumford[1], John Ketchum[2], Brian Cousens[1]
[1]Carleton University, Ottawa, Canada, [2]Northwest Territories Geoscience Office, Yellowknife, Canada

C7.3 Siderite chemistry: exploration implications for Proterozoic stratiform Zn-Pb-Ag mineralisation, northern Australia
Keith Scott[1], Ben Johnson[3], Greg Yaxley[1]
[1]Australian National University, Canberra ACT, Australia, [2]CSIRO, Nrth Ryde NSW, Australia, [3]Mineral Mining Group, Garbutt QLD, Australia

Lunch, Posters, Exhibition

13:30 - 14:30 Restaurant Felli

Keynote Address

14:30 - 15:15 Fellman Hall

Key5 Geochemistry of Landscapes Covered by Glacially Crushed Debris
William W. Shilts
Prairie Research Institute, University of Illinois-Urbana, Champaign, USA

Coffee, Posters, Exhibition

15:15 - 15:45 Main lobby

PARALLEL SESSIONS

A8: Harmful metals and arsenic - geochemical anomalies and contaminated soil

15:45 - 17:45 Fellman Hall **Chairs: Tiina Nieminen (Finland), Timo Tarvainen (Finland)**

A8.1 Natural arsenic in Northern Sweden - a risk assessment
Gunnar Jacks, Magnus Mörth, Zdenka Slejkovec
KTH, Stockholm, Sweden

A8.2 Baseline Geochemical Investigation of Heavy Metals in Soils around Polokwane Area, Limpopo Province, South Africa
Jason Samuel Ogola, Humbulani Rejune Mundalamo, Guenther Brandl
University of Venda, Thohoyandou- Limpopo Province, South Africa

A8.3 Relevance of Arsenic Binding to Humic Acid in the Presence of Copper Ions
Xiaolan Liu[1], Maarten Nachtegaal[1], Christian Ludwig[2], Evgeny Kleymenov[1], Yongguang Zhu[3]
[1]Paul Scherrer Institute (PSI), 5232 Villigen PSI, Switzerland, [2]Swiss Federal Institute of Technology (EPFL-IIE), CH-1015 Lausanne, Switzerland, [3]Research Center for Eco-Environmental Science (RCEES), Beijing 100085, China

A8.4 Redistribution of arsenic in two lakes affected by historical mining activities, Stollberg, Sweden
Mattias Bäckström
Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden

A8.5 Mercury in Bottom Sediments of the Amur River, Its Flood-Plain Lakes and Estuary, Eastern Siberia
Fyodor Kot[1], Konstantin Bakanov[2], Nikolay Goryachev[3]
[1]Technion-Israel Institute of Technology, Haifa, Israel, [2]Institute of Water and Ecological Problems, FEB RAS, Khabarovsk, Russia, [3]Ministry of Agriculture and Forestry, Biosecurity New Zealand, Auckland, New Zealand

B8: Indicator minerals and trace elements in exploration in glaciated terrain (cont.)

15:45 - 17:15 LS 2 **Chairs: Isabella McMartin (Canada), Beth McClenaghan (Canada), Norman Moles (United Kingdom)**

B8.1 Characterization of glacial dispersal from the Kiggavik Uranium Deposit, Nunavut using indicator minerals and till geochemistry
Scott Robinson[1], Beth McClenaghan[2], Roger Paulen[2], Dan Layton-Matthews[1], Charlie Jefferson[2], David Quirt[3], Peter Wollenberg[3]
[1]Queen's University, Kingston, Ontario, Canada, [2]Geological Survey of Canada, Ottawa, Ontario, Canada, [3]AREVA Resources Canada INC., Saskatoon, Saskatchewan, Canada

B8.2 Exploration at the thin- to thick-drift transition: challenges and approaches
Phillip Larson
Duluth Metals Limited, Duluth, MN, USA

B8.3 Stream Sediment Geochemistry used to generate and validate exploration target for Volcanogenic Massive Sulphides in the Peruvian Coastal Mountains
Keller Guerra
Votorantim Metais, Lima, Lima, Peru

B8.4 Glacial dispersal and mode of occurrence of metals in till and esker gravel at Kumpuselkä, northern Finland
Vesa Peuraniemi, Tiina Eskola
Department of Geosciences, Univeristy of Oulu, Oulu, Finland

B8.5 Post-glacial element transport from sulphide mineralisation through carbonate cover
Pim van Geffen[1,2], Kurt Kyser[1], Christopher Oates[2], Christian Ihlenfeld[3]
[1]Queen's University, Kingston, ON, Canada, [2] ioGlobal Solutions Inc, Canada, [3]Applied Geochemistry Solutions, Gerrards Cross, UK, [4]Anglo American plc, London, UK

B8.6 Geochemical exploration models for porphyry deposits in British Columbia, Canada
Fred Blaine, Craig Hart
Mineral Deposit Research Unit, University of British Columbia, Vancouver, BC, Canada

C8: Partial/selective digestion geochemistry

15:45 - 17:15 LS 3 **Chairs: Cliff Stanley (Canada), Paul Morris (Australia)**

C8.1 Exploring in Areas of Thick Cover: Fine Fraction Gold Chemistry from the Eastern Yilgarn Craton, Western Australia
Paul Morris
Geological Survey of Western Australia, Perth, Western Australia, Australia

C8.2 Snow samples as a viable method in the exploration for gold and base metals
Nadezda Yavorskaya, George Gale
GIS of NAD-ia, Winnipeg, Manitoba, Canada

C8.3 Conceptual and Mathematic Models of Dispersal Patterns and Trains in Areas of Glaciated Terrain
Alexey Marchenko
Tellur North-East L.L.C., Tellur Group of Companies, Saint Petersburg, Russia

C8.4 What Happens When We Dry a Soil Sample During Sample Preparation? : Implications for Partial Digestion Geochemistry
Cliff Stanley, Biniam Bisrat
Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada

C8.5 Partial Digestion Geochemistry in Soil Samples: Monitoring (pH-pE) Digestion Conditions to Understand How Samples Leach
Biniam Bisrat[1], Cliff Stanley[1], John Murimboh[2]
[1]Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada, [2]Dept. of Chemistry, Acadia University, Wolfville, Nova Scotia, Canada

C8.6 Estimating nickel in sulphide minerals in ultramafic nickel deposits
Scott Long
AMEC Mining and Metals Consulting Group, Phoenix, AZ, USA

Official Dinner

20:00 **Sky Hotel Ounasvaara**
Bus transfer from conference hotels
to dinner venue and back.

Friday 26 August

PARALLEL SESSIONS

A9: Applied Aqueous Geochemistry (cont.)

9:00 - 10:30 Fellman Hall Chairs: Kirsti Korkka-Niemi (Finland), Raija Pietilä (Finland), Jarkko Okkonen (Finland)

A9.1 Surface water-groundwater interactions at Lake Pyhäjärvi, SW Finland : Chemical and isotopic systematics
Kirsti Korkka-Niemi, Anne Rautio
University of Helsinki, Helsinki, Finland

A9.2 Tracing groundwater-river water interaction using geochemical indicators in the catchment of the River Vantaa and its tributaries, Southern Finland
Anne Rautio[1], Kirsti Korkka-Niemi[1], Anna-Liisa Kivimäki[2], Juha Karhu[1], Kirsti Lahti[2], Maria Nygård[1], Veli-Pekka Salonen[1], Heli Vahtera[2]
[1]University of Helsinki,Department of Geosciences and Geography, Helsinki, Finland, [2]Water Protection Association of the River Vantaa and Helsinki Region, Helsinki, Finland

A9.3 Interpretation of geochemical well test data for Wells OW-903B, OW-904B and OW-909 Olkaria Domes Geothermal Field, Kenya
Sylvia Joan Malimo
University of Iceland, Reykjavik, Iceland

A9.4 Application of a DGT -method for Determination of Nutrient and Trace Element Bioavailability in Peat Soil After a Clear-Cut
Marita Turunen, Liisa Ukonmaanaho, Marjatta Kantola, Arja Tervahauta, Tiina Maileena Nieminen
Finnish forest Research Institute, Vantaa, Finland

B9: Geochemical research in mine districts and the environment after closure of mines

9:00 - 10:30 LS 2 Chairs: Bruno Lemière (France), Päivi Kauppila (Finland)

B9.1 Geochemical assessment of arsenic toxicity in mine waste along the proposed Mineral Tramway Project, Redruth, Cornwall
Robert Bowell[1], Ben Rees[2]
[1]SRK Consulting, Cardiff, Wales, UK, [2]Geotechnology, Neath, Wales, UK

B9.2 Bonemeal filters for treatment of acidic and neutral metal-laden mine waters
Lotta Sartz[1], Erik Larsson[1], Mattias Bäckström[2]
[1]Bergskraft Bergslagen, Kopparberg, Sweden, [2]Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden

B9.3 Evidence for long-term pollution from mine sites in lake sediment records in the Haveri and Ylöjärvi mine sites, SW Finland
Annika Parviainen[1], Tommi Kauppila[2], Kirsti Loukola-Ruskeeniemi[3]
[1]Aalto University School of Engineering, Espoo, Finland, [2]Geological Survey of Finland, Kuopio, Finland, [3]Geological Survey of Finland, Espoo, Finland

C9: Recent developments in lithogeochemical methods with exploration applications

9:00 - 10:30 LS 3 Chairs: Hannu Makkonen (Finland), Hugh de Souza (Canada)

C9.1 Geochemical Exploration of Blind Gold-Copper Deposits by Ionex Technology In the Great Australian Basin, New South Wales, Australia
Issai Goldberg, Grigory Abramson, Bob Close
Interesources Pty Ltd, Sydney, NSW, Australia

C9.2 Recent Developments in Geochemical and Electrical Prospecting for Au and PGE: Methods and Case Studies
Alexey Marchenko[1], Konstantin Blinov[2], Vadim Ilchenko[3]
[1]Tellur North-East L.L.C., Tellur Group of Companies, Saint Petersburg, Russia, [2]Tellur Nord-West L.L.C., Tellur Group of Companies, Saint Petersburg, Russia, [3]Tellur North-East L.L.C., Tellur Group of Companies, Saint Petersburg, Russia

C9.3 Lithological Discrimination in Deeply Weathered Terrains Using Multielement Geochemistry An example from the Yanfolila Gold Project, SW Mali
Chris Benn[1], Neil Jones[2], Kiril Mugerman[2]
[1]Gold Fields Canada, Vancouver, Canada, [2]Gold Fields Mali, Bamako, Mali

C9.4 Application of 3D Multi-Element Geochemistry to Mineral Exploration and Development: Cerro Jumil Gold (Silver) Skarn Deposit, Mexico.
L Graham Closs[1], Dean Turner[1], Bill Bond[1]
[1]Colorado School of Mines, Golden, Colorado, USA, [2]Exploration Geotechnologies, Littleton, Colorado, USA, [3]Esperanza Resources Corp, Denver, Colorado, USA

Coffee, Posters, Exhibition

10:30 - 11:00 Main lobby

A10: Sampling and real-time analysis methods in geochemical studies

11:00 - 12:30 Fellman Hall Chairs: Graham L. Closs (United States), Juhani Ojala (Finland)

A10.1 Field Portable X-Ray Fluorescence Geochemical Analysis of Trees, Mull and Soils for Exploration and Environmental Site Assessment
Richard Glanzman[1], L Graham Closs[1]
[1]Glanzman Geochemical LLC, Lakewood, Colorado, USA, [2]Colorado School of Mines, Golden, Colorado, USA

A10.2 Practical application of portable XRF analyzer
Alexander Mikhailov[1]
[1]SRK Exploration Services, Cardiff, Wales, UK, [2]Mineral Exploration Network (Finland) ltd, Cardiff, Wales, UK

B10: Geochemical research in mine districts and the environment after closure of mines (cont.)

11:00 - 12:30 LS 2 Chairs: Bruno Lemière (France), Päivi Kauppila (Finland)

B10.1 Sewage Sludge as a Sealing Layer for the Remediation of Sulphide-bearing Mine Tailings - Ageing and Degradation of the Barrier Material
Peter Nason, Lena Alakangas, Björn Öhlander
Luleå University of Technology, Luleå, Norrbotten, Sweden

B10.2 Geochemical processes in an historical alum shale dump, Kvarntorp, Sweden
Mattias Bäckström, Sara Häller, Bert Allard
Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden

B10.3 Geology, geochemistry and hydrogeology of coal mine impacted catchments, West Coast, South Island, New Zealand
James Pope[1], *Andy Mackenzie*[1], *Paul Weber*[2]
[1]CRL Energy Ltd, Christchurch, New Zealand, [2]Solid Energy New Zealand Ltd, Christchurch, New Zealand

C10: Recent developments in lithogeochemical methods with exploration applications (cont.)

11:00 - 12:30 LS 3 Chairs: Hannu Makkonen (Finland), Hugh de Souza (Canada)

C10.1 Lithogeochemistry and Geology of the Palaeoproterozoic (1.88 Ga) Hitura Nickel Deposit, western Finland
Hannu V. Makkonen[1], *Mikko Suikkanen*[2], *Olli-Pekka Isomäki*[1], *Ville-Matti Seppä*[1]
[1]Belvedere Mining Oy, Nivala, Finland, [2]Talvivaaran Kaivososakeyhtiö Oyj, Sotkamo, Finland

C10.2 Interpretation of geochemical data to characterize variability in geometallurgical applications
Hugh de Souza, Cristian Dragusanu
SGS Minerals Services, Toronto, Ontario, Canada

C10.3 Pearce and General Element Ratio Diagrams: Molar Scatterplots Allowing Rigorous Investigation of Material Transfer in Geochemical Systems
Cliff Stanley
Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada

Lunch, Posters, Exhibition

12:30 - 13:30 Restaurant Felli

Keynote Address

13:30 - 14:15 Fellman Hall

Key6 Environmental Geochemistry of Sulfide Bearing Mine Wastes: Prediction and Remediation
David W. Blowes, Carol J. Ptacek
University of Waterloo, Department of Earth and Environmental Sciences, Canada

Conference Closing

14:15 - 15:00 Fellman Hall

Summary by AAG
Invitation to the 26th IAGS 2013
Closing

Posters

P1 An Ion Chromatography Method for the Determination of Soluble Salts in Soil Samples from Cyprus
Andreas Zissimos[1], Irene Christoforou[1], Eleni Morisseau[1], David Cohen[2]
[1]Geolgical Survey Department, Strovolos, Cyprus, [2]University of New South Wales, Sydney, NSW, Australia

P2 Novel Geological Exploration Applications of Mobile Metal Ion Technology using Dynamic Reaction Cell ICP-MS
Nicholas Turner, Pierrette Prince
SGS Minerals Services, Toronto, Canada

P3 Modifying the Diffusive Gradients in Thin Films Technique for the Geochemical Exploration of Gold
Andrew Lucas[1], Andrew Rate[1], Ursula Salmon[1], Hao Zhang[2]
[1]University of Western Australia, Perth, WA, Australia, [2]Lancaster University, Lancaster, UK

P4 Zircon U-Pb geochronology of the Jade of the Medal for the Beijing 2008 Olympic Games
Zhengyu Zhou, Hao Cheng
School of Ocean and Earth Science, Tongji University, Shanghai, China

P5 Examining the geochemical potential for using multiple isotope systems in the basement lithologies of the Athabasca Basin to vector towards mineralization
Robert Millar[1], Irvine R. Annesley[3], Kevin Ansdell[1]
[1]University of Saskatchewan, Saskatoon, SK, Canada, [2]Saskatchewan Research Council, Saskatoon, SK, Canada, [3]JNR Resources, Saskatoon, SK, Canada

P6 Magma genesis in the El Teniente Porphyry Copper and implications to tectono-magmatic evolution of the Central Chile Neogene Metallogenic Belt
Marcia Muñoz[1], Brian Townley[1], Reynaldo Charrier[1], Mark Fanning[2], Victor Maksaev[1], Katja Deckart[1]
[1]Department of Geology, University of Chile, Santiago, Chile, [2]Research School of Earth Sciences, Australian National University, Camberra, Australia

P7 Geochemistry of overburden and surface sea sediments at the Olkiluoto Island area, SW Finland
Anne-Maj Lahdenperä
Pöyry Finland oy, Vantaa, Finland

P8 A multispecies tracer test in a detritic aquifer (SE Spain)
Gloria Teijón[1], Joaquín Jiménez-Martínez[2], Lucila Candela[1]
[1]Department of Geotechnical Engineering. Technical University of Catalonia, Barcelona, Spain, [2]Geosciences Rennes UMR 6118. Université de Rennes 1, Rennes, France

P9 Fluoride contamination in ground- and surface-water in La Aldea valley (Gran Canaria, Canary Islands, Spain): past and present
Tatiana Cruz[1], Montserrat Espino-Mesa[2], Annetty Benavides[3], María del Carmen Cabrera[4], José Manuel Hernández-Moreno[5]
[1]University of Las Palmas de gran Canaria, Las Palmas, Gran Canaria, Spain, [2]Área de Salud, Las Palmas, Gran Canaria, Spain, [3]University of Las Palmas de gran Canaria, Las Palmas, Gran Canaria, Spain, [4]University of Las Palmas de gran Canaria, Las Palmas, Gran Canaria, Spain, [5]University of La Laguna, La Laguna, Tenerife, Spain

P10 Exploring for Ni mineralisation beneath cover using soil and vegetation at North Miitel, Kambalda, Western Australia
Melvyn Lintern, Ryan Noble, Nathan Reid, Ravi Anand
CSIRO, Kensington, WA, Australia

P11 Geochemical Cycle of Selenium in the Catchment of Fujiang River
Tao Yu[1], Zhongfang Yang[1], Qingye Hou[1], Xiaohuan Xi[2], Xueqi Xia[1]
[1]China University of Geosciences,Beijing, Beijing, China, [2]China Geological Survey, Beijing, China

P12 Biogeochemical Study over Iron Ore Deposit - A Case from Sanandaj-Sirjan Structural Zone - Iran
Adel Emami[1], Ahmad Reza Mokhtari[1], Nader Fathianpour[1], Mohammad Javad Zarei[1], Mohsen Soleimani[2]
[1]Department of Mining Engineering-Isfahan University of Technology, Isfahan, Iran, [2]Department of Soil Science-The University of Guilan, Rasht,Guilan, Iran

P13 Release of vanadium from LD-slag - Influence of organic carbon and water saturation
Viktor Sjöberg[1], Kristen Todd[1], Lotta Sartz[2], Stefan Karlsson[1]
[1]Man-Technology-Environment Research Centre, Örebro, Sweden, [2]Bergskraft Bergslagen, Kopparberg, Sweden

P14 Leaching of low-grade black shale for recovery of vanadium, molybdenum and uranium
Viktor Sjöberg, Heloise Tachauer, Anna Grandin, Stefan Karlsson
Man-Technology-Environment Research Centre, Örebro, Sweden

P15 Stable isotopes from fracture calcites and sulfides as an evidence for paleofluid circulation in crystalline bedrock at Olkiluoto, Finland
Elina Sahlstedt[1], Juha Karhu[1], Petteri Pitkänen[2]
[1]University of Helsinki, Helsinki, Finland, [2]Posiva Oy, Olkiluoto, Finland

P16 Bacterial and fungal community structures in manganese oxide deposits in Sambe hot spring in Shimane, Japan
Keiko Sasaki, Yoshitaka Uejima, Atsushi Sakamoto, Junichiro Ishibashi
Kyushu University, Fukuoka, Japan

P17 Lack of some plant material: selection of suitable dilution factor for pressed pellets measured by EDXRF
Ričardas Taraškevičius[1], Jolanta Radžiūnienė[2], Rimantė Zinkutė[1], Audronė Petrauskienė[3]
[1]Institute of Geology and Geography of Nature Research Centre, Vilnius, Lithuania, [2]Institute of Botany of Nature Research Centre, Vilnius, Lithuania, [3]Institute of Ecology of Nature Research Centre, Vilnius, Lithuania

P18 Investigations of two ombrotrophic peat bogs in Lithuania
Rimantė Zinkutė, Ieva Baužienė, Kazimieras Dilys, Julius Taminskas, Ričardas Taraškevičius
Nature Research Centre Institute of Geology and Geography, Vilnius, Lithuania

P19 Mobilization of Vanadium from LD slag by salt-roasting/alkaline heterotrophic leaching
Anna Grandin, Viktor Sjöberg, Stefan Karlsson
University of Örebro, Man-Technology-Environment Research Centre, Örebro, Sweden

P20 Biogeochemical Signatures and Relationships to Rare Earth Element and Zirconium Mineralization at the Norra Kärr Deposit, Southern Sweden
Britt Bluemel[1], Colin Dunn[2], Craig Hart[3], Mark Saxon[4]
[1]ioGlobal Solutions Inc, BC, Canada, [2]GSC, BC, Canada, [3]MDRU - UBC, BC, Canada, [4]Tasman Metals Inc, BC, Canada

P21 Transfer of chromium and nickel in soil-plant system in Slovakia
Eva Komanická, Ondrej Ďurža, Ján Čurlík, Ľubomir Jurkovič
Comenius University Bratislava, Faculty of Natural Sciences, Department of Geochemistry, Bratislava, Slovakia

P22 National geochemical survey in China
Xiaohuan Xi[1], Min Li[1], Zhongfang Yang[1], Hangxin Cheng[3], Guohua Zhou[3], Guiyi Xiao[1]
[1]China Geological Survey, Beijing, China, [2]China University of Geosciences, Beijing, China, [3]Institute of Geophysical and Geochemical Exploration, Hebei, China

P23 Identification of the hidden relations between variables and mineralization
Reza Ghavami-Riabi[1], Zohra Jangravi[1], E. Hajmolla ali[1]
[1]Shahrood Univ. of Technology, Shahrood, Semnan, Iran, [2]Kaniran Company, Tehran, Tehran, Iran

P24 Regional exploration for secondary carnotite uranium deposits in Western Australia using groundwater
Ryan Noble, David Gray, Nathan Reid
CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia

P25 GIS method as a basis for landscapes classification while choosing of geochemical methods of exploration (case study of the Maly Hinggan Area, the Far East of Russia)
Yuri Yu. Yurchenko, Sergey V. Sokolov
A.P. Karpinsky Russian Geological Research Institute (VSEGEI), St.Petersburg, Russia

P26 Mine site remdiation - an experience fron Northern Sweden
Karel Miskovsky, Gunnar Jacks, Lars Lövgrren, Ola Lövgren, Magnus Filipsson
KTH, Stockholm, Sweden

P27 Water Quality and Factors Affecting it in a Closed Mine in Northern Finland
Ulpu Väisänen
University of Oulu, Oulu, Finland

P28 The Environmental Geochemistry of the Hycroft Mine: A Case Study on the Limitation of Sobek Style Acid Generation Predictions
Amy Prestia[1], Robert Bowell[2], Deborah Lassiter[3]
[1]SRK Consulting, Reno, NV, USA, [2]SRK Consulting, Cardiff, Wales, UK, [3]Allied Nevada Gold Corporation, Reno, NV, USA

P29 Mobility of Potentially Toxic Elements from Contaminated Sediments in a Catchment Affected by Abandoned Lead and Zinc Mine (South Poland)
Urszula Aleksander-Kwaterczak, Dariusz Ciszewski
Department of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, 30 Mickiewicz Av., Krakow, Poland

P30 Metal tolerant wetland species in former Rautuvaara iron-copper mining area
Paavo Närhi[1], Marja Liisa Räisänen[2], Maarit Middleton[1], Marja-Liisa Sutinen[3], Raimo Sutinen[1]
[1]Geological Survey of Finland, Rovaniemi, Finland, [2]Centre for Economic Development, Transport and Environment, Kajaani, Finland, [3]Finnish Forest Research Institute, Rovaniemi, Finland

P31 Geochemical investigations of the success of a dry cover on backfilled pits at Kimheden copper mine, northern Sweden
Lucile Villain, Lena Alakangas, Björn Öhlander
Luleå University of Technology, Luleå, Sweden

P32 Environmental impacts of ancient small-scale highly contaminated Hg ore processing site (Idrija area, Slovenia)
Tamara Tersic[1], Mateja Gosar[1], Harald Biester[2]
[1]Geological survey of Slovenia, Ljubljana, Slovenia, [2]Technical University Braunsc, Braunschweig, Germany

P33 Neutralization of weathered acidic mine waste using bio ash - effects of mixing and layering
Mattias Bäckström[1], Lotta Sartz[1]
[1]Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden, [2]Bergskraft Bergslagen, Kopparberg, Sweden

P34 Attenuation of heavy metals by peat and glacial till in simulated waste rock dump leachate
Andrew Barnes[1], Rob Bowell[1], Matt Dey[1], Ruth Warrender[1], Mike Hutton Ashkenny[1], Devin Sapsford[2], Daniel Thomas[2], Klas Stromberg[3], Matt Blattman[3]
[1]1SRK Consulting (UK) Ltd, Cardiff, UK, [2]Cardiff University School of Engineering, Cardiff, UK, [3]3Northland Resources A.B., Lulea, Sweden

P36 Mercury contents in soils and sea sediments in Crete, Greece
Despina Pentari, Despina Katsimicha, Asimina Moraiti, Vasilis Perdikatsis, Konstantinos Komnitsas
Technical University of Crete Department of Mineral Resources Engineering, Chania, Crete, Greece

P35 Cancelled

P37 Chromium behaviour during water-serpentinites interaction: first results from RESPIRA project in a Tuscan quarry (Italy)
Ilaria Baneschi, Antonio Langone, Chiara Boschi, Samuele Agostini, Luigi Dalla, Andrea Dini, Massimo Guidi, Sonia Tonarini
IGG-CNR, Pisa, Italy

P38 Elevated trace element concentrations in soil solution of an acid sulphate forest soil
Tiina Maileena Nieminen[1], Kirsti Derome[2], Antti-Jussi Lindroos[1], Päivi Merilä[3], Liisa Ukonmaanaho[1]
[1]Metla, Vantaa, Finland, [2]Metla, Rovaniemi, Finland, [3]Metla, Parkano, Finland

P39 The uptake of Cu and Ni from smelter polluted-soil by planted tree seedlings
Eva Komanická[1], Heljä-Sisko Helmisaari[2], Tiina Maileena Nieminen[1]
[1]Metla, Vantaa, Finland, [2]Department of Forest Sciences, Helsinki University, Finland

P40 Geochemistry of potentially toxic elements in soils developed on karst in Croatia
Ozren Hasan, Slobodan Miko, Zoran Peh, Martina Šparica Miko
Hrvatski geološki institut - Croatian geological survey, Zagreb, Croatia

P41 Will the harvesting of peatland forest mobilize heavy metals from bedrock underlain by black-shale?
Liisa Ukonmaanaho[1], Mike Starr[1], Marjatta Kantola[1], Juha Piispanen[1], Mika Nieminen[1], Markku Mäkilä[1], Kirsti Loukola-Ruskeeniemi[1], Tiina Maileena Nieminen[1]
[1]Metla, Vantaa, Finland, [2]University of Helsinki, Helsinki, Finland, [3]Geological Survey of Finland, Espoo, Finland, [4]Metla, Muhos, Finland

P42 Deep Cover Geochemistry from an Ancient Glacial Landscape: geochemical exploration framework for Permian sedimentary profiles of the Troubridge Basin, South Australia
Verity Normington, S.M. Hill, Robert C. Dart
University of Adelaide, Adelaide, Australia

P43 Tracing the origin of gold nuggets at Palsinoja and Kultaoja in Finnish Lapland
Jari Nenonen[1], Peter Johansson[1]
[1]Geological Survey of Finland, Kuopio, Finland, [2]Geological Survey of Finland, Rovaniemi, Finland

P44 Till geochemistry in gold exploration at Petäjäselkä, northern Finland
Helena Hulkki, Tuomo Karinen, Pertti Sarala
Geological Survey of Finland, P.O. Box 77, FI-96101 Rovaniemi, Finland

P45 Geochemical variability in Daumantai warm period lithocomplexes
Valentinas Baltrūnas, Rimantė Zinkutė, Ričardas Taraškevičius, Bronislavas Karmaza, Vaidotas Kazakauskas, Valentas Katinas, Lina Lagunavičienė
Nature Research Centre Institute of Geology and Geography, Vilnius, Lithuania

P46 Development of Indicator Mineral Methods for Base Metal and Uranium Exploration in Glaciated Terrain
Beth McClenaghan[1], Roger Paulen[1], Anna Hicken[2], Natasha Oviatt[3], Scott Robinson[2], Dan Layton-Matthews[2], Sarah Gleeson[3], Stu Averill[4]
[1]Geological Survey of Canada, Ottawa, ON, Canada, [2]Queen's University, Kingston, ON, Canada, [3]University of Alberta, Edmonton, AB, Canada, [4]Overburden Drilling Management Ltd., Ottawa, ON, Canada

P47 "3-Dimensional" mineralogical investigation of a lamproite dyke from the Kostomuksha area (Karelia, Russia) using a combination of Electric Pulse Disaggregation (EPD) and Hydroseparation (HS) methods
Nikolay S. Rudashevsky[1], V. Ya. Gorkovetz[2], Vladimir N. Rudashevsky[3], Louis J. Cabri[3]
[1]Center for New Technologies, St. Petersburg, Russia, [2]Geological Institute, Karelian Scientific Center of Russian Academy of Sciences, -, Russia, [3]CNT Mineral Consulting Inc, Ottawa, Canada

P48 Geochemistry of platinum group elements (PGE) in chromitites from the Sabzevar ophiolitic complex, Northern Iran
Mohssen Moazzen, Majid Sayyaran
University of Tabriz, Tabriz, Iran

P49 Gold mineralizaton related to Nabijan pluton, Alborz-Azerbaijan magmatic belt, NW Iran
Ahmad Jahangiri, Maryam Yazdani
Dept of Geology University of Tabriz, Tabriz, Iran

P50 REE geochemistry and their mineral phases in Jammi carbonatite veins and fenites, southern side of Sokli complex, NE Finland
Thair Al Ani, Olli Sarapää
GTK, Rovaniemi, Finland

P51 Geochemistry and REE -Mineralogy of Virtasalmi kaolins, SE Finland
Thair Al Ani, Olli Sarapää
GTK, Rovaniemi, Finland

P52 Regolith Landform Mapping as an aid to the interpretation of Au-in-calcrete geochemical anomalies: an example from the Tunkillia Au prospect, South Australia
Robert C Dart, S M Hill, Karin M Barovich, David J Chittleborough
University Of Adelaide, Adelaide, South Australia, Australia

P53 Research Frontiers in Greenfields Exploration: Plant-Regolith-Bedrock Geochemical and Biogeochemical Relationships and Interactions in the Musgrave Province of Central Australia
Stephanie McLennan[1]*, Steven Hill*[1]*, Lachlan Rutherford*[2]*, Karin Barovich*[3]
[1]*Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, South Australia, Australia,* [2]*PepinNini Minerals Limited, Adelaide, South Australia, Australia,* [3]*School of Earth and Environmental Sciences, University of Adelaide, South Australia, Australia*

P54 Characteristics and weathering of particulate gold, Avoca alluvial gold deposit, Victoria, Australia
Charles Butt
CSIRO Earth Science & Resource Engineering, Kensington, Australia

P55 Gold Dispersion through Young Carbonate Cover Overlying the Woodlark Epithermal Gold System, Papua New Guinea
Dayna McGeeney[1]*, David Cohen*[1]*, Ian Graham*[1]*, Lee Spencer*[2]
[1]*University of New South Wales, Sydney, NSW, Australia,* [2]*Kula Gold Ltd, Sydney, NSW, Australia*

P56 Geochemical Exploration in Ravnnaluhppu, Karasjok, Northern Norway
Hannu Ahola, V. Juhani Ojala
Store Norske Gull AS, Rovaniemi, Finland

P57 Multi-Source Genetic Characteristics of the Natural gas in Oolitic reservoir of Feixianguan Formation in Northeastern Sichuan Basin, SW China
Tongshan Wang[1]*, Zhao Wenzhi*[1]*, Wang Hongjun*[1]*, Wang Zeng*[1]*, Li Qiufen*[1]*, Bian Congsheng*[1]*, Li Yongxin*[1]
[1]*PetroChina Research Institute of Petroleum Exploration & Development, Beijing, China,* [2]*PetroChina Exploration & Production Company, Beijing, China*

P58 Geochemical evidence of gas accumulating during uplift of Xujiahe coal-bearing measures, central Sichuan basin
Congsheng Bian, Hongjun Wang, Tongshan Wang, Yongxin Li
PetroChina Research Institute of Petroleum Exploration & Development, Beijing, China

P59 The physical evolution of hydrocarbon fluid of Shanxi Formation (P_{2sh}) in Yimeng area, NE Ordos Basin (China): evidence from PVT simulation of inclusion petroleum
Yunpeng Wang[1]*, Dehan Liu*[1]*, Qiao Feng*[2]*, Changyi Zhao*[3]*, Hongjun Wang*[1]
[1]*Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, 510640, China,* [2]*Shandong University of Sciences and Technology, Qingdao, 266510, China,* [3]*Research Institute of Petroleum Exploration and Development, PetroChina, Beijing, 100083, China*

P60 The Migration and Accumulation of the Jurassic Oil and Gas in Northern Qaidam Basin, China: An Integrated Geochemical Petroleum System Analysis
Changyi Zhao[1]*, Dongsheng Yang*[1]*, Yunpeng Wang*[2]
[1]*Research Institute of Petroleum Exploration & Development, PetroChina, Beijing, China,* [2]*Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China*

P61 Study on the particles related to the concealed ore deposits
Jianjin Cao, Xiaojun Wei, Hongling Ke, Chang Liu
Department of Earth Science, Sun Yat-sen University, Guangzhou, China

P62 Lithological Signatures and Exploration Implications from Overbank Sediment Sampling and MMI Analysis: Preliminary Findings from the National Geochemical Survey of Australia
Patrice de Caritat[1], Michelle Cooper[1], Alan Mann[2], Pierrette Prince[3]
[1]Geoscience Australia, Canberra, Australia, [2]Consultant, Perth, Australia, [3]SGS Minerals Services, Toronto, Canada

P63 Similarities and differences in the hydrocarbon geochemical signature of various Uranium lithologies
Dale Sutherland
Activation Laboratories Ltd., Ancaster, Ontario, Canada

P64 Utilization of weak leach methods in mineral potential mapping in glaciated terrain – an example from the Lätäseno Greenstone Belt, northwestern Finland
Pertti Sarala, Raija Pietilä, Riitta Pohjola
Geological Survey of Finland, Rovaniemi, Finland

P65 The timing of ore mineralization based on thermal maturity modelling of Kupferschiefer strata in the Fore-Sudetic Monocline, SW Poland
Pawel Kosakowski
Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Krokow, Poland

P66 Petrography and geochemistry of Sandstone Member of Asmari Formation, Ahvaz, Khouzestan Province, Iran
Babak Alizadeh
Padyab Tadjhiz Co., Tehran, Iran

P67 Exploring for Ni mineralisation beneath cover using gas collectors at North Miitel, Kambalda, Western Australia
Melvyn Lintern[1], Ryan Noble[1], Ravi Anand[1], Brian Townley[2]
[1]CSIRO, Kensington, WA, Australia, [2]University of Chile, Santiago, Chile

P68 Biogeochemistry and surficial geochemistry at the Tropicana Gold Deposit, Western Australia
Melvyn Lintern, Ravi Anand
CSIRO, Kensington, Australia

P69 3D geochemical patterns over a concealed gold deposit revealed by overburden drilling in desert terrains
Bimin Zhang[1], Xueqiu Wang[1], Qinghua Chi[1], Wensheng Yao[1], Shanfa Xu[1]
[1]Institute of Geophysical and Geochemical Exploration, CAGS, Langfang, Hebei, China, [2]Key Laboratory for Applied Geochemistry, CAGS, Langfang, Hebei, China

P70 Sulphide weathering and rates of anomaly formation from a column experiment
Ryan Noble[1], Robert Hough[1], Steven Wakelin[2], Ravinder Anand[1], Melvyn Lintern[1]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]AgResearch, Invermay, New Zealand

P71 Mineral exploration in areas of transported overburden: from groundwater - rock interaction processes to surface, a case study in the Inca de Oro District, northern Chile
Brian Townley[1], Carolina Soto[1], Rodrigo Luca[1], Luis Lopez[1], Alvaro Puig[2], Hugo Henriquez[2], Ravi Anand[3], Mel Lintern[3]
[1]Dept. of Geology, University of Chile, Santiago, Chile, [2]Codelco - Chile, Santiago, Chile, [3]CSIRO, Perth, Australia

P72 Prospects for Noble Metals and Copper-Nickel Mineralization in the border areas of Russia and Finland
Sergey S. Shevchenko, Sergey V. Sokolov, Gennady M. Belyaev, Yulia V. Makarova, Yuri Yu. Yurchenko
A.P. Karpinsky Russian Geological Research Institute (VSEGEI), St. Petersburg, Russia

P73 Geochemical Prospecting of Mineral Deposits in Areas with Increased Thickness of Loose Sediments
Sergey V. Sokolov, Yulia V. Makarova, Yuri Yu. Yurchenko
A.P.Karpinsky Russian Geological Research Institute (VSEGEI), St.Petersburg, Russia

P74 Geochemistry and Geology of the Sasare Iron Oxide-Copper-Gold-Uranium project, Zambia: Implications for Exploration of large low grade deposits
Robert Bowell[1], Chris Davies[2], William Mumbwa[3]
[1]SRK Consulting, Cardiff Wales, UK, [2]African Eagle Resources plc, London, UK, [3]African Eagle Resources, Lusaka, Zambia

P75 Carlin Type Au potential of the Turkestan-Alai and Southern Fergana Segments of the Southern Tianshan, Kyrgyzstan
Daniel Rickleman[1], Alex Archangelski[1], Michael Jackson[2], Josef Story[1], Vadim Lysenko[1], Tordali Zholdoshov[1], Omerbek Atabaev[1]
[1]Manas Resources, Bishkek, Kyrgyzstan, [2]CSA Global, Brisbane, Australia

P76 Application of portable XRF technology to identification of mineralization and alteration along drill in the Nihe iron deposit, Anhui, Eastern China
Qinglin Xia[1], Qiuming Cheng[2]
[1]China University of Geosciences, Wuhan, China, [2]York University, Toronto, Canada

P77 Application of portable XRF technology for hand specimen scale geochemical imaging and identification of sequences of mineralization in Jinding Pb/Zn Mineral Deposits in Yunnan, Southwestern China
Zhaoxian Yuan[1], Qiuming Cheng[1]
[1]China University of Geosciences, Wuhan, China, [2]York University, Toronto, Canada

P78 The Test Method of Geochemical Exploration for the Semi-arid Desert Prairie Landscape in West Hillside for the Great Xinganling, Inner Mongolia--result from the mining area and surrounding of the Weilasituo Cu deposits
Dapeng Li[1], Yuelong Chen[1], Jinbao Liu[2], Furong Leng[2]
[1]China University of Geosciences, Beijing, Beijing, China, [2]Geological Survey Institute of Inner Mongolia, Hohhot, Inner Mongolia, China

P79 Research on the Relation between Regions of High Morbidity of Cancer and the Multiple Environmental Pollution in the Process of Urbanization in the Pearl River Delta
Ming Chen, Yaoqiu Kuang, Ningsheng Huang
Guangzhou Institute of Geochemistry Chinese Academy of Sciences, Guangzhou, China

P80 The Fe isotopic composition of soils and waters from the Ravenna area (Northern Italy) and its significance for environmental studies
Francesca Castorina, Umberto Masi
Università "La Sapienza", Roma, Italy

P81 Search for geochemical indicators of pre-urban habitation sites: case study from Skomantai hill-fort and settlement, western Lithuania
Ričardas Taraškevičius[1], Miglė Stančikaitė[1], Audronė Bliujienė[2]
[1]Nature Research Centre, Vilnius, Lithuania, [2]Klaipeda University, Klaipėda, Lithuania

P82 Introducing "UrbanEnviron@Lisbon 2008" a GIS-platform for environmental and human health data management
Carla Patinha[1], Amélia Reis[1], Eduardo Ferreira da Silva[1], Ana Dias[1], Sofia Bartolomeu[2], António Sousa[3], Anabela Cachada[4], Maria Batista[5], Cátia Prazeres[5], Fernando Rocha[1], Cristiana Costa[1], Cristina Sequeira[1], Denise Terroso[1], Rui Figueira[3], Cecília Sérgio[6], Rita Salgueiro[1], Orquidia Neves[3], Armando Duarte[4]
[1]GEOBIOTEC, University of Aveiro, Aveiro, Portugal, [2]Physics Department, University of Aveiro, Aveiro, Portugal, [3]CERENA, Technical Superior Institute,, Lisbon, Portugal, [4]CESAM, University of Aveiro, Aveiro, Portugal, [5]LNEG, Lisbon, Portugal, [6]Jardim Botânico – MNHN, Lisbon, Portugal

P83 London Earth: anthropogenic and geological controls on the soil chemistry of the UK's largest city
Andreas J. Scheib, Dee M.A. Flight, Bob Lister, Cathy Scheib
British Geological Survey, Keyworth, Nottingham, UK

P84 Attenuation of Heavy Metals in Natural Wetland Receiving Acid Mine Drainage
Keiko Sasaki, Tagiru Ogino, Yuji Endo, Kunihiko Kurosawa
Kyushu University, Fukuoka, Japan

P85 Release of arsenic from damped sediments originally deposited in the Shinaki Dam receiving neutralized acidic river water, Gunma, central Japan
Kosei E. Yamaguchi, Eri Tanaka
Toho University, Chiba, Japan

Excursions

Pre-conference Excursions

Field excursion 1:

Active and ongoing gold exploration and mining in Northern Finland, 18-20 August 2011

Field excursion 2:

Care of mine districts and the environment after closure of mines, 18-20 August 2011

Mid-conference Excursions

Field excursion 3:

Chrome and PGE deposits associated with the 2.45 Ga layered intrusions of Northern Finland, 24 August 2011

Field excursion 4:

The Pyhä-Luosto Fell area and the Luosto Amethyst Mine , 24 August 2011

Post-conference Excursions

Field excursion 5:

Geochemical and indicator mineral exploration methods and ongoing projects in the glaciated terrains in northern Finland, 26-30 August 2011

Field excursion 6:

IOCG and Porphyry-Cu deposits in Northern Finland and Sweden, 27-28 August 2010

Field excursion 7:

Geochemistry in Khibiny mountains and Monchegorsk, Kola Peninsula, Russia, 27-31 August 2011

Workshops

WS 1:

Quality Assurance in Geochemical Analysis, Sun 21 August at 09:00, Santa's Hotel Santa Claus

WS 2:

Geochemistry for risk assessment of metal contaminated sites, Sun 21 August at 09:00, Santa's Hotel Santa Claus

WS 3:

Indicator mineral methods in mineral exploration, Sun 21 August at 09:00, Santa's Hotel Santa Claus

WS 4:

Prospectivity mapping in GIS: integrate geochemistry data with geophysics and geology, Sun 21 August at 09:00, Santa's Hotel Santa Claus

WS 5:

Exploration for orogenic gold deposits – with emphasis on geochemical exploration in glaciated Precambrian terrain, Sun 21 August at 09:00, Santa's Hotel Santa Claus

ioGAS Workshop,

Wednesday 24 August at 13:00 - 17:00, Santa's Hotel Santa Claus

Exhibition

For location see the Venue map.

1	Actlabs, Canada
2	Geological Survey of Finland
3	CNT Mineral Consulting Inc., Canada
4	Boliden, Sweden
5	FLSmidth, Australia
6	IMA Engineering Ltd Oy and Mine On-Line Service Oy, Finland
7	Olympus-InnovX, Finland
8	Holger Hartmann Oy, Finland
9	Acme Analytical Laboratories Ltd., Canada
10	Sintrol Oy, Finland
11	African Mineral Standards, South Africa
12	The Association of Applied Geochemists AAG
13	ALS Minerals, Sweden
14	SGS Minerals, Canada

Social Programme

Advance registration is required for all social events and optional tours, except for the Pub Night on Wednesday. If you have registered for the events in advance, you will find the event tickets in your conference materials. If you have not registered in advance, please contact the conference office for vacancies.

Conference Social Programme

Get-together Party

Sunday 21 August at 19-21

This casual evening will be arranged at Restaurant Valdemari by the riverside, just opposite to the Hotel Pohjanhovi (Jäämerentie 9), about 500 m across the Jätkänkynttilä bridge. Something to eat and drink, live music, dancing, meeting old friends and making new ones. Advance registration is required. No transfer provided.
Price: Included in the registration fee for registered conference participants and partners.

Welcome Reception

Monday 22 August at 18-20

The Welcome Reception will be start at the conference venue, in the main lobby at 18:00 after end of the day's technical programme. Advance registration is required. The reception will include a light meal with drinks. Bus transfer to the conference hotels after the reception will be provided.
Price: Included in the registration fee for registered conference participants and partners.

Concert and Rovaniemi City Reception

Tuesday 23 August at 19-22

Tuesday evening will start with a chamber music concert by Lapland Chamber Orchestra at the Rovaniemi church at 19:00 – 19:45 and continue with the Rovaniemi City Reception at the City Hall at 20:00 – 22:00. The evening will include a light meal with drinks. The Rovaniemi City Hall is at walking distance from the church, no bus transfer. Advance registration is required.
Price: Included in the registration fee for registered conference participants and partners.

Pub Night

Wednesday 24 August at 20-22

SGS Minerals Services sponsors a Pub Night for all conference participants and partners. The venue is Hemingways (Koskikatu 11) located in the city centre opposite to Santa's Hotel Santa Claus. Free beer or wine at 20-22! No advance registration.

Official Dinner

Thursday 25 August at 20-

The Official Dinner will take place at the panoramic Restaurant Sky Ounasvaara renowned as one of the best in Finland. The Restaurant Sky Ounasvaara is located on top of the Ounasvaara fell. The evening will include a served dinner with drinks. Advance registration is required. Bus transfer from/to the conference hotels will be provided – for more details check the separate transfer info.
Price: 90 €/person.

Optional Tours

Participants who have registered for the optional tours in advance will find the tour ticket in the conference materials. If you have not registered in advance, please check the conference office for vacancies.

Sightseeing Tour and Arktikum

Monday 22 August

Join a guided tour around Rovaniemi, visiting the main landmarks of the city. Visit to the Arktikum house where you can take time to see the exhibitions about Lapland and Arctic areas.
Time and duration: at 10-12 (2 hours)
Departure: Lapland Safaris Office, Koskikatu 1
(be on time!)
Price: 55 €

Riverboat Cruise to a Reindeer Farm

Tuesday 23 August

Join a boat cruise along the traditional log-floating route and enjoy the beautiful scenery of the Ounasjoki and Kemijoki river valleys. Travel through serene landscapes in a long wooden riverboat and experience the summer of the Arctic Circle. Visit a reindeer farm and learn about reindeer husbandry. Enjoy a tasty lunch and participate in a ceremonial crossing

of the Arctic Circle during your visit to the farm.
Time and duration: at 10-14 (3-4 hours)
Departure: Lapland Safaris Office, Koskikatu 1
(be on time!)
Price: 58 €

Excursion to the Ranua Wildlife Park

Wednesday 24 August

The Ranua Zoo is located 82 km from Rovaniemi. The zoo path (3 km) will lead you through the zoo where you will see over 50 species of northern and arctic animals, e.g. otter, hawk, moose and arctic fox. In the Ranua Zoo you can also find famous polar bear Manesse, brown bear Palle-Jooseppi and black raven Jaska! Buffet lunch will be served in the restaurant of the Zoo. After lunch you will have time to do some shopping in the souvenir and wine shops as well as in the Fazer chocolate and candy store.
Time and duration: at 10-15 (5 hours)
Departure: Lapland Safaris Office, Koskikatu 1
(be on time!)
Price: 95 €

Cruise on the River Ferry Kemijoen Helmi

Wednesday 24 August

Kemijoen Helmi is a river ferry with a homeport right at the city centre. The ferry is completely covered and has a fully licensed restaurant.
Time and duration: at 18-20 (2 hours)
Departure from the ferry homeport – for location check the IAGS Rovaniemi Map in the programme book.
Price: 15 €

The Secret of the Antler

Thursday 25 August

Reindeer antler has always been a raw material for Lappish utility and decorative articles. Reindeer antler is an ecological material as reindeer shed antlers every year. Come and visit the workshop of Decorative & Artistic handicrafts A. Kangasniemi. You will learn about how reindeer antler is used as a raw material and you can also make yourself a souvenir from reindeer antler. You will also visit a Lappish log-built home and enjoy coffee/tea or mulled wine and pastry.
Time and duration: at 10-13 (3 hours)
Departure: in front of Santa's Hotel Santa Claus, Korkalonkatu 29 (be on time!)
Group size: max. 20
Price: 50 €

Visit to the Santa Claus Village

Friday 26 August

In the Santa Claus Village you will have a chance to meet the "big man" himself. In the Santa's official post office you can send cards home for Christmas or order a Santa's letter for your children/grandchildren. The village also includes a wide variety of shops.
Time and duration: at 10-14 (3-4 hours)
Departure: Lapland Safaris Office, Koskikatu 1
(be on time!)
Price: 39 €

Visit It's Gold! -exhibition at Arktikum

It's Gold! -exhibition approaches this absorbing element from different points of view. The exhibition tells us about genesis, search, exploiting and wide-ranging use of gold. It also tells us about importance of gold for human beings and about the everlasting yearning of gold.

It's Gold! –exhibition is the 125-jubilee exhibition of the Geological Survey of Finland. It will be carried out in co-operation with the Geological Survey of Finland, the Provincial Museum of Lapland, Gold Prospector Museum and Agnico-Eagle Mines Limited, Kittilä. / Produced by Provincial Museum of Lapland.

Arktikum opening hours during IAGS 2011: every day 9:00 – 18:00
Price: 4 €. No advance registration. Show your IAGS 2011 badge at the ticket office.

General Information

Registration and Information

The IAGS Conference Office located in the university main lobby is open for registration and information as follows:

Monday 22 August	at 08:00 – 18:00
Tuesday 23 August	at 08:00 – 17:15
Wednesday 24 August	no scientific programme, conference office closed
Thursday 25 August	at 08:00 – 17:45
Friday 26 August	at 08:00 – 15:00

Contact information of the Conference Office **during the conference:**

phone	+358 (0)40 484 4462 and +358 (0)40 721 8260
fax	+358 (0)16 362 940
email	congress@ulapland.fi

Lunch

Lunch on Monday, Tuesday, Thursday and Friday are all included in the registration fee. Lunch is served in Restaurant Felli (entrance from the main lobby). Lunch includes bread and salad buffet, any of the warm meals on the day's menu, dessert and milk/water/juice. *Please pay for any extra purchases yourself.* **Show your name badge at the cashier – it is your lunch ticket.**

Opening hours of Restaurant Felli:

Open	
Mon-Thu	at 08:00-15:00
Fri	at 08:00-14:30

Lunchtime	
Mon-Thu	at 10:45-14:30
Fri	at 10:45-14:00

Coffee/Tea
Coffee/tea served from buffet tables in the main lobby during breaks marked in the programme is included in the registration fee.

Special diets
The special diets informed in advance in registration forms have been forwarded to all the restaurants handling catering for the event and they have been taken into account. Please contact the restaurant staff with any questions.

Access to Internet

You can check your email in two different ways:
1) in the Email room (107)

Username: **vieras33**
Password: **ia2011gs**
In the Email room there is also a printer.

2) using the university WLAN wireless network
Your need only the shared key: **43mSISAFqw**

Please ask the conference office for instructions how to configure your computer to use the Guest Wlan.

Bus transfers

Local bus transfers

Buses will run daily (Mon-Tue and Thu-Fri) between the hotels and the conference venue to the first session in the morning and back to the hotels after the last session in the afternoon. *The detailed summary of all conference-related bus transfer is as a separate hand out in the conference materials.*

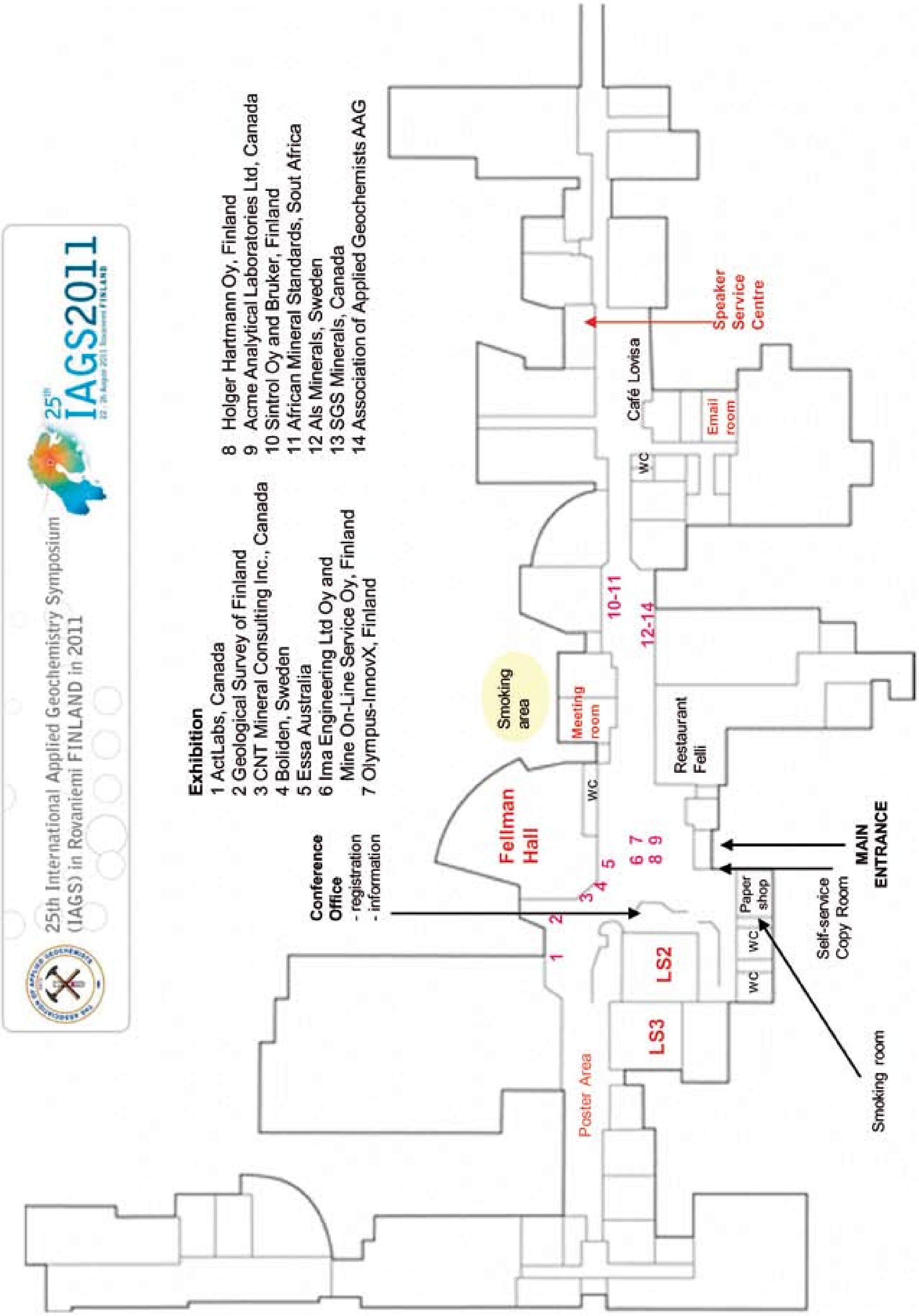
Local city buses (number 4) between the city centre and university run daily at irregular intervals in both directions. Ask the conference office information desk for the bus timetables.

From the airport and railway station to the city centre

Airport Express – bus from Airport to the city centre and back – drives to all the centre hotels as well as the bus station, ca. 15 minutes, price € 5/person. Airport Express departs from the airport after every flight arrival. Check your hotel reception about the pickup time from your hotel back to the airport. For further information call +358 (0)16 – 362 222.

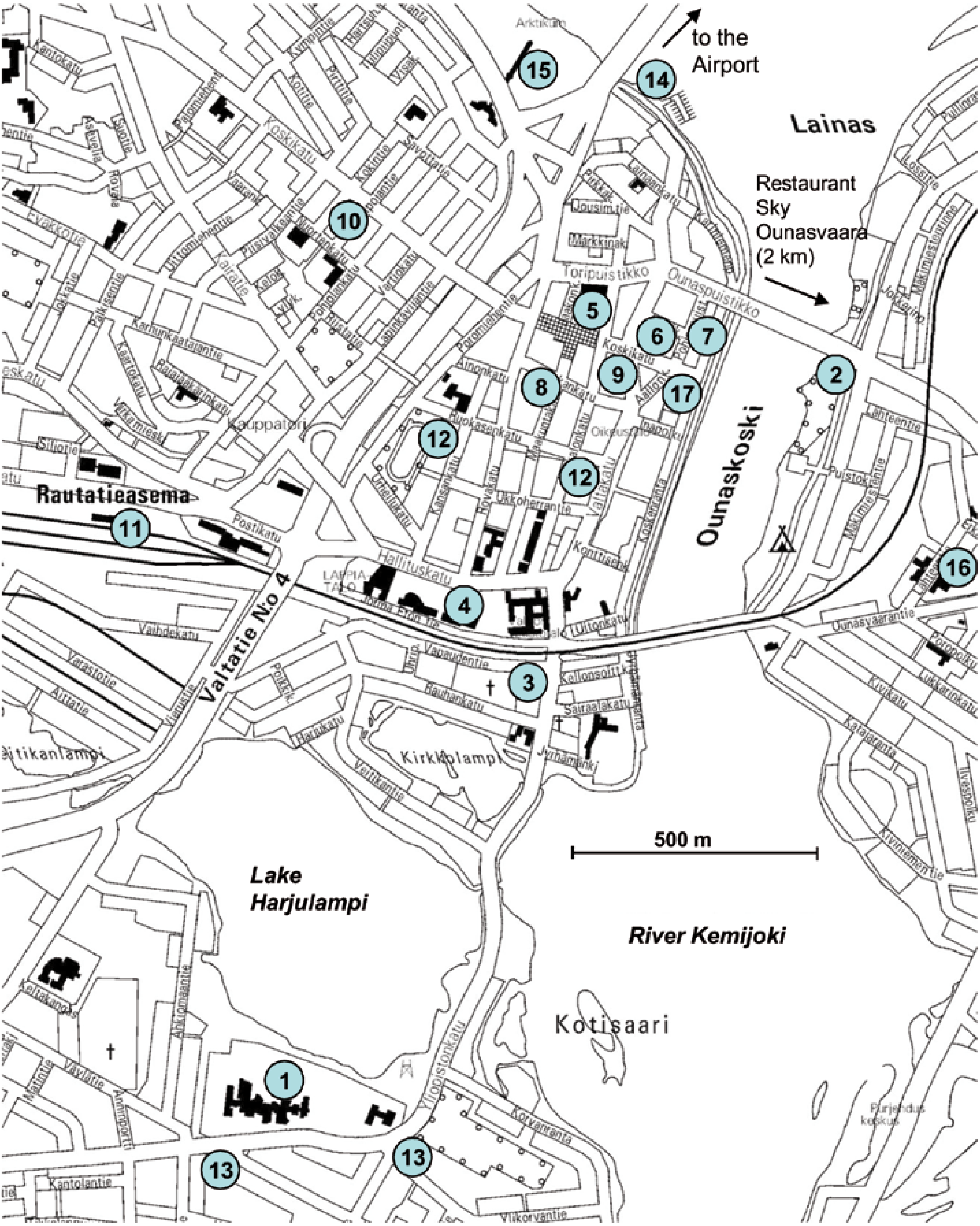
Normal Taxi: +358 (0)16 - 106 410.

Venue Map



Exhibition
1 ActLabs, Canada
2 Geological Survey of Finland
3 CNT Mineral Consulting Inc., Canada
4 Boliden, Sweden
5 Essa Australia
6 Ima Engineering Ltd Oy and
Mine On-Line Service Oy, Finland
7 Olympus-InnovX, Finland
8 Holger Hartmann Oy, Finland
9 Acme Analytical Laboratories Ltd, Canada
10 Sintrol Oy and Bruker, Finland
11 African Mineral Standards, Sout Africa
12 Als Minerals, Sweden
13 SGS Minerals, Canada
14 Association of Applied Geochemists AAG

Rovaniemi Map



1. Conference Venue
   University of Lapland, Yliopistonkatu 8
2. Restaurant Valdemari
   Get-together Party
   Jäämerentie 9
3. Rovaniemi Church
   Concert
   Rauhankatu 45
4. Rovaniemi City Hall
   Reception
   Hallituskatu 7
5. Santa's Hotel Santa Claus
   Korkalonkatu 29
6. Sokos Hotel Vaakuna
   Koskikatu 4
7. Hotel Rantasipi Pohjanhovi
   Pohjanpuistikko 2
8. City Hotel
   Pekankatu 9
9. Hotel Cumulus Rovaniemi
   Valtakatu 23
10. Hostel Rudolf
    Koskikatu 41
11. Railway Station
12. Bus stop (bus no 4 to university)
13. Bus stop (bus no 4 to city centre)
14. Homeport of Kemijoen Helmi
15. Arktikum
16. Geological Survey of Finland, Rovaniemi
    office, Lähteentie 2
17. Lapland Safaris Office
    Koskikatu 1

Abstracts

Keynote presentations

Keynote 1

Geochemical Microanalysis: What can you really do with all this high-tech gear?

Michael Wiedenbeck
Secondary Ion Mass Spectrometry Laboratory,
Helmholtz Centre Potsdam, Germany

Geochemical laboratory instrumentation has advanced rapidly during recent years, opening many new research opportunities that were not possible even one or two decades ago. Such technological advances have had a particularly dramatic impact in the realm of in situ microanalyses. Thanks to both steady improvements in established methods as well as the introduction of new analytical techniques, sampling size has commonly been reduced, data quality has been advanced and instrument reliability has generally improved. This talk will review the current state-of-the-art for a variety of in situ analytical methods and will use the trends of the past decade to discern future developments which might be expected during the coming years.

For many laboratory methods it is no longer the instrumentation which is the primary source of laboratory uncertainty; rather, the total absence of suitable, well characterised reference materials with which to calibrate a method can be a key limitation to data quality. Furthermore, the world-wide lack of certified materials for geochemical microanalysis prevents any rigorous method validation and also hampers quality assurance efforts. Although metrological issues vary greatly between the various analytical methods, it can be asserted that a shortage of suitable reference materials has become a significant contribution to the total analytical uncertainty budgets for many laboratory applications. Progress towards ever smaller sampling sizes may ultimately be stymied by a shortage of matrix matched reference materials whose compositions and homogeneity have been established at the required sampling mass. The production of reference materials for use at sub-ng test masses remains a topic within metrology theory which has yet to be adequately explored.

Finally, improved analytical capabilities have not been clearly paralleled by improvements in the end-user's understanding of laboratory results. The communication of laboratory data continues to be a challenge within geochemistry, and this it not limited only to the realm of in situ microanalysis. Variations in terminology and incomplete descriptions of data assessment procedures continue to pose a risk that data will be either over interpreted or that valuable information will be lost.

Keynote 2

Predictive geochemistry in areas of transported overburden: mechanisms of anomaly formation

Ravi Anand
CSIRO Earth Science and Resources Engineering,
Kensington, Australia

This paper presents a synthesis of the industry-supported three year CSIRO/AMIRA (Australian Mineral Industry Research Association) Project 778 "Predictive geochemistry in areas of transported overburden". Regions with substantial transported overburden present some of the most significant exploration problems, making exploration both difficult and expensive. Much of the focus of this research was on potential mechanisms that can move metals through the vadose (unsaturated) zone in areas of transported overburden in Australia and northern Chile. We have investigated the theoretical basis for upward movement of metals using pit, column and in vitro experiments and have conducted field tests to examine transport processes.

Chemical dispersion by hydrological and biological processes at the mineralised source can generate ions and hydrocarbon compounds by breakdown of ore and gangue minerals. At Inca de Oro, groundwater flow disperses ions and gases in the direction of flow, the effects of this are reflected in the groundwater hydrochemistry, on precipitation/dissolution processes of Cu sulphate minerals and on the physicochemical properties of overburden. Metallic dispersion into transported overburden is generally limited to its lower part at all Australian sites due to capillary and mechanical mechanisms. However, three mechanisms of vertical metal migration are important from source to the surface; biological, gaseous and to some extent capillary mechanisms. Upward element (Au, Zn, Cu, Cd, Ag, As, Mo, Bi and W) transfer by vegetation (Acacia aneura and Eucalyptus sp.) occurs in areas of transported overburden up to 35 m thick, but not in environments which lack significant supergene enrichment and have highly saline groundwater. At two sites, hydrogen isotopic investigations confirmed that vegetation relies on deep (>10 m depth) regolith and groundwater. Metals are subsequently released to the topsoil through the decay of leaf litter. However, the rate of accumulation in soil is determined by physical erosion of litter and soil balanced by net-primary productivity. In addition, in the near-surface environments, microbial populations show an anomalous bacterial community type in the soil over the surface projection of the mineralisation.

Anomalies in Ni (North Miitel Ni prospect) and Hg, Sb, S (Jaguar VMS deposit), detected by gas collectors, appear to have formed by gaseous transport. We have shown that geochemical anomalies can form rapidly under experimental conditions, and this assists in understanding the genesis of natural geochemical anomalies. Significant increases in concentrations of Au, Cu, Zn and Cd in soil over mineralised pits suggest that there has been vertical migration of metals though 2 m of sand after only a few months. Seasonal variations suggest the migration of elements from source to the surface may vary in time and intensity.

Vegetation, organic soil and collector devices are promising sampling media in areas of transported overburden. This research is ongoing as part of the CSIRO/AMIRA Project 778A.

Keynote 3

Analysis and mapping of stream sediment geochemical anomalies: should we logratio-transform the data?

Emmanuel John M. Carranza
Department of Earth Systems Analysis, Faculty of Geo-Information Science and Earth Observation (ITC) University of Twente, Enschede, The Netherlands

Traditional methods of statistical analysis of exploration geochemical (compositional) data have led to significant mineral deposit discoveries in the past. In contrast, there is lack of research and documentation of actual (as opposed to theoretical) benefits (e.g., mineral deposit discovery) of compositional data analysis and imputation of censored values to mineral exploration geochemistry. In the present study, examination of logratio- and ln-transformed stream sediment geochemical data containing ca. 30% of samples with censored values of a pathfinder element for the mineral deposit-type of interest yielded the following findings. Exclusion of those samples supports interpretation of multi-element anomalies reflecting presence of mineralization. However, multi-element anomaly maps obtained by exclusion of those samples are barely better than those derived by inclusion of those samples after replacing the censored values either with ½ of detection limit or with imputed values. Inclusion of ca. 30% of samples with censored values for a pathfinder element, by replacing them either with ½ of detection limit or with imputed values, results in anomalous multi-element associations that are strongly similar to those obtained by exclusion of those samples. Logratio (i.e., alr, clr, or ilr) transformation, compared to ln-transformation, of stream sediment geochemical data does not improve mapping of pathfinder element anomalies reflecting presence of mineralization. Stream sediment geochemical data, exclusive or inclusive of censored values (replaced either with ½ of detection limit or with imputed values), should be clr- or ilr-transformed to enhance recognition of anomalous multi-element associations reflecting mineralization. However, anomaly maps of multi-element associations derived from ilr-transformed data are better, albeit slightly, than those derived from clr-transformed data. Further investigations of various exploration geochemical datasets are needed to demonstrate and document the actual (as opposed to theoretical) benefits of developments in compositional data analysis and imputation of censored values to mineral exploration.

Keywords: Compositional data; Logratio transformations; Concentration-area plots; Pathfinder element; Epithermal-Au; Aroroy (Philippines)

Keynote 4

Geochemical mapping; past, present, future

Reijo Salminen
Geological Survey of Finland, Espoo, Finland

Future begins tomorrow, but where is the border between past and present. History of geochemistry can be dated back to the 17th century but history of applied geochemistry begins in 1930s and geochemical mapping even later. First geochemical mapping projects covering large areas were carried out in 1950s in Central and Eastern Africa.

In applied geochemistry, the 1960s and 1970s were a period of research and developing of methodologies. New analytical methods such as AAS made possible to determine quickly and at rather low detection limit element concentrations from a big number of samples. New computers and their more and more sophisticated software made possible to manage and process the big number of data. As a result of this development, a modern and effective regional geochemical mapping started in the beginning of the 1970s. At that time, every organization developed its own methodologies and labs. The 1990s formed a period when the major mapping projects were completed in many countries, mineral exploration ceased, environmental geochemistry substituted exploration and the globalization of geochemistry started.

A need to harmonize methodologies was detected and international co-operation was getting stronger.

The role of Finnish geochemists in the activities of IGCP 259 (International Geochemical Mapping) and IGCP 360 (Global Geochemical Baselines) was remarkable. These projects were conducted by A. Darnley. A. Björklund and N. Gustavsson from GTK are among the authors of the 'Blue book' (Darnley et al. 1995), which is today the basic document when geochemical mapping projects are planned in Africa, Asia, America or Europe. One of the main results of the international geochemical mapping projects until now is the Foregs Geochemical Atlas of Europe (Salminen et al. 2005). This project was initiated by the IGCP 360.

Future of the geochemistry has already started. In the 2000s, new ideas and applications came to exploration geochemistry. Spatial data analysis which uses geochemical mapping data as one element together with other geological information was taken into use. The younger generation started to develop and apply new methods and technologies in exploration and in medical geology. Applications of stable isotopes will be one of the key issues in the future. In environmental geochemistry, risk analysis in the connection of contaminated land sites will need more detailed information from speciation of elements and their bioavailability. Geochemists' expertise in developing methods for cleaning contaminated land is needed. The data and information which geochemists have demands them also to participate actively in social debate and preparation of legislation.

References:

Darnley, et al., 1995. Earth Science 19, UNESCO Publishing

Salminen et al. 2005. Geochemical Atlas of Europe. Geological Survey of Finland

Keynote 5

Geochemistry of Landscapes Covered by Glacially Crushed Debris

William W. Shilts
Prairie Research Institute, University of Illinois-Urbana, Champaign, USA

Sediment carried by modern glaciers and sediment covering formerly glaciated terrain is created largely by comminution (crushing) processes that dominate sediment production and generate virtually unweathered, fresh bedrock detritus (till). Entrained debris is and was diluted exponentially down ice by constant incorporation of debris at the base of a glacier. Because glaciers flow up and down slopes, gravity plays a secondary role in determining distribution of sediment components, and the geochemical signature of glacial sediment can be draped over the landscape, irrespective of topography, except in areas of mountain glaciation. Conversely, in areas unaffected by glaciations, soils and sediments are produced largely through the processes of chemical and physical weathering of source rocks, and gravity or chemical processes dominate the depositional patterns of sediments dispersed by wind or water. Glacial comminution processes create terminal grades which are defined as the sizes to which rocks and their constituent mineral phases can be reduced, given the energy available at the base of a glacier (Driemanis and Vagners, 1971). This physical partitioning of minerals into specific size grades based on their physical properties and on their size distribution in source rocks results in chemical partitioning that is related to the mix of mineral phases derived from the various bedrock lithologies traversed by the depositing glacier. For example, chromium can be concentrated in Chromite or Uvarovite, which are hard, uncleavable minerals with terminal grades in the sand-sizes, or in Fuchsite, a chromium-bearing mica, which has a terminal grade in the clay or <4 micron size fraction. Thus, if an ultramafic source rock is rich in Chromite, its geochemical signature will be most prominent in the sand fraction of a glacial sediment, whereas glacial abrasion of Fuchsite-rich ultramafic rocks will produce a glacial sediment in which chrome is concentrated in the <4 micron sizes. From this example it can be seen that in order to interpret geochemical analyses of glacial sediment samples, the concept of terminal grades must be carefully considered. Another result of the crushing process is that as minerals are reduced to progressively finer sizes, the reaction surface area of the sediment increases, enhancing the release or adsorption of chemical components, such as nutrients and (natural) pollutants. Finally, till or water and wind-deposited sediment derived from till, contain easily weathered mineral phases (carbonates, sulphides, some clays, etc.) that can be altered to significant depths, with accompanying release of chemical components. Consequently, sampling and interpretation strategies for weathered samples, even those collected below the true solum, must take into account these weathering characteristics.

Reference:

Driemanis, A. and Vagners, U. J. (1971). Bimodal distribution of rock and mineral fragments in basal tills. In: Till: A Symposium, R. P. Goldthwait, ed., pp. 237-250. Ohio State University Press, Columbus.

Keynote 6

Environmental Geochemistry of Sulfide Bearing Mine Wastes: Prediction and Remediation

David W. Blowes, Carol J. Ptacek
University of Waterloo, Department of Earth and Environmental Sciences, Canada

The oxidation of sulfide minerals in mill tailings impoundments and waste rock piles may result in the release of dissolved constituents, including H^+, SO_4^{2-}, Fe^{2+} and other dissolved metals (Blowes et al., 2003). The transport and release of these dissolved constituents have the potential to result in environmental degradation. The magnitude and duration of the environmental impacts of mine wastes is dependent on the balance between acid generating and acid consuming minerals within the waste materials, the extent of metal attenuation, and the nature of the hydrologic system (Blowes et al., 2003). The implementation of effective mine waste-management and remediation programs requires reliable predictions of the environmental impacts of mine wastes. Predictions should be based on a thorough understanding of the characteristics of the waste materials and a rigorous framework for integrating these processes.

Simulations conducted using reactive transport models can be used to assist in assessing the extent and duration of environmental impacts of mine wastes. When used in conjunction with field data, these models can be used to assess the potential effects of changes in the hydrological system and the mineralogy of the waste materials on the quality of drainage water (Mayer et al., 2002). Reactive transport models also can be used to evaluate the potential impacts of variations in the design and implementation of remedial measures.

Potential approaches to remediation include collection and treatment of discharge water and passive in situ remedial measures including the installation of permeable reactive barriers (Benner et al., 1999; Ludwig et al., 2009) or the in situ treatment of mine wastes within the disposal system (Hulshof et al., 2006; Lindsay et al., 2009). Field-scale installations of remediation systems demonstrate the potential for application of passive remediation systems, which promote sulfate reduction, leading to the attenuation of dissolved metals and sulfate.

References:
Benner, S.G., et al., 1999. Environ. Sci. Technol. 33: 2793-2799.
Blowes, D.W., et al., 2003. Treatise on Geochemistry, Vol. 9, Holland, H.D. and Turekian, K.K. (Eds.), Elsevier Science, Oxford, pp. 149-204.
Hulshof A.M.H. et al., 2006. Water Res. 40: 1816-1826.
Lindsay, M.B.J., et al., 2009, Environ. Sci. Technol. 43: 7086-7091.
Ludwig, R.D., et al., 2009. Environ. Sci. Technol. 43: 1970-1976.
Mayer, K.U., et al., 2002, Water Resour. Res. 38: 1174-1195.

Oral presentations

A1.1

SEM-based Automated Mineralogy of Follow-up Stream Sediment Geochemistry: A QEMSCAN Pilot Study from Northern Pakistan

Liaqat Ali[1], Charles Moon[1], Ben Williamson[1], Gavyn Rollinson[1]
[1] Camborne School of Mines, University of Exeter, Penryn, Cornwall, UK, [2]National Centre for Excellence in Geology, University of Peshawar, Peshawar, Pakistan

The use of automated SEM-based mineralogy is becoming common place in the mining industry, particularly in geometallurgy. This technique provides a comprehensive overview of the mineralogy of samples and is useful in locating rare grains. Currently in excess of 150 instruments have been installed worldwide, either of the Mineral Liberation Analyser or of the 'QEMSCAN' type. However, there are few descriptions of their use on conventional geochemical samples, no doubt due to the typical current cost of $500 per sample.

This study investigates the use of QEMSCAN to follow up on a regional geochemical survey covering 100,000 km^2 of northern Pakistan. Alluvial Au is widespread and appears to be spatially associated with major shear zones. Many anomalies in this survey remain uninvestigated, being of unknown sources and deposit types due to their remoteness. The strategy adopted in this study was to take -80-mesh stream sediment and panned concentrate samples in three areas in which the sources of the anomalies were unknown, complemented by two areas in which the sources were better understood. These samples were analysed by conventional ICP-MS and XRF and a detailed investigation of any gold grains observed in panned concentrates was carried out. Sixteen samples were run on the QEMSCAN: a stream sediment and panned concentrate sample from two sites in each unknown area, as well as samples of both media from the areas which are better known. Approximately 6000 grains were analysed in each sample at a resolution of 6 µm and results are reported as (1) a percentage of each mineral encountered; (2) a matrix showing the association with other minerals based on adjoining pixels; and (3) the size of the grains. Images of all grains were captured using EDX and key minerals of interest were imaged in detail. Results were reported for 34 mineral classes (Species Identification Protocol) chosen from initial qualitative SEM.

Stream sediment results allow some discrimination of sources: carbonates from silicate-dominated areas. The trace minerals are dominated by Fe oxides and Fe carbonates, as well as pyrite where water temperatures are low. Rare minerals appear to be detectable to 10s of ppm equivalent, and include PbSbO, Cu(O) phases as well as galena, arsenopyrite and chalcopyrite. In areas of known Sb mineralisation, stibnite and SbO phases are also present. Panned concentrates provide clearer discrimination of sulphide and oxide phases, notably in discriminating different copper-bearing phases. The grain imagery also provides information on the degree of oxidation of sources. In addition to the suspected types of mineralisation, pentlandite and cobaltite were also detected suggesting previously unknown styles. Automated mineralogy is a very useful and cost-effective technique to aid in follow-up of stream sediment and panned concentrate anomalies.

A1.2

New measurements of selenium and sulfur concentration in country rocks of the Duluth Complex, Minnesota, USA, and implications for the formation of the Ni-Cu-PGE deposits

Matthias Queffurus, Sarah-Jane Barnes
Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada

The assimilation process of country rocks by the mafic magma is believed to play a key role in the genesis of magmatic Ni-Cu-PGE sulfide deposits because this contamination, especially by S-rich sedimentary rocks, is thought to provide the S necessary for saturation of the mafic magma. High S/Se ratios are thought to be evidence that S has been derived from country rock sediments.

Previous work at the Duluth Complex has emphasized the importance of country rocks assimilation in the genesis of the mineralization (e.g., Mainwaring & Naldrett, 1977; Ripley, 1981; Andrews & Ripley, 1989) and the S/Se ratio has been used to examine the process (Ripley, 1990; Thériault & Barnes, 1998). Sulfur (S) and selenium (Se) were determined in the sulfide-bearing igneous rocks, xenoliths and the country rocks. However, the analytical methods at the time did not allow accurate determination of Se in the country rocks. We have redetermined S and Se concentrations and added new sulfur isotopes ($\delta^{34}S$) for the Virginia Formation (V.F.), unmetamorphosed sediments away from the contact, metamorphosed sediments at the contact and in xenoliths, and for the sulfide-bearing igneous rocks. Selenium concentrations were determined by TCF-INAA technique (Thiol Cotton Fiber - Instrumental Neutron Activation Analysis), developed by Savard et al. (2006), with a detection limit of 2 ppb.

It had been suggested that all the V.F. could be the source of S (Ripley, 1990; Thériault & Barnes, 1998). The preliminary results of our work show that most of the V.F. samples have S/Se ratios (1300-6000) lower than those of the ore. Only the samples close to the contact of a particularly S-rich layer, known as the Bedded Pyrrhotite Unit (BPU), and the xenoliths have S/Se ratios (> 20000) higher to than those of the sulfide-bearing igneous rocks. Ripley (1990) and Thériault & Barnes (1998) reported high S/Se ratios (8000-54000) for unmetamorphosed rocks of the V.F but our redeterminations of Se in these rocks show that the previous analyses were incorrect, probably due to a combination of proximity to the detection limit of the method used and interferences. The concentration of S (3-5%), the high S/Se ratio and the very high sulfur isotopic values ($\delta^{34}S = +16$ ‰) of rock samples from the BPU strongly indicate that this layer would be the main source of S assimilated by the mafic magma.

References:
Andrews, M.S. & Ripley, E.M., 1989. The Canadian Mineralogist 27, 293-310.
Mainwaring, P.R. & Naldrett, A.J., 1977. Economic Geology 72, 1269-1284.
Ripley, E.M. 1981. Economic Geology 76, 610-620.
Ripley, E.M. 1990. Economic Geology 85, 1935-1940.
Savard et al., 2006. Talanta 70, 566-571.
Thériault, R. & Barnes, S.-J., 1998. The Canadian Mineralogist 36, 869-886.

A1.3

Light Element Analysis by Portable XRF in Geochemical Applications

Michelle Cameron, Esa Nummi
Bruker Elemental, Kennewick, WA, USA

Portable X-ray fluorescence (XRF) instrumentation has become an accepted technique for field analysis in geochemical applications in recent years. Today, handheld XRF is an important tool for a variety of different geochemical and mining applications, ranging from geological exploration to analysis of ore concentrates.

Traditionally handheld XRF has been capable of only determining heavy elements, which has limited its feasibility for some applications. With the introduction of handheld XRF instruments based on Silicon Drift Detector (SDD) technology the range of elements which can be determined using portable XRF has extended to include low atomic number elements, such as magnesium, aluminum, silicon, phosphorus, and sulfur. These elements help to more accurately determine mineralogy of the sample and give new valuable information to mining and exploration geologists. In addition to the extended elemental range, the improved detector resolution and signal to noise ratio provide lower detection limits for all analyzed elements. This enables new SDD-based handheld XRF instruments to reliably determine lower concentrations than before. The capability to analyze accurately at the parts per million level is important not only for geological exploration, but also for many other applications such as identifying heavy element pollutants in soil.

The ability to determine the light element matrix of the geological sample with handheld XRF instrument provides entirely new information about the composition of the ore and at the same time makes the analysis for the principal elements more accurate. This presentation will provide a summary of the capabilities of modern SDD-based handheld XRF instruments in geochemical applications and provide several examples based on real geological samples.

A1.4
Nanoparticles of Re and precious metals in black shales: analytical determination and extraction

Galina Oleynikova[1]*, Elena Panova*[1]
[1]All Russian Geological Institute, Saint-Petersburg, Russia, [2]Saint-Petersburg state university, Saint-Petersburg, Russia

Mineral resource depletion cause the development of methods for exploration of low and ultra low concentrations of trace elements and methods of their extraction from rocks, ores and waste.

For rare and dispersed chemical elements the condition of dispersion is the basic. It is well-known, that the average maintenance of a chemical element in an earth's crust is the more is its share in the disperse form.

Application of modern technique and methods of direct visual observation of nano-particles has allowed to observe particles with size up to 0.25 nm. But determination of chemical composition of nano-particles has some difficulties. In the course of microprobe analysis due to extra small size of nano-particles the probe burns through them and does not give opportunity to evaluate their chemical composition independently from the matrix. Analytical sensitivity is 0.01% at the same time local composition of single particles of the sample does not reflect geochemical specificity of the whole rock.

It is necessary to find a way to separate fraction which consists of dispersed elements, i.e., to concentrate them by separation from the mineral matrix of a rock. As a basis for the method of separation of particles with the size less than 1mkm is taken the fact that under special conditions nano-particles can form in water colloid solutions which are stable for a long time. It is possible to separate colloid particles from water only using different coagulants or by means of ultra centrifugation. Appliance of filters with pores 1mkm for filtration allows to adhere to the upper particle size: all the particles in the solution are of nano size - up to 1 mkm. And after the evaporation of water from the solution a substation mass is measured. The fraction obtained in this way was called nano-dispersed fraction or nano-fraction. In nano-fraction chemical elements are in ionic, molecular and colloid form; it makes 0.01-6 weight. % of the sampels.

Then colloid-salt water solution of nano-fraction is analyzed by ISP MC method. Analysis of nanofraction water solutions maximizes the possibilities of the ISP MC method because no chemical reagents are used and they don't negatively affect the result. The method allows to lower by 2-3 orders of magnitude the detention limits for a wide range of rare trace elements: (whole sample/nano-fraction, ppm): Ag-0,05/0,0001; Au-0,002/0,0002; Pt-0,04/0,0004; Pd-0,03/0,0006; Rh-0,03/0,0001; Ru-0,1/0,0004; Ir-0,03/0,0001; Re-0,03/0,0001.

In nanofractions of black shales the following maximum maintenance of elements has been found out (mg/l): Re - 22,6; Ag - 9,7; Au - 1,4; Pd - 1,7; Pt - 0,5.

Degree extraction of rhenium and precious metals from nanofractions of black shales in relation to the total maintenance makes 10-100 %.

A2.1
Predicting Elemental Concentrations of Glacial Till by VSWIR Reflectance Spectroscopy

Maarit Middleton[1]*, Paavo Närhi*[1]*, Viljo Kuosmanen*[2]*, Raimo Sutinen*[1]
[1]Geological Survey of Finland, Rovaniemi, Finland,

[2]Geological Survey of Finland, Espoo, Finland

Chemometric modelling of soil element concentrations from diffuse visible and near-infrared (VSWIR, 350-2500 nm) reflectance spectroscopic measurements holds potential for soil element analyses. The ultimate goal would be to use VSWIR spectroscopy to reduce the number of wet chemical analyses, as in some cases the accuracy gained with VSWIR is almost equal to wet chemistry. Research has demonstrated its value particularly for organic agricultural soils (Viscarra Rossel et al., 2006), yet little is known about the VSWIR response to glacial tills. The objective of this research is to evaluate the capability of laboratory VSWIR reflectance spectroscopy to quantify the till chemical composition. The study focuses on local scale (limited geographic extent) relationships between reflectance and laboratory-determined concentrations of chemical elements in the mineral powder fraction of tills.

In this work, we studied soils with low organic matter content developed on unstratified glacial materials at two geologically similar sites on the mafic metavolcanic rocks of Greenstone belt in northern Finland. The till samples (n = 217) were composed primarily of quartz, plagioclase and amphibole having less than 3% of clinoclorite, talc and illite. Visible and near-infrared spectra of mineral powder (<0.006 mm) samples were measured in the laboratory, and the spectral reflectance was regressed with partial least-squares regression (PLSR) against partial elemental concentrations of till obtained by hot aqua regia leaching and inductively coupled plasma atomic emission spectrometry (ICP-AES) analysis.

PLRS resulted in simultaneous prediction (R2=0.80-0.89) of several soil chemical elements such as Al (validation RMSE 1802 mg kg^{-1}), Ba (5.85 mg kg^{-1}), Co (0.86 mg kg^{-1}), Cr (6.94 mg kg^{-1}), Cu (2.54 mg kg^{-1}), Fe (2088 mg kg^{-1}), Mg (449.60 mg kg^{-1}), Mn (0.82 mg kg^{-1}), Ni (3.24 mg kg^{-1}), V (4.88 mg kg^{-1}), and Zn (0.80 mg kg^{-1}). The electronic and vibrational molecular processes causing absorption might be responsible for accurate predictions of major elements such as Al, Fe and Mg. However, the concentrations of other major and trace elements could be predicted by the PLSR because they were cross-correlated to spectrally active soil elements or extraneous soil properties.

This paper demonstrates the capability of laboratory VSWIR spectroscopy for determining element concentrations of glacial tills. The results of this study show that, in local scale studies in geologically homogenous areas, the limited spread of the data may restrict the use of the spectroscopic-chemometric approach. Further work should focus on overcoming the issues of the VSWIR effects of clay and precipitate mineralogy in soil horizons and understanding the causality for cross-correlation in quantification of the elements. Then the spectroscopy-chemometric approach would truly aid in reducing the number of wet chemical analyses in mineral exploration, forest soil or other soil-related studies in terrains characterized by an abundance of glacial tills.

References:

Viscarra Rossel, R.A. et al., 2006. Geoderma 131 (1-2), 59-75.

A2.2

A new Approach to In-situ Density Determination of Drill Cores

Johanna Helena Susanna Dry, Jeremiah Pelo
Anglo American, Johannesburg, South Africa

Quality control management in many laboratories has increased to the point where significant analytical errors in the commodity elements are easily identified and rectified. Density measurements on the other hand have changed little over time with often relatively crude displacement methods still being used to generate critical density figures for subsequent use in resource calculation.

Bulk density implies the density of extractable volumes of rock inclusive of voids. The in-situ density includes the void and grain boundary water present in the rock in its natural state. Whilst the latter is important for estimation of the tonnage of material to be moved during mining, for resource estimates, however, dry bulk density is required (Lipton, 2000).

There are many ways of establishing the density of a material, but which do not necessarily measure the same definition of density. Specific gravity (SG) or relative density measurements are typically undertaken on pulp material by volumetric determination or by using a gas pycnometer on a small sample of between 5 and 10 g. SG usually measures density relative to water or gas.

Traditionally bulk density has been determined using the Caliper method or the Archimedes principle. The volume of a solid, often drill core, is determined by comparing the weight of the sample in air to the weight of the sample immersed in a liquid of known density - usually water. Specific gravity can vary significantly from bulk density in rocks that contain voids.

A simple and rapid method for determining in-situ density on solid drill cores has been developed. The methodology and instrumentation have been validated against conventional methods using drill core samples from a range of different lithologies. The methodology is non-destructive and has a working range up to 6 g/cm^3. A complete quality control programme has been developed during the test work which allows accurate measurement with excellent precision. Such quality data will significantly improve the confidence of information being used in ore reserve definitions. The methodology, instrumentation and QC practices will be discussed in this paper.

References:
Webb, P.A. 1977, Analytical Methods in fine Particle Technology, Norcross, USA
Lipton, I. T. 2001, Measuring of Bulk Density for Resource Estimation, Aus MIM

A2.3

Characterization of Variance in Reference Materials: Isolating Analytical, Digestion, and Sub-Sampling Errors and Determining a Fundamental Sampling Constant

Cliff Stanley[1], Nelson O'Driscoll[1], Pritam Ranjan[2]
[1]Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada, [2]Dept. of Mathematics & Statistics, Acadia University, Wolfville, Nova Scotia, Canada

Geochemical analysis of geological materials introduces errors at virtually every stage of sample preparation, digestion, and analysis. Although determining the error introduced during analysis is commonly undertaken using replicate analyses, specifically determining the digestion and sub-sampling error is commonly intractable. This is because digestion oftentimes destroys the sub-sample, preventing replicate digestion and the isolation of sub-sampling and digestion errors. This poses a significant problem in the analysis of samples used for data quality assessment (reference materials), because one cannot be sure how much of the observed error is introduced during digestion, and how much is introduced due to sub-sampling of a heterogeneous reference material.

Fortunately, by analyzing sub-sample replicates of a geological material of two different masses, and solving a system of three equations in three unknowns, the actual digestion error can be deduced and distinguished from the sub-sampling error. This provides a means to estimate sub-sampling and analytical error magnitudes, and allows analysts to identify the largest source of error in their geochemical determinations. If total error is too high, the analyst then knows which component error (the largest) to reduce to most efficiently reduce their overall error.

Furthermore, decoupling sub-sampling and digestion error provides a means to quantify the heterogeneity of reference materials using a fundamental sampling constant. This constant is equal to the product of sample mass and the sub-sampling variance (in units of mass 'times' concentration 'squared') and describes an essential characteristic of an element in a geological material (its degree of heterogeneity). As a result, this constant should be provided, along with the accepted element concentration, to purchasers of commercial reference materials so they not only have an idea of what the mean concentration will be, but also have an idea of what the variation about that concentration is. This would allow decomposition of the observed variance of analyses of replicate reference materials into sub-sampling, digestion, and analytical error components, and thus can be used to identify the most precise laboratory participating in round-robin geochemical analysis proficiency tests.

A2.4

Use of automated mineralogy for identification of multi-commodity indicator minerals

Hugh de Souza, Kim Gibbs, Chris Gunning, Sarah Prout
SGS Mineral Services, Lakefield, ON, Canada

The success of the indicator mineral surveys in identifying diamond bearing kimberlites be it in glacial or stream sediments has led to many attempts to use this approach for other commodities. In the case of gold deposits, the use of gold grains as indicators has had some success. For other commodities the success rate has not been as good. In part the reason has been that the indicator minerals for a range of mineral deposits such as metamorphosed VMS deposits, skarns, magmatic Ni-Cu massive sulphides, or copper porphyries, encompass a large range of minerals (Averill, 2001) that are not easily selected even when limited to grains larger than 250 ųm. Proportionally, a greater percentage of the indicator mineral population occurs in the finer fractions that are difficult to pick manually. The answer to this dilemma is to use scanning electron-beam (SEM) technologies for automated identification of minerals.

In particular, development of QEMSCAN technology has simplified indicator mineral selection by automating the identification of minerals in heavy mineral concentrates. The finest material can now be examined for their full mineral content yielding information such as indicator mineral abundances, mineral mass distribution or particle shapes or sizes. It is even possible to perform this on a split of the sample submitted for geochemical analysis allowing correlations between the mineral population and the geochemical data.

In this presentation we discuss the application of this technology to samples from an exploration project in Greenland, it use in diamond indicator mineral studies and in Ni-sulphide exploration.

Averill, S.A., 2001. Special Publication 185, Geological Society of London, 69-81

A3.1

Copper and Iron isotopes in mine tailings and their relationship to weathering processes

Nathalie Perez Rodriguez, Peter Nason,
Lena Alakangas, Björn Öhlander
Division of Geosciences, Luleå University of Technology, Luleå, Sweden

The milled ore material in mining activities (tailings) is usually left exposed to weathering processes that might lead to the release of elements and formation of secondary minerals. A profile from a test cell with tailings material from the Kristineberg mine site in northern Sweden was sampled and the ratios $^{65}Cu/^{63}Cu$ and $^{56}Fe/^{54}Fe$ measured to study the relation between changes in isotopic composition.

Copper and Fe are isotopically fractionated by different mechanisms, such as modification of redox state, dissolution and precipitation of Fe and Cu minerals (Herbert, 2008; Ehrlich, 2004), and complexation with organic matter and biochemical mechanisms (Bigalke, 2010). Previous research (Alakangas, 2006) proved evidence of ongoing oxidation of minerals like pyrite, pyrrhotite and sphalerite in the studied test cell, with clearly visible oxidized and unoxidised zones in the tailings material.

There are significant Cu and Fe isotopic variations occurring along the profile. A shift to the lighter Cu isotope is seen at the oxidation front stimulated by the formation of covellite from the transformation of pyrrhotite and chalcopyrite. On the other hand, an enrichment in the heavier Fe isotope occurs in the oxidation front caused by the presence of remaining pyrite from the oxidation process where the stronger ^{56}Fe bonds dominate. The general trend in the oxidation process of this test cell leaves the solid phase in the oxidised zone enriched in the lighter Cu and Fe isotopes compared to the values from the unoxidised zone. The presence of Fe-oxy(hydro)oxides in the oxidised zone contributes an increase in the lighter Fe isotope. During the formation of these secondary oxides the light ^{56}Fe is preferentially taken up (Fernandez and Borrok, 2009).

This work is one of the first studies that offer a link between the fractionation mechanisms of Cu and Fe in oxidising mine waste and offers hindsight of the redox processes occurring in mine tailings that could be used for further treatment.

References:

Alakangas, L., 2006. Pilot-scale studies of different covers on unoxidised sulphide-rich tailings in Northern Sweden: The geochemistry of leachate waters. Mine water and the environment 25, 171-183.
Bigalke, M. et al., 2010. Copper isotope fractionation during complexation with insolubilized humic acid. Environmental Science & Technology 44, 5496-5502.
Ehrlich, S. et al., 2004. Experimental study of the copper isotope fractionation between aqueous Cu(II) and covellite, CuS. Chemical Geology 209, 259-269.
Fernandez, A. and Borrok, D. M., 2009. Fractionation of Cu, Fe, and Zn isotopes during the oxidative weathering of sulfide-rich rocks. Chemical Geology 264, 1-12.
Herbert, R. B., 2008. Iron isotope fractionation by biogeochemical processes in mine tailings. Environmental Science & Technology 42, 1117-1122.

A3.2

Sulfur and lead isotope geochemistry of the carbonate-hosted Pb-Zn deposit of Jebel Ghozlane (Nappes zone, Northern Tunisia)

Nejib Jemmali[1,2], Fouad Souissi[1], Torsten W Vennemann[3], Emmanuel John M Carranza[4]
[1]Laboratoire des Matériaux Utiles, Sidi Thabet, Tunisia, [2]Laboratoire des Ressources Minérales et Environnement (LRME), Département de Géologie,, El Manar, Tunis, Tunisia, [3]Stable Isotope Lab., Inst. of Mineralogy and Geochemistry, University of Lausanne, Lausanne, Switzerland, [4]Dept. of Earth Systems Analysis, Faculty of Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands

The Pb-Zn mine at Jebel Ghozlane is located in the Nappes zone (northern Tunisia). The occurrence of the deposit as veins, stockworks, disseminations and replacement heaps at zones of contact between the Triassic dolostones and the Eocene limestones along major faults links the mineralization with tectonic processes. Barite and celestite in the deposit have $\delta^{34}S$ values (+14.3 - +24.0‰ VCDT) that are consistent with the derivation of sulfates from Triassic evaporites and probably Messinian seawater. The $\delta^{34}S$ values of galenas, varying between -9.1 and +22.1‰, can be split into two groups, one with positive $\delta^{34}S$ values (with a median of +13.2‰) and the other with negative $\delta^{34}S$ values (with a median of

-4.0‰). These data suggest mixing of two sulfur end-members of mineralizing fluids, each correspondingto different reduction mechanisms (bacterial sulfate reduction and abiotic thermochemical sulfate reduction) of Triassic evaporites and probably Messinian seawater. Pb isotopes in galena from the deposit yielded average ^{206}Pb/^{204}Pb, ^{207}Pb/^{204}Pb and ^{208}Pb/^{204}Pb ratios of 18.705, 15.667 and 38.734, respectively, implying a well-mixed multi-source upper crustal reservoir of metals. Trace elements indicate the presence of two types of galenas, namely 'pure' galena (with undetectable Zn and As) and As-rich galena (with 0.2-0.5% As), whereas sphalerite contains 0.7-0.9% of Cd. Microthermometric analysis of fluid inclusions in celestite shows that deposition of the ore was due to circulation of a warm (172+/-5 °C) fluid, composed of a heterogeneous mixture of saline (19.5+/-1 wt% NaCl eq) aqueous solution and a gaseous CO_2-rich phase bearing low amounts of other gases probably consisting of CH_4, N_2 and/or H_2S. Given the geological events related to the Alpine orogeny in the Nappes zone (nappe emplacement, bimodal volcanism, presence of inherited faults connected to deep-seated faults cutting the Mesozoic-Cenozoic cover and the Triassic salts and possibly extending into the basement) a Late-Miocene age is proposed for the Pb-Zn ore deposit at Jebel Ghozlane.

A3.3

Wild mushrooms as an indicators of vertical migration of ^{137}Cs in different types of forests at the Kivalo research area in Northern Finland

Jarkko Ylipieti, Kristina Rissanen
Radiation and Nuclear Safety Authority,
Rovaniemi, Finland

Radiation and Nuclear Safety Authority has monitored radioactivity concentrations in soil and mushrooms in forest stands at the Kivalo research area in the south part of Northern Finland since early 80's. After the Tshernobyl accident in 1986 monitoring changed into more systematical and also soil profiles were taken at the same time mushrooms as samplies. In this study ^{137}Cs activity concentrations were compared between soil profiles and mushrooms taken in 1993, 1999 and 2001. The aim of this study was to explore is it possible to use mushrooms as an indicators to determine vertical migration of ^{137}Cs in different types of forests.

The ^{137}Cs concentrations were measured from soil and mushrooms samples collected in pine, spruce, birch and mixed stands. Soil samples were taken in each stands from four different locations, which consist of three soil profile samples: organic, humus and mineral layer [((4x4)x3profile)x3year]. Nuclides emitting gamma radiation were measured in 144 soil and 38 mushroom samples. Analysed mushrooms were: Suillus variegatus (6), Lactarius rufus (3), Russula decolorans (6), Russula paludosa (2), Russula xerampelina (8), Cortinarius armillatus (6), Russula vinosa (3), Lactarius vietus (4).

The mean ^{137}Cs concentrations were 140 Bq/kg in organic, 130 Bq/kg in humus and 32 Bq/kg in mineral layer during 1993. Mean values in 1999 were 64, 61, 18 and in 2001 89, 86, 14, respectively. The most common types of mushrooms of pine forest were Suillus variegatus and Lactarius rufus. ^{137}Cs concentrations in Suillus variegatus were in 1200, 440 and 505 Bg/kg d.w. and Lactarius rufus 2200, 1000, 1500 Bg/kg d.w.. In spruce stands the most common species were Russula decolorans and Russula paludosa. These were represented as Russula, which ^{137}Cs concentrations were 580, 400 and 660 Bg/kg d.w.. In birch stand were used Russula xerampelina and Cortinarius armillatus (1100, 430, 360 and 4520, 2640, 3190)(Bg/kg d.w.) and in mixed stand Suillus variegates, Russula vinosa, Lactarius vietus, Russula xerampelina and Cortinarius armillatus (2360, 830, 710; 1300, 300, 450; 2090, 1500, 130; 1320, 400, 400; 5350, 6850, 3400) (Bg/kg d.w.).

Results indicate that ^{137}Cs migrates in time from the organic layer to the humus layer. The ^{137}Cs activity concentration correlate in humus layer with those measured in mushrooms while the total ^{137}Cs activity was decreased in the organic layer. The ^{137}Cs activity concentration in mushrooms decrease in 13 years after the fallout but after that increased at the most of the studied mushrooms.

A4.1

Using Trend surface modeling to identify the geochemical anomaly boundaries

Reza Ghavami-Riabi[1], Zohra Jangravi[1],
E. Hajmolla ali[1]
[1]Shahrood Univ. of Technology, Shahrood,
Semnan, Iran, [2]Kaniran Company, Tehran,
Tehran, Iran

Using multivariate analysis and anomaly separation methods together gives a better evaluation from the high priority areas for the follow up exploration program (Yu Chang et al., 1980; Sarma and Selvaraj, 1990; Unwin., 2009). For this propose, a case study of stream sediments geochemical samples from a polymetal deposit were used. The areas with high potential for the exploration were determined by using single and multivariate analyses and the spatial distribution geochemical anomaly maps were drawn (Jangravi, 2010). The multivariate analyses were identified the high correlations between Pb, Au, Ag, Zn, Cu with Sb, Cd, Bi, Mo. High concentration of Pb values, heavy minerals of Pb, Zn, Cu As, and the exist of barite veins in the study area were confirmed the formation of polymetal deposit in the study area. The results of heavy mineral studies in the study area and the spatial distribution geochemical anomaly map were combined to access to a based map for the follow up evaluation.

In order to clearly determine the anomaly boundaries in the study area, trend surface method were used on index ratio distinguished by the multivariate method (Au+Ag+Pb/Ti+Cr+Ga), the background values were removed and the anomaly areas were determined. The trend surface-order 4 was evaluated the best identification of the anomalous area according to the based map.

References:
Jangravi, Z., 2010, MSc Thesis, pp 118.
Sarma D.D. and Selvaraj J.B., 1990,,Computers and Geosciences, 16- 7, 897-909.
Unwin D.J., 2009, International Encyclopedia of Human Geography, 484-488.
Yu Chang.W. et al., 1980, Mathematical geology, chap.15, p.946.

A4.2

Drill hole geochemistry at Wharekirauponga, Golden Cross and Ohakuri epithermal gold prospects, New Zealand

Anthony Christie[1], Richard Carver[2], Joel Thomas[1], Al McOnie[3]
[1]GNS Science, Lower Hutt, New Zealand, [2]GC Xplore, Perth, Australia, [3]Consulting Geologist, Katikati, New Zealand

Exploration drill hole geochemistry has been compiled in Leapfrog 3D databases for three epithermal Au-Ag prospects in the North Island of New Zealand: Wharekirauponga (WKP) and Golden Cross in the Hauraki Goldfield, and Ohakuri in the Taupo Volcanic Zone. Host rocks are predominantly rhyolite for WKP, andesite and dacite for Golden Cross and rhyolitic ignimbrite for Ohakuri. All three exhibit anomalous As and Sb associated with the Au-Ag mineralisation, but concentrations of Cu, Pb and Zn are generally at background levels. Gold to silver ratios average 0.22 at WKP and 0.25 at Golden Cross, but are much lower at 0.05 at Ohakuri. The Au:Ag ratio generally increases with increasing Au grade. This effect is most pronounced at WKP, less so at Golden Cross, and very mild at Ohakuri. Gold concentrations peak in specific depth ranges: between RL 30 m and 130 m at WKP, between RL 125 m and 200 m at Golden Cross, and between RL 220 m and 260 m at Ohakuri, defining vertical Au zones. Antimony and As peak above and below the Au zones at WKP and Golden Cross, but at the top of the gold zone at Ohakuri.

A4.3

Multi-scale interactions of geological processes during mineralization: cascade dynamics model and multifractal simulation of geochemical landscapes

Lingqing Yao[1], Qiuming Cheng[1]
[1]China University of Geosciences, Wuhan, China,
[2]York University, Toronto, Canada

Relations between mineralization and certain geological processes are established mostly by geologist's knowledge of field observations. However, these relations are descriptive and a quantitative model of how certain geological processes strengthen or hinder mineralization is not clear, that is to say, the mechanism of the interactions between mineralization and the geological framework has not been thoroughly studied. The dynamics behind these interactions are key in the understanding of fractal or multifractal formations caused by mineralization, among which singularities arise due to anomalous concentration of metals in narrow space. From a statistical point of view, we think that cascade dynamics play an important role in mineralization and studying them can reveal the nature of the various interactions throughout the process. We have constructed a multiplicative cascade model to simulate these dynamics. The probabilities of mineral deposit occurrences are used to represent direct results of mineralization. Multifractal simulation of probabilities of mineral potential based on our model is exemplified by a case study dealing with hydrothermal gold deposits in southern Nova Scotia, Canada. Our research helps to understand how the singularity occurs during mineralization, which remains unanswered up to now, and the simulation may provide a more accurate distribution of mineral deposit occurrences that can be used to improve the results of the weights of evidence model in mapping mineral potential.

A4.4

Modern spatial analysis methods for geochemical landscape/image processing and interpretation

Qiuming Cheng[1]
[1]York University, Toronto, Canada, [2]China University of Geosciences, Wuhan, China

The role that numeric methods play or shall play in exploratory geochemical data processing; analysis and interpretation has been generally underestimated in several recently published review papers on the primary basis of application of classical statistics methods for anomaly classification and element association identification etc. While the classical statistics and multivariate statistical analysis methods have been commonly applied in analysis of geochemical data as mostly attribute values from point samples and these methods do not usually take into account the locations and spatial properties of samples. As more geochemical data becomes available due to the advancements of geochemical sampling and analytical techniques including various sensor technologies and portable devices which can generate semi-quantitative geochemical data with high spatial resolution geochemical data are no longer just point sample data. Instead geochemical landscape and images coverage become the source of geochemical information. Accordingly new and specialized analytical techniques are highly demanded for processing geochemical images and spatial patterns which contain vast amount of information. Not only should new data analysis techniques be developed but also some classical concepts such as anomalies and background need to be adopted to reflect the advances of the data and data processing techniques. This paper introduces several recently proposed spatial analysis techniques. These include self-organized mapping (SOM) technique which can convert the multidimensional geochemical data into 2D to 3D spatial maps showing the spatial relationship of the geochemical data; geographically weighted regression (GWR) and spatially weighted principle component analysis (SWPCA) which takes into account the location and geographical properties of samples. These spatially weighted multivariate models provide localized regressions to characterize the spatial variability of relationships among elements and their spatial distributions; Boost technique is a new technique for classification. It works with sequential weak classifiers which eventually lead to accurate classification of geochemical anomalies; singular data interpolation method is also a new method which can handle exploratory data without stationary and isotropy assumption. The utilizations of these nonlinear techniques will be demonstrated using several standard geochemical datasets for anomaly identification and interpretation of geochemical processes in mineral exploration.

A5.1

Hydrogeochemical baseline characterization and implications for exploration and environmental assessment of a porphyry molybdenum deposit, Malmbjerg, Greenland

Robert Bowell[1], Andrew Barnes[1], Devin Sapsford[2], Daniel Thomas[2], Jesper Konfoed[3]
[1]SRK Consulting, Cardiff Wales, UK, [2]School of Engineering, Cardiff, Wales, UK, [3]Quadra FNX, Vancouver, Canada, Canada

The Malmbjerg (a porphyry granitic ridge) in eas-tern Greenland hosts a significant world class molybdenum deposit of the ‘Climax’ (high-F low base metals) type. Geochemical assessment of the geological, mineralogical and geochemical characteristics of the deposit have been completed as part a feasibility study.

As a part of this study the influence of weathering at ambient and low temperature has been completed. The pyritic mineralisation of the Malmbjerg occurs as a shell around the molybdenite zone. However, in general, sulfide content of the rocks is low, being less than 0.03 wt% in much of the intrusive complex, the mafic and trachyte dykes and in the unmineralized sandstone unit.

The majority of rocks that are likely to be acid generating are the greisen zones, the pyritized sandstone, the pyritized granite and the mineralized porphyry units. Although sulfide content does not exceed 2wt%, inorganic carbon or carbonate minerals are virtually absent and are dominated by siderite which has a low capacity for acid buffering. Consequently the actual potential to neutralize acid is low in the system so any acid generation is noticeable. The majority of lithologies in the Malmbjerg deposit show low levels of reactivity and as such it is difficult by static testing to confirm the potential for acid generation. However, humidity cell testwork (run for up to 95 weeks) has demonstrated that leachate pH has in many samples demonstrated a gradual decrease in pH conditions over an extended period of time but at release rates significantly less than indicated by static testing alone.

Despite the low sulfide content and rate of oxidation, sulfide oxidation was still observed in humidity cells conducted at low temperature (less than 4°C) as well as at ambient temperature indicating that such reactions can still occur at low temperatures, presumably without the catalytic influence of biological activity. These results have important implications in the prediction and assessment of the potential for ARDML in low temperature arctic environments.

The consequence of the weathering characteristics of the porphyry is that spring melt water carries pathfinder signals of high fluoride, molybdenum, zinc, manganese and sulfate that are also observed in adjacent vallies. Thus similarity between the different spring waters indicates the presence of potentially other buried deposits in the area.

A5.2
Metal and sediment accumulation the in Lake Pyhäjärvi

Jari Mäkinen
Geological Survey of Finland, Kuopio, Finland

Lake Pyhäjärvi (115 km^2) in the Pyhäsalmi municipality is a headwater lake, with a morphology based on NW-SE- and N-S-directed bedrock faults. The mean and maximum depths of the lake are 6 m and 27 m, respectively. The main basin of the lake is the Isoselkä sub basin, while the smaller Kirkkoselkä sub basin occupies the NE-part of the lake.

The major soil type of the catchment (434 km^2) is till. In different time scales, several natural and anthropogenic loadings have focused on the lake and the most significant point source of metals has been the Pyhäsalmi Cu-Zn mine since 1962, which is located near the Kirkkoselkä subbasin.

To delineate the accumulation of dry matter (DM) and metals to the lake, dual frequency echo sounding (200 and 24 kHz, MD500, www.meridata.fi) and sediment sampling were performed at the lake. ICP-OES-analytics (EPA 3051) was used to determine the sediment chemical composition. Sediment dating was based on the ^{137}Cs-method (1986, Chernobyl fallout).

The major anthropogenic loading was detected in the top (< 12 cm) sediment section, representing the industrial period in general. Between 1966 - 2008, average DM accumulation was 157 g/m^2/a in the Kirkkoselkä sub basin, and 102 g/m^2/a in the Isoselkä sub basin. The impact of the mine on sediment composition was distinctive, because the mean Cu and Zn contents of Kirkkoselkä sediments (1966 - 2008) were 114 mg/kg and 620 mg/kg, respectively, but only 76 mg/kg 379, mg/kg in Isoselkä. Arsenic concentration, however, was higher in the Isoselkä (56 mg/kg), than in the Kirkkoselkä (38 mg/kg) subbasin. The As distribution is thus not linked to the mine, but rather to the natural background concentration in the catchment and to the internal sedimentation system in the lake.

The spatial distribution of sediments was “normal” in Kirkkoselkä: i.e. most of the DM and metal accumulation was focused on the deepest part of the subbasin (ca. 10 m). The situation was, however, reverse in Isoselkä, where the deepest part of the subbasin (> 21 m) is an erosional area while accumulation areas lie in the shallower areas. Furthermore, sediments in Isoselkä occur as dune like formations on the flanks of the deep, which points to the action of wind driven bottom currents.

The results show that proper selection of sediment sampling points requires knowledge of the sedimentation dynamics in the basin, because the deepest parts of the lake may be erosion areas. If sampling is systematically directed to the deepest parts of lakes without knowledge of accumulation/erosion systematics, results may give a distorted picture of the contaminant transport and accumulation in the basin.

A5.3
The Application of Predictive Geochemical Modelling to Determine Backfill Cover Requirements at Turquoise Ridge Joint Venture, Nevada

Ruth Warrender[1], Rob Bowell[1], Amy Prestia[2], Andy Barnes[1], Wayne Mansanares[3], Mark Miller[3]
[1]SRK Consulting (UK) Ltd, Cardiff, UK, [2]SRK Consulting (US), Reno, USA, [3]Barrick Turquoise Ridge, Nevada, USA

Predictive geochemical calculations have been completed for the Turquoise Ridge and Valmy Pits, Getchell gold mine, Nevada (USA) as part of an updated evaluation of waste rock disposal management. The purpose of the modelling exercise was to predict the concentrations of solutes that may emanate from the waste rock backfilled pits and to assess the impact of seepage from the pits on underlying groundwater chemistry. The results of the geochemical modelling will be used to assess the level of cover required for the backfilled pits in order to ensure that no degradation of groundwater occurs.

Geochemical modelling was carried out using the USGS-developed software PHREEQC (Parkhurst and Appelo, 1999). Source term solutions were developed from the results of Meteoric Water Mobility Procedure (MWMP) tests run on representative materials and then scaled to field conditions. Seepage water quality predictions were made based on the mass load mixing of waters contacting different lithologies in each of the backfilled pits. Water quality predictions were then made for a number of seepage scenarios, including 1 percent, 5 percent, 10 percent, 50 percent and 100 percent of mean annual precipitation that will infiltrate the backfill and report as seepage to groundwater.

The results of the modelling exercise demonstrate that the impact of the pits on the underlying groundwater is largely dependent on the amount of seepage. In general, significant changes in groundwater chemistry were noted when there was greater than 5 percent seepage from both the Turquoise Ridge and Valmy pits. Under the 100 percent seepage scenario, the impacted groundwater is likely to be characterised by elevated concentrations of arsenic, selenium, sulfate and manganese. However, the impact to groundwater may be greatly reduced if less than 5 percent seepage can be attained.

Full fate and transport modelling is currently being carried out to verify the risk posed by seepage from the pit backfill to down-gradient receptors. The results of the fate and transport modelling will be utilised to develop cover requirements for closure of the backfilled pits.

References:
Parkhurst, D.L. and C.A.J. Appelo, 1999. User's Guide to PHREEQC (Version 2). A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. USGS Open file report.

A5.4
Concentration dynamics in a boreal catchment – trace elements, REEs and humic substances

Stefan Karlsson, Bert Allard, Viktor Sjöberg
Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden

The focus of this study is the concentration dynamics of selected transition elements and REEs in a small creek draining a boreal catchment. The system under study contains coniferous stands with minor contribution of deciduous species while the shrub layer is mainly ferns and vaccinium species with a few grasses. The bedrock consists of granite/leptite with amphiboles and local lenses with calcareous material (i.e. calcite). The till soil has a similar composition. Annual precipitation is approximately 700 mm, with snow cover from December to March.

Weekly samples have been collected since 2006 at one site in the downstream area of the catchment to follow the dynamic changes of the aqueous phase. The samples were analysed for general hydrochemical parameters: Eh, pH, principal inorganic anions (ion chromatography), metals (ICP-MS) and organic matter. The latter was evaluated as TOC, DOC, molecular weight (GPC; Mn and Mw), UV/Vis and fluorescence spectra. Metal speciation in the aqueous phase was modelled.

The results show a pronounced seasonality for concentrations of elements as well as DOC and general hydrochemical parameters. The flow pattern is dominated by high flows at snow melt (some 200 l/sec) and autumn rains (80 l/sec) and no flow at all in late summer and winter, respectively.

Typical ranges are pH 4-7, TOC 5-80 mg/l, F^- 0.05-0.50 mg/l, Cl^- 1-5 mg/l, SO_4^{2-} 1-30 mg/l and NO_3^- <0.05-3 mg/l. The concentrations of principal anions and TOC are inversely related to water flow, i.e. low concentrations at high flow, possibly reflecting the residence time of the water at different depths in the soil before it reaches the creek.

The total metal concentrations show variations of up to 4 orders of magnitude. Some elements had a high correlation (r2 > 0.90) to TOC (Al, Co, Fe, (Ga), U, Pb, Sr, V, Zn) while others (Bi, Mn, Mo, (Ni), Rb, Tl) were unrelated. Only Al, Ca and Fe occasionally reached saturation according to the geochemical modelling. The TOC was dominated by molecular weights (Mw) in the range 1200 to 3000, that were always present, but at different concentrations. Organic matter with molecular weights exceeding 65,000 were found in late autumn and early winter. Evaluation of UV/Vis and fluorescence spectra, respectively, confirmed that the TOC mainly consisted of fulvic and humic acids. The seasonal variations of the water signature is further discussed.

A6.1
Speciation of trace metals in a contaminated stream at the Laver mine by using membrane filtration, ultrafiltration, DGT and transplanted aquatic moss

Björn Öhlander, Jerry Forsberg, Helene Österlund, Johan Ingri, Frauke Ecke, Lena Alakangas
Luleå University of Technology, Luleå, Sweden

Four metal speciation and fractionation techniques; Diffusive gradients in thin films (DGT), 1 kDa ultrafiltration, 0.22 µm membrane filtration and aquatic moss, were simultaneously applied in a small, contaminated stream in northern Sweden. The objectives were to investigate differences and similarities in what the different methods actually measure, and to study if DGT may give information on bioavailability of metals. Sampling was performed 10 times in the small stream Gråbergsbäcken, draining the tailings area of the abandoned Cu mine Laver. The normal DGT devices with Chelex cation exchanger were used. Ultrafiltration was performed with a manufacturer-specified cutoff of 1kDa. The membrane filters used had a pore size of 0.22 µm. Shoots from the aquatic moss Fontinalis Antipyretica L ex Hedw. were collected in a non-polluted brook with a native moss population, and transported to the sampling site for exposure.

The results show that 0.22 µm membrane filtration, 1 kDa ultrafiltration and DGT generally measured different metal fractions where <1 kDa ultrafiltered concentrations were lower than DGT labile concentrations which in turn were lower than <0.22 µm concentrations. Strong correlations between DGT and <1 kDa permeate for Al, Cu, Cd, Co and Zn imply that DGT can be a simple alternative to the time-consuming ultrafiltration procedure. The concentration differences between DGT and <1 kDa permeate indicate the occurrence of labile colloids discriminated by ultrafiltration. The DGT-labile concentrations of Fe, Al, Cu, Mn and Co were lower than corresponding <0.22 µm concentrations, suggesting that a fraction of these metals was associated to colloids not measured by DGT. These are most likely Fe- and Al-oxyhydroxides precipitating when acid drainage from the Laver mine is diluted and pH increases (Alakangas et al., 2010). Despite a rigorous sample cleaning, retention of particulate matter on the moss samples was revealed by a significant correlation between metal concentrations in moss and particulate Fe. Generally, elevated trace metal concentrations were found in moss exposed at the sampling site compared to reference moss from the non-polluted brook. No significant correlations were found between DGT-labile concentrations and moss concentrations. From this comparison, no conclusions can be drawn regarding the capability of DGT to measure the bioavailable metal fraction in water.

References:
Alakangas, L. et al., 2010. Estimation of temporal changes in oxidation rates of sulphides in copper mine tailings at Laver, Northern Sweden. Science of the Total Environment 408, 1386-1392.

A6.2

Carbon and Nitrogen Concentrations and Isotopic Composition in Sediments of Lakes Receiving Nitrogen Rich Mine Effluents

Sara Chlot, Anders Widerlund, Björn Öhlander
Div of Geosciences, Luleå University of Technology, Luleå, Sweden

Mine water discharged from the Kiruna and Boliden mine sites in northern Sweden contains elevated concentrations of nitrogen caused by undetonated ammonium nitrate-based explosives and cyanide used in gold extraction. In the present study, sediment cores were collected in two consecutive years from tailings- and clarification ponds and down stream lakes at these mine sites. Cores were analyzed for their carbon (C) and nitrogen (N) content and isotopic composition ($\delta^{13}C$ and $\delta^{15}N$). 210Pb-data enabled dating of the sediment cores using a constant initial concentration model (Turner & Delorme, 1996). Based on a multi-G model (Westrich & Berner, 1984), organic matter decomposition and remineralization of sedimentary N were described.

The range in sedimentary C concentration was rather similar for all collected cores (5- 18 %), while sedimentary N was relatively lower in Boliden sediments (0.5 -1 % compared to 0.5- 3 % at the Kiruna site). C/N ratios in the Kiruna sediments decreased towards the sediment surface from 15-10, except for C/N ratios in the tailings pond. On the contrary, C/N ratios in the Boliden sediments increased towards the surface from 20- 25 (clarification pond), and from 12-15 (lake) respectively. In both systems, lowest value of superficial sedimentary C/N ratio was found in the lakes with highest summer bio volume of phytoplankton. However, the generally higher ratios in the Boliden sediment indicate larger input of terrestrial or macrophyte origin.

Based on sedimentation rates and N concentration in surface sediment, total N (TN) deposition for the Kiruna lakes was calculated to be 4- 13 % of the TN discharged (70- 125 tonnes/year). For the Boliden lake, TN deposition was 1-2 % of the TN discharged (45 -100 tonnes/year). These rates are low compared to what has been observed by e.g. Heathwaite (1994). During ~50 years, about 10 tonnes of N have been deposited in the sediment of the Boliden clarification pond.

Towards the surface of the sediments of the Kiruna lakes and the Boliden clarification pond, $\delta^{13}C$ and $\delta^{15}N$ first remained rather constant and then increased. A fairly contrasting pattern was observed in the Boliden lake sediment. Based on 210Pb dating of the cores, changes in isotopic composition could be related to initiation of mining activity.

In conclusion, the results obtained revealed both within- and between system variations. Furthermore, C and N concentrations and isotopic composition of sedimentary organic matter seem to be a convenient tool for calculating N deposition on the sediment surface of receiving lakes, and for deducing which biogeochemical processes that have influenced N in the sediment.

References:
Heathwaite, A.L., 1994. Journal of Hydrology 159, 395-421.
Turner, L.J. & Delorme, L.D., 1996. Environmental Geology 28, 78-87.
Westrich, J.T. & Berner, R.A.,1984. Limnology and Oceanography 29, 236-249.

A6.3

Solid Characterization of Nano-Sized Hydroxyapatite after the Exposure to an Aqueous Fluoride Solution

Vanessa A. S. Sternitzke[1], Ralf Kaegi[2], C. Annette Johnson[1]
[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Water Resources and Drinking Water, Duebendorf, Switzerland, [2]Eawag, Eawag, Swiss Federal Institute of Aquatic Science and Technology, Department of Process Engineering, Duebendorf, Switzerland

Hydroxyapatite(Ca10(PO4)6(OH)2;HAP)isthemain constituent of bones and teeth. Its ability to take up fluoride is applied in dental care (Driessens, 1973) but also for drinking water purification (Bregnhoj, 1995). For the latter, the fluoride uptake capacity is a crucial factor for limiting the deployment of defluoridation filters. Although much research was performed on fluoride uptake on HAP within the last decades (e.g. Gasser et al., 1992; Dorozhkin, 1997), which focused on solution chemistry, there is still a lag in understanding the processes controlling fluoride uptake on HAP. Here we show what parameters are critical for fluoride uptake and how they affect the mineral properties.

Batch studies were performed at 25°C to investigate the uptake of fluoride as function of pH and initial fluoride concentration on synthetic nano-sized HAP over an equilibration time of 28 days. Samples were taken at adequate time intervals to determine the dissolved solution compositions, while the pH was adjusted by titration systems. The reacted material was collected for further analysis.

Using Fourier Transform Infrared Spectroscopy (FT-IR) and Transmission Electron Microscopy (TEM) the presence of fluorapatite ($Ca_{10}(PO_4)_6F_2$; FAP) on the reacted solid material was determined, which was consistent with observations from solution chemistry. By Nano Secondary Ion Mass Spectroscopy (NanoSIMS) we gained evidence for a thin surface layer of FAP on HAP.

To our knowledge it is the first time that the presence of a FAP surface layer on a nano-sized HAP crystal was qualitatively and quantitatively determined by micro- and spectroscopic analyses. The findings may help to optimize HAP-based filter systems in order to enhance their uptake capacities and to understand influences by solution compositions.

References:

Driessens, 1973; Nature 243, 420-421
Bregnhoj, 1995; PhD Thesis, University of Denmark
Gasser et al., 1992; Colloids and Surfaces; 74, 275-286
Dorozhkin, 1997; Journal of Crystal Growth; 182, 133-140

A6.4

Hydrogeochemical assessment of surface water - groundwater interaction: model development

Dmytro Siergieiev, Angela Lundberg
Luleå University of Technology, Luleå, Sweden

Previously river surface water and adjacent groundwater aquifers have chiefly been considered separately while little attention has been paid to the exchange between them. However, during the last decade the importance of the hyporheic zone, that delineates the boundary between surface water and groundwater, has been highlighted (Boulton et al., 1998). Today, river-aquifer interaction is an intensively evolving research area and the hydrogeochemical exchange that occurs within the ecotone comes into focus. Direct measurements of processes within the hyporheic zone are good tools to improve the current understanding of this hydrological compartment. However, this is both resource and time demanding, and it is not until now the amount of data and background knowledge has reached a level when descriptive and predictive simulations can be performed. The aim with this study is to model exchange processes occurring within the hyporheic zone of a regulated river.

Short and long term regulation in the Lule River, Northern Sweden, provokes hydrological and geochemical modifications of the hyporheic corridor.

Major hydrogeochemical processes on the river-groundwater interface have been studied during a one year cycle. Key parameters of both the river and aquifer have been measured at fixed points on a profile orthogonal to the river. Continuous time-series have been collected for the hydraulic head, temperature, electrical conductivity and pH, while major elements, nutrients and organic matter have been measured biweekly.

A conceptualized approach is targeted to simulate water fluxes, heat transfer and mass transport between the river and the aquifer. A coupled simulation of saturated and unsaturated processes in the hyporheic zone is applied. Finite-element software FEFLOW (Diersh, 2009) is set up to handle the 2D hyporheic exchange between the aquifer and the river. The finite-difference Coup-Model (Jansson & Karlberg, 2004) is used to model the unsaturated zone processes. Weather variables and hydraulic heads are driving forces of the simulation.

The exchange processes are modeled using state-of-the-art approach. The model will be calibrated against geochemical data, time-series of hydraulic head and temperature measured in the well close to the river, and seepage measurements performed in the river bed for part of the observation period and the rest of the data will be used for validation. As a result of model evaluation, increase of knowledge and better understanding of the hyporheic zone is expected.

References:

Boulton et al., 1998. The Annual Review of Ecology, Evolution, and Systematics 29, 59-81.
Diersch, H.J., 2009. FEFLOW reference manual. WASY Software, 292 pp.
Jansson, P.-E. & Karlberg, L., 2004. Royal Institute of Technology, Stockholm, 435 pp.

A7.1

Soil arsenic risk map of Pirkkala municipality, Finland

Timo Tarvainen[1], Birgitta Backman[1], Samrit Luoma[1], Vesa Vanninen[2], Jaana Jarva[1], Tarja Hatakka[1]
[1]Geological Survey of Finland, Espoo, Finland,
[2]Municipality of Pirkkala, Pirkkala, Finland

High natural concentrations of arsenic and some other elements is a special geological feature of the Tampere region in Finland, and the elevated concentrations should be taken into account in land use planning and in the assessment of soil contamination (Hatakka et al., 2010). The EU Life Environment funded RAMAS project investigated the occurrence of arsenic in the Tampere region in 2004-2007. The project designed a region-wide arsenic risk map based on arsenic concentrations in bedrock, soil or in groundwater and surface waters. Concerning the human health risks, potable water from drilled bedrock wells was determined to be the main exposure route (Ruskeeniemi et al., 2010).

Municipality of Pirkkala is located southeast of the city of Tampere. The region-wide arsenic risk map revealed elevated arsenic concentrations in Pirkkala. According to a recent decision of the Administrative Court of Hämeenlinna, the arsenic concentrations had to be taken into account in city planning in one area with elevated arsenic concentrations in soil and in the bedrock. In December 2010, the Geological Survey of Finland developed a local level soil arsenic risk map for Pirkkala. The map was based on soil arsenic analysis and investigations from earlier geochemical mapping and exploration projects as well as on fourteen new soil samples from selected new planning areas.

Arsenic concentrations up to 26 mg/kg were considered typical baseline concentrations for most soil types in the Tampere region (Hatakka et al. 2010). The local risk map of Pirkkala showed large areas with the soil arsenic concentrations of 50 - 100 mg/kg in the central part of the municipality. The highest concentrations were over 1000 mg/kg. Concentrations between 26 - 50 mg/kg were common in the western part of the municipality while the eastern part showed lower arsenic concentrations. However, the sampling density was rather low in the East and North-West Pirkkala.

The soil arsenic anomalies could not be delineated using regional geological maps even when the most common soil type, glacial till, reflects partly the underlying bedrock. From the investigated soil parent materials, till and sand tend to have higher arsenic concentrations than fine-grained sediments clay and silt. According to the health authorities of Pirkkala, elevated arsenic concentrations have been measured from well waters in the soil arsenic risk areas. The known arsenic risk areas will be taken into account in the city planning and construction in Pirkkala. Local arsenic risk map and associated measures will be included in the new building code of Pirkkala that will be in force on 1 January 2012.

References:
Hatakka et al., 2010. Geological Survey of Finland, Report of Investigation 182.
Ruskeeniemi, T. et al., 2010. Geological Survey of Finland, Special Paper 49.

A7.2

National geochemical baseline database - Tapir

Jaana Jarva, Timo Tarvainen, Mikael Eklund
Geological Survey of Finland, Espoo, Finland

In Finland, a new Government Decree on the assessment of soil contamination and remediation needs (214/2007) has generated a need for reliable and easily accessible data on soil geochemical baselines or ambient background values of potentially harmful elements. In the Decree, geochemical baselines refer to the natural geological concentrations and diffuse anthropogenic input of substances in soil.

Geological Survey of Finland (GTK) in cooperation with the Finnish Environment Institute (SYKE) has developed the national geochemical baseline database called 'Tapir' (Jarva et al., 2010). Finland has been divided into geochemical provinces to better provide information on regional geochemical baselines. In the regional till geochemical mapping, several metals (Co, Cr, Cu, Ni, V, Zn) showed anomalous concentration in seven provinces. Elevated arsenic concentrations have been reported in four provinces. The database combines information gathered by GTK, other research institutes, universities and consultant companies. Data on individual sampling sites are not publicly available, but all existing data are used in calculating regional statistics (Ikävalko et al., 2011). Statistics are separately calculated for each geochemical province and each soil type. The upper limit of baseline variation within a province is defined as the upper limit of a box-whisker-plot diagram. The province-specific upper limit value is often used as a trigger value for soil contamination assessment.

In addition to use as a trigger value for soil contamination assessment, baselines have been used to determine upper and lower guideline values for soils. These guideline values must be taken into account in the risk assessment in case of soil contamination. If regional geochemical baseline values are available, the national guideline values prescribed in the Decree based on ecological risk can be modified accordingly (Jarva et al. 2010).

GTK has carried out geochemical mappings at the regional and local level in areas where geochemical baselines are high due to geological conditions. This has allowed determining regional and localgeochemical baselines for such regions. In addition to soil contamination studies, regional and local geo-chemical baselines are also taken into account in the environmental permits and land use planning.

References:
Ikävalko et al., 2011. Geological Survey of Finland, Special Paper 49, 197 - 204.
Jarva et al., 2010. Science of the Total Environment 408, 4385 - 4395.

A7.3

Environmental assessment of Ni and Cd in topsoil and ground-level dust from urban playgrounds, public gardens and parks from Lisbon, Portugal

Amélia Reis[1], Carla Patinha[1], Eduardo Ferreira da Silva[1], Ana Dias[1], Sofia Bartolomeu[2], António Sousa[3], Anabela Cachada[4], Maria Batista[5], Cátia Prazeres[5], Rui Figueira[3], Cecilia Sérgio[6], Rita Salgueiro[1], Orquidia Neves[3], Armando Duarte[4]
[1]GEOBIOTEC, University of Aveiro, Aveiro, Portugal, [2]Physics Department, University of Aveiro, Aveiro, Portugal, [3]CERENA-Technical Superior Institute, Lisbon, Portugal, [4]CESAM, University of Aveiro, Aveiro, Portugal, [5]LNEG, Lisbon, Portugal, [6]Jardin Botânico - MNHN, Lisbon, Portugal

This study presents results from a project untitled "Geochemical survey of Lisbon urban soils: a baseline for future human health studies". Fifty one topsoil and 50 ground-level dust samples were collected in playgrounds, schoolyards, urban parks and public gardens. At each site, 1 uncontaminated moss transplant was fixed to a horizontal tree limb, which remained in situ for a period of 6 months. Soil were sieved to the <2 mm (usually used in environmental studies) and <250 μm (usually used in bioaccessibility testing) soil fractions. Dust samples were sieved to the <250 μm fraction. Total concentrations of potentially harmful elements (PHE) were determined by ICP-MS. Concentrations of PHE in the soil, one of the important pathways of exposure, where compared with those in dust and in moss. Oral bioaccessibility testing for Ni and Cd was carried out using the Unified Bioaccessibility Method (Wragg et al, 2009), validated by the Barge group. The results show that Ni in topsoil is uncorrelated with the physical-chemical soil parameters but is correlated with trace elements (TE) like Sr, Y, Sc, Mg, Cr, Ti or V. Higher Ni concentrations occur in soils of the Volcanic Complex of Lisbon (VS). Previous studies indicate that these are residual and in situ soils, a conclusion that is confirmed by the geochemical association found. So, the source of Ni is mostly geogenic. In dusts Ni is correlated with Mg, Cr, Ti and other TE typical of the VC, but it is also correlated with Ni, Cr, V concentrations in the topsoil, which implies that some dusts are re-suspended from soil. Bioaccessibility estimates of Ni are slightly higher in the stomach phase (G) and the samples with a higher fraction of bioaccessible Ni belong to the VC, meaning that although geogenic this PHE is bioaccessible in values that reach the 15 mg/kg. In topsoil, Cd is only correlated with Cu, Zn and Mo, indicating that Cd in soil is not related with the parent material but with anthropogenic sources. In dust Cd is correlated with other PHE like Sb, Pb, Cu and As. Levels of Cd in biomonitors indicate that there are anthropogenic sources emitting this PHE for the atmosphere, which may be dispersed by the wind or reach the soil through the deposition of Cd-laden particles. Bioaccessibility estimates are low and similar in the G phase and the stomach/intestinal phase (GI) but, unlike Ni, higher bioaccessibility estimates do not occur in the same samples in both phases. The different trends in Ni and Cd bioaccessibility between simulated G and GI phases are likely to be related to pH of each phase, by possible reactions with site-specific soil matrix components and potential ligands in the extracted solutions.

A7.4

Geochemistry of kindergarten playground soils in Zagreb, Croatia

Slobodan Miko, Martina Šparica Miko, Ozren Hasan, Saša Mesić, Nikolina Ilijanić
Hrvatski geološki institut - Croatian geological survey, Zagreb, Croatia

Potentially toxic elements (PTE) guidance values in soils in child-care centers and playgrounds have not been developed in Croatia. An evaluation of soil concentrations of PTE for 150 kindergarten centers and 50 playgrounds in Zagreb showed that Pb, Hg, P, (Cu) Sb, Ag (Au) can be attributed to anthropogenic pollution signature. Road dust contribution and paint containing lead seems to be the major sources of PTE to the playground soils. Playgrounds associated with day-care centers in Zagreb are located at 191 sites and host 28,000 children.

Potentially toxic elements (PTE) as urban soil contaminates of environmental concern have been targeted by numerous studies in the past 20 years (Kabata-Pendias & Mukherjee, 2007). Urban soils present a media that greatly affect health of young children due to their contamination by certain heavy metals from different sources (Ottesen et al., 2008).

The playground soils located in the central and former industrial sites in Zagreb are enriched with Pb, Hg, Sb, and Zn compared with sites located in new residential and former rural surroundings of Zagreb. The PCA extracted 5 major components responsible for variation in elemental distribution. The first factor contains a signal from the influence of lithological bedrock composition (Ca, Mg, Al, Fe, Th, Co, Cr, Ni), the second shows the Pb, Hg, P, (Cu) Sb, Ag (Au) attributed as an anthropogenic pollution signature. The significant inputs of anthropogenic origin are present in 20% of the playgrounds. Most of the analyzed old paints from playing equipment were identified as lead-based paint (Pb content >0,5%). In 16 the composite topsoil contained more than 100 mg/kg Pb. Lead, Hg, As, Zn, Cd and Cu concentrations in topsoils were found to be higher than those defined by health-based soil quality criteria at 10% of the child-care playgrounds. The association of Sb with Pb (r=0.8) in soils indicates that a large part of lead in the soil is derived from road dust that can be attributed to wear of brake linings (Månsson et al., 2009). The $^{206}Pb/^{207}Pb$ ratios of analysed soils with elevated Pb concentraions and paint chips have ratio values of <1.11 which is mainly attributed to petrol lead influence.

References:

Kabata-Pendias, A. & Mukherjee, A.B., 2007. Trace elements from soil to human, Springer-Verlag, Berlin, 550pp.

Månsson, N.S., Hjortenkrans, D.S.t. et al., 2009. Sources of antimony in an urban area, Environmental Chemistry 6(2) 160-169.

Ottesen, R. T. et al., 2008. Soil pollution in day-care centers and playgrounds in Norway: national action plan for mapping and remediation. Environmental Geochemistry and Health (in print).

A8.1

Natural arsenic in Northern Sweden - a risk assessment

Gunnar Jacks, Magnus Mörth, Zdenka Slejkovec
KTH, Stockholm, Sweden

Arsenic is an old poison that has made a "comeback" especially as a chronic toxicant in drinking water coming from groundwater sources (Bhattacharya et al., 1997). There are three mechanisms that mobilize arsenic into water, a high pH decreasing adsorption of anions, oxidation of sulphides and reduction of ferric compounds (Bhattacharya et al., 2007). The redox dependence in combination with the low permissible limits for water means that even moderate amounts of arsenic in soils and rocks could pose an environmental risk. In Northern Sweden large areas are underlain by metasediments containing about 1 % S with pyrite, arsenopyrite and sphalerite (Svensson, 1980). This project has investigated the cycling of arsenic in metasediment areas and in tills overlying them. The media taken into consideration is water, plants and the aquatic fauna like macroinver tebrates and fish.

Till rich in sulphidic metasediments oxidize and an accumulation of the released arsenic can be seen in the B-horizons of the podsols. In wetland ferric reduction raise the arsenic content in groundwater up to 100 mg/l as compared to the permissible limit for drinking water which is 10 mg/l. After discharge into drainages and streams the released ferrous iron oxidizes and the ferric precipitates may contain as much as 0,5 % As and sandy sediments 200-500 mg/kg As. Larger streams and lakes have above background concentrations of As and a number of lakes have in the order of 5-7 mg/l As. Wetland plants do show elevated As but only the silica rich Equisetum spp have largely elevated content up to 30 mg/kg. Presumably the uptake of arsenic occurs via similar mechanisms as for silica. The silica rich and crispy Equisetum spp are not palatable for wild grazing animals like reindeers and mooses. As in macroinvertebrates and fish has been speciated into As(III), As(V), MMA, DMA and arsenobetain (Slejkovec et al., 2004). The data for macroinvertebrates are somewhat difficult to decipher presumably due to problems in extraction. Fish show predominantly the less toxic organic arsenic, predominantly aresenobetain, and can be considered suitable for consumption.

Thus the overall assessment is that in spite of strikingly high concentrations in sediments and in groundwater the arsenic does not represent a great environmental risk neither for wild grazing animals nor for consumers of fish. Only wetland groundwater is a risk if used for water supply when high in iron and arsenic.

References:

Bhattacharya et al., 1997. Water Res Develop 13: 1-15.

Bhattacharya et al., 2007. Sci Tot Environ 379: 109-120.

Slejkovec et al., 2004. Talanta 62: 931-936.

Svensson, U., 1980. Swed. Geol. Survey Serie C 764, 79 pp.

A8.2

Baseline Geochemical Investigation of Heavy Metals in Soils around Polokwane Area, Limpopo Province, South Africa

Jason Samuel Ogola, Humbulani Rejune Mundalamo, Guenther Brandl
University of Venda, Thohoyandou- Limpopo Province, South Africa

In many developed countries, such as Scandinavia, Britain, Canada, Australia, geochemical mapping has been incorporated into the strategic systematic geosciences survey, which deals with geochemical data in order to prepare modern geochemical maps in line with the International Geochemical Base-Line (Mills, 1996). Geochemical baseline data are important for mineral exploration, epidemiological studies and environmental management (Plant et al., 2003). The Council for Geoscience of South Africa has already embarked on such surveys in a number of provinces in order to prepare the geochemical map of South Africa, which will then be used as the geochemical baseline data for mineral exploration and environmental management (Szczesniak, 1998).

This study therefore was a follow up of the findings of the Council for Geoscience. The focus was on the distribution and origin of heavy metals; mainly Pb, Zn, Cu, As and Cr. The work involved soil and rock sampling, and analysis of samples using atomic absorption spectrometry and X-ray fluorescence spectrometry.

The preliminary study established the occurrence of five anomalous targets around Polokwane area with maximum concentrations of metals in soil of (ppm): 82 Pb, 61 Zn, 58 Cu, 39 As and 765 Cr. A detailed study was carried out on the two of the five anomalies and the average soil concentrations were: (ppm): 5 Pb, 27 Zn, 23 Cu, <4 As, and 195 Cr and 31 Pb, 43 Zn, 27 Cu, 11 As and 256 Cr respectively. The concentrations of these metals in rocks within the two anomalies were: (ppm): 3.9 Pb, 52 Zn, 6.6 Cu, <4 As and 62 Cr and 3.1 Pb, 143 Zn, 157 Cu, <4 As and 122 Cr respectively. These concentrations of heavy metals in soils and rocks suggest that the porphyritic granite and the meta-volcanic amphibolite rocks that were analysed were the source of heavy metals within Polokwane area. The determined pollution index of soils registered Pi values from the two anomalies of 0.1 Pb, 0.1 Zn, 0.2 Cu, 0.1 As and 1.0 Cr (Tweefontein) and 0.3 Pb, 0.1 Zn, 0.3 Cu, 0.4 As and 1.3 Cr (Polokwane Airport). The findings indicated that soils within and around Polokwane Airport were polluted with Cr, thus not suitable for agricultural activity and can be of risk to human health through food chain.

References:

Mills, C.F., 1996. Environmental Geochemistry and Health 113, 1-5.
Plant et al., 2003. Geology and Health: Closing the Gap, Part III. Oxford University Press, New York, pp. 129-134.
Szczesniak, H.L. 1998. Open File Report No. 1998-0168, 1-15.

A8.3

Relevance of Arsenic Binding to Humic Acid in the Presence of Copper Ions

Xiaolan Liu[1], Maarten Nachtegaal[1], Christian Ludwig[2], Evgeny Kleymenov[1], Yongguang Zhu[3]
[1]Paul Scherrer Institute (PSI), 5232 Villigen PSI, Switzerland, [2]Swiss Federal Institute of Technology (EPFL-IIE), CH-1015 Lausanne, Switzerland, [3]Research Center for Eco-Environmental Science (RCEES), Beijing 100085, China

It has been estimated that more than 100 million people are at risk due to consumption of harmful arsenic-enriched groundwater (Smith et al., 2000). In northern China, arsenic contaminated drinking water is of special concern in poor rural areas. This indicates the high need of information about natural arsenic contamination, its transport, and possible removing mechanisms.

Recent studies indicated that soluble arsenic (As) concentrations in groundwater often correlate with high amounts of dissolved organic carbon (Redman et al., 2002). This suggests that dissolved organic matter (DOM) may play a major role in mobilizing As oxyanions by forming As-DOM complexes. The binding of As oxyanions to negatively charged DOM via a bridging metal cation (Me) is generally considered as the major reaction mechanism among all the possible reaction pathways for As-DOM complexation (Wang & Mulligan, 2009). However, no direct evidence of this reaction has been given. Till now, most studies were conducted by means of solution chemistry. In this context, X-ray absorption spectroscopy (XAS) is a valuable tool since it provides direct structural information (local coordination around As, up to 6 Angstrom).

Using a combination of chemical methods and normal/high-resolution XAS spectroscopy, we proved the occurrence of humic acid-copper-arsenate ternary complexes under environmentally relevant neutral pH conditions and successfully investigated their coordination environment for the first time. We found that As(V) can be linked to the copper octahedron after the release of equatorial water molecules in bidentate mono or binuclear forms. This strongly suggested that arsenic complexation with humic acid bridged by divalent Cu^{2+} can directly affect the toxicity, mobility and fate of arsenic in the environment. Use of this behavior may be developed as an effective option to reduce and avoid further As contamination. For this purpose, field studies are needed. Natural water samples collected from northern China are currently being analysed for the presence of As-(Metal)-DOM complexes. The findings of this study can help local people to obtain information about the As situation and to further develop remediation technologies, e.g. optimal filters to eliminate As complexes from drinking water.

References:
Smith et al., 2000. Bulletin of World Health Organization 78, 1093-1103.
Redman et al., 2002. Environ. Sci. Technol. 36, 2889-2896.
Wang, S. & Mulligan, C.N., 2009. Chemosphere 74, 274-279.

A8.4

Redistribution of arsenic in two lakes affected by historical mining activities, Stollberg, Sweden

Mattias Bäckström
Man-Technology-Environment Research Centre,
Örebro University, Örebro, Sweden

Mining and milling took place between 1898 and 1931 at lakes Staren and Plogen at Stollberg, Sweden. Silver, lead and zinc were the primary elements of interest. During the operation tailings were poured directly into lake Staren and the creek connecting the lakes. Remaining at the shores of lake Staren are approximately 50 000 m^3 non acid generating jig tailings containing, on average, 2 000 mg/kg arsenic, 15 000 mg/kg lead and 20 000 mg/kg zinc. In the lake sediments very high trace element concentrations are still found in the surface sediments (0-2 cm). For arsenic the concentrations are around 2 000 mg/kg, for lead around 8 000 mg/kg and for zinc around 12 000 mg/kg. It is estimated that the total amount of trace elements in both lakes are 270 ton arsenic, 3 400 ton lead and 5 000 ton zinc in the top 30 cm. Analysis of trace elements in surface waters, suspended matter, sediment traps, pore waters and sediment profiles during a year were performed in order to study the redistribution of trace elements within the lakes. Surface water concentrations were found to be relatively low and diffusion from the sediments is only significant for arsenic (Toevs et al., 2008). High trace element concentrations were found both in the suspended matter and in the material from the sediment traps close to the sediments. In the suspended matter arsenic concentrations were found to be between 1 700-2 400 mg/kg, lead concentrations between 1 000 and 1 800 mg/kg and zinc concentrations between 2 400 and 3 900 mg/kg.

Calculated arsenic/titanium ratios for the suspended matter as well as for the materials in the sediment traps indicate that a significant portion of the resuspended materials consist of tailings. A mass balance approach for both lakes indicates that lake Staren still receives tailings from the old dumps at the shores through erosion. Both lakes are, however, still working as sinks for trace elements even though diffusion of arsenic into the surface waters is significant (approximately 10 kg yearly). Contaminated sediment is today covered with sediments with lower trace element concentrations but due to resuspension and diffusion (Andrade et al., 2010; Martin and Pedersen, 2002) the surface sediment concentrations are still very high.

Results indicate that tailings still are redistributed within the sediments of the two lakes more than 80 years after closure of the mining activities at the lake shores.

References:
Andrade, C.F., Jamieson, H.E., Kyser, T.K., Praharaj, T. and Fortin, D., 2010. Applied Geochemistry, 25: 199-211
Martin, A.J. and Pedersen, T.F., 2002. Environmental Science & Technology, 36: 1516-1523
Toevs, G., Morra, M.J., Winowiecki, L., Strawn, D., Polizzotto, M.L. and Fendorf, S., 2008. Environmental Science & Technology, 42: 6823-6829

A8.5

Mercury in Bottom Sediments of the Amur River, Its Flood-Plain Lakes and Estuary, Eastern Siberia

Fyodor Kot[1], Konstantin Bakanov[2], Nikolay Goryachev[3]
[1]Technion-Israel Institute of Technology, Haifa, Israel, [2]Institute of Water and Ecological Problems, FEB RAS, Khabarovsk, Russia, [3]Ministry of Agriculture and Forestry, Biosecurity New Zealand, Auckland, New Zealand

The Amur River (Heilongjiang) is one of the world's largest rivers. It drains a 1,855,000 km^2 area of Eastern Asia that varies in geological, geochemical, and climate-landscape features. The region's environment is strongly affected by rapid economic development, boosted since the 1930s in the Russian and since the 1950s in the Chinese parts of the basin. Mercury (Hg) is a typical element of the region's mineralization; many cinnabar deposits and manifestations have been prospected here. Moreover, the territory is under heavy anthropogenic pressure due to intensive economic development that includes activities accompanied by noticeable emissions of Hg to the environment through poor waste management practices and accidental emergency discharges. Yet, information on Hg distribution and behaviour in this region is scarce and inadequate. In order to evaluate Hg levels and fate in this vast territory, surveys of river, lake, and estuarine bottom sediments, as integral indicators of the basin environmental status, were carried out in 1990, 1991, 1997, and 2004. The results showed the following: (1) stagnation of the Russian economy in the 1990s has resulted in a noticeable decrease of the Hg content in the Amur River sediments to the basin pristine level of about 0.05 mg kg^{-1}; (2) Hg distribution in the sediment depth proves the element redox-dependent behaviour; (3) in some cases, Hg enrichment may be related to the long-term anthropogenic emission; (4) Hg concentration in bottom sediments was found to increase in the following order-the Amur River mouth, the estuary, and the Sea of Okhotsk, showing the weakly non-conservative Hg behaviour during estuarine water mixing.

A9.1

Surface water-groundwater interactions at Lake Pyhäjärvi, SW Finland : Chemical and isotopic systematics

Kirsti Korkka-Niemi, Anne Rautio
University of Helsinki, Helsinki, Finland

In Finland, the Precambrian bedrock is covered by a thin layer of glacial and postglacial sediments varying in thickness from a few to some tens of meters. Most of the Finnish aquifers are shallow, unconfined sand and gravel deposits, i.e. eskers, ice-marginal end moraine complexes or minor beach terraces. The management of water resources has traditionally focused on either groundwater or surface water bodies. However, it is apparent that nearly all surface water features interact with groundwater.

General water chemistry and stable isotopic compositions are used to indicate the groundwater discharge from esker aquifers into Lake Pyhäjärvi and to evaluate the proportion of groundwater in inshore. The mesotrophic Lake Pyhäjärvi has a surface area of approx. 155 km^2, a perimeter length of 88 km and a mean depth of 5.5 m. Its drainage basin area is 616 km^2. There are two major rivers discharging into the lake and one outflowing river from the lake. Lake Pyhäjärvi provides an ideal, large lake system where it is possible to examine spatial patterns in shoreline groundwater seepage. The research was focused on a 20-km long northeastern shoreline at Lake Pyhäjärvi because the potential groundwater discharge zones are related to an esker aquifer.

Discharge sites were identified via measuring temperature, electrical conductivity (EC), and pH in the lake water; and measuring lake bed sediment temperatures. The fluxes of the order of 10^{-3} and 10^{-4} cm s^{-1} were measured using seepage meters at the study locations (Rautio and Korkka-Niemi, 2011).

Main ions, pH, EC, alkalinity, dissolved ox- ygen, TOC, total phosphorus and total nitrate were analysed from groundwater (from seepage meters and mini-piezometers), inshore water and surface water samples. The EC of groundwater is 1.5-4 times in magnitude of that in lake water, while the pH of groundwater is more than one unit lower. In addition, groundwater differs from surface and inshore waters due to lower TOC values and higher nitrate and chloride concentrations. Otherwise groundwater discharging into the lake has major ion concentrations typical of the shallow unconfined aquifer in the area (Ca-HCO$_3$-type water).

In isotope ratios, there is a significant difference between the groundwater ($\delta^{18}O$ values about -12‰ and δD values about -86 ‰ (VSMOW)), and the lake water ($\delta^{18}O$ values about-7.5‰ and δD values about -60‰ (VSMOW)) and, therefore, the isotope data can be used to confirm the discharge and to calculate mixing ratios.

According to cluster analysis (variables EC, dissolved oxygen, K, Na, Ca, Cl, HCO$_3$, and NO$_3$), two main clusters were obtained: groundwater and surface water/inshore water. Mixing-ratios of groundwater and surface water calculated using AquaChem.

Rautio, A. and Korkka-Niemi, K., 2011. Boreal Environment Research (in press)

A9.2

Tracing groundwater-river water interaction using geochemical indicators in the catchment of the River Vantaa and its tributaries, Southern Finland

Anne Rautio[1], Kirsti Korkka-Niemi[1], Anna-Liisa Kivimäki[2], Juha Karhu[1], Kirsti Lahti[2], Maria Nygård[1], Veli-Pekka Salonen[1], Heli Vahtera[2]
[1]University of Helsinki, Department of Geosciences and Geography, Helsinki, Finland, [2]Water Protection Association of the River Vantaa and Helsinki Region, Helsinki, Finland

Management of water resources in Finland has traditionally focused on either surface water or groundwater, but they have rarely been combined in this connection. However, surface and groundwater are normally interacting with each others. Here we present the first attempt to study groundwater and stream water interactions in Finland. The research was focused on the River Vantaa and its tributaries ranging 220 km. The River Vantaa is one of the raw water reserves for Finland's capital area (ca. 1 million people). In addition, within the River Vantaa drainage basin there are 25 important aquifers used by the local municipalities or water companies. The River Vantaa drainage basin is rather flat-lying or smoothly undulating glacial landscape. Aquifers are related to glaciofluvial sand and gravel deposits, i.e. eskers or ice-marginal end moraine complexes. The scope of this research was to identify the sections and branches of river systems where significant hydraulic connection between groundwater and river water exists and to evaluate the impacts of water exchange on water quality in the discharge/infiltration zones.

Field methods used in this study involved aerial infrared photography (Thermo Vision A40 sensor), thermal profiling of river sediments with multilevel sediment temperature probe (TP62_S, Umwelt Elektronik GmbH) and in situ water quality and water temperature measurements (YSI 600 XLM-V2-M). Based on aerial infrared photography and site specific measurements, approximately 350 groundwater-surface water interaction sites along the river system could be located. In narrow and shallow tributaries, stream flow rate and groundwater discharge will be directly measured with a flow meter (YSI FlowTracker Handheld-ADV®).

Water fluxes between groundwater and river systems were identified and quantified with water quality data (O_2, pH, EC, turbidity, CODMn, phosphorus and nitrogen compounds, microbiological indicators), main ionic concentrations, DOC and isotopic composition of oxygen and hydrogen ($\delta^{18}O$, $\delta^{2}H$) of river water, groundwater and discharging water. There are differences in chemical and microbiological compositions of river water and groundwater at certain locations. A significant difference in stable isotope ratios between the groundwater ($\delta^{18}O$ values about -12‰ and $\delta^{2}H$ values about -85‰ (VSMOW)), and surface water ($\delta^{18}O$ values about -10‰ and $\delta^{2}H$ values about -76‰ (VSMOW)) was measured. Therefore, the chemical and isotope data can be applied to confirm the water exchange and to calculate mixing ratios of groundwater and river water.

At this stage we can conclude, that groundwater discharge zones have a larger effect on water quality and quantity in the River Vantaa and its tributaries than has thus far been acknowledged. In some groundwater-surface water interaction sites there is a risk of river water infiltration into an aquifer during peak flow and flood periods, resulting in deterioration of groundwater quality.

A9.3

Interpretation of geochemical well test data for Wells OW-903B, OW-904B and OW-909 Olkaria Domes Geothermal Field, Kenya

Sylvia Joan Malimo
University of Iceland, Reykjavik, Iceland

Three wells (OW-903B, OW-904B and OW-909) from the Olkaria Domes; a sector of the Greater Olkaria Geothermal Area, Kenya were discharged for 3 months in early 2009. Olkaria Domes field lies to the west of Longonot Volcano and is the latest of these seven sectors to be deep drilled (Opondo, 2008). Three deep exploration wells were drilled between 1998 and 1999. Approximately 15 wells, both vertical and directional, have been drilled in the Domes area - as of May 2009- (Lagat, 2004 and Mungania, 1999). Olkaria East and Olkaria Northeast are fully developed with installed capacities of 45 MWe and 70 MWe. Optimization for the two power plants operated by the Kenya Electricity Generating Company (KENGEN) in Olkaria East and Olkaria Northeast fields are underway with more wells being drilled in the Olkaria East field. Olkaria Southwest has a 50 MWe binary plant operated by Orpower4 Inc., while a smaller binary plant of ~4 MWe is operated by Oserian Development Company (ODC).

This report describes the chemical composition of the fluids discharged from wells OW-903B, OW-904B and OW-909. Down hole temperatures range from 250 - 350°C which agree with the solute and gas geothermometers. The wells produce fluids with high pH; deep fluid pH ranges from 6.9 to 8.3. OW-909 has higher values for deep fluid TDS, pH and concentrations of anions (B, Cl, and F), Na and K than OW-903B and OW-904B. Olkaria Domes wells have a sodium bicarbonate water type similar to those in Olkaria West and Olkaria Central fields. Concentrations of most dissolved constituents were initially low but increased with increasing enthalpy; a considerable range is observed in concentrations. Deep fluids appear to be close to equilibrium with quartz and calcite. Very low Ca concentrations suggest that calcite scaling will not be a problem in the utilization of the Olkaria Domes geothermal fluids.

References:

Lagat, J.K., 2004. Geology, Hydrothermal Alteration and Fluid Inclusion Studies of the Olkaria Domes Geothermal field, Kenya. University of Iceland, MSc thesis, UNU-GTP, Iceland, Report 2.

Mungania, J., 1999. Reservoir Model of Olkaria-Domes Field. KenGen. Unpublished Internal Report.

Opondo, K.M., 2008. Fluid Characteristics of Three Exploration Wells Drilled at Olkaria Domes Field, Kenya. Proceedings of the 33rd Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California.

A9.4

Application of a DGT -method for Determination of Nutrient and Trace Element Bioavailability in Peat Soil After a Clear-Cut

Marita Turunen, Liisa Ukonmaanaho, Marjatta Kantola, Arja Tervahauta, Tiina Maileena Nieminen
Finnish forest Research Institute, Vantaa, Finland

The aim of this project is to study the suitability of DGT-technique (Diffusion Gradients in Thin films) for estimating the bioavailable and/or mobile pool of elements in peat soil after a forest clear-cut. Clear-cuts of forests on peatlands will increase in forthcoming years in Finland. Clear-cuts have been noticed to affect water quality and increase nutrient leaching (Ahtiainen, 1992; Nieminen, 2003). On the other hand, the total dissolved concentration of a trace metal is a poor predictor of plant availability or toxicity. The bioavailability of trace metals in the soil - plant system is not fully understood and cannot be accurately measured by current methodology in standard use. The aim of this project is to study the suitability of DGT-techniques (Diffusive Gradients in Thin films) (Davison and Zhang, 1994) for estimating the bioavailable and/or mobile pool of elements in peat soil water. The DGT technique uses a chelating resin separated from the soil by a diffusive gel, so that metal uptake by the DGT- device is controlled by diffusion. The chelating resin absorbs selectively the element under interest, e.g. chelex bounds many trace metals. Alternatively a Fe oxide binding layer can be used for phosphate.

The study area is located in Sotkamo black schist area in northeastern Finland. Water samples were taken from peat soils with differing lithology; one area was underlain by granit and one by black schist. Water samples were taken from stump removal pits and from the ditch outflow. First sampling was in October 2009, samples were analysed with the DGT in laboratory. The in situ test with DGT was performed in September 2010 at the same sites. The fractions of metals accumulated in DGT-resins were eluated with 0.2 M HNO_3 and analyzed with ICP AES as were the total dissolved metals (< 1µm).

The fractions of Ca, Mg and Mn absorbed by the chelex-resin in the DGT correlated with the total dissolved concentrations at both sampling times. Total dissolved Al was present in moderate concentrations (200- 2000 µg l^{-1}), but the DGT-fractions were under detection limits (160 µg l^{-1}). The DGT-accumulated concentrations of Zn, Cu and Ni were low (4-10 µg l^{-1}) in the samples from the black schist area and under detection limits for most of the granit area water samples. Further work will be needed to validate the use of the DGT in situ and in laboratory.

References:
Ahtiainen, M., 1992. Hydrobiologia 243/244: 45-473.
Davison, W. and Zhang, H., 1994. Nature 367: 546-548.
Nieminen, M., 2003. Boreal environment research. 8:53-59.

A10.1

Field Portable X-Ray Fluorescence Geochemical Analysis of Trees, Mull and Soils for Exploration and Environmental Site Assessment

Richard Glanzman[1], L Graham Closs[1]
[1]Glanzman Geochemical LLC, Lakewood, Colorado, USA, [2]Colorado School of Mines, Golden, Colorado, USA

The field portable X-ray fluorescence spectrometer (FPXRF) has become a unique highly productive geochemical tool in the past 10 years. As with many highly sophisticated technological tools, it is deceptively simple to use, easily carried and operated in the field, and can provide onsite, nondestructive chemical analysis of about 30 elements that fall within the working ranges of the instrument. It's most attractive aspect is as a screening tool that allows chemical analysis of a broad range of geological materials, thus allowing for decisions to be made in real time onsite. It does not replace traditional laboratory analysis but aids optimum direction for sample collection to solve the problem at hand. Near laboratory quality can be obtained when people appreciate the basic principles of X-ray fluorescence spectrometry, the physical characteristics that control quality and protocols that can be used to enhance data quality.

This paper describes two case histories and the lessons learned to expand the utility of the FPEXF in mineral -exploration and environmental studies: 1) the Caprock area, Colorado - a greenfields exploration property and 2) the Waldorf mined area, south of Georgetown, Colorado - an assessment of acid drainage in a former mine site.

The Caprock area was explored for Broken Hill-type massive sulfide mineralization. Geologic mapping and elevated but highly erratic and variable Cu+Pb+Zn soil anomalies were used to site select drill targets. An orientation survey using a tube-type FPXRF was used to analyze rocks, soils, mull, and trees to better define mineralization and to select the best media for subsequent drilling. Results for these media are presented. Soils proved to be best for exploration at this location.

The Waldorf mine area mineralization consisted of Pb-Ag-Au-Zn-Cu ores. Tailings were spread parallel to and into the wetlands and alluvium in the headwaters of Leavenworth Creek, south of Georgetown. Englemann spruce is the dominant tree type in the area. An earlier study employed laser inductively coupled plasma analysis of tree cores to monitor metal loading attributed to past mining activity (Witte et al., 2004). This study consisted of using the FPXRF to analyze tree bark and to compare results with the previous study.

Quadrant sampling of trees was carried out at both study sites and can indicate a direction to mineralization. Use of the FPXRF provided timely results to direct immediate follow-up.

References:
Glanzman, R.K. and Closs, L.G., 2007. Field Portable X-Ray Fluorescence Geochemical Analysis-Its Contribution to Onsite Real-time Project Evaluation. Proc. Exploration 07:291-301.
Witte, K.M., Wanty, R.B., and Ridley, W.I., 2004. Englemann Spruce (Picea engelmannii) as a biological monitor of change in soil metal loading related to past mining activity. Applied Geochem. 19:1367-1376.

A10.2
Practical application of portable XRF analyzer

Alexander Mikhailov[1]
[1]SRK Exploration Services, Cardiff, Wales, UK, 2Mineral Exploration Network (Finland) ltd, Cardiff, Wales, UK

Success of exploration depends on informative target selection and amount samples taken. But number of samples inevitable result in number of assays. And the cost of assaying could be up to 100,000 euros and more for just one prospect. Apart of cost there are some other problems associated with assaying in the external laboratory. They are sample transportation and time needed to get results.

The alternative to the external laboratory is portable field XRF analyzer. Although number of exploration geochemists are concern about detection limits portable XRF analyzer prove to be the best solution for junior exploration companies.

Application of XRF for base metals such as Cu, Pb, Zn and others is straightforward. Gold exploration is more challenging. But practical experience demonstrates that portable XRF is the most cost effective solution for junior companies with budget constrains.

B1.1
Application of Orientation Biogeochemical Exploration Method in the Vicinity of Ildong Fe-Pb-Zn Skarn Deposits in Korea

Suhyeon Jeon, Ji Young Park, Jongnam Kim, Hyo Taek Chon
Seoul National University, Department of Energy Resources Engineering, Seoul, Republic of Korea

Orientation biogeochemical exploration method was applied in the vicinity of Ildong Fe-Pb-Zn skarn deposits, which is located in Jeongseon district, Gangwon province in Korea. The skarn deposits occur in contact region between limestone and intrusive diorite and quart porphyry of Cretaceous age. The major ore minerals are magnetite, pyrite, arsenopyrite, sphalerite, galena, and manganese ores.

Sampling for rocks, soils and plants was conducted along 4 traverse lines and control areas. A total of 12 rock samples, 64 soil samples, and 320 plants samples (including 3 species such as leaves and branches of Quercus dentata and Fraxinus rhynchophylla Hance, and leaves of Pinus densiflora Siebold & Zucc.) were collected. Rock samples were pulverized and sieved by -200mesh, soil samples dried and sieved by -200mesh, and plants samples washed and dried. ICP-MS method was used for the analysis of rock and plant samples, and ICP-MS and INAA methods were used to analyze total elements contents in soils. After sequential leaching procedure by sodium acetate, ICP-MS method was applied to determine the exchangeable metal fractions in soils.

The concentration level of Cu, Pb, Zn, Mn, Cd, and As in soil collected from target areas (n=56) was 2-4.5 times higher than that from control areas (n=8). However, there were no specific contrasts of element contents in plant samples (each n=56) except both for Pb in Q. dentata leave (0.45-54.93 mg/kg Pb) and branch (0.73-25.89 mg/kg Pb) and Cd in P. densiflora (0.06-4.08 mg/kg Cd). The ratios of extractable metal/total metal in soils, and BAC (Biological Absorption Coefficient) for each plant samples indicated low values except for Cd which shows 0.2 and 0.214, respectively. Generally Q. dentata and P. densiflora leaves have relatively higher metal contents than others. Also element contents in soils and P. densiflora are positively correlated and these biogeochemical variations of Cd show similar trends. In conclusion, P. densiflora showed the possibility of Cd indicator in these skarn type Fe-base metal deposits.

B1.2
Orientation Biogeochemical Survey around Low-grade Uranium Deposits in Black Shale in Goesan District, Korea

Jongnam Kim[1]*, Kukhwan Kim*[2]*, Youngjune You*[2]*, Hyo Taek Chon*[1]
[1]Seoul National University, Seoul, Republic of Korea, [2]Korea Resources Corporation, Seoul, Republic of Korea

Orientation biogeochemical survey around low-grade uranium deposits occurring in black shale was carried out at Dukpyung area, Goesan district in Korea. The black shale occurs within the metasediments so called the Guryongsan Formation(Lee and Kim, 1972) in the Okchon Zone, which is found in the central part of Korea with an average width of 80 km and north-eastern trend. The metasediments in study area are mainly composed of black shale, slate, schist and phyllite. The objectives of this survey are firstly to study the relationship between uranium and other associated elements in soil and plants, secondly to evaluate biogeochemical methods in uranium exploration, and finally to compare the results of biogeochemical method with those of radiometric method.

Sampling was planned to perform along 3 survey lines two times, and each line crossing the strike of uranium-bearing formations is composed of 15 sampling points with 30 m intervals. At each sampling sites pine (Pinus densiflora) twig, Daimyo oak (Quercus dentata) leaves and twig, and soils were collected both from 3 survey lines, and the same kind of samples from 5 points were taken in control area. Soil samples were analyzed by INAA and ICP, and plant samples analyzed by ICP/MS after ashing. Ash yield of Daimyo oak leaves, Daimyo oak twigs and pine are 5.52%, 2.71% and 1.66%, respectively.

Uranium concentration level in soils (n=45) varies from 2.7 to 694 ppm (mean 91.8 ppm). In plant ash, uranium content in Daimyo oak (Quercus dentata) leaves range from 0.11 to 41.6 ppm (mean 18.4 ppm) and that of Daimyo oak twigs from 0.05 to 25.1 ppm (mean 16.5 ppm). Pine (Pinus densiflora) twigs contain uranium in the range of 0.29 to 14.6 ppm (mean 17.9 ppm). In general, uranium concentration of plant ash in this area is much higher than the average uranium value of 0.5 ppm (Brooks, 1982).

Uranium between soils and mineralized zones shows relatively good correlations. High uranium anomalies both in soils and ashed plants generally coincide with uranium mineralized areas, whileas some uranium anomalies are displaced a little downslope due to the topographic relief. The profiles of radiometric survey are considerably in agreement with those of biogeochemical method. Accordingly, pine (Pinus densiflora) twig, Daimyo oak (Quercus dentata) leaves and twigs are considered to have useful potential of biogeochemical indicators (Dunn, 1981, 2007).

References:
Brooks, R.R., 1982. Journal of Geochemical Exploration 16, 189-195
Dunn, C.E., 1981. Journal of Geochemical Exploration 15, 437-452
Dunn, C.E., 2007. Biogeochemistry in Mineral Exploration, Elsevier, Amsterdam.
Lee, C.H. & Kim, J.H., 1972, Explanatory Text of the Geological Map of Goesan. Geological Society of Korea, Korea

B1.3

Nickel uptake by Cypress Pine (Callitris glaucophylla) in the Miandetta area, Australia: Testing the limits of biogeochemistry

Kenneth McQueen[1]*, Augustine Alorbi*[1]
[1]University of Canberra, Canberra, ACT, Australia, [2]Australian National University, Canberra, ACT, Australia

This study documents nickel uptake by the widespread Australian native cypress pine species, Callitris glaucophylla. It shows pine needles from this species can effectively indicate elevated nickel contents in underlying saprolite to depths of 3m, but are unlikely to reveal anomalous levels below transported regolith >10m thick. Its roots extend at least 6 m, but are highly concentrated in the upper part of the soil. The study highlights some of the inherent uncertainties and significant potential for false negative results during biogeochemical mineral exploration.

At Miandetta, western NSW, mafic-ultramafic bodies with nickel contents of 1500-3000 ppm are enclosed in metasediments. One body (Site 1) has a ferruginous in situ weathering profile partly covered by thicker regolith with both in situ and transported components. A second body (Site 2) is overlain by transported alluvial regolith 10 to 50 m thick. Drilling at both sites for lateritic nickel and scandium mineralisation has provided information on the depth and composition of the regolith, including the deep saprolite. Mature white cypress pine trees are scattered over Site 1 and at Site 2 there is a line of remnant trees forming a wind break. The sites provide an excellent opportunity to investigate element uptake from the weathered ultramafic-mafic bedrock by this tree species and also to test the depth to which this can occur.

Sampled pine needles were washed in an ultrasound bath with distilled water, dried, macerated and analysed by INAA. A subsample was digested in nitric acid and analysed by ICP OES. Element contents were compared with values for pine needles at regional background sites. Needles from trees growing on the weathered ultramafic profile at Site 1 contain 12-30 ppm Ni. Two trees contain 0.7 and 0.8 ppm Co Multiple sampling of one tree over a year gave 5-30 ppm Ni (SD 11.2). Trees growing in mixed regolith <3 m thick contain 2-8 ppm Ni. Needles for trees growing in transported cover >10 m thick at Site 2 contain 2-3 ppm Ni, similar to background sample levels. The soil and underlying saprolite at Site 1 contains up to 2100 ppm Ni and at Site 2 the buried saprolite profile contains 1000-3700 ppm Ni. The transported regolith contains 17-145 ppm Ni. Other trace elements were analysed, but only Cu (3-5 ppm), Mn (60-1400 ppm) and Zn (10-25 ppm) were significant and their concentrations were not systematically correlated.

B1.4

Biogeochemical expression of buried mineralisation through barren transported cover: Regolith Expression of Iron-Oxide Copper Gold (IOCG) Mineralisation in the southeastern Middleback Ranges area, South Australia

Byron Dietman[1], Steven Hill[1], Geoff Johnson[2], Charlotte Mitchell[1], Chad Hicks[1]
[1]University of Adelaide, Adelaide, SA, Australia, [2]OneSteel Limited, Dulwich, SA, Australia

Iron-Oxide-Copper-Gold (IOCG) mineralisation is one of the most valuable and prospective mineral systems in Australia. Many of the mineral exploration challenges for IOCG mineralisation relate to their detection through transported (and typically deep) regolith. The Middleback Ranges is situated along the western boundary of the Olympic Domain and as such is highly prospective for IOCG mineralisation. The main exploration targets capable of hosting IOCG related mineralisation coincide with structural zones, readily visible but not directly assessable for target metal contents in geophysical imagery.

Previous geochemical exploration for Cu-Au and base metal mineralisation in the Middleback Ranges region has included soil and regolith carbonate (including calcrete) sampling. Although some zones of elevated trace metal contents were identified, large parts, especially in the south of the area, generally featured low target metal concentrations in these media. The area has since hosted a plant biogeochemical sampling program, which included foliage from red mallee (Eucalyptus socialis) and western myall (Acacia papyrocarpa) trees. The results from this program show elevated trace metal (especially Cu and Au) along major structural zones where in most cases the soils and regolith carbonate results had background levels of these target metals. This is an exciting outcome for biogeochemical exploration and warranted further investigation to better understand what characteristics of this area are conducive to plant biogeochemical approaches rather than soil and regolith carbonate geochemical approaches.

When the soil results are incorporated with a regolith-landform map it becomes apparent that most of the previous soil sampling sites were hosted in transported regolith, mostly relating to sheetwash fan and aeolian sediments, rather than being locally derived from the underlying potentially mineralised systems. The geochemical attributes of these sediments, therefore, largely conceal the potential for underlying mineralisation. The regolith carbonates in the southern parts of the area are of tabular groundwater type and largely correspond to a Miocene coastal lowland embayment (constrained between the Middleback and Moonabie ranges) that may have included Tertiary marine carbonates that have since weathered to form regolith carbonates. The regolith carbonates therefore typically host very low level trace metal geochemical signatures and have not entirely formed from local pedogenic processes that typically make pedogenic carbonates useful geochemical sampling media. This landscape setting therefore appears to be unsuitable for the previous soil and regolith carbonate geochemical exploration approaches, but much better for plant biogeochemical exploration approaches.

B2.1

Regolith carbonate geochemical and plant biogeochemical inter-relationships for the expression of deeply buried mineralisation at the Tunkillia gold prospect, central Gawler Craton, Australia

Benjamin G van der Hoek[1], S M Hill[1], Robert C Dart[1], B Van der Stelt[2]
[1]University of Adelaide, Adelaide, South Australia, Australia, [2]Minotaur Exploration Ltd., Adelaide, South Australia, Australia

The highly weathered and transported regolith that extends across much of the Australian continent provides a challenge for the successful application of surficial geochemical exploration approaches. The Tunkillia Au prospect in the central Gawler Craton of South Australia provides examples typical of many of these challenges. The landscape at Tunkillia is dominated by aeolian dunefields that has introduced exotic detritus and dilutes many traditional soil geochemical sampling media. The dunefields overlie variable thicknesses (metres to 10s of metres) of either; alluvial sediments associated with palaeodrainage systems, or broadly transported sheetflow sediments that have further dispersed surficial geochemical patterns. These sediments have been overprinted with regolith carbonate induration (e.g. calcretes) that have been widely used as a geochemical exploration sampling medium. The underlying weathered bedrock generally contains an upper kaolinic, Au-depleted zone (that may be approximately 30 m thick), overlying a variety of weathered bedrock materials including supergene Au zones, ferruginous saprolite, and saprock.

Regolith carbonates have been useful as a regional geochemical sampling medium, providing the initial geochemical expression of Au mineralisation in the area. At a more detailed sampling scale, however, the regolith carbonates have provided:

- elevated Au concentrations overlying buried Au mineralisation;

- low Au concentrations that do not overlie buried Au mineralisation;

- elevated Au concentrations that do not overlie buried Au mineralisation; and,

- low Au concentrations overlying buried Au mineralisation.

Although the first two points here are ideal outcomes for a geochemical sampling medium, the latter two points are problematic outcomes.

Plant sampling as part of a biogeochemical research and exploration program has now been conducted across many parts of the Tunkillia Au prospect where regolith carbonates have been previously sampled followed by exploration drilling. This biogeochemical program has mainly included the sampling of the widespread and abundant tree species, black oaks (Casuarina pauper) and Victoria Desert mallee (Eucalyptus concinna).

This study shows that a plant biogeochemical program has been able to provide an expression of buried mineralisation where previous regolith carbonate sampling has not been successful. Strong chemical genetic linkages also occur between these media. It supports the recommendation of integrating detailed (<1 km sample spacing) plant biogeochemical programs with regional regolith geochemical programs (e.g. regolith carbonate sampling) to help better define drilling targets in areas of deep and transported regolith.

B2.2
Metal mobilisation from soils and sediments by hydroxycarboxylic acids of natural origin

Zandra Arwidsson[1], *Marie Ålund*[2], *Bert Allard*[2], *Stefan Karlsson*[2]
[1]SAKAB AB, Kumla, Sweden, [2]Man-Technology-Environment Reserach Centre, Örebro University, Örebro, Sweden

The effects of complexing agents, hydroxycarboxylic acids of natural origin, on the release of metals from contaminated soils have been studied (Arwidsson, 2009). The selected acids were isosaccharinic acid (ISA), generated by decomposition of cellulose (degradation of wood at high pH), fulvic acid (FA) isolated from humic matter (leaching/degradation of peat) and citric acid (CA), a fungal metabolite.

Four soils from industrial sites with elevated levels of particularly As, Cr, Cu, Ni and Pb at maximum levels of 15, 1.2, 1.7, 0.2 and 4.0 g kg^{-1}, respectively, were leached in batches with alkaline solutions (pH around 12, buffered by $Ca(OH)_2$) containing wood degradation products (around 0.7 g l^{-1} TOC), peat degradation products (2.1 g l^{-1}) or citric acid (various concentrations). Solutions containing strong synthetic complexing agents (polyamine polycarboxylic acids, EDDS and MGDA) were used for comparison. A sequential leaching procedure was also followed as a reference.

The leachates were sampled after 24 h, 1 w and 5 w, and analysed (ICP-OES) with respect to major elements and some trace elements, including Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Ti, V, Zn.

The leaching of metals was generally less efficient with ISA and FA than with the synthetic chelating agents. Enhanced leaching by natural products were observed particularly of Cu, Pb and Zn after long contract time (5 w), as well as of Fe, that may act as a scavenger of these metals in the soil. Comparisons are only semi-quantitative since the concentrations of active complexing groups were not identical. It is, however, evident that these acids (ISA, FA) that can be generated in nature, may have a significant or even dominating influence on the solubility and mobility of certain metals (like Cu, Pb and Zn) in the soil at elevated pH.

Reference:

Arwidsson, Z, 2009. Organic complexes for remediation of heavy metal contaminated soil. Orebro Studies in Environmental Science12, Orebro University (Diss)

B2.3
On Soil Boron-Organic Matter Association and Bioavailability

Fyodor Kot, Ronit Farran, Malik Kochva, Avi Shaviv
Technion-Israel Institute of Technology, Haifa, Israel

Boron (B) bioessentiality is a well-established fact. The element is involved in biochemical reactions and biogeochemical cycles, including “plant-soil” system. The apparent contradiction between experimental results and in field observations, suggests that B uptake is determined by factors that are as yet unknown (Hu & Brown, 1997). Only a few works included soil B-organic matter forms in their schemes (Kot, 2010). We studied B in fractions of Mediterranean red sandy and dark clay carbonaceous soils, with special emphasis on humus and water-mobile components.

Boron is turned to be highly "soluble" - average 7 % of the total content - in <0.45 µm filtrate. Surprisingly, none of B has been detected in <0.20 µm filtrate, indicating B binding to coarser colloids, probably to bacterial cells, but not simply to dissolved boric acid or borates as is often supposed. The fact of the absence (or probably very low contents) of "truly soluble" B leads to a question concerning the source of the plant/biota available element in the soil. Unlike most other micronutrients, plant roots require a continuous external supply of B, otherwise loss of membrane function occurs within minutes (Blaser-Grill et al., 1989). Jenny & Overstreet (1939) proposed a mechanism that includes nutrient transfer when the root makes direct contact with hydrated or dissolvable species held on colloid surfaces. Asad et al. (1997) suggested that most of B is chelated and this acts as a buffer for the nutrient supply.

In the soils considered, most B was found within humic compounds - 54 % (28-71%), in the following range: humus > free (non-silicate) Fe > water-mobile colloids > easy-reducible (Mn) minerals = residual fraction = carbonates; none of B has been detected in aluminosilicates. Among humic components, the major B pool was found within humin and humic- and fulvic-Fe/Al complexes, i.e. the most refractory humic components that were not affected by the commonly adopted procedures (like procedure of IHSS). In contrast to the divalent cations (Ca^{2+}, Mg^{2+}), Fe^{3+} and Al^{3+} form strong coordination complexes with humic substances and provide strong cohesion to solid soil particles.

The B preferential binding may indicate soil humin origin from refractory components of plant cell-walls and membranes, like lignin. Boron in soil is much more organophilic than it is often supposed.

References:
Asad, A. et al., 1997. Plant and Soil 188, 21-32.
Blaser-Grill, J. et al., 1989. Plant Physiology 90, 280-284.
Jenny, H. & Overstreet, R., 1939. Soil Science 47, 257-272.
Hu, H. & Brown, P.H., 1997. Plant and Soil 193, 49-58.
Kot, F.S., 2010. Reviews in Environmental Sciences and Biotechnology 8, 3-28.

B2.4

Riparian Eucalypt Biogeochemistry for the expression of Groundwater Salinity Hazards in the Murray River, near Loxton, South Australia

Stephanie McLennan, Steven Hill

Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, South Australia, Australia

Salinisation of the Murray River and adjacent floodplains is an ongoing problem in southeast Australia, affecting human populations and the environment. Until now, monitoring rising salinity typically requires access to bores or geophysical data that can be expensive to obtain and require specialised knowledge to interpret. The potential of biogeochemistry as an environmental monitoring tool, specifically its innovative application in groundwater salinity detection, is explored in this study as well as proposing a comprehensive approach to further defining the application of this technique. A biogeochemical sampling program using leaves from Eucalyptus camaldulensis (river red gum) and Eucalyptus largiflorens (black box) was designed for the study area at Clark's Floodplain, near Loxton, South Australia. Results of the survey were then compared with three geophysical surveys, groundwater analyses, and a regolith-landform map to assess how well the survey acted as a proxy for groundwater quality, particularly salinity. Key environmental factors contributing to salinity were also identified. Statistical and spatial analyses of Na, Mo, Cu, Mn, Fe, U, Au, Cd, Ca, P, Mg, Ti, K, and S biogeochemical data were conducted.

From the biogeochemical survey, it is evident that Na, K, and Mo show strong correlation with conductivity variations in the upper 9 m of sediment, which corresponds with the location of saline groundwater in the area, and are suitable pathfinder elements for groundwater salinity. The increase in Mo content in leaves with increasing groundwater salinity could reflect the response of plants to such stressful conditions. As an aside to the main objectives of this study, these variations in Mo content in plants with varying groundwater salinity has major implications for interpreting Mo values in mineral exploration programs. These are anomalies that might otherwise be assumed to be related to Mo mineralisation or pathfinder expression of other mineralisation styles.

The study supports the potential for plant biogeochemistry for groundwater monitoring and salinity risk assessment but the technique works best as part of an integrated, multi-disciplinary approach, incorporating regolith-landform mapping and, where available, geophysical and water chemistry data. The study also demonstrates potential for further plant biogeochemical research in areas where contaminated groundwater and groundwater salinity are environmental management issues.

B3.1

Termite mound anomaly formation processes: Understanding termite induced surface metal flux

Aaron Stewart[1], Ravi Anand[1], Michael Verrall[1], Jamie Laird[2], Chris Ryan[3]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Australia, [2]University of Melbourne School of Physics, Melbourne, Australia, [3]University of Tasmania Centre of Excellence in Ore Deposits (CODES), Tasmania, Australia

Sampling of termite nest structures is now an important geochemical tool for identification of ore deposits buried beneath transported cover (Arhin and Nude, 2010; Prasad and Saradhi, 1984). Termites have the ability to bring particles to the surface and dig down to the water table giving rise to bioturbation processes that can be exploited for mineral exploration.

Small (<60 cm) mounds of the termite Tumulitermes tumuli (Froggatt) located on areas of transported overburden over mineralisation have been investigated at two study sites. Sampling termite nests revealed the ability of termites to transport materials to the surface to create element anomalies in areas of shallow overburden (5 m) at the site of gold mineralization but not in areas of deeper overburden (20 m) at the VMS site. Particle size fractions of the termite mound were investigated with ICP-MS to identify target metal distributions. Localisation and chemical form of metals within individual termites was investigated using SEM/EDX analysis, PIXE and Synchrotron XFM/XANES for termites from the VMS site.

There are two principal mechanisms of metal transfer by termites. The Au is primarily within Fe pisoliths which have been brought to the surface by termites during construction of the nest. The Au in termite nest material is highly biased towards larger (>2000 μm) fractions. At the VMS site, the mechanism of movement within termite bodies involves input through ingested fine particles, food, groundwater and/or direct absorbance through the insect cuticle. Although there was no anomaly in nest material over the VMS deposit, the specific location of high levels of Zn, Mn, P, K and Ca was found within excretory bodies of the termites themselves. Excretory bodies (<5 μm) are the principal host of these elements within the termite and represent the biological metal input into the local environment that occurs at the time of insect death/decay or when the living insect excretes.

This termite forms smaller nests than species previously studied for mineral exploration (Petts et al., 2009). However, in areas where transported overburden is shallow it is capable of bringing sufficient particles to the surface to create anomalies. This species is widespread across central and western Australia and represents a potential resource for mineral exploration.

References:
Arhin, E., and Nude, P.M., 2010. Geochemistry: Exploration, Environment, Analysis 10, 401-406.
Prasad, E.A.V., and Saradhi, D.V., 1984. Current Science 53, 649-651.
Petts, A.E., Hill, S.M., and Worrall, L., 2009. Geochemistry: Exploration, Environment, Analysis 9, 257-266.

B3.2

Validation of the Electrochemical Cell Model using observations of surficial hydrocarbon geochemical signatures relative to mineral exploration

Dale Sutherland
Activation Laboratories Ltd., Ancaster, Ontario, Canada

The spatial 3D zonation and forensic identification signature developed by nano-scale semi-volatile hydrocarbon compounds found in surficial sample surveys provide a highly confident vectoring tool to blind mineral targets as a deep-penetrating geochemistry.

Redox conditions develop over many types of buried geological bodies including those of sought after mineral targets. This chemical gradient leads to the development of the generally accepted electrochemical cell model. However, the detection of redox conditions in the overburden or data from geophysical induced potential type measurements are not sufficient evidence to confidently state the existence of a mineral deposit of exploration interest.

Bacteria populations seek both the redox chemical gradients and metallic ore zones for use in their metabolic processes. Bacteria leach elements from the ore body which are then used as a catalyst to synthesize organic hydrocarbons in their cytoplasm. In the death phase of these microbes, cell membranes break down and the intracellular hydrocarbons they have synthesized are released. These hydrocarbons provide a complex, and thus highly specific, forensic signature directly related to the identification of the geological target at depth. The hydrocarbons rise through the overburden at different rates depending on their structure, molecular weight, size, solubility, partition coefficients, etc. Differences in these characteristics result in a separation or geochromatography of the various hydrocarbon chemical classes. The fluxes of hydrocarbon classes are then gradually caught up and shaped by the various electro-potential gradients in the overburden defined by the electrochemical cell model. Surveys of surficial samples thus provide a snapshot in time of the hydrocarbon flux pathways as they reach the surface of the redox zone. The 3D shape of the mapped hydrocarbon classes detected reflects the electrochemical cell gradients and geophysical dynamics of the cell. This provides a strong vectoring tool to the location of the centre of the exploration target zone at depth.

The Soil Gas Hydrocarbon (SGH) geochemistry developed by Activation Laboratories has been referred to as a redox cell locator, but it is much more than that. Although a misnomer, SGH can use a wide variety of surficial sample types in a survey, and detects a suite of 162 unique non-gaseous semi-volatile hydrocarbons. This provides a highly specific, multi-measurement based, forensic signature for identification of the target type at depth.

This presentation will provide examples of the direct 3D spatial evidence of various conditions of the electrochemical cell above mineralization using observations of the SGH hydrocarbon class signatures and thus provide validation of the electrochemical cell model.

References:
Smith, G.H. & Ellis, M.M., 1963. Amer. Assoc. Pet. Geol. Bull., 47:1897-1903
Hamilton, S. M. ,1998. J. Geochem. Explor., 63:155-172
Tomkins, R.,1990. Oil and Gas J., 24 Sept.: 126-134
Govett, G.J.S. 1987. J. Geochem. Explor., 28:201-221

B3.3

History of geochemistry societies ALAGO and SBGq and their meaning for the Brazilian and Latin American scientific development

Carlos S. Bandeira de Mello
Cenpes/Petrobras, -, Brazil

Geochemistry activities in Brazil initiated in 1881, when Claude Henri Gorceix, a French engineer, accepted the invitation of the Brazilian Emperor, D. Pedro II, to establish a chemical analytical laboratory in Brazil. Gorceix chose to install the laboratory in Ouro Preto, the richest gold prospecting city in Minas Gerais state. Within a few years, he made lots of chemical analyses in rocks and minerals including Rare Earth elements. After that the geochemical research developed mainly in some universities mostly related to precious metals. Only in the 40´s, during the World War II, chemists and geochemists started to dedicate the use of geochemistry data for prospection mainly regarding elements and minerals needed by the allied countries. During that time thousands of samples were analyzed for uranium, thorium, niobium and other elements.

In beginning of 1960´s, undergraduate courses started to pop-up mainly due to a great increment in the mineral research in Brazil. In 1970´s graduation courses at M. Sc level also started.

The 1980´s constituted a very important time, when the increasing number of professionals motivated the creation of geochemistry association. In 1980, a Technician-scientific Commission of Geochemistry - CTCGq in the Brazilian Geologic Society was created. The Brazilian Society of Geochemistry - SBGq was really founded five years later, in 1985. Eight years passed until the Latin American Association of Organic Geochemistry - ALAGO was created in 1988. In 1987, the official magazine of the SBGq Geochimica Brasiliensis - GB, started together with the first Geochemical Brazilian Congress. Publication of the ALAGO magazine started in 1995.

Between 1980 and the 2009, SBGq published a total of 3569 papers. From this, 3253 originated from twenty scientific meetings and 316 from 23 volumes of the GB.

The ALAGO published 1284 articles, between 1995 and 2009. This total corresponds to the 1250 papers in 12 congresses and 34 in 7 volumes of magazines. From this total, Brazil collaborates with 35 % of the presentations, followed by Venezuela with 19 %. United States, Mexico, France and Colombia with 30 % and other 28 countries with 16%. In publication terms in the magazine of ALAGO, Venezuela collaborates with 44 % of articles, followed by Brazil with 38 %. Mexico, Colombia and Cuba complete 18 %. Therefore, the geochemistry societies have given significant contributions in several areas not only in Brazil, but throughout Latin America.

References:
Bandeira, C.S., et al., 2004. História da SBGq. www.sbgq.org.br
Trindade, L.A., et al., 2005. The History of organic Geochemistry in Latin America. 229 th ACS National Meeting. USA.

B4.1

Findings of nanoscale metal particles: direct evidence for deep-penetrating geochemistry

Xueqiu Wang, Rong Ye
Institute of Geophysical and Geochemical Exploration, Langfang, Hebei, China

Deep-penetrating geochemical methods have revealed that anomalies do exist at surface overlying deep-seated mineral deposits. We do not yet fully understand the dispersion processes though many researchers recently have given different migration models (Malmqvist and Kristiansson, 1985; Cameron et al. 2004; Hamilton et al., 2004; Wang, 2005). Gases probably play an important role in the transport of nanoscale particles of metals from deep-seated mineralization (Wang et al., 1997). However, there is no direct observation evidence for nanome- ter particles of metals.

Particles of metals were collected both in gases and in soils over a Cu-Ni deposit at a depth of 400-700 meters in the verge of Nanyang basin, Henan, China. Geogas-carried particles were sampled from holes 100 cm deep by pumping through a collector with Germanium grid. Soils from a depth of 30-60 cm were dried and then sieved to 400 mesh (38 μm), then the sieved soils were vibrated and captured by Germanium grid. The nanometer particles were observed using a transmission electron microscope (TEM) equipped with an energy dispersive spectroscope.

Particle diameters range from 10 to 200 nm, most of them are generally tens of nanometers in diameters with ordered crystal structure observed by the TEM. The particles tend to assemblage shaped like a grape cluster. The particles are composed of native copper, compound metals of Cu-Fe, Cu-Fe-Mn, Cu-Ag, Cu-Cr, Cu-Ni, and compound metals with Si, Al, Ca, O, P. The facts show that nanoscale particles both in gases and soils are from the same source and the nanoscale particles with ordered crystal structures further indicate that they originate from the concealed Cu-Ni deposit.

The migration model can be interpreted that nanoscale particles of metals from the ore body are adsorbed onto surface of gas bubbles and migrated with an ascending flow of gases upward to the surface, arriving at the surface, part of particles are persisting in the soil gases and the other part of particles are trapped by soil geochemical barriers. The findings of nanoscale particles of mineralization metals provide direct observation evidence for migration mechanism of deep-penetrating geochemistry and a new method for separation of nanoscale particles from soils to search for concealed deposits.

References:
Cameron et al., 2004. Geochemistry: exploration, environment, analysis, 4: 7-32.
Hamilton et al., 2004. Geochemistry: Exploration, Environment, Analysis, 4 :33-34.
Malmqvist, L. and Kristiansson. K., 1985. Geoexploration, 23:447-453.
Wang, X., 2005. Geological Bulletin of China, 24: 892-896.
Wang, X., et al., 1997. J. Geochem. Explor. 58(1):63-72.

B4.2

Landscape Geochemical Constraints on Vertical and Lateral Element Dispersion within an area of Deep Cover: an example from the Mundi Mundi Plains, Broken Hill, Australia

Charlotte Mitchell, S. M. Hill

University of Adelaide, Adelaide, SA,
Australia

As exploration moves from areas of shallow cover, geochemical exploration faces increasing demand to become more effective in areas of deep transported cover. The major challenge is not the identification or the defining of ever-subtle geochemical expressions of targets, but rather, to be able to reliably account for the dispersion pathways of elements that create the geochemical exploration target. The problem is typically manifested when a mineral explorer has identified a range of surficial geochemical patterns that they wish to investigate, and have drilled vertically down from identified surface expressions to no avail. The fundamental dispersion pathways that need to be more effectively distinguished are due to lateral and vertical dispersion. Currently there are numerous models to account for the physical and chemical dispersion of elements through depths of transported regolith, both vertically and laterally, but the actual constraint and recognition of these are difficult in practice.

The study area is the Umberumberka Creek catchment. It is an ephemeral drainage system, with its headwaters in the Barrier Ranges near Broken Hill and flows generally westward onto the Mundi Mundi Plains. The contemporary landscape of the Mundi Mundi Plains includes alluvial and sheetwash fans up to 10s of kilometres in diameter, along with aeolian sandplains and linear dunefields. Previous geochemical exploration studies in the region have been major advocates of surficial and near surface geochemical characteristics expressing bedrock-hosted mineralisation through >100m of at least Tertiary (and in some places Mesozoic) and Recent sedimentary cover. The catchment area, however, is not only host to mineralisation beneath the transported cover of the Mundi Mundi Plains, but also within the Barrier Ranges that form the headwaters of the catchment area. The Barrier Ranges headwaters host numerous occurrences of Pb, Ag, Zn and Cu mineralisation, including the world-class Broken Hill ore body. Previous geochemical exploration studies in the area have tended to downplay the potential of lateral dispersion from the catchment headwaters out onto the Mundi Mundi Plains, suggesting that the anomalies are derived from vertical dispersion from buried mineralisation.

In this study we compile some of the characteristics and constraints on vertical and lateral geochemical dispersion through an area of >100 m of transported cover overlying highly prospective and mineralised bedrock, and how we can use biogeochemistry and stream sediment sampling in combination with regolith-landform mapping to define the previously poorly constrained lateral dispersion pathways.

B4.3

Geochemical Exploration in the deep cover of the Olympic Dam IOCG Province, South Australia: context and examples from the lower parts of the Mesozoic sequence in the southwestern Eromanga Basin

Robert C Dart, S M Hill
University Of Adelaide, Adelaide, South Australia, Australia

The development of successful geochemical exploration techniques for areas of deep transported cover is a major exploration frontier. Although geochemical exploration techniques have been widely and successfully used in areas with up to 10s of metres of cover, the areas of greater than 100 metres of cover have been problematic for developing robust and reliable geochemical exploration techniques. Although there has been hope of developing surficial geochemical exploration techniques for these areas of deep cover, another approach is to better characterise, sample and interpret the geochemistry of components of the deep cover profiles. This study considers this approach for the lower part of the sequence of Mesozoic sediments of the southwestern Eromanga Basin that overlie the highly prospective Olympic Dam IOCG province.

Exploration drilling has been extensive in parts of the Olympic Dam IOCG province, where the objective has typically been to drill through several hundred metres of cover to obtain samples of the buried prospective bedrock host. If useful samples can be taken from within the overlying cover however, then the exploration drilling may become more efficient. Previous difficulties have been the ability to identify suitable sampling media within the cover and then to obtain a representative sample, as well as enough associated information to be able to link analytical results to four dimensional geochemical dispersion models.

In this study the approach has been to first develop a series of palaeo-geographic reconstructions that link into geochemical dispersion vectors for select packages of the lower parts of the Mesozoic cover. The two stratigraphic units considered here are the mostly fluvial, late Jurassic to early Cretaceous Algebuckina Sandstone, and the early Cretaceous marginal marine Cadna-owie Formation. Further to this, type section and other key profiles have been selected, logged to record the key lithological and weathering over printed interfaces within the sequence, and sampled for geochemical, mineralogical and physical characterisation. These results provide a regional framework for geochemical exploration using interfaces within these sedimentary units. The results demonstrate the potential for basal physical interfaces (particularly within the Algebuckina Sandstone) as well as intra-formational palaeo-redox interfaces (particularly within the Cadna-owie Formation) to host geochemical signatures that can be related to target mineral systems. The basal sedimentary interface of the Algebuckina Sandstone, although locally hosting elevated Au and base metal contents, has been difficult to representatively sample. In contrast the much finer grained and distinctly coloured palaeo-redox interfaces, such as within the Cadna-owie Formation contain broader areas of elevated target metal contents and are more efficiently sampled in a representative manner.

B4.4

A landscape evolution approach to understanding the geochemical origins of regolith carbonates in the Eucla Basin, southern Australia

Ashlyn Kate Johnson[1], S. M Hill[1], David Chittleborough[1], David Mitchell[1]
[1]Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, Adelaide, South Australia, Australia, [2]Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, Adelaide, South Australia, Australia, [3]School of Earth & Environmental Sciences, University of Adelaide, Adelaide, South Australia, Australia, [4]Iluka Resources Limited, Adelaide, South Australia, Australia

Although regolith carbonates (especially calcretes) have been widely used as a sampling medium for geochemical exploration in southern Australia and many other parts of the world, our understanding of the geochemical pathways associated with the origins and development of these materials and their association with Au is limited/deficient. Trace elements and Sr-isotopes have been employed to define the geochemical pathways but these approaches have, so far at least, been of limited success. Of particular concern has been that although pedogenic carbonates have been specified as the target regolith carbonate sampling medium for geochemical exploration for Au, these carbonates have not always been clearly distinguished from other types, such as groundwater carbonates nor has there been an adequate distinction made between carbonates formed from pedogenic processes across a range of substrate types and those that have formed specifically from the weathering of Cenozoic marine limestones. Weathered marine limestones that invariablyhost geochemical characteristics independent of underlying of bedrock and associated mineralisation, have been unknowingly (unwittingly?) sampled across large parts of southern Australia. Here we describe a range of geochemical settings responsible for the development of regolith carbonates and their trace metal compositions, particularly focussing on the weathering of Cenozoic marine limestones in southern Australia. These results also have implications of stratigraphic and palaeo-environmental significance especially when considered from a basin-hinterland geochemical evolution perspective.

The study area is centred on the Eucla Basin, which formed along the central portion of Australia's continental margin during the Cenozoic. The basin straddles the sedimentary areas in between the Yilgarn Craton in the west and the Gawler Craton in the east, which are two of the most highly prospective areas for mineral exploration in the world, that have both been bastions of regional regolith carbonate sampling for geochemical exploration. The sedimentary record, especially of marine limestones, within this basin provides an important palaeo-environmental and chronological context for the development of regolith carbonates within the basin area and its flanking hinterland. Definition of the sedimentary record is combined with multi-element and isotope geochemistry, thin section analysis, and element ratios from resistate mineral size fractions to support the case for widespread pedogenic carbonates having formed from the reworking and weathering of marine limestones across many parts of southern Australia. Quite apart from the sobering, implications for the use of regolith carbonates in geochemical exploration programs, this study provides the stratigraphic context for transported cover on the basin margins.

B5.1

Using gum trees for Au exploration in the Eastern Goldfields (Western Australia)

Melvyn Lintern, Ravi Anand
CSIRO, Kensington, WA, Australia

Bio-, soil and gas geochemistry techniques were tested at a Au deposit (near Kalgoorlie, Western Australia) to examine potential mechanisms of anomaly formation. Suitability of these techniques for exploration in Tertiary palaeochannel-dominated terrain was examined. Supergene Au mineralisation occurs in saprolite approximately 5-10 m beneath a 35-45 m palaeochannel at the tested site.

A high-contrast, well-defined biogeochemical Au anomaly occurs over the deposit. that is most prominent in the foliage of large gum trees (Eucalyptus spp.). Concentrations of Au in foliage are highly variable over mineralisation with adjacent trees showing both very high and background Au concentrations. Variability in Au concentrations in different branches from the same tree above mineralisation and also within different leaves from the same branch indicate "hot spots" due to the non-homogenous formation of biogenic particulate Au (phytonuggets) within the foliage. Despite non-anomalous, generally low and variable Au concentrations within a single tree trunk, heartwood and sapwood are major storage organs for Au in gum trees due to their large mass. Soil was analysed for adsorbed gas by the heating a fine fraction of the soil and analsyisng the volatiles by gas chromatography (the Soil Desorption Pyrolysis technique). Several compounds (including methane) had marginally elevated concentrations (relative to other samples) in soil 0-0.1 m from the tree above mineralisation. Elevated soil concentrations were also found away from the mineralisation in the far W and E of the traverse.

A model is proposed for the formation of the Au anomaly at the deposit:

a) Gold is released from the vegetation through litter fall, leaf exudates, limb/branch loss and plant death And is partly re-recycled through living plants

b) Gold at the surface is supplemented through deep-rooted trees that absorb Au from the supergene mineralisation.

c) Gold is lost from the surface through processes of physical erosion (litter and soil) and water-soluble Au during run-off.

d) A dynamic equilibrium is created with the Au contents of the soil and vegetation that is mediated through local climate/environmental conditions.

The implications for mineral exploration from this study are important. It suggests that vegetation generates anomalies at surface by adsorbing Au from at least 35 m beneath the surface. The soil is far easier to collect than the foliage and provides a broader anomaly. The erratic nature of Au accumulation in foliage suggests that sampling around the tree is beneficial to reduce the erratic effect of phytonuggets in biasing the data. Bulk litter and bark are not anomalous over mineralisation at the site and are not recommended to be sampled. Specific components of the litter e.g. leaves, may be targeted but this requires more study.

B5.2

An integrated groundwater and regolith study of metal migration through cover at a Ni sulphide deposit, Western Australia

Ryan Noble[1], Melvyn Lintern[1], Ravinder Anand[1], David Gray[1], Nathan Reid[1], Brian Townley[2]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]Department of Earth Sciences, University of Chile, Santiago, Chile

Regolith profiles, soils and groundwater were sam- pled and tested at the North Miitel NiS prospect to assess potential mechanisms of anomaly formation and to assess the suitability of various sample media for exploration of buried Ni deposits in the SE Yilgarn Craton of Western Australia.

The North Miitel Ni prospect is situated on the western flanks of the Widgiemooltha Dome (~60 km south of Kambalda) and is hosted within komatiitic peridotites. Mineralisation is characterised by >0.5 % Ni with elevated concentrations of Cu, Co, Zn and PGE compared to background. The thin (<5 m) saprock is overlain by up to 20 m of transported cover, comprising sand, calcareous soil, red clays and mottled clays. A palaeochannel up to 60 m thick occurs on the eastern side of the study area. Eucalypts are the dominant vegetation in this semi-arid environment.

Subtle near-surface elevated concentrations that would normally be overlooked are related to Ni in the carbonate and clay:sand interface. Results of regolith geochemical analysis show the zone of supergene Ni (>180 ppm) occurs at ~15 m depth in saprock and saprolite, is only a few metres thick and not greatly enriched compared to background (~70 ppm). Vertical dispersion into the transported overburden for Ni is limited (<2 m) above the water table (~10 m depth). Metal migration at North Miitel appears to be hydromorphic, with some evident capillarity mobilising some metals above the water table, but only for a few metres, suggesting another mechanism must occur for the observed subtle expression of anomalous Ni near the surface. Laterally, groundwater mobilises metals and forms a larger geochemical halo over a few hundred metres with Ni, Co, Pt and Pd anomalies.

Results suggest near surface Ni signatures are derived from some gaseous transport mechanism, but more testing is required to confirm this. Use of partial extractions did not greatly enhance anomaly signatures at the surface. Saprolite and groundwater are the best sample media to detect mineralisation at this site with groundwater exhibiting a larger halo in the order of a few hundred metres from the Ni-rich saprock zones.

B5.3

Geophysical, geological and indirect geochemical exploration of covered terrains in Northern Chile: from regional to local scale

Brian Townley[1], Diana Comte[3], Daniel Carrizo[2], Alvaro Puig[4], Gonzalo Yañez[4]
[1]Dept. of Geology, University of Chile, Santiago, Chile, [2]Mining Technology Center, University of Chile, Santiago, Chile, [3]Dept. of Geophysics, University of Chile, Santiago, Chile, [4]Codelco - Chile, Santiago, Chile

In northern Chile, mining exploration is challenged to prospect in areas of covered terrains, a great part buried beneath 10's to 100's of meters of Miocene to recent transported overburden. Such challenge has been met by integration of exploration tools, including geophysics, geology of surroundings and interpretation of geological and structural features beneath cover, and indirect geochemistry. Such tools provide information and interpretations that range in scale from regional (geophysics and geology) to district (geology) to local (indirect geochemistry).

In this study we present the combined results of regional to local exploration in the Cerro Overa - Altamira region, in the Atacama region of northern Chile. At regional scale the use of seismic profiling geophysical tools has allowed the interpretation of regional structural patterns, in particular, deep location and distribution of highly fractured and/or water saturated basement rocks, and distribution of igneous and volcanic rocks in depth. In addition, interpretation has allowed the determination of regional structural patterns and profiling of deeper roots of structural systems, in this region, the Atacama Fault System showing mainly a NS to slightly NW-SE strike, parallel systems connected in echelon by ENE-WSW faults. Deep distribution of fault zones, of highly fractured and/or water saturated rocks and of regional intrusive and volcanic rocks was contrasted to regional geology and structural maps, to interpret basement geological and structural features beneath transported overburden. Location of copper deposits in the region, such as the Altamira copper deposit and the Casualidad IOCG deposit are interpreted as spatially related to singular fault splays, these having a marked secondary permeability control.

Regional to district scale studies by integration of geophysics and geology, and interpretation of basement geology, provide the broad targeting local areas, in which indirect geochemical tools may be used for finer targeting. In the Casualidad district, a broad geochemical survey, employing passive time-integrated collector devices (Ore Hound GOCC®) was carried out. Combination of geochemical and hydrocarbon compounds allowed discrimination of the surface expression of the Casualidad IOCG deposit, and the interpretation of structural patterns in which mineralization may have potential continuation north and east of the current deposit. Discontinuities, as interpreted from the geochemical surveys, present patterns which are similar to those determined from regional geophysical and geological interpretations. Integration of exploration tools allow progressive interpretation and targeting, from regional to local.

Acknowledgements: Research was fully funded within Codelco - Chile research programs.

B5.4

Multifractal Methods for Identification of Weak Anomalies Caused by Buried Sources from Surface Geochemical Landscape in Covered Terrances

Qiuming Cheng[1]
[1]York University, Toronto, Canada, [2]China University of Geosciences, Wuhan, China

While a map scale commonly considered in the exploration geochemical field as an indicator of sampling density and coverage of study area, new developments of the of scaling and nonlinear modeling techniques have brought new ways for processing geochemical data and new ideas for interpreting geochemical anomalies in geological modeling and mineral exploration. Anomalies identified on geochemical maps are often scale-dependent in the sense that anomalies identified at one scale may not be the same or may not even exist at other scales. However, the nonlinear regulations, discovered in the field of geocomplexity, quantifying these types of changes of anomalies delineated at multiple scales, are known only in small group of researchers rather than practitioners in the field of geochemical exploration. Scaling has been found as common property of geochemical landscape which characterizes the change regulations of patterns of geochemical landscape measured through scales. How to utilize the scaling property to assist in delineation of geochemical anomalies especially weak anomalies caused by buried sources in covered terrane is a challenging but promising research direction which will change the basic concept of anomalies and methods for anomalies delineation. Traditional statistics based on main variances of the geochemical data have limitations for characterizing small sample population such as anomalies associated with mineralization or other types of rare events. This paper introduces several state-of-the-art concepts and methods in utilization of scaling properties in visualization and interpretation of geochemical data in assisting mineral exploration. These include a singularity analysis, a powerful technique for identification of weak anomalies caused by buried sources and a generalized self-similarity analysis for decomposing anomalies from complex background. The case studies to be conducted in this paper are from China for prediction of undiscovered buried Sn and Cu mineral deposits in Geijiu district, Fe and Cu deposits in Xinjiang district with covers of desert and Fe, Cu and Mo mineral deposits in Eastern Inner Mongolia covered by with grass and regolith.

B6.1

Classification of waste from extractive industry as inert - the use of litogeochemical data to define inert rock types

Teemu Karlsson, Anna Tornivaara, Hannu Luodes, Soile Aatos, Maria Nikkarinen, Päivi Kauppila
Geological Survey of Finland, Kuopio, Finland

The sustainable use of natural resources is one of the biggest challenges of the present day. Recycling of the waste from extractive industry aims to fulfill this objective. Potential for recycling and usage is higher if the waste is inert. The background to this project and the need to create a list of inert rock types lies in the European mining waste directive (2006/21/EC), the commission decision (2009/359/EC) and the Finnish decree on extractive waste (VNa 717/2009). This study concentrated especially on waste rocks from quarries, and the aim of the study was to create a list of Finnish rocks that could be defined as inert. The Finnish Rock Geochemical Database (Rasilainen et al., 2007) was used as background material in creating the list of inert rock types. The database includes chemical and geological description of 6544 bed rock samples, covering extensively the whole Finland.

The rock types of the original database were reorganized and regrouped to reduce their number. Based on the lithogeochemical database, the minimum and maximum values, median, mean, 75th and 90th percentiles of the newly formed rock groups were calculated for the potentially harmful elements included in the national decree of extractive waste (VNa 717/2009). The values were then compared with the corresponding environmental threshold- and reference values defined in the decree on the assessment of soil contamination and remedation needs (VNa 214/2007). The threshold value for molybdenium was defined in the SAMASE-project (Puolanne et al., 1994) and the sulphur values in the decree of extractive waste (VNa 717/2009). Based on the comparison, the rock types were divided into two groups: 1. Proposed inert rocks and 2. Other rocks. The main criterion was that the 90th percentiles were below the threshold values.

Based on the Rock Geochemical Database of Finland, the proposed inert group rock types do not probably contain amounts of harmful elements included in the decree of extractive waste (VNa 717/2009) that exceed the threshold values, so they can be absolved of additional analyses. Anomalous heavy metal-, arsenic- or sulphur concentrations and acid productivity are usually related to sulphide minerals. Therefore, also the proposed inert group rocks have to be revised to verify the sulphide mineral content before they can be defined as inert waste.

B6.2

Geochemical Baselines in the Pirkanmaa region, Finland

Tarja Hatakka, Timo Tarvainen, Jaana Jarva, Birgitta Backman, Mikael Eklund, Pekka Huhta, Niilo Kärkkäinen, Samrit Luoma
Geological Survey of Finland, Espoo, Finland

The Geological Survey of Finland (GTK) has recently published a report that summarizes the results of geochemical mapping projects carried out in the Pirkanmaa region of Southern Finland (Hatakka et al., 2010). In the Pirkanmaa region, the concentrations of arsenic and certain metals (Co, Cr, Cu, Ni, Pb, V and Zn) in soils and bedrock are known to be high (Loukola-Ruskeeniemi et al., 2007).

For risk assessment in the case of soil contamination, the Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007) provides a possibility to take into account geochemical baselines rather than the threshold values that are given in the Decree. According to the Finnish national geochemical baseline database, TAPIR (Jarva et al., 2010), in which Finland has been divided into geochemical provinces to provide regional geochemical baselines, the southern part of Pirkanmaa region belongs to the arsenic province and the metal province of Southern Finland. In these provinces, the baseline concentrations of arsenic and some metals are higher than the threshold values given in the Decree.

Based on natural arsenic concentrations in soils, the Pirkanmaa region can be divided into three parts. In the southern part, the upper recommended limits of baseline variation for arsenic in natural soils are 29 mg/kg for sand, 26 mg/kg for till and 15 mg/kg for clay. In the middle part, the respective values are 5.8 mg/kg for sand, 18 mg/kg for till and 7.4 mg/kg for clay, while in the northern part, the upper recommended limit for clay is 8.7 mg/kg. For other soils in northern Pirkanmaa, the threshold value for arsenic, 5 mg/kg, is suitable.

Based on the natural metal concentrations in soils, the Pirkanmaa region can be divided into two parts: the southern part where, for example, the upper recommended limits of baseline variation for cobalt in natural soils are 21 mg/kg for sand, 26 mg/kg for till and 39 mg/kg for clay, and the northern part, where the respective value for cobalt in clay is 29 mg/kg. For other soils in northern Pirkanmaa, the threshold value for cobalt, 20 mg/kg, is suitable.

References:
Hatakka et al., 2010. Geological Survey of Finland, Report of Investigation 182.
Jarva, et al., 2010. Science of the Total Environment 408, 4385 - 4395.
Loukola-Ruskeeniemi et al., 2007. Helsinki University of Technology. Geoenvironmental Technology Section. Special Publications.

B6.3

Relationships between bedrock geochemistry and till geochemistry in the Redstone area, south cental British Columbia, Canada

Jaakko Hietava[1]
[1]University of Oulu, Oulu, Finland, [2]Outokumpu Chrome Oy, Kemi, Finland

The Chilcotin Group basalt (CGB) is a Late Oligocene to Pleistocene extrusive rock unit located in the south central parts of British Columbia, Canada. This rock unit is generally considered to be widespread across the Interior Plateau and thus it hampers mineral exploration interest within the region (Ferbey et al, 2009).

This poster summarizes the methods used in assessing the areal extent of the CGB and a Jurassic-age intrusive complex in the study area. It also discusses glacial dispersal length within the study area, and the possibility of finding subcropping granitoids, which have positive correlation possible mineralization in the study area. The primary research method used was till geochemistry, with contributing evidence provided by whole-rock analysis of bedrock samples, petrographical thin sections and previous research.

The geochemical properties of specific bedrock units in the study area produce correlating patterns in the sampled basal till units, and this data was used to differentiate a geochemical signature of the CGB in till. Major element data proved to be most useful, and SiO_2, Fe_2O_3, TiO_2 and Cr_2O_3 concentrations were linked with other data to interpret the areal distribution of the CGB and the intrusive complex (Hietava, 2010). The results provided in this study benefit the mineral exploration community using till geochemistry as an exploration tool in the Interior Plateau.

Data sets used in this study provide new evidence on the areal extent of the CGB in the study area. This fact leads to an interpretation that the CGB is not as widespread as previously thought and that more prospective mineralized rock units could be found in areas where CGB is located. This study also discovered that the intrusive complex located in the southwest corner of the study area could be larger than previously thought.

References:
Ferbey et al, 2009. Geological Fieldwork 2008, British Columbia Ministry of Mines, Energy & Petroleum Resources, Paper 2009-1, pp. 117-126.
Hietava, T. J. O., 2010. M.Sc. Thesis, University of Oulu.

B6.4

Factors that affect the occurrence of Cr(VI) in acidic mine waters

Auri Koivuhuhta[1], Marja Liisa Räisänen[2]
[1]University of Eastern Finland, Kuopio, Finland, [2]Centre for Economic Development, Transport and the Environment, Kajaani, Finland

Occurrence of hexavalent chromium is not well-known in mining environments, because of the lack of specific Cr(VI) measurements. Although, it is known that Cr(VI) can have hazardous effects on biota even in low concentrations. Many factors (NOM, Fe(II), MnO_2, etc.) that affect chromium species have been studied in laboratory environments. Furthermore, Cr(VI) is also known to be soluble in natural waters in alkaline conditions. However, the different environmental conditions affect the factors and mining environments differ from natural environments, e.g. contain high elemental concentrations in acidic or neutral mine water.

In the present study, the Cr(VI) concentrations in water were measured in an abandoned sulfide mine site, Otravaara, Finland. Field measurements (pH, redox, T, O_2) and water samples were taken over four years, mostly in spring time. Total and dissolved (0,45 µm) elemental concentrations were determined by ICP-MS/AES, chromium species were analyzed by SPE-method (Koivuhuhta et al., 2008) and ICP-MS/GFAAS, Fe(II) by a spectrophotometry method and DOC (dissolved organic carbon) by an SFS-EN 1484-method. Fe(II) and DOC were determined twice (in 2009 and 2010).

Concentrations of Cr(VI) varied between 12-88 µg/L near the waste rock pile, and were higher in autumn than in spring time. The results showed that Cr(VI) correlates with Fe(II), Mn and DOC. It also appeared that Fe(II) can reduce Cr(VI) at low pH (< 3), while MnO_2 oxidize Cr(III) to Cr(VI) in pH 4-5, which was comparable to the findings of Pettine et al. (1998). Additionally, the effects of weathering/aging, DOC, temperature and redox are discussed.

The results indicate that in some cases Fe(II) does not instantly reduce Cr(VI), depending on pH. Many other factors also influence the occurrence of Cr(VI) in mine water environments. These results prove that more case studies, monitoring and the adequate information about the occurrence and fate of hexavalent chromium is needed.

References:
Koivuhuhta et al., 2008. Bulletin of the Geological Society of Finland 80:2, 125-136
Pettine et al., 1998. Geochimica et Cosmochimica Acta 62:9, 1509-1519

B6.5

Quaternary geology, till geochemistry and heavy minerals at Suurikuusikko, Kittilä, northern Finland

Anne Peltoniemi-Taivalkoski[1], Pertti Sarala[2]
[1]-, Rovaniemi, Finland, [2]Geological Survey of Finland, Rovaniemi, Finland

Surficial geology, till geochemistry and heavy minerals were studied at the Kittilä Mine during 2007-2009. This research was a joint project between the Geological Survey of Finland and Agnico-Eagle Finland. An aim of this study was to clarify the till stratigraphy of the area and see, if three known Au-bearing zones in the Suurikuusikko open pit have produced a recognizable geochemical signature in the glacigenic overburden. The methods were conventional geochemistry for till and pre-glacial weathered bedrock surface, using ICP-OES and GFAAS after partial leaching with aqua regia, FAAS with syanide leaching (for Au analysis), mobile XRF, and heavy mineral research. Samples for the Quaternary chronology of stratified inter-till layers and deposits were also taken, and dated by the OSL method.

The glacigenic overburden in this area has three till beds representing different glacial phases. The lowest till, which is observed only in places on the distal side of bedrock highs relative to the glacial transport direction, represents the oldest (Early Weichselian) ice advance with an ice flow direction from NW to SE. The uppermost tills represent the latest glaciation phase, having an indication of glacial advance stage in the bottom and a retreat phase on the top of the sequence. Glaciotectonically deformed stratified sediments that were part of a west-east oriented melt-water channel crosscut the till deposits in the middle of the Suurikuusikko open pit area. The sediments were deposited at the end of Early Weichselian, about 73,000-78,000 years ago.

Based on the till stratigraphy and geochemistry of this area, the transport distance of till debris and pebbles was estimated to be short for the bottommost till bed. The upper till beds had much longer transportation, and give no clear lithological and chemical indication of the local, underlying bedrock.

The most suitable indicator elements in till, besides the gold itself, are As, K, Mn and Sb with the heavy minerals like arsenopyrite and pyrite. Instead, the number of visible (microscopic) gold grains in heavy mineral concentrates both in till and weathered bedrock samples was low reflecting very fine-grained gold particle size and/or the occurrence of gold in the lattice of sulfide minerals.

B6.6

Pathways of metals from bedrock and soil into water and berries in the Sarvlaxviken area, SE Finland

Sari Myllymäki[1], Krister Sundblad[1], Kirsti Korkka-Niemi[2], Eila Varjo1, Mira Valkama[1], Rainer Huopalahti[3]

[1]Department of Geography and Geology, University of Turku, Turku, Finland, [2]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland, [3]Department of Biochemistry and Food Chemistry, University of Turku, Turku, Finland

During the last few years, natural accumulations of a number of metals, among them Cu, Zn, Pb, Sn, As, In and Cd, have been recognized in both bedrock and soil in the Sarvlaxviken area, southeastern Finland. The metal accumulations occur in veins in the rapakivi granite (Cook et al., 2011; Valkama et al., 2011) and as dispersions in the adjacent soil (till) cover (Sundblad et al., 2011).

In order to find out if the metal anomalous geological formations also could influence surface water, groundwater and vegetation, a test area was selected at Högberget, immediately east of Sarvlaxviken. At Högberget, a cm-wide metal-rich vein was known in the rapakivi granite and surrounded by a soil cover with high metal contents, among which up to 37 ppm As, 23 ppm Sn, 0.7 ppm In and 0.6 ppm Cd were noted.

Twelve groundwater or surface water samples from eight locations were taken from ditches or dug pits using mini-piezometers to assess the metal concentrations of waters near the bedrock and soil anomalies. Alkalinity, EC, pH, main ions, F and some trace elements (Cu, Zn, Pb, Sn, As, In, Cd) were analysed in these water samples. Blueberry samples were collected at two and raspberry samples at three locations on and around Högberget. Berries were analysed for As, Cd, K, Mg, P, Cu, Fe, Mn, Zn concentrations.

A water sample, collected 11 metres from the vein, turned out to be very acid (pH 3.6) and to have high contents of the same metals (Zn, As, Cd, Sn, Pb, In) that had been encountered in the adjacent bed rock vein and soil. Blueberries, collected a few metres from the analyzed water sampling site, showed also anomalous metal contents, particularly with respect to Cd. Two raspberry samples, collected 300 metres down-hill from the metal rich bedrock, had so high Cd contents that they exceeded the acceptance levels for human food.

The geochemical pathway of metals from a metal-rich vein through soil and water into the berries is obvious in the studied area. There is no connection to any anthropogenic source for this metal-rich geochemical environment; it is simply a reflection of geological processes with a clear influence on the berries.

References:

Cook, N.J., Sundblad, K., Valkama, M., Nygård, R., Ciobanu, C.L. and Danyushevsky, L., 2011. Chemical Geology, doi: 10.1016/j.chemgeo.2011.02.006.

Sundblad, K., Valkama, M., Penttinen, K. and Nygård, R., 2011. Abstract 25th International Applied Geochemistry Symposium, Rovaniemi, Finland.

Valkama, M., Broman, C., Sundblad, K., Cook, N.J. and Nygård, R., 2011. Abstract 25th International Applied Geochemistry Symposium, Rovaniemi, Finland.

B6.7

Alteration styles and geochemical zonation at the Raitevarri Cu-Au occurrence, Karasjok, Norway

Jani Jäsberg[1], Pasi Eilu[2], V. Juhani Ojala[3]

[1]University of Turku, Turku, Finland, [2]Geological Survey of Finland, Espoo, Finland, [3]Store Norske Gull AS, Rovaniemi, Finland

The Raitevarri Cu-Au occurrence is situated 40 km SW of the Karasjok village in Finnmark, Norway. The Geological Survey of Norway found the occurrence in 1967 (NGU ore database, 2011). At Raitevarri, Cu-Au mineralisation is hosted by a unit of quartz-hornblende-plagioclase gneisses enclosed within the Palaeoproterozoic Karasjok Greenstone Belt. This meta-igneous unit is poorly exposed, but based on scarce outcrops and geophysical measurements it covers an area of about 20 km^2 (NGU ore database, 2011). The sporadically mineralised zone in the gneisses has a length of more than 7 km and its width varies from 300 m in the NW to 1500 m in the SE (Ihlen, 2005).

In 2009, Store Norske Gull A/S conducted soil sampling in the NW part of the gneisses, which revealed an oval-shaped soil anomaly of 300 m wide and 700 m long. Later same year, a drilling campaign was conducted and a previously unknown hydrothermally altered and mineralised body was discovered. For the present study, 14 drill cores in profiles RAI-500 and RAI-600 from this newly discovered target were sampled and photographed. Also the whole-rock chemical data from the drill profiles were used to examine lithochemical zoning and alteration-related chemical changes.

Two distinctly different types of alteration are recognized: (1) a plagioclase-epidote-chlorite assemblage, associated with quartz-epidote veins with amphibole selvages, and (2) a phyllic alteration assemblage (quartz-muscovite-pyrite±chlorite±tourmaline), associated with quartz-muscovite-sulphide or quartz-tourmaline-sulphide± muscovite± chlorite veins. The former alteration is detected in thin-section studies, whereas the latter alteration is widespread and easy to detect from the hand-samples because of the bleached appearance. The phyllic alteration is associated with a significant gain in Cu, Au, Mo, Ag, As, Bi, Se, and Te as well as loss in Zn, Pb, Cd, and Mn. On the other hand, all the elements depleted in the phyllic zone appear enriched in the least-altered gneisses and country rocks.

The metal zonation in drill profile RAI-500 shows two central zones where Cu, Au, and Mo anomalies coincide. The Cu-Au-Mo enriched zones are surrounded by zones with elevated Zn, Mn, Pb, and Cd concentrations. The interpretation is that the Cu-Au-Mo zones represent high-temperature proximal alteration, whereas the Zn-Pb-Mn-Cd zones represent a distal, lower temperature alteration.

References:

Grant, J.A., 1986. Economic Geology, 81, 1976-1982.

Ihlen, P.M., 2005. Geological Survey of Norway (NGU) Report 2005.076, 55 p.

Geological Survey of Norway (NGU) Ore Database, 2011. Rai'tevarri Online at: http://aps.ngu.no/pls/oradb/minres_deposit_fakta.Main?p_objid=740&p_spraak=E accessed 23 May 2011.

B6.8

Till geochemistry and indicator minerals in the interpretation of the thick till sequence at Muhos, central western Finland

Juha-Pekka Lunkka, Vesa Peuraniemi, Tiina Nikarmaa

Department of Geosciences, University of Oulu, Oulu, Finland

Recent drilling at Muhos, central western Finland has revealed that an exceptionally thick Quaternary sediment cover overlying the Neoproterozoic Muhos Formation occurs in the Oulujoki River Valley.

Here we report preliminary geochemical results from four till units from the core site Muhos 1. The site is located at 27 metres above present sea level, ca. one kilometre south of Oulujoki River at the distance of ca. 30 kilometres from the present shore of the Baltic Sea.

The drilling at this site was performed with GM 200 GTT drilling platform using 1 metre long sample tubes (HDPV, diameter 5 cm) inside the metal cover tubes. The coring penetrated down to the Neoproterozoic siltstone bedrock 54.5 m below the ground surface (m bgs) and the sediment core recovery was over 75%.

Sedimentary sequence from ground surface down to the local siltstone bedrock consists of the following lithostratigraphical units: Unit 1: 0 - 10 m bgs, silt, mud, silt and sand, Unit 2: ca. 10 - 18 m bgs, till and sand, Unit 3: ca. 18 - 27 m bgs, sand and silt , Unit 4: ca. 27 - 37 m bgs, till, Unit 5: ca. 37 - 38 m bgs, sand and silt and Unit 6: ca. 38 - 54.5 m bgs, till.

Geochemistry of the fine fraction and heavy minerals of the sand fraction were studied from four till units that are thought to have been deposited during the Saalian and the Weichselian glaciations. Fine fraction was separated with dry-sieving and analyzed chemically by XRF and AAS. Heavy fraction was separated by using Na-heteropolytungstate (d = 2.82 g/ml). Mineralogical composition of the heavy fraction was studied by SEM+EDS.

Till units have different geochemical and indicator mineral signatures reflecting their provenance areas. Interesting feature is the occurrence of barite, pyrite and chalcopyrite in the lowermost till units.

B7.1

Exploration for Concealed Deposits using Porphyry Indicator Minerals (PIMs): Application of Apatite Texture and Chemistry

Farhad Bouzari[1], Craig J.R. Hart[1], Shaun Barker[1], Thomas Bissig[1]

[1]Mineral Deposit Research Unit, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, British Columbia, Canada, [2]Geoscience BC, Vancouver, British Columbia, Canada

Apatite, zircon and, to a lesser extent, rutile and titanite are common resistate minerals in porphyry systems. Apatite is by far the most common resistate mineral occurring across a wide range of host-rocks and alteration assemblages. More critically, the physical and chemical properties of apatite are distinctive in altered mineralized rocks. Apatite in fresh host rocks displays strong luminescence of yellow to yellow-green due to excitation by Mn^{2+}. Apatite in altered host rocks looks very similar to those in fresh host rocks when examined by eye, or using a polarizing microscope and SEM. However, cathodoluminescence microscopy reveals that apatite in altered host rocks have a unique green luminescence. The most intensely-altered apatite shows dark-green to grey luminescence, producing complex textures with remnants of bright green-luminescent apatite. Electron microprobe analysis indicate that apatite in fresh and altered host rocks have similar Ca and P but distinct trace element concentrations. Most notably, Mn and Na are depleted in altered apatite but Mg, Cl and S are also removed during alteration. These results indicate that porphyry-altered apatite can be easily recognized both visually and geochemically in heavy mineral separates providing a useful tool to increase exploration targeting success, especially in glacial, fluvial and regolith terrains.

B7.2

Glacial Dispersal of Indicator Minerals from the Izok Lake Zn-Cu-Pb-Ag VMS Deposit, Nunavut, Canada

Anna Hicken[1], Beth McClenaghan[2], Dan Layton-Matthews[1], Roger Paulen[2]
[1]Queen's University, Kingston, Ontario, Canada, [2]Geological Survey of Canada, Ottawa, Ontario, Canada

The use of indicator minerals and their chemistry applied to diamond exploration is well established. VMS deposits also have a suite of characteristic indicator minerals, however, little research has been carried out to define which minerals may be useful to exploration in glaciated terrain and few indicator mineral case studies have been conducted down-ice of known VMS deposits. As part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM) Program (2008-2013) in partnership with Queen's University and Minerals and Metals Group (MMG), the Izok Lake Zn-Cu-Pb-Ag VMS deposit in northern Canada is being studied to determine which specific pathfinder indicator minerals and elements can be successfully applied to drift prospecting for VMS deposits.

Surficial deposits of the region are dominated by a silty-sand till, which was deposited by the Laurentide Ice Sheet. This sandy till is an ideal sample medium for applying indicator mineral methods. The glacial history of the Izok Lake area consisted of four ice-flow phases, the oldest flow trending 255°, a weak flow at 315°, a strong flow at 292° which sculpted most of the landforms, and a rock polish east of the Iznogoudh Lake area which is a result of the youngest ice flow that trended at 318°.

Bedrock and till samples were collected around the Izok Lake deposit in 2009 and 2010 for till matrix geochemical analysis and recovery of indicator minerals. A preliminary list of indicator minerals that define the signature of the Izok Lake VMS deposit includes: gahnite (Zn spinel), chalcopyrite, sphalerite, galena, pyrite, pyrrhotite, gold, spessartine, Mn-axinite and kyanite. These indicator minerals define a WNW trending dispersal train at least ~ 8 km down-ice of the Izok Lake deposit, in the dominant ice flow trajectory. Copper, Pb, Ag, Zn, Cd, Sb, Au, Bi, Mg, Se, Tl and In (aqua regia digestion/ICP-MS) are pathfinder elements for the Izok Lake deposit in the <0.063 mm fraction of till.

B7.3

Magnetite composition applied to drift prospecting methods for IOCG exploration in the Great Bear magmatic zone, Canada: results from the NICO Au-Co-Bi deposit

Isabelle McMartin[1], Louise Corriveau[1], Georges Beaudoin[2], Simon Jackson[1], Philippe Normandeau[3]
[1]Geological Survey of Canada, Ottawa, Ontario, Canada, [2]Department of Geology and Geological Engineering, Laval University, Quebec City, Quebec, Canada, [3]Department of Earth and Planetary Sciences, McGill University, Montreal, Quebec, Canada

An applied Quaternary research activity was undertaken in the Great Bear magmatic zone, Northwest Territories, Canada, to provide a practical guide to geochemical and indicator mineral exploration for iron oxide copper-gold (IOCG) deposits in glaciated terrain. An orientation study was initiated in 2007 and continued in 2009 around the NICO Au-Co-Bi deposit, an atypical magnetite-group IOCG deposit with arsenopyrite mineralization within amphibole-magnetite-K-feldspar-biotite alteration in 1.88 Ga metasedimentary rocks. Bedrock (n=30) and till (n=20) samples were collected up-ice, proximal to, and down-ice from mineralization, host hydrothermal systems and least altered bedrock. The minor and trace element composition of sand-sized ferromagnetic minerals is used to evaluate whether the NICO deposit can be fingerprinted by drift prospecting using Fe-oxide composition.

The ferromagnetic fraction (0.25-2 mm) is abundant in most bedrock and till samples and consists of individual magnetite (dominant) or hematite grains, bedrock fragments with disseminated magnetite, non-ferromagnetic minerals with small magnetite inclusions, and magnetite-hematite mixtures. Electron microprobe analyses of grains demonstrate that the trace element signature of Fe-oxides is a prospective discriminator for IOCG exploration. Most Fe-oxide grains from bedrock and till collected at or near the NICO deposit have lower Ti+V concentrations compared to grains from samples collected from least-altered metasedimentary rocks up-ice of NICO. There is also a strong correspondence between the composition of grains from bedrock collected in altered NICO metasedimentary rocks and grains from till collected over or directly down-ice of NICO. Furthermore, preliminary in situ trace element analysis by LA-ICP-MS of magnetite grains from NICO bedrock and till samples show relatively high As-Bi-Cu-Sb-W-U-Zr-Ag-LREE concentrations. This distinct element association is similar to the enrichments found in the bulk geochemistry of the <0.063 mm fraction of till collected over the NICO deposit, and reflects major differences in composition between the country/barren host rocks versus the mineralized rocks. Geochemical analysis of the pulverized ferromagnetic fraction of the till matrix will potentially show this signature. Further examination and analysis of the ferromagnetic fraction will help to identify discrimination criteria for the different types of mineralization and host rocks. In addition, the examination of Fe-oxide grains from samples collected in the vicinity of the Sue-Dianne Cu-Ag-Au hematite-group IOCG deposit, and additional showings across the Great Bear magmatic zone, will help to develop criteria that contribute vectors to a range of IOCG deposits. This work is part of the Geological Survey of Canada's Geomapping for Energy and Minerals Program aimed at improving mineral exploration effectiveness and discovery rates in Canada's North.

B7.4

Microchemical characterization of placer gold: Application in exploring glaciated terrains for volcano-hydrothermal and orogenic gold mineralization

Norman Moles[1], Rob Chapman[2]
[1]University of Brighton, Brighton, UK, [2]University of Leeds, Leeds, UK

Placer (alluvial) gold occurrences are widely used to guide exploration for bedrock gold mineralization in areas of glaciated terrain. Previous studies in the UK and Ireland (Chapman et al., 2000a, b; 2006) have shown that, notwithstanding widespread Quaternary glaciations, dispersal is typically limited to <1-3km and the alloy composition of placer gold and mineralogy of microscopic inclusions generally match the characteristics of nearby bedrock mineralization where known. Therefore, morphological and microchemical characteristics of gold grains can be used to deduce the likely location and nature of concealed bedrock mineralization. Populations of gold grains exhibiting homogenous alloy composition are commonly ssociated with orogenic gold, whereas greater heterogeneity (within populations and individual grains) is characteristic of VHMS-associated gold a(Morisson et al., 1991; Huston et al., 1992).

In this study we present results of microchemical characterization of placer gold in the Caledonides of southeast Ireland. Here a 30-50km wide belt of weakly metamorphosed Lower Palaeozoic volcanic and sedimentary strata is prospective for both orogenic (mesothermal) gold veins and volcano-hydrothermal massive sulphide deposits. Historically, an estimated 10,000oz of gold was recovered from placer operations in one 10 km^2 area (Goldmines River, County Wicklow); 10 km along strike is the formerly-rich Avoca VHMS copper deposit. Glacial deposits are widespread; bedrock exposure is restricted to hilltops and incised river beds.

We employed large volume sluicing techniques to recover gold particles and heavy mineral concentrate from >40 sites. Placer gold abundance is spatially clustered with considerable compositional variation indicating multiple occurrences of bedrock mineralization. Volcanic bedrock is spatially associated with abundant alluvial gold at some sites but not others. At some sites grains are angular, indicating minimal transport from sources, and heavy concentrates include distinctive minerals such as barite. Mineral inclusions within gold grains have two main signatures: a simple pyrite-arsenopyrite assemblage, and a complex assemblage including base metal sulphides ±sulphosalts. Gold abundance and alloy composition are not systematically related, however Goldmines River orogenic-type gold is distinctly Ag-rich compared to surrounding areas. Some grains show internal heterogeneity which is used to interpret primary environments and post-depositional alteration.

The signature of placer gold in SE Ireland is consistent with the mineralogy of the Au-Zn-Pb-Ag-Sb-barite type VHMS mineralization (formed from relatively low temperature (200±50°C), near neutral brines, with orogenic-sourced gold generated by remobilisation during regional metamorphism.

We recommend that similar techniques are applied in other glaciated regions with poor bedrock exposure that are prospective for Au-VHMS mineralization.

References:

Chapman, R.J., Leake, R.C. & Moles, N.R., 2000a. Journal of Geochemical Exploration 71, 241-268.
Chapman, R.J. et al., 2000ba. Economic Geology 95, 1753-1773.
Chapman R.J. et al., 2006. Journal of Applied Geochemistry 21, 904-918.
Huston, D. et al., 1992. Economic Geology 87, 542-563.
Morisson, G.W. et al., 1991. Ore Geology Reviews 6, 333-364.

B8.1

Characterization of glacial dispersal from the Kiggavik Uranium Deposit, Nunavut using indicator minerals and till geochemistry

Scott Robinson[1], Beth McClenaghan[2], Roger Paulen[2], Dan Layton-Matthews[1], Charlie Jefferson[2], David Quirt[3], Peter Wollenberg[3]

[1]Queen's University, Kingston, Ontario, Canada, [2]Geological Survey of Canada, Ottawa, Ontario, Canada, [3]AREVA Resources Canada INC., Saskatoon, Saskatchewan, Canada

Over the past 20 years, mineral exploration in the glaciated terrain of Canada and Fennoscandia has successfully utilized till indicator mineral methods for diamond and gold. More recently, indicator mineral methods for base metals and other commodities have been developed, however, relatively few published case studies have documented the glacial dispersal from uranium deposits using indicator minerals and till geochemistry.

In the summer of 2010, a drift prospecting study was initiated at the Kiggavik uranium deposit as part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM) Program (2008-2013), and is a collaborative effort with Queen's University, Overburden Drilling Management Limited, and AREVA Resources Canada Incorporated. The purpose of this study is to investigate and characterize the glacial dispersal of uranium-rich debris (till) down-ice of the Kiggavik uranium deposit. Samples of sub-cropping bedrock representing hydrothermally-altered and unaltered host rocks of mineralized zones from the Kiggavik deposit were collected for mineralogical and geochemical comparisons with the overlying till, as well as host rocks in the surrounding area.

The deposit is located within the zone affected by the migration of the Keewatin Ice Divide of the Laurentide Ice Sheet. Landforms, striae, and clast dispersal provide a record of simple to complex net transport. Multiple ice-flow trajectories had been documented in the area and this knowledge was used to plan the surface till sampling survey. The oldest ice-flow phase observed was a subtle E-SE trajectory, possibly during the onset of the Laurentide Ice Sheet. A powerful NW-NNW ice flow, assumed to have occurred during the peak of Wisconsin glaciation, is dominant, with most landforms conforming to this trajectory. A westward ice flow direction related to the Dubawnt ice stream is commonly observed in striations on outcrop and is believed to have been the last ice flow that eroded the deposit. Surface till samples (n=71) were collected from active mud boils up-ice from, overlying, and at specific distances in a fan-shaped pattern down-ice of the deposit (10 m, 100 m, 200 m, 500 m, 1 km, 2 km, 3 km, 5 km, 10 km) with respect to the NNW, NW and W ice flows.

Both till and bedrock samples were processed using a shaking table and heavy liquids to recover indicator minerals from the <2.0 mm heavy mineral (SG 3.2) concentrates. The <0.063 mm and <0.002 mm size-fractions of till were analyzed geochemically and were compared to geochemical signatures of the mineralized and country rocks to identify glacial pathfinder elements. Further geochemical analyses will be conducted to illustrate the preferred partitioning of uranium in till.

B8.2

Exploration at the thin- to thick-drift transition: challenges and approaches

Phillip Larson

Duluth Metals Limited, Duluth, MN, USA

Duluth Metals currently has interest in >250 km^2 of mineral rights overlying the Duluth Complex, a large intra-cratonic rift-related mafic intrusive complex in northeastern Minnesota, USA. The complex is an emerging Cu-Ni-PGE magmatic sulphide district, with >3 Gt in resources with ~0.45 % Cu, ~0.13 % Ni, and substantial PGE credit identified to date in the basal zone. The existing resource, combined with a lack of systematic exploration away from the basal zone, makes the bulk of the Duluth Complex a highly prospective greenfields exploration area. The entire area has been glaciated, and integration of geochemical and mineralogical drift exploration techniques to the ongoing exploration program is a key component to driving future exploration success.

Application of off-the-shelf techniques demonstrated to work on glaciated shield terranes elsewhere is complicated by the property's position near the transition from thin bedrock-mantling drift characteristic of the interior zone of the Laurentide ice sheet to the thick drift sequences characteristic of the marginal zone. The northern part of the tenement is characterized by glacially-scoured competent bedrock with rugged topography reflecting the base of a pre-glacial saprolite, mantled by a thin veneer of till and glaciofluvial sediment. Tills in this area are composed predominantly of locally derived material with transport lengths of ~1-10 km. To the south, a thick (~100 m) glacial drift sequence, comprised of multiple depositional packages deposited over multiple glacial cycles, overlies in situ pre-glacial saprolite. Tills in these packages are typically composed of exotic lithologies with transport lengths of ~100-1000 km. The transition between the thin- to thick-drift sequences is abrupt, occurring over length scales of 1-10 km.

The sporadic occurrence of pre-glacial saprolite presents an additional challenge to interpretation of surficial geochemical and mineralogical data. Saprolite near the thin- to thick-drift transition was only incompletely stripped from bedrock during the last glaciation, and may still be present in deeply weathered fractures and faults. It is anticipated that the geochemical and mineralogical signal of sub-cropping sulphide mineralization in overlying drift may reflect erosion of gossan rather than competent bedrock.

Duluth Metals is applying a range of geochemical, lithological, and mineralogical analytical techniques to characterize till in the project area. The mean transport length of till-forming material will be assessed to map areas where till composition reflects short transport lengths and local bedrock, as opposed to long transport lengths and exotic lithologies. Results of a pilot study indicate fine-fraction till geochemistry reliably detects anomalous Cu-Ni-PGE mineralization, whether ultimately derived from sound bedrock or gossan. Indicator mineral assemblages coincident with geochemical anomalies will be used to infer the character of anomaly sources, both their geology and state of preservation (competent bedrock vs. gossan).

B8.3

Stream Sediment Geochemistry used to generate and validate exploration target for Volcanogenic Massive Sulphides in the Peruvian Coastal Mountains

Keller Guerra
Votorantim Metais, Lima, Lima, Peru

The Peruvian coastal mountains are an area that hosted one of the main metallotects (Romero, D 2007), known as the Casma Group, which has VMS deposits (Sherlock & Logan, 2000). These Cretaceous volcanic-sedimentary rocks formations are distributed along 1000 Km. of the Peruvian Coast.

Through the use of Stream Sediment Geochemistry it was possible to identify favorable targets for the exploration of new deposits of this type (Hale & Plant, 1994). Zinc, Lead, Copper and Barium anomalies are some of the main VMS within the work area.

The purpose of this study is to document the use of geochemistry of sediments as an important tool for the prospecting and using barium as one of the pathfinder elements that have enabled the identification and provision of greater support to a large number of anomalies of interest due to its connection to these types of deposits.

References:
Sherlock, R. & Logan, M., 2000. VMS Deposits of Latin America, pp 375 - 439.
Romero, D., 2007. La Cuenca Cretácico Superior-Paleoceno del Perú Central: Un Metalotecto para la Exploración de SMV, Ejemplo Mina Maria Teresa. Msc thesis Master Internacional Aprovechamiento de los Recursos Minerales. 99 pages.
Hale, M. & Plant, J., 1994. Drainage Geochemistry, pp 147 - 183.

B8.4

Glacial dispersal and mode of occurrence of metals in till and esker gravel at Kumpuselkä, northern Finland

Vesa Peuraniemi, Tiina Eskola
Department of Geosciences, Univeristy of Oulu, Oulu, Finland

Kumpuselkä study area is situated 20 km north of the city of Oulu, northern Finland. The bedrock of the palaeoproterozoic schist area is composed of mica schists, basic volcanic, black schists and narrow dolomitic limestone horizons. At Kumpuselkä a quartz vein with Cu-Zn-Pb-Au disseminations was discovered in connection with quarrying operations. Quaternary deposits in the study area consists of glaciofluvial late Weichselian Kumpuselkä esker chain with WNW-ESE orientation, till and hummocky moraine field. Till bed beneath esker is composed of two till facies. The lower facies is grey sandy and stony till covering the bedrock surface. The upper facies is grey, relatively loose stony till with sand and gravel lenses. Esker material is poorly sorted stony gravel. The older ice movement direction in the area is from NW and the younger one from WNW.

Samples from till and esker gravel were taken for geochemical and heavy mineral studies. Fine fraction of the samples was analyzed by AAS after total dissolution. Mode of occurrence of metals was studied by partial dissolution techniques using different extractions.

Heavy fraction of the samples was separated with Goldhound spiral concentrator and analyzed chemically by AAS. Mineralogical composition of the heavy fractions was studied both from separate grains and polished thin sections using stereomicroscope, XRD, polarizing microscope and SEM+EDS.

The results of partial extraction analyses show that base metals are bound as sulphides in till but in the esker gravel the share of Fe oxides as resident sites of base metals is important.

Both the till and gravel samples contain a lot of unweathered pyrite grains. Heavy fraction of the till contains also unweathered base metal sulphides as chalcopyrite, sphalerite, galena, arsenopyrite, cobaltian arsenopyrite and cobaltite. Esker gravel samples contain anomalous amounts of Cu, Zn and

Pb in their fine fraction but no sulphide minerals of those metals were found in the heavy fraction. The specific case in the heavy fractions are the broken chromite grains. They indicate long-distance (100 km) glacial transport from northwest, from the Kemi ultramafic intrusion during an earlier pre-Salpausselkä ice movement phase.

As secondary sulphate minerals gypsum, pickeringite, kieserite and Mg-sulphate were found on the floor of the gravel pit (Eskola and Peuraniemi, 2008). Base metals released by surficial weathering are highly enriched in the sulphate precipitations.

References:
Eskola, T. & Peuraniemi, V., 2008. Mineralogical Magazine 72, 415-417.

B8.5
Post-glacial element transport from sulphide mineralisation through carbonate cover

Pim van Geffen[1],[2], Kurt Kyser[1], Christopher Oates[2], Christian Ihlenfeld[3]
[1]Queen's University, Kingston, ON, Canada, [2]ioGlobal Solutions Inc, Canada, [3]Applied Geochemistry Solutions, Gerrards Cross, UK, [4]Anglo American plc, London, UK

Paleoproterozoic volcanogenic massive sulphide (VMS) Cu-Zn mineralisation is buried under more than 100 m of Paleozoic dolomite sequences and Quaternary glacial till at the Talbot Lake prospect near Flin Flon, Manitoba, Canada (Bezys & Bamburak, 2001). This mineral occurrence is recognised in the geochemistry of surface sampling media. The clay fraction of the till-based soil contains pronounced anomalies of Zn, Cu, Ag, Pb, Au, Mn, Hg, Cd, Co, Bi and Se, which is ascribed to the formation of clay-organic complexes with carbon-isotopic compositions of $\delta^{13}C < -20‰$.

Lead isotope-ratios indicate the VMS origin of the near-surface anomaly in distinctly low values of $^{206}Pb/^{204}Pb$, compared to a more radiogenic till signature. The overall low $^{206}Pb/^{204}Pb$ ratios in the organic surface media black spruce bark, moss and humus also indicate input from a magmatic sulphide source, but likely reflect fallout from the Flin Flon smelter stack at 160 km to the northwest, which is the dominant wind direction in the area. Black spruce tree rings that pre-date industrial sources of atmospheric metal input record the local geochemistry at the time of heartwood growth and their root systems tap into large volumes of soil (Dunn, 2007; Kozuskanich, 2009).

The complex process of element migration from buried mineralisation to the surface includes oxidation of sulphides, mobilisation and complexation of metal ions, physical upward transport, and deposition of indicator elements in near-surface sampling media (Aspandiar, 2008). To account for a significant flux of indicator elements through the carbonate cover and into the relatively recently deposited till blanket, post-glacial groundwater upwelling (Boulton & Caban, 1995) is proposed to act as a major mechanism driving upward element migration.

References:
Aspandiar, M.F. et al., 2008. CRC-LEME, CSIRO Open File Report 246
Bezys, R. & Bamburak, J., 2001. Report of Activities, Manitoba Geological Survey, 159-163
Boulton, G.S. & Caban, P., 1995. Quaternary Science Reviews 14, 563-587
Dunn, C.E. 2007., Handbook of Exploration and Environmental Geochemistry 9. Elsevier
Kozuskanich, J.C. et al., 2009. Geochemistry: Exploration, Environment, Analysis 9, 151-157

B8.6
Geochemical exploration models for porphyry deposits in British Columbia, Canada

Fred Blaine, Craig Hart
Mineral Deposit Research Unit, University of British Columbia, Vancouver, BC, Canada

Exploration geochemistry using surficial media is an integral tool in the exploration for ore deposits worldwide; however, it is commonly not used to its fullest potential. Modern, multi-element analytical techniques and large-scale sampling programs generate increasingly large datasets which can be daunting for the geologist/geochemist responsible for their interpretation. In addition, the geochemical expression of an ore-deposit in the surface environment can be influenced by a number of factors, including the nature of the deposit itself, as well as the physical and geochemical environment in which the signatures develop. Geochemical exploration models, developed based on the geochemical expressions of known deposits in various sampling media, can provide the necessary framework for the effective interpretation of data, as well as aid in the design of site- and target-specific sampling programs.

Following the pioneering work of Bradshaw (1975), a significant amount of work has been conducted to advance these conceptual models using case histories for different ore deposit types and varied regolith environments in Australia (Butt et al., 2005 and references therein). However, research into empirically derived models directly applicable to the conditions found in North America, specifically the Canadian Cordillera, has been minimal. As a first approach to this problem, this study focuses on the development of climate and regolith-environment specific models for porphyry deposits in British Columbia. The large amount of data required for this study was obtained through industry and government sources; including the British Columbia Geological Survey's (BCGS) assessment report information system (ARIS), which provides public access to historical data collected by the mineral exploration industry.

Over 40 porphyry deposits/prospects have been selected and historical geochemical survey data for these deposits has been collected, validated and compiled to develop a comprehensive geochemical database for the area. Porphyries have been classified based on significant controls on surficial geochemical expression (cover type/transport, climate, topography and porphyry-type) and geochemical behaviour and distribution in various sampling media has been compared to develop representative geochemical exploration models based on these criteria.

References:
Bradshaw, P.M.D., 1975. Journal of Geochemical Exploration 4, pp. 1-213
Butt, C.R.M.; Robertson, I.D.M.; Scott, K.M.; Cornelius, M., 2005. CRC-LEME and CSIRO Exploration and Mining, http://www.crcleme.org.au/Pubs/Monographs/RegExpOre.html

B9.1

Geochemical assessment of arsenic toxicity in mine waste along the proposed Mineral Tramway Project, Redruth, Cornwall

Robert Bowell[1], Ben Rees[2]
[1]SRK Consulting, Cardiff, Wales, UK, [2]Geotechnology, Neath, Wales, UK

Many abandoned mine sites in Cornwall show elevated concentrations of arsenic which can cause contamination of surrounding soil and water resources. Often these sites have important historical and cultural value that requires access to be maintained, despite the potential toxicity of arsenic. In northern Cornwall a proposed World Heritage site focused on mines in the Gwennap, Camborne and Redruth area is just such an area. Several mine sites along a proposed tourist route were assessed and the proximity of footpaths to areas of potential contamination considered. The route of the mineral tramway was found to include areas of surface sediment that contains elevated and bioavailable metals. The arsenic concentration in soils along the proposed footpaths and exposed mine waste varies from 47ppm through to 33,280ppm. Most values fell in the range of 2400 to 6000ppm.

Using a Physiologically Based Extraction Test (PBET) the maximum amount of arsenic observed to be bioavailable, as determined by the test, varied from 4 ppm through to a maximum of 9000 ppm with a correlation between total and bioavailable concentrations in the lowest and highest total arsenic concentration. However when viewed as a portion of the total the correlation was not so apparent, particularly for samples in the modal range. The bioavailable portion varied from 5 to 49 percent of the total varying significantly from site to site.

Mineralogical and further selective extraction evaluation identified that the PBET released arsenic is not so much associated with total concentration but is correlated to arsenic held within the weak "ionic-held" arsenic; strongly adsorbed arsenic; arsenic associated with amorphous iron and calcium oxide phases and poorly crystallized arsenate salts.

Utilizing this information it was possible to develop a risk based assessment of mine waste in the proposed Industrial World Heritage Site. Based on the risk assessment and metal geochemistry of the waste, limited remedial works have been designed along with educational signage describing the hazards and risks posed at each of the site. The measures recommended are pragmatic and limited to avoid sterilisation of the mining heritage and the interest of other stakeholders.Controlling all of the potential risks posed by an abandoned mine site is unrealistic, as this would require sterilisation of much of the mining land and would reduce the historical, aesthetic, archaeological and cultural value of the site. The measures recommended provide a practical system for site management to minimise the risks posed to users of the Tramway and are based on the appropriate application of geochemical testwork in the assessment of human health risks.

B9.2

Bonemeal filters for treatment of acidic and neutral metal-laden mine waters

Lotta Sartz[1], Erik Larsson[1], Mattias Bäckström[2]
[1]Bergskraft Bergslagen, Kopparberg, Sweden,
[2]Man-Technology-Environment Research Centre,
Örebro University, Örebro, Sweden

Metal pollution from historic mines is the single most important source of metal pollution in Sweden and there is a need for simple, cost-effective mine water treatment technologies. Since 2005, a research program for historic mine sites remediation is in operation in Kopparberg, Sweden. Kopparberg is located in a mining region called Bergslagen with many abandoned mines, three operating and three to five planned mines.

Experiments from laboratory to field-like conditions are evaluated on a test field for applied research at the historic mine site Ljusnarsbergsfältet, Kopparberg. Alkaline residues and by-products are frequently used in the experiments and the present study reports on a passive filter design with bonemeal. Bonemeal has earlier been used to sorb lead, copper and zinc in solution (Nwachukwu & Pulford) and reduce metal availability in acidic (pH<7) soils by formation of metal phosphates (Hodson et al., 2000). Rieuwerts et al. (2009) also suggested formation of metal phosphates as the dominating mechanism behind lead and zinc removal from solution.

Large compositional variations of mine waters can be found at different mine sites, e.g. pH, iron/aluminum content or particulate/dissolved contaminates. Since October 2010, bonemeal filters have been tested for two different mine waters: (1) acidic (pH 3.5-4) mine water with high concentrations of iron and aluminum (5 and 15 mg/l respectively) and (2) neutral (pH 7) mine water with lower concentrations of iron and aluminum (3 and 2 mg/l respectively). Concentrations of lead and zinc were 0.5 and 15 mg/l and 0.5 and 0.7 mg/l for the acidic and neutral mine waters respectively. In the neutral mine water, lead and zinc were mainly (80 %) in particulate form, while these elements were dissolved in the acidic mine water.

Total size of the filters was 1 m^3 and an up-flow filter design was used to achieve good contact between the water and the filter material. Lead and zinc concentrations were reduced with 100 % and 86 % respectively for the acid system, but only with 50 % (lead) and 33 % (zinc) for the neutral system. The less efficient removal of zinc compared to lead in the acid system was probably due to pH, which was too low (6-6.5) to quantitatively immobilize zinc by sorption. The experiments are continuing, and variations in water flow will be made for the neutral system. However, a preliminary conclusion is that bonemeal filters are better suited for treatment of acid mine waters with dissolved contaminants than mine waters with particulate contaminants.

References:
Hodson et al., 2000. Environmental Science & Technology 34, 3501-3507.
Nwachukwu, O.I. & Pulford, I.D., 2008. Soil Use and Management 24:2, 199-207.
Rieuwerts et al., 2009. Environmental Monitoring and Assessment 148, 149-158.

B9.3

Evidence for long-term pollution from mine sites in lake sediment records in the Haveri and Ylöjärvi mine sites, SW Finland

Annika Parviainen[1], Tommi Kauppila[2], Kirsti Loukola-Ruskeeniemi[3]

[1]Bergskraft Bergslagen, Kopparberg, Sweden, [1]Aalto University School of Engineering, Espoo, Finland, [2]Geological Survey of Finland, Kuopio, Finland, [3]Geological Survey of Finland, Espoo, Finland

Sulfide oxidation in mine tailings and waste rock piles causes drainage waters charged with Fe, trace elements and SO_4 affecting the water quality of ad- jacent surface water bodies. As a consequence, trace elements are accumulated in the lake bottom sediments providing a long-term record of the contamination events related to local mining history. Using the ^{137}Cs analysis, the lake sediment samples can be dated and divided into sediments deposited before, during and after mining operations. Hence, the mining impact can be compared to the background values of pre-mining sediments, located deeper in the lake sediment profile.

The Haveri Au-Cu mine and Ylöjärvi Cu-W-As mine, in SW Finland, were active through 1940's to 1960's producing 1.5 and 4 Mt of tailings, respectively. The tailings impoundments have been exposed to air and rainwater for decades producing acid mine drainage (AMD), and the surface water contamination is well established in both sites (Carlson et al., 2002; Parviainen, 2009).

In both sites, the lake sediment records highlighted that the elemental concentrations started to increase drastically in the sediments accumulated during active mining period and shortly after that. In Haveri, the after mining peaks were more important for both mineral matter-related (Al, Ca, K, Mg, V, Ti) and sulfide-related (S, Ag, As, Cd, Co, Cu, Mo, Ni, Pb, Zn) elements (Kihlman & Kauppila, 2010), whereas in Ylöjärvi the highest peaks occurred during mid-mining period. In both sites, Co, Ni, V and S, as well as, Zn in Ylöjärvi persisted with concentrations well above background values years after mine closure. Other metals generally decreased gradually and established to a level slightly above pre-mining concentrations.

This implies that the drainage water from the active mine was a major source of contaminants in Ylöjärvi, whereas AMD generation after the cessation of tailings deposition caused the main metal transport into the lake in Haveri. The present AMD, even though exhibiting considerable concentrations of trace elements (Carlson et al., 2002; Parviainen, 2009), does not have a great impact on the lake sediment quality in comparison to previous events. The elemental release and transport from a mine site, and consequently the deposition into lake sediment records, depends on factors like mineralogy of the ore deposit, implemented extraction and enrichment techniques, waste management and prevailing pH-

Eh conditions within the tailings facility.

References:
Carlson et al., 2002. Geological Survey of Finland, Report S/41/0000/3/2002. 54 p. (in Finnish)
Kihlman, S. & Kauppila, T., 2010. Mine Water and Environment 29, 116-134
Parviainen, A., 2009. Mine Water and Environment, 28: 4, 291-304.

B10.1

Sewage Sludge as a Sealing Layer for the Remediation of Sulphide-bearing Mine Tailings - Ageing and Degradation of the Barrier Material

Peter Nason, Lena Alakangas, Björn Öhlander
Luleå University of Technology, Luleå, Norrbotten, Sweden

Using sewage sludge as an organic barrier to mitigate oxygen diffusion to underlying sulphidic tailings was performed in experimental pilot-scale test cells, northern Sweden and was proved to be successful over an 8 year period (Nason et al., 2010). However, degradation and ageing of the sewage sludge may limit its function in the long-term as indicated by surface applications of sewage sludge, as the exposure of the material to atmospheric oxygen may cause aerobic degradation of the organic matter fraction (Peppas et al., 2000), nitrification (Cravotta, 1998) and subsequent structural disintegration (Ahlberg, 2006).

A pilot-scale test cell with a 0.3m sewage sludge sealing layer capped by a 1.2m protective layer of glacial till was used to cover tailings. Quantification of the changing properties of the sewage sludge after an 8 year period occurred using temperature data and solid sludge and leachate geochemistry. It was found that all layers were frozen between December to April and that a perched water table formed above the sealing layer from April to August (Shcherbakova, 2006). The subsequent lack of contact of the sludge with oxygen minimised aerobic degradation of the organic fraction, prevented nitrification and created an anoxic environment in the sludge. Nitrate in the leachate was <1mg/l and the subsequent lack of acidification created a neutral pH in the sludge and underlying tailings. Elevated alkalinity (360-600 mg/l) and low sulphate (9-67 mg/l) in the leachate indicated that sulphate reduction by anaerobic degradation of the organic matter had occurred in the sludge. On average, the organic fraction was reduced by 80%, but was most prevalent at the sludge to tailings interface where 92 % of the organic matter had been lost since deposition. Mass balance calculations of the sludge revealed a 19.6 % total loss of volume due to the organic matter degradation and leaching of Cd, Cu, Hg, Zn and P that were elevated in the original sludge material. No structural degradation as experienced by surface applications such as shrinkage or cracking occurred as the barrier was not exposed to oxygen.

The integrity and function of the sub-surface sewage sludge layer was less compromised compared to a surface layer as degradation was dominated by anaerobic processes. However, organic degradation rates were high and it is recommended that this type of application is effective only as a medium-term solution for mitigating oxygen diffusion to underlying sulphidic tailings and for preventing acid rock drainage.

References:
Ahlberg, G., 2006. Göteborg University. Doctoral Thesis: 20.
Cravotta, C. A., 1998. Ground Water 36(1): 9-19.
Nason et al., 2010. IMWA 2010: Nova Scotia, Canada, Cape Breton University Press.
Peppas et al., 2000. Minerals Engineering 13(5): 563-574.
Shcherbakova, E., 2006. Luleå University of Technology. Doctoral Thesis.

B10.2

Geochemical processes in an historical alum shale dump, Kvarntorp, Sweden

Mattias Bäckström, Sara Häller, Bert Allard
Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden

During WW2 oil was produced in Sweden through pyrolysis of alum shale. During the years 1942-1966 waste products were deposited in open pits and in a large waste dump. It is estimated that this waste dump consists of finer fraction (3 Mt), coke (2 Mt) and ash (23 Mt) with a total volume of 40 million m3. Combination of hot ash, pyrite (12 %) and organic matter (18 % kerogene) has led to significantly elevated temperatures (>700 °C) in the waste dump and the processes are still active 45 years later. Oxidation of pyrite can increase the temperature to 70-100 °C, followed by ignition of kerogene giving rise to temperatures close to 1 000 °C (Bharati et al., 1995; Puura, 1998).

Several methods, both geotechnical and chemical, were used in order to study the evolution of leachates from the waste dump. Sampling of solid samples was performed as well as installation of shallow ground water wells.

Due to the heterogeneity of the dump low pH (3.2) waters are found in areas with non processed shale (weathered pyrite) while high pH (12.2) waters are found in areas with CaO (burnt calcite). Elevated levels of for instance molybdenum (935 µg/l), nickel (1 190 µg/l), uranium (1 760 µg/l) and zinc (2 170 µg/l) are found in the shallow ground waters.

Today the waste dump has an elevated temperature and minimal runoff is formed compared to the evaporation. No significant runoff will be formed until the waste deposit reaches lower temperatures (below 70°C on average). It has been estimated that the volume of runoff will increase from 0.5 L/s to 5 L/s when the deposit is cool. Chemistry will also change when the temperature has decreased (higher rates of oxidation of pyrite and kerogene (Puura 1998)) with somewhat lower pH and increased leaching of trace elements. Available amounts for leaching to the environment are estimated from leaching studies to be 310 ton Ni, 820 ton U, 2 000 ton V and 780 ton Mo.

Today the environmental impact from the waste deposit is relatively small and local. However, in 100-150 years the waste dump will cool off and start to leach significantly higher loads of trace elements to the surroundings. Further studies on both the cooling and the chemical leaching are needed in order to be able to handle the increased trace element loadings in the future.

References:

Bharati, S., Patience, R.L., Larter, S.R., Standen, G. and Poplett, I.J., 1995. Org. Geochem. 23(11/12): 1043-1058.
Puura, E., 1998. Weathering of mining waste rock containing alum shale and limestone: A case-study of the Maardu dumps, Estonia. Dissertation, Royal Institute of Technology, Stockholm, Sweden.
Puura, E. and Neretnieks, I., 2000. Environ. Geol. 39(6): 560-566.

B10.3

Geology, geochemistry and hydrogeology of coal mine impacted catchments, West Coast, South Island, New Zealand

James Pope[1], Andy Mackenzie[1], Paul Weber[2]
[1]CRL Energy Ltd, Christchurch, New Zealand,
[2]Solid Energy New Zealand Ltd, Christchurch, New Zealand

The West Coast of the South Island of New Zealand hosts an active thermal and coking coal mining industry. The geology is stratigraphically and structurally complex, the topography is steep, the rainfall is several meters per year and the environmental geochemistry is challenging. Most acid mine drainage (AMD) in this region relates to the Eocene Brunner Coal Measures. This sedimentary unit was deposited in delta or estuarine environments with abundant marine sulphate that chemically reduces to form sulphide minerals after deposition. In general, the Brunner Coal Measures have the potential to produce acid mine drainage upon excavation of the rock and subsequent oxidation.

The oxidation of sulphide minerals within the Brunner Coal Measures produce AMD seeps with chemistry that can be acidic and contain elevated concentrations of trace elements such as Zn and Ni. Acidity after formation of AMD is moderated by a series of minerals that occur in different parts of the downstream catchment and include melanterite, jarosite, alunite, schwertanite, ferrihydrite and gibbsite. These minerals buffer the acidity of the system over different pH ranges. The concentration of trace elements in downstream environments does not reach saturation with respect to trace element rich minerals. Some trace elements concentrations are regulated by adsorption onto, or co-precipitation within, Fe and Al minerals. However, other trace elements are conservative within AMD impacted streams and are only attenuated by dilution.

The hydrogeology of many streams draining mine sites in the West Coast region responds rapidly to rainfall and flow rates can increase and decrease by two orders of magnitude within 24 hours. In some areas the acidity of AMD impacted streams is not diluted by rainfall events, instead as flow rates increase the pH and concentrations of acidic cations (Fe and Al) are maintained. This reflects storage of acid in the system in reactive sulphate minerals or rapid oxidation of sulphide minerals in the AMD formation zone.

Geological, geochemical and hydrogeological information from the Garvey Creek Coalfield in the West Coast region is presented. We demonstrate the difficulties relating management of AMD through selective waste rock handling, the geochemistry of storage and release of acid in the AMD formation zone, conservative trace element concentrations and lack of dilution of acid under different flow conditions. All these factors make the West Coast region a challenging environment in which to manage AMD.

C1.1

A Geochemical Picture of a Metallogenic Province Using the Zinc Deposits of Alaska as an Example

Issai Goldberg[1], Grigory Abramson[1], Lev Natapov[1], Chris Haslam[1]
[1]Interesources Pty Ltd, Sydney, Australia,
[2]Interesources Pty Ltd, Sydney, Australia, [3]Macquarie University, Sydney, Australia, [4]Exploration Strategy, Melbourne, Australia

Metallogenic provinces identified on the basis of polar geochemical zoning differ in size and in geographical setting from metallogenic provinces defined solely on a geodynamic and tectonic setting. This presentation provides an insight as to why the latter are not always readily defined by geochemical data.

Using data on the distribution of Zn contents in stream sediments in Alaska (U.S. Geological Survey Open-File Report 2004-1001), four areas can be identified where a regional scale positive Zn anomaly (enrichment zone) is geographically associated with a regional scale negative anomaly (depletion zone). Such geochemical structures are called polar geochemical systems. The largest are the North and Central geochemical systems, and each is approximately 200,000 km^2 in size. In terms of rank, these super-regional systems are equivalent to metallogenic provinces. Almost all of Alaska's Zn deposits are found within the enrichment zones of these systems. The geochemical systems exhibit a degree of zoning. SEDEX type deposits and skarn deposits tend to occur on the western flank of the systems: polymetallic vein deposits and various styles of VMS deposits tend to occur in the central part and on the eastern flank. Geochemical systems of metallogenic rank are characterized by fractality, from district scale to deposit scale. A preliminary estimate of the extent of apparent redistribution of Zn from the depletion zone to the enrichment zone in one of the Alaskan geochemical systems (mass-balance calculations) was made. The apparent deficiency of Zn in the depletion zone of that system is of the order of hundreds of millions of tons. By way of contrast, Alaska's reported Zn resources are a few tens of millions of tons. Geochemical mapping to define polar geochemical systems of metallogenic province rank, and particularly the enrichment zones (which contain the great majority of the economic deposits), offers a means of rapidly evaluating large areas in many parts of the world using a low sampling density.

References:

Goldberg, I.S, Abramson, G.Y., Haslam, C.O. and Los, V.L., 2007. Depletion and enrichment zones in the Bendigo gold field. A possible source of gold and implications for exploration: Economic Geology, v. 102, p. 281-293.

Grossman, J.N. and Grosz, A.E., 2008.The National Geochemical Survey - Database and Documentation. U.S. Geological Survey Open-File Report 2004-1001, updated 2008. September 30, Version 5, National Geochemical Survey

Nokleberg, W.J., et al., 1997. Summary Circum-North Pacific tectonic and stratigraphic Terrane map. Scale 1: 10,000,000. USGS, Open-File Report, (1), p. 96-727.

C1.2

Inferring Bio-Availability of Nutrients from Overbank Sediment Sampling and MMI Analysis: Preliminary Findings from the National Geochemical Survey of Australia

Alan Mann[1], *Patrice de Caritat*[1], *Pierrette Prince*[1]
[1]Consultant, Perth, Australia, [2]Geoscience Australia, Canberra, Australia, [3]SGS, Toronto, Canada

The National Geochemical Survey of Australia (NGSA) was initiated in late 2006, and details of progress were published, among others, in Caritat et al. (2009). The ultra-low density geochemical survey was facilitated by, and based on, overbank sediment sampling at strategic locations in the landscape. Included in the analysis methods was a partial extraction method by the Mobile Metal Ion (MMI) technique (Mann, 2010) of sediment sampled at 0-10 cm depth, air-dried and sieved to <2 mm.

The MMI method is based on solubilisation of adsorbed ions and potentially can provide a measure of bio-availability.

Of the ten elements considered essential for plant growth (Ca, Cu, Fe, K, Mg, Mn, N, P, S and Zn), only two (N and S) were not included in the 53 elements analysed after MMI extraction of the overbank samples. Comparison of MMI concentrations for elements from a number of soils with the corresponding total analysis for the same soil samples provides an estimate of the recovery % by MMI in a similar manner to that used by Albanese (2008) to evaluate ammonium acetate-EDTA as a measure of bio-availability.

Individual maps for the eight nutrients based on MMI analysis provide some very interesting and potentially useful information. For example, highest "bio-available" Fe concentrations are not related to the Fe-rich soils and rocks of the Pilbara, but to high rainfall areas close to the coast, where processes akin to lateritisation are still taking place. The distribution pattern for Mn appears to follow that of Fe. The bio-availability of elements such as Ca, Mg and K is related to lithology, whilst bio-available P is probably reflective of application of fertilisers in agricultural districts. Distribution of bio-available Cu and possibly Zn appears to be correlated with mining activity in some cases.

A multiplicative index for the eight nutrients has been calculated and mapped as a potential indicator of the most nutrient favourable areas based on this definition of bio-availability. It suggests that some high areas with very high Fe (e.g., areas with laterites) are not as fertile as others due to the binding of nutrients such as P and Cu into iron oxides. Central and southern New South Wales, the Great Southern of Western Australia and parts of Tasmania are highlighted by this index.

References:
Albanese, S., 2008. Geochemistry: Exploration, Environment, Analysis 8, 49.
Caritat, P. de, Cooper, M., & Morris, P., 2009. Proceedings of IAGS, Fredericton, 915.
Mann, A.W., 2010. Geochemistry: Exploration, Environment, Analysis 10, 17-26.

C1.3

China Geochemical Baselines

Xueqiu Wang, Qin Zhang, Qinghua Chi, Shanfa Xu, Lanshi Nie, Bimin Zhang, Jian Zhou
Institute of Geophysical and Geochemical Exploration, Langfang, Hebei, China

The objective of the China Geochemical Baselines Project (CGB), a contribution to the IUGS/IAGC Task Group on Global Geochemical Baselines (Darnley, et al., 1995), is to document China's nationwide geochemical baselines, spatial distribution and evolution of all elements.

Each Global Reference Network grid (GRN) is divided into 4 CGB grids. Approximately 1500 CGB grids cover the whole of China (9.6 million km^2). Two sampling sites are designed to collect homogeneous samples of soils/overbank/floodplain sediments from each CGB grid. At each site, two samples are taken from top horizon (0-25 cm depth) and deep horizon (>100 cm depth). Different typical rock samples for different geologic times are simultaneously collected in each CGB grid to interpret the geogenic sources of secondary geochemical patterns and to explore evolution of elements with geologic times from Archeozoic to Quaternary.

A 1000 g sample is ground to <200 mesh in an agate or pure-aluminium-porcelain mill. A 500 g sample is sent to the lab for analyses. The rest of sample is bottled and archived. Seventy-six elements are determined by ICP-MS/AES following 4-acid digestion and XRF following fusion as backbone methods combined with other 10 methods. Analytical quality is under strict control by using standard reference samples.

Internet-based software named Digital Chemical Earth, similar to Google Earth, is being developed, which can manage the geochemical database and allow people to access vast amounts of geochemical data and maps through the Internet.

A 5-year term, from 2008 to 2012, is planned for covering the whole China's mainland. A one-year pilot study was conducted in 2008 to test and refine the recommended protocols and to optimize field logistics for the geochemical sampling. After completion of the pilot studies, approximately 1 700 soil sites (3 400 samples) and 7 000 rock samples have been collected in eastern China from 2009 to 2010. Sampling is expected to be completed in 2012 with the data and atlas published in 2013.

Preliminary results show that 1) most of trace elements are more concentrated in the top horizon than in the deep horizon of soils, 2) many of toxic elements such as Hg, As, Cd, Pb and halogen elements such as F, Cl, Br and I mainly tend to concentrate in top soil and are influenced by human activities, 3) precious metals such as Au, Ag, PGE and other mineralization-related elements such as W, Sn, Cu, and U are related to metallogenic provinces and geology, 4) major elements such Ca and Al show the influence of both climate and geology.

References:
Darnley et al., 1995. Earth Science 19, UNESCO Publishing

C1.4

The quest for REE: known and new exploration targets in Greenland identified by regional stream sediment data

Agnete Steenfelt
GEUS, Copenhagen, Denmark

Recently increased demand for rare earth elements (REE) has accentuated the search for REE deposits worldwide, including Greenland. Known deposits are being re-evaluated and tested, and new targets are sought.

Geological exploration immediately focuses on known magmatic sources, carbonatites and rare agpaitic rocks, and such occurrences in Greenland are presently under investigation. A search for unknown occurrences can advantageously make use of the stream sediment geochemical database at Geological Survey of Denmark and Greenland (GEUS).

About 70% of the ice-free area of Greenland (~280,000 km^2) have been covered by stream sediment surveys at reconnaissance to regional scale and a large proportion of the samples have been analysed by instrumental neutron activation for seven REE (La, Ce, Nd, Sm, Eu, Tb, Yb, Lu). While Lu and Tb concentrations commonly are at or below analytical detection limit, the remaining elements are determined with reasonable precision. Analytical bias between batches and labs is recorded, but does not invalidate the significance of regional variation in concentration. The data base presently contains REE data for 10,350 samples.

Element correlations for the entire data set show that LREE, La, Ce, Nd, Sm are mutually highly correlated, so are HREE, Yb and Lu, while Eu shows poorer correlation with the other REE, thereby illustrating the diversity in mineral hosts for the suite of REE. Geochemical maps of La, Eu and Yb show 1) the three elements are unevenly distributed with distinct areas of enrichment, and 2) differences in distribution patterns are observed between the three elements. La, Eu and Yb anomalies form clusters indicating target areas.

South Greenland, particularly the Mesoproterozoic Gardar Alkaline Igneous Province, hosts most of the anomalies and those with the highest concentrations. Three types of host rock are known, nepheline syenites, carbonatites, and granites, which can be distinguished in the REE fractionation patterns recorded in the stream sediment samples. Outside the Gardar province, high HREE values are encountered in samples from streams draining Palaeoproterozoic sediments intruded by rapakivi-type granites and REE fractionation for these samples are again different from those of the Gardar. With the experience from South Greenland, the sources of REE anomalies in remaining Greenland may be evaluated.

The stream sediment data further supply information on the abundance of other valuable specialty metals like Nb, Ta, Y associated with some of the REE deposits, as well as on U and Th. Since the latter two may be regarded an asset or a liability, the stream sediment data immediately adds information of relevance to the desirability of further work with an indicated REE target.

C2.1

The National Geochemical Survey of Australia: A New, Quasi-Continental Geochemical Atlas and Dataset to Support Mineral Exploration and Environmental Applications

Patrice de Caritat, Michelle Cooper
Geoscience Australia, Canberra, Australia

The National Geochemical Survey of Australia (NGSA) project was launched in 2007 as part of the Australian Government's Energy Security Initiative. Knowledge of the concentrations and distributions of chemical elements in the near-surface environment, used in combination with other datasets, can contribute to making exploration for energy and mineral resources more cost-effective and less risky. As a spin-off, the multi-element dataset can also have applications in environmental fields.

During precursor pilot projects, various sampling media, grain-size fractions and analytical methods were tested. It emerged that catchment utlet sediments (from either overbank or floodplain landforms, or from similar low-lying settings) were an ideal sampling medium found across Australia. These sediments are well-mixed composites of the dominant rock and soil types of a catchment, and are typically fine-grained. Results from the pilot projects indicated that catchment outlet sediments could oreflect geochemical signatures from basement and mineralisation, even through thick transported overburden.

Building on these methods, the NGSA project targeted catchment outlet sediments as a uniform sampling medium. A shallow (0-10 cm) and a deeper (~60-80 cm) sediment sample was collected at the outlet of 1186 catchments covering ~80 % of the country. Sampling was carried out by State and Northern Territory geoscience agencies following protocols described in the Field Manual and practiced during in-field training with Geoscience Australia project staff. All sampling equipment (augers, shovels, etc.) and consumables (bags, labels, etc.) were provided centrally. Dry and moist Munsell colours, soil pH, digital photographs, site information and GPS coordinates were recorded in the field.

In the laboratory, the samples were dried and a split was archived for future use. Electrical conductivity and pH of 1:5 (soil:water) slurries, and laser particle size distribution were recorded on bulk splits. Another split was further dry-sieved into two grain-size fractions (<2 mm and <75 µm) for chemical analysis after total, aqua regia (including low level Au) and Mobile Metal Ion digestions, as well as by specialised methods for Pt group elements, F and Se, as documented in the Sample Preparation Manual.

Quality control consisted of minimising contamination in the field and laboratory, sampling every 10th catchment in duplicate, and inserting blind laboratory sample splits, project and international standards and certified reference materials (CRMs) in the suite of samples sent to the various laboratories. In addition, each laboratory had its own quality control measures of repeating analyses and inserting CRMs in the analysis stream.

Applications of NGSA data to mineral exploration and nutrient distribution are discussed by Caritat et al. and Mann et al. (this volume). The public release of the data, geochemical maps and reports occurred in June 2011.

C2.2

Element Associations in Southern Labrador Lake Sediments - a Comparison of Two Regions and Two Sample Densities

Stephen Amor, John McConnell, Jerry Ricketts
Geochemistry, Geophysics and Terrain Sciences Section, Geological Survey of Newfoundland and Labrador, St. John's, NL, Canada

A multi-level exercise in R-mode factor analysis shows that only five agencies control about 90% of the variability in lake sediment composition in southeastern and southwestern Labrador. The influence of these agencies is little affected by sample density and the lithology of the lakes' catchment basins also plays a limited role, although the strength of some of the agencies varies with lake size and sampling depth.

The study area in southeastern Labrador is underlain primarily by rocks of the Grenville Province which, in this area, is subdivided into a northern exterior thrust belt, composed predominantly of crust formed during the Labradorian Orogeny, and a southern interior magmatic belt. In the southwestern study area the geology consists mainly of Archean and Paleoproterozoic granitic and gneissic rocks of the Churchill Province. There has been no exploitation of metallic minerals in either area, although documented mineral occurrences are more numerous in the southeast.

The database for each area consists of low-density (one sample per 16 km^2) lake-sediment data collected during the Geological Survey of Canada's National Geochemical Reconnaissance (NGR) program, and high-density (one sample per 4 km2) data collected during subsequent surveys conducted by the Geological Survey of Newfoundland and Labrador.

The metal associations thus identified indicate five principal controls on sediment content:

1. A Na-Ba-Sc (± Cr, Rb, F, Th, K, Al, Mg, Ca, Zr, Sr, Li, V, Nb, Ti, Nb, Hf, Ta) factor that appears to be related to the amount of clastic sediment in the sample material. This factor accounts for between 15 and 28 % of the total data variance and is most strongly manifested in larger lakes. The strength of this factor creates the potential for false anomalies of several economically-important elements
2. An Fe-Mn-Co Zn (± Nb, V) factor, accounting for 24-28 % of total data variance, probably associated with hydroxide co-precipitation with the first two elements and related to stronger oxidizing conditions in sediments in smaller lakes
3. A REE-Th factor, accounting for 21-27 % of total data variance, more strongly manifested in the data from southeastern Labrador
4. A Cu-Ni (± Hg, Zn, Cr) factor accounting for 9-15 % of total data variance, more strongly manifested in the samples from southwestern Labrador, despite only 2 % derived from catchment basins dominated by mafic or ultramafic rocks, compared to 17 % in southeastern Labrador
5. A LOI-Br (± Hg) factor accounting for 10% of total data variance, showing slightly higher preference for shallow lakes

The results indicate that the lower-density surveys are capable of detecting the same regional geochemical patterns as their high-density counterparts, although the latter are more likely to detect the small-scale deviations from broader patterns with which much applied geochemistry is concerned.

C2.3

Regional Biogeochemical Investigations in the Northeast Yilgarn Craton, Western Australia

Nathan Reid[1], *Melvyn Lintern*[1], *Ryan Noble*[1],
Ravinder Anand[1], *David Gray*[1], *Gordon Sutton*[2],
RichardJarrett[2]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]CSIRO Mathematics, Informatics and Statistics, Urrbrae, South Australia, Australia

Regional biogeochemical surveys have proven beneficial in parts of the northern hemisphere. Although the Western Australian climate is very different, ore targets, access problems and the hindrance of a transported overburden are analogous and, thus, vegetation sampling is potentially a valuable addition to other exploration techniques. A 92,000 km^2 area of the Yilgarn Craton was selected with numerous Ni, Au, U and VMS deposits. Acacia aneura (mulga) was sampled (at an approximate density of one plant per 70 km^2) as it is one of the most widespread plant species across Australia.

Mulga samples were collected at water wells corresponding to a regional hydrogeochemistry sampling program (Gray et al., 2009). The samples were dried, split, milled, dissolved in aqua regia and analysed using ICP-MS and ICP-OES.

The research generated a large, robust, statistically verified geochemical data set for a single plant species over a big area. The data set provides the ability to detect lithological signatures over the region, separating Archaean greenstones from granites using geochemical indices and multivariate statistics. Individual elements showed distinct patterns relating to their behaviour in mulga. Uranium in mulga is the only distinct indicator in this region targeting secondary U deposits, and is successful for most known prospects. Detection of Au prospects/deposits across the region was improved by the use of a Au mineral exploration index. Some of the major camps were not seen, possibly due to the thickness of cover being too great at this scale of sampling. Nickel prospects were identified where the samples were close to the prospects (within 1-2 km) or possibly where the cover was thinner. The Leinster and Murrin Murrin areas were highlighted in Ni, Co, Cr and Fe with haloes up to 20 km wide. Detection of VMS style deposits is hampered by Zn and Cu being essential plant nutrients and geochemical patterns bearing little relationship to deposits regionally but more to individual plant health. However, high Zn values seen on the regional scale may be worth further (closer-spaced) investigation. Zinc, Cu, Cd and

Ag highlight individual deposits when closer-spaced sample data were added.

The results from this regional mapping program are encouraging for extending this technique into other less explored areas. There is little correlation between hydrogeochemistry and biogeochemistry which means that one cannot be used as a surrogate for the other; however, both are useful tools in detecting different expressions of mineralisation using different chemical properties. Also, mulga can be sampled without the need to drill.

References:
Gray, D.J., et al., 2009. Geological Survey of Western Australia, Record 2009/21, 78p.

C2.4

Modelling lithology using groundwater, vegetation and laterite chemistry: results from the Yilgarn Craton, Western Australia

David Gray[1], Ryan Noble[1], Gordon Sutton[2], Nathan Reid[1], Melvyn Lintern[1], Terry Rankine[1], Richard Jarrett[2]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]CSIRO Mathematic, Informatics and Statistics, Urrbrae, South Australia, Australia

Regional scale geochemical sampling can open up new areas for exploration, particularly in areas of transported cover. Earlier project work by Cornelius et al. (2007), Gray et al. (2009) and Reid et al. (2010) generated large regional geochemical data sets for parts of the Yilgarn Craton using laterite, groundwater and mulga vegetation sample media, respectively. Initial testing of groundwater data (Gray et al., 2009) revealed the major lithology types of greenstone and granite. Uranium concentrations highlighted granites, whereas V and Cr were indicative of underlying greenstones. However, whether this observation could be modelled, statistically tested and applied to other data sets was unknown.

The data sets (each > 1000 samples) were classified as granite or greenstone based on maps from the Geological Survey of Western Australia (GSWA) as a broad classification of rock types. Using R statistical code, binomial general linear models were generated using all variables and also in a forward-backward "restricted" variable selection, selecting the variable that provided greater discrimination. Cross validation tests resulted in a predictive error of approximately 20 %. Unexpectedly, the MrVBF (mulit-resolution Valley Bottom Flatness) index values (Gallant et al., 2003) used as a surrogate for transported cover depth did not influence the predictive capability of the models, which worked well in most areas. Similar models applied to the laterite data have an error rate close to 10%. Other modelling methods were trialled including logistic regression, linear discriminant analysis and classification trees.

There is little correlation between the groundwater and vegetation chemistry from samples collected in close proximity (<1000 m) indicating in regional geochemistry one sample medium cannot be used as a surrogate for the other; however, both are useful tools in detecting different styles of mineralisation and lithology using different chemical properties. We will show the results of the models, the key variables used (some expected, some unusual), explain how the errors compared and what value can be gained from this analysis in the form of generating new targets. A number of these targets are under transported cover in palaeochannels. The application of this study into basins in Australia and similar terrains elsewhere should give mining companies more confidence in their abilities to generate regional targets in greenfields exploration of covered terrain.

References:
Cornelius et al., 2007. Geological Survey of Western Australia, Record 2007/9, 44p.
Gallant & Dowling, 2003. Water Resources Research, 39, 1347.
Gray et al., 2009 Geological Survey of Western Australia, Record 2009/21, 78p.
Reid et al., 2010. Geological Survey of Western Australia Record 2010/4 156 p.

C3.1

Distribution and mobility of Niobium in European soils

Andreas Scheib, Dee Flight
British Geological Survey, Keyworth, Nottingham, UK

The EuroGeoSurvey's Geochemical Mapping of Agricultural and Grazing Land Soil (GEMAS) project and its 32 participating organisations mapped European soils at a density of 1 site per 2,500 km^2 providing geochemical data for over 50 elements (EGS, 2008). At each site, two types of soils were collected, one "Ap" sample from the ploughing layer of arable fields at 0-20 cm and one "Gr" sample from permanent grazing land at 0-10 cm below surface. Analyses of the < 2 mm fraction of 2024 Gr and 2108 Ap samples were carried out by a) inductively coupled plasma atomic emission spectrometer (ICP-AES) and inductively coupled plasma emission mass spectrometer (ICP-MS) following aqua regia extraction as well as b) X-ray fluorescence spectrometry (XRFS) on Gr samples only. Whilst the latter method gives the total concentration, aqua regia gives only the chemically extractable fraction.

The refractory element Niobium (Nb) is of growing interest because of its application and use as an alloying element in high-grade structural steel, as well as in electronic components. However, there is very little published information on Nb concentration levels in the environment and its potential health effects. GEMAS data for Nb is presented with the aim to establish and enhancing understanding of the baseline distribution and typical mobility within European soils.

The median baseline concentration of Nb in Gr soils of Europe is 12 mg/kg (XRFS), which is more than a magnitude greater than the median of 0.52 mg/kg following aqua regia extraction and ICP analyses. This shows that a large proportion (>95%) of Nb in soils is highly immobile. Comparing the chemically mobile concentration, determined by ICP following aqua regia extraction in Gr and Ap (collected from the same sampling cells), shows that the median concentration in Gr soils is 0.07 mg/kg (13%) higher than in Ap soils. This relative depletion of aqua regia-soluble Nb in Ap soils may be a result of physical agricultural practises, such as tillage.

Across Europe, elevated concentrations of chemically mobile Nb are closely related to the occurrence of Caledonian granitic and plutonic rocks in Scandinavia and northern Britain, Hercynian granites across the European continent (e.g. Massif Central and Bohemian Massif) as well as carbonate rocks of southern Italy. The larger resistant and immobile portion of Nb in soils however, is more spatially dispersed and not only confined to areas of plutonic outcrop. Elevated concentrations (>15 mg/kg) also occur across areas of known aeolian sediments, such as loess of central Europe, and residual soils related to karstified carbonate rocks across Croatia and Slovenia.

References:
EGS, 2008. EuroGeoSurveys geochemical mapping of agricultural and grazing land in Europe (GEMAS) - Field manual. NGU report 2008.038, Trondheim, Norway, 46p.

C3.2

How Much Influence do Humans Exert on Regional Geochemical Patterns? - The Cyprus Case

David Cohen[1], Neil Rutherford[1], Eleni Morisseau[2], Andreas Zissimos[2]
[1]University of New South Wales, Sydney, NSW, Australia, [2]Geological Survey Department, Strovolos, Cyprus

Large-scale geochemical mapping programs have been implemented in many parts of the world for environmental, exploration and other resource-related purposes (Garrett et al., 2008). One objective is to differentiate natural from anthropogenic sources (Reimann & Caritat, 2005) from which some authorities derive general "background" values for the purposes of environmental regulation.

Cyprus hosts the Troodos Ophiolite Complex and associated Cyprus-style Cu mineralisation flanked by carbonate-rich marine units. Cyprus has a long history of human settlement with Cu mining since Phoenician times. There are a number of large abandonned mine pits. The regolith displays significant recent disturbance in many regions, especially terracing for agriculture and landscaping for development.

The Republic of Cyprus has been geochemically mapped using soils collected from two depths (0-25 and 50-75 cm), in a grid-cell sampling array, and subsequent analysis by aqua regia/ICP-MS, INAA and other methods (Cohen et al. 2011). Sampling was conducted at 1 site per ~1 km^2.

Major and trace element geochemical patterns in soils across Cyprus are dominated by parent lithology and subsequent natural processes. Various combinations of elements permit mapping of subtle differences between rock types and regolith-landform variations at the km-scale. Linear geochemical anomalies defined by various rare elements such as Hg and Re appear to reflect deep geological structures that transect the island. Along the coast, there is physical reworking and concentrating of heavy minerals shedding from Troodos.

In urban and industrial areas there are elevated levels at a number of sites for a small number of elements, including Pb, Sn, As and Cu, although this is more pronounced in the top soil than the sub soil. Mining activities have contributed to increased concentrations in soil of elements, but this is restricted to <2 km around mine sites. Higher contents of mobile elements (Na, Br and B) reflect seawater influences or hydromorphic dispersion of elements from the mountains, with limited effects related to fertiliser use or irrigation.

Patterns related to major geological terrains are retained at low sampling densities, but most anthropogenic influences occur at scales not reflected at lower sampling densities. For most elements, there is no single "background" level that can be set to differentiate natural element concentrations from potential contamination (supporting Reimann & Garrett, 2005), though the main individual lithologies in Cyprus display relatively restricted ranges for a number of elements in the associated soils.

References:
Cohen, D.R. et al., 2011. Geochemical Atlas of Cy-

prus. UNSW Press, Sydney.
Garrett, R.G. et al., 2008. Geochemistry: Exploration, Environment, Analysis, 8, 205-217.
Reimann, C. & Caritat, P de., 2005. Science of the Total Environment, 337, 91-107.
Reimann, C. & Garrett, R.G., 2005. Science of the Total Environment, 350, 12-27.
Smith, D.B. & Reimann, C., 2008. Geochemistry: Exploration, Environment, Analysis, 8, 219-227.

C4.1

Palaeo-redox Fronts Exposed within a Key Section at Four Mile West, South Australia

Stephen Hore[1], Steven Hill[2]
[1]Geological Survey of South Australia (PIRSA), Adelaide, Australia, [2]Centre for Tectonics, Resources and Exploration (TRaX), School of Earth & Environmental Sciences, University of Adelaide, Adelaide, Australia

The Four Mile sedimentary uranium resource is a significant recent discovery; the total inferred mineral resource inventory is 71 million lbs U_3O_8 at an average grade of 0.33 % U_3O_8. The deposits, Four Mile East and Four Mile West, were located by pattern drilling and intersected at about 100m below the colluvial-alluvial plain surface east of the Northern Flinders Ranges of South Australia. They are located within the Mount Painter region which is well known for its exposed uranium-rich breccias, uraniferous granites and gneisses in the ranges, and roll-front uranium deposits in adjacent plains.

Shortly after reports of the resource discovery, the authors' field-based projects recognised and interpreted a key sedimentary section exposed within a drainage depression above and immediately adjacent to mineralisation at Four Mile West, and now referred to as the 'Dead Tree Section'. This section includes an expression of many of the major sedimentary units associated with uranium mineralisation, as well as kaolinitic alteration, related geochemistry and important post-depositional alteration and subsequent weathering features.

In summary, up-faulted against Mesoproterozoic crystalline basement, the exposed 'Dead Tree Section' consists of diamictic Mesozoic sediments overlain by sands and silts of the Eocene Eyre Formation, with an uppermost 2 m thick pedogenic silcrete. This is overlain by approximately 8 m of coarse sands of the Miocene Namba Formation and then by variable thicknesses of mixed alluvial, colluvial and aeolian sediments associated with the recent and contemporary landscape and drainage systems.

The tilting and faulting of the section helps to conveniently expose the sequence and further constrains the controls on the regional geological and landscape history and the context for sediment-hosted uranium mineralisation.

Within the Eyre Formation there is a 10 m thick zone of red-yellow-white weathered sediments, the red and yellow colouration is due to iron oxides, mostly goethite and haematite, whereas the white areas are quartz and kaolin dominated. Coarse quartzose sand beds include parabolic red colouration within the otherwise white sand and the sharp discordant boundary within this lithology implies a sense of a redox interface. In detail, contained within the generally iron-enriched sands, are numerous randomly spaced dense curvilinear haematite segregations, typical of the morphology of 'classical' roll-fronts.

Whole rock geochemistry results of the haematite segregations indicate relatively high concentrations of U and Th as well as anomalous V, Cr, As and Mo concentrations relative to the sedimentary units elsewhere in the section. This suggests that although this section is now completely oxidised such interfaces may still contain vestiges of their previous geochemical characteristics.

These variably coloured weathered zones are interpreted to represent palaeo-redox interfaces within the sedimentary sequence that have now been oxidised, and the curvilinear haematite segregations described here approximate a palaeo-roll-front, redox interface.

C4.2

Application of Fractal Concentration-Area Model Based on Enrichment Factor to Delineate Geochemical Anomalies in Stream Sediment Surveys (Case study: Jebal-e-Barez 100,000 Sheet, Iran)

Ali Rafiee
Zanjan University, Zanjan, Iran

The geochemical study, in the stream sediment media, is one of the preliminary exploration techniques that are used very frequently and prosperously both in the mineral exploration and environmental research. The first and also extremely important feature of stream sediment media that directly affects the obtained results is its vector nature which is often ignored. In the stream sediment media, each sample is representative of all materials that can be found in its upland catchment area. Therefore the identified anomalies in this media can be generated by the material resulting from the weathering of the bedrocks without mineralization but enriched by some syngenetic elements, environmental contaminations and probably mineralization.

The enrichment index can be applied to eliminate the effects of syngenetic elements caused by upland bedrocks; however this technique has particular complexities for the stream sediment media. The current study presents a method to calculate the enrichment index for each sample and for each analysed element by taking into account the bedrocks found in the upland drainage basin.

A new approach is also applied by using the concentration-area (C-A) fractal technique for stream sediment sampling media (Cheng et al., 1994; Cheng, 1999). An enrichment factor of each analysed element is defined as a new variable and the C-A method is applied for this variable instead of the element concentration. By defining the enrichment factor, the bedrock geology of each drainage basin is considered in order to reduce the background effect. It should be mentioned that the directional and vector nature of the stream sediment data is also considered for calculating the enrichment factor. A new technique is applied to attribute the values of each sample to its drainage basin by taking into account geometric equations for converting the geochemical data into the pixel data.

Finally, the fractal concept is used over the converted data to distinguish the different populations and to calculate the threshold values for both the raw data and the enrichment index. All of the above mentioned processes are applied on the regional geochemical data of the Jebal-e-Barez located in the southeast part of Iran (Rafiee, 2005).

References:
Cheng et al., 1994. Journal of Geochemical Exploration 51 (2), 109-130.
Cheng, Q., 1999. Computers & Geosciences, V.25 N.9, 949-961.
Rafiee, A., 2005. 20th World mining congress proceeding, Iran, 461-472.

C4.3

Characterizing the Hydrocarbon Microseepage-induced Alteration Using Mineralogical, Geochemical and Spectrometric Methods: A Case Study in East Sichuan (China)

Yunpeng Wang, Hua Su, Xuan Ding
Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China

For better understanding the hydrocarbon micro seepage-induced alteration to the ground surface soil, we studied the mineralogical and geochemical compositions of surface soil samples in two selected sections along gas-bearing structures in East Sichuan area, China. The adsorbed hydrocarbons were analyzed using gas chromatography (GC), fluorescence and ultraviolet (UV) spectrometer. For probing the mechanism of remote sensing, the soil spectra are measured in the range of visible to near infrared (VI-NIR) bands. We found anomalies of soil mineral including clay minerals such as kaolinite, illite and chlorite, and chemical composition of surface soil such as increase of ferrous iron and decrease of ferric iron, as well as carbonate mineral are coincide in space with the anomalies of adsorbed hydrocarbons. These anomalies are found in the fault area at the edge of gas traps. These evidences suggest a close connection between microseepaged hydrocarbons and these anomalies of soil mineral, chemical as well as organic geochemical components. We also found the decrease of spectral reflectance in 400-600nm and 2200-2350 nm for the anomaly soils, which also reflect the increase of ferrous-iron content and the decrease of ferric-iron content, as well as increase of clay- and carbonate-mineral contents, respectively. Remote sensing data including Landsat TM (Thematic Mapper) data and NASA's ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data were used to extract the hydrocarbon microseepage-induced alteration from surface soils over gas traps. Several techniques including band ratio, spectral angle mapper classification, principal component analysis, were used to identify and map the alterations. The image anomalies of remote sensing are also distributed in consistent with the section anomalies of mineral, geochemical and spectral components. The results of our study show a possibility for oil gas prospecting by integrating mineral, geochemical and remote sensing methods, which has been reported in other areas (Carrere & Harold, 1991; Khan & Jacobson, 2008; Petrovic, 2008).

References:
Carrere, V. & LANG, Harold, R. 1991. AAPG International Conference, London, England, 2009.
Khan, S.D. & Jacobson, S., 2008. Geological Society of America Bulletin 120, 96-105
Petrovic, A., 2008. Joint Meeting of The Geological Society of America etc. paper 196-6.

Acknowledgments: China Giant S&T Programs (2008ZX05008-002) and NSFC project (40872091) are acknowledged for the finanical support.

C4.4

Geochemical exploration for rare earths and gold in the Tana Belt, southern side of the Lapland Granulite Belt, Finland

Olli Sarapää, Pertti Sarala
Geological Survey of Finland, Rovaniemi, Finland

Geological Survey of Finland (GTK) has started a project for mapping areas potential for 'high-tech' metals in Finland metals. The Tana belt, immediately to the south of the Lapland Granulite Belt, northern Finland, was selected as one of the main targets as the area includes prominent REE anomalies in regional till geochemical and lithogeochemical data (Salminen, 1995; Rasilainen et al., 2008). These data indicate high La and Y concentrations in both till and bedrock in arkose gneiss areas in an area 200 km wide. Especially interesting is that high Y values in till and rock samples indicate enrichment of the heavy REE in the bedrock. Simultaneously with the REE exploration, also all indications of gold will be tested: The region includes a number of known, small Au occurrences in bedrock and extensive areas nugget gold in the regolith.

The strongly deformed Tana belt comprises amphibolite, garnet-biotite and arkose gneisses, and was thrusted together with the Lapland Granulite Belt onto the Central Lapland Greenstone Belt during 1.9-1.8 Ga. The present main Au- and REE targets locate in Mäkärä and Vaulo, 15 and 25 km northwest from the Vuotso village. The area is located in the latest ice divide zone of the last (late Weichselian) glaciation. Subglacial erosion has been weak and the till transport distance short. Bedrock is covered by 5-30 m thick kaolinitic saprolite and the overlying till, usually clay-rich, has a thickness of 0.5-15 m.

At Mäkärä, a recent exploration trench revealed a 13 m wide haematite-goethite-kaolinite gossan which contains 3 ppm gold. Earlier studies in the area suggest that the hydrothermal quartz-haematite-pyrite veins at Mäkärä are generally narrow (1 mm - 2 m) and are in connection with tensional fractures (Eilu & Pankka 2009). The REE content in saprolite at Mäkärä is 0.005 % (max 0.1 %) and at Vaulo up to 0.4%, which is nearly at the same level as in the ionic adsorption clays in China. Typical REE-rich minerals are monazite, rhabdophane, xenotime and probably kaolinite. In grid sampling data, with the sampling interval of 200 m, Au content in till has a strong positive correlation with the positive electromagnetic anomalies, caused by the weathered sulphidic bedrock. On the other hand, the highest La and Y contents correlate well with the Th maxims of the radiation datasets.

References:
Eilu, P. & Pankka, H., 2009. FINGOLD - a public database on gold deposits in Finland. Version 1.1 [Electronic resource]. Espoo: Geological Survey of Finland. Optical disc (CD-ROM)
Rasilainen, K., Lahtinen, R. & Bornhorst, T.J., 2008. Geological Survey of Finland, Report of Investigation 171. 94 p.
Salminen, R. (ed.), 1995. Geological Survey of Finland, Report of Investigation 130, 47 p. + 24 app. maps.

C5.1

Surface Geochemical Exploration at the Rompas Au-U Discovery, Ylitornio, Finland

Lars Dahlenborg, Erkki Vanhanen, Terry Lees, Michael Hudson
Mawson Resources Ltd, Vancouver, Canada

Rompas is a new discovery which located in the Early Proterozoic Peräpohja schist belt in Northern Finland. Bonanza grade gold and uranium mineralization has been discovered at surface over an area exceeding 6km strike and 200 m width. Traditionally, this part of Finland has not been regarded as prospective terrain and the Peräpohja belt has been subject to little systematic exploration.

Rompas is an Au-U metasomatic vein deposit hosted in metasedimentary and igneous host rocks. Native gold and uraninite are generally identified in en echelon structures, including shears, jogs, boudins, veins and vein intersections. The first full exploration season at Rompas in 2010 identified 171 grab samples which averaged 1,127.9 g/t Au and 3.6 % U and ranged from 0.1 g/t to 22,723 g/t Au and 0 to 47.9 % U and 80 channel samples which averaged 0.59 metres @ 203.66 g/t Au and 0.73 % U within a sampling footprint of 6.0 kilometres strike and 200-250 metres width.

The poorly exposed bedrock of the area is composed of quartzites, dolomites, mafic lavas, dykes and sills, amphibolites and mica schists along with black schists. Quartzites, mafic lavas and dolomites belonging to the Kivalo group and mica schists to the Paakkola group. Black schists are concentrated to zones between these two groups. The project area can be divided into several geomorphological domains which include thin till cover, outcrop, ground moraine, hills and large bog areas, ribbed moraine ridges mainly of the Rogen type, hummocky ribbed moraine and large eskers.

Three different scale surface geochemical surveys have been performed within the area of interest, which has 90-95 % cover:

1. A regional C horizon till geochemical survey collected over 500km^2 within the central northern part of the Peräpohja schist belt;
2. A semi-regional C horizon till survey that concentrated over the main mineralized trend within an area of 150km^2;
3. A detailed local scale survey over the immediate strike extent of the mineralized zone. This survey consisted of three different sample media: C-horizon till; in-situ weathered bedrock samples and organic samples.

Results of the surveys show that there are discrete, coherent anomalies in all surveys with sample media performing differently according to the geomorphological domain. The better geochemical pathfinder associations at Rompas are Au with Te, and U with Se and REE.

Although Rompas is at the very early stages of discovery, surface geochemical data corresponds well with known mineralization and has been proven as an effective exploration method to identify targets for further geochemical in-fill sampling and drilling.

C5.2

Geochemistry, Petrology and Fluid Characteristics of Rapakivi-hosted Polymetallic Quartz Veins in the Sarvlaxviken area, southeastern Finland

Mira Valkama[1], Curt Broman2, Krister Sundblad[1], Nigel J. Cook[3], Rune Nygård[4]
[1]Department of Geography and Geology, University of Turku, Turku, Finland, [2]Department of Geological Sciences, University of Stockholm, Stockholm, Sweden, [3]Centre for Tectonics, Resources and Exploration (TRaX), School of Earth and Environmental Sciences, University of Adelaide, Adelaide, Australia, [4]Ödemarksvägen 107, Broby, Finland

In 2008-2009, a number of polymetallic quartz veins, hosted by coarse-grained wiborgitic rapakivi, were discovered in the Sarvlaxviken area, southeastern Finland. Each vein has a characteristic geochemical composition and mineral assemblage but they still can be divided into five groups: Korsvik, Högberget, Korsvikberget, Virbäcken and Mjölknäs. The Korsvik group is enriched in Cu, In, As and Bi; locally also Sn, Mn and W. The In contents of these veins are very high, up to 1,490 ppm, and roquesite ($CuInS_2$) is the main In-carrier. Chalcopyrite, bornite, stannoidite, arsenopyrite, cassiterite and wolframite are also abundant. The specific geochemical signature of the Korsvik group is critical for the formation of several mineral phases; high In/Zn ratios are necessary for the formation of roquesite while high Sn contents control the formation of stannoidite on the expense of bornite. The Högberget group is enriched in Cu, In, As, Sn, Bi, Be, W, Zn, Pb, Cd, Mn and Ga. It is dominated by arsenopyrite with sphalerite, wolframite, chalcopyrite and cassiterite as accessories. The Korsvikberget group is strongly enriched in As (up to 17.3 %) with lesser amounts of Sn, Bi and In. Arsenopyrite predominate (99 %) with a few grains of pyrite, bornite, sphalerite and ilmenite. The Virbäcken group is enriched in Cu, In, Ag, As, Bi, Be and W and characterized by chalcopyrite with accessory arsenopyrite, sphalerite, cassiterite, Bi-minerals (native bismuth, bismuthinite and emplectite) and Ag-minerals (e.g. Ag-bearing cosalite). The Mjölknäs group is enriched in Zn, Pb, Cd and Mn and dominated by sphalerite and galena.

Fluid inclusions in quartz from the Korsvik group are mainly primary aqueous inclusions with variable vapour to liquid ratios; a few contain an additional CO_2-component. Aqueous inclusions with a low salinity (< 3 eq. wt. % NaCl) dominate, but groups of medium-salinity (10-15 eq. wt. % NaCl) inclusions are present as well, indicating a gradually increasing salinity.

In conclusion, all polymetallic quartz veins of Sarvlaxviken are enriched in Cu, As and In, locally also Sn, W, Bi, Be, Pb, Cd, Mn, Ga, Zn and Ag. Preliminary fluid inclusion data suggest that the ore-transporting fluid at Korsvik was a magmatic aqueous low-salinity (< 3 eq. wt. % NaCl) vapour, exsolved at a late stage of magma crystallization and that the sulphides subsequently deposited in response to rapid cooling and condensation of the vapour. The specific geochemical compositions and mineral assemblages for other vein groups imply slightly different formation conditions for them.

Reference:
Cook, N.J., Sundblad, K., Valkama, M., Nygård, R., Ciobanu, C.L. and Danyushevsky, L., 2011. Chemical Geology, doi: 10.1016/j.chemgeo.2011.02.006.

C5.3

Exploration potential in the appinitic rocks of the central Lapland granitoid complex, Finland

Laura S Lauri[1], Olli Sarapää[1], Thair Al Ani[2]
[1]Geological Survey of Finland, Rovaniemi, Finland, [2]Geological Survey of Finland, Espoo, Finland

Appinites, first described from Scotland (see e.g., Bowes & McArthur, 1976), are a suite of mantle-derived, alkali-rich, dioritic to syenitic igneous rocks, which have high amounts of P and REE. Paleoproterozoic (ca. 1.79 Ga; Ahtonen et al., 2007) appinitic intrusions are widespread within the central Lapland granitoid complex (CLGC). They form numerous small stocks or dikes and some large intrusions, which are clearly discernible on the aeromagnetic map due to abundant magnetite. Appinites are post-kinematic to the tectonic movements in the CLGC and are commonly associated with presumably coeval granites, forming possible magma mixing/mingling systems.

The appinites have plagioclase, hornblende, biotite and magnetite as the main minerals. Syenites are rich in feldspar and commonly contain quartz that may be secondary. Accessory phases include apatite, ilmenite, titanite, zircon, sulfides, monazite, allanite, and baryte.

SiO_2 content in the appinites varies between ~50–60 wt.%. K_2O contents are between 1.8-3.6

wt.%. Ba (1000-1850 ppm), Sr (500-700 ppm) and Zr (300-500 ppm) contents are high in most samples. P_2O_5 content in appinites is mostly between 1-2 wt.% but may exceed 3.5 wt.% in some intrusions. REE contents are commonly highest (REEtot up to 1000 ppm) in the syenitic members of the suite and in the mingled rocks that contain both appinite and granite. LREE (La to Sm) are more abundant than HREE (Gd to Lu). Monazite and REE-carbonates are the main REE-bearing minerals in all samples.

Appinite suite has potential for phosphate and REE deposits. Indications of PGE ore potential in some appinite intrusions have been reported elsewhere (Power et al., 2004), but up to date no PGE have been found within the CLGC appinites. The main problem in exploration activities within the CLGC appinite suite is that the intrusions are deeply weathered and commonly covered by thick Quaternary deposits. Mobil metal ion (MMI) sampling coupled with diamond drilling targeted by soil sampling and geophysical (aeromagnetic/ ground geophysical) anomalies has recently been tried by the Geological Survey of Finland (GTK).

References:
Ahtonen et al., 2007. Bulletin of the Geological Society of Finland 79, 143-174.
Bowes, D.R. & McArthur, A.C., 1976. Krystalinikum 12, 31-46.
Power et al., 2004. Mineralogical Magazine 68: 2, 395-411.

C5.4

Regolith-landform mapping and exploration geochemistry in south Mali

A.P.J. Bristow[1], *C.R.M. Butt*[2]
[1]Peruvian Latín Resources SAC, Lima, Peru, [2]CSIRO Earth Science & Resource Engineering, Bentley, Australia

Reconnaissance regolith-landform maps have been prepared for two deeply weathered areas in important mineral districts of SW Mali: Finkolo-Misséni, south of the Syama gold mine, and Djelimagara, between the Sadiola and Loulo gold mines. Both areas are centred on greenstone belts of Proterozoic Birimian rocks of the West African Craton, which host most of the Au and base metal deposits of the region. In both areas, isolated outcrops of resistant bedrock and small remnant plateaux of residual lateritic duricrust form some of the highest elements of the landscape and probably represent the oldest land surface. However, the higher elevations are dominated by concave, scarp-bound, ferricrete plateaux, cuestas and slopes - landforms that closely resemble those developed in residual lateritic terrain*. Colluvium and alluvium, including further ferricrete, are also present at lower elevations and, overall, about 50 % of the terrain is depositional.

Previous research in the region appears not to have recognized the transported nature of the high level ferricretes and underestimates the extent of transported overburden in the terrain. The landscape has been interpreted to have evolved by successive formation and erosion of essentially residual regolith. However, recognition of the presence of the ferricretes has significant implications for interpretation of the geomorphological history, to include major topographic inversion. The erosional events were triggered, in part at least, by the post-Cretaceous basin and swell epeirogenic tectonics of the Craton, which also resulted in 'planation surfaces' of similar age occurring at different elevations. Partial erosion of the original residual lateritic regolith (duricrust and underlying saprolite) contributed initially to the formation of a colluvial unit, which was subsequently ferruginized and indurated to form the high level ferricrete. During later erosion, detritus from both the lateritic regolith and the ferricrete formed younger colluvial deposits, and active erosion of all of these units is contributing to the alluvium in the present day drainages.

This re-interpretation has considerable implications for exploration. Whilst conventional surface sampling appropriate to lateritic terrain is effective in residual areas, it is ineffective in depositional areas, unless termite activity has contributed saprolite-derived materials to the fine fraction of the soil. Otherwise, drilling, at least to the top of saprolite, will be necessary for effective sampling. Careful regolith-landform mapping and recognition of the nature and origin of surficial materials are essential pre-requisites to successful, cost-effective exploration in these terrains.

*Lateritic duricrust and lateritic residuum refer to the upper, ferruginous horizons of a residual lateritic profile; ferricrete refers to indurated, Fe oxide-cemented colluvial or alluvial sediments.

C6.1

Soil geochemistry and magnetometry evidence for extensive and complex rapakivi-related mineralization in the Sarvlaxviken area, southeastern Finland

Krister Sundblad[1], *Mira Valkama*[1], *Karoliina Penttinen*[1], *Rune Nygård*[2]
[1]University of Turku, Turku, Finland, [2]Ödemarksvägen 107, Broby, Finland

Numerous polymetallic quartz and greisen veins are known in the western margin of the 1.65 Ga Wiborg rapakivi batholith, southeastern Finland. The most spectacular have been found in the Sarvlaxviken area, including the first discovery sites of roquesite ($CuInS_2$) in Finland (Cook et al., 2011). The polymetallic quartz veins are best documented east of the Sarvlaxviken bay where they are enriched in Cu, As, In, Sn, W, Bi, Be, Pb, Cd, Mn, Ga, Zn and Ag, with specific geochemical signatures in each vein population (Valkama et al., 2011). The polymetallic greisen veins have been recognized in locally-derived ore boulders west and south of Sarvlaxviken and with slightly different metal signatures (e.g. Zn-Cd-In, As-U and Cu-Zn-Cd-In-Bi).

More than 1000 soil samples were collected in the Sarvlaxviken area in 2008-2010 as part of the activities in international field courses in exploration and environmental geochemistry, organized by the University of Turku. Four soil anomaly populations have been identified:

a) The anomalies east of Sarvlaxviken fit nicely to the specific geochemical signatures in each of the Korsvik, Korsvikbergen, Högberget and Virbäcken veins (cf. Valkama et al., 2011), showing that the distance to the metal sources must be very short (< 50 m). The extensive distribution of each soil anomaly indicates that many more veins must exist in each of these vein populations.

b) The anomalies in the Marviken-Stormossen area, west of Sarvlaxviken are characterized by Zn, Cd, In, Fe, Mn, Sn and Pb and form a semi-continuous km-long arc-shaped structure. They coincide with a distinct magnetometry anomaly. It is assumed that polymetallic greisen veins, rather than quartz veins, constitute the source for this soil anomaly.

c) A km-long, EW-trending Zn-Cd-In anomaly occurs at Lillträsket, even further west of Sarvlaxviken. The presence of a 0.5 m thick, Zn-Cd-In-rich greisen vein in a local boulder suggests that polymetallic greisen veins constitute the source for this soil anomaly.

d) A poorly defined As-In-Sn-Zn anomaly at Strömslandet, south of Sarvlaxviken, coincides with polymetallic greisen veins in several short-transported boulders.

Bedrock observations indicate that the mineralizations responsible for soil anomalies a, b and d are hosted by coarse-grained wiborgitic rapakivi granites, although close to km-sized medium-grained rapakivi granite stocks. The presumed greisen mineralization at Lillträsket appears to extend from rapakivi granites into Svecofennian rocks.

In conclusion, the soil and magnetometry anomalies as well as the vein/boulder discoveries and bedrock observations show that the western margin of the Wiborg batholith (and immediate Svecofennian surroundings) are intensely mineralized with polymetallic quartz and greisen veins.

References:
Cook, N.J., Sundblad, K., Valkama, M., Nygård, R., Ciobanu, C.L. and Danyushevsky, L., 2011. Chemical Geology, doi: 10.1016/j.chemgeo.2011.02006.
Valkama, M., Broman, C., Sundblad, K., Cook, N.J. and Nygård, R., 2011. Abstract IAGS, Rovaniemi, Finland.

C6.2

A multi-element geochemical approach to finding copper in the central African Copperbelt

Frank Santaguida[1], Doug Jack[2], Mattias Fackel[2], Hugh Carruthers[2], Godeffroid Kazardi[2], Alex Ferrar[2], Everisto Gocha[2]
[1]FQM Kevitsa Mining Oy, Sodankylä, Finland, [2]First Quantum Minerals Ltd., Ndola, Zambia

Ore deposits in the Central African Copperbelt (CACB) have long been mined for Cu and Co. Most of these were mined for Cu-oxide mineralization that was well exposed at surface. Copper sulphide mineralization has increasingly been mined in the CACB and their discovery has required more advanced methods of exploration, including collection of multi-element soil geochemical datasets.

The CACB deposits are generally stratabound and have been subdivided according to basic litho-stratigraphic types: 1) arenite-hosted, 2) argillite-hosted and 3) dolomite-rock hosted (Selley et al., 2005; Dewaele et al., 2006). Vein-style mineralization also occurs where copper is discordant, but constrained to a favourable horizon or lithologic unit. Each of these types contain examples of "giant" sized (> 2 Mt contained Cu) resources. Aside from copper-oxide mineralization, the arenite- and argillite-hosted deposits demonstrate a chalcocite-bornite-chalcopyrite-pyrite-pyrrhotite mineral progression from the core to the periphery of the deposits. This zoning is not well understood in the dolomite-hosted deposits.

Overall, metals such as Zn, Pb, Ag, Mo, and Ni in all three stratbound types are quite low compared to other sediment-hosted copper deposits (Hitzman et al., 2005); however, only a few of the CACB deposits have been systematically studied. At Mwambasi, a relatively small arenite-hosted deposit, elevated Ag and Bi correlate to the bornite halo around the core of the mineralization (McGolderick et al., 2003). At Lonshi Mine, high Ag and Bi correspond directly to chalcocite vein-mineralization, while Mo-As are generally elevated within the entire copper zone. At Frontier Mine, all metals within the brecciated shale are particularly low, but Ag-Bi are enriched within the core of the Cu orebody. Pyrite mineralization on the periphery of several small, shale-hosted Cu prospects in the CACB also show enrichment of Ag-Bi.

Despite the low levels in the bedrock, copper sulphide mineralization can be well expressed in soil geochemical surveys by multi-element patterns that are defined at several scales. In particular, Bi and As in soils, which are accurately measured to low detection limits by several analytical methods, consistently highlight Cu mineralization. The Cu-Co ores are considered to form as a multi-stage ore forming process governed by long-lived fluid conditions at consistent redox, temperature, and solubility (Hitzman et al, 2005). The soil signatures record the accumulated effect of these conditions and are therefore useful in the exploration for further resources.

References:
Dewaele et al., 2006. Journal of African Earth Sciences: 46, 455-469.
Hitzman et al. 2005. Economic Geology 100th Anniversary Volume. 609-642.
McGolderick et al., 2003. Unpublished AMIRA Project P544 Final Report. Chapter 12.
Selley et al., 2005. Economic Geology 100th Anniversary Volume. 965-1000.

C6.3

Tourmaline- and sulfide-bearing, graphitic pelitic gneisses of the Paleoproterozoic Wollaston Group, northern Saskatchewan: new insights into understanding the carbon-sulfur-boron-uranium geochemical system with implications for U/C-type uranium deposits

Irvine R. Annesley[1], Robert Millar[2]
[1]JNR Resources Inc., Saskatoon, Saskatchewan, Canada, [2]Department Geological Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [3]Saskatchewan Research Council, Saskatoon, Saskatchewan, Canada

The Proterozoic Athabasca Basin in northwestern Saskatchewan, Canada contains the largest unconformity-type (U/C-type) uranium deposits in the world. The basin, covering circa 100,000 km^2, is comprised of an essentially unmetamorphosed sedimentary rock sequence. It is underlain by polydeformed high-grade basement rocks of Archean to Paleoproterozoic age, which include in its eastern part, basal Wollaston Group graphitic pelitic gneisses and intrusive leucogranites and granitic pegmatites (Annesley et al., 2005; Cuney & Kyser, 2008).

Significant research has been undertaken on the Athabasca Basin sandstone formations, as well as the underlying Archean/Paleoproterozoic basement complex, to discover how these "giant" uranium deposits formed. Many researchers agree that oxidized basinal brines flowed through the Athabasca Basin and the basement rocks below the unconformity, and that mixing of oxidized basinal brines with reducing fluids or reduced rocks caused changes in the redox chemistry of fluids transporting uranium to precipitate uranium near the breached unconformity (Jefferson et al., 2007; Cuney & Kyser, 2008; and references therein). However, there remain many unknowns to the formation of these deposits; including the nature of the reductant(s).

Tourmaline is ubiquitous in the eastern basement complex, in which it occurs within graphitic pelitic to pelitic to psammopelitic gneisses, tourmalinites, migmatites, psammitic gneisses, meta-quartzites, leucogranites, granitic pegmatites, and quartz veins as part of either a prograde metamorphic or magmatic or retrograde metamorphic and/or low-temperatue hydrothermal mineral assemblage. In most cases, the tourmaline composition can be placed within the 4-component shorl-dravite-foitite-magnesiofoitite mineral chemistry space.

Our present study focuses on tourmaline- and sulfide-bearing, graphitic pelitic gneisses of the Paleoproterozoic Wollaston Group from the eastern Athabasca Basin; distal and proximal to known U/C-type uranium mineralization. Field and petrographic observations of these gneisses, in conjunction with mineral chemistry data, petrogenetic grids, P-T-t calculations, and recent literature thermodynamic models, show that there were four or five major graphite(CM)-sulfide-tourmaline-forming events. This reflects significant carbon-sulfur-boron (C-S-B) geochemical cycling within the basement complex to the eastern Athabasca Basin. These events occurred from Trans-Hudson orogenic time (i.e. related to deformation, metamorphism, and magmatism) to post-depositional Athabasca time (i.e. related to fault-reactivation, intense alteration, and geochemical remobilization). We also show that the C-S-B events are tied to different types of uranium-forming events, including the world-class U/C-type uranium deposits of the Athabasca Basin.

Eventually, this research will add constraints to the U/C-type uranium deposit model, and aid in targeting new resources in Saskatchewan.

References:
Annesley et al., 2005. Canadian Journal Earth Science, 42, 573-597.
Cuney, M. & Kyser T.K., 2008. Recent and not-so-recent developments in uranium deposits and implications for exploration, Mineral. Assoc. Canada, Chapter 8, 39, 161-219.
Jefferson et al, 2007. EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta. Geol Survey Canada, Bulletin 588, 23-67.

C6.4

The Frederick Project: Geochemical exploration for sediment-hosted base metals in covered terrain in the Bangemall Basin, Western Australia

Richard Mazzucchelli
Searchtech Pty Ltd, Kalamunda, WA, Australia

The Frederick Project involves greenfields exploration for sediment-hosted Cu-Pb-Zn-Ag in the Meso-Proterozoic Bangemall Basin in northwest Western Australia. A statistical interpretation of the geochemical mapping carried out by the Geological Survey of Western Australia (over 20,000 samples collected over some 350,000 sq. km) had highlighted a strong anomaly of regional extent in the northeast corner of the Mt Phillips 1:250,000 map sheet. Anomalism was especially strong for multi-element functions reflecting chalcophile elements and base metals. The anomalous area occurs in the Bangemall Basin, which is considered prospective for sediment-hosted base metal mineralisation. The anomalous GSWA samples appear to reflect dispersion from exposed areas. Numerous base metal and uranium occurrences have been mapped in the Mt Augustus area but no significant mineralisation has been found. There are extensive concealed areas in which any mineralisation present would not have been detected.

Hydrogeochemistry was adopted as the primary technique to explore the concealed areas within the regional anomaly. A linear Cu anomaly was found to be spatially associated with a conspicuously straight section of the Frederick River, interpreted to be a fault. Reconnaissance lag sampling (2000 x 400m) located a strong Pb anomaly, flanking one of the few outcrops of basement in the area. Regression analysis also highlighted some subtle response for Cu, Pb and Zn, but it was concluded that geochemical response in lag was not sufficiently consistent to reliably map the distribution of bedrock mineralisation.

The next phase of exploration involved soil sampling on a 400 x 100m grid and analysis for a 32 element suite using a partial digestion. The partial digestion serves to enhance response to bedrock dispersion both by selectively leaching the mobile components from the regolith and optimising analytical sensitivity. Multi-element analysis increases the likelihood of recognising subtle bedrock response, allowing the use of multi-variate statistical search techniques such as factor analysis. The survey successfully located numerous features considered to reflect bedrock including:

- Previously unrecognised extensions to the Pb anomaly located by lag sampling;
- A widespread but unusual metasomatic overprint associated with major mineralisation elsewhere in the Basin; and
- A promising multi-element anomaly dominated by pathfinders associated with base metal mineralisation such as In, Tl, Cd, Hg with lesser but significant Ag, Cu, Pb, Zn, U, and Mo.

The economic significance of the various geochemical anomalies located has yet to be determined, but the results demonstrate the ability to delineate bedrock mineralisation with surface geochemical sampling techniques despite the obviously transported nature of the overburden.

C7.1

Trace Element and Radiogenic Isotope Geochemistry of the ~1.1 Ga Midcontinent Rift of North America: Implications for the Discovery of Ni-Cu-PGE Deposits

Pete Hollings[1], Mark Smyk[1]
[1]Lakehead University, Thunder Bay, Ontario, Canada, [2]Ontario Geological Survey, Thunder Bay, Ontario, Canada

The Midcontinent Rift (MCR) of North America comprises ~1,500,000 km^3 of basaltic sheets, flows and intrusive rocks emplaced in the Lake Superior region during the Mesoproterozoic ca. 1.1 Ga (Klewin and Shirey, 1992), that have been subdivided into the Keweenawan Supergroup and Midcontinent Rift Intrusive Supersuite by Morey and Green (1982) and Miller et al. (2002). The mafic rocks preserved on the northern flank of Lake Superior represent the older portions of the rift sequence (Heaman et al., 2007). Recent work has shown that the rocks of the MCR in Ontario are considerably more diverse and long-lived than was previously recognized (Heaman et al., 2007; Hollings et al., 2007a, b, 2010). The recognition of older ages in mafic to ultramafic intrusions that are often host to platinum group element (PGE) mineralization, suggests that this newly recognized phase of rift activity may be the critical period for mineralization.

Recent discoveries of copper-nickel-PGE deposits have been made in ultramafic intrusions of the Midcontinent Rift Intrusive Supersuite. These include Magma Metals Ltd. Thunder Bay North property in Ontario (9.3 Mt @ 2.44 g/t Pt-Equivalent), Rio Tinto/Kennecott Eagle Minerals Eagle deposit in Michigan (3.6 Mt @ 3.47% Ni, 2.93% Cu) and Rio Tinto's Tamarack property in Minnesota (9 to 11 Mt @ 1.0 – 1.1% Ni, 0.6 – 0.7% Cu). These newly discovered deposits are often associated with magma conduits or chonoliths. The relatively small size of the host intrusions makes them a challenging target for exploration.

Recent studies of the geochemistry and geochronology of MCR-related rocks in and around Thunder Bay have provided a solid framework for explorationists (Hollings et al., 2010). The complexity of the dike and sill suites on the northern flank of the rift suggests that the early phases of rifting occurred in distinct and changing stress fields prior to the main extensional rifting preserved in younger rocks to the south. The whole rock, trace element and radiogenic isotope geochemistry and geochronology of the intrusions suggest a long-lived and complex magmatic history for the MCR. Ongoing research into coeval volcanic and intrusive rocks related to mineralized intrusions has prompted the consideration of new models for MCR development and mineralization. These new models can be utilized to generate exploration targets and techniques that better characterize and locate mineralized intrusions.

References:
Heaman, L., et al. 2007. CJES, 44, 1055-1086
Hollings, P., et al. 2007a. CJES, 44, 1087-1110.
Hollings, P., et al. 2007b. CJES, 44, 1111-1129.
Hollings, P., et al. 2010. Precambrian Research, 183, 553-571.
Klewin, K.W., and Shirey, S.B. 1992. Tectonophysics, 213, 33-40.
Miller, J.D., et al., 2002. Minnesota Geological Survey, Report of Investigations 58, 5-20.
Morey, G.B. and Green, J.C. 1982. GSA Memoir 156, 15-26.

C7.2

Geology and Geochemistry of the Simpson Island Dyke, NWT, Canada

Thomas Mumford[1], John Ketchum[2], Brian Cousens[1]
[1]Carleton University, Ottawa, Canada, [2]Northwest Territories Geoscience Office, Yellowknife, Canada

The southern portion of the Slave province of Canada contains a number of complex alkaline intrusions, all dated around 2100-2200 Ma. These intrusions mark the end of a 300 Ma period of igneous quiescence in the Slave, and the initiation of the break-up of the Sclavia supercraton (Bleeker & Hall, 2007). One of the oldest of these alkaline intrusions is the Simpson Island Dyke (SID), located in the East Arm of Great Slave Lake, NWT, approximately 125 km southeast of Yellowknife. By studying the SID, we expect to constrain the composition of the mantle beneath the Slave during this period, and gain insight into the evolution of the other complexes within the region, notably the Blachford Lake Intrusive Suite which hosts the world class Nechalacho REE deposit.

Fieldwork during 2010 expanded the known extent of the SID. From this work we present new geochemical, isotopic, and geochronologic data related to the dyke, and present a new model for its formation. The dyke outcrops over a length of 31 km, and has a maximum thickness of 120 m. The SID is unique in that it becomes progressively more evolved from west to east, varying from an olivine gabbro to an albite syenite. Geochemistry done along strike of the dyke, displays an almost continuous fractional crystallization trend (e.g. Zr = 123 - 600 ppm).

Previous work on the SID attributed the compositional variation to a vertical feature resulting from in situ fractional crystallization, and concluded that the current geometry of the dyke is related to extensive faulting and rotation (Badham, 1979). New field evidence suggests that observed compositional variation in the SID can be explained without the use of intense deformation. Internal structures within the SID indicate that a deeper evolving magma chamber may have fed the system, and the current geometry is an expression of dyke propagation during rifting.

References:
Badham, J.P.N., 1979. Canadian Journal of Earth Sciences 16, 60-72.
Bleeker, W. & Hall, B., 2007. Geological Association of Canada, Special Publication No. 5, 849-879.

C7.3

Siderite chemistry: exploration implications for Proterozoic stratiform Zn-Pb-Ag mineralisation, northern Australia

Keith Scott[1], Ben Johnson[3], Greg Yaxley[1]
[1]Australian National University, Canberra ACT, Australia, [2]CSIRO, Nrth Ryde NSW, Australia, [3]Mineral Mining Group, Garbutt QLD, Australia

Siderite is intimately associated with the major Proterozoic stratiform Zn-Pb-Ag deposits in northern Australia. Although such siderite is a minor component in deposits like McArthur River and Mount Isa, there is major development of siderite at the Lady Loretta deposit (Carr, 1984; Large & McGoldrick, 1998) and siderite in the ore and hanging wall at Century (Broadbent et al., 1998). In both these latter cases, substantial Zn may also be incorporated into the siderite structure. However siderite is also widespread at particular horizons in the Proterozoic metasediments and associated with discordant vein mineralisation of the region. Thus the significance of siderite occurrences with mineralisation needs thorough evaluation. This study uses an electron microprobe to determine siderite compositions from both ore and barren environments in the Century region to provide a better framework for such an evaluation.

Regional results show that the siderite in

Proterozoic McNamara Group metasediments tends to be Mg-rich with low Mn content (Mn/Fe=0.03-0.06) whereas that associated with discordant mineralisation is also Mg-rich but with more Mn (Mn/Fe~ 0.11). However siderite associated with the ore and hanging wall at Century is particularly Mn-rich (Mn/Fe>0.25) and Zn-rich (up to 14 mol% Zn). In contrast, at the Lady Loretta deposit, although the Mg content of siderite varies greatly, the Mn/Fe ratios are consistently ~0.03. Thus the Century ore environment appears to be particularly Mn-rich relative to other northern Australian stratiform Zn-Pb-Ag deposits.

References:
Broadbent, G.C., Meyers, R.E. and Wright, J.V., 1998. Economic Geology 93, 1264-1294.
Carr, G.R., 1984. Journal of Geochemical Exploration 22, 217-238.
Large, R.R. & McGoldrick, P.J., 1998. Journal of Geochemical Exploration 63, 37-56.

C8.1
Exploring in Areas of Thick Cover: Fine Fraction Gold Chemistry from the Eastern Yilgarn Craton, Western Australia

Paul Morris
Geological Survey of Western Australia, Perth, Western Australia, Australia

The East Wongatha area, on the eastern edge of the Archean Yilgarn Craton in Western Australia, is a relatively unexplored and geologically poorly understood part of the State, due to its thick and contiguous regolith cover (ranging from 5 to 120 m thick) and < 4 % outcrop. Exploring through this cover is compounded by the two most prospective bedrock units (the Yilgarn Craton and adjoining Albany-Fraser Orogen) being partly covered by a succession of Paleozoic sedimentary rocks up to 400 m thick.

Regolith is dominated by well sorted largely allochthonous quartz-rich sand (> 70% by area), with minor silt and clay. In order to minimise the dilution effect of this sand, a regolith geochemistry program carried out by GSWA at a sample density of 1/16km^2 over an area of approximately 13 000 km^2 analysed the <50 micron (silt and clay) fraction, which was digested with aqua regia and finished by ICP. Despite the thick regolith cover greenstones are not only outlined on the Yilgarn Craton, but can also be traced along strike and below Paleozoic sedimentary rocks (as indicated by aeromagnetic data) by elements such as Cr and Ni. Gold in this fine fraction (range <1 ppb to 29 ppb) is also found in anomalous concentrations over the inferred extent of Archean greenstones, as well as in regolith over Paleozoic sedimentary rocks on the basin margin. The distribution of anomalous gold is consistent with the well known relationship of gold mineralization and greenstones from elsewhere in the Yilgarn Craton, and the occurrence of uranium-base metal-gold mineralization at a redox front on the basin margin in the south of the project area.

The <50 micron fraction of 50 samples with varying gold concentrations were digested with deionized water and analysed by ICP. The strong correlation between aqua regia and deionized water-digested gold indicates that gold in the fine fraction of regolith is either water soluble or present as nano-scale particles (e.g. Hough et al., 2008; Noble et al., 2009). The relationship of anomalous gold concentration in regolith and potential bedrock hosts indicates that gold and other elements have migrated vertically through tens of metres of regolith and sedimentary rock cover (cf. Cameron et al., 2004; Klussman, 2009).

References:
Cameron et al., 2004. Geochemistry: Exploration, Environment, Analysis 4: 7-32.
Hough et al., 2008. Geology 36, 571-574.
Klussman, R. 2009. Geochemistry: Exploration, Environment, Analysis 9: 201-213.
Noble et al., 2009. EXPLORE 142:1-8.

C8.2
Snow samples as a viable method in the exploration for gold and base metals

Nadezda Yavorskaya, George Gale
GIS of NAD-ia, Winnipeg, Manitoba, Canada

Both Enzyme Leach (EL) and Mobile Metal Ion (MMI) selective digestions are used in the exploration because of their successful track record in different climatic regions. Case studies clearly demonstrate that both the MMI and EL selective digestions provide the explorationist with useful information, which, when used in conjunction with other exploration tools, can assist with the identification of potential diamond drill targets (Bajc, 1998).

Some problems encountered in the use of mobile ion technology in the exploration for gold and base metal deposits have been the inconsistency of sample media, size distribution of material and variations introduced by different samplers. In snow-covered areas, it is possible that the same processes responsible for the deposition of metals in soils could also be actively depositing metals in snow, which may be a viable sample medium for mineral exploration using EL and MMI.

The concept was tested using a limited number of samples over known gold occurrences, an extensive survey at a known high-grade VMS deposit and a regional survey over areas with high potential to contain VMS mineralization in Manitoba, Canada. One of the unknowns was the level of contamination resulting from a smelter some 100 km away from tested areas. The survey program was designed to test for possible contamination from the smelter, sample variability, analytical variability and repeatability and establish snow threshold values for the area.

Snow samples collected over several known gold occurrences showed positive anomalies at each site sampled. These results prompted the authors to conduct surveys over a known VMS-type deposit and in areas with geophysical conductors that were prospective for VMS type mineralization. Soils were analyzed at the site of one gold deposit and one VMS deposit using both the MMI and Enzyme Leach methodologies. The snow survey was designed to test gold and base metal responses in areas that had yielded above background responses for Cu, Zn and Au using selective leach digestions on soils. The resulting Au, Cu and Zn snow anomalies are similar to those obtained using the partial leach soil surveys.
Snow geochemical surveys may be a useful and cost effective tool to probe blind or buried anomalies identified by geophysical surveys.

References:
Bajc, A.F., 1998. Journal of Geochemical Exploration, Volume 61, Issues 1-3, 113-148.

C8.3

Conceptual and Mathematic Models of Dispersal Patterns and Trains in Areas of Glaciated Terrain

Alexey Marchenko
Tellur North-East L.L.C., Tellur Group of Companies, Saint Petersburg, Russia

Conceptual and mathematic models of secondary geochemical anomalies are ultimate basis for correct interpretation of geochemical prospecting data, especially while performing estimation of inferred resources (Solovov, 1987).

The peculiar features of secondary geochemical anomalies in glaciogenic deposits mostly correspond to the period of continental glaciation. Different processes of formation of various types of glaciogenic deposits resulted in differences between main types of dispersal fans and trains. Four types of conceptual and mathematic models were developed and described (Marchenko, 2005):
(1) models of dispersal patterns in the bottom layers of basal tills, ribbon-type as usual, formed by indicator minerals which had been transported in the debris-saturated basal ice or displaced by traction immediately beneath it due to layered movement of the basal ice;
(2) models of dispersal patterns in lodgement tills deposited from englacier debris which had been transported by ice flows;
(3) models of dispersal fans and trains, including boulder ones, in ablation melt-out tills built up from englacier and/or superglacier debris;
(4) models of dispersal trains in eskers related to paleostreams in the former ice shield channels.

For modeling dispersal patterns in Holocene deposits, the models of joint diffusive and convective migration are applied. It has been shown that not diffusive but upward convective or quasi-convective migration can transport mobile forms of metals for significant distances from their sources through drift to the ground surface. Case histories have verified that vertical prolongations of superimposed halos in mobile and secondary weakly-confined forms of elements can be up to tens and hundreds meters. Among very probable quasi-convective vehicles for mobile forms of metals are vertical streams of Earth’s gaseous bubbles (Putikov & Wen, 2000). The relatively simple mathematical models for vertically extended superimposed dispersal halos (so called jet halos) were suggested by author (Marchenko, 1998) and since 1990th have been under further development. For areas of glaciated terrain, it is important to note that there are different sources of superimposed halos in soils, including (1) sources in the upper part of bedrock, and (2) dispersal fans or trains in the underlying glaciogenic deposits.

References:
Marchenko, A.G., 1998. Predictive and Exploration Geochemistry at the Eve of the XXI Century. IMGRE, Moscow, pp. 83-86. (In Russian).
Marchenko, A.G., 2005. Geology, Geochemistry and Ecology of the North-West of Russia. SPbSU, St-Petersburg, pp. 55-62. (In Russian).
Putikov, O.F. & Wen, B., 2000. Handbook of Exploration Geochemistry, Vol. 7, Chapter 2. Elsevier Science B. V., pp. 17-79.
Solovov, A.P., 1987. Geochemical Prospecting for Mineral Deposits. Mir Publishers, Moscow, 287 p.

C8.4

What Happens When We Dry a Soil Sample During Sample Preparation? : Implications for Partial Digestion Geochemistry

Cliff Stanley, Biniam Bisrat
Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada

The use of partial digestion geochemistry in mineral exploration is justified by several assumptions: (i) a mineral deposit occurs at depth beneath permeable cover, (ii) elements from that mineral deposit are transported vertically through the overburden to the surface (by yet to be identified processes), and (iii) those elements become fixed in the soil, mostly via adsorption. As a result, (iv) partial digestions can then be used to liberate these labile elements, (v) allowing geochemical analysis, and (vi) interpretations that lead to the recognition of anomalous concentrations serving as indications of subjacent mineralization.

Unfortunately, many partial digestions are designed to dissolve specific phases within soils (e.g., organic matter by Na-pyrophosphate, Fe-oxy-hydroxide minerals by hydroxylamine hydrochloride). As a result, these partial digestions are far stronger than necessary, as only desorption of the particle surfaces, and not complete dissolution of the underlying particle, is required to liberate these adsorbed ions. Furthermore, these partial digestions are commonly less selective than fully appreciated. As a result, they not only liberate elements on and within the target minerals, but also solubilize elements on and within other phases. Consequently, such partial digestions tend to degrade the resulting geochemical contrast, impeding proper geochemical interpretation.

In order to properly undertake partial digestion geochemistry, one needs to know the composition of the samples to be digested. Understanding in what form (e.g., within minerals, dissolved in pore waters, adsorbed onto particle surfaces) a pathfinder element resides in undisturbed soils is critical to this effort. Unfortunately, such soils can undergo significant modification during sample preparation, changing the element speciation and altering how partial digestion geochemistry should be undertaken. Probably the most important modification to soil samples occurring during sample preparation involves drying of the sample.

Because most soil samples are collected from the groundwater-undersaturated vadose zone, they consist of particles coated with variable thicknesses of pore water. The amount of pore water may vary substantially, but most soil samples loose 5 to 25 % of their mass during drying, providing a clue as to how much pore water is actually present. As drying proceeds, the concentrations of elements dissolved in these pore waters increase, causing additional adsorption onto mineral surfaces, and leading to saturation and precipitation of simple soluble salts as samples approach dryness.

Because such adsorption and precipitation are both completely reversible processes, digestion using deionized water should be able to achieve the desired reversals, desorbing ions from mineral surfaces and dissolving highly soluble salts that formed during drying. Thus, deionized water as a partial digestion can be expected to effectively solubilize labile ions transported from mineral deposits at depth, producing the geochemical anomalies necessary for discovering buried mineralization.

C8.5

Partial Digestion Geochemistry in Soil Samples: Monitoring (pH-pE) Digestion Conditions to Understand How Samples Leach

Biniam Bisrat[1], Cliff Stanley[1], John Murimboh[2]
[1]Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada, [2]Dept. of Chemistry, Acadia University, Wolfville, Nova Scotia, Canada

Partial digestion geochemistry has been used in mineral exploration to detect surface anomalies associated with buried mineralization. A variety of partial digestion reagents have been used, but many are stronger than necessary to solubilize adsorbed ions from the surfaces of soil particles, and thus create noise that impedes anomaly recognition. Weaker partial digestions are also not optimal, as their very weakness allows soils matrices to control digestion conditions, and when variable can create results that are not comparable. As a result, when using weak partial digestions, it is necessary to monitor the digestion conditions to ensure proper subsequent geochemical interpretation.

To investigate what actually happens during partial digestion, B-horizon soil samples from several study areas were leached using deionized water (probably the weakest partial digestion possible) and simultaneously analyzed by ICP-MS. A suite of 10 metals were analyzed every 30 seconds for up to the 2 hour digestion period. During this time, solution pH and pE conditions were also measured every 30 seconds. Analogous digestions were also undertaken using a weak (0.01 M) $CaCl_2$ salt solution, and under an argon atmosphere, to provide variations in digestion conditions that constrain the samples in different ways, providing insight into partial digestion controls and mechanisms.

The results of these experiments provide significant insight into how and why partial digestion conditions change over time, and how these changes can result in un-intended, and sometimes, completely disastrous results. Essentially, results conclusively demonstrate that Fe-oxy-hydroxide minerals within the matrices of soil samples simultaneously buffer both the pH and pE conditions of the digestions. As a result, samples with different matrices commonly undergo leaching under vastly different chemical conditions, undermining interpretation because the consequent results can't be rigorously compared. Thus, these results illustrate why significant geochemical contrast commonly occurs in many partial digestions surveys. More importantly, results also demonstrate that partial digestion concentrations obtained with less than 10 minutes of leaching are typically less influenced by soil matrix effects, precisely because they have not had time to exert their influence, and thus provide more accurate exploration results and better geochemical contrast than conventional (longer) leach times.

C8.6

Estimating nickel in sulphide minerals in ultramafic nickel deposits

Scott Long
AMEC Mining and Metals Consulting Group,
Phoenix, AZ, USA

Nickel contained in silicate minerals such as olivine is not amenable to recovery by the process of sulphide flotation. In making preliminary resource estimates of nickel resources in ultramafic deposits it is therefore desirable to estimate "potentially recoverable" nickel (sulphide-nickel) rather than total nickel. This issue is most important in prospects where much of the potential resource comes from rocks where more than five percent of the total nickel content is in non-sulphide minerals.

Historically, aqua regia digestion has been a commonly used "partial extraction" approach, used in some projects instead of a more robust "total" approach, such as four acid digestion or XRF. In some projects, all samples are subjected to a "total metal" determination and a subset is assayed by a partial digestion technique. In such cases a linear regression can be estimated for each rock type to produce an estimate of recoverable nickel, although this approach is less desirable.

Some projects have achieved a "partial extraction" nickel result that shows an improved correlation with metallurgical recovery using a peroxide ammonium acetate leach. This method uses a mixture of hydrogen peroxide and ammonium hydroxide with timed agitation. Best results appear to be obtained if the solution is acidified and heated after decanting or filtering out the insoluble residue.

A case study is presented in which three approaches to estimating sulphide-nickel are compared using metallurgical test results as a benchmark. The peroxide/ammonium-citrate assay method correlated best with metallurgical results. An indirect method, using total nickel and sulphur assays calibrated to the metallurgical result to obtain recovery factors, worked nearly as well. Aqua regia assays had the poorest correlation.

C9.1

Geochemical Exploration of Blind Gold-Copper Deposits by Ionex Technology In the Great Australian Basin, New South Wales, Australia

Issai Goldberg, Grigory Abramson, Bob Close
Interesources Pty Ltd, Sydney, NSW, Australia

The metallogeny of eastern part of NSW (Australia) is characterised by significant ore metal deposits (Au, Ag, Cu, PB and others) localised within the Lachlan Orogen. The northern part of this structure is covered by young sediments of the Great Australian Basin and is practically unexplored.

Geochemical exploration was carried out by Interesources Pty Ltd. using Ionex technology aiming to locate potential gold and copper deposits hidden by young sediments. Ionex recommended an area totalling 2,200 km^2 as a favourable to find gold, copper and base metals, following analysis of the distribution of mineral deposit associations within Lachlan Orogen.

Four stages of soil geochemical exploration were carried out within the prime study area at scales of 1:500,000, 1:100,000, 1:25,000 and 1:10,000 respectively. After each stage the least prospective areas were reduced by 50 % to 70 % thus allowing a focus on better target areas. Exploration was conducted using MPF method, a partial extraction technique.

Data interpretation is based on model of the ore geochemical systems and is characterised by coincident of enrichment and depletion zones of ore forming elements and regular distribution of siderophile elements in nuclear part of the system (Goldberg et al., 2007; Abramson, 2009). The method defines multi element regularities both in the bedrock and at surface covered areas.

The main results of the geochemical investigations in the studied area can be summarised as follows: Stage I - the regional scale 1:500,000 (soil sampling 5km x 5km). Four well defined local strongly anomalous sites are outlined. Within these sites a combination of positive anomalies (enrichment zones) of Au, As, Ag, Cu and also in part Mo is observed. Au enrichîment zones are coincided with adjacent Au depletion zones. These positive anomalies are surrounded by Ni and Co siderophile element enrichment zones that localise the nucleus of this system. In the more detailed surveys (Stages II-IV) the areas with similar structures were selected for further evaluation.

Geochemical anomalies also locally correspond to bedrock structures found by airborne geophysical data (magnetic and gravimetric). Induced Polarisation (IP) data on two areas (after Stage IV) showed the existence of moderate polarisation zones about 100 m deep within interpreted bedrock. This combination of geochemical and geophysical anomalies is considered highly prospective for localising mineral deposits. As a result of over two year exploration two sites were identified for drilling.

References:
Abramson, G., 2009. Proceeding the 24th IAGS, Federicton, pps. 103-106.
Goldberg, I.S., Abramson, G.Y., Haslam, C.O. and Los, VL, 2007. Economic Geology, v. 203, pps 281-293.

C9.2

Recent Developments in Geochemical and Electrical Prospecting for Au and PGE: Methods and Case Studies

Alexey Marchenko[1], Konstantin Blinov[2], Vadim Ilchenko[3]
[1]Tellur North-East L.L.C., Tellur Group of Companies, Saint Petersburg, Russia, [2]Tellur Nord-West L.L.C., Tellur Group of Companies, Saint Petersburg, Russia, [3]Tellur North-East L.L.C., Tellur Group of Companies, Saint Petersburg, Russia

Prospecting for Au and PGE with the use of conventional techniques is often difficult, especially if noble metal deposits are deep seated, of small size, or covered by drift. Joint application of geochemical and geoelectrical methods makes it possible to get hidden information about gold-bearing and PGE-bearing objects, that helps to encounter prospective local areas and discover ore bodies. However, low-sulfide Au and PGE ores are weakly differentiated in geochemical and geophysical fields; geochemical and geophysical anomalies are usually of low contrast. These may require application of specific and/or advanced methods of geochemical and geophysical prospecting.

First of all, the on-ground geochemical and geophysical prospecting should include: (a) stream sediment geochemical prospecting at reconnaissance stages and soil geochemical prospecting at follow-up stages; (b) Induced Polarization (IP) electrical prospecting, including surveys and soundings, with measurements of apparent or differential polarizability and apparent resistivity. Other methods are added if necessary.

In areas of residual overburden, soil samples are analyzed for Au, PGE and other pathfinder elements by FA/AAA, ICP/AES, ICP/MS and other quantitative techniques. For ICP analyzes, near total multi-acid digestion is pref erable, but aqua regia digestion is appropriate as well. It is essential to determine not only direct indicators such as elements forming enrichment zones, but also indirect indicators such as elements forming depletion zones and negative geochemical anomalies. Compilation of results of our case studies and published data allows choosing of most probable direct and indirect geochemical pathfinders of Au and PGE for main types of ores.

In areas covered by drifts, it is necessary to develop and apply new geochemical exploration techniques which are deep-penetrating ones and enable revelation of concealed ore deposits. Modified Method of Diffusive Extraction of elements (MDE-M) is aimed at leaching from soils water-extractable and weakly adsorbed forms of elements that allows revelation of superimposed dispersion halos. Another promising technique is Modified Gaseous Geochemical Prospecting method with catching ground gases by means of the Dew-Type Traps (MGGP-DTT). These methods, in complex IP prospecting, were successfully applied to geochemical exploration for PGE in Kola Peninsula.

IP electrical prospecting makes it possible to find zones with both massive and disseminated sulfides, graphite, quartz, other altered zones and ore-bearing veins. Special algorithms of IP data processing and interpretation enable construction of 2D and 3D geoelectrical models and estimation of sulfide content in depth. In turn, geochemical investigations of geophysical anomalies give information about element composition of their sources.

The examples of case studies in various regions (Kola-Karelian region, Eastern Siberia, Peruvian Andes, etc.) will be included in our presentation.

C9.3

Lithological Discrimination in Deeply Weathered Terrains Using Multielement Geochemistry An example from the Yanfolila Gold Project, SW Mali

Chris Benn[1], Neil Jones[2], Kiril Mugerman[2]
[1]Gold Fields Canada, Vancouver, Canada, [2]Gold Fields Mali, Bamako, Mali

Lithogeochemistry has been successfully applied to gold exploration in deeply weathered terrains (Prendergast, 2007, Whitbread and Moore, 2004). The previously published studies have concentrated on fresh material but have used elements that are sufficiently robust for the outcomes to be applied at different levels of regolith profile. This paper describes the application of lithological discriminators determined in fresh material to saprolite and soil material. Robust classification templates have been constructed for the fresh, saprolite and soil material and incorporated into commercial software programs so that the project team can make rapid interpretations of new data.

The Yanfolila Gold Project is located in SW Mali and is hosted in a volcano-sedimentary sequence that is part of a middle Proterozic Birrimian age greenstone belt. A previously announced resource of 1.25 Moz has been defined and there is an ongoing exploration program. Consistent logging of the main rock types is difficult because of deep weathering and strong hydrothermal alteration.

Modern analytical methods such as a combination of ICP-MS and ICP-OES after digesting the samples with a four acid digest allow the detection of a very wide range of elements at very low detection limits. Systematic sampling and analysis of fresh material in diamond drill core produced data that allowed the discrimination of basalts, mafic sediments, siliciclastic sediments and felsic intrusives. Classification diagrams that were considered to be robust enough to be still valid in the weathering environment (saprolite) were constructed.

The classification diagrams were successfully validated using a set of bottom of hole air core drill samples and an interpreted geological map from logging of the drill cuttings for an area that covered one of the gold resources. The same classification diagrams were used for multielement data for soil samples that covered the same test area. At least one of the diagrams produced a separation of mafic and felsic rock types for the soil samples.

Careful development of classification diagrams using fresh material can produce a rapid and very cost effective of identifying basic rock types in weathered material.

The technique will be further developed by collecting geochemical data using a field portable XRF (FPXRF) and then devising modified discrimination templates. This will allow real time and cost efficient geochemical data to be collected.

References:
Prendergast, K., 2007. GEAA v7, 99-108.
Whitbread, M.A. & Moore, C.L., 2004. GEAA v4, 129-141.

C9.4

Application of 3D Multi-Element Geochemistry to Mineral Exploration and Development: Cerro Jumil Gold (Silver) Skarn Deposit, Mexico

L Graham Closs[1], Dean Turner[1], Bill Bond[1]
[1]Colorado School of Mines, Golden, Colorado, USA, [2]Exploration Geotechnologies, Littleton, Colorado, USA, [3]Esperanza Resources Corp, Denver, Colorado, USA

Three-dimensional geochemical modeling of multi-element drill hole data can provide key insights for the development of mineral system zonation models (Jackson, 2007). These models can be used to distinguish proximal to distal geochemical signatures, and to identify vector criteria to target mineralization. The contribution of 3D geochemical models to understanding mineralized systems is broadly recognized by the exploration community. As drill delineation of a mineral deposit progresses from exploration to resource definition, 3D geochemical models can also be an important adjunct for defining geologic, alteration, and mineralized domains for geostatistical modeling. The use of 3D geochemistry as an input for resource estimation has not been widely embraced by industry, and presents an opportunity to use this rich source of information to improve the resource modeling process and results.

This paper presents a case study that utilized 3D geochemical models in the development of a Canadian National Instrument 43-101 compliant resource estimate for the Cerro Jumil gold (silver) skarn deposit, located in Morelos, Mexico. The study is based upon an extensive drill database totaling 24,401 samples taken from 66 core holes (11,933m) and 180 reverse circulation holes (29,933m). This drilling covers the known extent of gold-silver mineralization on a nominal 35 m grid pattern. The samples were analyzed for 34/35 elements using aqua regia digestion and conventional ICP-AES determination. Gold was analyzed by fire assay with either an AAS finish or gravimetric finish (for higher grade samples >10g/t Au).

Univariate, and multivariate statistical, geostatistical, and spatial analytic techniques were employed in data analysis, synthesis and interpretation. A series of block models were developed using the multi-element geochemical data that were subsequently integrated with drill hole geologic and alteration information. This integration of 3D geochemical models with traditional geologic information provided a superior delineation of the precious metals mineralized zones at Cerro Jumil. Results are presented for precious metals, base metals and pathfinder elements. The collective contribution results in improved geostatistical modeling and resource reporting for the project and suggests directions for future exploration elsewhere on the property.

References:
Jackson, R.G., 2007. Applications of 3D Geochemistry to Mineral Exploration. Proc. Exploration 07: 317-330.

C10.1

Lithogeochemistry and Geology of the Palaeoproterozoic (1.88 Ga) Hitura Nickel Deposit, western Finland

Hannu V. Makkonen[1]*, Mikko Suikkanen*[2]*, Olli-Pekka Isomäki*[1]*, Ville-Matti Seppä*[1]
[1]Belvedere Mining Oy, Nivala, Finland, [2]Talvivaaran Kaivososakeyhtiö Oyj, Sotkamo, Finland

The Hitura ultramafic complex in western Finland consists of three separate, closely-spaced serpentinite massifs surrounded by migmatised mica gneisses. The horizontal extent of the complex at the bedrock surface is 0.3 km by 1.3 km. Deepest drilling intersections are at about 800 m level. Geophysical surveys indicate that the intrusion continues to at least 1000 m below the surface. The core of the complex is serpentinite and marginal zones consist of amphibole-rich ultramafic rocks. A minimum age estimate of 1877±2 Ma for the Hitura ultramafic complex is constrained by a felsic dyke intersecting the complex (Isohanni et al., 1985).

Nickel sulfide ore occurs mainly in the marginal zone parallel to the contact of the northern ultramafic body. Mining started at Hitura in 1970 and has continued, with intermittent breaks, until the present day, with a total of 16 Mt ore at 0.6 % Ni having been mined.

A lithogeochemical study on the Hitura complex was made to gain a better understanding of the genesis and further ore potential of the deposit. A total of 129 whole rock XRF analyses were made from drill core samples. Nickel, copper and cobalt were also analyzed from sulfide selective leach to get the metal content of the sulfide fraction. The difference between the XRF nickel content and nickel content in the sulfide fraction was used as the whole-rock silicate nickel content. Because the Hitura serpentinites are primarily olivine-rich cumulates the whole-rock silicate nickel content is close to the nickel content of the primary magmatic olivine. In addition the CIPW normative mineral composition was used to calculate the nickel content of the primary olivine. Microprobe analyses were made from rare olivine grains, from serpentine and from magnetite.

These results led to a reinterpretation of the Hitura complex. The internal stratigraphy of the northern ultramafic body was revealed, as shown for example by increases in whole-rock MgO, normative olivine and normative forsterite, Ni/Co of the sulphide fraction and decreases in whole rock SiO2 content towards the intrusion contact. A possible mechanism for generating this chemostratigraphy was a combination of flow differentiation and gravitational settling. Calculated olivine nickel and forsterite compositions indicate that olivine crystallized under sulfur-saturated conditions. The North and Middle Hitura bodies have similar olivine nickel contents while the South Hitura body has distinctly lower ones, suggesting more fractionated or more depleted melts for South Hitura.

According to the new results the Hitura complex can be interpreted as a sill-like cumulate body, which was folded to form its present shape. Consequently, the richest nickel sulfide ore is found in the marginal zone of the ultramafic complex, which represents the stratigraphic footwall of the primary olivine cumulate body.

C10.2

Interpretation of geochemical data to characterize variability in geometallurgical applications

Hugh de Souza, Cristian Dragusanu
SGS Minerals Services, Toronto, Ontario, Canada

The SGS Geometallurgical Framework is an iterative multi-stage process that is based on identifying implicit spatial domains in an orebody. This results in better modeling of metallurgical parameters to predict metal outputs as a means to reducing mine development risk. The domains are a unique combination of geological, geochemical, mineralogical and textural characteristics and provide a basis for representative sampling for metallurgical testing. However, as metallurgical testing is only performed on a small proportion of samples from the orebody, a key goal of the geometallurgical process is to relate metallurgical performance to its mineralogical components (Turner, 2010) If such relationships are realized it becomes possible to populate the block model for metallurgical response based on the mineralogical spatial variability.

The reality, however, for many advanced exploration project is that mineralogical data are often unavailable as they are not always considered a priority. Frequently, the only common data set that might exist for an orebody consists of geochemical data. The thesis presented here is that careful interpretation of these results yields meaningful and quantitative mineralogical data that can be used as proxies for the actual mineralogy for correlations with the metallurgical response.

Where whole rock data are available either by classical XRF methods or fusion ICP, recasting the major oxides into minerals can be used for normative calculations in a similar way to the well known CIPW calculations. This approach has been extended to other rock types, for example, the BQUANT calculations of Kimmerle et al. (1997) for quantifying bauxite mineralogy. Mass balance solvers based on a list of identified mineral species allow normative abundances to be close to actual modal abundances, that can be fully exploited in a geometallurgical approach. Alteration tracking by geochemical indices derived from major or minor element ratios can be used to establish metallogenetic hosting domain classifiers specific to ore types showing different mineral processing responses. The challenge of using the appropriate index is a consequence of the analytical technique involved, including the type of digestion that determines the recovery of a specific element. Where (OH) or water of crystallization data are available, they provide an index of alteration and potentially a proxy for hardness, a key metallurgical parameter related to grinding performance. In addition, we will show how S data from aqua regia digests are used to differentiate primary mineralization from sulphate and clay bearing leach cap zones.

References:
Kimmerle, F. et al., 1997. BQUANT: Cost-Effective Calculations of Bauxite Mineralogy, in: Light Metals, 9 - 11.
Turner, G., 2010. Vision for a risk averse integrated geometallurgy framework. Proc. 42nd Annual CMP Conference

C10.3

Pearce and General Element Ratio Diagrams: Molar Scatterplots Allowing Rigorous Investigation of Material Transfer in Geochemical Systems

Cliff Stanley
Dept. of Earth & Environmental Science, Acadia University, Wolfville, Nova Scotia, Canada

Element ratios are used in lithogeochemistry to avoid the effects of closure, a mathematical distortion of rock compositions caused by the constraint that the sum of element concentrations in a rock equal 100 %. As a result, examination of concentration ratios, instead of concentrations themselves, significantly simplifies data interpretation. Furthermore, use of molar ratios ensures that their variations relate to mineral formulae and chemical reaction stoichiometries. The imposition of a final constraint, that the denominator element is conserved (does not participate in material transfer process(es) that have caused compositional variation), creates a simple proportionality with material transfer. The resulting ratios (called Pearce element ratios - PER's) can then be used to identify the processes responsible for compositional variations in rocks. To test various petrologic or metasomatic material transfer hypotheses, linear combinations of PER's with common denominators can be plotted on scatterplots, and this strategy has successfully provided an understanding of the processes responsible for observed lithogeochemical variation.

An alternative molar element ratio has been developed that can likewise be used to investigate how material transfer processes have affected a suite of rocks. These general element ratios (GER's) are analogous to PER's, and are also plotted on scatterplots. However, these ratios contain a common denominator that is not only un-conserved, but also responds in a predictable way to the material transfer process being tested by the diagram. As a result, the behaviors of samples on such GER diagrams are more complicated than the analogous behavior of samples on GER diagrams, but are nevertheless just as predictable. Consequently, GER diagrams can also be used to test petrologic and metasomatic hypotheses to discover why rock compositions vary.

An important attribute of both PER and GER diagrams is that quantitative descriptions of the extent of material transfer can be determined by where samples plot on the diagrams. On PER diagrams, material transfer is proportional to ratio changes, so the axes numerically describe the extent of material transfer. On GER diagrams, the lever rule (common to petrologic T-X diagrams) applies, so results are equally quantitative. Thus, the extent of material transfer (e.g., fractional crystallization, hydrothermal alteration, weathering, sediment winnowing, etc.) can be determined for each sample. Many of these measures provide useful exploration vectors to mineralization.

Lastly, these PER and GER diagrams (collectively described as molar element ratio - MER - diagrams) allow investigation of the compositional controls in all lithogeochemical systems, because a conserved element will exist (thus PER diagrams can be used), or it won't (so GER diagrams can be used).

SS1

The early stages of geochemical mapping in Finland

Kalevi Kauranne
Espoo, Finland

Personal memories are here presented how pedogeochemical prospecting was started in Finland during the early 1950s and why it was extended to the whole country covering geochemical mapping in the early 1970s. A short description will be presented how complicated the process was, how many persons were involved knowingly or without it, how many factors do influence the results: human, technical, geological, geographical, political etc. It has been very rewarding to be closely incorporated with the very interesting development of applied geochemistry both in own country as well as internationally.

SS2
Highlights of exploration geochemistry in Finland

Heikki Papunen
Department of Geology, University of Turku, Turku, Finland

First attempts in Finland to apply geochemistry in mineral exploration date back to the 1940s, when the glacial boulder tracing was completed with till geochemistry. In mineralised areas ore element assays of vegetation were also tested with positive indications. Stream sediment surveys were applied for target generation in Lapland and eastern Finland early in the 1960s, and the study resulted in the discovery of the Pahtavuoma Zn-Cu deposit in 1971. Till geochemistry gradually became the main method and organic/mineral stream sediments were used only as regional target selection. Understanding of till stratigraphy and the directions and transport distances of the glacial float were instrumental in the interpretations of geochemical anomalies (Salonen 1986).

A curious atmogeochemical application was developed in the 1960s at the Geological Survey, where a dog was trained to sniff odour of sulphide boulders. Such a trained dog initially indicated the "Lari" Cu ore body at the Hällinmäki mining camp.

A new analytical technique generated at the Geological Survey Rovaniemi office allowed regional geochemical exploration for gold. The method applied reductive co-precipitation of gold with mercury from the aqua regia leach and analysing the precipitate with GFAAS (Niskavaara & Kontas, 1990). Application of the method pinpointed several new gold discoveries in Central Lapland.

Comprehensive lithogeochemical exploration programs were initiated in the 1960s. The nickel program of Outokumpu Oy included an initial study on the distribution of nickel between sulphide and silicate fractions The follow-up analytical program with several thousands of samples around Finland revealed areas favourable for Ni-Cu deposits (Häkli, 1971), and it was also instrumental in the discovery of the Laukunkangas Ni-Cu ore depoist. The completion of the program in the 1990s with a GeoNickel study led to a predictive model for Ni-Cu-PGE fertile intrusions (Lamberg, 2005). Another successful lithogeochemical study was targeted in the secondary cobalt dispersion halos of the Outokumpu-type ores, and the program led in 1965 to the discovery of blind Vuonos ore body in the Outokumpu mining camp (Huhma, 1970). Basic lithogeochemical exploration programs were realized on the ultramafic rocks of Lapland, on VMS-type deposits of the Vihanti, Orijärvi and Pyhäsalmi areas, Cu-W deposits of the Ylöjärvi batholit, porphyry-type Cu-Mo deposits and on gold mineralizations of southern Finland

References:
Häkli, T. A., 1971. Geological Society Finland, Bull. 43 (2), 247-263.
Huhma, M., 1970. Geological Society Finland, Bull. 42, 67-88.
Lamberg, P., 2005. Geological Survey Finland. Bull. 402.
Niskavaara, H. & Kontas, E., 1990. Analytica Chimica Acta 231 (2), 273-282.
Salonen, V.-P., 1986. Geological Survey Finland. Bull. 338.

SS3
Regional geochemical surveys in Australia

C.R.M. Butt
CSIRO Earth Science & Resource Engineering, Bentley, Australia

Regional geochemical surveys are a major omission from the pre-competitive exploration data available in Australia. The need for such surveys was first promoted in the 1960s and some surveys were undertaken from that time, mainly by industry. Nevertheless, in 1978, the Bureau of Mineral Resources (now Geoscience Australia), State Surveys and the mineral industry considered that 'in the short and medium term, systematic geochemical mapping of Australia should not be attempted'. As well as cost, this reticence was in part due to the absence of a sample medium suitable for all terrains, except at the broadest scales. The limited development of connected drainage, for example, restricts the general use of stream sediments to regions with relatively higher relief. Thus, during 1994-2001, the Geological Survey of Western Australia surveyed several individual 1:250,000 map sheets, based where possible on stream sediment sampling, but for those in areas of low relief and deep weathering, it was necessary to supplement the coverage with a range of other media, somewhat compromising the data. This lack of a uniform sample medium is a problem common to many land areas of the size of the Australian continent, and the solution is to adopt terrain-specific sampling procedures. Examples of such surveys in Australia include:

Laterite surveys based on sampling residual ferruginous pisoliths in deeply weathered terrain. These can be applied over a range of scales and were the basis of a regional survey covering 250,000 km^2 of the western Yilgarn Craton, sampled on a 9-km triangular grid. Ferruginous lag provides an analogous transported sample that is also present in depositional areas, where it may detect distal anomalies, although ineffective for exploring through the cover sediments themselves.

Pedogenic calcrete surveys, applicable at regional to local scales in semi-arid southern Australia, including areas with shallow (<10m overburden). These are specific for gold and have been especially effective on the Gawler Craton, contributing to a major increase in exploration.

Fine fraction soil surveys in arid areas that detect mineralization and lithological changes through transported overburden

Hydrogeochemical groundwater surveys, especially in arid pastoral regions, where stock bores supplement exploration drilling.

Biogeochemical surveys based on sampling specific Acacia and Eucalyptus species.

Even where such surveys partially or wholly overlap, levelling data to provide continuous coverage is a major challenge.

SS4

Mineral Exploration at Spitsbergen in the High Arctic

Rolf Tore Ottesen[1] *and Morten Often*[2]
[1]Geological Survey of Norway, Trondheim, Norway,
[2]Store Norske Gull AS, Longyearbyen, Norway

Svalbard is one of the few places in the world which provides excellent access to study sections that represent most of the Earth's history, although a large part of the land area is covered by glaciers. This is due to limited soil cover in Svalbard, such that the rock formations are not hidden by vegetation. The naked landscape permits clear insight into its geological structure. The geological record ranges from Archaean to Recent and shows a multi-orogenic development with prominent tectonic events.

In the 1980s there was great interest in prospecting for oil, gas and minerals in Spitsbergen, the main island of Svalbard. Norsk Hydro and Store Norske Spitsbergen Kulkompani contacted the Geological Survey of Norway (NGU) in 1986 and asked for help to map the island geochemically. Overbank sediment samples had just been mapped in Norway, and it was agreed to use the same sample media in Spitsbergen. 650 samples of overbank sediments were collected and analyzed for the content of 50 elements. All the data were released for public use in 2005. A marked arsenic province along the west coast has been the target for gold prospecting on Spitsbergen. High concentrations of gold are detected in bedrock. A marked REE province exists in the northeastern part of the island.

SS5

The use of dogs in prospecting

Jorma O. Valkama[1], *V. Juhani Ojala*[2]
[1]Geological Survey of Finland, Rovaniemi, Finland,
[2]Store Norske Gull AS, Rovaniemi, Finland

Between 1964 and 1994, dogs (German Shepherds) were used by the Geological Survey of Finland (GTK) for tracing sulphide-containing boulders. Professor A. Kahma and T. Mustonen wondered in spring 1962whether dogs could smell a rock containing sulphide ore, they, as most geologists world wide, have noticed, sulphides give an odor especially when broken. They contacted late Mr Pentti Mattsson, a well know Finnish dog trainer, and asked if it would be possible to train a dog to smell ore. Mattsson asked if they smell, then it would be possible to train dogs for such a purpose. Mattsson started training a dog with pyrite boulders and soon they organised variety of experiments, with which the dog coped very well. Even in the winter, while braving freezing weather and deep snow, the dog found chalcopyrite boulders under the snow, and their belief about the dog's skills began to get stronger. The world's first prospecting dog Mattsson trained was Rajan Lari. Lari was trained to become the first prospecting dog in Finland and in the whole world.

GTK used 16 prospecting dogs between 1964 and 1994 and mid 1980's there were eight dogs being used around Finland. The training methods for prospecting dogs were based on Pentti Mattsson's results obtained through experiments. In one test conducted in Virtasalmi in 1965, in an area covering over 9 km^2, the dog found 1330 boulders containing sulphide in the test area, whereas the boulder prospector managed to find only 270 boulders, even though he knew that he was competing against a dog. The dogs were most effective smelling sulphide bearing rocks, including pyrrhotite, chalcopyrite, pyrite, galena and molybdenum. Based on Mattsson's example and training methods, the training of the world's first drug detection dogs began in the UK.

The dog's effective working time was about six years and fieldwork period was about 6 months per year. The costs incurred by a prospecting dog consist mainly of the dog trainer's salary and other maintenance costs. The most valuable use was after a boulder discovery when dogs could quickly find more boulders to trace the source, and dogs played a role locating several mineralisations. In 1994, even though the overall results had been quite good, the use of dog was considered to be too expensive.

AAG's Distinguished Lecturers

AAG1

Considerations for optimizing screen (metallics) gold fire assay

Scott Long
AMEC, Mining & Metals: Mining Consulting Group (formely MRDI), USA

Screen fire assays for gold use the same procedures as "conventional" gold fire assays, except that some steps are added preceding the fire assay that create from each sample two or more samples subjected to fire assay. These samples are created by passing a pulverized sample through a fine screen to produce a small mass atop the screen (the "coarse fraction") and a much larger "fine fraction". The coarse fraction is fire-assayed in its entirety and one or more representative samples of the fine fraction are also assayed. The mass-weighted average of the coarse and fine fractions is calculated for the final result.

The size, shape, and composition of a sample's gold particles determine how much benefit can be obtained from screen fire assaying compared with conventional fire assay. The size of the largest gold particles determine the "nugget effect". Clifton's "20 particle rule" provides an easy way to estimate from the maximum gold particle size, the minimum fire assay mass needed to obtain a repeatable result at a specified minimum gold grade.

Important parameters that should be tailored to a project's needs are:

- Amount of grinding: over-grinding can result in Au losses and/or contamination.
- Screen size: a finer screen size produces a more reliable result but adds cost if the mass of the coarse fraction is too large to be assayed in one crucible
- Sub-sampling the fine fraction: mistakes are commonplace; good agreement of duplicates in the sub-sample does not indicate accurate results, quite the contrary is more often true.

Duplicates and standard reference materials are seldom used to evaluate and monitor screen fire assay performance. Such controls should be used, particularly in an initial evaluation of any laboratory. Such standards can be made by placing 20 gold particles obtained from gravimetric gold fire assay into a gold certified reference material. The weights (and inferred sizes) of the individual particles are used to evaluate the effectiveness of the screening. One must use a certified reference material that included sufficiently fine screening as part of its preparation process.

AAG2

The Role of Applied Geochemistry in the Mining Life Cycle

Robert Bowell
SRK Consulting, Cardiff, UK

The field of geochemistry involves study of the chemical composition of the Earth, chemical processes and reactions that govern the composition of rocks, water, and soils, and the cycles of matter and energy that transport the Earth's chemical components in time and space, and their interaction with the hydrosphere and the atmosphere. In the context of mining projects, the skills of applied geochemistry can be utilized at almost every step in a mining project from initial discovery through development, production and final closure.

This presentation will present an overview of the role of applied geochemistry in the Mine Life Cycle. The role of geochemistry in exploration is well understood and this presentation will rather focus on the role of geochemistry in mine design, engineering studies and environmental assessment. The concept of the sub-discipline Geochemical Engineering will be explored in the context of mining and the presentation illustrated with case studies from operational and developing mines globally.

Poster presentations

P1

An Ion Chromatography Method for the Determination of Soluble Salts in Soil Samples from Cyprus

Andreas Zissimos[1], Irene Christoforou[1], Eleni Morisseau[1], David Cohen[2]
[1]Geolgical Survey Department, Strovolos, Cyprus, [2]University of New South Wales, Sydney, NSW, Australia

The soluble salt content of soils is an important indicator of potential environmental stress. Despite the importance of soluble salts in environmental monitoring, there are no commonly-agreed standards for their determination. Ion chromatography has been used in the past for measuring soluble salts with varying success (Park et al., 2002).

The Geochemical Atlas of Cyprus involved analysis of >11,000 soil samples from 5,516 sites (Cohen et al., 2011). In addition to total and aqua regia-extractable metals, an in-house method has been developed for aqueous extraction of soluble salts from the soils with determination by liquid chromatography. After extraction of the soluble ions into water and filtering, dissolved anions were determined by liquid chromatography using a Shimadzu ion chromatograph with a 50 µl sample loop. The system included an anion guard column, a column for simultaneous separation of anions, an anion self-generating suppressor package, a pulsed electrochemical detector and advanced gradient pump. Eluents were delivered to the columns by a Shimadzu eluent degasser.

Elevated values of F^- are observed in the vicinity of salt lakes in Cyprus. The average F^- concentration is 17.4 mg/kg and the maximum is 1,380 mg/kg (world average: 200-300 mg/kg). Poor correlation between F^- and NO_3^- suggests elevated F^- is not related to fertilisers, the major source of F^- contamination in agricultural soils (Neumüller, 1981). Apatite is a common accessory mineral in mafics and slowly breaks down in soils (Kabata Pendias & Pendias, 1984). Apatite was detected in heavy mineral concentrates at various sites across Cyprus. The main source of Cl^- is meteoric waters, although saltwater intrusions occur along the coast. In the salt lakes Cl^- values range up to 0.3 %. Elsewhere the mean Cl^- is 587 mg/kg. The major source of NO_3^- in Cyprus soils is synthetic fertilisers. The mean NO_3^- value is 63.2 mg/kg and the maximum value is 3,000 mg/kg. Most high values are within "nitrate-vulnerable zones" (GSD, 2000) where the mean is 130 mg/kg. The main geogenic source of SO_4^{2-} is sulfide oxidation, otherwise contents closely reflect parent geology. The mean is 150.2 mg/kg and the maximum is 1.6,% near a Cu mine.

The results of the chemical analysis indicate a correlation between the concentration of some soluble salt ions, F^-, Cl^- and SO_4^{2-} , and parent lithology to the soils (geogenic) and NO_3^- with non-geogenic processes related to land use.

References:

Cohen, D.R. et al., 2011. Geochemical Atlas of Cyprus. UNSW Press, Sydney.

Geological Survey Department of Cyprus, 2000. Study of the Protection of Waters Caused by Nitrates from Agricultural Sources (Directive 91/676/EEC).

Kabata Pendias, A. & Pendias, H., 1984. Trace elements in soil and plants, CRC Press, Boca Raton. 209-215.

Neumüller, O., 1981. Römpps Chemie Lexikon, 8th Ed. Franck'sch Verlagshandlung.

Park, H.M. et al., 2002. Analytical Sciences, 18, 343.

P2

Novel Geological Exploration Applications of Mobile Metal Ion Technology using Dynamic Reac-tion Cell ICP-MS

Nicholas Turner, Pierrette Prince
SGS Minerals Services, Toronto, Canada

Mobile Metal Ion (MMITM) Technology is a commercially available leach that is used for a variety of resource identification and lithological projects (Mann et al., 1998). The principle of MMI is that mobile ions associated with an ore body rise to the surface over a period of time. These ions adhere to soil particles at the surface and can be selectively extracted by mixing the sample with MMI solution. The resultant extract is measured for a variety of elements using ICP-MS in order to determine the position of the ore body through identification of anomalies over background levels. Originally, this technique was used for precious and base metal target commodities, but has since expanded to provide data on a wide range of potential ore bodies. There are, however, some critical elements that cannot be measured at low levels using ICP-MS because of matrix and sample interferences. The aim of the work described here was to use Dynamic Reaction Cell (DRC) ICP-MS technology to overcome these issues to expand the applicability of the MMI technique to new areas of exploration.

Chromium is an important element in the identification of kimberlitic pipes for diamond exploration and for ultramafic lithologies in nickel exploration. However, it is a difficult element to measure at low concentrations due to matrix interferences. A new method was developed using DRC-ICP-MS with ammonia gas to eliminate the interfering species, resulting in a limit of detection of 1ppb. A successful test was carried out over a known nickel deposit to show the effectiveness of Cr analysis using this methodology. Vanadium is an important element in uranium exploration, but cannot be measured at low levels due to interference from chloride based ions. Again, using ammonia gas, the interfering ions can be removed during analysis and a low detection limit (1ppb) achieved. The importance of vanadium was illustrated by its relationship with uranium at a known uranium deposit in Australia.

Sulphur is a further element that is important in various fields such as nickel and oil and gas explorations. There is a significant impediment to sulphur analysis by ICP-MS, in that oxygen species occur at the same mass, severely limiting its measurement. A new method was developed using additional oxygen gas in the DRC in order to move the sulphur by oxidation and measuring the SO^+ product at mass 50. A detection limit of 0.1ppm was achieved, and shown to work over a known nickel sulphide deposit. Further testing of an anomaly over a known natural gas deposit illustrated the potential use of the technique to oil and gas exploration.

Reference:
Mann, A.W., Birrell, R.D., Mann, A.T., Humphreys, D.B. and Perdix, J.L., 1998. Journal of Geochemical Exploration, 61, 87-102.

P3

Modifying the Diffusive Gradients in Thin Films Technique for the Geochemical Exploration of Gold

Andrew Lucas[1], Andrew Rate[1], Ursula Salmon[1], Hao Zhang[2]
[1]University of Western Australia, Perth, WA, Australia, [2]Lancaster University, Lancaster, UK

Gold is a precious metal that exists in soils, sediments and natural waters at extremely low concentrations (>1 ppb). The diffusive gradients in thin films (DGT) technique, which has been used extensively to monitor trace concentrations of metals in soils, sediments and waters, is likely to be ideally suited for geochemical exploration for gold in these environments. This article details the development of a DGT method for the analysis of gold in solution, and introduces a new binding-layer based on activated carbon. The performance of this new technique was assessed by: 1) determining the diffusion coefficient of gold (as aqueous gold (III) chloride); 2) assessing the capacity of the new binding layer to adsorb gold; 3) determining the elution methodology from the binding layer; 4) assessing possible interference from other environmentally labile metals, and; 5) determining the effect of ionic strength and pH on performance. The technique has significant potential to be used for the geochemical exploration of gold in aqueous environments.

References:
Ma, Y. and Rate, A. W., 2009. Geochemistry: Exploration, Environment, Analysis 9, 353-367.
Radford, N. W. and Burton, P. E., 1999. Journal of Geochemical Exploration 66, 71-83.
Zhang, H. and Davison, W., 1999. Analytica Chimica Acta 398, 329-340.

P4

Zircon U-Pb geochronology of the Jade of the Medal for the Beijing 2008 Olympic Games

Zhengyu Zhou, Hao Cheng
School of Ocean and Earth Science, Tongji University, Shanghai, China

Jade is a semiprecious gemstone and is found widely around the world, particularly in ultramafic rocks associated with ophiolite complexes and in metamorphosed dolomites (Harlow & Sorensen, 2005). Jade is essentially a monomineralic rock that occurs in two forms: most commonly as a tremolite-amphibole type, nephrite, and less commonly, the pyroxene-type, jadeitite.

The medal for the Beijing 2008 Olympic Games is designed with inspiration coming from “bi”, China’s ancient jade piece inscribed with a dragon pattern. The jade is a jade of the nephrite type. Nephrite jade normally comprises >99 % microcrystalline amphibole, generally in the tremolite-actinolite series but, with high quality, close to tremolite. The specialist can recognise particular features in jades from different ‘fields’, for example, in terms of toughness, texture, colour and inclusions, but these features are not necessarily distinctive. Furthermore, there is thus little potential variation in major element composition, either amongst nephrites at any one locality, or between unrelated localities around the world (Adams et al., 2007). A potentially distinctive feature of jades is their geological age. All jades are formed by recrystallisation of original rocks (protolith) at low-moderate temperatures and pressures, either during metamorphism and/or metasomatism.

Combined petrologic and zircon U-Pb analyses were performed for the Kunlun nephrite in an attempt to unravel its origin in comparison with the host rocks. The nephrite orebodies are hosted by high-angle thrust faults with the diabase intrusive within the dolomite strata. Ca decreases sharply from dolomite to contact zone, while Mg decreases from diabase intrusive and dolomite strata to the nephrite. The dolomite supplied Ca and most of Mg for forming the nephrite, while the diabase offered Si and Mg. SIMS zircons U-Pb ages of 210 Ma is interpreted as the crystallization age of the nephrite and providing a maximum age for mineralization, which is in good agreement with the age of the closing of paleo-tethys ocean. Previous researches on basalts and lithospheric evolution of the east Kunlun orogen have indicated that the paleo-Tethys ocean began to subduct northward in early Indosinian. And the late Indosinian tectonic episode in east Kunlun could be described as an extension-contraction cycle in a convergent plate margin setting above the subduction zone. The extension period due to the subduction of paleo-tethys ocean crust provide the intrusive of the diabase thus formed a favourable ore-forming setting for nephrite mineralization. The contractional period characterized by the final closing of the ocean and the strong collision provide the structural force which leads to the recrystallization of the tremolite and the formation of the typical micro-fibrous interlace texture of the nephrite.

References:
Harlow, G.E. & Sorensen, S.S., 2005. International Geology Review 47, 113-146.
Adamsa et al., Lithos 97, 307-322.

P5

Examining the geochemical potential for using multiple isotope systems in the basement lithologies of the Athabasca Basin to vector towards mineralization

Robert Millar[1], Irvine R. Annesley[3], Kevin Ansdell[1]
[1]University of Saskatchewan, Saskatoon, SK, Canada, [2]Saskatchewan Research Council, Saskatoon, SK, Canada, [3]JNR Resources, Saskatoon, SK, Canada

The Proterozoic Athabasca Basin in northwestern Saskatchewan, Canada contains the largest unconformity-type (U/C-type) uranium deposits in the world. Covering nearly 100,000 km^2 the Athabasca Basin is comprised of a sedimentary rock sequence underlain by Archean to Paleoproterozoic metamorphosed basement rocks, which include graphitic pelitic gneisses and granitic pegmatites (Annesley et al., 2005). Major faults cutting these rocks, and related to the Talston Magmatic Zone and the Trans Hudson Orogen, were reactivated episodically and thus provided focal points for fluid flow and mixing.

Many researchers agree that oxidized basinal brines flowed through the Athabasca Basin and the basement rocks below the unconformity. Mixing of oxidized basinal brines with reducing fluids or reduced rocks caused changes in the redox chemistry of fluids transporting uranium to precipitate uranium below, at or above the unconformity (Alexandre et al., 2005). This project focuses on basement rocks from the eastern Athabasca basin (i.e. within the eastern Mudjatik Domain and western Wollaston Domain) proximal to known uranium mineralization at Dawn Lake (circa 10ktU at a grade of approximately 1.5%) (Jefferson et al. 2007).

The Dawn Lake region encompasses relatively fresh to altered basement lithologies containing many different mineral assemblages. An abundance of Li, B, Th, Pb, and U is precipitated within minerals such as chlorite, micas, tourmaline, monazite and zircons. We have selected a suite of samples with these minerals proximal to some U/C-type uranium deposits.

U-Th-Pb radiogenic isotopes have been used extensively in the Athabasca basin to date deposits and as a pathfinder to new discoveries. Many researchers have determined in several studies outside of the Athabasca Basin that the B and Li isotope systems have good potential in determining fluid flow pathways and their conditions (Tomascak, 2004). Both d^{11}B and d ^{7}Li increase with increased hydrothermal activity and fluid flow as the heavier isotope preferentially partition into the fluids.

Initial geochemical results from a group of granitic pegmatites, graphitic pelitic gneisses, and pelitic gneisses show that there are significant amounts of Li, B, Th, Pb, and U, and their isotopes in all of these rock types. The availability of the minerals in the research area provides the possibility of using multiple isotope systems including radiogenic U-Th-Pb along with the stable isotope systems B and Li to constrain fluid flows in the basement lithologies below the Athabasca basin.

References:
Alexandre et al., 2005. Economic Geology, 100, 1547-1563.
Annesley et al., 2005. Canadian Journal Earth Science, 42, 573-597
Jefferson et al., 2007. EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta. Geol Survey Canada, Bulletin 588, 23-67.
Tomascak, 2004. Reviews in Mineralogy &Geochemistry, 55, 153-195.

P6

Magma genesis in the El Teniente Porphyry Copper and implications to tectono-magmatic evolution of the Central Chile Neogene Metallogenic Belt

Marcia Muñoz[1], Brian Townley[1], Reynaldo Charrier[1], Mark Fanning[2], Victor Maksaev[1], Katja Deckart[1]
[1]Department of Geology, University of Chile, Santiago, Chile, [2]Research School of Earth Sciences, Australian National University, Camberra, Australia

The Neogene Metallogenic Belt of the Andes of Central Chile, between 32º-36ºS, is one of the most richly endowed copper provinces in the world. It hosts several world class porphyry copper deposits formed during Miocene-Pliocene times. Among this is the El Teniente, a mega-deposit associated with upper-crustal multievent intrusive and hydrothermal processes. We have addressed the petrogenesis of the heavily-altered, mineralization-related, igneous rocks from El Teniente through microanalythical techniques over igneous zircon crystals. Five syn- and late- mineralization intrusive rocks, stocks and dykes, ranging from ~ 6.4-4.4 Ma (Maksaev et al., 2004) were selected for sampling. Analyses include the study of crystal morphology and internal structure (CL-imaging), and in-situ determinations of U-Pb ages, chemical (U, Th, Ti, REE) and O-isotopic composition (SHRIMP), and Hf-isotopic composition (LA-ICP-MS).

El Teniente zircons show morphological and chemical characteristics typical of crustal zircons, but they qualitatively characterize an evolutionary trend for the evolving magmatic system. Zircon Hf and O isotopic composition indicate a primary control from the source as opposed to any significant crustal contamination and AFC-like processes involved in magma genesis. The initial Hf signature (total average 7.4 ± 1.2, 2σ) indicates a relatively juvenile source. The δ^{18}OZrc average of 4.7 ± 1.0‰ (2σ) is lower than the normal mantle zircon range of 5.3 ± 0.3‰ (1σ), and reflects crystallization from low-^{18}O magmas.

Lately published data on Hf isotopic composition of barren igneous rocks from Central Chile shows that Cenozoic magmatism, including that from El Teniente, is remarkably homogeneous through little more than 25 m.y. This strongly suggests that a common and stable source, probably located deep lithosphere, has buffered the observed composition. Dehydration melting of this zone in response to crustal thickening is likely to generate fertile magmas with a low-^{18}O signature, like those from El Teniente. This is a process occurring at a regional scale and can explain regional simultaneous formation of this type of deposits as seen in the Neogene Metallogenic Belt from central Chile.

According to these results, in the context Cenozoic evolution of Central Chile, main difference between barren and fertile magmas resides in the melting processes. In turn, this is reflected in a depleted O-isotopic composition, which constitutes a tectono-magmatic marker for potential porphyry copper environments from background. Combined with geology and structural studies, these studies can provide information for regional to local exploration of giant porphyry copper systems in the Andes of Central Chile.

Acknowledgements: Research was fully funded by project Anillo ACT-18 project, PBCT program, jointly with CODELCO - Chile, and the DPP - Univ. de Chile.

References:
Maksaev et al., 2004. Andean Metallogeny: New Discoveries, Concepts and Updates, Society of Economic Geologists Special Publication 11: 15-54.

P7

Geochemistry of overburden and surface sea sediments at the Olkiluoto Island area, SW Finland

Anne-Maj Lahdenperä
Pöyry Finland oy, Vantaa, Finland

The Olkiluoto Island is selected for the final disposal repository site for the spent nuclear fuel from the Finnish nuclear power plants. Due to land uplift, in coastal areas of the Bothnian Sea, sea-bottom sediments are continuously emerging from the sea, starting a rapid succession along the shores. The development of the shoreline will induce changes in local biosphere conditions, such as ecosystem succession, sediment redistribution and groundwater discharge and recharge. Olkiluoto is relatively flat, with an average elevation being about 5 m.a.s.l. During the next several thousand years, the bays surrounding the coastal areas will narrow and become isolated as lakes and further develop toward mires (Haapanen et al., 2009).

The soils at Olkiluoto are young, and thus the soil horizons are not well developed. The main soil types are sandy and fine-textured till with clay, sand and weathered layers. The geochemical and physical properties of overburden are of interest both for understanding of the site evolution and for radionuclide analyses. The overburden changes the composition of the infiltrating water and thus affects the groundwater discharge and recharge.

The geochemical properties of 21 deep soil pits are investigated detailed at Olkiluoto. Samples were taken from vertical overburden profiles of the humus and different mineral soil layers. The concentrations of multi-element analysis of the easily leachable and total concentrations were measured, as well pH, carbon, nitrogen, moisture and grain-size distribution (Lintinen et al., 2003; Lintinen & Kahelin, 2003; Lahdenperä, 2009).

Ten recent gyttja/muddy clay and three sandy/gravel surface sediment cores were sampled from the Olkiluoto sea area during the Geomari cruise (Kotilainen et al., 2008). In addition, Alleco Ltd sampled 57 surface sea sediment cores from the six transects by diving from the Olkiluoto offshore, providing new information on variation and continuity of physical and geochemical properties of the near coastal sea areas around the Olkiluoto Island (Ilmarinen et al., 2009). The analyses included: pH, carbon, nitrogen, LOI, moisture, grain size distribution, and the total element concentrations.

The main reasons for the heterogeneous of the soil and sediment geochemistry were variation in organic matter content and the amount of clay and fine fraction contents between the sampling sites and their depths. Organic matter, gyttja, clay and silt fractions are the most active due their large surface area.

References:
Haapanen et al., 2009. POSIVA Report 2009-02. 424p.
lmarinen et al., 2009. Posiva Working Report 2009-12.
Kotilainen et al., 2008. Geomari Cruise Report, GSF.
Lahdenperä, A-M., 2009. Posiva Working Report 2009-109. 88 p.
Lintinen et al., 2003. Posiva Working Report 2003-01. 123 p.
Lintinen, P. & Kahelin, H., 2003. Posiva Working Report 2003-38. 29 p.

P8

A multispecies tracer test in a detritic aquifer (SE Spain)

Gloria Teijón[1], Joaquín Jiménez-Martínez[2], Lucila Candela[1]
[1]Department of Geotechnical Engineering. Technical University of Catalonia, Barcelona, Spain, [2]Geosciences Rennes UMR 6118. Université de Rennes 1, Rennes, France

At the Mar Menor area (SE Spain) tracer tests were conducted in an unconfined detritic aquifer (Robles-Arenas and Candela, 2010), in order to define geohydrological properties of the media for pollutants transport modelling purposes. The tests, which took place during three days in July 2010, were conducted in two steps using non-reactive and reactive tracers: 1) a single-well tracer test (push-pull) with pentafluorobenzoic acid (PFBA), and 2) a cross-hole tracer test under induced hydraulic gradient conditions performed with LiBr and I131 (Ptak and Teusch, 1994). Lithium (as LiBr) was selected as a weakly-sorbing tracer by cation exchange processes, as reactive tracers can provide additional information on conceptual transport model as well as in-situ sorption parameters.

Starting heads at pumping well and piezometer (in full screen), were at 0.84 m depth. The distance between them was 3.45 m. The pump setting was 12 m deep. A pumping test at a 1L/s discharge, was carried out until steady-state flux conditions were reached as determined from pressure sensors, before the second tracer test. The drawdown was 4.52 and 0.16 m for pumping well and piezometer, respectively. Pumped water was manually sampled at specified time intervals to be analysed at the laboratory (PFBA and LiBr) or in the field monitored (I131). Temperature, electrical conductivity, pH and turbidity were also monitored.

The first tracer test consisted of a PFBA 14.4 mM solution punctually injected in the pumping well. After drifting with the natural gradient for 750 min, tracer was pumped back and sampled at given times (during 300 min) in the pumping well. Break through occurred immediately after pumping. Once steady-state flux conditions were established, a pulse injection (full mixing column) of both LiBr 2.3 M and 90 mCi of I131 was initiated in the piezometer and recovered by pumping. Ten minutes after injection, manual grab water samples were taken from a pumping well bypass for LiBr content, while radio-tracer measurements were directly recorded in a Mount Sopris Instrument Company device. Sampling and readings (at 60 s interval) lasted after 1050 min of the injection.

All tracer responses were analysed qualitatively, also observed non-conservative Li tracer response was compared with the conservative tracers behaviour. Br and I131 increasing concentration in samples was observed, but a decreasing rate and clear peak were not observed. It is possible, that I131 concentration was below the detectable limits or retention occurred by soil adsorption (Hamid and Warkentin, 1967); the possibility that the test finished before a peak was observed should be also taken into consideration.

References:
Hamid, A. & Warketin, B.P., 1967. Soil Science 104: 4, 279-282.
Ptak, T. & Teusch, G., 1994. Journal of Hydrology 159, 79-104.
Robles-Arenas, V. & Candela, L., 2010. GeologicaActa 8:3, 235-248.

P9

Fluoride contamination in ground- and surface-water in La Aldea valley (Gran Canaria, Canary Islands, Spain): past and present

Tatiana Cruz[1], Montserrat Espino-Mesa[2], Annetty Benavides[3], María del Carmen Cabrera[4], José Manuel Hernández-Moreno[5]
[1]University of Las Palmas de gran Canaria, Las Palmas, Gran Canaria, Spain, [2]Área de Salud, Las Palmas, Gran Canaria, Spain, [3]University of Las Palmas de gran Canaria, Las Palmas, Gran Canaria, Spain, [4]University of Las Palmas de gran Canaria, Las Palmas, Gran Canaria, Spain, 5University of La Laguna, La Laguna, Tenerife, Spain

Dental fluorosis has had a high prevalence in some regions of the Canary Islands until the mid nineties when municipal water supplies were changed. In these regions, large fluoride concentration in groundwater was associated with alkaline volcanism (Espino-Mesa et al., 1983). One of these regions, the Aldea aquifer, located on the coastal western side of the Gran Canaria Island, offers peculiar characteristics for hydrogeological investigation (Cruz, 2008). It is the lower part of a ravine where a sedimentary unit (consisting of detritical material with phonolites-trachytes, ignimbrites and basalts boulders) is located beneath a volcanic unit consisting of Miocene basalts. The eastern limit of the aquifer is constituted by a mechanic contact with a volcanic Caldera that was filled by Miocene trachytes, and phonolitic ignimbrites. Hydrothermal deposits crop up along the intra-caldera border (Azulejos). There is a residual relief (Las Tabladas) in the study area with a complex geology, where azulejos deposits crop out. The area main economic activity is intensive greenhouse horticulture. Irrigation water comes mainly from three dams located upstream of the study area, but more than 370 large-diameter wells are exploited in times of drought. The intensive agriculture has an important impact on the aquifer, degrading groundwater quality and, during droughts, causing the drawdown of groundwater levels. Currently, a desalinization plant provides water for irrigation and human consumption.

In this work, quality from several types of water (dams, wells, springs, source, ooze, return flows and irrigation water) at different sampling dates has been studied. Fluoride concentration in soils and rocks was also determined (total and batch analysis). Solution chemistry and mineral equilibrium were performed using the Aquachem computer program. The areas with high fluoride concentrations have been identified, and the possible causes for its variation have been investigated. Fluoride concentration seemed to be limited by fluorite solubility. Hydrothermal deposits showed the highest fluoride concentration and solubility. Water-rock interaction is probably the main reason for the high concentration of ions in groundwater increased by cyclic reuse of irrigation water.

References:
Cruz, T., 2008. Doctoral Thesis. University of Las Palmas de Gran Canaria.
Espino-Mesa, M. et al., 1983. Proceedings V Spanish National Congress of Chemistry. Chemistry and technology of water. Puerto de la Cruz (Tenerife). Vol III(453-463).

P10

Exploring for Ni mineralisation beneath cover using soil and vegetation at North Miitel, Kambalda, Western Australia

Melvyn Lintern, Ryan Noble, Nathan Reid, Ravi Anand
CSIRO, Kensington, WA, Australia

In this study, eucalyptus trees and some other common plants were investigated at North Miitel Ni deposit for their use in exploring for Ni mineralisation beneath cover. North Miitel is located ~90 km S of Kalgoorlie, Western Australia.

Economic Ni ore is deep (~400 m) in the North Miitel area. The mineralisation is typical of the Kambalda-style, komatiite-hosted NiS ore bodies, and consists of massive, matrix and disseminated sulphides.

Small pods of NiS mineralisation occur higher in the profile, with a minor zone of supergene enrichment at the weathering front. This enrichment zone is thin (vertically <2 m) and does not have a large lateral dispersion, which may be attributed to the paucity of deep weathering (~5 m). The in situ weathered zone is barely 2 m thick in places. The cover sequence itself is 5-10 m deep and is comprised (from the surface) of 2 m of aeolian sediments (clay, sand and pedogenic carbonate), 6 m of lacustrine and mottled clays and 2 m of residual clays.

The study was divided into two: a preliminary traverse followed by a more extensive grid-based survey. A preliminary traverse (1.5 km in length) orientated perpendicular to the strike of the mineralisation (NNE) investigated the use of leaves, bark, litter, organic-rich soil and soils from pits. This was followed up by a more extensive 3x3 km survey of litter and organic-rich soil on a 150 m offset grid. The results showed that the surface soil and biogeochemistry were influenced to some degree by contamination from the haul road. Directly over mineralisation some elements showed anomalous concentrations but data were erratic and not significant using hypergeometric statistics. In summary, our assessment of the potential to explore through cover in the North Miitel area indicates that mineralisation or shallow supergene-enrichment beneath transported cover is effectively blind to these surface sampling techniques in areas with secondary surface contamination.

Despite the shallow mineralisation and highly saline groundwater, the plants are ineffective at identifying buried mineralisation at North Miitel. Plant-root movement is most likely retarded by the saline (and acidic) nature of the groundwater. The roots may not grow beneath the water table or lower depths of the regolith and in turn cannot adsorb metals from the thin, supergene zone directly overlying the mineralisation. While many biogeochemical successes are reported in the literature it is also important to record failures as this will assist us defining the boundaries of which, where, how and when geochemical techniques work.

P11

Geochemical Cycle of Selenium in the Catchment of Fujiang River

Tao Yu[1], Zhongfang Yang[1], Qingye Hou[1], Xiaohuan Xi[2], Xueqi Xia[1]

[1]China University of Geosciences,Beijing, Beijing, China, 2China Geological Survey, Beijing, China

The China Geological Survey (CGS) has conducted a multi-purpose regional geochemical survey projectcovering an area over 1,600,000 km^2 in China since 1999 (Xi, 2005). The catchment of the Fujiang River, as a part of Yangtze River, covers an area of approximately 36,400 km^2. Previous investigation indicates that selenium concentrations of soils varied from high to low along the river, and higher selenium concentrations are mainly distributed along riverside areas with width less than 3 km to the river bed.

In each sample site, crops and soils were collected after harvesting season. Atmospheric deposition, fertilizer, infiltration materials of precipitation water, irrigation water were also collected. Atmospheric deposition sampling equipments were placed for one year. The samples were analyzed for selenium by ICP-MS and accuracy and precision of determinations were controlled by standard reference samples .

Element contents in top soils are correlated with the soil-forming parent materials and the leaching degree of the elements in the process of soil formation, and are also closely related to human activities (Yang et al., 2007; Tan, 2004). In regional scale, Se input is from fertilization, irrigation and atmospheric deposition, and output is due to crop absorption, infiltration of precipitation, and elements from solids to gases to reduce sublimation, etc (Zhao et al., 2005).

We calculated the flux of Se in the tilth soils. The total input flux of Se is 20.45 $g{\bullet}hm^{-2}{\bullet}a^{-1}$ by average, ranging from 5.74 $g{\bullet}hm^{-2}{\bullet}a^{-1}$ to 46.37 $g{\bullet}hm^{-2}{\bullet}a^{-1}$, and the total output flux ranges from 0.29 $g{\bullet}hm^{-2}{\bullet}a^{-1}$ to 22.69 $g{\bullet}hm^{-2}{\bullet}a^{-1}$ with average of 2.58 $g{\bullet}hm^{-2}{\bullet}a^{-1}$.

The net flux is determined by the ratio of MInput/Moutput, and it is positive if the ratio is bigger than 1. The net flux of Se is 7.93, showing that the element has been accumulated in topsoil. It can be concluded that the external source of input flux of Se is from the atmospheric deposition, accounting for 89%, and from other sources like irrigation water, fertilizer.

Using multi-source-mixed model we calculated the change rate of soil selenium, which is caused by the changes of actual input and output flux. The change rate of selenium in tilth soils is + 6.81 $\mu g{\bullet}kg^{-1}{\bullet}a^{-1}$. Further research on selenium cycle is being conducted in some Kashin-beck disease region in Sichuan province.

References:

Xi, X., 2005. Quantery Science. 25:3, 269-274.
Yang X.E., et al. 2007. Environ. Geochem. Health. 29, 413-428.
Tan, J.A., 2004. Geological Environment and Health. Chemical Industry Press. Beijing.
Zhao et al., 2005. Chinese Journal of Ecolo-gy. 24:10, 1197-1203.

P12

Biogeochemical Study over Iron Ore Deposit - A Case from Sanandaj-Sirjan Structural Zone - Iran

Adel Emami[1], Ahmad Reza Mokhtari[1], Nader Fathianpour[1], Mohammad Javad Zarei[1], Mohsen Soleimani[2]
[1]Department of Mining Engineering-Isfahan University of Technology, Isfahan, Iran, [2]Department of Soil Science-The University of Guilan, Rasht,Guilan, Iran

Due to ability of plants to selectively accumulate metals they have been described as the miners of the Earth's crust (1). Different type of plants are then used to assist in exploration for minerals by analyzing different organs like stems, twigs, foliage, bark, flowers and seeds. In the present study ability of three species are evaluated in revealing the location of an iron ore body in central Iran.

The research area is located in north-west of Isfahan province in Iran which forms part of Sanandaj-Sirjan structural zone. Mineralization is an iron ore deposit assumed to be of skarn type. There are numerous deposits many of them iron ore in this structural zone that biogeochemical exploration may be of great value in locating this type of deposits.

Reconnaissance stage of the research displayed that three plants species have high coverage over the area: Astragalus, Blessed Thistle and Festuca. In order to evaluate the capability of these species in highlighting the position of mineralization, it was decided to test all of them over the mineralization and background areas. Ten sites were selected for sampling and sampling was accomplished by taking whole plant (roots and aerial organs), comprising three plant samples and a soil sample in every site. Five samples were collected from mineralized sites and five over the background.

Plant samples were divided into two parts, root(s) and aerial section and were treated separately. 1 gr of sample was digested by HNO_3, HCl and H_2O_2 and resulting solutions were analyzed by ICP-OES.

Results have demonstrated the capability of all species in locating the mineralized zone but amongst analyzed sections Blessed Thistle and then Festuca have given more promising results.

References:

Baker, D.A., 1983. Uptake of Cations and Their Transport within a Plant. In: Robb, D.A. (ed) Metals

and Micronutrients: Uptake and Utilization by Plants. Pierpoint WS, Academic Press, New York.
Jones, J. B., Jr.; Case, V. W., 1990. Sampling, Handling and Analyzing Plant Tissue Samples, pp. 389-427. In: Westerman. R.L. (Ed.), Soil Testing and Plant Analysis. SSSA, No.3, Medison, WI.

P13

Release of vanadium from LD-slag - Influence of organic carbon and water saturation

Viktor Sjöberg[1], Kristen Todd[1], Lotta Sartz[2], Stefan Karlsson[1]
[1]Man-Technology-Environment Research Centre, Örebro, Sweden, [2]Bergskraft Bergslagen, Kopparberg, Sweden

Production of high quality steel by the Linz-Donawitz process generates large amounts of slag (LD-slag) mainly composed of calcium and iron oxides (Merox, 2006). In Sweden today, the use of the slag is limited due to its high content of potentially toxic elements such as vanadium (some 17 ppm) and chromium (some 3 ppm). With special permission it is possible to use the slag as filling material in for instance roads, but the hygroscopic behavior of the LD-slag (volume increase of 30 % is not rare) often makes it inappropriate for that purpose (Merox, 2006). It can also be used in the manufacturing of cement and small amounts are presently used for that purpose. Consequently, the majority of the produced LD-slag cannot be used and ends up in waste heaps, usually near the smelter. Those heaps are an environmental threat but have also a high economical value due to the content of vanadium. Annually the Swedish company SSAB produces LD-slag containing approximately 4000 ton of vanadium which is equal to approximately 5 to 10 % of the world annual production (Ye, 2006). However, today there is no available low-cost method for production of vanadium from LD-slag.

This report focuses on a low-cost method to mobilize vanadium from the highly alkaline LD-slag without the use of expensive mineral acids and large amounts of energy. Instead organic carbon in the form of aspen (Populus tremula) wood shavings was added to the material to enhance the colonization of microorganisms. Possibly also generate polyhydroxy carboxylic acids by alkaline hydrolysis of wood. After 5 weeks at room temperature the release of vanadium from a 1:1 mixture of aspen wood shavings and LD-slag kept at the mixtures field capacity was 30-fold compared with mixtures saturated with water. After a year, more than 10 % of the total vanadium content had been mobilized from LD-slag and wood shavings kept at field capacity. Two conclusions can be drawn from the results, i) Addition of organic carbon to LD-slag accelerates the mobilization of vanadium with a minimum of technical and economic ef fort and ii) It is highly questionable to cover waste heaps of LD-slag with soil to protect the environment since the organic carbon in the soil may enhance the release of vanadium.

References:

SSAB Merox AB, 2006. URL: www.merox.se/index.pl/ld_slagg97-104
Ye, G., 2006. Stålkretsloppet D 816.

P14

Leaching of low-grade black shale for recovery of vanadium, molybdenum and uranium

Viktor Sjöberg, Heloise Tachauer, Anna Grandin, Stefan Karlsson
Man-Technology-Environment Research Centre, Örebro, Sweden

Today, the demand for rare elements increases in the EU (Critical raw materials for the EU, 2010). Since the number of known high grade mineral sources is limited, these conditions may require that low-grade sources are processed. One such (low-grade) source is shale and residues from different kinds of shale processing. In mid Sweden, county of Kumla, shale was processed from 1942 to 1966 in order to produce oil by pyrolysis. As a result, 40 million m3 of crushed original shale at particle sizes too small to be processed as well as pyrolyzed shale was stored on the site. To estimate the total content of vanadium, molybdenum and uranium in the residue, slightly weathered original shale was dissolved by microwave assisted digestion in concentrated HNO_3 for 60 min at 1200 W and 180°C, after which the supernatant was analyzed by ICP-MS. Approximately 400 g/ton, 200 g/ton and 30 g/ton of vanadium, molybdenum and uranium were found, respectively, why it could be concluded that the residue is a potential source for those elements.

Research about mobilization of vanadium and uranium from shale is mostly limited to two fields, i) leaching with mineral acids at concentrations over 0.5 M (Avvaru et al., 2008; Li et al., 2009) and ii) bioleaching, with sugar as carbon source and well defined growth medium (Kalinowski et al., 2004; Mishra et al., 2009). In order to find more economically motivated and environmental friendly techniques to mobilize those elements a number of methods were tested. They range from conventional acid leaching with mineral acids (6 N HNO_3, HCl and H_2SO_4) to heterotrophic bioleaching and microwave assisted digestion.

Mixtures of dilute acids (<5 % HNO_3 and HCl) in combination with microwaves showed the most promising results with mobilized amounts close to or better than those from microwave assisted digestion, which was used as a reference method for total content determination. Pretreating with an oxidizing agent (H_2O_2) mobilized 5.4 % vanadium after 24 hrs which was close to the 6.5 % mobilized by 6 N HCl during the same time. Heterotrophic leaching, with aspen (Populus tremula) wood shavings as carbon source, was conducted for 8 weeks and mobilized some 0.4 % vanadium, 0.6 % molybdenum and 3.3 % uranium. However, extended time of incubation and increased sample size can probably increase the yield further.

References:
Critical raw materials for the EU, Report of the Adhoc Working Group on defining critical raw materials, 2010.
Li et al., 2009. Hydrometallurgy 98, 308-313
Avvaru et al., 2008. Chemical Engineering and Processing 47, 2107-2113
Mishra et al., 2009. Hydrometallurgy 95, 175-177
Kalinowski et al., 2004. Geoderma 122, 177-194.

P15

Stable isotopes from fracture calcites and sulfides as an evidence for paleofluid circulation in crystalline bedrock at Olkiluoto, Finland

Elina Sahlstedt[1], Juha Karhu[1], Petteri Pitkänen[2]
[1]University of Helsinki, Helsinki, Finland, [2]Posiva Oy, Olkiluoto, Finland

Minerals crystallized on fracture surfaces bear evidence of fluid flow in deep bedrock. Fissure fillings are a typical result of hydrothermal circulation. Later reactivation of the fractures can result in formation of low temperature fracture fillings, typically calcite, often as tiny platelets or euhedral minerals, as is the case at Olkiluoto (Sahlstedt et al., 2010). Olkiluoto is the planned site for geological disposal of spent nuclear fuel in Finland and research on paleofluid flow will provide vital information for the safety assessment of the repository.

Stable carbon and oxygen isotopic composition of fracture calcite (Sahlstedt et al., 2010) and sulfur isotopic composition of pyrite and marcasite has been analyzed from drill-core samples collected from the upper ~500 m of bedrock at Olkiluoto. The $\delta^{13}C$ values of calcite and the $\delta^{34}S$ values of pyrite/marcasite both show extreme variations, from -30.3 to +31.2 ‰ (VPDB), and from -50 to +82 ‰ (CDT), respectively. In comparison, variation in calcite $\delta^{18}O$ values is less extensive, from -16.7 to -6.6 ‰ (VPDB). The data set can be interpreted in light of the present-day geochemical regime of deep groundwaters at Olkiluoto. The $\delta^{13}C$ values of late-stage calcites show a depth dependent trend, with typically high $\delta^{13}C$ value at depths of ~50 to 400 m, indicative of microbial methanogenesis at these depths (Sahlstedt et al., 2010). Pyrite is not associated with late-stage calcite having high, positive $\delta^{13}C$ values.

In contrast, pyrite is common in calcite fillings preceeding late-stage calcite. Furthermore, there is some evidence for pyrite precipitation succeeding the formation of calcite influenced by methanogenesis. Currently, sulfidic redox environment reaches depths of ~300 m at Olkiluoto (Pitkänen et al., 2004). Therefore, it seems apparent that the sulfidic-methanic redox boundary has shifted with time at Olkiluoto. The highly variable $\delta^{34}S$ values of pyrite/marcasite, from -50.4 to +82.1 ‰, associated with calcite formed at ambient and relatively low temperatures (up to ~90°C, Sahlstedt et al., 2010) are interpreted to have been influenced by bacterial sulfate reduction and further modified by Rayleigh fractionation. A possible forcing agent for redox shifts has been infiltrating marine waters, which also provide a sulfate source for bacterial redox reactions. Marine waters are known to have covered the area repeatedly during the Quaternary, and relicts of the brackish Littorina Sea waters are presently encountered in bedrock fractures at Olkiluoto (Pitkänen et al., 2004).

References:
Pitkänen et al., 2004. Posiva Report 2003-07, Posiva Oy, Olkiluoto.
Sahlstedt et al., 2010. Isotopes in Environmental and Health Studies, 46:3, 370-391.

P16

Bacterial and fungal community structures in manganese oxide deposits in Sambe hot spring in Shimane, Japan

Keiko Sasaki, Yoshitaka Uejima, Atsushi Sakamoto, Junichiro Ishibashi
Kyushu University, Fukuoka, Japan

Massive manganese deposits were spread out in the hot spring area at pH 5.8-6.7 in south part of Mt. Sambe in Shimane, Japan. The deposits were considered to be formed by microbial oxidation of Mn^{2+} ions derived from the hot spring water. Microbial contribution to the formation of the manganese deposits was investigated in combination with water chemistry, characterization of sediments as well as microbial community structure analysis. The sediment was characterized to be poorly crystalline birnessite including organic matters. SEM observation clearly revealed that a number of diatom was associated with Mn oxides. There might be a relationship of mutual coexistence between the diatom and Mn-oxidizing fungi and/or bacteria in the environment.

Several colonies were isolated from the Mn sediments on agar medium containing 55 ppm of Mn^{2+} at pH 4.5-6.8. Microbial community structure analysis for the extracted DNA from these colonies with PCR-DGGE method was performed using the fungal primers and bacterial primers, separately. On the basis of the sequence of the ^{16}S rRNA gene, Pseudomonas putida, Phoma sp., and Plectosphaerella cucumerina were found as the dominant spices of Mn-oxidizing bacteria and fungi, suggesting that they largely contribute to form manganese oxide deposits in Sambe hot spring. EPMA results suggest that distribution of Ba in Mn oxides showed more positive correlation with Mn contents, where there is better developed crystalinity of Mn oxides. It is considered that microbially Mn-oxidizing activity affects to development in the crystalinity, indirectly leading to increase in Ba contents in Mn oxides.

P17

Lack of some plant material: selection of suitable dilution factor for pressed pellets measured by EDXRF

Ričardas Taraškevičius[1], Jolanta Radžiūnienė[2], Rimantė Zinkutė[1], Audronė Petrauskienė[3]
[1]Institute of Geology and Geography of Nature Research Centre, Vilnius, Lithuania, [2]Institute of Botany of Nature Research Centre, Vilnius, Lithuania, [3]Institute of Ecology of Nature Research Centre, Vilnius, Lithuania

Self-regeneration of biological properties of disturbed sandy soil is long-lasting. Sewage sludge is widely used for fertilization (Kapots et al., 2000). To analyse if such practice is suitable, the sewage sludge from Vilnius wastewater treatment plant was introduced in 1989 on part of the territory of closed gravel quarry. The contents of some harmful metals in this sludge exceeded their background values many times. Complex investigations of biological-geochemical changes were done in this area until 1995. Though since that time nothing is known about further changes on the area, the sewage sludge compost is still transported to areas with disturbed or infertile soil.

In 2010 complex investigation in abovementioned part of quarry and control (background) part were done. Topsoil samples were taken in selected area for determination of relationship between geochemical composition, species composition and abundance of individuals of soil fauna (microarthropods). Geobotanic evaluation of the vegetation diversity was also done.

For evaluation of biogeochemical accumulation the samples of Calamagrostis epigejos, Festuca rubra, Elytrigia repens, Artemisia campestris, Tanacetum vulgare and Rumex acetosa were taken. The stems and leaves of the last 3 plants were analysed as different material.

It was decided to use the same EDXRF equipment both for soil and plant samples. Instrument manufactures recommend to use dilution factor DF=0.82 as ratio of weight of material to total weight of material and Licowax binder.

Low weight of some plant samples obliges to choose suitable DF<0.82 value which secures preparation of stable 3 mm thick pressed pellets having 20 mm diameter and enables reliable quantitative determination of maximum number of chemical elements.

Before milling plants were ashed at 240°C temperature. Three main DF values were used for dilution: 0.25; 0.50 and 0.75. For some materials also DF values 0.17 and 0.67 were used. Total weight of pressed pellet had to be 2 g.

Two parallel pressed pellets were prepared from each plant using different DF values. They were analysed by for determination of more than 30 chemical elements. The generalisation of results was done taking into account two indices: relative standard deviations and contents of elements in pellets. The value DF=0.25 was chosen for investigation of the influence of dry ashing temperatures 2100°C, 2400°C, 3000°C on the contents of chemical elements in different plant species.

References:
Kapots, V., Karinš, Z., Lazdinš, A., 2000. Baltic forestry. 6. 2 (11): 24-28.

P18

Investigations of two ombrotrophic peat bogs in Lithuania

Rimantė Zinkutė, Ieva Baužienė, Kazimieras Dilys, Julius Taminskas, Ričardas Taraškevičius
Nature Research Centre Institute of Geology and Geography, Vilnius, Lithuania

Besides determination of climate cyclicity, the beginning of geochemical investigation of Lithuanian ombrotrophic peat bogs which are archives of atmospheric deposition is the aim of KVARTERAS project. Two of them were selected: Žudiškės near Vilnius and Rėkyva near Šiauliai. From each bog two parallel about 0.5 m long undisturbed peat cores were taken, sliced into 1-2 cm layers and air-dried. Moisture content was determined in all samples. The color of the dried (105°C) ground samples was characterized by Munsell scale. The layers of one core were used for geochemical analysis (29 samples in

Žudiškės and 45 in Rėkyva), of another core for determination of ash content, decomposition degree, botanical composition and bulk density. Several layers from both cores were chosen for ^{210}Pb dating. Total contents of elements will be determined by EDXRF equipment SPECTRO XEPOS using TURBOQUANT for pressed pellets calibration.

Prior to analysis of cores, experimental measurements of 4 peat samples from Žudiškės were done aiming to choose sample preparation scheme. After milling with zirconium oxide grinding jars and balls and mixing with Licowax, 20 mm diameter pressed pellets will be prepared. The content of some chemical elements in ombrotrophic peat might be below detection limit. Dry ashing is sometimes used for pre-concentration of chemical elements in peat (Orru & Orru, 2008). However, plant analysis has shown decrease of Cl, Br, Cr at higher than 200°C temperature (Koch et al., 1999). Besides, when ash content is low, the amount of ashed material can be too small.

All experimental samples were heated at 105°C, their part was analysed without ashing, another part was ashed at 160°C, 190°C, 200°C, 210°C, 240°C, 250°C, 300°C, 350°C, 450°C and 550°C. Two different dilution factors DF were used: 0.75 and 0.17. When DF=0.75 measurements of pellets from both unashed and ashed peat have resulted in detectable contents of Pb, Zn, V, Cu, As, Mn, Ni, Al, Si, P, S, Cl, K, Ca, Ti, Fe, Br, Rb, Sr, Sn, Sb, Y, Zr, most of the elements were detectable also when DF=0.17. Dry ashing in higher temperatures resulted in loss of Sn, Sb, As, Br, Cl, S, P. Therefore peat dry ashing for pre-concentration should be done in rather low temperature, e.g. 240°C. Lower DF resulted in higher contents of most chemical elements.

References:

Koch, S. et al., 1999. Losses of elements in plant samples under dry ashing process. Journal of Radioanalytical and Nuclear Chemistry, 239(3), 591-594.
Orru, H. & Orru, M., 2006. Sources and distribution of trace elements in Estonian peat. Global and planetary change 53, 249-258.

P19

Mobilization of Vanadium from LD slag by salt-roasting/alkaline heterotrophic leaching

Anna Grandin, Viktor Sjöberg, Stefan Karlsson
University of Örebro, Man-Technology-Environment Research Centre, Örebro, Sweden

Vanadium is employed almost exclusively in ferrous and non-ferrous alloys due to its high tensile strength, fatigue restistance and hardness. The iron and steel industry represents approximately 85% of the vanadium-bearing products. (Moskalyk & Alfantazi, 2003) An increasing demand for metals in general has resulted in high-grade ore reserves become scarce. There exists, however, large amounts of low-grade material which might serve as sources, such as LD slag containing some 27,800 µg vanadium/g (Mácsik & Jacobsson, 1996). Conventional technologies for vanadium extraction, such as salt roasting, are however very expensive and often associated with environmental problems.

In this report we present some aspects of the possibility to recover vanadium from LD slag by using the natural microflora with aspen (Populus tremula) wood as carbon source. The aim was to compare the technology of salt roasting of LD slag with heterotrophic leaching, with respect to extraction of vanadium, as a simple technology.

Salt roasting was performed with sodium chloride, sodium carbonate and sodium sulphate in different ratios and temperatures for conversion of calcium vanadate to water soluble sodium vanadate. The pellet formed was dissolved in deionized water (18.2 MΩ) at room temperature.

The heterotrophic leaching was set up by LD slag stratified with Aspen wood shavings, saturated with deionized water (18.2 MΩ) and allowed to drain. The systems were kept at field capacity at room temperature. After leaching with deionized water, the solution phase was analyzed for anions (IC), LMW carboxylic acids (CE), total organic carbon (TOC analyzer) and vanadium (ICP-MS).

Sodium carbonate and LD slag in ratio 1:3 roasted for 2 hrs at 900ºC proved to be the most efficient process in order to convert vanadium to water soluble species were 18,400 µg vanadium/g LD slag was released. Microwave assisted acid digestion released some 17,300 µg/g from homogenized samples of LD-slag and was used as a reference method. It should be noted that in industrial processing, multiple-hearth furnace or rotary kilns are used for salt roasting since temperature control is critical (Wooley, 2005).

After 8 weeks of incubation the amount of released vanadium was 52 µg/g. The release increased exponentially according to the function f(x)=0.8*1.44x, which would give an expected release of 1175 µg/g after 20 weeks of incubation. The results show a positive trend that indicates increased leaching rates. From an environmental and economical point of view, heterotrophic leaching under alkaline conditions might be an alternative in mobilization of vanadium.

References:

Moskalyk, RR. & Alfantazi, AM., 2003. Minerals Engineering 16, 793-805.
Mácsik, J. & Jacobsson, A., 1996. Waste Management, 16, 699-709.

Wooley M., 2005. Vanadium Compounds. Kirk-Othmer Encyclopedia of Chemical Technology, vol. 20.

P20

Biogeochemical Signatures and Relationships to Rare Earth Element and Zirconium Mineralization at the Norra Kärr Deposit, Southern Sweden

Britt Bluemel[1]*, Colin Dunn*[2]*, Craig Hart3,*
Mark Saxon[4]
[1]ioGlobal Solutions Inc, BC, Canada, [2]GSC, BC, Canada, [3]MDRU - UBC, BC, Canada, [4]Tasman Metals Inc, BC, Canada

Organic media in mineral exploration have been utilized since the early 1930s, when V. M. Goldschmidt made the observation that the "humus of forest soils was very much enriched in most of the minor elements" (Rose et al., 1979). The elemental chemistry of residual soil is dominated by the bedrock protolith, and it logically follows that any vegetation growing from that soil may also be naturally enriched in particular elements from the mineralized bedrock below.

Biogeochemical exploration can be more useful than traditional soil surveys, particularly at the grassroots scale, because tree and plant root systems interact with a large volume of soil over an extensive region, and therefore provide a broader signal than a soil sample collected at one specific site, from one specific horizon. Sampling trees and shrubs provides an integrated signal from a much wider area; therefore more ground can be covered with a single sample than with other grassroots exploration methods.

The Norra Kärr rare metal deposit is located in southern Sweden, approximately 300km southwest of Stockholm. This peralkaline nepheline syenite complex enriched in heavy rare earth elements (HREEs), is approximately 1300 m long. It ranges from 200 m to 400 m in width, and has been well defined by diamond drilling which was completed in the summer of 2010.

The sample species will consist of common northern ferns, spruce, and Ah horizon wherever available. Evidence from the Eden project, which was a comparison of the different rates of elemental in various species of plants across the globe, suggests that Zr is concentrated in ferns, as is La, but to a slightly lesser degree. This is of particular importance for this project because heavy rare earth elements, which at Norra Kärr are particularly abundant compared to LREEs, are often found in the zirconosilicates of peralkaline systems, and though zircon is considered immobile, one of the aims of this project is to determine if this is true for all environments.

References:
Rose, A.W., Hawkes, H.E. and Webb, J.S., 1979. Geochemistry in mineral exploration. In: (2nd ed.), Academic
Press, London (1979), p. 456.
C. Dunn. Personal Communication regarding the efficacy of Zr and La uptake by various plants based on preliminary findings from the Eden Project. April 3rd, 2011.
Adamson, O.J., 1944. The Petrology of the Norra Kärr District, An Occurrence of Alkaline Rocks in Southern Sweden.

P21

Transfer of chromium and nickel in soil-plant system in Slovakia

Eva Komanická, Ondrej Ďurža, Ján Čurlík,
Ĺubomir Jurkovič
Comenius University Bratislava, Faculty of Natural Sciences, Department of Geochemistry, Bratislava, Slovakia

Anomalous concentrations of geogenic chromium and nickel were detected in soils developed on Flysch sedimentary rocks in Slovakia (Čurlík et al., 2004). Contents of these elements are also high in fluvial sediments in Eastern Slovakian rivers and at the bottom land of river Váh. It is a consequence of material derived from Flysch rocks being transported away by rivers to plants. The main objective of the research was to study the presence of geogenic soil contamination in the soil-plant system of the Flysch Belt (Paleogene) in the Eastern Slovakia.

We randomly collected representative soil samples from the 11 studied sites (Lúčka, Červená Voda, Kamienka, Forbasy, Milpoš, Drienica, Oľšov, Vyšné Ružbachy, Stará Ľubovňa, Šambron, Hromoš). All chemical analyses from soils were performed by HS ICP-AAS. We sampled needles from the Scots pine (Pinus sylvestris) and wheat (Triticum vulgare), barley (Hordeum vulgare), oat (Avena sativa) from the same sites. The assimilation organs (needles) were oven-dried at 40°C and milled. Their chemical content was analyzed by ETAAS.

Chromium concentrations in soils were from 107 to 441 $mgkg^{-1}$ and nickel concentrations were from 34 to 164 $mgkg^{-1}$. On geogenic contaminated soils, Scots pine contained from 0.78 to 2.2 $mgkg^{-1}$ of chromium and from 0.7 to 29.1 $mgkg^{-1}$ of nickel. In the case of crops, concentrations of chromium were from 0.19 to 0.3 $mgkg^{-1}$ and for nickel from 0.09 to 5.68 $mgkg^{-1}$. Limits for the soil were considerably exceeded. Results confirmed some of the findings about bioaccumulation in plants and their possible movement in soil-plant system.

Acknowledgement: The study has been supported by APVV-0231-07.

References:

Čurlík, J., Šefčík, P. and Polc, R., 2004. Pedogeochemická mapa regiónu Popradská kotlina a Horný Šariš. M=1:50 000. ŠGÚDŠ. Bratislava. 42 p (in Slovak).

P22

National geochemical survey in China

Xiaohuan Xi[1], Min Li[1], Zhongfang Yang[1], Hangxin Cheng[3], Guohua Zhou[3], Guiyi Xiao[1]
[1]China Geological Survey, Beijing, China, [2]China University of Geosciences, Beijing, China, [3]Institute of Geophysical and Geochemical Exploration, Hebei, China

The national Multi-Purpose Regional Geochemical Survey across China has been conducted since 1999 and has covered an area of 1.65 million km^2 until 2010 (Xi, 2008). It is aimed at geological research, environmental protection and land resource management.

Top soils at 0-20 cm depth were sampled at a density of 1 sample per km^2, whereas deep soils from 150-200 cm depth were collected at a density of 1 sample per 4 km^2. Top soil samples from four sites and deep soil samples from four sites were composited prior to chemical analysis. Fifty-two elements, pH and TOC were determined.

Anomalies (single points or areas) of As, Cd, Pb, Hg, Cr, F, I and Se have been delineated and studied, with emphasis on the origins of anomalies and related ecological effects in various ecosystems. Studies show that elemental concentrations in soils mostly depends on the concentration of the soil parent material (geological background). Wet and dry atmospheric deposition is the most important source of heavy metal input in agro-ecosystems (Yang, 2005a,b). Therefore, a new method of soil quality assessment has been developed by comprehensively assessing soil physical properties, harmful elements and nutrients in soils, fertilizers, irrigation water, wet and dry atmospheric deposition, and plants. This type of soil quality assessment has proved to be a useful tool for land resource management and protection.

The implementation of the Multi-purpose Regional Geochemical Survey has primarily ascertained the current quality status of most farmland in China. It has also played an important role in scientific management and protection of land resources, agricultural economic restructuring, the famous special agricultural development, scientific and rational fertilization, soil protection, endemic diseases prevention, mineral resource potential evaluation and other basic geological research.

References:

Xi, X., 2008. Earth Science Frontiers, 15, 1-8.

P23

Identification of the hidden relations between variables and mineralization

Reza Ghavami-Riabi[1], Zohra Jangravi[1], E. Hajmolla ali[1]
[1]Shahrood Univ. of Technology, Shahrood, Semnan, Iran, [2]Kaniran Company, Tehran, Tehran, Iran

To investigate the real relations between the variables in high potential area in the geochemical stream sediment data set, the appropriate data set need to analyze (Davis, 2002; Reimann, et al., 2002; Templ M., 2003) . For this propose, the single and multivariate statistical analyses were done in two conditions in an area with probably polymetal deposit. Firstly, statistical analyses were done in the northern part of the Zuzan II area, which includes of high potential areas. Secondly, the same statistical analyses were done on anomalous data set, which mostly includes of anomalous samples and some of background samples.

The investigation of the correlation coefficients in high potential areas identified high correlation between Pb and Ag, Cd, Cu, Zn, Bi and good correlation between Pb and Sb, Mo, and Mn. On anomalous data set, the highest correlation is identified between Pb and Ag, Au, Zn and good correlation between Pb and Cu and Cd. Ti, Ga and Cr was shown a negative correlation with Pb on anomalous data set (Jangravi, 2010). In order to identify the high potential areas and anomalous data, the correlation of Pb with Ag and Au was considered.

The cluster analysis of anomalous data set could completely separate Pb, Ag, Au, Cu, Zn, Cd from the rest of elements. Dendogram of the high potential areas data set could grouped Pb, Ag, Au, Cu, Zn, Cd, Bi, Sb, Mo with K, Rb, Sn, U, Th, Y, Cs as one cluster (Jangravi, 2010). Therefore, the cluster analysis of the anomalous data set illustrates a better classification of the variables.

The PCA analysis of the high potential areas introduce the first factor, which includes of Pb, Cu, Ag, Au, Cd, Bi, Sb, Mo, as mineralized factor that control 22.9 % of the variations. The PCA analysis of the anomalous data set consider the third factor, which involve of Pb, Ag, Au, Sb, Cu, Zn, as mineralized factor that control 9.8 % of the variations. In the current data set, the first (V, Ti, Cr, Ga, Zr, Hf, Fe) and second (La, U, Y, Sn, Cs) factors, which could be related to rock forming process, control 20 % and

21 % of the variations (Jangravi, 2010).

According to the statistical analyses and the cross-plots, a polymetal mineralization might affect the study area. An exploration ratio of Ag+Au+Pb/Ti+Cr+Ga was identified to separate the anomalous areas from the background in the study area. Trend surface modeling of the ratio could identify the boundaries of the anomaly areas in the whole study area.

References:
Jangravi, Z., 2010. MSc Thesis, pp 118.
Templ, M., 2003. Vienna Univ. of Technology, 137p.
Reimann et al., 2002. Applied Geochemistry, 17,185-206.
Davis, J.C., 2002. J. Wiley in New York, 638p.

P24

Regional exploration for secondary carnotite uranium deposits in Western Australia using groundwater

Ryan Noble, David Gray, Nathan Reid
CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia

Regional scale exploration has significant risk, but is necessary if new U ore deposits are to be found for the growing, global energy demand. Shallow calcrete aquifers in the northern Yilgarn Craton of Western Australia are the host to numerous secondary carnotite uranium deposits. Approximately 1400 shallow aquifer groundwater samples were collected and analysed to test if secondary channel and playa U mineralisation may be found using a regional sample spacing (>5 km). Results show this is effective. All the economic deposits and most of the minor deposits and occurrences in the region are associated with groundwater that has carnotite approaching or exceeding saturated conditions. Soluble U concentrations alone identified the largest deposit (Yeelirrie) and several smaller deposits, but this method was not as successful as the mineral saturation indices. Thickness of cover and palaeodrainage distribution combined with surface drainage and catchment boundaries provided background information of U primary sources and for areas with the highest exploration potential for secondary carnotite U deposits. Granites in the south east of the study area are less prospective with regard to secondary U deposits. Groundwater geochemistry in conjunction with palaeodrainage mapping may greatly improve exploration through cover where radiometric geophysics is not effective or available. Data filtering using drainage and depth of cover parameters was valuable in generating appropriate “background” concentrations, as U was commonly in greater concentrations in the saline channels. The study of regional, shallow groundwater for U shows multiple benefits for mineral exploration, the economy and potable water quality.

P25

GIS method as a basis for landscapes classification while choosing of geochemical methods of exploration (case study of the Maly Hinggan Area, the Far East of Russia)

Yuri Yu. Yurchenko, Sergey V. Sokolov
A.P. Karpinsky Russian Geological Research Institute (VSEGEI), St.Petersburg, Russia

Landscape zoning is an integral component during geochemical exploration at any scale. The main goal of zoning is rational choosing of geochemical methods of exploration, which are effective in different landscape environments.

The exposure of the area is of great importance for geochemical exploration, especially lithogeochemical ones, both after primary and secondary dispersion halos and stream sediments (Sokolov and Yurchenko, 2010). The experience shows that the morphometric analysis on the basis of a digital elevation model (DEM) is the most effective method of zoning as regards this indicator. Particularly, the use of DEM for landscape-environmental zoning was tested by B.A. Novakovsky et al (2003). Basic elements of DEM are maps of angles and exposure of slopes, maps of basal surface of n-order streams and others. Introduction of available geological data (structural-tectonic maps, maps of the Quaternary deposits and others) in the DEM structure allows the most correct zoning (both quantitatively and qualitatively) depending on conditions of geochemical exploration.

Using the morphometric analysis basic elements combined with modern GIS technologies and integrated analysis of geological and geochemical information made it possible to make landscape zoning of the Maly Hinggan Area depending on conditions of geochemical exploration. Using the obtained data, the authors identified type landscape topographies in accordance with their exposure based on the angle of slope.

The proposed technology based on digital elevation models allows landscape zoning of areas and separate sites in a wide range of scales from 1:10 000 to 1: 1 000 000.

References:
Novakovsky, B.A., Prasolov, S.V. and Prasolova, A.I., 2003. Digital elevation models of real and abstract geofields. Moscow: Scientific World, 64 p. (in

Russian).

Sokolov, S.V. and Yurchenko, Yu.Yu., 2010. Digital elevation model as a basis for zoning depending on conditions of geochemical exploration (case study of the Maly Hinggan, the Far East) // Geoinformatics, No. 4, 54-60. (in Russian)

P26

Mine site remdiation - an experience fron Northern Sweden

Karel Miskovsky, Gunnar Jacks, Lars Lövgrren,
Ola Lövgren, Magnus Filipsson
KTH, Stockholm, Sweden

Lake Hornträsket gradually lost its fish population and its biodiversity over two decades. There are three closed sulphide mines in the catchment and a semi-quantitative metal budget for the lake indicated that one of the mines situated close to the shore of the lake contributed most of the metals and was responsible for the main part of the copper load on the lake. Copper was considered to be the major toxic element. Out of the other two mines, one was remediated as an open pit lake (Ramstedt et al., 2003), still leaking metals, but there were traps in the drainage. The third mine is small with surrounding peat bog and no metal transport to the lake could be traced. In addition to the mines there was a considerable background transport of zinc from the forest, most likely caused by drainage of tills formed from metasediments with about 1 % S (Svensson, 1980).

The remediation work was concentrated to the mine close to the lake shore. After closure of the mine in the late 1990s the waste rock bulldozed into the open pit quarries and covered with till. This allowed oxidation of the coarse fill in the open pits. The remediation measures taken into consideration were: 1) diversion of groundwater from upstream areas 2) neutralisation of the waste rock and 3) decreasing the vertical infiltration into the mining waste areas. The diversion of upstream drainage decreased the metal transport by about 50 %. An injection of mesa chalk, a waste product from pulp and paper factories was used mixed with a fraction of sewage sludge. This worked well in the two open pits but was not efficient in an area where ore used to be stored and in a parking area built up on a peat bog by a rock fill about two metres thick. The peat prevented the injection. Sprinkling of mesa chalk over the area was neither efficient. By a network of piezometers hot spots in the form of piles of sulphidic ore were localised. These hot spots have been dug out and brought to a safe depository.

The measures have gradually decreased the metal contents in the lake and the copper content has decreased from 150 mg/l to 40 mg/l. Taking into account the biological availability of the copper an acceptable should be 20 mg/l (Meador, 1991). The lake has a long turnover time while an improvement is expected to take 5-6 years. The zinc concentrations will remain elevated but should not be a threat to the lake fauna.

References:
Meador J P. (1991) Aquatic Toxicol 19(1): 13-31.
Ramstedt et al. (2003) Appl Geochem 18(1): 97-108.
Svensson U. (1980) Swed Geol Survey, Series C 764, 79 pp.

P27

Water Quality and Factors Affecting it in a Closed Mine in Northern Finland

Ulpu Väisänen
University of Oulu, Oulu, Finland

An environmental study in a closed mine of Rautuvaara was carried out in Kolari, northern Finland. The bedrock of the area encompassed iron oxide-copper-gold ore. Iron ore with magnetite was excavated from the underground mine and two open pits in 1975-1988. The aim of the study was to find out chemical and geochemical conditions and quality of groundwater, surface water and surficial deposits in the tailings and in their surroundings, and to find out impacts of the tailings on waters.

Thickness, composition and oxidation of sulphides in the tailings were studied. Samples of groundwater, surface water and infiltrated water through the embankments were analysed. Deposits of the tailings and reference areas in the surroundings were studied by means of drilling and analysing samples from the drilling cores. Groundwater observation wells were installed in the tailings and in the reference area. Geophysical methods, such as electromagnetic and electrical measurements, were also used.

The tailings are located on a gentle slope. The lower parts are under water in the tailings impoundments. The deposits of the tailings, saturated with water, have not oxidized, and nearly no acidification and dissolution of heavy metals in water has happened. In the upper parts of the tailings the deposits are not saturated with water, which is causing weathering, due to contact with oxygen. Material of the tailings is producing acid while weathering. Weathered material has iron sulphides in surface layers to the depth of 2-3 metres. Dissolving of arsenic and other metals has happened, due to oxidizing of sulphides and acidification of waters (Räisänen et al., 2007). Some high concentrations of copper, arsenic and nickel were found in this area, exceeding the limits of contaminated soil. High arsenic concentrations were especially found in oxidized material including gold.

Oxidizing, causing dissolution of metals and acidification of water has happened only in a small area in the dry, upper part of the tailings. High concentrations of aluminium, iron and manganese were found in waters of dug pits in this area. In the other parts of the tailings and in the surroundings groundwater and surface water were not contaminated, and pH values were similar to those in natural waters in northern Finland.

The recommendations are to keep the tailings saturated with water in the impoundments, for preventing oxidizing of surficial deposits, acidification of waters and dissolution of heavy metals and other harmful substances in waters.

References:
Räisänen, M. L., Väisänen, U., Lanne, E., Turunen, P. & Väänänen, J., 2007. Rautuvaaran kaivoksen rikastushiekka-altaan kemiallinen nykytila, vaikutukset pohjavesiin ja suositukset jälkihoidolle. Geological Survey of Finland, Report R/591/42/2006, pp. 1-43.

P28

The Environmental Geochemistry of the Hycroft Mine: A Case Study on the Limitation of Sobek Style Acid Generation Predictions

Amy Prestia[1], *Robert Bowell*[2], *Deborah Lassiter*[3]
[1]SRK Consulting, Reno, NV, USA, [2]SRK Consulting, Cardiff, Wales, UK, [3]Allied Nevada Gold Corporation, Reno, NV, USA

The Hycroft Mine is an open pit gold mine situated along the eastern edge of the Black Rock Desert in northwest Nevada, a semi-arid region where the annual evaporation significantly exceeds precipitation. The Hycroft deposit is hosted in volcanic breccias and conglomerates of the Tertiary Kamma Mountain volcanic group that have been faulted by north trending structures that acted as conduits for hydrothermal fluids. An acid leaching event resulted in the development of vuggy, quartz alunite altered zones produced by the removal of most minerals, including those capable of buffering acid. Accessory minerals associated with the acid leach zones are rare, except deposits of native sulfur and gypsum, which are locally abundant.

The complex sulfur mineralogy of the Hycroft deposit, coupled with the deficiency of acid neutralizing minerals, limits the application of traditional Sobek style Acid-Base Accounting (ABA) methods that rely upon sulfur speciation data to predict acid generation potential. A comparison of results from geochemical predictive tests including the modified Sobek ABA method, the Net Acid Generation (NAG) test and kinetic humidity cell tests (HCTs) illustrates the complexity of interpreting ABA data for acid leach material containing elemental sulfur and low solubility sulfate minerals such as alunite. This comparison indicates that the ABA data over predict the potential for acid generation, and are inconsistent with the HCT, which is considered a more definitive test for the prediction of acid and metals mobility. A good correlation is, however, observed between the HCT and NAG results, indicating the NAG test is a more effective tool for predicting the geochemical behavior of the Hycroft deposit.

The presence of native sulfur presents additional challenges with respect to acid generation prediction due to the unique properties of this mineral. Acid leach material containing native sulfur was predicted to be non-acid generating from the NAG test results. However, even though native sulfur is insoluble in water, the exposure of sulfur to moisture and air under the aggressive conditions of the test resulted in the formation of sulfuric acid, and acidic conditions developed after the buffering capacity of the material was consumed. The actual amount of acid and metal release generated by this mechanism is limited in comparison to that associated with pyrite oxidation, which is the main contributor to acid rock drainage. Furthermore, the semi-arid conditions that prevail at the site are not likely to produce conditions similar to the HCT that would result in a measureable release of acidity from acid leach material containing native sulfur.

This study demonstrates the importance of considering the site specific mineralogical characteristics of the deposit in the selection of the most appropriate geochemical test methods to use in the prediction of potential acid generation.

P29

Mobility of Potentially Toxic Elements from Contaminated Sediments in a Catchment Affected by Abandoned Lead and Zinc Mine (South Poland)

Urszula Aleksander-Kwaterczak, Dariusz Ciszewski
Department of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, 30 Mickiewicz Av., Krakow, Poland

Metalliferous ore mining and smelting industry release potentially toxic elements into soils and surface waters. Metals which enter river catchment are further mobilized with the rate depending on chemistry of waters and sediments as well as hydrological factors. The rate of metal mobility is affected not only by the high total metal concentration but also by the large proportion of the most mobile fractions. Metals in these easy mobile fractions are considered as potentially dangerous for human health and plant and animal organisms.

Contamination of aquatic sediments with heavy metals was investigated in the Matylda catchment, affected for over 100 years by mine waters from the lead and zinc mine "Matylda" in Chrzanow in southern Poland. The mine was established in the upper section of the valley in 1850 and during the peak of production (50-70s of the 20th century) produced 100-140 thousand tons per year of Pb and Zn ores. Waters of the Matylda stream were supplied to fish ponds and associated wetlands situated in the upper and middle valley reach. The mine was closed in 1972 whereas fish ponds are still used for recreational angling.

The main objective of this study was to assess the metal mobility and their potential bioavailability in sediments sampled from fish ponds streams and floodplain profiles on the basis of metal chemical forms determined using standard BCR procedure (Rauret et al 1999) and method of ICP-MS. Total content of Zn, Pb and Cd in sediments reaches about 6 %, 5 % and 800 mg/kg, respectively. Whereas, copper concentrations vary between 20-200 mg/kg and iron concentration reaches in many samples 2-4 %. In the Matylda stream sediments, regardless on the sample location, Cu and Pb occur mainly in the sulphidic-organic fraction, up to 85 % and 70 %, in that order. Cadmium and zinc are present mainly in the most mobile fractions - exchangeable and carbonates, up to 95 % of Cd and 85 % of Zn. The investigations show that content of cadmium solely in the most mobile exchangeable fraction exceeds in some surface sediment samples 100 mg/kg, of zinc 2,5% and 8,000 mg/kg of lead. This suggests high bioavailability of the mine-originated heavy metals and possible intake of them by fishes introduced periodically to ponds. However, the expected rate of this intake is rather low due to short time fishes are in ponds (usually up to several months) but it seems that angling should be banned before mine-originated sediments are dredged.

References:
Rauret G., Lopez-Sanchez J.F., Sahuquillo A., Davidson C., Ure A., and Quevauviller Ph., 1999. J. Environ. Monitor. 1, 57-61.

P30

Metal tolerant wetland species in former Rautuvaara iron-copper mining area

Paavo Närhi[1], Marja Liisa Räisänen[2], Maarit Middleton[1], Marja-Liisa Sutinen[3], Raimo Sutinen[1]
[1]Geological Survey of Finland, Rovaniemi, Finland, [2]Centre for Economic Development, Transport and Environment, Kajaani, Finland, [3]Finnish Forest Research Institute, Rovaniemi, Finland

Metals constitute a threat to natural ecosystems because they can be toxic at low concentrations and bioaccumulate. In mining, especially tailings can damage adjacent ecosystems. Phytostabilization is an approach in which metal tolerant plant species stabilize polluted sediments and reduce further environmental degradation. Contructed wetlands can be used to purify mine drainage waters. Suitable plant species for phytostabilization tolerate high concentrations of toxic elements and have low shoot accumulation rates of these elements. If plants accumulate high concentration of toxic element in shoots, it may disperse into the environment through herbivores or at senescense.

The Rautuvaara iron-copper mining area in western Finnish Lapland operated from 1975 to 1996. The tailings impoundment contains anomalously high concentrations of Cu, Zn, As, Ni and Co and generates acids. In Sphagnum-dominated treeless wetlands the main contamination, migrated tailings plumes, dates back to 1970's and 1980's. At each wetland site plant species coverages were estimated and migrated tailings plume was sampled. The samples were extracted with concentrated nitric acid and element concentrations were analyzed using ICP-MS and ICP-AES. A nonmetric multidimensional scaling using Bray-Curtis dissimilarities was applied to data to analyze plume variables contributing to the vegetation composition.

Tailings contamination has substantially increased the concentrations of soil toxic elements and changed wetland vegetation compositions. With regard to fertility, concentrations of soil Ca, Mg, and P had increased through contamination. Carex rostrata Stokes (bottle sedge), Equisetum palustre L. (marsh horsetail), and Eriophorum angustifolium Honck. (common cottongrass) tolerated anomalously high concentrations of As, Co, Cu, S, and Zn. Stoltz & Greger (2002) and Matthews et al. (2004, 2005) have also found C. rostrata and E. angustifolium to tolerate high concentrations of As, Cd, Cu, Pb, and Zn. Multiple metal tolerances and generally low known translocation rates in case of C. rostrata and E. angustifolium (Stoltz & Greger, 2002; Liu et al., 2006; Nyquist & Greger, 2009) indicate that C. rostrata, E. palustre, and E. angustifolium are suitable species in phytostabilization of metalliferous tailings and effluents.

References:
Liu, W. et al., 2006. Journal of Environmental Sciences 18, 287-291.
Matthews, D.J. et al., 2004. Wetlands 24, 859-869.
Matthews, D.J. et al., 2005. Environmental Pollution

134, 343-351.
Nyquist, J. & Greger, M., 2009. Ecological Engineering 35, 630-642.
Stoltz, E. & Greger, M., 2002. Environmental and Experimental Botany 47, 271-280.

P31

Geochemical investigations of the success of a dry cover on backfilled pits at Kimheden copper mine, northern Sweden

Lucile Villain, Lena Alakangas, Björn Öhlander
Luleå University of Technology, Luleå, Sweden

Dry covers on sulphidic mine waste aim at limiting oxygen diffusion and water infiltration into the waste, in order to reduce sulphide oxidation and the potential to generate acid mine drainage (Höglund et al., 2004). Monitoring the evolution of element concentrations, pH and oxidation conditions in the mine drainage from soil covered mine waste can therefore give information on the success of the dry cover.

In 1996, the two open pits of Kimheden copper mine (northern Sweden) were backfilled with 25-year oxidised waste rocks, and sealed with a composite dry cover of granitic composition (0.3 m clayey till - 1.5 m unsorted till). This measure intended to counteract the production of acid mine drainage that had failed to be mitigated since closure of the mine in 1974. Annual chemical monitoring data of the mine drainage since 1983 provided by the mining company, and extended water sampling for research purposes in the mine area in 2009-2010, give a basis for the evaluation of the effectiveness of the dry cover.

The results show that the concentrations of Cu and Zn in the drainage have appreciably decreased after application of the cover - from 7 mg/l and 0.6 mg/l to 0.4 mg/l and 0.1 mg/l respectively, at the downstream sampling location - (Villain et al., 2010). However, the concentrations are still high, and pH has only increased from 2.8 to 3.7 (downstream). This indicates that acid generating reactions occur and that the neutralisation capacity of the site is low, keeping the elements dissolved in the water. Furthermore, data downstream reveals no evolution in concentrations of elements, pH and conductivity in the last ten years, and therefore improvement of water quality has ceased. The persistence of acidity and release of metals in the discharge could be caused by failure of the cover to limit sulphide oxidation in the waste rocks. An alternative explanation is the progressive dissolution of oxidation products releasing stored acidity and metals, and/or precipitation of secondary minerals releasing additional acidity (INAP, 2009). In order to determine which processes are dominant, measurements of dissolved Fe(II) and Fe(III) concentrations and speciation modelling have been conducted. The results suggest that backfilled waste rocks are still oxygenated in spite of capping, indicating that aerobic sulphide oxidation and acidity production must still occur in the waste. However, the results also show that formation of ferric hydroxides is an equally important acid-generating reaction in the seepage from the waste.

References:
Höglund et al., 2004. MiMi - Performance Assessment: main report, chapter 6. Luleå, pp. 55-92.
INAP, 2009. GARD Guide, chapter 2.4.3. http://www.gardguide.com/.
Villain et al., 2010. Mine water & innovative thinking: proceedings. Wolkersdorfer, C. & Freund, A., Cape Breton University Press, 515-518.

P32

Environmental impacts of ancient small-scale highly contaminated Hg ore processing site (Idrija area, Slovenia)

Tamara Tersic[1], Mateja Gosar[1], Harald Biester[2]
[1]Geological survey of Slovenia, Ljubljana, Slovenia, [2]Technical University Braunsc, Braunschweig, Germany

The production of mercury in Idrija started at the end of the 15th century. In the first decade of mercury mining in Idrija the ore was roasted in piles. After that the ore was roasted for 150 years, until 1652, in earthen vessels at various sites in the woods around Idrija. Up to now 21 localities of ancient roasting sites have been established on the hills in vicinity and in more distant localities (Gosar & Čar, 2006). Roasting of ore in that time resulted in considerable losses. The determined mercury contents in soils at old roasting sites are very high, and they surpass all hitherto described localities at Idrija and in its surroundings. Locality Pšenk is one out of 21 localities of ancient roasting sites established on the hills surrounding Idrija. Detailed soil sampling was performed on 210 x 180 m big area to establish the extension of mercury pollution and to investigate mercury transformations and transport characteristics through the 400 year-long period. Soil and humus samples were collected from 73 sampling points. 3 soil profiles were sampled to determine vertical distribution of Hg in soil (Teršič, 2010). The main mercury phases were determined by the mercury-thermo-desorption technique. The determined Hg contents in soil samples of the investigated area vary from 5.5 to almost 9,000 mg/kg with the median of 200.0 mg/kg. In humus Hg contents are ranging from 1.4 to 4.200 mg/kg with the median of 20.0 mg/kg (Teršič, 2010). Extremely high Hg contents were found in investigated soil profiles where it riches 37,020 mg/kg. In general Hg concentrations in all three studied profiles show a gradual decrease with depth. The Hg-thermo-desorption curves indicate the presence of mercury in the form of cinnabar and that of mercury bound to organic or mineral soil matter. The distribution of mercury species in soil and humus show almost equal distribution of cinnabar and non-cinnabar Hg compounds in investigated samples. Laboratory leaching experiments have confirmed significant Hg contents in soil and humus leachates. Contaminated soils are thus one of the primary concerns for persistent mercury release into the aquatic ecosystem.

References:
Gosar, M. & Čar, J., 2006. Geologija 49, 91-101.
Teršič, T., 2010: Environmental influences of historical small scale ore processing at Idrija area, Ph. D. thesis, University Ljubljana, pp. 1-203.

P33

Neutralization of weathered acidic mine waste using bio ash - effects of mixing and layering

Mattias Bäckström[1], Lotta Sartz[1]
[1]Man-Technology-Environment Research Centre, Örebro University, Örebro, Sweden, 2Bergskraft Bergslagen, Kopparberg, Sweden

Already oxidized sulphidic mine waste needs addition of a neutralizing agent in order to decrease the leaching of acid metal laden waters (Davis et al., 1999). Earlier studies have shown that both the types of alkaline amendment (carbonate or hydroxide) as well as different mixing strategies (layers or total mixing) give different results with regards to pH in the resulting waters (Sartz, 2010). This might have implications for planning remedial actions for acidic historical mine waste. The aim of this study was to investigate the effects of different orders between acid and alkaline materials on the generated leachate.

Weathered mine waste (1 kg) was mixed with bio ash (1 kg) in three different systems. Every system consisted of two sequential containers; (I) bio ash followed by mine waste, (II) mine waste followed by bio ash, (III) mine waste/bio ash followed by mine waste/bio ash. The bio ash contained 30 % calcite and only minor amounts of burnt lime. Distilled water was added at a rate of L/S 0.6 three times a week. pH from the first container with only bio ash was initially around 8.5 increasing to 11 after L/S 4. Initially, final pH (after the second container) was 3 in system I, around 8 in system II and around 7 in system III. At L/S 12.8 (at 20 additions of water), however, pH was found to be 6.4 in system I, 8.5 in system II and around pH 7.2 in system III.

Lowest pH was thus found in the system with mine waste in the second container while highest pH was found in the system with alkaline ash in the second container. Alkalinity and acidity changed rapidly in the different systems due to wash out effects. At L/S 12.8 alkalinity was found to be between 0.36 and 0.64 meq/l in all systems. Highest final alkalinity was found in system I and lowest final alkalinity was found in system II, indicating that different orders of acid and alkaline materials give different dissolution rates for the carbonates present in the ash. System I, for instance, with lowest final pH has the highest alkalinity due to increased dissolution of the carbonates in the ash. Preliminary results, however, indicate that all systems give good pH with regards to element immobilization.

In addition to pH and alkalinity, electrical conductivity, sulphate, major cat ions and trace elements were measured.

References:
Davis, A., Eary, L.E. and Helgen, S., 1999. Environmental Science & Technology, 33: 2626-2632
Sartz, L., 2010. Alkaline by-products as amendments for remediation of historic mine sites. Dissertation, Örebro University

P34

Attenuation of heavy metals by peat and glacial till in simulated waste rock dump leachate

Andrew Barnes[1], Rob Bowell[1], Matt Dey[1], Ruth Warrender[1], Mike Hutton Ashkenny[1], Devin Sapsford[2], Daniel Thomas[2], Klas Stromberg[3], Matt Blattman[3]
[1]SRK Consulting (UK) Ltd, Cardiff, UK, [2]Cardiff University School of Engineering, Cardiff, UK, [3]Northland Resources A.B., Lulea, Sweden

Peat has commonly been used as a low cost polar adsorbent for the removal of heavy metals and organics from contaminated waters and waste waters (Couillard, 1994; Koivula et al., 2009). The high capacity of peat to attenuate heavy metals (such as Cu^{+2} and Ni^{+2}) is largely due to adsorption of metals to active sites on lignin in the alcohol, aldehydes, ketones, acids, phenolic hydroxides, and ether functional groups (Gupta et al., 2009).

As well as conventional uses for peat, the potential for use of this material for the mitigation of leachate generated from metal and coal mine waste is significant. This is especially so in cases where peat would usually be a waste material and / or bi-product such as is typical in many high latitude mine sites. Where the pre-stripping of peat is required prior to mining or where peat is present under the footprint of a planned waste rock and tailings facility, the potential of peat to be seen as a valuable resource rather than a waste material is clearly evident. In addition, as long as long term stability issues are properly accounted for it is wise to deposit peat under waste facilities as it is well known that storage of peat for later use during mine closure can result in desiccation and a significant risk of auto-combustion. In addition peat is commonly pre-stripped alongside surficial deposits of glacial till.

To demonstrate the adsorption capacity of peat and glacial till collected from a proposed mine development in north Sweden, column experiments were undertaken where simulated waste rock dump leachate was circulated through the peat and till materials. The simulated leachate was made using a hydrogen peroxide leach of waste rock from the proposed mine development. The waste rock samples were composited in proportion to their tonnage within the proposed pit in order to give the most representative leachate solution.

Results show that both materials had significant capacity to attenuate copper and nickel contained within the simulated leachate. In addition the till material showed good attenuation of iron and aluminium that may be potentially released from the peat material. In addition, both materials showed some potential to release lead and zinc in the short term. The observed adsorption / desorption characteristics can be explained by prior equilibrium of the peat with trace elements in the shallow groundwater and subsequently leached through ion exchange by the waste rock leachate. The study shows that Peat is a highly effective sorbent for nickel and copper that may be released from mine waste facilities but that initial desorption of trace elements adsorbed during prior surface loading can occur and should be accounted for during mine planning.

References:
Couillard, D., 1994. The use of peat in wastewater treatment. Water Research 28(6). 1261-1274.
Gupta, B. Sen., Curran, M., Hasan, S. and Ghosh, T.K., 2009. Journal of Environmental Management 90, 954-960.
Koivula, M.P., Kujala, K., Ronkkomaki, H. and Makela, M., 2009. Journal of Hazardous Materials 164, 345-352.

P36

Mercury contents in soils and sea sediments in Crete, Greece

Despina Pentari, Despina Katsimicha, Asimina Moraiti, Vasilis Perdikatsis, Konstantinos Komnitsas
Technical University of Crete Department of Mineral Resources Engineering, Chania, Crete, Greece

Mercury has been listed among the most significant environmental pollutants. Obviously, the distinction between natural and non-natural Hg contributions as well as point and non-point sources of such contamination in atmosphere, aquatic and terrestrial environment is not always definite and absolute (Manta et al., 2002). What is more is that due to its volatility and chemical persistence, Hg can be involved in extensive air-soil exchange processes and once released to the atmosphere may be transported over long distances (Rodrigues et al., 2006). As a consequence, soils and sediments can be considered as very important pools acting both as source and sink in the global biogeochemical cycle of Hg (Xinmin et al., 2006).

The aim of the present work was the detection of mercury contamination derived from human activities in local geochemical systems existed in different areas of Crete, Greece. For this purpose, 28 samples (surface soil and sea sediments) were obtained from regions considered both potentially contaminated and uncontaminated (natural background Hg levels). The mineralogy and the organic matter of the samples were defined by X-Ray Diffraction (XRD) and Total Organic Carbon (TOC) analyses respectively. The contents in major elements were determined by X-Ray Fluorescence spectroscopy (XRF), while the contents of total Hg and trace elements were determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) after the dissolution of samples by acid treatment. Finally, the association between Hg and other elements was examined using the Linear Correlation Coefficients, while the Geoaccumulation Index (Igeo) and the Enrichment Factor (EF) were also calculated.

The majority of the measured Hg concentrations of the samples did not exceed the environmental limit of 0.2 $\mathrm{mgkg^{-1}}$ Hg recommended for soils in Greece and other European Community countries (UNEP, 2002). The findings of the present work are in accordance with previous observations in Greek soils (FOREGS, 2005). Despite this, research has to be continued and focused on localized Hg enrichments in order to determine all possible contamination sources, identify potential pathways and assess its fate.

References:
Manta et al., 2002. The Science of the Total Environment 300, pp. 229-243.
Rodrigues et al., 2006. The Science of the Total Environment 368, pp. 926-936.
Xinmin et al., 2006. The Science of the Total Environment 368, pp. 713-722.
FOREGS, 2005. Forum of the European Geological

Surveys, (http://www.gsf.fi/publ/ foregsatlas/map_compare.html).
UNEP, 2002. United Nations Environment Programme Chemicals, Geneva, Switzerland, (http://www.chem.unep.ch/mercury/Report/Final%20report/finalassessment-report-25nov02. pdf).

P37

Chromium behaviour during water-serpentinites interaction: first results from RESPIRA project in a Tuscan quarry (Italy)

Ilaria Baneschi, Antonio Langone, Chiara Boschi, Samuele Agostini, Luigi Dalla, Andrea Dini, Massimo Guidi, Sonia Tonarini
IGG-CNR, Pisa, Italy

Serpentine outcrops, such as the reworked and altered ophiolites cropping out in the Tuscan area (Western Italy) bear high level of Cr. Leaching of chromium into soils, and possible groundwater contamination by means of oxidation to its hexavalent form (Cr(VI)) is an environmental concern, due to poisoning effects on living organisms and human health. Spring waters in serpentinites may have high Cr(VI) contents (locally >20 mg/l), indicating a possible remobilization of Cr into groundwaters, Hence, RESPIRA project, financed by EU and Regione Toscana, aims to trace paths and processes defining chromium mobility within altered rocks and soils applying a multidisciplinary approach.

A serpentinite quarry in the coastal Tuscany was chosen due to the favourable rock exposure, the occurrence of well-developed soils at the top of the quarry, and spring waters at the bottom of the quarry.

Two springs emerging directly from serpentinites were sampled and preserved directly in the field for Cr (VI) analyses. These waters are Mg-bicarbonate and show alkaline pH values (8.1±0.1) as consequence of the interaction with ultramafic rocks. During this process the total inorganic carbon (TIC) diminishes, possibly due to the precipitation of carbonates.

Springwaters collected from the surroundings, and circulating within carbonates and marls (sedimentary cover of ophiolites) are Ca-bicarbonate with slightly acid pH (6.8±0.2). Their pCO_2 range from 2.3E-2 to 1.0E-1 atm.

XRF analyses of two soil profiles, from the upper horizons to the undisturbed serpentinites, revealed a weak variation in Cr from values comparable with serpentinite bedrock (3100 ppm; deepest horizons) to depleted values into the uppermost horizons (2765 ppm). This variation reflects the mineralogical composition of the soils horizons: Cr-bearing phases occur preferentially in the deepest horizons. Preliminary high-resolution BSE images (FEG-SEM) and chemical analyses (EMP) of minerals revealed a major degree of alteration of primary Cr-bearing phases from soils, such as Mg-chromite, with respect to the serpentinites. Mg-chromite is generally replaced by Fe-chromite and magnetite towards the rims and/or near fractures. In several cases, the alteration products of the Mg-chromite is characterised by fine-grained aggregates of Fe-chromite/magnetite and phyllosilicates. Indeed, locally these alteration products show a microporosity.

These preliminary results reveal that integrating geochemistry and petrography should be successful to model the Cr mobility from natural outcrops, mines and quarries. Further investigations will improve our results.

P38

Elevated trace element concentrations in soil solution of an acid sulphate forest soil

Tiina Maileena Nieminen[1], Kirsti Derome[2], Antti-Jussi Lindroos[1], Päivi Merilä[3], Liisa Ukonmaanaho[1]
[1]Metla, Vantaa, Finland, [2]Metla, Rovaniemi, Finland, [3]Metla, Parkano, Finland

Finland has the largest known occurrence of acid sulphate soils in Europe, roughly 1000 km^2 using Soil Taxonomy Criteria (Yli-Halla et al., 1999). Practically all recognized acid sulphate soils are in agricultural use and the knowledge of their distribution in forest soils is scarce. Even less is known about the influence of soil processes related to the oxidation of sulphide sediments on forest ecosystems and consequently on watercourses surrounding them. The aim of this study was to investigate the quality of soil solution in a Norway spruce (Picea abies L. Karst.) stand located on an acid sulphate soil.

The 7 sites of this study were spruce dominated forests belonging to the Finnish permanent monitoring programme of the EU-Forest Focus-FutMon / pan-European ICP forests Level II network (Merilä et al., 2007). At one of the sites the chemical properties of the soil have been reported to reflect the formation of an acid sulphate (AS) soil (Lindroos et al., 2007). The soil texture of the AS-site is till with a relatively high proportion of of silt and sand.. Although the age of the soil is only ca. 300-400 years, clearly distinguishable podsolic horizons have developed in the surface soil as a result of the spruce cover (Lindroos et al., 2007). Soil solution samples were taken in 2008 at 4-week intervals during the snowfree period using suction cup lysimeters at depths of 20 and 40 cm (6 replicates). Soil solution samples were filtered through a 0.45µm membrane filter, and Al, Fe, and Ni concentrations were determined by ICP/IRIS. SO_4-S was analyzed by ioncromatography. The pH was measured from an unfiltered subsample.

We found clearly lower pH –values, and higher concentrations of SO_4-S, Al, Fe and Ni in soil solution of the AS site compared to background spruce sites on podsolic soil. According to our results Norway spruce appears to tolerate extremely low pH and elevated concentrations of metals in the soil solution. The results are encouraging in the point of view of revegetation of metal contaminated sites.

References:
Lindroos, A-J., Derome, J., Raitio, H. and Rautio, P., 2007. Water, Air, and Soil Pollut. 180: 155-170.
Merilä, P., Kilponen, T. and Derome, J. (Eds.), 2007. Working Papers of the Finnish Forest Research Institute 45.
Yli-Halla, M, Puustinen, M. and Koskiaho, J., 1999. Soil Use and Management 15: 62-67.

P39

The uptake of Cu and Ni from smelter polluted-soil by planted tree seedlings

Eva Komanicka[1], Heljä-Sisko Helmisaari[2], Tiina Maileena Nieminen[1]
[1]Metla, Vantaa, Finland, [2]Department of Forest Sciences, Helsinki University, Finland

In Finland anthropogenic sources of Cu and Ni are from metallurgical industry, mainly from smelting of ores (Jalkanen, 2000). The effects of heavy metals on the forest ecosystem have been accomplished at one of the most metal polluted areas in Finland. The area is severely damaged and the understorey vegetation is almost completely lacking. The main objective of this study was to determine the effect of a mulch cover (mixture of biocompost and woodchips) on Cu and Ni uptake by treee seedlings from smelter polluted forest soil at Harjavalta in southwestern Finland.

Pine and birch seedling were planted in soil pockets (2 L, depth about 20 cm) containing mulch. Six plots (5 x 5 m^2) for both species were established. Half of the plots were covered by a mulch layer by spreading it directly on top of the forest floor. The other half was left untreated (control). The mulch consisted of a mixture of household biocompost and woodchips (saw mill waste). After a 10 year period 3 seedlings from each experimental plot were harvested, and their chemical content was analyzed by ICP-IRIS after dry ashing (Helmi-saari et al., 2007).

On the plots covered by mulch, the mean Cu and Ni concentrations both in Scots pine and Downy birch were lower in roots compared to the control plots. On the other hand, the concentrations of Ni in stems showed slightly higher concentrations in the mulch treatment than in the control. The Cu concentrations for their part were slightly higher in the mulch treatment in the case of birch stem, but an opposite pattern was seen in the case of pine stem, although the differences were small. Between-treatment comparison of Ni concentrations in pine bark showed higher value in the control, while there was no clear difference between the Cu concentrations. Birch Cu concentrations in the bark were somewhat higher and Ni concentrations somewhat lower in the mulch treatment compared to the control.

References:
Helmisaari, H.-S., Salemaa, M., Derome, J., Kiikkilä, O., Uhlig, C. and Nieminen, T., 2007. Journal of Environmental Quality 36:1145-1153.
Jalkanen, L., 2000. Finnish Meteorological Institute Contribution 29. 106 p.

P40

Geochemistry of potentially toxic elements in soils developed on karst in Croatia

Ozren Hasan, Slobodan Miko, Zoran Peh, Martina Šparica Miko
Hrvatski geološki institut - Croatian geological survey, Zagreb, Croatia

Regional geochemical baselines in topsoils developed on karst in Croatia were determined for potentially toxic elements (PTE). The concentrations of PTE in the Croatian karst soils differ due to mineralogical composition and different types of climate which influence pedogenesis (mountain and Mediterranean). Some of the PTE (Pb, Cd, Zn, Se and Hg) correlate with the amount of annual rainfall which in mountain areas is > 3500 mm. A total of 894 sampling sites were analyzed covering 50 % of Croatian karst region.

Evaluation of anthropogenic impact on soils developed on karst evaluated by calculation of enrichment factors, and their mobility potential was assessed with various chemical extractions. Total concentrations and aqua regia extracts were used to evaluate the extraction capacity of aqua regia for PTE, since this method for determination of PTE in soils is defined by Croatian environmental protocols. Soils were found to be mostly impacted on a regional scale by Pb, Cd, Zn, Hg and Se and locally Cu by agricultural activities. The distributions of Cr, Ni, Co, Mn, Mo, V and As are linked substantially to pedogenic processes and content of clay minerals, Fe-Mn oxides and possible bauxite influence.

Within the karst of the Dalmatian region more than 2000 deposits of bauxite were located within a belt 150 km long, and were mined during the second half of the 20th century. The bauxites are enriched Cr, V, As, Cd, Ni and Pb. The results of a geochemical topsoil mapping program (Halamić, 2009), that covered the whole Croatian karst region with almost 1700 sampling sites, showed that the soils from the Dalmatian region had 30 to 50 % higher concentrations of these metals than other karst regions. As most of the underlying carbonate rocks contain low insoluble residua the chemistry of mineral dust from which the soils were formed originated from two sources during the LGM - the Po and the Neretva river floodplains which were submerged during the Holocene sea level rise. These two different provenances give the distinct geochemical patterns. The high concentrations of Al, As, Co, Cu, Fe, La, Pb, Ni, Mn, Th, V, Cr, and Zn have higher mean values in soils transported (by wind) on carbonate bedrock from the Neretva floodplain during the LGM than those from the Po plain. These signatures in both geochemical provinces are influenced by various degrees by bauxite dust derived during mining activities.

References:
Halamić, J. & Miko, S., 2009. Geokemijski atlas Republike Hrvatske
(Geochemical Atlas of the Republic of Croatia), Croatian geological survey, 88p.

P41

Will the harvesting of peatland forest mobilize heavy metals from bedrock underlain by black-shale?

Liisa Ukonmaanaho[1], Mike Starr[1], Marjatta Kantola1, Juha Piispanen[1], Mika Nieminen[1], Markku Mäkilä[1], Kirsti Loukola-Ruskeeniemi[1], Tiina Maileena Nieminen[1]
[1]Metla, Vantaa, Finland, [2]University of Helsinki, Helsinki, Finland, [3]Geological Survey of Finland, Espoo, Finland, [4]Metla, Muhos, Finland

Heavy metals are in high levels eco-toxicological and harmful to human health. Much of the heavy metals in the environment is the result of atmospheric inputs. Forest canopies, particularly coniferous forests, are effective in capturing dry deposition loads of heavy metals, resulting in substantially greater total deposition loads reaching the soil than in non-forested areas. Because of its strong affinity for organic matter, much of the heavy metal deposition load reaching the forest floor is adsorbed in the surface soil layer. The surface layer of peatlands, in particular, shows strong enrichment in heavy metals. However, the harvesting and other disturbances of the forest floor might increase leaching of nutrients and heavy metals. This leaching might be greater from peatland areas underlain by black-shale (known to be rich in easily weathering heavy metals) compared with areas underlain by granitic bedrock.

Our aim is to compare the effects of stem-only harvesting (SOH) and whole-tree harvesting (WTH) on the release and transport of heavy metals to surface waters. We will further investigate differences in heavy metal losses between catchments on different bedrock types (black shale/ granitic bedrock).

In 2007, study plots were established nearby Sotkamo area (Finland) and a runoff gauge was installed in the outlet of the ditch of each catchment. In 2009, two of the catchments were harvested using SOH, and four of the catchments were subjected to WTH. The remaining two catchments were left unharvested to serve as controls. The study was conducted as a pair-catchment study. Ditch water samples have been collected since 2008 during snow free period, year 2008 representing a calibration year. Heavy metals and nutrients have been determined from the samples. Additionally, peat cores, biomass and needle samples have been taken from the sites and their nutrient and heavy metal concentrations have been determined.

Preliminary results indicated that There were differences in ditch water quality before and after harvesting, but the underlain bedrock type didn't effect on to the quality of the ditch water as much as was expected.

P42

Deep Cover Geochemistry from an Ancient Glacial Landscape: geochemical exploration framework for Permian sedimentary profiles of the Troubridge Basin, South Australia

Verity Normington, S.M. Hill, Robert C. Dart
University of Adelaide, Adelaide, Australia

Permian sediments are associated with some of the areas of deepest sedimentary cover in South Australia. The Permian sedimentary cover has, therefore, been a frustrating mineral exploration impediment, especially because it covers parts of highly prospective mineral provinces, such as the northwestern and southern margins of the Olympic Domain of the Gawler Craton. The Permian in South Australia is associated with a series of sedimentary basins (or more precisely discrete remnants of a more widespread sedimentary cover) of which the Troubridge Basin is one of the most accessible and best exposed. This study has defined some of the geochemical characteristics of these sediments with the aim of providing a regional context to geochemical exploration within this sedimentary cover, in particular to identify potential regional geochemical sampling media that may distinguish between distal and proximal geochemical settings for buried mineralisation targets.

The Troubridge Basin extends across the Adelaide region and westwards onto the south-eastern margins of the Olympic Domain of the Gawler Craton, which is highly prospective for IOCG mineralisation, and eastwards over the base metal prospective Neoproterozoic to Cambrian Delamarian Orogen and Kanmantoo Trough. Sediments are mostly glacigene and include lodgement tills, diamictons, glacio-lacustrine sediments, sub-aerial and sub-aqueous fluvio-glacial sediments and glacio-marine sediments. The sediments are broadly defined within the Cape Jervis Formation and their age is best constrained from early Permian microfossil assemblages from the upper parts of the sequence.

The approach here has been to first refine the palaeo-landscape reconstructions associated with these sediments to better constrain the physical dispersion characteristics and vectors. Within this context a series of key sedimentary sections have been identified for detailed geochemical characterisation. Included here has been the identification of geochemical interfaces within the sediments. These include physical interfaces, such as basal gravels, resistate mineral lags and changes in sediment lithology, as well as chemical interfaces, which include redox boundaries, aquifer systems, and weathering and induration overprints. This approach, therefore considers the geochemical characteristics of both the primary sedimentary features as well as the secondary weathering overprints. Most significant here has been the recognition of redox-related chemical interfaces and associated indurations, which are readily identifiable in sections and drill-holes, relatively efficient to representatively sample and host trace elements related to the different mineral systems for which different parts of the basin are prospective (e.g. base metals and IOCG mineralisation).

P43

Tracing the origin of gold nuggets at Palsinoja and Kultaoja in Finnish Lapland

Jari Nenonen[1], Peter Johansson[1]
[1]Geological Survey of Finland, Kuopio, Finland,
[2]Geological Survey of Finland, Rovaniemi, Finland

The study area of Palsinoja is located in the southern part of Inari, Finnish Lapland. The purpose of this study was to analyze the gold content of the area and the origin of nuggets and to test sampling methods used in GTK.

During the study, the gamma-spectrometric drill hole measurements was tested in co-operation with Astrock co. GPR measurements was made to determine the depth of bedrock surface and to design the location of sampling pits. For examining of the area there were made 10 drilling holes for sampling and gamma-spectrometric measurements. The drill hole sampling was supplemented by the test pits made by tractor excavator, from which the corresponding samples were taken. Till samples were taken for heavy mineral studies and geochemical analyzes. The content of gamma-radiation was measured from the sampling holes.

According to the results the sampling methods were suitable to this kind of study. The gamma-spectrometric drill hole logging was useful and handy addition to the other study methods in gold nugget tracing. The gamma-spectrometric measurements correlates well with heavy radioactive monatzite and gold nuggets. According to the results amount of gold nuggets in the study area was smaller than studied before. Most likely the origin area of gold nuggets on Palsi River valley is the big fault zone on the west side of the study area.

The study area of Kultaoja is located in the northernmost part of Sodankylä, Finnish Lapland. The goal of the study was to determine the origin of angular and un-migrated gold nuggets In the Kultaoja area. These gold nuggets were found by local gold diggers. The study was carried out with tractor excavator. Till and bedrock samples were taken for heavy mineral studies and geochemical analyzes. Two meters wide, weathered, gold bearing quartz-hematite-carbonate vein was found as a result. It seems that the gold bearing vein is connected to the younger bedrock structures which cuts vertically the local granulite bedrock. During the gold digging history of Lapland this case is the first time when we can point out the origin area of studied gold nuggets.

References

Johansson, P., Huhta, P., Nenonen, J., Hirvasniemi, H., 2000. Kultakaira. Geological outdoor map and guide book of Ivalojoki-Saariselkä. Geological Survey of Finland.
Saarnisto, M. and Tamminen, E., 1985. End report of the Lapland's gold project, report 3, the University of Oulu, faculty of geology, 88 p.

P44

Till geochemistry in gold exploration at Petäjäselkä, northern Finland

Helena Hulkki, Tuomo Karinen, Pertti Sarala
Geological Survey of Finland, P.O. Box 77, FI-96101 Rovaniemi, Finland

The Geological Survey of Finland (GTK) has done gold exploration in the Petäjäselkä target since 1980s based on the gold anomalies found in the regional till geochemical mapping, but more intensively during 2002-2009. The target is located in the municipality of Kittilä about 20 km southeast from the Kittilä Gold Mine. The bedrock is composed of mafic volcanic rocks of the Paleoproterozoic Central Lapland Greenstone Belt and BIF and tuffite-graphite schists of the Porkonen formation. The bedrock has undergone extensive hydrothermal alteration which is connected with weakness zones (shears, faults) trending in various directions.

The terrain in Petäjäselkä is composed of glacigenic deposits consisting mainly of till. The thickness of till cover is ranging from 1 to 3 m in the higher ground and is over 5 m in the lowland areas. Over 20 m till deposits are observed in the northern parts. Main ice-flow direction has been from the west to the east, although exceptional directions (from SW and NE) can be found in places due to variable relief. Glacial transport distance for till is usually low, because the area situates in the central part of the cold-based Late Weichselian glacier and in the ice-divide zone of the last deglaciation. Pre-glacial weathered bedrock surface with the thickness of 0.5-3.0 m is commonly observed between the fresh bedrock and till.

In the present study geochemical sampling of till and weathered surface of bedrock using 250 m grid covers 52 km^2 and is supported by the test trench studies with till stratigraphy, till geochemistry, heavy mineral studies and channel sampling. High gold contents of till (> 20 ppb) have been observed largely in Petäjäselkä with median 6.2 ppb and maximum 904 ppb. Many of these anomalous places have been diamond drilled. Results prove that gold has been enriched in sulfide-carbonate-quartz-rich veinlets with two major gold-bearing zones associated both with cherty rocks in Kerolaki, and the carbonate and sericite altered rocks in Selkä-Mäntypää. Furthermore, over 1 ppm Au content has been commonly analyzed in the bedrock. The best gold-enriched intersection in diamond drill core in Kerolaki is 1.05 m @ 12.6 ppm and 1.00 m @ 3.1 ppm in the eastern part of Selkä-Mäntypää. Strong enrichment of gold was discovered from Ranta-Mäntypää with the best section having 3.00 m @ 28.2 ppm.

P45

Geochemical variability in Daumantai warm period lithocomplexes

Valentinas Baltrūnas, Rimantė Zinkutė, Ričardas Taraškevičius, Bronislavas Karmaza, Vaidotas Kazakauskas, Valentas Katinas, Lina Lagunavičienė
Nature Research Centre Institute of Geology and Geography, Vilnius, Lithuania

In autumn of 2010 KVARTERAS project was started for detailed analysis of palaeoenvironmental conditions in Quaternary interglacials in order to find out the factors determining the species migration, invasion and adaptation. The aim is to establish the cyclicity of the natural and anthropogenic environmental changes during the main interglacials according to biogeochemical and other indicators. Analysis of geochemical variability is useful for this aim.

This research deals with Daumantai outcrop which is located on the right bank of Šventoji River where the pre-Preistocene sediment sequence is exposed. This sand and silt sequence lies with sedimentation break on Devonian sandstone and is covered by glacigenic sediments. The sequence has a long history of investigations aimed at search of stratigraphic boundary between Neogene and Quaternary which is related to climate cooling. The cyclicity has been noticed in the sequence which is related to climate changes.

At the end of 2010 new samples were taken from 2.3-19.2 m depth interval of the outcrop. Their number is 156. The following lithocomplexes were distinguished earlier in this interval (Šinkūnas et al., 2001): 16.55-19.25 m (L-V), 10.5-16.55 m (L-IV) and 2.2-10.5 m (L-III). Sand of L-V is the coarsest and less sorted, meanwhile sand of L-IV and L-III is well sorted and finer in L-III than in L-IV.

Total contents of chemical elements were determined by EDXRF equipment SPECTRO XEPOS using TURBOQUANT calibration method for pressed pellets. Sample preparation included drying, milling, mixing with binder and pressing.

The contents of 19 chemical elements were above detection limit DL in all samples. Their arrangement according to decrease of relative standard deviation RSD in 156 samples K(109)>Sr(107)>Rb(106)>Fe(93)>Al(92)>Th(85)=Y(85)>Cl(84)>V(80)=Pb(80)>Mn(74)>Ti(67)>Ba(65)>Zr(47)>Hf(41)>Zn(40)>P(24)>Si(13)>Sn(11) indicates higher variation of elements related to fine fractions or carbonates. Median contents of most of these elements increase upwards from L-V to L-III, except Si and Sn, which have the opposite tendency. The highest RSD values of Al, K, Fe, Ti, V, Sr, Ba, Pb and Th are in L-V, of Rb, Mn, P, Zn, Y, Cl in L-IV and of Si and Sn in L-III. Other 15 elements are above DL in more than 50 % of samples, according to decrease of RSD their arrangement is S(358)>As(159)>Ni(113)=Ca(113)>Ga(104)>Mg(92)>Br(91)>Cu(89)>Na(86)>Cr(81)>Nb(62)>I(47)>Te(45)>Mo(34)>Sb(33). The contents of most of these elements also increase upwards, except Te, Sb, I with opposite tendency and S. The highest variability of Te, Sb, I is in L-III, of Na in L-IV, of other 11 elements in L-V.

References:
Šinkūnas, P., et al., 2001. Sedimentological aspects

of deposits in Daumantai and Vetygala outcrops (in Lithuanian). Litosfera 5: 67-79.

P46

Development of Indicator Mineral Methods for Base Metal and Uranium Exploration in Glaciated Terrain

Beth McClenaghan[1]*, Roger Paulen*[1]*, Anna Hicken*[2]*, Natasha Oviatt*[3]*, Scott Robinson*[2]*, Dan Layton-Matthews*[2]*, Sarah Gleeson*[3]*, Stu Averill*[4]

[1]Geological Survey of Canada, Ottawa, ON, Canada, [2]Queen's University, Kingston, ON, Canada, [3]University of Alberta, Edmonton, AB, Canada, [4]Overburden Drilling Management Ltd., Ottawa, ON, Canada

Analogous to kimberlites, base metal and uranium deposits have characteristic suites of indicator minerals that can be recovered from surficial sediments. However, limited research has been conducted to document the abundance and chemistry of these minerals within the deposits and how they are dispersed in glacial sediments. To address this knowledge gap, the Geological Survey of Canada (GSC) through its Geo-mapping for Energy and Minerals (GEM) Program, has collected suites of bedrock and till samples around two base metal and one uranium deposit in Canada. The objectives of these case studies are to characterize the geochemical and mineralogical signature of specific deposit types at the deposit- and camp-scale at varying distances up- and down-ice, to define background and to establish methods for indicator mineral recovery and characterization. Results from case studies at the Izok Lake Zn-Cu-Pb-Ag VMS deposit, Pine Point Pb-Zn MVT deposits, and the Kiggavik U deposit will be presented. These case studies add to the broad spectrum of commodities (diamonds, base and precious metals, uranium) that indicator minerals methods are now used for.

P47

"3-Dimensional" mineralogical investigation of a lamproite dyke from the Kostomuksha area (Karelia, Russia) using a combination of Electric Pulse Disaggregation (EPD) and Hydroseparation (HS) methods

Nikolay S. Rudashevsky[1]*, V. Ya. Gorkovetz*[2]*,*
Vladimir N. Rudashevsky[3]*, Louis J. Cabri*[3]

[1]Center for New Technologies, St. Petersburg, Russia, [2]Geological Institute, Karelian Scientific Center of Russian Academy of Sciences, -, Russia, [3]CNT Mineral Consulting Inc, Ottawa, Canada

The mineralogy of a 2.5 kg drill core sample from a 2 m thick lamproite dyke (Kostomuksha iron deposit region; Gorkovetz et al., 2009) was studied by using newly developed "3-Dimensional" EPD & HS mineral processing technology. The chemical composition of this rock is typical for lamproites and dominant primary minerals (tetra-ferriphlogopite and phlogopite) are Mg-and Ti-rich. The lamproite phenocrysts are completely replaced by saponite and calcite intergrown in a mica matrix. Mica and calcite-saponite aggregates contain fine (<50 µm) inclusions of different accessory minerals.

After EPD processing, screening, and HS separation (Rudashevsky et al., 1995, 2002, Cabri et al., 2008), the heavy mineral concentrates (40-250 µm), mounted in polished sections after some hand-picking, were characterized by scanning electron microscopy and microprobe analysis.

The heavy mineral HS concentrates contain titanium oxides-(Nb) (rutile and anatase), base metal sulphides (pyrite, chalcopyrite, pentlandite, etc.), native metals (native iron, copper, Fe-Cr-Ni alloy, etc.), relicts of rock-forming minerals (sanidine, amphiboles of the edenite-ferro-edenite isomorphic series and grunerite, very rare diopside and hypersthene), apatite-(Sr,Ce), chromespinels, magnetite, and other characteristic lamproites accessory minerals (e.g. barite, henrymeyerite, priderite, baotite, alstonite/barytocalcite, strontianite, monazite-Ce, calcium catapleiite/calcium hilairite, and wadeite). Thus, according to chemical and mineralogical compositions these rocks can be characterized as completely replaced sanidine-amphibole-phlogopite basic lamproites. Study of heavy mineral HS concentrates resulted in characterization of xenocrystals derived from different deep earth rocks (e. g. probably diamond-bearing xenoliths from mantle peridotites): 1) chrome-diopside; 2) Cr-pyrope; 3) almandine, 4) corundum, 5). high-Cr magnesio-chromite (Cr_2O_3 up to 63.4 wt. %).

Using "3-Dimensional" EPD & HS mineral processing technology 40 different minerals were characterized, including those considered most characteristic for lamproites, even though these rocks were completely replaced by secondary silicates. In contrast, only 18 minerals were found in polished sections. Such complex mineralogical results, preserving unique ontogenetic evidence of minerals, enables reconstruction of the mineral paragenesis for all stages of formation as well as providing important data on the potential diamond-bearing nature of these lamproites.

References:

Cabri, L.J., et al., 2008. Canadian Mineral Processors 40th Ann Mtg., Proceedings, Paper 14, 211-235.
Gorkovetz, V. Ya., et. al., 2009. Geology and ores of Karelia, Part 12. Petrozavodsk. Karelian Scientific

Center of Russian Academy of Sciences. 94-95.
Rudashevsky, N.S., et al., 1995. Transactions, Institution Mining Metallurgy, Proceedings Australasian Institute Mining Metallurgy (Sect. C), 104, C25-C29.
Rudashevsky, N.S., et al., 2002. Transactions, Institution Mining Metallurgy, Proceedings Australasian Institute Mining Metallurgy (Sect. B), 111, B87-B94.

P48

Geochemistry of platinum group elements (PGE) in chromitites from the Sabzevar ophiolitic complex, Northern Iran

Mohssen Moazzen, Majid Sayyaran
University of Tabriz, Tabriz, Iran

PGE-bearing chromitites are associated with Sabzevar ophiolitic complex rocks in Northern Iran. The rock units in the study area include dunite, serpentinized harzburgite, chromitite, serpentinite, diabasic dykes and gabbro. Primary and secondary textures and structures are developed in the chromitites due to magmatic processes and following tectonic events during emplacements. Also some textural features are post-deformational. The primary textures are disseminated, net, nodular and massive textures and the secondary textures include pull-apart, folded, cataclastic, mylonitic and brecciated textures. The Cr_2O_3, Fe_2O_3, MgO, Al_2O_3 and TiO_2 content of the chromite and discrimination diagrams based on the platinum group elements chemistry, confirm a podiform nature for the studied chromitites. Chromites are Cr-rich and Al-poor. Correlation between three valance elements and other cations and also Cr/Fe ratio indicate that the oxygen fugacity was low and the rate of partial melting was high during generation of the parental melts in the lower part of the upper mantle. Investigations using SEM show that Ni-Fe alloys are formed within the chromite crystals as a result a low oxygen fugacity condition. The La-Ce alloys (confirmed by SEM studies) are attributed to hydrothermal and serpentinization processes, after formation of the chromitites. Depletion of all PGE in comparison with those from the Bushveld-type deposits indicates the low content or absence of sulfur during formation of the chromitites. The positive correlation between Cr/(Cr+Al) with all PGE shows simultaneous crystallization of phases containing these elements at relatively high depth . The average content of PGE in Sabzevar chromitites is in the range of PGE content of podiform chromitites from other parts of the world especially those from chromitites of the Oman ophiolite.

P49

Gold mineralizaton related to Nabijan pluton, Alborz-Azerbaijan magmatic belt, NW Iran

Ahmad Jahangiri, Maryam Yazdani
Dept of Geology University of Tabriz, Tabriz, Iran

Cenozoic Alborz-Azerbaidjan magmatic belt comprises numerous calc-alkaline plutonic batholite and stocks that followed by dacitic sub-volcanic adakitic domes intrusions. This magmatic event accompanied by porphyry and skarn copper mineralization and epithermal gold mineralization. The Nabijan pluton forms a diorite, monzo-diorite, monzo-gabbro intrusion in Alborz-Azarbaidjan magmatic belt in NW Iran. The intrusive occurs as stock and intruded into Upper Cretaceous impure limestones and Eocene volcanic rocks. In contact with impure limestone host rocks hornblend-hornfels, epidote-biotite-hornfels, garnet-marble metamorphic rocks developed as skarn zone. The studied samples indicate calc-alkaline magmatic character and enrichment in incompatible elements such as Rb, Ba, Sr, Zr, Ce and negative anomalies of Nb, Ta and Ti with subduction related geochemical significant. Gold mineralization is associated with silicic veins, stockwork veinlets, and hydrothermal alteration and skarn zone. The quartz veins and vienlets are irregular, intersect and open space filling associated with euhedral to subhedral quartz minerals, iron oxides and hydroxides, pyrite, chalcopyrite, bornite, sphalerite and galena. Gold occurs as microscopic and sub microscopic grains in quartz and pyrite. The Au content in this zone is measured up to 4900 ppb. Disseminated sulfide zone is developed under silicic zone. The depth of disseminated sulfide zone based on geophysical exploration is determined up to 90 meters. The essential minerals of skarn zone are calcite, garnet, magnetite, epidote, talk, and pyrite. The Au content of skarn zone varies based on wall rock composition and is measured from 30 ppb up to 5 ppm.

P50

REE geochemistry and their mineral phases in Jammi carbonatite veins and fenites, southern side of Sokli complex, NE Finland

Thair Al Ani, Olli Sarapää
GTK, Rovaniemi, Finland

The Jammi area is located 4 km south of the core of the Sokli carbonatite complex, NE Finland. Bedrock in the Jammi area consists of Archaean mafic volcanic rocks and tonalitic gneiss, which were intruded by the Devonian Sokli carbonatite causing a argescale, intense fenitization of the country rocks (Vartiainen 1994, 2001). The rocks are albite-fenlites, crosscutting late carbonatite and lamprophyric dykes, with the mineral assemblages of calcite-dolomite-aegirine-albite-apatite-phlogopite.

Material for the mineralogical and geochemical study was selected from the cores drilled in the area by GTK, from which Kontio and Pankka (2006) have reported high lanthanum and zinc contents in carbonatite dykes. Whole-rock geochemical data indicate that the carbonatite dykes are characterized by enrichment in incompatible elements, such as P_2O_5 (19.9 %), Sr (1.9%), Ba (6.8%), Zn (0.3%) and REE (1.8%). The samples also show a high total REE (0.11-1.83 %), including 0.11-1.81 % LREE and 0.002-0.041 % HREE. Seven rare earth minerals have been analysed in detail from the area, including Sr-rare-earth apatite, monazite, ancylite (Ce), bastnäsite (Ce), strontianite, baryte and brabanite.

The Jammi carbonatite and fenite samples show similar REE patterns with highest LREE enrichment and steep slopes towards the HREEs. The REE distribution in the whole-rock data is controlled by carbonate and apatite. REE-rich accessory phases such as monazite and ancylite (Ce) influence the whole-rock pattern only where present in large amounts.

Mineralogical and chemical evidence demonstrates that hydrothermal processes were responsible for the REE mineralization in the Jammi carbonatite veins and confirms that such processes are predominant in the formation of REE minerals in carbonatites. During late-stage processes, apatite and carbonate minerals have been replaced by various assemblages of REE-Sr-Ba minerals. Apatite of the late carbonatite dykes contains significant amounts of Sr and REE, which suggests that the rare earth elements are a potential by-product of the future phosphate production in the Sokli area.

References:
Kontio, M. & Pankka, H., 2006. Tutkimus työselostus Savukosken kunnassa valtausalueella Jammi 1, kaiv. rek. nro 7819/1 tehdyistä malmitutkimuksista 2004-2005. Geological Survey of Finland, Report M06/4723/2006/1/10. 8 p.
Vartiainen, H., 2001. Res Terrae. Ser. A 20. Oulu: University of Oulu, 8-24.
Vartiainen, H. & Vitikka, A., 1994. Geochemistry International 31, 103-106.

P51

Geochemistry and REE -Mineralogy of Virtasalmi kaolins, SE Finland

Thair Al Ani, Olli Sarapää
GTK, Rovaniemi, Finland

Mineralogical and geochemical study on Virtasalmi kaolin occurrences includes three objectives. 1) to determine the abundance and distribution of REE in the studied kaolin profiles, 2) to address the factors controlling the distribution pattern and behaviour of REE during kaolinization process, and 3) to find out the potential of Virtasalmi kaolins for ionic adsorption type REE-deposits. The samples for mineralogical and chemical studies were selected from the drill cores of the Litmanen, Eteläkylä, Vuorijoki and Montola deposits. The detailed description of these deposits has been presented by Sarapää (1996).

Two factors affect the REE concentration in Virtasalmi kaolins: (1) REE enrichment, 50-85 % of the REE are related to ionic adsorption from solution onto kaolinite and halloysite minerals during weathering process. (2) The residual REE-bearing minerals, such as monazite and zircon, derived from parent rocks were the second source of REEs enrichment in kaolins.

Chondrite-normalized REE patterns of the Virtasalmi kaolins show an overall enrichment of LREE (Lan/Smn=3-5 and Lan/Ybn = 6-19), HREE depletion (Gdn/Ybn = 1.3-2.6) and slightly negative Eu anomaly (Eu/Eu* >1), probably inherited from the parent rocks. The HREE and Y complexes remained in solution, separated from the LREE and subsequently precipitated at deeper levels of the weathering profiles. High HREE contents in some of the studied profiles were produced by adsorption of REE and Y onto kaolinite surfaces.

The present study also shows that the total aqua regia-soluble REE content of kaolin in basal part of weathering profile is up to 0.1-0.2 % in the Litmanen and Eteläkylä deposits.

References:
Sarapää, Olli, 1996. Proterozoic primary kaolin deposits at Virtasalmi, southeastern Finland. Espoo: Geological Survey of Finland. 152 p. + 6 app.

P52

Regolith Landform Mapping as an aid to the interpretation of Au-in-calcrete geochemical anomalies: an example from the Tunkillia Au prospect, South Australia

Robert C Dart, S M Hill, Karin M Barovich, David J Chittleborough
University Of Adelaide, Adelaide, South Australia, Australia

The Tunkillia Au prospect is in the central Gawler Craton, approximately 550 km northwest of Ade laide, South Australia. The prospect with a defined resource of about 800,000 oz of Au, is coincident with an extensive calcrete anomaly of > 10 ppb Au that extends for approximately 20 km with a width of up to 3 km. Despite multiple exploration drilling programs costing in excess of $10 million, the Tunkillia Au prospect remains the only significant discovery within the regionally extensive calcrete anomaly.

The above example is only one of several anomalous Au-in-calcrete areas identified in the region, which have all seen similar drilling activity at high cost with minimal success. A way to efficiently rank these anomalies and to identify potential targets within them, other than blanket drilling, is required. A regolith landform mapping study of the Tunkillia Au-in-calcrete anomaly demonstrated that the potential Au source area matching that of the known Au mineralisation could be predicted. The observations made during this research could have been recorded at the time of initial sample collection, and may have led to faster and therefore cheaper discovery of the underlying mineralisation.

The regolith landforms of the anomalous area can be divided into three parts, which together form a terrain with a minimal slope towards the north of < 1 %. The southern area includes known mineralisation and consists of a large dunefield, which marks the eastern boundary of the Great Victoria Desert. The central area consists of large erosional plains that are gradually being buried by migrating dunes. The northern area consists of a number of ephemeral lakes that are fed by numerous shallow (< 25 cm) drainage depressions.

Importantly, regolith landform mapping identified palaeo-drainage pathways in the dune swales that connected with contemporary drainage systems on the plains. The head of this drainage system was found to be near the known area of mineralisation at Tunkillia, which sits on the northern side of a drainage divide. Additionally, the spatial extent of this palaeo/contemporary drainage system matched the defined Au-in-calcrete anomaly. Hence a potential transportation pathway for Au and other pathfinder elements had been identified.

The above example demonstrates that analysing geochemical data without knowledge of landscape controls can provide costly and misleading interpretations. The highest Au-in-calcrete assay may not necessarily be located directly above mineralisation, but instead have undergone lateral dispersion.

Regolith landform mapping used in this way can provide a framework to help account for many features of the geochemical signatures observed in exploration, especially with regard to the lateral extent and spatial pattern of the anomaly.

P53
Research Frontiers in Greenfields Exploration: Plant-Regolith-Bedrock Geochemical and Biogeochemical Relationships and Interactions in the Musgrave Province of Central Australia

Stephanie McLennan[1], Steven Hill[1], Lachlan Rutherford[2], Karin Barovich[3]
[1]Deep Exploration Technologies Cooperative Research Centre, School of Earth & Environmental Sciences, University of Adelaide, South Australia, Australia, [2]PepinNini Minerals Limited, Adelaide, South Australia, Australia, [3]School of Earth and Environmental Sciences, University of Adelaide, South Australia, Australia

The Musgrave Province in South Australia provides a major mineral exploration frontier with extensive areas of transported cover, rugged terrain, and harsh climate that can be difficult for travel, as well as indigenous landholding that restricts external access. To date, a well established geochemical exploration approach has not been developed for the region. Plant biogeochemical exploration techniques should be ideal in this region for three main reasons: i) there is abundant vegetation cover (especially including spinifex that has been characterised elsewhere in arid Australia); ii) samples can be collected over a short period of time and economically analysed; and, iii) plant sampling programs require minimal sample size, and can be conducted on foot, thus minimising environmental impact. This study characterises the biogeochemical expression of possible mineralisation under transported cover within PepinNini Minerals Limited's Woodroffe and Mt Caroline tenements of the central Musgrave Province, South Australia. The biogeochemical results are compared against regional geophysical expressions of underlying bedrock as well as vacuum drilling results that were drilled and sampled after plant sampling had taken place (hence minimising detrital contamination of plant samples).

The results suggest spinifex (Triodia basedowii) leaf samples provide an expression of subsurface geochemistry through elevated metal contents overlying geophysical expression of bedrock units or by providing coherent patterns of results along transects crossing different rock types and deep palaeodrainage systems. The results highlight the broad Ni-Cu sulphide prospectivity of the Mt Caroline intrusion (with locally elevated Ni, Cu and Co in the basal parts of the mafic intrusion) as well as unexpected Au prospectivity in the wider region. The biogeochemical results have a poor correlation with the vacuum drilling sample geochemistry. This could be due to the imprecise constraints on the downhole source of vacuum drilling samples or it shows the poor relationships between regolith geochemistry and plant biogeochemistry, perhaps because the plants are sampling from deeper in the profile, more closely approximating the bed rock geochemistry that underlies the vacuum drilling samples.

In the longer term, the biogeochemistry and regolith geochemistry characteristics will be compared with further regional plant and regolith samples, diamond drillhole geochemistry and regional groundwater samples from water bores. This combined analysis program should provide a geochemical-biogeochemical-hydrogeochemical three-dimensional landscape and element dispersion model for the region, incorporating landscape features and processes from fresh rock to fresh air.

P54

Characteristics and weathering of particulate gold, Avoca alluvial gold deposit, Victoria, Australia

Charles Butt
CSIRO Earth Science & Resource Engineering, Kensington, Australia

Placer gold in the Avoca district, Victoria, Australia, and in many other alluvial deposits in the region, has long been considered by many geologists to be supergene. The morphology, composition and crystallography of gold from the deposit has been examined to determine its origin. Gold was discovered at Avoca in 1853 and exploited by extensive shallow mining. The deposits were re-mined in 1991-2000. Particulate gold, generally 100 µm to 1 cm, occurs in Tertiary clay, sand and gravel, 2-20 m deep, in NE - trending palaeodrainage systems incised into metamorphosed Ordovician shales and sandstones. Primary gold mineralization in the region is associated with quartz veining in the Ordovician sediments.

The grains range from irregular to equant, rod-like or flat. Some have angular projections and cavities with xenomorphic imprints after quartz and pyrite; rarely, angular quartz and gold are intergrown. Surfaces are smooth and pristine. Other grains are well rounded with pitted surfaces. Many grains have pristine surfaces on cavity walls and pitted surfaces on extremities. Pristine surfaces have 1 - >12 % Ag, whereas pitted surfaces have no detectable silver. Internally, pitted surfaces have a zone <10-200 µm thick with <1 % Ag, with the remainder of each individual grain having a uniform composition (range ~1 % to 15 % Ag, similar to corresponding pristine external surfaces). There is a wide compositional range at each site. Most grains are polycrystalline, generally with equant and twinned crystals, typical of annealing at high temperatures. Many grains have inclusions of galena. External and internal cavities have fine single crystals (1-3 µm) and intergrown crystal clusters of pure gold in a clay - iron oxide matrix. The clusters consist of poorly-terminated to spherical or ovoid crystals with a bud-like habit. In section, the clusters appears as elongate particles to >5 µm, some branching.

The silver content, internal crystal fabrics and/or sulphide inclusions indicate the grains are all hypogene. The Ag-depleted rims are a product of weathering and the only supergene gold is the very fine crystals and dendritic clusters, presumably precipitated from gold released during the weathering of the ‘host’ grain. The high variability in silver contents between grains implies they are derived from several sources or, more probably, the sources themselves are inhomogeneous. The sediments were weathered after deposition and most of the gold grains have external evidence of weathering. All rounded surfaces are pitted and depleted in silver, and some rounding may be due to corrosion. Preservation of the delicate crystal clusters implies that their formation was post-depositional. Other than the probability of acidity due to iron oxidation and hydrolysis, the conditions of weathering are unknown. However, they were probably similar to a humid soil-like environment with abundant organic matter that could complex with and dissolve silver and gold.

P55

Gold Dispersion through Young Carbonate Cover Overlying the Woodlark Epithermal Gold System, Papua New Guinea

Dayna McGeeney[1], David Cohen[1], Ian Graham[1], Lee Spencer[2]
[1]University of New South Wales, Sydney, NSW, Australia, [2]Kula Gold Ltd, Sydney, NSW, Australia

Transported regolith or sedimentary rock cover limit the effectiveness of conventional geochemical exploration techniques to detect underlying sulphide mineralisation using surface samples. Various combinations of selective extractions and multivariate data modeling methods permit isolation of trace element signals that reflect subtle geochemical dispersion haloes in transported cover in a range of environments (Mokhtari et al., 2009; Kelley et al., 2003; Hamilton et al., 2004). Various models have been proposed to account for the dispersion.

The Miocene Okiduse Volcanics on Woodlark Island host carbonate-base metal-Au epithermal mineralization. The Okiduse is covered by up to 90 m of Pleistocene Kiriwina Formation basal conglomerates, estuarine muds and porous reefal limestones. All units, including the limestone, are faulted due to ongoing tectonic deformation of the region. There is multi-phase lateritic weathering of the Okiduse-Kiriwina profiles. Oxidised palaeo-beach sand deposits, sandwiched between bioturbated estuarine muds and coralline limestone, contain economic grades of Au in some areas. Hydrothermal alteration and silicification of the basal parts of the limestone, is typically accompanied by elevated Au. There is physical incorporation of heavy minerals derived from the volcanics into the muds and basal sections of the limestone. Diagenetic pyrite occurs in the muds and replaces coral fragments.

Drill and trench regolith profile samples were analysed to examine the relationship between form and distribution of Au in the volcanic and Kiriwina, and assist in development of surface geochemical exploration methods. Based on a comparison of aqua regia and distilled water extraction data, a significant proportion of the Au is mobile in the Kiriwina (0.1-1% of the total Au extractable by water). Manganese, Hg, Cd, Br and I concentrations are elevated in the conglomerates compared with the overlying Kiriwina or underlying Okiduse, with exceptionally high Hg in the colluvium at the Kulumadau prospect.

Au may be mobilising as thiosulphate complexes (Webster and Mann 1985), colloidal Au or organic-bound Au species. The existence of a chemically mobile Au component with the tectonic activity of the region (following the model of Cameron et al. 2004) may explain some of the vertical patterns of Au distribution through the Kiriwina.

References:
Cameron, E.M. et al., 2004. Geochemistry: Exploration Environment Analysis, 4, 7-32.
Cohen, D.R. et al., 2010. Geochemistry: Exploration Environment Analysis, 10, 3-16.
Hamilton, S.M et al., 2004, Geochemistry: Exploration Environment Analysis, 4, 45-58.
Kelley, D.L. et al., 2003. Geochemistry: Exploration Environment Analysis, 3, 85-104.
McGeeney, D.E., 2011. Stratigraphy and Gold Distribution in the Kiriwina Fmn, Woodlark Island, PNG. Hons thesis, UNSW.
Mokhtari, A.R. et al., 2009. Geochemistry: Exploration Environment Analysis, 9, 227-236.
Spencer, L.K. et al., 2010. Woodlark Island, PNG: An Expanding Epithermal Gold Province. Proc of 13th Quad IAGOD Symp, Adelaide, 125-126.
Webster J.G. and Mann A.W., 1984. Journal of Geochemical Exploration, 22, 21-42.

P56

Geochemical Exploration in Ravnnaluhppu, Karasjok, Northern Norway

Hannu Ahola, V. Juhani Ojala

Ravnnaluhppu Cu-Au occurrence is in the N-trending Karasjok greenstone belt (KGB) in northern Norway, 3 km east of the Karasjok town. The Cu-Au mineralization is hosted by a sequence of mafic metavolcanic rocks, felsic and black schists. The KGB is a part of a Palaeoproterozoic greenstone belt array extending for more than 500 km across the northern Fennoscandian shield. Ravnnaluhppu is situated in the slope of the Karasjok river valley approximately 200 m above the present sea level. The main Quaternary deposits in the sampling area are till, diamicton and sand (valley fills). In 2004, Store Norske Gull AS (SNG) targeted the Ravnnaluhppu area, because previous exploration had revealed combined geophysical (electromagnetics and magnetics) and geochemical anomalies. In addition, an old exploration pit with copper showings was found in the area. In 2007, geological mapping and soil sampling for a selective leach method (Mobile Metal Ion) was done in the area. In 2008, three diamond drill holes were drilled to test the geochemical and selective leach anomalies. In 2008, a comparison between two selective leach assay methods, the Mobile Metal Ion and the Ionic Leach, was done in the Ravnnaluhppu area. In 2009, exploration continued with a more detailed ground geophysical survey and geochemical sampling. The soil samples were assayed with the aqua regia digest. In addition, a portable XRF analyzer (Niton) was used to map the geochemical soil anomaly. Later in the summer the anomalies were drill tested. During SNG exploration in the Ravnnaluhppu area, five C-horizon overburden samples (5 l) have been collected for a heavy mineral study, primarily to count the Au nuggets.

Based on the drilling results (up to 1 % Cu and 1,7 g/t Au @ 1m), the geochemical methods applied in the Ravnnaluhppu area were successful in detecting the Cu-Au mineralization under the cover. Strongest Cu-anomalies in soil exceed 800 ppm with the aqua regia digest and over 100 times the background values with the selective leach method. One heavy mineral sample in the area counted 29 gold nuggets and two other samples count more than 20 nuggets. Most of the nuggets are 0,02-0,05 mm in size (largest 0,15 mm) and angular to subangular in shape. Although the area is interpreted to be influenced by glacial, meltwater and gravitational processes the overburden geochemical and heavy mineral anomalies are found on top of the mineralized bedrock. In addition, the geochemical anomalies are diluted to background levels in a relatively short distance (<100 m).

The anomaly patterns of the conventional and selective leach geochemistry are similar. Furhermore, the two different selective leach methods tested were comparable in the Ravnnaluhppu area.

P57

Multi-Source Genetic Characteristics of the Natural gas in Oolitic reservoir of Feixianguan Formation in Northeastern Sichuan Basin, SW China

Tongshan Wang[1], *Zhao Wenzhi*[1], *Wang Hongjun*[1], *Wang Zeng*[1], *Li Qiufen*[1], *Bian Congsheng*[1], *Li Yongxin*[1]
[1]PetroChina Research Institute of Petroleum Exploration & Development, Beijing, China, [2]PetroChina Exploration & Production Company, Beijing, China

Since industrial high-production gas flows high production were obtained in oolitic reservoirs in 1995, a number of medium to giant gas fields have been discovered in the Triassic Feixianguan Formation in NE Sichuan, SW China. Based on a series of geochemical studies, it is apparent that natural gas in the oolitic reservoir comes from multiple source rocks, where the gas source supply is sufficient, and large scale and high abundance gas accumulations are found. Three lines of evidence are discussed below. Results of this study provide a solid theoretical basis to accelerate exploration and development of natural gas in the Sichuan Basin.

Across-plot of natural gas $\delta^{13}C1$-$\delta^{13}C2$, shows that the $\delta^{13}C1$ and $\delta^{13}C2$ values of natural gas in the oolitic reservoir plot between those of natural gas generated from the Longtan coal measures and those of oil cracking gas derived from deep source Silurian and Cambrian rocks. It is shown that multiple source rocks make significant contributions to gas? accumulations in ooilitic reservoirs.

$^{40}Ar/^{36}Ar$ can be used to estimate the age of natural gas source rocks due to the accumulative time effect of argon isotope (Xu et al., 1994). The $^{40}Ar/^{36}Ar$ values of natural gas in oolitic reservoir are measured and the result ranges from 1,280 to 1,690, which implies the age of gas source rocks should range from 383 Ma (Late Devonian) to 323 Ma (Early Carboniferous). However, these two sets of source rocks in Sichuan basin are eroded, a more reasonable explanation is that the natural gas in the oolitic reservoir should come from several sets of source rocks, which are earlier than 383 Ma (Cambrian and Silurian) and later than 323 Ma (Permian), instead of single source.

Gas source rocks can also be identified using the carbon isotope fractionation variation index. The $\delta^{13}C2$ value of natural gas is 1-2‰ lower than that of kerogen, while the $\delta^{13}C$ value of solid bitumen is consistent with that of kerogen (Isaksen et al., 2004). A chart of the $\delta^{13}C$ values demonstrates the correlation among natural gas, solid bitumen and kerogen. Natural gas in the oolitic reservoir is correlative with the source rocks of Upper Permian, Lower Permian, Silurian and Cambrian. Obviously the natural gas in the oolitic reservoir has multiple sources.

This study shows that there is potential for further exploration success in NE Sichuan. It is believed that more natural gas reserves derived from multi-source rocks could be found in this area in the near future.

References:
Xu, Y C. et al., 1994. Natural Gas Origin, Chapter 12. Science Publishing House, Beijing, pp: 278-284.
Isaksen G H. 2004. AAPG Bulletin, 88: 1545-1572.

P58

Geochemical evidence of gas accumulating during uplift of Xujiahe coal-bearing measures, central Sichuan basin

Congsheng Bian, Hongjun Wang, Tongshan Wang, Yongxin Li
PetroChina Research Institute of Petroleum Exploration & Development, Beijing, China

The Upper Triassic Xujiahe Formation contains a set of subaerialclastic rocks with coal-bearing deposits, including six members from bottom to top, among which member I, III and V are source rock and caps and member II, IV and VI are reservoir rocks. Many gas fields have been discovered now and the geochemical characteristics of these gas fields show that the Xujiahe formation is an independent gas system.

Research on the burial and erosion history of the central Sichuan area indicates that the Xujiahe formation underwent rapid buried from the Jurassic to the early Cretaceous to a depth of 4500-5000 m. The maturity of the source rock reached 1.2-1.5 % Ro, therefore, the source rock became thermally mature and generated mass gases. From late Cretaceous to now, the whole Xujiahe formation was elevated and eroded, with the total erosion thickness about 1500-2500 m. In the meantime the gas generation process in large part ceased.

Gaseous hydrocarbon inclusions have been found in micro-fractures in quartz formed during the period of uplift. The homogenization temperature of coeval saline inclusions of the gaseous hydrocarbon inclusions ranges from 110-130°C, and the freezing point temperature is -20°C-5°C. The high homogenization temperature and low freezing point temperature suggest that the hydrocarbon inclusions are formed during uplifting period of Xujiahe formation, and the gas accumulation occurred at a large scale. A physical simulation experiment designed according to the lithological structure of the Xujiahe formation, proved the occurrence of desorption and gas expansion in the process of uplift, and the quantity of the gas in this period reached 20-40 % of maximum expulsive gas from the source rock.

The carbon isotope signature of the Xujiahe hydrocarbon in central Sichuan does not match the maturity of the Xujiahe source rock. The carbon isotope ratio of both methane and ethane is 4‰ and 2‰ lower than that generated by the same maturity source rock of coal rocks. However, a similar phenomenon was not found in the Xujiahe reservoirs in the west Sichuan basin where the erosion thickness is less more than 600 m. Our study shows that the gas with lower maturity was probably generated and absorbed in the coal-source rocks in early stages, which desorbed from the coal series and charged into the reservoirs as pressure and temperature decreased in the process of uplift.

References:
Zhao Wenzhi, et al., 2010. Petroleum exploration and development 37:2, 146-157
Etuan Zhang, et al., 2008. AAPG Bull 92:8, 1077-1106.
Dai Jingxing, etal., 1992. Scientific Sinica 2, 185-193.
Carlos R., et al., 2002. AAPG Bull 86:10, 1310-1345.

P59

The physical evolution of hydrocarbon fluid of Shanxi Formation (P_{2sh}) in Yimeng area, NE Ordos Basin (China): evidence from PVT simulation of inclusion petroleum

Yunpeng Wang[1], Dehan Liu[1], Qiao Feng[2], Changyi Zhao[3], Hongjun Wang[1]
[1]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, 510640, China, [2]Shandong University of Sciences and Technology, Qingdao, 266510, China, [3]Research Institute of Petroleum Exploration and Development, PetroChina, Beijing, 100083, China

The Ordos Basin is one of the largest gas provinces in China. Gases have been discovered throughout all Upper Palaeozoic strata from the Benxi, Taiyuan, Shanxi, Shihezi formations to the Shiqianfeng formation. However, these reservoirs are mainly a kind of stratigraphic gas traps with characteristics of lower porosity, lower permeability, lower reservoir pressure and lower gas density. The development of these gas fields is very difficult using current technology and the gas productions are generally low. The present fluid pressure of reservoirs varies from 6.94-36.32 MPa, typical of a low-pressure reservoir. Until now, , the formation mechanism of low fluid pressure of a gas reservoir has not been well understood, which therefore hinders the exploration and development of gas fields in the whole basin. In this study, we used PVT simulation software to estimate the composition, PT phase envelope and isochore of single petroleum inclusion in the Ordos's Yimeng gas field, Well M-5. The data are used to quantify pressure histories of reservoir fluid and study the physical evolution of the hydrocarbon fluid of the Shanxi Formation (P2sh), in order to better understand the formation mechanism of low pressure for reservoir fluid.

Our results for four single inclusions show that the values of trapping pressure are around 35.83-43.26 MPa for inclusion fluid, with trapping temperature about 119.5-123.1°C. Well M-5 is located in Northern Yimeng area and its present reservoir pressure is 21.99MPa. The estimated reservoir temperature is about 57-60°C, with a thermal gradient of 2.85°C/100M. The average burial depth for the inclusions is estimated about 3000m. From the burial history, these inclusions formed from 140-150 Ma (J2). These four inclusions are all primary inclusions in primary pores. Combining the geologic setting of Well M-5 and the occurrence of inclusions, an earlier petroleum event may be determined. Because the secondary pores of reservoir rocks were not well developed before J2 and the generation volume and rate of oil were not very strong, this petroleum-generating event was not great. Although filled bitumen is also found in reservoir rocks of neighbouring wells (i.e. Well Shan-118), which confirms our findings, the areas with similar conclusions and filled bitumen are still very limited. Only in Well M-5 and several wells located in its surrounding areas, we found the amounts of oil inclusions and filled bitumen. Compared with trapping pressures, the present pressure of the reservoir has a totally different formation mechanism. The present low reservoir pressure is not connected to the earlier oil-generation event.

Acknowledgments:
China Giant S&T Programs (2008ZX05008-002) and NSFC project (40872091) are acknowledged for the financial support.

P60

The Migration and Accumulation of the Jurassic Oil and Gas in Northern Qaidam Basin, China: An Integrated Geochemical Petroleum System Analysis

Changyi Zhao[1], Dongsheng Yang[1], Yunpeng Wang[2]
[1]Research Institute of Petroleum Exploration & Development, PetroChina, Beijing, China, [2]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China

Burial and thermal analysis indicates that the Jurassic hydrocarbon source rock entered the oil window after Miocene, and then the generation oil charged and migrated. The main migration and accumulation periods are in the later Himalayan movement (E_3-N_2^2).

Physical and chemical compositions of oil in Lenghu area, Qaidam show obvious vertical migration fractionation and the molecular compositions of natural gases vary along the migration direction. The contents of methane and N_2 in the natural gases of Mahai area are higher than those of southern Baxian area while the heavy gases (C_2-C_5) are lower comparatively. In similar, the carbon isotopes of natural gases from southern Baxian to Mahai become negative. These gas geochemical properties suggest the oil and gas migration direction is from southern Baxian to Mahai. The ratios of 20Rββ/ (αα+ββ) of C_{29} sterane vary from 0.64 in Mahai to 0.54 in southern Baxian, showing a longer migration distance of Mahai oil.

Geological analysis shows that the distribution of oil and gas are controlled by fault structure. Oil and gas fields are generally located along the fault connecting the Jurassic source rocks and traps, and the crossing area of NE and NW fault and the turning area of the fault structure have good accumulation areas for oil and gas due to their developed structural traps.

We found that the thrust faults developed since later Neogene are not good for oil gas accumulation due to their limited cutting depth, which can not connect the source kitchen and traps. However, the faults developed on the basis of earlier faults are promising areas for oil and gases due to their greater cutting depth which connected the source kitchen and traps and acted as the migration routes. The unconformity is another important migration paths in this area, and the palaeo-uplifts developed in earlier Tertiary are the main migration targets. The end of Neogene is the critical moment of the oil migration and accumulation, and the migration is mainly in lateral way at earlier stage and vertical way in later stage. Besides the structural trap, the stratigraphic trap is also important for oil gas accumulations in this area. Our study shows that Eboliang-1 structure and Kun-1 structure are the best exploration of oil-gas accumulation.

Acknowledgments:
China national 973 programs (2007CB209501), China Giant S&T Programs (2008ZX05008-002) and NSFC project (40872091) are acknowledged for the finanical support.

P61

Study on the particles related to the concealed ore deposits

Jianjin Cao, Xiaojun Wei, Hongling Ke, Chang Liu

Department of Earth Science, Sun Yat-sen University, Guangzhou, China

Ascending gas flows from deep ground (geogas) have been reported (Kristiansson & Malmqvist, 1982; Etiope & Lombardi, 1996; Wang et al., 1997). In our work, copper grids for transmission electron microscope were used to capture particles carried by geogas at the Changkeng gold deposit, Gaoyao city, China. Under the transmission electron microscope, native gold particles and other metal particles were identified (Cao et al., 2009). Accordingly, we propose that the characteristics (shape, size, chemical composition, ultrastructure, and paradigmatic relation) and content (the amount of particles per unit area of copper grids) of the particles related to concealed ore deposits can be used for the exploration of mineral resource. The particles can be hosted by gas-liquid-solid in soil above concealed ore bodies.

Up to now, in China, we have studied geogas particles of the Tongchanghe copper deposit of Guizhou province (Cao et al., 2010a), Qingmingshan copper-nickel deposit of Guangxi province, Kafang copper deposit of Yunnan province, Fankou lead-zinc deposit of Guangdong province amongst others, but not the Changkeng gold deposit. The particles from soil gas above concealed ore bodies have spherical, long strip, acicular-like, near-ellipse, or irregular shape. They may be single particle or aggregates of small particles. Usually, they are oxide, sulfate, hydroxide, chloride, and native metal either crystalline or amorphous.

Particles related to concealed ore deposits may have formed by mineralization, formed by oxidation of primary ore. Other processes include biological action and faulting (Cao et al., 2010b). These particles may be transported by ascending gas flow from depth to the earth's surface.

These particles provide abundant and direct information about concealed orebodies. Using their shape, size, chemical composition, ultrastructure, paradigmatic relation, and content to probe concealed orebodies will be a more effective and more ccurate exploration method.

Acknowledgements:
The project was supported by the National High-Tech Research and Development Program of China (863 Program) (Grant No. 2008AA06Z101) and the National Natural Science Foundation of China (Grant Nos. 40773037, 41030425, 40673044, and 41072263).

References:
Kristiansson, K. & Malmqvist, L., 1982. Geophysics 47, 1444-1452.
Etiope, G. & Lombardi, S., 1996. Environmental Geology 27, 226-232.

Wang, X.Q. et al., 1997. Journal of Geochemical Exploration 58, 63-72.
Cao, J.J. et al., 2009. Journal of Geochemical Exploration 101, 247-253.
Cao, J.J. et al., 2010a. Science China Earth Sciences, 53, 1647-1654.
Cao, J.J. et al., 2010b.Geofluids, 10, 438-446.

P62

Lithological Signatures and Exploration Implications from Overbank Sediment Sampling and MMI Analysis: Preliminary Findings from the National Geochemical Survey of Australia

Patrice de Caritat[1], Michelle Cooper[1], Alan Mann[2], Pierrette Prince[3]
[1]Geoscience Australia, Canberra, Australia, [2]Consultant, Perth, Australia, [3]SGS Minerals Services, Toronto, Canada

The National Geochemical Survey of Australia (NGSA) was initiated in late 2006 and details of progress were published in Caritat et al. (2009). The ultra-low density geochemical survey was based on overbank sediment sampling at strategic locations in the landscape. Included in the analysis methods was a partial extraction by the Mobile Metal Ion (MMI) technique (Mann, 2010) of sediment sampled at the depth of 0-10 cm, air-dried and sieved to <2 mm.

The MMI method is based on solubilisation of ions loosely adsorbed onto the surfaces of minerals and, where present, organic matter. Thus, MMI results can be indicative of elements that have moved relatively recently through the regolith, and these can reflect unusual element concentrations at depth, whether reflecting lithology or mineralisation.

Broad lithological types (sedimentary, igneous, etc.) appear to be reflected by the geochemical patterns of several elements as determined by MMI analysis. For example, sedimentary provinces such as the Great Australian Basin and the Murray-Darling Basin are commonly associated with elevated MMI Ba, Ga or Sr values. Felsic igneous intrusive rocks along much of the eastern seaboard of Australia and in south-western Western Australia, are typically coincident with high MMI concentrations of La, Ce and other rare earth elements. Medium to high grade metamorphic rocks do not appear to be characterised by anomalously high concentrations of any element as analysed by MMI, but can be characterised by moderately elevated concentrations of Cs, K, Mo, Rb and W in the MMI data.

The applicability of ultra low-density MMI data to exploration for commodities including Au, Cu, Pb, Zn, Ni and U has also been investigated. For example, the MMI Au concentrations range from <0.1 ppb to 19.8 ppb, with a median value at 0.2 ppb. A map of MMI Au distribution shows that several of the NGSA data points above the 90th percentile occur close to some of Australia's largest Au mines: Wiluna/Jundee, Mt Magnet/Hill 50, Granny Smith/Sunrise Dam/Sons of Gwalia, Super Pit/Kanowna Belle/Paddington/St Ives and Marvel Loch/Bullfinch/Bounty in WA; Stawell and Fosterville in Victoria; Lake Cowal/Cadia/Peak Hill/Ridgeway in NSW; Tom's Gully in the NT; and Mt Rawdon, Sarsfield and Vera-Nancy in Queensland. Only a few major Au deposits are not reflected by high MMI Au values (e.g., Plutonic and Meekatharra in WA; Northparkes in NSW; Coyote and The Granites in the NT). Conversely, a large number of high MMI Au data points do not occur near large known Au deposits and may point to potential for undiscovered resources.

References:
Caritat, P. de, Cooper, M., & Morris, P., 2009. Proceedings of IAGS, Fredericton, 915.
Mann, A.W., 2010. Geochemistry: Exploration, Environment, Analysis 10, 17-26.

P63

Similarities and differences in the hydrocarbon geochemical signature of various Uranium lithologies

Dale Sutherland
Activation Laboratories Ltd., Ancaster, Ontario, Canada

Redox conditions develop over many types of buried geological bodies including those of sought after mineral targets. Above these geological occurrences a chemically reduced zone or reduced "chimney" is often formed. This leads to the development of the generally accepted electrochemical cell model. However, the detection of redox conditions in the overburden, or data from geophysical induced potential type measurements, or direct measurements of helium or radon residues as soil gases, are not sufficient evidence to confidently state the existence of the presence of buried uranium targets.

Bacteria leach elements from the ore body which are then used as a catalyst to synthesize organic hydrocarbons in their cytoplasm. In the death phase of these microbes, cell membranes break down and the intracellular hydrocarbons they have synthesized are released. These hydrocarbons provide a complex, and thus highly specific, forensic signature directly related to the identification of various types of mineralization at depth.

The Soil Gas Hydrocarbon (SGH) geochemistry developed by Activation Laboratories has been referred to as a redox cell locator, but it is much more than that. Although a misnomer, SGH can use a wide variety of surficial sample types in a survey, and detects a suite of 162 unique non-gaseous semi-volatile hydrocarbons. The spatial diffusion and effusion of these hydrocarbons shaped by the electro-potential gradients in the overburden provides a multi-measurement forensic signature for identification of buried exploration targets including those for uranium.

Specific combinations of the hydrocarbon classes identify the target type even at over 500 metres in depth. The expected order of dispersion or geochromatography of these classes is also able to vector to the central vertical projection of mineral targets at depth. SGH is a dual purpose deep penetrating predictive geochemistry that can thus both locate and identify blind Uranium, Gold, SEDEX, VMS, Nickel, Copper and Polymetallic mineral targets, as well as Lithium Pegmatites, Kimberlite pipes and Petroleum plays.

This presentation will focus on examples of the similarities and differences in the SGH geochemical results from over unconformity, roll front, breccia pipe and IOCGU type Uranium deposits in areas of difficult terrain.

References:
Hamilton, S. M.,1998, J. Geochem. Explor., 63:155-172
Adkinson, C.W. & Reimer, G.M., 1976. US Geol. Survey, Open File Report, 76-860
Govett, G.J.S., 1987. J. Geochem. Explor., 28:201-221

P64

Utilization of weak leach methods in mineral potential mapping in glaciated terrain – an example from the Lätäseno Greenstone Belt, northwestern Finland

Pertti Sarala, Raija Pietilä, Riitta Pohjola
Geological Survey of Finland, Rovaniemi, Finland

The Lätäseno Greenstone Belt is in the Käsivarsi area of northwestern Finnish Lapland. Several mapping and exploration projects have been carried out in the area by the Geological Survey of Finland and exploration companies of which the latest focused on the bedrock mapping during 2006-2008. However, large areas remained still poorly understood due to thick glacial overburden. To estimate the effectiveness of surficial geochemical sampling and analyses in this area, several geochemical methods including weak leach i.e. mobile metal ion method have been evaluated. One aspect was to test the practicality of different sampling methods in challenging work conditions typical of the Finnish fell area. Furthermore, the aims were to clarify the composition of till, to get a comparable picture of chemistry of different sampling media, and try to estimate the transport distance of till.

For testing, 1.5-3 km long sampling profiles with the sampling interval of 50 m were used. The profiles were designed to cross different lithological units and bedrock structures, bearing mind the main glacial flow direction from south to north. The method was surficial soil sampling that included 1) samples for the weak leach analysis collected following the sampling guide of MMI (samples from the 10-25 cm under the humus layer), but using both ammonium acetate and pH modified 0.1g/l NaCN leaching methods, 2) conventional till sampling using samples from the C-horizon of the Podsol soil profile with interval one sample at every second test pit at the depth 50-100 cm (analyzed by the ICP-OES and ICP-MS after aqua regia dissolution) and 3) duplicate till sampling for mobile XRF method testing. Furthermore, water and stream sediment samples (25-35 samples/year) including both mineral and organic fractions from the small rivers and lakes in the study area were collected and analyzed in Labtium laboratory mainly by the ICP-MS.

Results indicate that some base metals and gold are elevated in the study area. Clear Ni-Cr-Cu-Mn-Zn anomaly was recognized in till and water, and stream sediment samples in the western part of study area relating to south-north oriented contact of magnetic and non-magnetic rocks. One bedrock drilling profile was situated to the sampling line where the highest nickel anomaly was found in till by the different geochemical methods. However, the drill core indicated only mafic volcanic and sedimentary rocks to be present in the area without any signs of mineralization. The geochemical results showed that high base metal anomalies in weak leach samples are the most probably coming from the till (transport distance several kilometers), and the effect of underlying bedrock is weak. This should be considered when doing future studies in the area.

65

The timing of ore mineralization based on thermal maturity modelling of Kupferschiefer strata in the Fore-Sudetic Monocline, SW Poland

Pawel Kosakowski
Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Krokow, Poland

The study area is located in the southwest part of the Fore-Sudetic Monocline (SW Poland), part of the Southern Permian Basin, formed after the Late Carboniferous inversion. The Kupferschiefer horizon represents a unique upper Permian facies, Prich in organic matter and base and precious metals (Bechtel et al., 2001; Pieczonka and Piestrzyński, 2006). This organic matter has been deposited under anoxic or suboxic shallow shelf conditions, which favor the concentration of organic matter and its preservation. Metal zones and variations in organic composition indicate that upwelling oxidized ore fluids were reduced by organic material and Fe-sulfides in the shale, inducing the precipitation of Cu-sulfides.

The characteristics of organic matter indicates that the organic carbon content ranges from 0.9 to 16.1 wt.% (average 4.0. wt.%) with a high hydrocarbon content, up to 45.8 mg HC/g of rock and hydrocarbon potential, up to 625 mg HC/g TOC (Kotarba et al., 2006). Data from Rock-Eval pyrolysis, biomarkers and elemental analyses show to the presence of the sapropelic Type-II and mixed humic/sapropelic Type-II/III kerogen. The maturity level corresponds to a low-temperature thermogenic processes ("oil window" - 0.5 - 1.3% Ro), which is locally as high as 1.65% ("gas window").

The timing of Kupferschiefer ore mineralization with respect to stratigraphy is a matter of broad debate in the literature. Paleomagnetic dating of hematite, K-Ar ages of diagenetic illite, as well as the age of thucholite and metallic lead place the ore mineralization from Late Permian to Early Triassic up to the Cretaceous. To resolve the controversy about timing of ore formation with respect to irreversibility of organic matter alteration, the maturity of kerogen was numerically modelled. The maturity analyses using BasinMod® numerical modelling indicated that the Kupferschiefer organic matter was thermally mature within a low-temperature thermogenic processes (0.5 to 1.3 % Ro, i.e. 90 to 170°C) during the Middle to Upper Triassic time interval (Kotarba et al., 2006; Kosakowski et al., 2006). Heat transfer, connected with the inflow of hydrothermal fluids causing changes within the organic matter, was also responsible for ore mineralization of Kupferschiefer strata durint the Middle to Late Triassic in the southern part of the Fore-Sudetic Monocline (Kosakowski et al., 2007).

References:

Bechtel, A., Gratzer, R., Püttmann, W., Oszczepalski, S., 2001. Organic Geochemistry 32, 377-395.
Kosakowski, P., Markiewicz, A., Kotarba, M.J., Oszczepalski3, S., Więcław, D., 2007. Biuletyn Państwowego Instytutu Geologicznego 423, 139-150
Kotarba, M.J., Peryt, T.M., Kosakowski, P., Więcław, D., 2006. Marine Petroleum Geology 23, 371-386.
Pieczonka, J., Piestrzyński, A., 2006. Mineral Resources Management 22, 187-202.

P66

Petrography and geochemistry of Sandstone Member of Asmari Formation, Ahvaz, Khouzestan Province, Iran

Babak Alizadeh
Padyab Tadjhiz Co., Tehran, Iran

An integrated petrographic and geochemical study of the Ahwaz Sandstone Member of Oligocene- Miocene age, Asmari Formation in Zagros, southwest Iran, was carried out to infer their provenance and tectonic setting. This study is based on the analysis of core samples from three subsurface sections in Ahwaz oil field in the Dezful embayment subzone.

On the basis of the framework composition and whole-rock geochemistry (major elements), the sandstones are classified as quartzarenite, sublitharenite, and subarkose types. Petro- graphic studies reveal that these sandstones contain quartz, feldspars and fragments of sedimentary and metasedimentary rocks. The modal analysis data of 50 collected (medium size and well sorted) samples, imply a recycled orogen and craton interior tectonic provenance. Moreover, petrographic point count data indicate quartz-rich sedimentary (recycled), middle to high-grade metamorphic, and plutonic par- ent rocks for the Ahwaz Sandstone. Tectonic setting discrimination diagrams based on major elements suggest a quartzose sedimentary provenance in a passive continental margin. As indicated by the CIW´ index (chemical index of weathering) of the Ahwaz Sandstone (average value of 67) their source area underwent "intense" recycling but "moderate" degree of chemical weathering. The petrography and geochemistry results are consistent with a semiarid climate and low-relief highlands.

Refferences:

Alavi, M., 2004, Regional stratigraphy of the Zagros fold-thrust belt of Iran and its proforeland evolution: American Journal of Science, 304, 1–20.
Basu, A., Young, S., Suttner, L., James, W., Mack, G.H., 1975, Re-evalution of the use of undulatory extinction and crystallinity in detrital quartz for provenance interpretation: Journal of Sediment Petrology, 45, 873–885.

P67

Exploring for Ni mineralisation beneath cover using gas collectors at North Miitel, Kambalda, Western Australia

Melvyn Lintern[1], Ryan Noble[1], Ravi Anand[1], Brian Townley[2]
[1]CSIRO, Kensington, WA, Australia, [2]University of Chile, Santiago, Chile

The use of gas to explore for deeply buried mineral deposits has been used sporadically for many decades. Various commodities have been explored for with varying success. In Australia, gas geochemistry has been used to explore for U, VMS and Au deposits. Gas geochemistry may involve the analysis of metals, radioactive decay products or organic gaseous compounds generated as a result of biogenic or abiogenic processes. Sampling may be undertaken directly, or via a natural or artificial substrate. Direct measurements often involve the collection of gases using a pump. Conversely, surficial samples such as clay can be collected directly and further treated in the laboratory using, for example, heat or solvents to extract the analytes. Static artificial substrates or collector devices require a period of time for equilibration and for the gases to adsorb. In this study, collector devices were used to accumulate metals and organic gaseous compounds from above the deeply buried (400 m) primary North Miitel Ni mineralisation, located 90 km south of Kalgoorlie in Western Australia. Weak secondary mineralisation occurs in the thin oxidized zone at the unconformity with Cainozoic sediments 15 m below the surface.

The collectors are small separate water-resistant bags containing activated carbon and kaolinite that were placed inside polypropylene pipe and buried to a depth of 40 cm for 100 days and are adapted from the ORE HOUND GOCC® developed by one of us (BT). They were installed along an E-W line that perpendicularly crossed mineralisation. A set of field duplicates were installed in addition. The carbon and kaolinite were removed from the collector after 100 days and sent to Actlabs (Canada) for analysis.

Abundances of Ni absorbed to the activated carbon in the collector devices significantly correlated with mineralisation. No other element significantly correlated with mineralisation, except for a weak trend in the alkali and alkali-earth elements. The use of the SGH (Soil Gas Hydrocarbon) technique reported a positive result for gaseous hydrocarbons for predicting the Ni mineralisation. Controls, blanks and duplicates for Ni showed good reproducibility.

It appears that gases produced at depth at or close to mineralisation, and diffusing through the regolith, may be bringing Ni to the surface either in gaseous or nano-particulate form. What is unclear is whether the gases are generated in fresh rock mineralisation (at 400 m) or in weaker supergene mineralisation immediately below the transported regolith at 15 m depth. Further studies are required in this area to substantiate these results, but the technique is promising in an environment where other surface techniques such as soil or bio- geochemistry have been less successful.

P68

Biogeochemistry and surficial geochemistry at the Tropicana Gold Deposit, Western Australia

Melvyn Lintern, Ravi Anand
CSIRO, Kensington, Australia

A new Au province is developing adjacent to the eastern margin of the Yilgarn Craton, Western Australia. Located in the Albany-Fraser Belt it extends for several hundred km in a NE-SW orientation. Recently the Tropicana JV (AngloGold Ashanti Australia Ltd and Independence Group NL announced reserves of 5 Moz Au (2.1 g/t) as the largest discovery in the area - Tropicana-Havana, located 330 km ENE of Kalgoorlie. This new province provided an opportunity to evaluate biogeochemical methods.

Host rock dating indicates the late Archaean mineralised basement rocks may form part of the tectonically reworked eastern edge of the Yilgarn Craton. Gold mineralisation postdates peak granulite-facies metamorphism and formed from variably oxidised, higher temperature, silica-undersaturated fluids (Doyle et al., 2009). Mineralisation is hosted within gneiss and Au is concentrated in ore shoots within the saprolite beginning at 10-20 m below the surface.

At Tropicana-Havana the basement and overburden have undergone further weathering to depths of 40 to 50 m since emplacement. Generally, the weathering profile consists (from the surface) of aeolian sand dunes of variable thickness (1-20 m) overlying 4-20 m of clay- and gravel-rich transported sediments with some calcrete. Cover over the Tropicana-Havana deposits is between 10-20 m.

The ferricrete (inverted ferruginised valley sediments) on the rise adjacent to the Havana deposit, which has partly dispersed down slope, is several metres thick and is anomalous in Au. Organic-rich soil, litter, and eucalypt foliage were collected and analysed for Au and sixty other elements. Ferricrete was also collected from drill cuttings, small pits and from the surface.

At Havana, Au was strongly anomalous above mineralisation in eucalypt foliage (max. of 4 ppb), and litter (max. of 10 ppb, background <0.1 ppb), but contrast was lower in organic-rich soil (max. of 5 ppb, background of 1-2 ppb). Ferricrete was absent above mineralisation but samples upslope of the projected mineralisation were anomalous (e.g. 600 ppb Au in ferricrete). For Tropicana, anomalous concentrations of Au occur above mineralisation in eucalypt foliage, litter, organic-rich soil and ferricrete.

Ferricrete may have some use as an exploration sample medium at a regional scale in the

Albany-Fraser region but further evaluation needs to be undertaken. The absence of calcrete at many locations at Tropicana JV means that it cannot be used as a ubiquitous sample medium but may have applications further south. At a local scale, vegetation and organic-rich soil may be used to locate mineralisation, but its limitation in this environment requires further testing e.g. depth of transported overburden.

References:
Doyle, M., Gibbs, D., and Savage, J., 2009. Proceedings of the 10th Biennial SGA Meeting of The Society for Geology Applied to Mineral Deposits: 50-52.

P69

3D geochemical patterns over a concealed gold deposit revealed by overburden drilling in desert terrains

Bimin Zhang[1], Xueqiu Wang[1], Qinghua Chi[1], Wensheng Yao[1], Shanfa Xu[1]
[1]Institute of Geophysical and Geochemical Exploration, CAGS, Langfang, Hebei, China, [2]Key Laboratory for Applied Geochemistry, CAGS, Langfang, Hebei, China

Desert terrains widely distributed in northwestern and northern China are covered by widespread regolith sediments which mask geochemical signals from ore bodies and are major obstacles to mineral exploration (Wang et al., 2007). In recent years, deep-penetrating geochemistry has been proven to be effective in search for concealed deposits (Cameron et al., 2004). However, we have a little understanding of the dispersion patterns. In this study, Air reverse circulation (ARC) drilling technology is used to revealed the 3D distribution patterns of elements in regolith sediments over Jinwozi gold deposit, which is covered by tens of metres of regolith sediments, in order to trace the migration track and to understand the migration mechanisms.

An ARC drilling program was conducted along four traverse lines across the ore body. The interval of traverse lines is about 250m. Each line has 15-20 bore holes with spacing interval of 50-100 m. Samples were collected continuously every meter from ground surface to bed rocks. They were sieved into three fractions: +40, 40-100, and -100 mesh in the field. Samples types (regolith materials, weathered rock and bedrock) can be recognized by sample colors, granularity and mineral compositions. All the samples were ground to -200 mesh (75 μm) and analysed for Au, Ag by GF-AAS and As, Hg by HG-AFS. Ba, Cu, La, Pb, Sb, Sr, Th, U, Zn were analysey by ICP-MS.

3D distribution maps of elements generated show that 1) anomalies continuosly occur in the different depths of regolith sediments over the ore body, 2) gold tend to be enriched in top and bottom horizon, and depleted in middle horizon in vertical direction, 3) the anomalous distribution in bottom is restricted in the lowest places at the interface of sediments and bedrocks, 4) laterally the anomalous extension in the bottom is narrow within a width of hundreds of metres, and that in top soils is much wider and extends to several kilometers.

Enrichment of elements in the bottom materials is due to the weathering of ore body and is mechanically transported and deposited in the lowest places under the pediplanation. The broad pattern at surface soils is led by continuously vertical migration from ore body to surface and further lateral diffusion by wind and seasonal raining water in all directions.

References:
Wang et al., 2007. Geochemistry: Exploration, Environment, Analysis, 7, 163-171.
Cameron et al., 2004. Journal of Geochemical Exploration,4,7-32.

P70

Sulphide weathering and rates of anomaly formation from a column experiment

Ryan Noble[1], Robert Hough[1], Steven Wakelin[2], Ravinder Anand[1], Melvyn Lintern[1]
[1]CSIRO Earth Science and Resource Engineering, Kensington, Western Australia, Australia, [2]AgResearch, Invermay, New Zealand

Unsaturated evaporative column experiments were used to investigate weathering of sulphides, influence of bacteria and mobility of metals via primarily hydromorphic dispersion and quantify rates and patterns of anomaly formation. VMS ore (including two 1 cm pieces) was placed in the bottom of polycarbonate columns (30 cm height) and covered with previously characterised sand and a layer of coarse acid washed sand. Water was added to the base of the columns every two weeks. The experiment was run for 393 days. The surface crust and another crust at 1 cm depth developed over time and were sampled every 3 months. At the end of the experiment, the column profiles were sampled every 5 cm to the base. All samples were extracted with weak hydroxylamine hydrochloride and analysed by ICP-MS/OES.

Metals showed two typical dispersion patterns. One was associated with the crust at 1 cm depth from rapid weathering and mobility of Ca, Mg, S, Zn and Co. The other pattern was a gradual diffusion throughout the column of Pb, Ag, Cu, As, In, Pb and Fe; all showed maximum concentrations at depth with dispersion over a few cm. Evidence of sulphide weathering was observed using scanning electron microscopy. Numerous smooth surfaces in the fresh sulphide pieces prior to the experiment became rough and etched. Nucleic acid staining (SYTO-9) with confocal microscopy showed bacteria in all the columns, but only in the sand sections. Minimal fluorescence in the ore-rich zone and the crust showed bacteria do not contribute significantly to metal mobility under these conditions.

The weathering was dominantly inorganic. The evapotranspiration rate in the experiment was equivalent to approximately 10 years in a temperate Perth (Western Australia) landscape. The extent of capillarity in the columns was approximately the same height as the crust formed at 1cm depth from the surface. The experiment showed strong geochemical anomalies can form rapidly in a few thousand years, probably incrementally related to fluctuating water tables, and assists understanding the genesis of natural geochemical anomalies. The mobility of metals varied in dispersion pattern and rate which is important for understanding the size and dispersion kinetics of anomaly formation and, in turn, aids geochemical targeting.

P71

Mineral exploration in areas of transported overburden: from groundwater - rock interaction processes to surface, a case study in the Inca de Oro District, northern Chile

Brian Townley[1]*, Carolina Soto*[1]*, Rodrigo Luca*[1]*, Luis Lopez*[1]*, Alvaro Puig*[2]*, Hugo Henriquez*[2]*, Ravi Anand*[3]*, Mel Lintern*[3]

[1]Dept. of Geology, University of Chile, Santiago, Chile, [2]Codelco - Chile, Santiago, Chile, [3]CSIRO, Perth, Australia

Mineral exploration in areas of transported overburden has employed diverse targeting tools in recent history, geophysical and geochemical tools, combined with geology, among the standard. In the particular case of geochemistry, indirect techniques have been riddled with problems, much of this due to poor knowledge on processes and mechanisms that lead to a surface geochemical expression from an underlying ore deposit, processes occurring at the deposit, and mechanisms by which a surface expression is developed. In addition, poor knowledge of landscape evolution and regolith formation does not allow to properly discriminating surface geochemical expressions from surface sedimentary and regolith processes.

In this study we present the results of a throughout study of the Inca de Oro porphyry copper system, located in the Atacama region of northern Chile. The Inca de Oro porphyry copper (Codelco - Chile) lies beneath 100 to 200 m of transported overburden, mostly Atacama gravels, dating back from Miocene to present. The porphyry copper deposit is hosted within cretaceous volcanic and intrusive rocks, the ore deposit itself intercepted by the present time water table, the upper part above the water saturated zone. Groundwater flows from southeast to northwest, crossing from gravels, into rock, and back out to gravel. Groundwater sampling from 16 boreholes, upflow, within and downflow from the deposit, together with hydrological flow models, allowed hydrochemical static modeling of rock-water interactions and determination of geochemical behavior of ore rock related elements in groundwater.

Study of overburden, through drillcore sampling, from rock-overburden interface to surface, allowed profiling geochemical behavior from ore deposit to near surface. In addition, trench sampling, down to 2 m, allowed understanding surface and subsurface behaviors. In addition, a full study of regolith at surface, by means of a detailed soil/overburden sampling grid, was focused on understanding regolith formation, landscape evolution, such as to assess soil/overburden geochemical heterogeneity, determine surface processes variability, and attempt discrimination from the surface geochemical expression of the buried Inca de Oro deposit.

Passive collector devices were also employed along the same grid, such as to assess real time gaseous processes as a potential mechanism of surface geochemical expression of the ore deposit at surface. An integrated model was determined, with new insights on geochemical exploration in areas of transported overburden.

Acknowledgements: Funding was provided by project AMIRA P778 and Codelco - Chile.

P72

Prospects for Noble Metals and Copper-Nickel Mineralization in the border areas of Russia and Finland

Sergey S. Shevchenko, Sergey V. Sokolov, Gennady M. Belyaev, Yulia V. Makarova, Yuri Yu. Yurchenko

A.P. Karpinsky Russian Geological Research Institute (VSEGEI), St. Petersburg, Russia

A principally new in Russia, forecast-geochemical map of the Karelia-Kola Region (north of the 64th parallel) at 1M scale has been compiled. It is based on data on element contents in stream sediments and soils of the horizon B identified by the method of superfine fraction (MASF) analysis. The essence of the method is isolation of superfine fraction from unconsolidated sediment samples with subsequent transfer of adsorbed-saline forms in solution, and then their analysis by precision analytical techniques (ICP-AES, etc.). About 3 000 sample-duplicates were chosen in the course of multipurpose 1M scale geochemical mapping and processed according to this technology.

Subsequent to the results of the research, the following things are made: elaboration of a scheme of the territory structural-geochemical zoning; specification of the known metallogenic zone limits; revealing of 43 anomalous geochemical clusters differentiated in ore-formation accessories and scale of predicted noble metal and copper-nickel mineralization (Sokolov S.V. et al., 2010). Kuolayarvi, Kostomuksha, and South Kovdor anomalous geochemical clusters located in the border areas of Russia and Finland are the most perspective in contrast range, complexity, and productivity of geochemical halos as well as in estimation of mineragenetic potential.

Kuolayarvi anomalous geochemical cluster (AGC) was marked out after contrast spatially combined geochemical anomalies of Au, Pt,Pd,Cu,Ni,Co, etc. Mayskoye gold deposit, Kayraly ore show and U,Cu,Ni,Co mineralization shows are located within this cluster. According to geochemical data, the cluster is perspective for discovery of large noble metal deposits in chlorite and alkaline metasomatites and copper-nickel (with PGM) objects of the Pechenga type. Predicted mineralization is similar to known ore objects within the gold district Kuusamo in Finland in lithologic-petrographic, ore-mineralogical, and geochemical characteristics (Eilu P, 1999).

Kostomuksha AGC is defined by contrast geochemical anomalies of Au,Zn,Pb,Cu,Co,Ni, etc.; it includes Taloveys gold deposit, Berendey, Kurgelampi, Ruvinvaara and other ore shows, as well as deposits of Fe in ferruginous quartzites and Cu,Mo,U mineralization. According to our data, the cluster is perspective for Pt mineralization in iron ores and metasomatites.

South Kovdor AGC is characterized by contrast geochemical anomalies of Au,Sb,As,Ag,Te,W, etc. According to geological and geochemical data, complex mineralization of gold-copper-nickel type in propylites is predicted within this cluster. Minergenic potential of the cluster corresponds to a large (reserves) deposit. This is a new for Russia ore-formation type, which is widely presented in the Baltic Shield and adjacent areas. Ore objects of the cluster are similar to the Keyvitsa (Kevitsa) and Ninimyaki (Niinimaaki) ore deposits in Finland in the composition and levels of element contents.

References

Sokolov S.V. et al., 2010. Gold of the Kola Peninsula and adjacent areas. Proceedings of All-Russiana Scientific Conference. Apatity, Sept. 26-29. P.133-135 (in Russian)

Eilu P. 1999. Geol. Surv. Finland. Rep. Jnvest. N°146.

P73

Geochemical Prospecting of Mineral Deposits in Areas with Increased Thickness of Loose Sediments

Sergey V. Sokolov, Yulia V. Makarova, Yuri Yu. Yurchenko

A.P.Karpinsky Russian Geological Research Institute (VSEGEI), St.Petersburg, Russia

The use of routine geochemical prospecting methods after mechanical secondary halos on semi-covered and covered terrains with increased thickness of Quaternary cover of various geneses is not effective. Special technologies oriented to revealing of superimposed secondary (adsorbed-saline) halos that make prediction and mineral deposits prospecting more successful.

A new method of mineral deposits prospecting - the method of analysis of superfine fraction (MASF), has been elaborated at VSEGEI. Following the MASF technology in modification after the secondary halos, sampling is carried out in transeluvial-accumulative and accumulative elementary geochemical landscapes and barrier zones. “G” or “B” soil horizons are sampled. During small and medium-scale mapping after the secondary halos, sampling is conducted in a square network of 10x10 km,etc. In landscapes of weakly partitioned low mountains, MASF in the modification of stream leakage is used. Alluvial sediments of estuarine parts of low-order streams with catchment areas are sampled in concordance with the scale of ongoing geochemical explorations. When shooting is at 1M scale- about 100km^2 (mostly III order streams), 500K- 25km^2 (II order streams), 200K- 1,5-7km^2 (I order streams), 50K- 0,5-2km^2 (erosion gully, I order small streams). During geochemical exploration at scale 25K-10K and larger, depending on the assumed form of expected ore objects, sampling by a square network (250x250,etc.) or rectangular network (250x50,etc.) may be used.

Isolation of superfine fraction is produced in laboratory conditions on a high-productive unit - PVS (elaborated at ‘VSEGEI’). Subsequent analysis is to solubilize sorption-salt forms of elements according to a special technique with subsequent determination of their contents by high-precision analytical methods (ICP,etc.).

MASF is comparable to the best world analogues (MMI, and others) on its prospecting information value. However, it is the best adapted to the Russian landscape types and is characterized by high productivity and optimal price/quality ratio.

Application area of MASF:

1. Plain and weakly partitioned areas of the Precambrian shields and ledges of folded platform basement with wide development of far-brought loose sediments of different genesis (including moraine ones) up to 10 m thick and more (covered terrains).
2. Landscapes of weakly partitioned low mountains and plateaus with increased thickness of residual loose formations to 3-5 m or more (semi-covered terrains).
3. Open terrains of mountain-fold structures, within which areas covered by the Quaternary sediments of increased thickness are observed.
4. Landscapes of plate complexes of the Precambrian platforms (covered terrains).

Currently, MASF is widely used in Russia during geochemical works at scales from 1M to 10K, both in governmental and private enterprises (IMGRE,etc.). Within a short period of MASF application in geochemical exploration, the first positive results of perspective geochemical halos confirmation by drilling in Karelian-Kola Region, in the Sayan Mountains, in the Taimyr Peninsula, in the Northeast Russia were obtained.

P74

Geochemistry and Geology of the Sasare Iron Oxide-Copper-Gold-Uranium project, Zambia: Implications for Exploration of large low grade deposits

Robert Bowell[1], Chris Davies[2], William Mumbwa[3]
[1]SRK Consulting, Cardiff Wales, UK, [2]African Eagle Resources plc, London, UK, [3]African Eagle Resources, Lusaka, Zambia

The Sasare Iron-Oxide -Copper-Gold (IOCG) Province in Eastern Zambia is marked by a number of copper deposits with IOCG characteristics.. Such deposits can be very large, comparable in size and grade to porphyry copper deposits and therefore constitute extremely attractive exploration targets.

The deposit lies in the Southern Irumide Belt that extends into Mozambique and the Zambezi Belt. Here the Irumide crust was extensively re-worked under upper-amphibolite facies conditions during Pan-African orogenesis. The Sasare IOCG Province lies within the Petauke-Sinda Terrane which is a suite of calc-alkaline plutonic gneisses and granitoids overlain by supracrustal metasediments and volcanics together interpreted as an accreted island arc.

At the Mweze and Eagle Eye prospects the copper mineralization typically occurs 300-500 m from the granite contact in the volcanics, whereas at Ndomba, the mineralization occurs at the contact with the granite in a strongly sheared and brecciated zone associated with Fe and K alteration. Gold mineralization is also associated with the copper mineralization and possibly represents a more distal expression of the IOCG system.

Geochemical soil sampling was initially undertaken on a 100 x 50 m grid over 10-km^2 around the Mweze-Eagle Eye prospects to embrace the numerous copper shows associated with the amphibolites near the granite contact. The detailed soil grid was later extended towards the east and south to cover the entire Mweze syncline, as far as the Sasare gold mine, and north to cover the southern part of the Chapalapata granite. Finally, the Sasare Group and Granite contact to the west were covered by a 400 m hexagonal grid .

Initial interpretation using 100 and 600 ppm as anomaly threshold values revealed extensive areas of anomalous copper in soils extending for some 13km. Subsequent statistical analysis was performed for each element, including determination of the mean, standard deviation, median, and the 75th and 98th percentiles. These calculations were performed globally across the whole data set and for each lithological unit separately.

Geological mapping and soil geochemistry have also shown extensive hydrothermal alteration in the project area. Sodic and calc-silicate alteration, on a km-wide scale. An albite-specularite zone north of the Mweze prospect, near the contact with the Chapalapata granite, can be traced for a distance of 2 kilometres. Elsewhere in the project area iron alteration is also extensive. Magnetite-quartz-rich zones, occasionally associated with copper oxides, also occur at Mweze West.

IOCG deposits have been documented in all continents but are currently only exploited from a few examples. Identification of the regional geological and geochemical characteristics of economic versus uneconomic IOCGU deposits is essential to provide a more efficient method of delineation.

P75

Carlin Type Au potential of the Turkestan-Alai and Southern Fergana Segments of the Southern Tianshan, Kyrgyzstan

Daniel Rickleman[1], Alex Archangelski[1], Michael Jackson[2], Josef Story[1], Vadim Lysenko[1], Tordali Zholdoshov[1], Omerbek Atabaev[1]
[1]Manas Resources, Bishkek, Kyrgyzstan, [2]CSA Global, Brisbane, Australia

The recent discoveries of the Obdilla and Shambesai gold deposits in the Kyrgyzstan Southern Tianshan represent a new deposit style previously unknown in the region. These deposits are considered Carlin Style, most similar to the Chinese Carlin examples.

The Shambesai and Obdilla deposits show the characteristics of Carlin deposits as outlined by Cline et al. (2005). These include 1. epigenitic, sediment hosted, disseminated Au; 2. Submicron Au in pyrite; 3. Silty, pyritic, carbonaceous, calcareous host rocks; 4. low to high grade; 5. Alteration of decarbonitisation, argilitisation, silicification. Shambesai and Obdilla do not meet two of the Cline et al. (2005) characteristics - large, and occur in trends and districts. However, it is beleieved these remaining criteria may yet be met since the deposits are open and the host geology extends for many tens of kilometres.

The Turkestan-Alai and Southern Fergana region was historically a mercury and antimony producing area where mineralisation is similarly associated with the limestone and upper sediments contact. These deposits occur within the highly folded and deformed units of the Alay Segment of the Southern Tianshan which, with over 300km of strike length, is now considered to have excellent discovery potential for similar style gold deposits.

References:
Brookfield, M.E., 2000. Geological development and Phanerozoic crustal accretion in the western segment of the southern Tien Shan Kyrgyzstan, Uzbekistan and Tajikistan. Tectonophysics. 328. 1-14.
Cline, J.S., Hofstra, A.H., Muntean, J.L., Tosdal, R.M., and Hickey, K.A., 2005. Carlin-type gold deposits in Nevada: Critical geologic characteristics and viable models. Economic Geology 100th Anniversary Volume. 451-484.
Fillipova, I. B., Bush, V. A. and Didenko, A. N., 200.1 Middle Paleozoic subduction belts: the leading factor in the formation of the Central Asian fold-and-thrust belt. Russian Journal of Earth Sciences: 3. 405-426.
Jackson, M. and Louw, G., 2009. Geology and Mineral Resource Evaluation at the
Shambesai Gold Project. CSA Global Pty Ltd.Technical Report Report No. R204.2009.
Konopelko, D., Biske, G., Seltmann, R., Eklund, O. and Belyatsky, B., 2007. Hercynian post-collisional A-type granites of the Kokshaal Range, Southern Tien Shan, Kyrgyzstan. Lithos: 97. 140-160.
Li, Z.P and Peters, S.G., 1998. Comparative Geology and Geochemistry of Sedimentary-Rock-Hosted Carlin-Type Gold Deposits in the People's Republic of China and in Nevada, USA. USGS Open File Report 98-466.
Nikonorov V.V., Karaev Yu.V., Borisov F.I, Tolsky V.I., Zamaletdinov T.S., Larina, T.V. and Gorbaneva T.V., 2007. Gold Resources of Kyrgyzstan. State Agency for Geology and Mineral Resources under the Government of the Kyrgyz Republic. The Kyrgyz Methodical Expedition for Geological and Economical Research.

P76

Application of portable XRF technology to identification of mineralization and alteration along drill in the Nihe iron deposit, Anhui, Eastern China

Qinglin Xia[1], *Qiuming Cheng*[2]
[1]China University of Geosciences, Wuhan, China,
[2]York University, Toronto, Canada

Portable X-ray fluorescence spectrum (PXRF) is a new analysis techniques in-situ and is usually applied in both geochemical research at geological outcrop scale and heavy metal pollution assessment in soil. In this study, PXRF was used to recognize lithology section and to analyze the content of Fe, Mn, Cr, Co, Ni, Ti, V, Cu, Zn, Pb, Ag, Mo, K, Ca, As, Sb, Bi, Cs, Zr and Nb along 5 drill holes in the Nihe iron deposit in Anhui, East China. Nihe mineral deposit is a newly discovered large iron deposits and its main ore bodies are found 700 m below the surface. It is essential to create a comprehensive mine model with geological, geophysical and geochemical data for mine development and for further exploration in its surrounding areas. High resolution samples were collected from 5 drill cores and each sample consists of 6-10 readings that were averaged to form a representative values of 22 elements. Based on these data, the spatial distribution of these elements is obtained. The results have shown that (1) the areas with high values of Fe obtained by PXRF have high spatial correlation with the areas with high grade of Fe delineated by chemical analysis; (2) Fe anomalies, Fe-V-Mn-Cr-Ni-Ti-Bi anomalies, Zn anomalies and Zn-Cu-Cd anomalies are good indicators for Fe mineralization, Cu and Zn mineralization, respectively; and (3) K and Ca anomalies are good indicators for potash feldspar alteration and anhydrite alteration, respectively. These results indicate that PXRF is convenient, quick, practical, reliable and nondestructive technique of low cost for identifying of mineralization and alteration along drill in the field.

P77

Application of portable XRF technology for hand specimen scale geochemical imaging and identification of sequences of mineralization in Jinding Pb/Zn Mineral Deposits in Yunnan, Southwestern China

Zhaoxian Yuan[1], Qiuming Cheng[1]
[1]China University of Geosciences, Wuhan, China, [2]York University, Toronto, Canada

Portable X-ray fluorescence spectrum (PXRF) was used to hand specimen collected from Jinding Pb/Zn mineral deposits in Yunnan, Southwestern China. Geochemical images were created using the concentration values analyse using PXRF on a polished sample surfaces of about 10x10 cm dimension at 3mm spatial resolution. The concentration values of 22 elements including Fe, Mn, Cr, Co, Ni, Ti, V, Cu, Zn, Pb, Ag, Mo, K, Ca, As, Sb, Bi, Cs, Zr and Nb were analysed. The spatial distributions of these concentration values and associations of values obtained using principle component analysis (PCA) were created and interpreted. The results have shown two main mineralization relations with earlier stage of mainly Zn mineralization and larger stage of mainly Pb mineralization. The earlier mineralization forms circular distribution of Zn concentration with large extents in the hand specimen whereas the later minerlization forms elongate zone which cross the Zn zone and in the overlapped regions mineralization show both Pb and Zn as dominate minerals. The results visulizated from the distributions of relevant elements as well as the score distribution obtained using PCA are generally in agreement with observation of mineral assemblage under micropscrope. The study has demonstrated that PXRF is convenient, effective and practical for identifying of mineralization on hand specimen.

P78

The Test Method of Geochemical Exploration for the Semi-arid Desert Prairie Landscape in West Hillside for the Great Xinganling, Inner Mongolia--result from the mining area and surrounding of the Weilasituo Cu deposits

Dapeng Li[1], Yuelong Chen[1], Jinbao Liu[2], Furong Leng[2]
[1]China University of Geosciences, Beijing, Beijing, China, [2]Geological Survey Institute of Inner Mongolia, Hohhot, Inner Mongolia, China

Through the study of the geochemical exploration data for the mining area and surrounding area of the Weilasituo Cu deposits, we conclude that the -120 meshes sampling show the best effect, with -5~20 meshes a little poor. Sampling with -5 meshes shows new anomaly, while the composite sampling of -5~20 meshes and -120 meshes shows anomaly among the -120 meshes, -5 meshes and -5~20 meshes. The -5~20 meshes sampling was only taken a proportion of 22.5% given the thought of the characteristics of the prairie landscape. Samplings with -5~20 meshes and -5 meshes (pay attention to the area with aeolian sand) were chosen in the bedrock exposed area and areal coverage respectively to improve the field work efficiency. According to the test results, -5 meshes sampling and -5~20 meshes sampling have anomaly with same grade. Therefore, the accordant mapping can be made if these two sampling grade are chosen. The results fit for the semiarid desert to prairie landscape for the geochemical exploration with a scale of 1: 200,000, and also fit for the geochemical survey with a scale of 1:50,000. Thus, it can be also used in farmland and alluvial-proluvial plain. It can also resolve the sampling problem for the areas where the -5~20 meshes samples are hard to get.

P79

Research on the Relation between Regions of High Morbidity of Cancer and the Multiple Environmental Pollution in the Process of Urbanization in the Pearl River Delta

Ming Chen, Yaoqiu Kuang, Ningsheng Huang
Guangzhou Institute of Geochemistry Chinese Academy of Sciences, Guangzhou, China

The Process of Urbanization gets more and more resources and energies from the environment while discharges much more pollutions to the environment. These pollutions would cause high morbidity of some regional diseases. According to the 3rd Chinese survey in retrospective sample of cause of death : The city resident malignant tumor mortality in China already have gone up to the first place, its mortality($150.18/10^6$) is higher than rural($128.65/10^6$).

The morbidity of cancer consists of many factors, many stages, and it's a gradual process as the result of more than a decade's or even several decades' accumulation. Carcinogenic factors include not only the interior factors like heredity, immunity and age, but also the exterior ones around like chemical factors, physical factors and virus infection, among which the change of environmental chemistry is the most important factor. In environment, chemical carcinogenic factors are numerous variety, this paper classifies three kinds of pollution according to their propagation channel for air pollution(AP) , water pollution(WP) and the soil contamination(SC), and has put forward the formula: $C = \Sigma(AP+WP+SC)$ to show what causes the high morbidity of cancer synthesizes the associated action of three kinds of pollution. Moreover, the paper illustrates the relation between regions of high morbidity of cancer and the multiple environmental pollution in the process of urbanization in Pearl River Delta. First, according to the assessment of the eight heavy metal elements of Cd, Hg, Pb, As, Cr, Ni, Cu, Zn, the size of grade-3 and above soil is 3024 km^2 , 30.23% of the investigated area, which is moderately or heavily polluted. The size of grade-2 soil is 6681 km^2 , 66.78% of the investigated area, which is slightly polluted. Secondly, the water pollution is complicated. On the one hand, the acid rain may activate the heavy metal and other inorganic substance in soil to move into the water and the food chain. On the other hand, the water in the Pearl River Delta is suffering more from pernicious organic pollutants. Thirdly, the air has been seriously polluted. The haze weather in the Pearl River Delta region covers more than 100 days in a year. In recent years, the waste gas of motor vehicles increases rapidly besides the industrial waste gas discharged, which causes a rise of organic pollutants in the rainfall. In it, the polycyclic aromatic hydrocarbons compound is carcinogenic, teratogenic and mutagenic, which intensely impair the organs in human body. Take nasopharyngeal carcinoma for example, it has been called the Guangdong cancer, because the morbidity of this kind of cancer in Guangdong, especially in the Pearl River Delta is much higher than the average level of the whole nation.

P80

The Fe isotopic composition of soils and waters from the Ravenna area (Northern Italy) and its significance for environmental studies

Francesca Castorina, Umberto Masi
Università "La Sapienza", Roma, Italy

Stable Fe-isotope ratios have been measured by TIMS in samples of natural and cultivated soils as well as surface waters from a sector of the Ravenna area located next to the industrial zone that host particularly iron mills, and contoured by fields exploited by intensively agriculture. The soils, that can be classified as entisols in interdune lowlands and are composed of quartz, feldspars, calcite, muscovite, chlorite and dolomite, were analyzed following a three-step sequential chemical procedure, to obtain different extractable fractions and, thus, determine the potential sources of Fe in poorly-crystalline Fe oxides, crystalline Fe oxides and silicate-bound Fe (Wiederhold et al., 2007). Iron isotope ratios of bulk soil digests were compared with those of the different Fe fractions. In particular, the δ56Fe of the hydrochloric extracts of the soils, that can represent the metal fraction available to the plants and, thus, provide information on health of the vegetal ecosystem, range narrowly, increasing from slightly negative values in upper horizons to slightly positive values downward each profile. This trend suggests the Fe isotopes are little fractionated biologically during the pedogenesis. Preliminary analyses of waters from the irrigation network related to both natural and cultivated soils, display slightly negative δ56Fe. As a whole, the isotopic signatures of both soils and waters suggest the natural cycle of Fe in these materials is unaffected by significant anthropogenic contributions, despite the location of the study area just in front of major pollution sources. This conclusion is consistent with what has been acknowledged by a study on the distribution of potentially toxic metals and stable/radiogenic isotopes, carried out on the same materials from the Ravenna area. Lastly, the results corroborate previous information on fractionation mechanisms of Fe isotopes and help in the development of these isotopes as tracers for biogeochemical Fe cycling in nature.

References:
Wiederhold et al., 2007. Geochimica et Cosmochimica Acta, 71, 5821-5833.

P81

Search for geochemical indicators of pre-urban habitation sites: case study from Skomantai hill-fort and settlement, western Lithuania

Ričardas Taraškevičius[1], Miglė Stančikaitė[1], Audronė Bliujienė[2]
[1]Nature Research Centre, Vilnius, Lithuania, [2]Klaipeda University, Klaipėda, Lithuania

The aim of the interdisciplinary project „Impact of anthropogenic factors upon the expansion of invasive species in the context of Holocene paleoecosystem changes" is to describe the pattern and chronology of the invasive processes in Lithuania throughout the Late Holocene in the context of the changing human activity and palaeoecological situation. Investigation of the pre-urban habitation sites is included in it. Such sites comprising the hill-forts and settlements were the starting points for proto-towns (Bliujienė, 2003).

Geochemical indictors can be used for assessment of not only present but also historical urban changes due to anthropogenic activity. Revealing of syngenetic element groups characterised by either enrichment or depletion can be useful.

In this study the results of the lithological-geochemical investigations of the Quaternary sediments, which served as the natural basement for the Skomantai pre-urban habitation site, are presented. The hill-fort and the settlement are dated to the large chronological span from the Roman Period to the 13th century. The Skomantai hill fort rises on the top of the foreland formed on the bank of the glaciofluvial valley (now occupied by the Veiviržas River) formed by the Late Weichselian Glaciation. The height difference between the hill fort's plateau and the river is approximately 17 m. Skomantai territory is formed by the Quaternary deposits consisting of basal till covered by glaciolimnic sand.

Aiming to characterise possible cultural layer and at the same time to preserve historical heritage, the exploration holes until 1.0-1.3 m depth were dug with minimum damaged area of the settlement. Sediment cores of deeper horizons were taken by boring with hand-held borer from the bottom of these holes until basal till. Fine grained sand samples were taken from the walls of holes and sediment core sandy layers taking into account the changes of their colour. These colour changes were presumed to be possible indicators of anthropogenic or natural factors. The number of investigated sites was 28 and total number of samples was 210. Archeobotanic investigations of surroundings were also done.

Total contents of more than 30 chemical elements were measured by EDXRF equipment. Two subsamples were prepared from each sample and mean values of two results were calculated. The relationship between lithological, possible paleoanthropological and geochemical features was analysed using various multivariate statistical methods. Specific chemical elements or groups of correlated elements were distinguished which indicate properties predetermined by natural lithological or possible anthropogenic factors.

Reference:
Bliujienė, A., 2003. Interarchaeologia, 1,147-166.

P82

Introducing "UrbanEnviron@Lisbon 2008" a GIS-platform for environmental and human health data management

Carla Patinha[1], Amélia Reis[1], Eduardo Ferreira da Silva[1], Ana Dias[1], Sofia Bartolomeu[2], António Sousa[3], Anabela Cachada[4], Maria Batista[5], Cátia Prazeres[5], Fernando Rocha[1], Cristiana Costa[1], Cristina Sequeira[1], Denise Terroso[1], Rui Figueira[3], Cecilia Sérgio[6], Rita Salgueiro[1], Orquidia Neves[3], Armando Duarte[4]
[1]GEOBIOTEC, University of Aveiro, Aveiro, Portugal, [2]Physics Department, University of Aveiro, Aveiro, Portugal, [3]CERENA, Technical Superior Institute,, Lisbon, Portugal, [4]CESAM, University of Aveiro, Aveiro, Portugal, [5]LNEG, Lisbon, Portugal, [6]Jardim Botânico – MNHN, Lisbon, Portugal

The project untitled "PTDC/CTE-GEX/68523/2006 URBSOIL-LISBON: Geochemical survey of Lisbon urban soils: a baseline for future human health studies" proposes an urban geochemistry study of Lisbon city focusing the contamination of its environmental compartments (soil and ground-level dust) by urban activities, in order to assess the risk that potentially harmful substances (PHS), inorganic elements and organic compounds, in those environmental compartments may pose to human health.

The main aim of the project was to establish a geochemical baseline (concentration at a specific point in time of a chemical parameter in a sample of geological material) in a GIS format, intuitive and accessible to potential end-users and stakeholders (scientists, general public, policy makers/legislators and urban designers/planners). But, a dramatic cutback in the initial budget has led to dramatic changes in the research plan. The project became a target survey, despite all the constraints attached to the challenge of doing a target survey without a previous systematic survey. Instead of a target land use/area survey we used a strategy based on a target land use/vulnerable organism survey. As children are particularly vulnerable to PHS only urban recreational spaces used by them were sampled. Bryophytes were used as biomonitors of the urban environmental quality. Fifty one topsoil and 50 ground-level dust samples were collected in playgrounds, schoolyards, urban parks and public gardens. At each site, 1 uncontaminated moss transplant was fixed to a horizontal tree limb, which remained in situ for a period of 6 months. Such a low number of samples (0.6 samples/km2) doesn't fulfill the requirements of a baseline but enables gathering a GIS platform (UrbanEnviron@Lisbon 2008) with relevant data for future environmental/public health studies in Lisbon city.

Geochemical, geological, topographic, geographic, environmental, demographic data and site specific parameters like land use, soil/dust size fraction, soil/dust mineralogy, oral bioaccessibility estimates and PHE partitioning among the soil phases were assembled and integrated in the GIS database. Data on biomonitors were also integrated in GIS platform. This database was used to identify areas of probable risk within the city of Lisbon that were selected to carry out studies on human health.

Data integration was carried out through statistical methods like Multiple Regression Analysis, Cluster Analysis, Principal Component Analysis and Correspondence Analysis. The GIS-platform is intended to be a suitable tool, freely at the disposal of end-users and stakeholders to support those delivering recommendations on land management requirements (management of the environment), show how to ensure that new urban recreational outdoor spaces are fit for purpose, including ensuring that there are no unacceptable risks to human health from PHS, and perhaps promoting platforms of analysis and engagement for ongoing cooperation among all stakeholders.

P83

London Earth: anthropogenic and geological controls on the soil chemistry of the UK's largest city

Andreas J. Scheib, Dee M.A. Flight, Bob Lister, Cathy Scheib
British Geological Survey, Keyworth, Nottingham, UK

The soil geochemical survey of the Greater London (UK) area, comprising over 6400 sample sites, is the most detailed and comprehensive urban mapping project carried out to date. In order to give insight into the environmental impacts of urbanisation and industrialisation, as well as to characterise the geochemical baseline of the UK's most populous city, samples were collected at a density of 4 sites per km^2. The <2 mm fraction from the topsoil samples (5 - 20 cm) was analysed by X-ray fluorescence spectrometry (XRFS). Resulting data for over 50 elements were subject to rigorous quality control procedures to ensure accurate and inter-comparable data.

Anthropogenic modification to soil baseline concentrations is evident across the urban area. A notable feature is the 'central zone' of higher concentrations of, for example, Pb, Sb, Ca, Zn, Cu, Sn and As in the oldest, most intensely urbanised parts of the city. In the cases of Pb and Sb in particular, high-density traffic is a likely source. Local 'hotspots' of elevated concentrations, related to particular anthropogenic activities, can also be identified. For example Se, Cd, Ni, Cu and Zn show particularly elevated concentrations in the vicinity of an industrial area on the banks of the river Lee in north London, whilst Cr and Cd also display high concentrations around Heathrow airport in the west.

Despite these anthropogenic controls, a strong geological control on soil chemistry is observed for many elements. This is particularly evident in south London where high baseline concentrations of, for example, Ca, Ce, I, La, Mn, Nd, P, Sr, Y and Zr, relate to the influence of the Cretaceous chalk bedrock. In the north-western quadrant of London and along the northern boundary of the project area, high baseline concentrations for a number of elements (Al, Fe, Mg, K, Cr, La, Ti, Ga, Rb and Ni) are associated with the outcrop of Palaeogene clays. Elevated levels of Hf and Zr correspond to areas of Eocene marine and Quaternary wind-blown deposits.

One of the most interesting features of the mapped data is the consistently low concentrations of metals associated with the Royal Parks (Bushy and Richmond), Hampton Court and nearby Wimbledon Common in southwest London, which contrast with surrounding areas. Throughout the urban evolution of London these parks have avoided significant residential or industrial activity and remain free of imported soil, wastes or 'made ground'. Consequently, comparison of geochemical baselines within and outside the parks, where underlying geology is consistent, can help to provide an indication of ambient anthropogenic geochemical modification of London's soils.

P84

Attenuation of Heavy Metals in Natural Wetland Receiving Acid Mine Drainage

Keiko Sasaki, Tagiru Ogino, Yuji Endo, Kunihiko Kurosawa
Kyushu University, Fukuoka, Japan

The mechanism of surface water remediation in a natural wetland that is receiving heavy metal-rich acidic mine drainage was investigated. Selective sequential extraction was useful to derive the mechanisms of heavy metal removal in the wetland. In the upstream portion of the wetland, dissolved Fe was removed mainly as oxide-bounded mineral phases, such as hydroxides. These are important for the subsequent removal of other heavy metals. Other ion-exchangeable and carbonate-bounded heavy metals are also observed in the upstream, associated with Fe oxides. Organic matter and Fe-Mn oxides in the upstream remove Cu and Zn ions from the drainage, respectively. In the middle of portion of the wetland the removal of heavy metal ions in relatively low concentrations occurs by the emergent vegetation. Greater clay abundance and higher microbial activity of sulfate reducing bacteria in the downstream parts achieved low-level removal of metals. Multi-cell wetlands are recommended for the treatment of acidic metal bearing surface water drainage, if sufficient land area and expenses are available to construct.

P85

Release of arsenic from damped sediments originally deposited in the Shinaki Dam receiving neutralized acidic river water, Gunma, central Japan

Kosei E. Yamaguchi, Eri Tanaka
Toho University, Chiba, Japan

The Yukawa River, originating from the Kusatsu-Shirane volcanic district in central Japan, is rich in sulfate because of natural oxidation of sulfide minerals in its source hot spring area and becomes acidic with pH as low as 2. Artificial neutralization has been done on the Yukawa River for nearly fifty years by adding pulverized $CaCO_3$ in suspension at its mid-downstream. The Shinaki Dam was constructed to precipitate and store the treated sediments for assurance of water quality, because water flowing out of the dam eventually merges to the Tone River system, supplying drinking water to Tokyo area. However, the sediments have been filling the dam with unexpected speed. The sediments are now dredged and transported to nearby mountains for damping by local government. Those sediments are expected to contain significant amount of As, because of its high concentration in the Yukawa River (up to 10 mg/L) and co-precipitation with $Fe(OH)_3$ produced by increase of pH from ~2 to ~5 through artificial neutralization. Arsenic is a harmful to living organisms and a ubiquitous element in hot springs in volcanic district. Once released from the damped sediments, As would cause serious environmental problems. Thus, chemical stability of the damped sediments needs to be guaranteed; however, environmental acids such as acid rain and organic acids would dissolve $Fe(OH)_3$ to release adsorbed As. It is therefore important to investigate the stability of the damped sediments by attack of acids mentioned above.

We performed a preliminary laboratory experiments to assess how much arsenic was released with time by leaching the sediments in the Shinaki Dam after addition of various 0.10 M reagents organic acids (acetic, oxalic, formic, and citric acids). We used ICP-MS for measurement of As and other metal concentration and ICP-AES for Fe and Ca. We confirmed that almost all As in the sediments (~0.5 wt.%) were released by the leaching within three days. Formic and oxalic acid was found to be the most effective media to liberate As. Because temporal changes in the concentrations of As and Fe in leachate were found to be similar, we suggest that nearly all As in sediments was adsorbed on the $Fe(OH)_3$ and releases by its dissolution by added organic acids. We are continuing this study by using (1) more dilute organic acids with their concentration close to natural level in the Kusatsu-Shirane district and (2) natural (therefore a mixture of) organic acids contained in soils collected nearby the dam. The results of this study have important implications for how we should treat the sediments in the Shinaki dam for water quality assurance.

Workshops

WS1
Quality Assurance in Geochemical Analysis

Michael Wiedenbeck
GFZ German Research Centre for Geosciences, Potsdam, Germany

The interpretation of quantitative geochemical data is commonly beset by a lack of clarity in exactly what has been analyzed and exactly what is being reported. Furthermore, the procedure by which a particular analytical procedure has been validated or which parameters have been included when determining a result's uncertainty budget commonly remain unclear to the data end-user

This workshop will provide an overview of the basic concepts of geochemical metrology. Core themes which will be presented include: method validation, the estimation of analytical uncertainty, the concept of metrological traceability, the production and proper use of reference materials and the role of proficiency testing in assuring data quality. Participants will also be introduced to current usage in metrological terminology. As an example, the different between the classical concepts of "accuracy" and "precisions" vs. the modern concepts of analytical bias and total measurement uncertainty will be discussed.

WS1
Geochemistry for risk assessment of metal contaminated sites

Päivi M. Kauppila[1], Timo Tarvainen[2] and Tommi Kauppila[1]
[1]Geological Survey of Finland, Kuopio, Finland,
[2]Geological Survey of Finland, Espoo, Finland

Risk assessment of metal contaminated sites including old mining sites requires geochemical methods of analysis, modelling and long-term prediction. This workshop focuses on current research developments and best available methods/practices within this field of increasing importance. The specific topics include combining field measurements and reactive transport modelling at contaminated sites, methods of long-term prediction of environmental impacts from mining wastes, use of soil solution partition coefficients (Kd) for assessment of risk of groundwater contamination, and techniques for assessment of metal contaminant availability to plants.

The keynote lecturer in the workshop is Professor David Blowes from the Department of Earth and Environmental Sciences at the University of Waterloo, Canada. Introductory speeches will be given by Dr Bruno Lemiere from BRGM (Bureau de Recherches Géologiques et Minières; Geological Survey of France), Dr Timo Tarvainen from the Geological Survey of Finland, and Dr Tiina M. Nieminen and M.Sc. Marita Turunen from the Finnish Forest Research Institute (METLA). Commentary speech on mine waste characterization in Finland is given by Dr Päivi M. Kauppila. After each speech there is time for discussions and questions by the workshop participants.

Keywords: contamination, soil, mine, analytical methods, modelling

WS3

Indicator mineral methods in mineral exploration

Beth McClengahan[1], Vesa Peuraniemi[2] and Marja Lehtonen[3]
[1]Geological Survey of Canada, Ottawa, Canada [2]University of Oulu,Oulu, Finland, [3]Geological Survey of Finland, Espoo, Finland

This one-day workshop builds on the success of the indicator mineral workshop held at the 25th International Applied Geochemistry Symposium. This workshop will review principles, methods, and developments in the application of indicator mineral methods to mineral exploration. In the 1970s and 1980s, indicator mineral methods were used mainly for tin and tungsten and gold prospecting. Since playing a key role in the discovery of the Lac de Gras diamond field in northern Canada in the 1990s, indicator mineral methods have risen in prominence. The scope of the method has expanded, and the range of commodities being sought has broadened to include base and rare metals, as well as diamond and precious metals. The workshop consists of presentations by some of the most experienced practitioners in the field. Indicator mineral methods applied to exploration for gold, porphyry Cu, rare metals, magmatic Ni-Cu and diamonds will be presented as well as heavy mineral recovery methods, the application of Fe oxide mineral chemistry, and the value of sulphides and sulphate minerals.

WS4

Prospectivity mapping in GIS: integrate geochemistry data with geophysics and geology

Vesa Nykänen
Geological Survey of Finland, Rovaniemi, Finland

Prospectivity mapping is used to define areas favourable for mineral exploration. It can be applied in various scales from global to local scale exploration targeting. Geographical information systems (GIS) provide a flexible and powerful platform to apply spatial data analysis techniques as a tool for prospectivity mapping by integrating geochemical, geophyscical and geological data. These techniques include e.g. weights of evidence, logistic regression, fuzzy logic and neural networks.

Definition of the exploration model can be based on a genetic ore deposit model or a mineral system model. This gives the framework for the data used for creating a predictive prospectivity analysis for mineral exploration targeting. Essential part of the procedure is the pre-processing of the raw data into meaningful map patterns for the given task. These pre-processing techniques include data interpolation, classification, clustering, rescaling, filtering, image processing, raster calculation etc. A common expression for describing these methods in GIS platform is geoprocessing. After creating the map patterns indicating the vectors towards a mineral deposit type we can apply various data integration techniques in GIS to create a single prospectivity map delineating positive areas for mineral exploration. Application of these techniques using ArcGIS software and add-on applications will be discussed and demonstrated during this one day workshop. The examples presented in this workshop give insights into the use of the techniques for exploration of orogenic gold, IOCG and magmatic Ni-Cu deposits.

WS5

Exploration for orogenic gold depositsWith emphasis on geochemical exploration in glaciated Precambrian terrain

Pasi Eilu[1], Pertti Sarala[1], V. Juhani Ojala[2]
[1]Geological Survey of Finland, Espoo/Rovaniemi, Finland, [2]Store Norske Gull, Rovaniemi, Finland

An orogenic gold deposit is a structurally controlled gold occurrence formed during one of the major stages of an orogeny by orogenic fluids. Any rock type within a greenstone or schist belt, a metamorphosed supracrustal rock, dyke, or intrusion within or intrusion bounding such belt may host an orogenic gold deposit. There is strong structural control of mineralization at a variety of scales but the favoured host is typically the locally most reactive and/or most competent lithological unit. These deposits are not present in post- or anorogenic intrusions or unmetamorphosed supracrustal rocks. Most of the Precambrian deposits were formed during 2.70-2.60 Ga and 2.10-1.70 Ga. These epochs appear to be related to rapid crustal growth and accretionary stages of supercontinents. Mineralisation typically takes place during the last major stage of an orogeny. The late timing of this deposit type to provide important geological aids in exploration as the geometry of the geological units has not significantly changed after the mineralisation. Hence computer aided methods like geomechanical stress modelling can be utilised to model structurally favourable sites.

In greenschist facies settings, mineralisation typically takes place slightly after the metamorphic peak, but in amphibolite facies at the local regional-metamorphic peak. The ore bodies typically have a strongly flattened ellipsoidal shape, are plate-like, may have a steep or a gentle dip and plunge of ore shoots. An ore body can be 0.5-50 m wide, 100 m - 2 km long, consisting of a vein network, an en echelon vein swarm, or just of one single large vein. The depth extent of an ore body may well be much larger than its extent along strike. An individual vein can be 1 cm - 10 m thick and 20-1000 m long. In most cases, gold occurs as native gold, free in gangue and with main sulphides, and as inclusions and in fractures of gangue and sulphide grains. In a few cases, most of gold is in the lattice of or submicroscopic inclusions in pyrite or arsenopyrite.

All deposits are developed by an alteration halo characterised by proximal to distal carbonatisation and proximal sericitisation or biotitisation. Also, proximal sulphidation may be distinct if the host rock is iron rich. Elements enriched typically include As, Au, CO_2, K, Rb, S, Sb, Te, W; in some cases also Ag, B, Bi, Co, Cu, and Se are enriched. The Au/Ag is consistently >1, typically 5-10. Enrichment or depletion of Ca, Fe, Mn or Mg are non-existent, and Na mobility, if present, is minor and spatially restricted to the ore itself. Alteration mineral assemblages, alteration indices based on CO_2 and K, and trace (pathfinder) elements enriched in the deposits can be used in defining exploration targets and vectors to ore in bedrock.

Surficial geological, till geochemical and indicator mineral studies are effective methods in gold exploration in glaciated terrains. By test pit surveys and stratigraphic controlled till geochemical and heavy mineral sampling glacial transport distances and mechanisms, secondary element dispersions, and ice flow directions can be estimated. Strong changes in glacial dynamics and erosional and depositional conditions lead to a variable degree of preservation of earlier deposits and pre-Quaternary regolith, and deposition of complex glacigenic formations.

Excursions

Field excursion 1.
Active and ongoing gold exploration and mining in Northern Finland

Pasi Eilu, Vesa Nykänen
Geological Survey of Finland, Espoo/Rovaniemi, Finland

This excursion includes visits to the Pahtavaara and Kittilä gold mines, Mustajärvi and Hanhimaa gold occurrences, and Rumatmaat Au-U occurrence. In addition, the field trip provides an introduction to the Palaeoproterozoic metallogenic evolution of the region.

Pahtavaara is an active gold mine (in production 1996-2000, 2003-), with a total in situ size estimate of 13 t gold at the average grade of 2.7 g/t (production + resource, December 2010), in a komatiitic sequence at the eastern part of the Central Lapland greenstone belt. It comprises a swarm of subparallel lodes; nearly all gold is free native. It has many of the alteration characteristics of amphibolite-facies orogenic gold deposits and an obvious structural control, but has an anomalous barite-gold association and a very high fineness (>99.5 % Au) of gold. Pahtavaara is best interpreted as a metamorphosed seafloor alteration system with ore lenses as either carbonate- and barite-bearing cherts or quartz-carbonate-barite veins. The gold may have been introduced later, but its grain size, textural position (occurs with silicates, not sulphides) and high fineness point to a pre-peak metamorphic timing.

Kittilä Mine, also known by the name Suurikuusikko, is the largest gold deposit in northern Europe. It has a current in situ resource of 194 t gold, at the average grade of 3.6 g/t. Production started in 2008. The deposit is a Palaeoproterozoic orogenic gold deposit hosted by albitised, mafic to intermediate, volcanic rock and tuffite. It comprises a number of ore bodies in a 4-km long section of the subvertical, compressional, Suurikuusikko shear zone. This NNE-trending shear zone, which has a dextral component, is known to be gold-enriched for its entire length of >20 km. The deposit is open at the depth of >1.4 km and along strike. The gold is refractory gold: 71 % of gold in the lattice of, and as tiny inclusions in, arsenopyrite and 22 % in pyrite, in both thin veins and altered host rock.

Mustajärvi is a Palaeoproterozoic orogenic gold occurrence with no resource estimate available. It is characterised by carbonate- and tourmaline-quartz veins in albitised schists. The occurrence is controlled by a NE-trending shear zone possibly branching from the WNW-trending Sirkka shear zone. Native gold is present in quartz veins and their alteration haloes. Saprolitic part of the deposit is presently exploited in a small scale.

Three orogenic gold occurrences are known from the N-trending Hanhimaa shear zone which is parallel to the Suurikuusikko shear zone 10 km to the east. The area has seen only minor exploration, including trenching, drilling, and till-geochemical and ground-geophysical surveys. Hosts to mineralisation include mafic volcanic rocks. In addition to gold, some of the Hanhimaa occurrences are, partially, also enriched in Ag, Cu, Pb and Zn.

Rompas is a new gold-uranium discovery in Palaeoproterozoic Peräpohja schist belt in SW Lapland. Bonanza-grade Au and U mineralisation occur at surface over an area 6 km long and 200 m wide. Only surface sampling has been performed in the area: weighted average of all 80 channel samples from the 2010 program is 0.59 m @ 203.7 g/t Au, 0.73 % U. Mineralisation appears to be hydrothermal in nature and fracture-controlled in metavolcanic host rocks. The occurrence may be related to a buried intrusive that may be an apophyse or down-dip extension of a granitoid complex a few kilometres to the north of the property.

Field excursion 2.
Care of mine districts and the environment after closure of mines

Päivi Kauppila[1], Maria Nikkarinen[1], Marja-Liisa Räisänen[2], Teemu Karlsson[1]
[1]Geological Survey of Finland, Kuopio, Finland, [2]Centre for Economic Development, Transport and the Environment, Kajaani, Finland

The Finnish mining industry lives its upswing. At the same time with the gradually increasing mining activities in Finland, the need of post-treatment of closed mines and related environmental issues of operating ones are becoming more and more important. This field trip includes visits to old and active mining areas, and looks at their baseline studies, monitoring, care after mining, environmental changes and geochemistry before and after the mining operations.

The reopened Luikonlahti mining area is an interesting example of the cyclic life of some mine sites. Besides the original Cu-ore waste, the tailings site contains a layer of more recent talc ore material, which will be topped again when the concentrating plant processes ore from the nearby Kylylahti copper mine. An example of passive treatment for tailings leachate will be provided as well as an overview of the concentration process and the Kylylahti mine.

The copper plays a major role also in the Outokumpu area, which is well known for the closed copper mine, once the biggest in Europe. The old tailings site of Keretti has been recovered and is now used as a golf course. Besides getting acquainted with the after treatment and history of the Outokumpu mine, also the GSF Mineral Processing Laboratory will be visited for their environmental research.

Additional examples of mine care will be provided in Sotkamo. The Talvivaara Ni-mine presents the newest generation of Finnish mines. The bioheap leaching technique used to extract metals from the ore, together with the planned uranium recovery, require a careful observing of the environmental issues and a modern environmental monitoring system. Another example of large scale mining activity integrated with environmental care is the Lahnaslampi talc mine, which is the biggest single talc producing unit in the world.

Further insight for the closed mines will be presented in Taivalkoski. Vanadium is not currently mined in Finland and one of the two closed vanadium mines is the Mustavaara mine. While the landscaping of the old mine is yet unfinished, there has been activity to reopen it.

To increase the different ways to enjoy the clean nature, the Geological Survey of Finland has been publishing geological hiking maps. The most recent publication concerns the Syöte area, which will be the topic of the last part of the excursion. Besides the normal useful information for hikers, a geological hiking map contains insight for the soil types, natural formations and geological sights.

Field excursion 3.
Chrome and PGE deposits associated with the 2.45 Ga layered intrusions of Northern Finland

Tuomo Törmänen, Tuomo Karinen
Geological Survey of Finland, Rovaniemi, Finland

This field trip includes visits to the Kemi chrome mine and PGE+Ni-Cu exploration projects at the Konttijärvi deposit of the Portimo layered intrusion complex. In addition, the field trip provides an introduction to the 2.45Ga layered intrusions of Northern Finland and associated ore deposits.

The 2.45-2.44 Ga mafic layered intrusions of northern Finland and NW Russia record a global magmatic event with coeval intrusions and dyke swarms occurring in Australia, Canada, India, Antarctica and Scotland. There are about 20 of these intrusions in Finland; most of them occurring along an E-W trending, 300 km long Tornio-Näränkävaara belt in northern Finland. The intrusions occur at or close to the contact of Archean basement and overlying early Proterozoic volcano-sedimentary sequences. The contact between the intrusions and supracrustal rocks is erosional, indicating relatively shallow emplacement of the intrusions, followed by rapid uplift and erosion and subsequent deposition of the volcano-sedimentary sequences. Most of the intrusions are made of more ultramafic basal parts followed by more mafic, gabbroic upper part. Repetition of ultramafic and mafic layers, i.e. the occurrence of megacyclic units is a typical feature for the intrusions. Three different types of parental magmas have been recognised based on the composition of chilled margins, cumulates and cogenetic dykes. Two of these have boninitic or siliceous high-magnesian basaltic affinities, with either a high Cr or low Cr content. The third magma type is a more evolved tholeiitic basalt.

All the different mineralisation types associated with mafic layered intrusions are present in the Finnish intrusions, including basal chromite and PGE-enriched base metal sulphide accumulations, stratiform PGE, Cr and Fe-Ti-V occurrences, and offset PGE-Cu-Ni deposits below the intrusions. However, only two deposits have been commercially exploited, so far. These are the closed Mustavaara vanadium mine in the western part of the Torni-Näränkävaara bet, and the Kemi Cr-mine, which has been in production since 1968. The Kemi intrusion is ca 15 km long and 0.2-2 km wide. The main chromite layer occurs in the basal ultramafic part of the intrusion. It is 40 metres thick on average, but the thickness varies from a few meters up to 160 meters. The average Cr_2O_3 content of the ore is about 26% and the average Cr-Fe ratio is 1.6. Annual production is about 1.3 Mt of ore, from an underground mine. Proven ore reserves are 36 Mt with an additional mineral resource of 87 Mt.

The most advanced PGE-Ni-Cu project is the Gold Fields Arctic Platinum Project, hosted by the Konttijärvi and Suhanko intrusions of the the Portimo complex, in the central parts of the Tornio-Näränkävaara belt. The current mineral resource is 168.3 Mt @ 2.3 g/t 2PGE+Au with 0.1 % Ni and 0.2 % Cu. Most of the resources occur in two contact type PGE - base metal sulphide deposits; the Konttijärvi deposit and the Ahmavaara deposit. These occur at the basal marginal series of the host intrusions. Currently Gold Fields is conducting pilot plant scale flotation and metallurgical tests on 50 t bulk samples from the two deposits.

Field excursion 4.
The Pyhä-Luosto Fell area and the Luosto Amethyst Mine

Peter Johansson
Geological Survey of Finland, Rovaniemi, Finland

The excursion to the Pyhä-Luosto Fell area includes a visit to the Pyhä-Luosto National Park and its Visitor Centre and to the Amethyst Mine at Luosto. The Pyhä - Luosto fell range with surrounding moraine areas and mires form a national park of 142 km^2 in Finnish Lapland. It contains geological monuments and sites with special scientific importance in sedimentology, glacial geology, geomorphology and aesthetic value. It is actually a residual mountain that has resisted millions of years of erosion better than the surrounding rock types. The bedrock itself consists of about 2 billion old quartzite and conglomerate. Some quartz veins contain more unusual colour varieties, including rosy quartz, smoky quartz and amethyst, which is transparent or translucent, violet or purple variety of quartz. On the top of Lampivaara fell there is the only operative amethyst mine in Europe, that welcomes visitors.

Rugged canyons divide the mountain range like huge cuts into several tops. Isokuru, the most remarkable canyon, with a depth of 220 metres is Finland's deepest. Preglacial weakness zones in the bedrock together with weathering and glacial and glaciofluvial erosion during the Quaternary period influenced the formation of canyons. Due to postglacial congelifraction the rocks have broken down, so that the mountain tops and slopes are now covered by block fields. Blocks have rolled down the slopes to the floors of the gorges.

In spite of considerable differences in elevation and blocky terrain, which make it difficult to walk, Pyhä-Luosto is very popular with nature tourists and summer hikers. Various structures have been made to facilitate hiking, such as information boards, cabins, shelters, wooden walkways and steps. In 2010 the national park was visited by 120,000 persons. Metsähallitus, the national forest administration, which also administrates the National Park, has built a Visitor Centre at Pyhä in 1984. Its permanent exhibition "Down by the Sea" is a presentation of the geological history of the area. Changing exhibitions and various events are held there, including geological lectures and guided tours as a tool for environmental education. Special activity programmes for children are also arranged. A new house for the Visitor Centre will be open in 2012.

Johansson, P., Räisänen, J., Räsänen, J., Hirvasniemi, H., Molkoselkä, P., Silén, P. and Valkama, J 2007. Pyhä-Luosto: Geological outdoor map 1:50 000. Rovaniemi, Geological Survey of Finland.

Field excursion 5.
Geochemical and indicator mineral exploration methods and ongoing projects in the glaciated terrains in northern Finland

Pertti Sarala[1], V. Juhani Ojala[1]
[1]Geological Survey of Finland, Rovaniemi, Finland,
[2]Store Norsk Gull As, Rovaniemi, Finland

This field trip provides an introduction to the regional Quaternary geology of the area and stops in several glacial deposit examples, demonstrations of indicator mineral and till geochemical exploration methods. Practical examples are seen in visits to the Kittilä and Sodankylä area and in Karasjok (Norway). In addition, the trip includes visits to the Kittilä gold mine, Petäjäselkä gold occurrence, Mäkäräselkä high-tech metal-Au occurrence, Ravnnaluhppu Cu-Au-occurrence (Karasjok, Norway) and Kevitsa Ni-Cu-PGE-project. Visits to the Inari Sami Museum and the Tankavaara gold prospecting museum are also included.

Finnish Lapland has repeatedly situated in the central part of the Scandinavian glaciations. Glacial deposits indicate several glacial phases of different glaciations with separate till units and variable striae and till fabrics. However, glacial morphology is mainly indicating only the last deglaciation phase when the ice divide zone situated in the Central Lapland area crossing it with west-east orientation. Glacier margin was divided into ice-lobes having variable flow directions seen on the orientation of active-ice moraine morphology and esker chains. The Central Lapland area was mainly on supra-aquatic position during deglaciation although large, time-transgressively developed ice-lakes were common. In places, up to tens of metres thick pre-Quaternary weathered bedrock surface exists and is a remark of several hundreds of million years weathering crust. Typically the weathering crust only couple of metres thick and consists of the saprock part of the weathering profile.

Kittilä Au Mine is the largest producing gold mine in western Europe. The mine was opened in 2008 and and the current resource is 56.3 Mt averaging 3.88 g/t gold (6.8 Moz/219 t Au). The deposit is a Palaeoproterozoic orogenic gold deposit and it is open at the depth of 1.4 km and along strike. The deposit is hosted by the subvertical, compressional, a 4-km long section of Suurikuusikko shear zone. The gold is refractory: 71 % of gold in the lattice of, and as tiny inclusions in, arsenopyrite and 22 % in pyrite.

Use of surficial geology and different till geochemical sampling, and indicator mineral field concentration methods is demonstrated in several exploration targets. The Petäjäselkä gold occurrence (best intersections 3 m @ 28.2 g/t Au, 1.05 m @ 12.6 g/t Au) in the Central Lapland Greenstone Belt having strongly folded and faulted cherty and carbonate and sericite altered mafic metavolcanic rocks. The Mäkäräselkä high-tech metal - Au occurrence in Vuotso is consisting mineralized hematite and magnetite veins hosted by Archaean granitoid gneiss; the veins are controlled by tensional fractures of a NW-trending major shear zone. Although the target is highly potential for high-tech metal mineralization, the best section relates to gold (3 m @ 2.2 ppm Au). The Ravnnaluhppu Cu-Au-occurrence (Karasjok, Norway) is located in the Karasjok Greenstone Belt which is the northern part of the Lapland Greenstone Belt. The mineralization (best intersections 1 m @ 1.7 g/t Au, 9 m @ 0.5 % Cu including 1 m @ 1 % Cu) is hosted by a sequence of folded and faulted mafic metavolcanic rocks, felsic and black schists.

Kevitsa Ni-Cu-PGE Mine is under construction and it has an estimated measured and indicated resource of 275 million tonnes grading 0.3% Ni, 0.4% Cu 0.11 g/t Au, 0.2 g/t Pt and 0.15 g/t Pt. The deposit is hosted by the Kevitsa ultramafic intrusion dated at 2.01 Ga with U-Pb in zircon. The size of the intrusion is about 4 x 5 km and the disseminated sulphide ore zone is located in the upper part of the ultramafic zone, in the NE part of the intrusion.

Field excursion 6.
IOCG and Porphyry-Cu deposits in northern Finland and Sweden

Tero Niiranen
Geological Survey of Finland, Rovaniemi, Finland

Excursion route: Rovaniemi-Kolari-Pajala-Gällivare-Rovaniemi

The field excursion visits the iron and iron-copper-gold deposits in Kolari-Pajala area currently under development by Northland Resources S.A. and the Aitik Cu-Ag-Au mine in Gällivare operated by New Boliden Ab.

At Kolari we will visit the Hannukainen Fe-Cu-Au deposit which was operated by Rautaruukki Oyj and subsequently by Outokumpu Oyj between 1981 and 1990 total production being about 4.5 Mt @ 43 % Fe, 0.48 % Cu, and 0.29 g/t Au. Northland Resources has been developing the Hannukainen deposit since 2005 and the current resource estimate for the Hannukainen is 110 Mt @ 33.9 % Fe and 0.17 % Cu (measured + indicated, 15 % Fe, cut off) with additional 88 Mt inferred resources. The Hannukainen deposit is controlled by a thrust zone which is part of the crustal-scale Kolari-Pajala shear zone system. The ore is hosted by altered varieties of 1.86 Ga diorite intrusion and 2.2-2.05 Ga mafic volcanic rocks. The deposit has been suggested to belong to IOCG class.

At Pajala the excursion visits two iron deposits, the Sahavaara and Tapuli. Both deposits are skarn-hosted magnetite deposits. The resource estimate for the Tapuli is 101 Mt @ 26.9 % Fe (measured & indicated). For the Sahavaara, the current resource estimate is 64.9 Mt @ 42.5 % Fe (measured & indicated) with additional 34.7 Mt in inferred category. Both the Tapuli and Sahavaara deposits are hosted by 2.4-1.98 Ga sedimentary sequence of dolomitic marbles, phyllites, and graphitic schists.

At Gällivare, we will visit the Aitik Cu-Ag-Au mine which is one of Europe's largest copper producer. Mining at Aitik started at 1968 and since then about 500 Mt of ore has been mined from a open pit operation. The total ore reserves in 2009 were 747 Mt grading 0.25 % Cu, 1.7 g/t Ag, and 0.14 g/t Au. In 2010 the ore production was 27.6 Mt. The Aitik deposit is hosted by gneissic varieties of regionally wide spread calc-alkaline Haparanda Suite intrusives and co-magmatic volcanic rocks. The geological features for the Aitik deposit suggest that it is a metamorphosed porphyry-copper deposit.

Field excursion 7. Geochemistry in Khibiny mountains and Monchegorsk, Kola Peninsula, Russia

Yuri Voytekhovsky[1], Jouni Pihlaja[1]
[1]Russian Academy of Sciences, Kola Science Centre, Geological Institute, Apatity, Russia, [2]Geological Survey of Finland, Rovaniemi, Finland

This excursion starts with a workshop in the Geological Institute KSC RAS, in Apatity including presentations on the petrology and geochemistry of the Khibiny alkaline massif and isotope geochemistry and geochronology of the Kola Peninsula focusing on the Monchegorsk intrusions. During a couple of next days there are visits to geologically spectacular ore fields of the Khibiny and Monchegorsk. Different types of mine activity relating to apatite and Cu-Ni with PGE deposits with the environmental issues are to be seen during the excursion.

The Khibiny massif situates in the central part of the Kola Peninsula, 66°33'-67°55'N, 33°13'-37°16'E. It is a dome-shaped mountain massif with the highest point of 1200 m above the sea level. The massif is intersected by deep canyons and wide river valleys. Some of the mountains are cupped with extensive plateaus, and encircled with cirques and steep slopes. Topographic features bear evidence of glacial activity; moraine ridges are present in the river valleys. The Khibiny pluton is located in the contact of the Archaean gneisses and Proterozoic Pechenga-Imandra-Varzuga palaeoriftogenic volcanic-sedimentary complexes, which form the Lapland-Kola-Belomorian collisional structure. The Khibiny massif is a concentrically zoned multiphase intrusion composed of agpaitic nepheline syenites, and in minor amount of ultrabasic alkaline rocks. On the eastern slope of Mt. Takhtarvumchorr albitites are widespread.

The Monchegorsk pluton belongs to the Kola Province of PGE-bearing layered intrusions. The U-Pb age of the pluton is 2509-2487 Ma. It occurs in gneisses of the Kola-Belomorian complex and diorites with the age of 2932-2630 Ma. The horseshoe-shaped exposed area of the Monchepluton rocks is more than 60 km^2. The general structure is affected by the south-east part of the pluton, the Vurechuaivench Foothills, lying monoclinally and joining through the bottom fold with the trough-like branch near the Nyud and Poaz. It gently dips south-eastwards under the supracrustal complex of the Imandra-Varzuga zone. The rocks of Fm. Purnacha lie on the weathered surface of the Vurechuaivench gabbronorites, and its basal conglomerates contain gabbronorite pebbles.

The lowest zone of the pluton is in its SW part within the contact with the Monchetundra massif. The western part of the pluton consists mainly of bronsitites and harzburgites, while the eastern part includes plagioclase-bearing rocks generally represented by mesocratic norites and gabbronorites. The rocks of the pluton show insignificant cryptic layering. The layered rocks of the pluton are cut by numerous gabbro-pegmatite veins, gabbronorite dykes, later dolerites and lamprophyres. There are about 36 ore deposits and occurrences of Cu-Ni, PGE-bearing and chromite mineralization in Monchegorsk region. 21 of them are confined to the rocks of the Monchegorsk pluton.

Extracting Cu, Ni, Co and PGE from sulphide ores cause harm to the environment. Every ore producer faces this problem. Russia is no exception and the towns Nikel, Zapolyarny and Monchegorsk ecology testifies to the fact. Several years ago JSC "Severonikel" started investing in the recultivation of soils about Mts. Nittis, Kumuzhiya and Travyanaya. The Greenpeace-friendly organizations of the Kola Peninsula become all the more active. The administration of the region has been financially maintaining the ecological tourism.

Author Index

The organizers wish to thank warmly the following organizations that have supported and sponsored the IAGS 2011 organization.

AGNICO-EAGLE
NEWMONT
SGS

ALS Minerals
LABTIUM
Kevitsa Mining
A subsidiary of First Quantum Minerals Ltd
Store Norske
Pyhäsalmi Mine Oy
AcmeLabs™

BOLIDEN
National Research FLAGSHIPS
Minerals Down Under
CSIRO
MAWSON

Rovaniemi
FEDERATION OF FINNISH LEARNED SOCIETIES

ISBN 978-952-9618-63-7 (printed)
ISBN 978-952-9618-64-4 (CD)
ISBN 978-952-9618-65-1 (PDF)
ISSN 0783-1331