



Special thanks to Patrick Highsmith for assembling focus topics for this issue, Soil Gas Chemistry

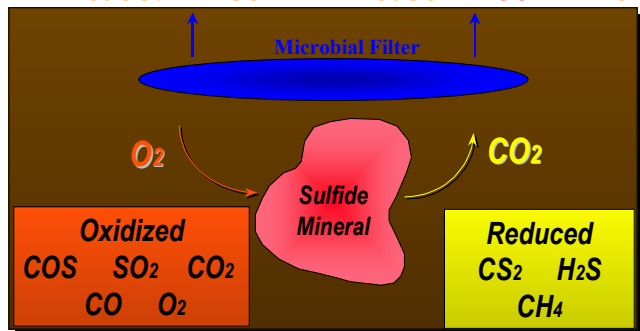
Overview of Soil Gas Theory

Patrick Highsmith
ALS Chemex Labs
Email: Patrick.Highsmith@alschemex.com

Mineral exploration is being irreversibly forced into covered terranes. After all, we have been hearing for several years that “all the easy ones have been found”. While this is arguably a platitude, or even an excuse for some, it is largely true. At the very least, we are all working in more mature areas, often where the prospective rocks are not exposed. As commodity prices surge, hopefully dragging exploration budgets along for the ride, exploration is returning to areas of deep overburden and explorers seem more willing to invest in new technologies to probe these depths.

Soil gases remain a tantalizing sample medium for mineral exploration in covered terrane - at least for some of us. Dating back to the mid-1950's in the Soviet Union, explorers have considered the gaseous products of sulfide oxidation as a target sample medium. Western geologists and geochemists made serious forays into soil gas geochemistry for mineral exploration as evidenced by three important PhD dissertations on the subject (Lovell, 1979; Oakes, 1984; and Jaacks, 1984). During the 1980's, significant advances in the practical application of the technology followed, but much of this was veiled in company secrecy. Klusman (1993) authored the definitive text on the subject, incorporating summaries of past work and numerous case studies from different sample media in many applications.

Soil Gas Geochemistry Operating Principle



Modified after Jaacks, 1993

Figure 1 - Simplified Model for Soil Gas Genesis

continued on page 12

Newsletter for the Association of Exploration Geochemists

Geochemical Evaluation of Mining Environmental Assessment

Rob Bowell
SRK Consulting — rbowell@srk.co.uk

The Association of Exploration Geochemists is currently in a state of change with an acceptance of a growing membership in fields related to exploration geochemistry, principally analytical and environmental geochemistry. The former will be reviewed in a future explore but in this article the assessment of environmental impact from mining projects is reviewed and a case made for the importance of geochemical skills possessed by exploration geochemists.

Far from environmental geochemistry being unrelated to exploration geochemistry, it is argued that, at least in



Figure 2: Acid Pond at the base of a waste rock dump, Bisbee, Arizona.

continued on page 2



AEG Presidential Address

David Kelley

Happy New Year to you all. It was great to see many of you at the IGES this past Fall in Dublin, Ireland. I thought the meeting was excellent in its organization thanks to Gerry Stanley and his Local Organizing Committee. The meeting was also a great success due to the scientific content, workshops, field excursions and social events. After my attempt at Irish dancing I thought I was a natural, but someone mentioned to me that everyone feels that way when the dancing is preceded by whiskey tasting. I do not have the moves that Eion Cameron displayed in Santiago but I'm working on it. It was also a privilege to witness Gerry Govett receive the prestigious Honorary Member Award. This is the sixth such award given in our association. Congratulations, Gerry.

continued on page 8



Quality Analysis...
Innovative Technologies

PGE & GOLD

**New Unique
Techniques
for Discovery**
in ...
Water
Rock
Soil
Sediment
Humus
Vegetation

actlabs.com **ASK US**

Activation Laboratories Ltd.
1336 Sandhill Drive Ancaster, Ontario L9G 4V5
Phone: 1.905.648.9611
Fax: 1.905.648.9613
E-mail: hoffman@actlabs.com

Paid Advertisement

Geochemical Evaluation of Mining...

continued from Page 1

.....

respect of mining environmental assessment, it has essentially the same goal (if for different purposes): that of determining anomalous concentrations of chemical elements in natural materials (e.g. Figure 1). In addition, an important objective is to identify the pathways, mechanisms and controls on the processes that facilitate this element transfer.

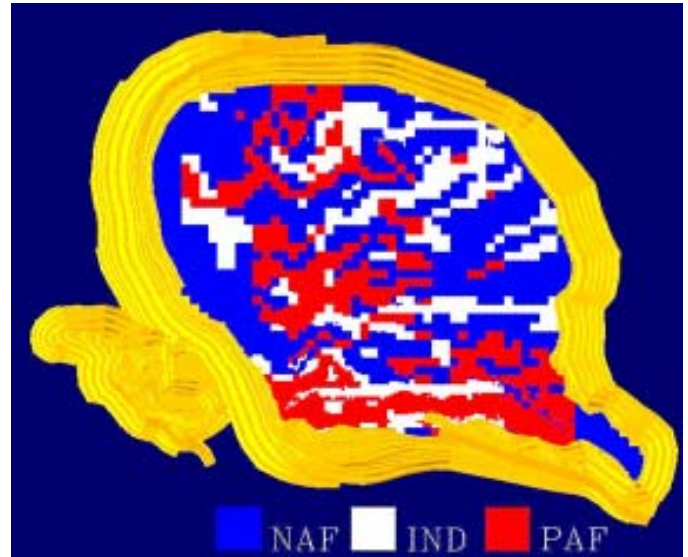


Figure 1: Geochemical mapping showing distribution of acid generating (PAF), neutralizing (NAF) and indifferent or unable to establish behaviour (IND) rock types in a pit. Gold deposit in Tanzania.

Continued on Page 3

Geosoft Inc. www.geosoft.com Africa. Australia. Europe. Latin America. North America.



GEOSOFT

Essential Software for Exploration

Oasis montaj

Target for ArcGIS

acquire

Geosoft software solutions support exploration companies from initial target identification through to resource development.

Rapidly view and analyze all your exploration data in **Oasis montaj**, Geosoft's powerful mapping and processing software for large volume geophysical, geochemical and geological data.

Simplify your surface and drillhole mapping within your GIS environment with **Target for ArcGIS**.

Manage your data and streamline reporting with **Exploration Essentials**, one affordable solution for exploration that combines Metech's acQuire data management system with Geosoft's Target mapping and Chimera geochemical analysis software.

Preview the new Oasis montaj 6.0 and demo Target for ArcGIS at PDAC 2004!



For more information contact Geosoft at sales@geosoft.com. Visit us at www.geosoft.com.

Paid Advertisement

Geochemical Evaluation of Mining...

continued from Page 2

.....

An essential component in the evaluation of a mineral deposit or a mine development project is the consideration of environmental impact, particularly the leaching of deleterious elements such as arsenic and many of the transition metals or of Acid Rock Drainage (ARD) generation. A major part of this assessment is the potential for the materials within the mineral deposit to degrade land or water. With metal and coal mining, the principal concerns are for metal leaching and generation of acid mine drainage.

Metal leaching and generation of acidic drainage from a mineral deposit is a naturally occurring process (Nordstrom, 1982). This can cause a negative impact on the receiving environment (Figure 2 - page 1). The cost of treating problematic elements such as metals or of treating ARD can be high. But, if the major source(s) can be identified, then selective treatment may be more effective than the treatment of a much larger quantity of non-problematic material with which it is arbitrarily classified.

Typically the approach taken historically was to wait until an impact occurred and then design remediation (engineering task, Figure 3). Often this was costly and inappropriate technology was applied so environmental impact were not completely mitigated. A more recent approach has been to acquire estimates of reactivity from laboratory testwork and use this as input components to

predictive modeling. Whilst this approach is effective in gaining predictions, very often the predictions do not match reality and unnecessary costs are incurred by the project both in the prediction and then based on this through any work undertaken or regulatory bond applied. Rarely is the third segment of the process (Figure 3) applied, which is to provide a detailed environmental geologic assessment at an early stage in the mineral property development.

The processes that govern generation of acidic leachate and mobilisation of metals (grouped collectively as Acid Rock Drainage or ARD in this paper) can be characterized and classed (SRK, 1989; Nordstrom and Alpers, 1999a). Equally, despite individual peculiarities, mineral deposits can also be classified according to mineralogic and geologic characteristics. Logically it follows that ARD characteristics can also be classed according to geologic rock type (Ficklin et al., 1992; Plumlee, 1994; du Bray, 1995; Howell et al., 2000). In terms of water parameters, different metal mineral deposits can be observed to show striking differences in terms of metal (Figure 4) and anion (Figure 5) chemistry.

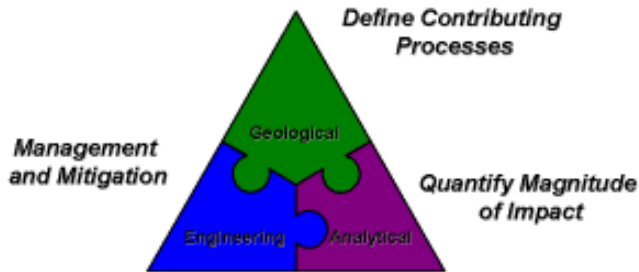


Figure 3: Three-phase approach in evaluating ARD

TABLE OF CONTENTS

Focus On: Overview of Soil Gas Theory.....	1
Soil Gas Carbon Dioxide and Oxygen for Mineral Exploration	14
Thermally Speciated Mercury in Mineral Exploration	16
Kimberlite Exploration Integrating SGH SM Geochemistry	20
New Soil-Gas Chemistry Technique Effective Under Transport Cover	24
Message from the President	1
Geochemical Evaluation of Mining Environmental Assessment.....	1
Reader's Forum.....	9
Call for Papers	25
Calendar of Events	26
AEG Application for Membership.....	28
AEG Short Courses	31

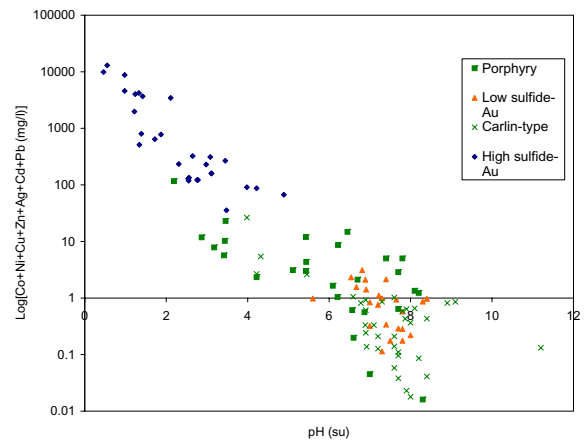


Figure 4: Flicklin diagram for different metal mines

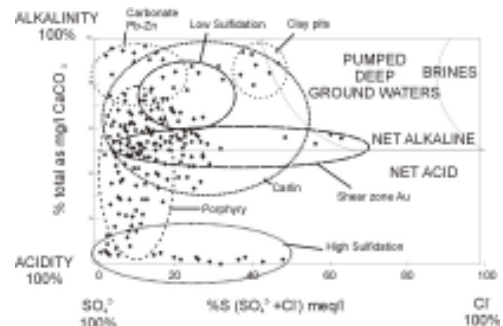


Figure 5: Younger diagram for different metal mines

The geology of a mineral deposit exerts a fundamental control on interaction with the environment. Other important controls such as geochemical and biologically mediated processes, hydrogeology, hydrology, climate, topography, mining and mineral processing methods generally modify the environmental effects inferred by the geology.

In the assessment of the acid generating potential of rock or ore types, two key factors need to be determined:

- The presence of acid generating phases
- The presence of acid consuming phases

Geochemical Evaluation of Mining...

continued from Page 3

Acid Generation

Primary acid generating minerals are sulfides of the type, MS_2 , the most common being FeS_2 . The mechanisms of sulfide oxidation involve the transfer of electrons and for most sulfides essentially involve electrochemical “corrosion” (Thornber, 1983, 1992). Sulfides are “geo-batteries” with the emphasis on “self-corrosion” by sulfide ores. These electrochemical reactions are a combination of a *reduction* reaction at a cathode, on the more noble phase and an *oxidation* reaction at the anode on the more reactive phase.

Additionally hydrogen ions are released in the process of metal hydrolysis and this is most pronounced when the cation is iron due to the further oxidation of Fe^{2+} to Fe^{3+} and hydrolysis to form $Fe(OH)_3$ (Table 1). It should be noted that not all sulfides on oxidation generate acidity (Thornber, 1992). Indeed sulfides of the type M_2S such as chalcocite actually consume H^+ on oxidation.

The rate of sulfide oxidation can be controlled by the



Figure 6: Extensive oxidation of a Kuroko style massive sulfide deposit, Parys Mountain, Wales

rate at which oxygen is supplied and reduced at the cathode-solution interface. The separation of the cathodic oxygen-consuming, alkali-producing reaction from the anodic, oxidizing, acid-producing reaction will have a major control on the mineralogy of the resulting assemblage. The greater the distance between cathode and anode; The more extensive the conducting area; and consequently the greater the potential for sulfide oxidation.

Massive sulfide ores and sulfide-rich zones, such as those in high sulfidation epithermal systems are generally good conductors, and hence reflect significant weathering (Figure 6). The exception is with massive sphalerite, which is an insulator (Thornber, 1992). Where sulfides are more dispersed, such as in some gold-quartz vein ores, distance between oxidizing sulfides is greater and conduction is reduced so the extent of oxidation is not so great. Each sulfide grain weathers as an isolated cell and the only influence that one sulfide grain can have on another is via aqueous solution. Access by dissolved oxygen will determine leaching and sulfide composition will influence pH, water chemistry, reaction rate, and secondary mineralogy. Generally, leaching is greatest near the surface.

On weathering, sulfides can release all acid potential



Figure 7: Melanterite stalactites developed in an exploration adit, Pascua-Lama project, Chile-Argentina

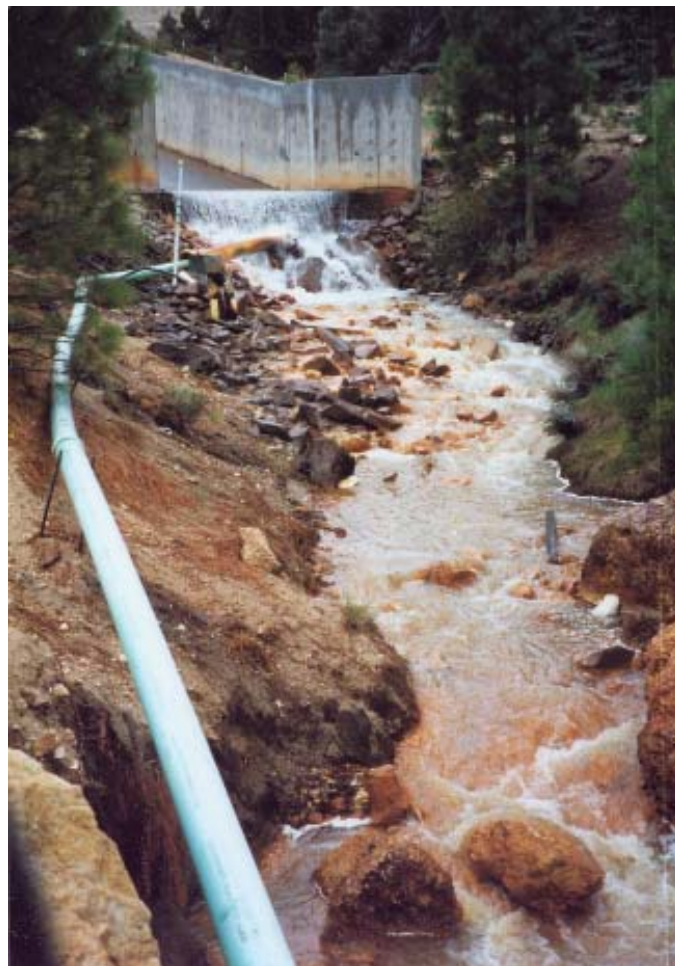


Figure 8: Impact of site ARD impacting fresh storm water, Leviathan mine, California

continued on page 5

Geochemical Evaluation of Mining...

continued from Page 4

producing a range of hydroxides and oxides such as goethite. Alternatively they can release only a portion of the total acidity and store some acidity in secondary salts that are stable only in oxidizing acidic pH environments, such as melanterite, FeSO₄·7H₂O (Figure 7). These minerals are highly soluble so can represent an instantaneous source of acidic sulfate-rich water upon dissolution and hydrolysis

Subsequent oxidation of ferrous iron and hydrolysis of ferric iron at pH > 2 provides an additional source of acidity. Hence these minerals are important as both sinks and sources of acidity, sulfate and possibly metal ions on precipitation and rapid release on exposure to moisture (Cravotta, 1994).

Buffering of acid capacity

Acid-neutralization reactions result from mineral buffering of H⁺ in drainage. This buffering is frequently accompanied by the precipitation of secondary minerals (Lawrence and Wang, 1997). These reactions can reduce acid generation by forming an inhibitory surface coating on the reactive sulfides. Under acidic conditions, carbonate minerals (e.g, calcite, dolomite and magnesite) readily dissolve and provide bicarbonate alkalinity which results in neutralization of acid and precipitation of metal hydroxides. The major buffering mineral groups and characteristics with respect to ARD are shown in Table 2.

The order of carbonate neutralizing capacity is calcite>dolomite>ankerite>siderite. In the case of siderite and to a lesser extent ankerite the reason for the limited neutralizing capacity is that ferrous iron in these minerals are an additional source of acidity due to the strong hydrolysis of ferrous iron in solution. This order of reactivity is partly controlled by equilibrium mass-action constraints and partly by kinetic limitations (Morse, 1983). Carbonate minerals (especially calcite) have often erroneously been

thought of as the only geologic source of Neutralization Potential (NP). However, carbonates dominate only limestone, dolomite and marble rock types whilst the majority of geologic materials are composed of silicates and hydroxide-oxide minerals.

Silicate weathering as a proton sink has been

Table 1: Oxidation reactions of Iron sulfide and sulfate minerals generating acidity <i>(from Bowell et al., 2000 based on compilations by Kleinman and Pacelli, 1991; Thornber, 1992)</i>	
<i>Reaction 1</i>	
a)	FeS ₂ + 7/2O ₂ + H ₂ O = Fe ²⁺ + 2SO ₄ ²⁻ + 2H ⁺
b)	2FeS ₂ + 7O ₂ + 2H ₂ O = 2FeSO ₄ + 2H ₂ SO ₄
<i>Reaction 2</i>	
a)	Fe ²⁺ + H ₂ O + O ₂ = Fe(OH) ₃ + 2H ⁺
b)	2FeSO ₄ + H ₂ SO ₄ + 1/2O ₂ = Fe ₂ (SO ₄) ₃ + H ₂ O
<i>Reaction 3</i>	
	Fe ²⁺ + •O ₂ + H ⁺ = Fe ³⁺ + •H ₂ O
<i>Reaction 4</i>	
	FeS ₂ + 14Fe ³⁺ + 8H ₂ O = 15Fe ²⁺ + 2SO ₄ ²⁻ + 16H ⁺
<i>Stage 1</i>	
Reaction 1: proceeds abiotically and by bacterial oxidation (reaction b more common with bacterial oxidation)	
Reaction 2: proceeds abiotically, slows as pH falls (reaction b more common with bacterial oxidation)	
pH approximately 4.5 or higher, high sulphate, low Fe, low pH.	
<i>Stage 2</i>	
Reaction 1: proceeds abiotically and by bacterial oxidation (reaction b more common with bacterial oxidation)	
Reaction 2: proceeds at rate determined primarily by activity of bacteria such as <i>T.ferrooxidans</i>	
pH approximately 2.5-4.5, high sulphate, Fe and low pH. Low Fe ³⁺ /Fe ²⁺ ratio.	
<i>Stage 3</i>	
Reaction 3: proceeds at rate determined by activity of <i>T.ferrooxidans</i>	
Reaction 4: proceeds at rate determined by rate of reaction 3	
pH generally below 2.5, high sulphate, total Fe and low pH. High Fe ³⁺ /Fe ²⁺ ratio.	

continued on page 6

Table 2. Grouping of minerals according to their neutralization potential <i>(from Bowell et al., 2000 based on compilations by SRK, 1989; Sverdrup, 1990).</i>				
Group Name	Typical minerals	Buffering pH range ¹ (su)	Approx. NP ² range	Relative reactivity ³
1. Dissolving	Calcite, aragonite, dolomite, magnesite, aragonite, portlandite and brucite	6-11.2	7.8-14.8	1.0
2. Fast weathering	Anorthite, nepheline, olivine, garnet, jadeite, leucite, spodumene, kutnahorite diopside, siderite and wollastonite	5.5-11	2.8-6.2	0.6
3. Intermediate weathering	Epidote, zoisite, enstatite, hyperthene, augite, hedenbergite, hornblende, glaucophane, tremolite, actinolite, anthophyllite, serpentine, chrysotile, talc, chlorite, biotite.	4.8-7.3	1.7-5.8	0.4
4. Slow weathering	Albite, oligoclase, labradorite, vermiculite, montmorillonite, manganite, goethite, gibbsite and kaolinite.	2.4-5.1	0.5-2.9	0.02
5. Very slow weathering	K-feldspar, ferrihydrite and muscovite	2.2-4.1	0.2-0.6	0.01
6. Inert	Quartz, hematite, rutile and zircon	3.3-3.5	<0.01	0.004

¹ buffering pH range evaluated by crushing 5g of pure mineral and mixing with 5ml of distilled water and left to react for 30 minutes. The pH of the distilled water was 3.4 su

² NP range assessed as equivalent buffering potential of 10 g of pure mineral to calcite and titrated with hydrochloric acid. So for example, 10g of portlandite (Ca(OH)₂) was found to have the equivalent capacity to neutralise HCl acid as 14.8g of calcite. Whereas 10g of hornblende was required to buffer HCl acid to a similar pH to only 3.1g of calcite.

³ Calculated from Sverdrup's equation (1990), see below and based on 100% mono-mineral sample

Geochemical Evaluation of Mining...

continued from Page 5

demonstrated in previous studies (Sverdrup, 1990; Bhatti et al, 1994; Moss and Edmunds, 1992). To assess the buffering capacity of mine wastes, silicate and hydroxide minerals therefore must also be considered. From soil acidification studies, Sverdrup (1990) divided the most common minerals into six groups according to pH dependency of their dissolution rate (Table 2 - previous page).

From the relative weathering rates the mineral groups show, minerals in groups 4-6 will be poor to negligible neutralizing materials due to their sluggish reaction rates. Even the intermediate and fast weathering groups, are not practical neutralizing materials unless they occur in excess of ~10% (Sverdrup, 1990).

Metal leaching and attenuation processes

The primary leaching processes include sulfide oxidation and associated mineral buffering, both of which increase the total dissolved solid load in the resulting water. The accumulation of solutes in solution will lead to saturation with respect to some species. Consequently in response to either saturation or destabilisation as aqueous species, these compounds precipitate as secondary minerals such as arsenates, phosphates, carbonates, sulfates or hydroxides. Additionally some of these solutes can be attenuated through surface adsorption onto mineral surfaces, noticeably iron hydroxides and clays. Metal release and attenuation processes can generally be thought of as occurring continuously in a mine drainage stream and the net effect is what is measured in an environmental assessment (Figure 8).

The process of element binding at the mineral solution interface and like solubility is pH dependent, for example the adsorption of arsenic species by goethite (Bowell, 1994). Many oxide surfaces change from being positive at low pH (thus attracting anions) to negative at high pH (attracting cations). Mine drainage chemistry and particularly the level of heavy metals has been shown to be influenced by adsorption onto precipitated hydrous ferric oxide, or HFO (this may also include minerals like schwertmannite, goethite and jarosite amongst others; Fuge et al., 1994; Bigham, 1994).

An important control on the diversity of the precipitated mineral assemblage is pH. For example, in the oxidation of sulfides at low pH, Fe oxyhydroxides, scorodite and sulfates are formed while at higher pH other salts such as Ca-arsenates, smithsonite and malachite are precipitated. Clay minerals such as smectite ($\text{Na}_3(\text{Al,Mg})_2\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot n\text{H}_2\text{O}$) may also be responsible for the concentration of base metals in ochres, particularly in low pH HFO promoting cation adsorption at a lower pH than with Fe-oxyhydroxides (Parfitt, 1978). The formation of smectite clays in secondary mineral zones will be controlled by the geology with propylitic alteration zones more likely to produce complex clay minerals than in Carlin type illite alteration zones.

In order to make this assessment, testwork or modelling programs are conducted to predict the magnitude of impact and to assess future changes. Very often this work is carried out late in a development timetable and can lead to

frustrating and costly delays for the developer. However, the prediction of geochemical impacts from a mineral deposit can be qualitatively determined at an early stage in development and used to execute a more efficient impact assessment. Such processes are well known to exploration geochemists

Summary

In this introduction some of the important geologic controls on the environmental impacts associated with metal mineral deposits have been described. The importance of understanding geologic processes that generate and control environmental impacts is proposed here to be fundamental not just in evaluation but also in future prediction and mitigation of the effects of acid generation and metal leaching.

The processes that generate acidity and leach metals are essentially the reaction between rocks and the environment as the rock mineralogy attempts to define equilibrium with prevailing environmental conditions. Consequently an assessment of ARD can gain considerable benefit from a geologist's knowledge of the geochemical behavior of mineral deposits as well as the changes that can be anticipated over the property with respect to structural changes, groundwater flow and mineralogical variations in the lithologies.

At the reconnaissance stage, the main task is the identification of the major acid-generation or acid-neutralising rock units. This can be achieved by examining the mineralogical content of the known rock types, their competency, petrology and extent of weathering. In highly weathered outcrops, secondary minerals can be identified and natural run-off characterized.

Once a mineralized target has been delineated a more valuable assessment can be acquired with information on mineralogical variations, porosity and structural integrity of relevant lithologies. These data are essential in the rapid assessment of acid-generating/neutralizing potential. Petrology of representative core samples will allow the description of the relationship between various sulfide and gangue minerals to be assessed. Examination of exposed sub-outcrop will reveal the nature and extent of oxidation and chemistry of secondary mineral products if not identified elsewhere. A further task is to delineate likely deleterious trace elements. This information is best collected from whole rock geochemistry acquired during exploration activities.

At the feasibility stage, a comprehensive environmental impact statement for permitting purposes is generally prepared with various detailed monitoring programs and specific studies. Any ARD studies can be significantly enhanced by allowing field geologists an opportunity to be involved in the selection of representative material to reflect the broad range of potential environmental interactions anticipated from exposed underground and pit wall lithologies, waste rock and ore stockpiles.

The geo-environmental understanding of mineral deposits is essential in defining remediation objectives. In many situations, natural drainage is poor and it is inappropriate and in a few cases impossible to remediate a

continued on Page 7

Geochemical Evaluation of Mining...

continued from Page 6

.....
 site to "pristine conditions" with water quality required to drinking water standards. However, in many states in the USA and in many national government agencies the natural occurrence of ARD has yet to be accepted. The development of valid geo-environmental models provides a challenge to current regulatory requirements. In the future they may support the setting of more realistic closure objectives that account for local geologic variations.

REFERENCES

- Bhatti, T.M., Bigham, J.M., Vuorinen, A. and Tuovinen, O.H., 1994. Alteration of mica and feldspars associated with the microbiological oxidation of pyrrhotite and pyrite, in: Alpers, C.N. and Blowes, D.W. eds., *Environmental Geochemistry of Sulfide Oxidation*. ACS Symposium, Series 550, p.90-107.
- Bigham, J.M., 1994. Mineralogy of ochre deposits, in: J.L.Jambor and D.W. Blowes, eds., *Environmental Geochemistry of Sulfide Mine Waste*, Mineralogical Association of Canada, p.103-131.
- Bowell, R.J., 1994. Arsenic sorption by Iron oxyhydroxides and oxides: *Applied Geochemistry*, v.9., p.279-286.
- Bowell, R.J., Rees, S.B. and Parshley, J.V. 2000. Geochemical prediction of metal leaching and acid generation: geologic controls and baseline assessment. In: Cluer, J.K., Price, J.G., Struhsacker, E.M., Hardyman, R.F. and Morris, C.L. eds., *Geology and Ore Deposits 2000: The Great Basin and Beyond: Geological Society of Nevada Symposium Proceedings*, Reno/Sparks, May 2000, p.799-823.
- Cravotta, C.A. III, 1994. Secondary iron-sulfate minerals as sources of sulfate and acidity: in: C.N. Alpers and D.W. Blowes, eds, *Environmental Geochemistry of Sulfide Oxidation*. Am.Chem. Soc. Sym. Series 550, p.345-364.
- Du Bray, E.A. ed., 1995. Preliminary compilation of descriptive geoenvironmental mineral deposit models, U.S.Geological Survey Open File Report 95-831.
- Ficklin, W.H., Plumlee, G.S., Smith, K.S., and McHugh, J.B., 1992. Geochemical classification of mine drainage and natural drainage in mineralized areas. *Proc., 7th Water-Rock Conference*, Utah, Balkema, p.381-384.
- Fuge, R., Pearce, F.M., Pearce, N.J.G. and Perkins, W.T., 1994. Acid mine drainage in Wales and influence of ochre precipitation on water chemistry, in: C.N. Alpers and D.W. Blowes, eds, *Environmental Geochemistry of Sulfide Oxidation* Am.Chem. Soc. Sym. Series 550, p.261-274.
- Gray, J.E., Coolbaugh, M.F., Plumlee, G.S., and Atkinson, W.W., 1994, *Environmental Geology of the Summitville, Colorado: Economic Geology*, v.89, p.2006-2014.
- Kleinmann, R.L.P. and Pacelli, R.R., 1991. Biogeochemistry of acid mine drainage: *Mining. Engineering*, v.33, p.300-306.
- Lawrence, R.W. and Wang, Y., 1997. Determination of Neutralization in the prediction of acid rock drainage, in: *Proceedings ICARD'97*, Vancouver, p.451-464.
- McKibben, M.A. and Barnes, H.L., 1986. Oxidation of pyrite in low temperature acidic solutions: Rate laws and surface textures: *Geochimica et Cosmochimica Acta.*, v.50, p.1509-1520.
- Morse, J.W., 1983. The kinetics of calcium carbonate dissolution and precipitation, in: Reeder, R.J., ed., *Reviews*

in *Mineralogy*. Mineralogical Society of America, v.11, p.227-264.

- Moss, P.D. and Edmunds, W.M., 1992. Processes controlling acid attenuation in an unsaturated zone of a Triassic sandstone aquifer (UK), in the absence of carbonate minerals. *Applied Geochemistry*, v.7, p.573-583.
- Nevada Division of Environmental Protection, 1990. *Waste Rock and Overburden Evaluation*. Bureau of Mining Regulation and Reclamation, 3p.
- Nordstrom, D.K., 1982. Aqueous pyrite oxidation and the consequent formation of secondary minerals, in: *Acid Sulfate Weathering*, Soil Science Society of America, Madison, Wisconsin, p. 37-46.
- Nordstrom, D.K. and Alpers, C.N., 1999a. Geochemistry of Acid Mine Waters, in: Plumlee, G.S. and Logsdon, M.J., eds., *The Environmental Geochemistry of Mineral Deposits*. *Reviews in Economic Geology*, v.6A., Soc. Econ.Geol. Inc., Littleton, CO., p.133-160.
- Nordstrom, D.K. and Alpers, C.N., 1999b. Negative pH, efflorescent mineralogy and consequences for environmental restoration at the Iron Mountain Superfund site, California: *Proceedings of the National Academy of Science*, v.96, p.3455-3462.
- Parfitt, R.L., 1978. Chemical properties of variable charge soils, in: Theng, B.K., ed., *Soils with variable charge*, Special Publication of the New Zealand Soil Science Society, p.167-194.
- Plumlee, G., 1994. Environmental Geology models of Mineral Deposits: *SEG Newsletter*, v.16, p.5-6
- Price, W.A., 1997. Draft Guidelines and Recommend Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine sites in British Columbia British Columbia Ministry of Employment and Investment, Energy and Minerals Division, Smithers, BC, April, 143p.
- SRK, 1989, Draft ARD Technical Guide, volume 1. British Columbia AMD Task Force (1985-90).
- Sverdrup, H.U., 1990. The kinetics of base cation release due to chemical weathering. Lund University Press, Lund, 246p.
- Thornber, M.R., 1983. Mineralogical and electrochemical stability of the nickel-iron sulphides pentlandite and violarite: *Journal of Applied Electrochemistry*, v.13, p.253-267.
- Thornber, M.R., 1992. Chemical processes during weathering, in: Butt, C.R.M. and Zeegers, H., eds., *Handbook of Exploration Geochemistry*, vol 4: *Regolith Exploration Geochemistry in Tropical Terrains*, Elsevier, p. 65-99.



Shea Clark Smith

MINERALS EXPLORATION & ENVIRONMENTAL GEOCHEMISTRY

Advanced survey, analytical and interpretational methods for exploration through exotic overburden.

PLANT • SOIL • GAS • ROCK • STANDARDS SPECIALTY SAMPLE PREPARATION

P.O. Box 18325, Reno, Nevada 89511
 Tel: 775-849-2235 • Fax: 775-849-2335
 SheaClarkSmith@compuserve.com

Presidential Address...

continued from Page 1

Looking forward, the Local Organizing Committee headed by Nigel Radford is well on their way to organizing our next IGES in Perth, 2005. This should be another outstanding meeting.

If the recent ballot sent to all voting members is any indication, 2004 will prove to be a year of change and transition for the AEG. The ballot contained three important issues addressing the term of the Presidency, changes to the By-laws, and the name change of the association to the Association of Applied Geochemists (AAG). By the time you read this message, the final decision on these matters will be settled.

At the Annual General Meeting (AGM) held September 1, 2003 in Dublin, Ireland, Graham Taylor proposed that the term of Presidency be extended to 2 years instead of 1. Many expressed the view that it takes nearly a year to understand and act on the issues affecting the association. Graham also reminded us that due to the decreasing number of applied geochemists being trained in universities world-wide, we may someday run short of viable candidates for the position of President. I hope this is never the case, but as someone recently pointed out, the appointment of me as President may be an indication that this is already happening. This was the same someone who commented on my dancing ability.

The ballot also contained a vote on the amended By-laws, making them consistent with the previously approved amendments to the Preamble, and cleaning up several inconsistencies and outdated procedures (like mail-in ballots).

By far the most important issue on the ballot was the final vote on changing the name of the association to the Association of Applied Geochemists. As many of you are aware, debate over the name change has been ongoing since 2001. At the AGM in Dublin, fellows voted overwhelmingly in favor of this name, and Council recently passed a motion to support the decision of the Fellows, making the ballot sent to all Fellows the final say on the matter.

Support for the name AAG primarily centers around the fact that it describes who we are and what we do. As applied geochemists, our mandate is to solve real-world problems using geochemistry regardless of the discipline. For those of you who were at the IGES in Dublin, you witnessed this first hand. Papers presented on secondary dispersion processes through transported overburden have implications for both exploration and environmental disciplines and the talk on a new continuous leach method has the potential to revolutionize the approach to selective extractions and the understanding of true anomalous responses.

Changing our name to AAG allows us to broaden our scope from one that traditionally has dealt with all aspects of applied geochemistry related to mineral resources. How broad this new scope will be is up to us to decide, but conceivably it might include petroleum, forestry, agriculture, land use planning and health, to mention a few. If the final vote is in favour of the name change to AAG, I will be working with the other Officers and Council over the next few months to address the many issues that will result from our name

change and how we can best serve our members. As always, if you have any comments on these matters (and I know that some of you do), please send me your thoughts.

Before closing, I would like to acknowledge and thank Steve Amor for his efforts as President, and also for his active involvement as Chair of the Web Site AND Symposium Committees. We wish Steve the best of luck as he pursues a new career path. I would also like to thank all of the dedicated professionals that make the AEG possible and a worthwhile organization to belong to. Gwendy Hall is doing an outstanding job as Editor-in-Chief of our journal **Geochemistry: Exploration, Environment, Analysis**. Gwendy and Dave Smith continue to provide continuity for the revolving executive posts providing what will hopefully be a smooth transition for Rob Bowell, our new Vice President, and myself. The AEG is also fortunate to have a very capable Business Manager in Betty Arseneault. David Garnett has just ended another term on Council, in which he finalized the By-law revisions and served on several other committees. David Garnett has served the AEG in so many different ways I would have to re-read every edition of **EXPLORE** to list them all. He may be off Council, but he is not off the hook!

The AEG was also well represented this past year by Cliff Stanley, our Distinguished Lecturer, and we look forward to another year of Cliff serving in this role. Many of you have noticed and commented that Mary Doherty has taken **EXPLORE** to a new level through the use of focus topics and by soliciting interesting and useful technical contributions. I couldn't agree more. This made my job as Business Manager of **EXPLORE** even easier because the advertisers have noticed the improvement. Speaking of this, David Seneshen has agreed to become the new Business Manager of **EXPLORE** after a brief transition period. I look forward to seeing Dave's new ideas and approach with **EXPLORE**.

My last comment is a bit of a sales pitch, but we need your input. There are so many ways that you can help the association, like submitting papers to GEEA or technical articles to **EXPLORE**, serving on the various committees listed in the back of this newsletter, becoming a Fellow if you are not a voting member, encouraging a co-worker to join our association, or mentoring a young geoscientist in applied geochemistry. During a time of change, your active participation is needed more than ever.

Sincerely,

David Kelley

WMC Exploration

8008 E. Arapahoe Ct, #110, Englewood, CO 80112 USA

Tel: 720-554-8318 dave.kelley@wmc.com



**Support Your Organization
ADVERTISE
in EXPLORE Magazine**

Readers' Forum



11 January 2004

The Editor, for publication in January 2004 issue of *Explore*

An Open Letter to all Fellows

In the January issue of *Explore* last year a number of Fellows from around the world put their name to a letter to the Editor arguing the case for changing the name of AEG to **Association of Applied Geochemists (AAG)**. Similar letters appeared in subsequent issues of *Explore*. Since then the Fellows at the AGM in Dublin voted overwhelmingly for AAG, and now the Council has voted similarly. We understand that the ballot to vote on the matter will have been despatched by the time that this letter is published.

As so much time has elapsed since the issue of a name change was first raised (we believe early 2001), we would like to take this opportunity to again put the case for change as we see it.

1. We believe that the AEG must broaden its scope and activities to survive as a viable scientific entity. Much discussion has focussed on environmental geochemistry as an add-on to mineral exploration. It is not only environmental geochemists we wish to attract. Geochemistry is, and will become more so, a major tool for all aspects of land use (including groundwater), the fields of human and animal health related to the geochemistry of bedrock and the regolith, as well as the broad field of what is generally understood as environmental geochemistry. All these activities require the involvement and innovation of analytical geochemists and those who specialise in data handling and interpretation. We are sure that there are many other geochemical activities that we have not yet met, or have not yet been developed.

News from Geosoft

Visit Geosoft at the Prospectors and Developers meeting (PDAC), Toronto Canada, March 2004.

We will be at Booth 407-409.

Geosoft's Oasis montaj provides robust gridding tools and an integrated environment for expert visualizing of all your exploration data. New features included in Oasis montaj 6.0 include: eLicensing, a Project Explorer tool, enhanced Metadata and Mapping capabilities, and new Light Table capabilities with transparency settings for both 2D raster images and vector line work. Now available as a stand-alone mapping and processing package, the new montaj 6.0 includes advanced gridding utilities as part of its standard configuration! With Geosoft's GIS exploration software, Target for ArcGIS, you can now visualize your exploration data in ESRI's ArcView. Use Target for quick and easy drillhole plotting and surface mapping in ArcGIS. Geosoft can provide a complete software solution for your exploration data management, mapping and analysis needs.

Contact sales@geosoft.com today to book SolutionTime with a Geosoft data specialist at PDAC.

2. Given (1) above it is not appropriate to simply focus on mineral exploration and environmental geochemistry. It is too restrictive and exclusive.
3. Our conclusion is, therefore, that we should use a name that describes what we are, is discipline neutral, and does not limit us in the future. This name is, in our view, **Association of Applied Geochemists**.

To those of you who have expressed concern at a loss of identity for exploration geochemistry, we suggest that there is a better chance to maintain it as an identifiable discipline as, say, a special interest group within a strong organisation rather than as a single discipline in a withering organisation.

If you believe that we must expand our activities to survive, please make sure that you vote for Association of Applied Geochemists.

David Cohen, Gerry Govett, Ken McQueen, Jim Morrison (AUSTRALIA)

Colin Dunn, Mark Fedikow, Bob Garrett, Chris Gleeson, Eric Grunsky, John Hansuld, David Lentz, Terry Merserau, Ian Nichol, Barry Smee, Art Smith (CANADA)

Reijo Salminen (FINLAND)

Alecos Demetriades (GREECE)

Benedetto De Vivo (ITALY)

Phil Westerhof (NETHERLANDS)

Ian Devereaux (NEW ZEALAND)

Bjorn Bolviken (NORWAY)

Iftikhar A. Malik (PAKISTAN)

Ashlyn Armour-Brown (UK)

Lloyd James, Graham Closs (USA)

A rock solid reputation for absolute accuracy

Since 1982, Becquerel Laboratories has been meeting the analytical requirements of clients in the geological and mineral exploration sector.

Our company is a world leader in Neutron Activation Analysis (NAA). An ultra-sensitive technique, NAA is an ideal quality control procedure to complement and verify results from other analytical techniques. It provides cost-effective, timely analysis and one simple method can analyze over 30 separate elements.

For absolute accuracy, trust the analytical expertise of Becquerel Laboratories.

For more information call 1-877-726-3080 or visit www.becquerellabs.com



*ISO 17025

For Scope of Accreditation No. 422
Pour la portée d'accréditation no. 422

*Accredited to ISO 17025 by the Standards Council of Canada as a testing laboratory for specific tests.

Becquerel
LABORATORIES

6790 Kitimat Road, Unit 4
Mississauga, Ontario
Canada L5N 5L9

absolute accuracy

Readers' Forum...

continued from page 9



Response to Reply. Article "Theory behind the use of soil pH measurements as an inexpensive guide to buried mineralization, with examples" by Barry Smee in **EXPLORE** 118, Jan 2003.

Discussions may be found in **EXPLORE** Issues 120 and 121.

Reply to Barry Smee

Submitted by: Alan Mann

Dissolution and Solubility of Base Metals in pH-Neutral Solutions

A.W. Mann

Much of the recent criticism (Smee, 2003a, 2003b) of Selective Weak Extractions (SWE) in general, and of Mobile Metal Ion (MMI) extractions in particular has been directed at their perceived difficulty in dealing with analysis of base metals in carbonate environments. A great deal of the misunderstanding has arisen because it has been assumed that buffered acidic solutions are required for the extraction and analysis of base metals. It appears to have not been appreciated or acknowledged that it is possible to extract and maintain base metals in weakly buffered and/or near-neutral pH solutions, providing that appropriate complexing ions are present in the solution. It is the purpose of this short article to provide information to hopefully dispel once and for all these misconceptions. It should be pointed out that the main concept involved here is not new – just often

Coming soon in the AEG **EXPLORE** newsletter:

Technical articles and letters to the editor are encouraged as submissions for discussion within the newsletter. Each issue of **EXPLORE** contains a series of short discussion papers which provide either an update on a particular geochemical topic, or present current debates about issues of interest. Suggestions for future "Focus" topics may be forwarded to the editor,

Chris Benn

(Email: Chris.J.Benn@BHPBilliton.com).

Issue: Focus topic and Contact:

123 Update from Universities
Mary Doherty
marydoherty@earthlink.net

Contributor Deadline February 29, 2004

Publication Date: April 2004

124 Update from Geochemical Laboratories

Contributor Deadline May 2004

Publication Date: July 2004

Errata

Correction: Apologies are extended for the name reversal of the following new members

Mr. Heinrich Williams
Southdale Johannesburg
South Africa

and

Dr. Grant B. Douglas
CSIRO Land & Water
Wembley, Australia

forgotten. It is well known that a weak solution of sodium cyanide (0.1g/l) for example will extract and maintain copper in solution (to several ppm at least) despite being unbuffered and having a near-neutral pH. Copper-cyanide complexes alter the solution equilibria. Acidity and buffering capacity are not essential to base metal solubility.

The low solubility of base metals in water at pH values between pH=5.5 and pH=8.5 has long been recognized. In a theoretical study of the effect of complexing ions on the solubilities of base metals, Mann and Deutscher (1977 and 1980) showed that even in the presence of moderate amounts of the common anions, chloride, sulphate and carbonate, the solubility of Cu, Pb and Zn decreases by several orders of magnitude with increasing pH, to a minimum (of less than 100ppb) between pH 6.5 and 7. In the presence of strong complexing agents however, this situation does not pertain, and solutions with greater than the minimum solubility can be maintained at relatively constant values with increasing pH, as shown in Figure 1.

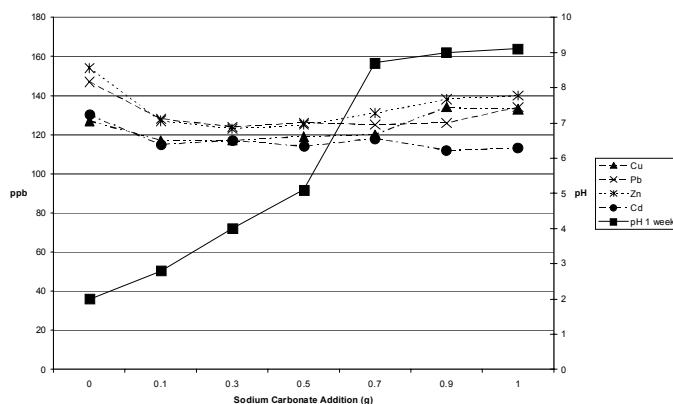


Figure 1. Concentrations of base metals in an MMI-A solution over the pH range 2 to 9.

In this experiment various additions of sodium carbonate were used to increase the pH of the MMI-A solution initially with a pH near 2, and containing in excess of 100ppb of Cu, Pb, Zn and Cd to a pH value near 9. It is clear that even in the presence of a known precipitating anion for base metals (carbonate), the solution concentrations are relatively unaffected by the pH change. The MMI-A extractant does not contain cyanide, but a number of

Readers' Forum...

continued from page 10



complexing agents to ensure the dissolution and solubility of Cu, Pb, Zn and Cd over a wide pH range. In this case the sample concentrations and pH were measured after a one week equilibration period.

Were the pH change in such a solution to be carried out by the addition of pure calcium carbonate however, adsorption of base metals would occur, and the solution concentration of base metals would fall. Only in the situation where the adsorption capacity of any solid carbonate present is exceeded and complexing ions are present, are appreciable concentrations of base metals seen in carbonate dominated soils, at neutral pH values. Such situations have been observed in the carbonate dominated base-metal rich soil profiles around Zacatecus in Mexico. Figure 2 shows the results of MMI-A extractions of soils across one such zone.

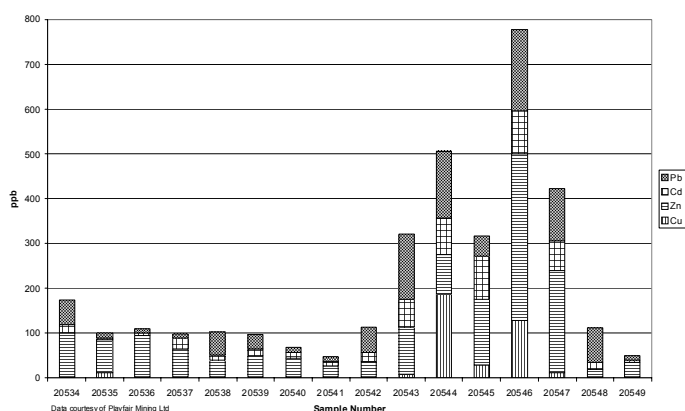


Figure 2. Base metal concentrations in MMI-A extractions of soils across a zone of mineralization, Zacatecus, Mexico.

Despite the presence of carbonate in all samples, over 100ppb of Cu, Pb, Zn and Cd has been extracted and maintained in solution in samples by the MMI-A extractant, identifying a mineralized zone beneath the carbonated soil (samples 20543-20547). At this location the dispersion of base metals from source has ensured the carbonate contains very high concentrations of base metals (verified by total digestion and analysis) and the adsorption capacity of the carbonate is well and truly exceeded. It is common in carbonate environments for soil samples away from mineralization sources, or beneath massive carbonate layers, to record very low base metal values, due to the very effective (natural) adsorption of base metals by carbonate. These very low values for “mobile” base metals commonly observed in carbonate environments are often attributed solely to “analytical problems”.

More recently, a multi-element extractant MMI-M, containing a number of complexing ligands and designed to operate at near neutral pH, has been developed. Over twenty five elements including precious and base metals, can be extracted from soils and analyzed using this leachant. Comparison of the results for the extraction of base metals in MMI-M, with those obtained previously using MMI-A,

are very similar. The results for Cu from a base-metals prospect in Western Australia are shown in Figure 3.

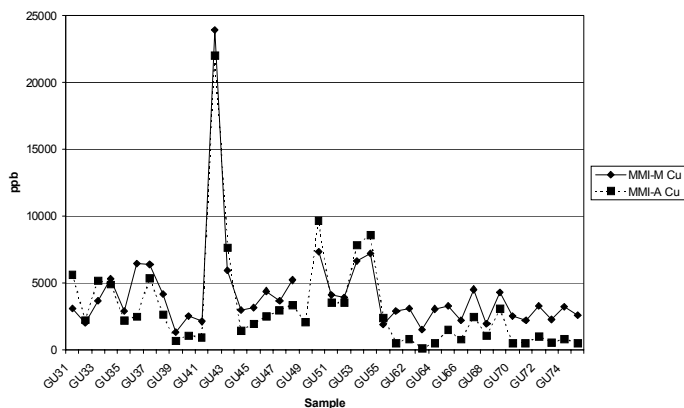


Figure 3. Results for Cu extraction from soils from the Gutha prospect, Western Australia with MMI-M (at pH>7) compared to those using MMI-A (at pH=2).

These samples are not carbonate-rich i.e. the extractions with MMI-A were conducted at a pH close to 2. The pH of solutions after the MMI-M extraction were between pH=7 and pH=7.5. The results are very similar, despite the fact that one extraction is done at an acid pH, and one at near neutral pH. One is buffered to a greater extent than the other. The extractants have some complexes in common and exhibit a similar ability to extract and maintain Cu, up to concentrations in excess of 20ppm. The presence of complexing agents is clearly of greater importance to the extraction procedure than is the pH or buffering capacity. (Whilst there is very good correlation between the data from the two extractions ($R^2=0.87$) it should be pointed out that raw data from the two sets is distinct, different, and should not be used interchangeably or amalgamated without statistical treatment).

References

- Mann, A.W., and Deutscher, R.L., 1977. Solution geochemistry of copper in water containing carbonate, sulphate and chloride ions. *Chem. Geol.*, 19, 253-265.
- Mann, A.W., and Deutscher, R.L., 1980. Solution geochemistry of lead and zinc in water containing carbonate, sulphate and chloride ions. *Chem. Geol.*, 29, 293-311.
- Smee, B.L., 2003a. Theory behind the use of soil pH measurements as an inexpensive guide to buried mineralization, with examples. *Explore*, 118.
- Smee, B.L., 2003b. Reply to A.W. Mann, *Explore*, 121.



Alan Coope Fund

Contribution:
Newmont Mining \$10,000.

Focus on: Overview of Soil Gas Theory...

continued from page 1



At its most basic level, soil gas geochemistry is attractive for exploring beneath overburden because of the very high mobility of gases. It is easy to imagine gases moving rapidly upward through overburden. If the gases reaching the surface includes a signature of buried mineral deposits, their utility as a prospecting tool is obvious.

The concept of gas generation and migration is actually a complex interplay among many elements, gaseous compounds, and environmental variables. Consider a long list of gases that may be involved and have been addressed, at least superficially in the literature:

- Simple, abundant, inorganic gases (O_2 , CO_2 , N_2)
- Sulfur gases related to sulfide mineralization (H_2S , COS , CS_2 , etc.)
- Volatile metals and semi-metallic hydrides (AsH_3 , SbH_3 , Hg , etc.)
- Light and heavy hydrocarbons (C2 – C17)
- Radiogenic daughter gases (He, Rn)

The Model and Processes at Work

Figure 1 (see front page) is a simplified model illustrating the involvement of oxygen and carbon dioxide in the oxidation of sulfide minerals. A simple sulfide mineral, pyrite, is shown to be oxidizing in the presence of water. Through a series of reactions, oxygen is consumed and iron oxide and acidity are the reaction products. The resulting acid reacts with any available carbonate in the wallrocks generating carbon dioxide. Taylor et al (1982) demonstrated experimentally that a number of the sulfur gases cited on the diagram are generated during this oxidation process. Attempting to incorporate the microbiological variable in these reactions, the blue oval is meant to suggest a degree of catalysis or facilitation by microorganisms, which is likely not yet fully understood.

Many of the soil gas references in the literature cite some variant of this primary oxidation process as the most likely source of the gaseous target agents. There are a few problems with this process being accountable for gases that are measured at the surface. Not the least of these problems is the water table. If the mineral deposit is below the water table, as it is in a number of the case studies cited below, there may not be adequate available oxygen to drive sulfide oxidation. Even if there is adequate oxygen, many of these compounds would be dissolved into the groundwater, having insufficient vapor pressure to elute as bubbles and rise by buoyancy through the water table.

Furthermore, many of the gases listed above are reduced compounds, highly unstable in the presence of oxygen (H_2S , heavy hydrocarbons, and the hydrides). This means that they would not survive long enough to reach the surface, even if generated at a point of oxidation well above the water table (Taylor et al, 1982).

The glass is half full however; soil gas enthusiasts fear not! Recent overburden geochemistry research has significantly improved our understanding of at least one process that may be responsible for moving trace elements and gases through overburden. As part of CAMIRO and

Ontario Geological Survey/Geological Survey of Canada research projects on overburden geochemistry in Canada, Stewart Hamilton and co-authors are developing an improved model to account for transport of trace elements through overburden (Figure 2). The investigators have demonstrated the presence of a reduced column above mineral deposits in the Abitibi clay belt of northeastern Ontario. This gradient in oxidation potential is postulated to be the driving mechanism for redistributing elements in the overburden, possibly explaining anomalies in partial leaches and other geochemical techniques. (Hamilton, 2000; Hamilton et al, 2004A, and Hamilton et al, 2004B)

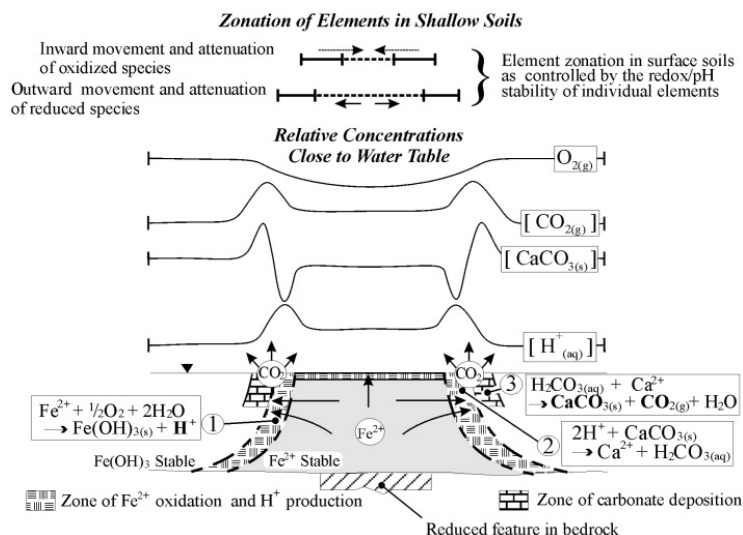


Figure 2 - Model for Development of Geochemical Anomalies by Electrochemical Processes. Hamilton et al, 2004A.

While not yet specifically addressing the migration or fixation of soil gases at the surface, the implications of this process are important to soil gas dispersion theory. The presence of a reduced column in the overburden above a mineral deposit should cultivate the propagation of reduced gaseous species. Inasmuch as the presence of a “reduced column” is a matter of relative abundance of reduced versus oxidized species, this phenomenon almost certainly extends above the water table to some degree. Gaseous migration above the water table may therefore be influenced by this reducing environment. However, the infinite oxidizing capacity of the atmosphere dramatically threatens the stability of reduced gases near the atmospheric interface.

Nonetheless, anomalous concentrations of reduced gases, derived from numerous sample media, are reported in this issue and in the literature. Surely there is something to these reports. Perhaps we need to consider other mechanisms for the genesis of these gaseous species. While some isotopic evidence exists, as yet there is insufficient research to categorically link any gaseous signature at the surface to a subsurface source. In certain environments the oxidation-reduction model does constitute a viable mechanism for some gaseous anomalies.

The flanks and top of the reduced column are, by definition, undergoing active oxidation. As shown in Figure 2, this zone can be a major oxygen consumer. The acid attack

continued on page 13

Focus on: Overview of Soil Gas Theory...

continued from page 12



on any local carbonates could also result in significant carbon dioxide off-gassing. That reduction/oxidation (Redox) interface could also result in the liberation of certain sulfur gases. Viewed in this context, this oxidation potential model merely translates the site of active oxidation upwards to the top of the reduced column, which is more realistic when the mineral deposit is far below the water table.

Importantly, major redox boundaries are very often heavily colonized by bacteria. Such microbial population centers are likely sources of gases resulting from their metabolic processes (e.g., CO₂, CH₄, H₂S). (Ehrlich, 1996.) Furthermore, the sheer biomass along these redox interfaces may be a significant source of organic carbon, subject to volatilization as hydrocarbons. If a surface soil sample is anomalously rich in certain types of microbial life, perhaps it could produce an organic gas response when thermally treated or ionized. If this were true, the “soil gases” released during desorption would actually be an indication of anomalous biota rather than direct gas flux. Research is currently underway in Canada to better understand the occurrence of bacteria in soils over mineral deposits, particularly associated with local pH and oxidation-reduction potential (ORP) anomalies.

The point of interest here is that some of the soil gas we measure over mineral deposits could be an indirect response caused by processes such as microbial metabolism and oxidation of reduced species some distance above the mineral deposit. As empirical explorers, we are interested in reproducible patterns that are indicative of mineralization, whether or not we fully understand the mechanism. Therefore, using soil gas geochemistry, we hope to uncover evidence of these processes in whole gas samples from soil pore spaces or as gaseous species sorbed to adsorbent substrate in the near surface.

According to this redox model and its logical extensions, there may be considerable crossover between low concentration soil geochemical methods, such as partial leaches, and soil gas geochemistry. This is particularly true today because most commercially available “soil gas” techniques are based on soil desorption principles. Are the gases, in fact, indicators of the redox processes, just as some of the elements detected in partial leaches are redox active?

Powerful processes are no doubt at work here. It is tempting to try to describe them in terms of a continuum, extending from basic physio-chemical concepts, that account for geochemical responses in soil and soil gas. Figure 3, a hypothetical and idealized cross section view, theorizes a complex structural “plumbing system” superimposed on Hamilton’s redox model. A hypothetical geochemical profile reflects the sort of patterns which are commonly seen in soil and soil gas geochemical analyses. The oxidation-reduction gradient re-mobilizes many constituents of the mineral deposit environment, and at the water table some volatile participation is highly likely (CO₂, O₂, sulfur gases, and light hydrocarbons). Given the proposed strong structural control on geochemical patterns, various theories for migration of trace elements, such as evapotranspiration and seismic

pumping, could also be accommodated in this model.

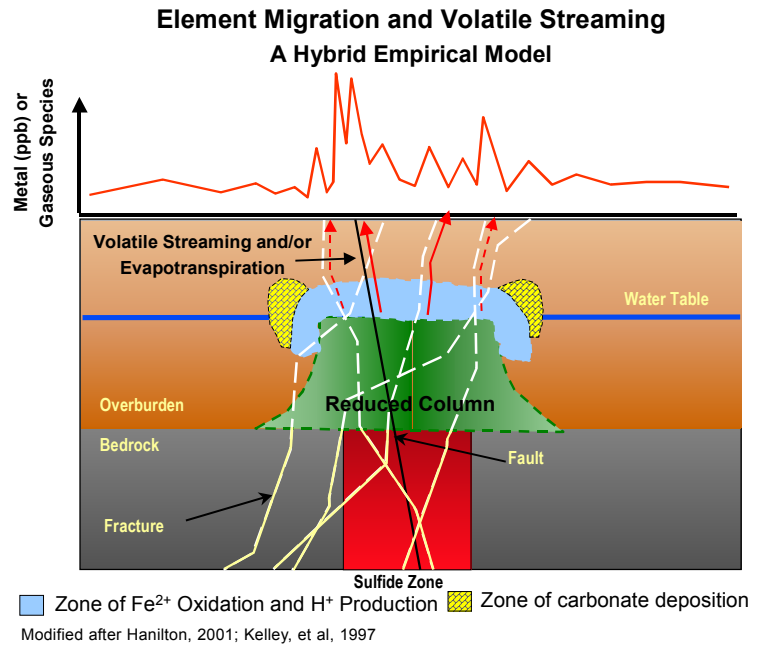


Figure 3 - Proposed Model for RedOx Driven Volatile Streaming and Element Migration

continued on page 21



simplifying complexity

GAS - Geochemical Analysis System

GAS is for exploration professionals who are frustrated with the limitations of generic data analysis products. GAS is a simple, powerful geochemical data exploration tool. Unlike the generic tools GAS offers discrimination plots, ternary diagrams, map views and other geochemistry-oriented views.

Typical uses of GAS include:

- Analysis of alteration systems
- Identification of new vectors to mineralization
- Efficient classification of new data using previously defined templates
- Verification of geological logs using whole rock geochem

GAS has built-in data transformations, such as chondrate normalisations, or you can define your own.



- Plot Types
- Scatter
 - Histogram
 - Ternary
 - Spider
 - Map

Features

- Easy to use
- Multiple Plot Types
- Discrimination Plots
- Power Data Categorisation
- Transfer Categorised Data to GIS

www.karjeni.com email: sales@karjeni.com
 Suite B, 1161 Hay St. West Perth Western Australia 6005
 PO Box 1178 West Perth Western Australia 6872
 Tel: +61 8 9322 9623 Fax: +61 8 9322 9614

Soil Gas Carbon Dioxide and Oxygen for Mineral Exploration



Patrick Highsmith
 ALS Chemex Labs
 Email: Patrick.Highsmith@alschemex.com

Introduction

Considering the body of work on soil gas applications, one reasonable interpretation is that direct measurement of carbon dioxide and oxygen in soil pore space gases is one of the most cost effective alternatives for detecting buried mineral deposits. These two gases occur at percentage levels, hence they are easily measured in the field with relatively inexpensive equipment. There are technical issues that must be carefully considered when implementing CO₂-O₂ surveys, but this review will show that these are manageable. This short discussion will focus on the carbon dioxide and oxygen technique, but it may be inferred that other gas species may hold similar potential by whole gas-based methods. Other contributions in this issue focus on various adsorption-based methods. The reader is referred to Klusman (1993) and other sources for thorough technical treatments of soil gas geochemistry concepts.

As practiced now, this CO₂ – O₂ soil gas method seeks to overcome problems with earlier trials through larger samples, field-based analysis, monitoring meteorological and background variation, and improved interpretive techniques. The field equipment is displayed in Figure 1. Careful

Instantaneous CO₂/O₂ Method Hardware and Sampling Protocol

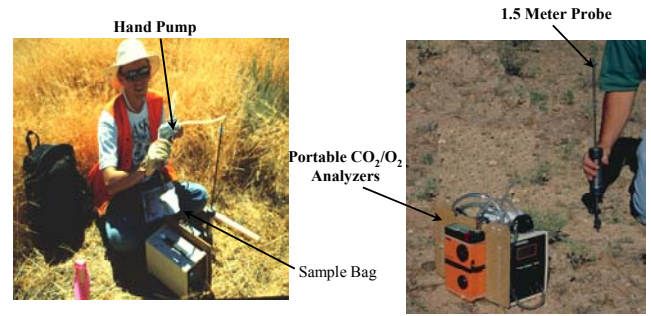


Figure 1 - Field Equipment for CO₂/O₂ Method

sampling and real-time analysis ensures that a stable sample is collected. These surveys always include base stations so that background conditions and meteorological variation can be accounted for. Very often, the interpretation of geochemical data is focused too much on numerical absolutes. This sort of real-time soil gas data is dynamic and complex, the patterns of peaks and valleys may be more significant than the magnitude of any of the spikes. In general, the data tend to map two types of features – large reducing bodies consuming oxygen over a large area and narrow, structurally or “plumbing” defined features that control gas movement.

As discussed in the overview, the fundamental premise behind much of soil gas geochemistry is the oxidation potential (Eh) of the mineral deposit and surrounding environment. In its simplest interpretation, this means that a reduced mineral deposit should consume oxygen as it oxidizes. The process of mineral deposit oxidation generates acidity, which may also attack any available carbonate and generate carbon dioxide. It is also true that microbial activity in the subsurface generates carbon dioxide. Therefore, elevated carbon dioxide and depleted oxygen in the soil atmosphere may be indicative of buried mineral deposits.

Case Studies

Two different types of soil gas responses can be seen in the following examples from copper skarn and intrusive-related gold prospects. Figure 2 is a profile across the Ruby

Ruby Star Cu Skarn, Arizona, USA Line 21700E - Looking West

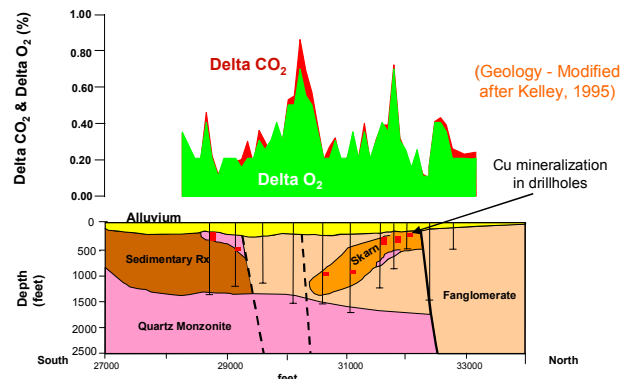


Figure 2 - Soil Gas Profile from Ruby Star Deposit, AZ

continued on page 15

ASSAYS AND GEOCHEMICAL ANALYSES

ACME
ANALYTICAL
LABORATORIES
LTD.

ISO 9001:2000
FM 63007
Vancouver 2003

ICP Mass Spec Analysis **CDN \$15.75 US \$12.60**

(Aqua regia digest on 1g sample)

37 Elements including:

Au 0.2 ppb	Ag 2 ppb	As 0.1 ppm	Bi 0.02 ppm	Cd 0.01 ppm	Co 0.1 ppm	Cu 0.01 ppm
Hg 5 ppb	Ga 0.1 ppm	Mo 0.02 ppm	Ni 0.1 ppm	Pb 0.01 ppm	S 0.02 %	Zn 0.1 ppm
Sb 0.02 ppm	Sc 0.1 ppm	Se 0.1 ppm	Te 0.02 ppm	Tl 0.02 ppm	W 0.2 ppm	

852 East Hastings St.
 Vancouver • BC
 Canada • V6A 1R6
 Tel: 1-604-253-3158
 Fax: 1-604-253-1716
 Toll Free:
 1-800-990-2263

www.acmelab.com

MEXICO
 GM LACME Laboratories SA de CV
 Leonardo@acmelab.com

SOUTH AMERICA
 ACME Analytical Laboratories (Chile) Ltda.
 acmechile@123.cl

Focus on: Soil Gas Carbon Dioxide and... continued from page 14



Star deposit in the Mission-Pima district of southern Arizona, USA. The soil gas CO₂ and O₂ data are charted as the absolute values of the difference between down hole concentrations and atmospheric values, or Delta CO₂ and Delta O₂. Peaks in carbon dioxide represent increased CO₂ relative to atmospheric values, whereas peaks in oxygen are depletion relative to atmospheric content.

In this example, there is a strong structurally-controlled CO₂-O₂ response to mineralization. The biggest spike is a multi-point anomaly in elevated CO₂ and depleted O₂ over an interpreted fault near the middle of the line. This fault almost certainly cuts sulfide mineralization in the megabreccia skarn body at depth. Another sharp spike occurs just south of a major fault that bounds the skarn block. There are copper sulfide drill intercepts directly beneath this area. A few more modest spikes occur over drill intercepts in the skarn block and in the sliver of quartz monzonite near the south end of the line. Note the strong correlation between the patterns in carbon dioxide and oxygen.

The next example is from the Kori Kollo district of Bolivia (Figure 3). The traverse is from an area of drill-intercepted base metal sulfides with anomalous gold to the

Soil Gas Orientation Survey at Kori Kollo, Bolivia Kiska - Line 16 - Looking NW

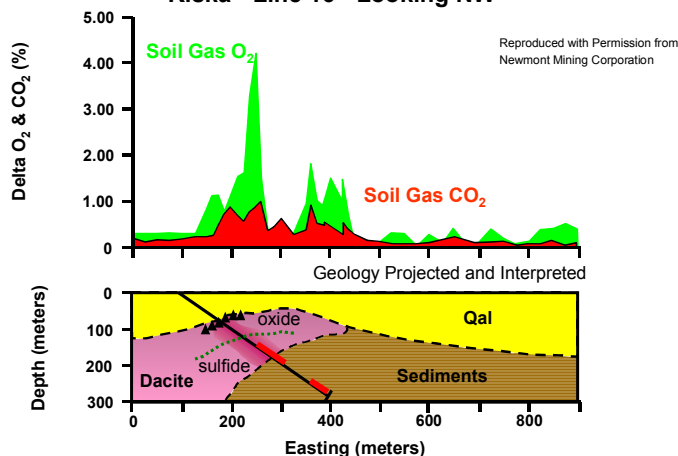


Figure 3 - Soil Gas Profile from Kiska Prospect, Bolivia

south and west of the Kori Kollo mine. The mineralization in this area occurs in sulfide veins associated with dacite porphyries. Here there are drill indicated base metal rich sulfides at two different intervals in the intrusive and sedimentary rocks. The overburden at Kiska is very fine grained, perhaps lacustrine sediments, and rain water pooled at the surface in many areas.

The data from Kiska seem to reflect the vertical projection of the sulfide intercepts with very significant oxygen depletion and moderate carbon dioxide enrichment. The anomalous patterns in both gases are relatively broad, apparently indicating significant widths of sulfide minerals. There is insufficient geological control to assess whether or not this response is due to faulting. There is also a striking difference between the carbon dioxide and oxygen signatures of this mineralization. Based on similar patterns observed

in data from other projects where major precipitation events interrupted sampling, it is likely that this strong disequilibrium phenomenon is related to recent precipitation in the survey area. It is possible that bicarbonate under-saturated rainwater infiltrating the soil profile dissolved carbon dioxide, thereby suppressing the CO₂ soil gas response.

Conclusions

These examples demonstrate the utility of soil gas carbon dioxide and oxygen for mineral exploration beneath overburden. The most common types of anomalies are reflected in these two data sets – structurally controlled spikes versus soil gas plumes over reduced (sulfide) bodies. There is also evidence in the Bolivian data of meteorological effects on soil gases and how the response to mineral deposits tends to overwhelm those effects. It is also important to note that this method requires extraction of soil pore space gases, so it cannot be applied in areas of saturated ground or extremely shallow water tables. The reader is further referred to **EXPLORE** no. 119, April 2003, for two more examples of CO₂/O₂ data. Properly managed with base stations, calibrations to atmospheric concentrations, and careful sampling protocols, this inexpensive method can be an effective part of an overburden exploration strategy.

Perhaps the spread of soil gas CO₂/O₂ geochemistry as a mainstream exploration tool is hampered by a lack of commercial providers of the service. Virtually all of the work done in this field has been conducted by company geochemists and geologists or a short list of consulting geochemists. There is a relatively steep learning curve when deploying any new technology, but few methods can go from testing to targeting as quickly as this simple soil gas method.

References

- Kelley, D.L, 1995, Geochemical orientation studies: Ruby Star project, Pima County, Arizona, USA: Unpublished report, BHP Minerals International Exploration, Inc, Denver, Colorado, 16 p.
- Klusman, R.W., 1993, Soil gas and related methods for natural resource exploration: John Wiley & Sons, Chichester, UK, 483 p.





ROCKLABS

REFERENCE MATERIALS
FOR GOLD ASSAYING QA/QC

Quality Reference Materials affordable for use on an every batch basis. Wide range of values.

Available in sachets for geologists or 2.5 kg jars for laboratories.

Used in over 30 countries.

Check Certificates and range at www.rocklabs.com



ROCKLABS LTD 161 NEILSON STREET, P.O BOX 18-142
AUCKLAND, NEW ZEALAND

Telephone: 64 9 634 7896
Fax: 64 9 634 6896
E-mail: rocklabs@clear.net.nz

Thermally Speciated Mercury in Mineral Exploration



Shea Clark Smith

Minerals Exploration & Environmental Geochemistry

P.O. Box 18325, Reno, Nevada, U.S.A. 89511

SheaClarkSmith@compuserve.com

Abstract

The high fugacity of elemental mercury and its various mobile compounds and complexes, make it well suited for soil gas surveys in search of blind and deeply buried mineralization.

Mercury is easily oxidized and reduced by the influences of both inorganic and organic processes. These create suites of mercury species that are part of the total mercury flux. By comparing the various mercury species that are detected in soils overlying deep zones of metal enrichment, vectoring strategies that relate near-surface to deep ore can be explored.

Novel fingerprint methods using stepped thermal desorption reveal differences between naturally occurring and anthropogenic sources of mercury (Beister et al, 1999). These methods focus on data derived from the thermal desorption of soil above 100C. However, detectable mercury is released below 100C, and this mercury seems to be related to emanations from deeply buried mineralization. These low reduction enthalpies suggest that extremely volatile mercury compounds, possibly organo-Hg complexes, are responsible for the anomalies that indicate the deepest ore.

Introduction

Many base and precious metal ores are associated with mineralizing events that include the hydrothermal circulation of saline solutions in and around metallic deposits. Mercury is one of a suite of toxic metals that is associated with this contemporaneous and late hydrothermal activity. As the solutions cool and the toxic metals are deposited, a spatial relationship is created where mercury and the other toxics can be used as geochemical pathfinders in the search for these ores and geothermal occurrences.

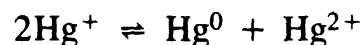
The evolution of mercury vapor from deeply buried ground water/mineral interaction results in a vertically migrating flux that probably occurs as a mixture of various mercury species. Depending on the changing conditions of the oxidation-reduction potential of the rock/soil column,

one or several species of mercury may be responsible for its vertical and lateral dispersion at any given time. For instance, mercury can exist as a relatively mobile chloride, as a less mobile sulfate, or as a refractory sulfide. The mobilities of these various mercury species are also affected by the composition of the rock / soil column. For example, the bonds between mercuric chloride and clay are stronger than the bonds between native mercury and iron oxide, but weaker than the bonds between native mercury and humic acid.

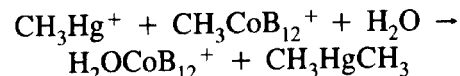
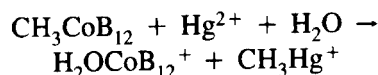
Controlled thermal desorption of soils and sediment is not a new concept in mineral exploration. McNerny and Buseck (1977) used it as they improved methods related to their Jerome Mercury Detector. Kromer et al. (1981) did several studies over two lead-zinc vein deposits where they determined mercury speciation by differential thermal analysis (DTA). They were able to demonstrate that various mercury species evolve from an oxidizing vein deposit, but were unable to show that speciation analysis improves the likelihood of finding deep (>12 m) mineralization. Maciolek and Jones (1988) also used DTA to reveal concentric mercury halos lying over precious metal deposits. Their work drew significantly from Russian literature (circa 1980), where mercury desorption and sublimation curves are discussed for various deposits through temperatures ranging from 200° C to 600° C.

CHEMICAL SPECIATION

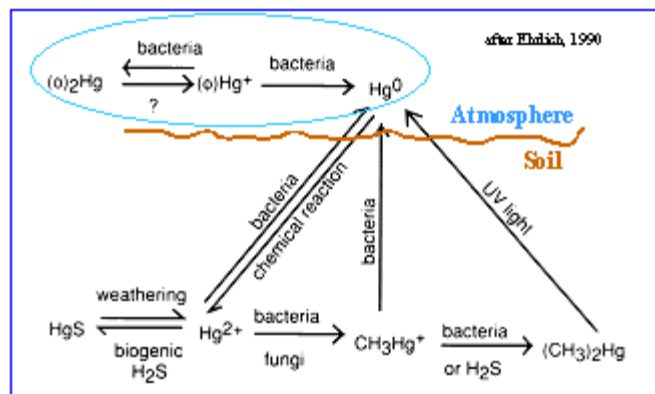
Sulfide oxidation → disproportionation



Methylation from methyl cobalamin



BIO-ORGANIC SPECIATION



continued on page 17



Kelly A. Monier
Member - Owner / Service Technician

GeoPro Services, LLC
Specializing in Geochemical Data Management

- Submittal Tracking
- Lab Liaison
- Data Compilation
- Data Quality Monitoring
- Historical Database Development

7225 East 28th Street • Tucson, Arizona 85710 USA
phone/fax: 520-733-9884
kmonier@cox.net
www.geoprodataservices.com

Thermally Speciated Mercury in Mineral...

continued from page 16



The current work looks at mercury evolved from thermally desorbed soils and analyzed by cold vapor atomic fluorescence spectrometry (CVAFS). This offers an immense improvement in analytical capability and permits the detection of all natural background concentrations. The typical reporting range for the method is 10 ppb to 0.010 ppb Hg. Consequently, the very smallest of mercury concentrations can be detected, making it possible to see very weakly bound mercury on the surfaces of soil particles without disturbing other mineral species in the substrate. This achieves a response that is similar to buried integrative collectors that require 8-10 weeks to load. In addition, other mercury species can be detected by systematically increasing the desorption temperature. The result is a mercury response to deeply buried mineralization that permits several vectoring strategies as the relationships of near-surface to deep ore are explored. Overall, this new mercury method achieves new levels of reliability in finding precious metal, base metal, and PGM deposits, as well as very deeply buried geothermal occurrences.

Speciation

Mercury compounds derive from inorganic processes, organic, and bio-organic processes. Disproportionation is an inorganic equilibrium between elemental mercury and two of its "reactive" states. The Hg^+ and Hg^{2+} ions are available for reactions with metabolic by-products (like cobalamin) that shift the disproportionation equilibrium to increasing amounts of elemental mercury, Hg^{2+} , and the formation of dimethylmercury. Bacteria and fungi intervene to create several more organomercury compounds. These various mercury species can be detected by step-wise thermal desorption. As a mercury containing mineral is heated, it sublimes to give mercury vapor. If the temperature is plotted versus the amount of mercury given off at that temperature, a signature profile is constructed for that compound. Biester et al (1999) has done much of this work showing characteristic profiles for $HgCl_2$, Hg_2Cl_2 , CH_3HgCl , $HgSO_4$, HgO , and various forms of HgS . He also shows signature profiles for mercury and mercury compounds that result from bonding to various substrates, like iron oxide, clay, a standard soil, and humic acid. Curiously, many of the mercury-compound and mercury-substrate profiles display multiple peaks, suggesting that bonds of different strengths are being broken as mercury is driven from the compound or the substrate.

Substrate Effects


The sublimation of elemental mercury is affected by the substrate to which the mercury mineral is bound. Biester demonstrates this with sublimation curves using iron oxide, clay and humic soils. Generally, higher desorption temperatures are required to release mercury minerals from the substrate.

continued on page 18

Experience

At ALS Chemex we want you to have the best experience possible and we believe this comes from years of work in the industry. That's why we have put together a team of the most seasoned analytical chemists, geochemists and technical experts we can find so that we can go beyond international analysis standards and provide you with quality service and results.

No matter where in the world your project is, ALS Chemex has an office nearby with experts ready to assist you. For your nearest location, visit www.alschemex.com.



ALS Chemex
EXCELLENCE IN ANALYTICAL CHEMISTRY

Thermally Speciated Mercury in Mineral... continued from page 17

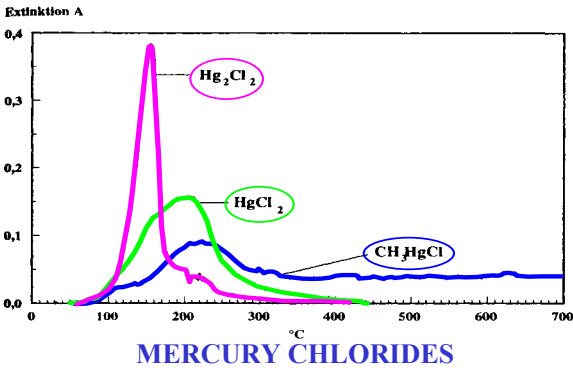


Abb. 6: Abdampfkurven der Hg-Chloride

From Biester, 1994

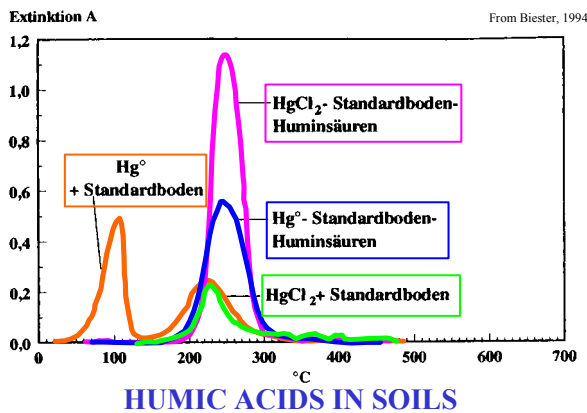


Abb. 11: Vergleich Abdampfkurven des Hg⁰- und des HgCl₂-inkubierten Standardbodens mit ihren extrahierten Hg-Humaten

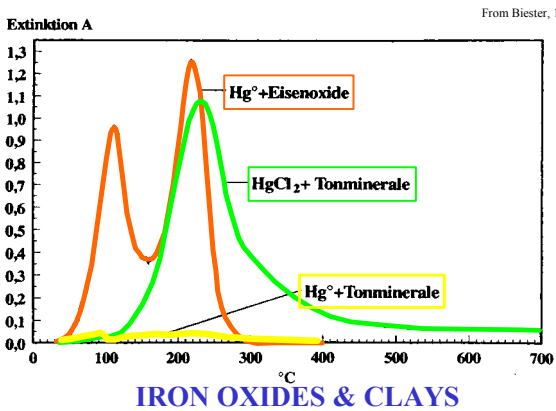


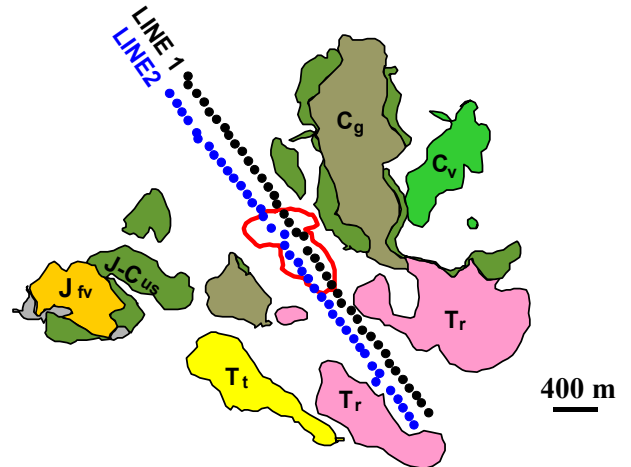
Abb. 9: Abdampfkurven der Hg-inkubierten Tonminerale und Eisenoxide

GAS'm™

The introductory work by Biester and other investigators provides a basis for the use of operationally defined thermal desorption in mineral exploration. Assuming that appropriate sample collection and preparation procedures give each sample in a survey a relatively constant composition (clay-rich), then the application of a specific desorption temperature should evolve proportional amounts of mercury from sample to sample depending on the equilibrium condition of that sample in the mercury flux.

MEG Labs has invested over 7 years into the development of this low temperature desorption method and has had increasing success as we improve our knowledge and understanding about extremely volatile mercury species. Here is just one of many examples of our work:

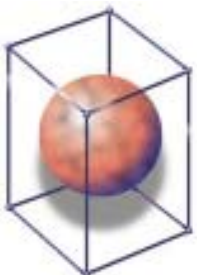
Volcanogenic Hydrothermal Massive Sulfide



Example from Sonora, Mexico

This unidentified VHMS deposit lies under a thin veneer of alluvium overlying approximately 300 m of Tertiary volcanic and volcanoclastic rocks. The closest approach of the deposit to the surface is 150 m. Soil samples were taken on 100 meter centers. The samples were first desorbed at a mid-range temperature, but the resulting profile was not particularly diagnostic. The samples were then desorbed at a high temperature and three anomalous zones appear. The robust anomalies from the high temperature desorption were

continued on page 19




Robert G. Jackson
Consulting Geochemist

3D Zonation Modeling and Vectoring Methods to discover Blind Deposits Survey Designs and Data Interpretation

Seeking new target possibilities through 3D visualization

150 E. Flora Lane
Spring Creek, NV, U.S.A. 89815
rgjackson@ctnis.com 775-777-1619



Contact us: Ph - +618 9472 7344
Fx - +618 9472 7345
email: mmi@mmigeochem.com

High Resolution Geochemistry
providing

- Ultra low level analyses,
- Data is robust, repeatable and routinely available,
- Applicable and effective for a variety of commodities, in difficult soil types & terrains,
- Provides superior anomaly to background definition.

Successful global case studies available for precious and base Metal exploration, and the discrimination of potential diamond host rocks.

Mobile Metal Ion Geochemistry
The New Frontier — Yes, we do understand

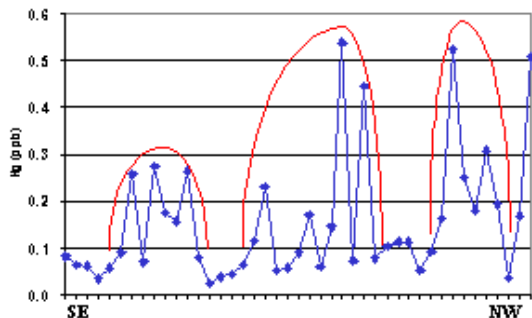
Thermally Speciated Mercury in Mineral...

continued from page 18

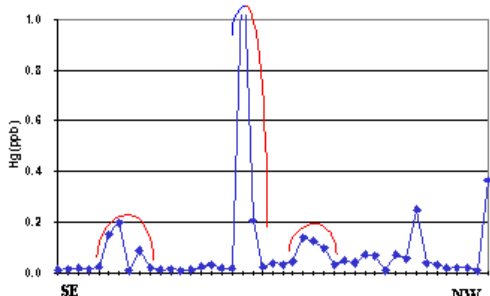


only vaguely captured by the mid-range desorption profile, so a third, low-temperature run was done. At this temperature a coherent zone 1200 m in length appears that is highly correlated with the mid- and high-temperature desorption profiles.

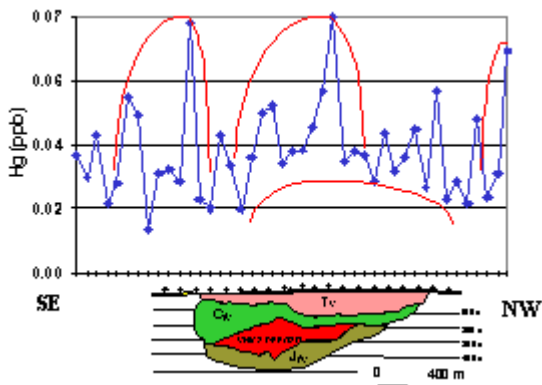
MID-TEMP DESORB



HIGH-TEMP DESORB



LOW-TEMP DESORB



This VHMS example illustrates how the signature desorption profile can be used to determine the most effective desorption temperatures for exploration in various terrain, geologic, and economic settings. Furthermore, the differences in the release of mercury as a function of temperature should indicate certain geometries of the deposit, including the influences of local structure.

Conclusions

Mercury soil gas is a reliable way to locate deep mineral occurrences using surface soil samples. Soils are desorbed with incremental thermal treatments. Weakly bound mercury is released at low temperatures while more refractory mercury species are decomposed at higher temperatures. Thermal desorption is directly proportional to the energy required to break the bonds that hold elemental mercury in mineral compounds and to the soil substrate. The

relationships between low-thermal and high thermal anomalies indicate the geochemical processes that created the operationally defined mercury speciation.

Mercury soil gas is an excellent tool for mapping structures, which are usually indicated by high-thermal desorption data. The more subtle patterns from low-thermal desorption data usually indicate deep mineralization, particularly if the geometry and footprint of those patterns suggest a body of significant tonnage.

References

Barton, M.D., Staude, J-M. G., Zurcher, L., and Megaw, P.K.M., Porphyry Copper and Other Intrusion-Related Mineralization on Mexico, in Pierce, F.W, and Bolm, J.G. (Editors), Porphyry Copper Deposits of the American Cordillera, Arizona Geological Survey Digest 20, Tucson, AZ, 1995.p. 487-524.

Biester, H., Gosar, M., and Muller,G., 1999, Mercury speciation in tailings of the Idrija mercury mine. Journal Geochemical Exploration 65, 195-204.

Klusman, R.W., 1993, Soil Gas and Related Methods for Natural Resources Exploration. John Wiley & Sons, New York. pp.483

Kromer, E., Griedrich, G., and Wallner, P., 1981. Mercury and mercury compounds in surface air, soil gas, and rocks. Journal Geochemical Exploration 15, 51-62.

Maciolek and Jones (ca. 1988, unpublished research)



Goldschmidt Geochemistry

Copenhagen 2004

Processes in Geochemistry
Forces, Fluxes and Structure

Conference Themes
The Dynamic Solid
The Dynamic Interface
Fluids of the Earth
The Earth's Surface
The Deep Earth
Early Earth, Moon, Planets

University of Copenhagen
Denmark
5 to 11 June 2004

Sponsored by
European Association for Geochemistry
Geochemical Society
Mineralogical Society of America
Geochemical Society of Japan

Hosted by
The Nordic Countries

Abstract Deadline: 26 January 2004
Early Registration Closes: 2 April 2004

Goldschmidt 2004
Geological Institute, University of Copenhagen
Øster Voldgade 10
DK-1350 Copenhagen K, Denmark
goldschmidt@geol.ku.dk

www.goldschmidt2004.dk

Rosenborg Castle, 5 minute walk from the Geological Institute (Photo and Design: Sveene)

Kimberlite Exploration Integrating SGHSM Geochemistry



David M. Leng and Dale A. Sutherland
Activation Laboratories Ltd.
Ancaster, Ontario, Canada, L9G 4V5

Abstract:

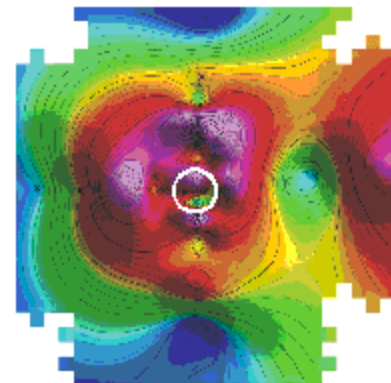
Soil Gas Hydrocarbons (SGHSM) is a method of geochemical exploration, which detects 162 specific hydrocarbon compounds in the C5-C17 carbon series range. Hydrocarbon compounds that have migrated from a mineralised body in the subsurface through cover rock and overburden are adsorbed onto surficial soils. SGHSM analyses detect these hydrocarbons and these are of use to the explorationist as a method of detecting blind mineralised bodies. Recent research has shown that there are relationships between specific commodities and compound classes that are unique to them.

Identifying these relationships provides a 'hydrocarbon fingerprint' that is unique to a specific commodity. The suite of compounds detected within soils over kimberlite pipes has also been found to be unique, bearing little resemblance to the suite of compounds detected in soils over base metal deposits. This basis of classifying compounds to a particular commodity type provides a diagnostic method of interpreting the results of an SGHSM survey. Knowledge gained out of 'fingerprinting' a particular commodity type gave rise to the investigation of a neural-net (NN) software system as a means of reducing interpretive time and enhancing SGHSM survey findings. 'Score maps' from the NN depict compound similarities within an SGHSM dataset. Initial NN research conducted on several Canadian kimberlite pipes has provided some of the most startling results to date.

Introduction:

Soils that have been dried <40°C and sieved at minus 60 mesh are extracted for hydrocarbons and are subsequently analysed by gas chromatography-mass spectrometry (GC-MS). Compound separation is done within the GC and detection is accomplished with the MS. This highly developed method of analysis allows for monitoring of specific compounds and provides detection limits of 1 part-per-trillion (ppt).

Integration of NN with SGHSM facilitates rapid and robust interpretations. Multiple compound and class responses with built-in redundancies, ensure a reduction in spurious responses.



Research conducted with CAMIRO over the past seven years has focused on the applicability of SGHSM to a variety of geographical locations, differing commodity types and varying cover thicknesses. Given the recent explosion in diamond exploration, it came as no surprise that a portion of the most recent research was focused on how SGHSM could be applied for diamond exploration. Soils from several Canadian kimberlite pipes were the subject of study as SGHSM analyses were performed on the blindly submitted samples. After the analyses had been performed, UTM coordinates for the soil sample locations were provided, which permitted evaluation of the surveys. Results from these surveys were quite revealing, as responses were found in multiple compounds across multiple compound classes – sharply delineating the pipes.

One of the primary benefits gained from an SGHSM survey is the amount of highly specific data obtained. A dataset is usually comprised of a 'site signature' which represents the hydrocarbon background of the survey region. The 'mineral signature' is the portion of the 'site signature' which is indicative of a particular commodity type. 'Site signature' compounds usually occur at much higher concentrations than those of the target 'mineral signature'.

Research involving a NN system allowed the interpretation of the kimberlite SGHSM datasets. Employed as a predictive tool, the NN system was 'trained' on one of the datasets and then allowed to evaluate the other datasets.

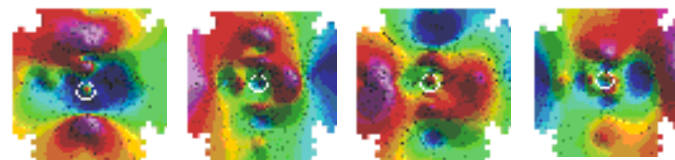


Figure 1. Four diagrams depict individual NN score-maps from an SGHSM survey over a Canadian kimberlite pipe. The NN was initially trained on one pipe at another location to establish the 'learning set' for the NN. Parameters that were established as part of the 'learning set' were then applied to other kimberlite pipes.

On their own, each individual score-map exhibits a particular compound class. Examined collectively, the diagrams exhibit the vectoring behaviour of the compound classes. Certain classes are more tightly constrained over the pipe itself, whereas other classes are constrained to the periphery of the pipe. This concentric nature of the responses is analogous to zonation based on chemical properties of the various classes.

continued on page 21



GCXPLORE

67 Chelmsford Rd
Mt Lawley WA
Australia 6050
Ph 618-92279905

Richard Carver Consulting Geochemist

- Extensive International Experience
Australia - China - Africa
- Project Management
- Survey design & implementation
- Laboratory Audits
- QA/QC & Data due diligence
- Data & Database compilation
- Arcview/MapInfo GIS

richard.carver@gcxplore.com
Web www.gcxplore.com

Kimberlite Exploration Integrating... *continued from page 20*



The NN system was basically ‘taught’ a series of observations; in essence, it was guided to look for other such observations based on previous knowledge. The NN system is able to establish connections between patterns in datasets that may be far too complex for the human eye to evaluate. During the NN interpretation of the Canadian kimberlite pipes, the NN revealed minute relationships of specific organo-sulphur compounds which were previously unseen. The NN processing eases the interpretation by reducing workload and also has the benefit of commodity-specific experience. Furthermore, NN interpretation has the ability to evaluate strong anomalies in relation to subtle mineral responses. Thus subtle responses are not overlooked, which removes human bias. The NN sets developed are able to recognize a wide variety of anomaly patterns (halo, apical, singular, concentric) and it works best when sampling is conducted in a grid formation rather than in a single line. Irregular survey design introduces a numerical anisotropy which may yield false responses as the algorithm attempts to explain the data spatially.

Due to differences in diffusion and mobility rates, it was observed through the NN interpretation that SGHSM

compound classes might provide a vectored response in proximity of the pipe. Certain compound classes were tightly constrained around the pipe, whereas other compounds were not as constrained and had a more divergent, yet definitive response. A possible and plausible reason for this ‘concentric’ response over and around the pipes is that the compounds are behaving as they do in a GC. The compound separation around the pipe may be a result of ‘geochromatography’ in the overburden.

Several NN sets have been developed for SGHSM data processing. Each has been specifically “trained” on a particular commodity type. For each commodity there are individual NN sets that are used to interpret several compound classes. The NN applies the specific commodity signature identified in previously known study sites onto the client’s SGHSM survey data. When given sample coordinates, the result is the consolidation of 162 individual compound maps, previously used to review SGHSM data, into 19 compound class NN score maps specific to the commodity sought. These NN processed maps are not a simple summation of each compound class. Rather, the NN has determined, based on previous experience, the significance of each compound relative to each other in a compound class and applies them to the new data.



Focus on: Overview of Soil Gas Theory... *continued from page 13*



Introduction to Soil Gas Methodologies

While some of the theory behind soil gas geochemistry is undefined, we haven’t let that stand in the way of getting out and sniffing gas! There are several options available for adding this tool to your exploration programs. Four different soil gas methodologies are described below. Three of these four are provided as a commercial analysis on soil samples. The fourth technique is based on sampling whole soil gases with a probe based system measuring CO₂ and O₂.

The following reviews of soil gas techniques are presented by the service providers or developers of the methods. Soil gas methods fall into two categories: whole gas methods and desorption based methods. Herein we have contributions determining instantaneous CO₂ and O₂, and three commercial adsorption based techniques:

- Gas’*m* Mercury Analysis
- Soil Desorption Pyrolysis (SDP)
- Soil Gas Hydrocarbons (SGH)

Desorption Based Soil Gas Methods

The concept behind soil gas collectors is that the gas signal is sampled over time, thus integrating the response. The integrated sampling should be less susceptible to meteorological changes and other sources of short-term variance. Desorption of soil gases also has the added benefit of being practicable where extraction of pore space gases is not possible, such as saturated ground or very shallow water tables. Adsorption based soil gas methods come in two basic

forms: static trapping devices or natural collectors. The three methods discussed here all rely on some fraction of soil samples to collect a mobile gas phase. Once collected, the gaseous target compounds may be extracted by solvent digestion or some sort of thermal desorption. A myriad of gaseous targets are available, but some providers focus on narrower families of gases.

There are a few techniques for sampling soil gases using engineered collectors, such as activated charcoal, the Gore Sorber[®] module, or the BRGM soil gas cups. These collectors are generally deployed for a period of weeks prior to collection and analysis. These types of static trapping devices have never been very popular in mineral exploration, partly because of their perceived complexity and cost and partly because multiple trips to the field are required. However, an engineered sorption substrate has certain advantages with respect to sampling specificity, desorption characteristics, and possibly sensitivity. An engineered sorbent should also be more homogeneous than natural sample media, thus precision may be improved.

There is a considerable volume of work with soil gas collectors methods in the petroleum field. Microseepage of hydrocarbons to the surface is documented over petroleum reservoirs (Klusman, 1993). Of course, there is an important distinction to be made here between the high vapor pressures of light hydrocarbons in petroleum reservoirs and the trace hydrocarbon gases likely to evolve from mineral deposits.

Natural media, such as soils, require only one field visit and have been “deployed” through geologic time. Therefore the soil gas signal should be less susceptible to sampling error and theoretically more robust and precise than short term sampling. Any natural sample medium will be

continued on page 22

Focus on: Overview of Soil Gas Theory...

continued from page 21



inhomogeneous however, so the desorption characteristics may vary from sample to sample. Since the specifics of desorption or extraction conditions may not be known, there may also be questions about the source of the desorbed gases.

In recent years, considerable development has taken place in working with soil desorption and volatiles analysis. One advantage of this approach is that the samples are returned to a lab for analysis, where state-of-the-art analytical technology can be brought to bear. The commercial methods reported herein rely on sophisticated analytical technology to achieve sub-ppb detection limits for many gases. While admirable strides have been made, the per sample costs still reflect the laboratory infrastructure required.

Whole Gas Soil Gas Methods

Whole gas methods rely on extraction of the gases from the soil pore spaces using probes and some sort of pumping system. The gas can be collected for later analysis or analyzed immediately in the field. Various techniques have been used over the years, but the most popular derivations are multi-gas analysis by mass spectrometer and carbon dioxide/oxygen analyses with portable analyzers.

Howard McCarthy of the USGS has worked extensively on the measurement of soil gases in various terranes with a vehicle mounted mass spectrometer (McCarthy et al, 1986A & B). Whereas, Lovell (1979) and Lovell et al (1979, 1980, and 1983) reported on the forerunner of the current carbon dioxide/oxygen sampling system developed and modified by Jaacks (pers. comm.) and this author. The fundamental differences between McCarthy's multi-gas work and the CO₂/O₂ work reported below are the complexity of the analytical finish, the sample volumes, and the portability of the field equipment. Carbon dioxide and oxygen are stable gases occurring in percentage levels that are easily measured in the field. As discussed above, these two gases are useful indicators of mineral deposits because of their participation in oxidation-reduction (RedOx) related processes. However, the low cost is one of the driving factors behind the development of the carbon dioxide-oxygen method.

Real time extraction of soil gases is subject to a number of complexities, principle among them are meteorological variation and variable biological activity (Klusman, 1993). However, careful field craft can moderate most of these effects. The carbon dioxide and oxygen method discussed herein always includes base stations in order to monitor changing meteorological effects and background fluctuations.

The State of Commercial Applications

Consider the four methods discussed elsewhere in this issue. As noted above, much of the development of soil gas technologies has been empirically based. These brief overviews do not offer enough space to explain any of the methods in detail.

Some of the contributions assume some knowledge of the methods, while others have provided more background

information. Hopefully this introductory section will assist the reader with theoretical background and some history on the philosophy of soil gas practitioners. Interested parties are encouraged to review some of the references provided and to contact the providers of these services directly.

There are marked differences among the methods. In general, the offerings discussed here range from the "do-it-yourself" and less expensive single or double analyte methods (Gas'm mercury and CO₂/O₂) to the more expensive and complex multi-gas data reported from mass spectrometers or gas chromatograph-mass spectrometers (SDP and SGH).

The different philosophies among the service providers and technical practitioners are apparent in the details, or lack thereof. It is apparent that some of the discussions of the proprietary methods withhold considerable detail. There is also much emphasis on sophisticated data processing from the purveyors of SDP and SGH. The mercury and oxygen-carbon dioxide methods rely much more on pattern recognition; no recipe is offered for target fingerprinting. These realities place a considerable burden on the geochemist in selecting methods. Either the client must place a huge amount of trust in the service provider or there is an inescapable need for orientation surveys to provide the confidence for large-scale application. As discussed above, the exact genesis of the touted gaseous responses is not well understood, nor are there convincing examples of "soil gas discoveries" described in this issue or the literature.

Perhaps it is not difficult to understand why soil gas geochemistry has seen such limited wide-scale application. Exploration technologists should be empiricists, so there's no requirement for every question to be answered. However, discoveries are hard to come by; and they usually originate from multi-discipline data. In the absence of spectacular documented success, it is wise to seek a reasonable theoretical understanding of our exploration tools. The reader is encouraged to consider the scientific theory behind soil gas geochemistry, review some of the fundamental references provided herein, and evaluate the various methods in that context. Only then will the service providers and experienced consultants be pressed to improve the fundamentals and make the breakthroughs which will lead to discovery.

While it is exciting to see such an unprecedented variety of soil gas services available to the mineral explorer, it remains to be seen whether any method will gain wide acceptance with so many unanswered questions. Meanwhile, a few intrepid exploration groups are applying systematic soil gas geochemistry on their projects. It promises to be very interesting as their results become known. A few confirmed discoveries would fuel the fire like no technical diatribe ever could!

References

- Ehrlich, H.L., 1996. Geomicrobiology, 3rd Edition: Marcel Dekker, Inc., New York, USA, 719 pages.
- Hamilton, S.M., Cameron, E.M., McClenaghan, M.B., and Hall, G.E.M., 2004. Redox, pH and SP variation over mineralization in thick

continued on page 23

Focus on: Overview of Soil Gas Theory...

continued from page 22



- glacial overburden (II): field investigations at Cross Lake VMS property. *Geochemistry: Exploration, Environment, Analysis*, Vol. 4, 14 p.
- Hamilton, S.M., Cameron, E.M., McClenaghan, M.B., and Hall, G.E.M., 2004. Redox, pH and SP variation over mineralization in thick glacial overburden (I): methodologies and field investigations at Marsh Zone gold property. *Geochemistry: Exploration, Environment, Analysis*, Vol. 4, 12 p.
- Hamilton, S.M., 2000. Spontaneous Potentials and Electrochemical Cells. In *Geochemical Remote Sensing of the Subsurface; (Chapter 3) Handbook of Exploration Geochemistry*, Volume 7, G.J.S. Govett and M. Hale, Ed.s, Elsevier Science, p. 81-119.
- Hinkle, M.E., Lovell, J.S., 2000. Sulphur Gases. In *Geochemical Remote Sensing of the Subsurface; (Chapter 3) Handbook of Exploration Geochemistry*, Volume 7, G.J.S. Govett and M. Hale, Ed.s, Elsevier Science.
- Jaacks, J. A., 1984. Meteorological influence upon mercury, radon, and helium soil gas emissions, Ph.D. Thesis, Colorado School of Mines, Golden, CO, 170 pp..
- Kelley, D.L., Highsmith, R.P., Jaack, J.A., 1997. Vapor dispersion of metals: BHP Minerals International Exploration, Inc., Golden, CO, USA, Un-published company poster.
- Klusman, R.W., 1993. Soil gas and related methods for natural resource exploration: John Wiley & Sons, Chichester, UK, 483 p.
- Lovell, J.S., 1979. Application of vapour geochemistry to mineral exploration: Unpublished Ph.D. thesis, University of London, London, United Kingdom.
- Lovell, J.S., and Hale, M., 1983. Application of soil-air carbon dioxide and oxygen measurements to mineral exploration: *Transactions of the Institute of Mining and Metallurgy (Section B: Applied Earth Science)*, volume 92, p. B28 – B32.
- Lovell, J.S., Hale, M., and Webb, J.S., 1979. Soil air disequilibria as a guide to concealed mineralization at Keel, Eire: *in Prospecting in Areas of Glaciated Terrain (London: IMM, 1979)*, p. 45-50.
- Lovell, J.S., Hale, M., and Webb, J.S., 1980. Vapour geochemistry in mineral exploration: *Mining Magazine*, September, 1980, pp. 229-239.
- Lovell, J.S., Hale, M., and Webb, J.S., 1983. Soil air carbon dioxide and oxygen measurements as a guide to concealed mineralization in semi-arid and arid regions: *Journal of Geochemical Exploration*, volume 19, p. 305 – 317.
- Lovell, J.S., 2000. Oxygen and carbon dioxide in soil air. In *Geochemical Remote Sensing of the Subsurface; (Chapter 3) Handbook of Exploration Geochemistry*, Volume 7, G.J.S. Govett and M. Hale, Ed.s, Elsevier Science, p. 81-119.
- McCarthy, J.H., Jr., Lambe, R. N., and Dietrich, J.A., 1986. A case study of soil gases as an exploration guide in glaciated terrain-Crandon Massive Sulfide Deposit,

- Wisconsin: *Econ. Geol.* v. 91, p. 408-420.
- McCarthy, J.H., Jr., and Reimer, G.M., 1986. Advances in soil gas exploration for natural resources. *Journal of Geophysical Research*, 91, pp. 12327 - 12338.
- Oakes, B.W., 1984. Vapour geochemical pathfinders for oxidizing sulphide mineralization beneath exotic overburden, Ph.D. Thesis, Royal School of Mines, Imperial College of Science and Technology, London, United Kingdom.
- Polito, P.A., Clarke, J.D.A., Bone, Y., and Viellenave, J., 2002. A CO₂-O₂-light hydrocarbon-soil gas anomaly above the Junction orogenic gold deposit: a potential alternative exploration technique. *Geochemistry: Exploration, Environment, Analysis*, Vol. 2, pp. 333-344.
- Taylor, C. H., Kesler, S. E., and Cloke, P. L., 1982. Sulfur gases produced by the decomposition of sulfide minerals: application to geochemical exploration: *Journal of Geochemical Exploration*, vol. 17, p. 165-185.



AEG Distinguished Lecturer

The Distinguished Lecture Series is being given by **Cliff Stanley**.

The following lectures are offered:

- Lecture 1: Litho-geochemistry: *What you discover depends on where you stand*
- Lecture 2: Hydrothermal alteration zones at two massive sulphide deposits: *Contrasts in litho-geochemical expression due to host rock controls*
- Lecture 3: Molar element ratio analysis of granitoid batholiths: *Insights into magmatic and assimilation processes that affect exploration strategies and tactics*

Organizations interested in sponsoring a lecture should contact Robert Bowell (rbowell@srk.co.uk) for further information.

New Soil-Gas Chemistry Technique Effective Under Transport Cover



Steve Windle
SDP Pty Ltd.
Email: steve@sdpsoilgas.com

Soil Desorption Pyrolysis “SDP” is an emerging penetrative geochemical technique which is achieving successes in challenging environments such as young alluvium, deeply weathered regolith, till, glaciolacustrine clays and black soil floodplains.

SDP is applicable to multiple commodities, including gold, base metals, diamonds and petroleum. As far as gold is concerned, the method has been tested on FeOx copper-gold targets, Carlin-Style and Porphyry systems, with limited work on Archaean shear-zone gold.

SDP differs from other methods in a number of key aspects. First, a shallow soil sample is taken, distributed over about a square meter. After sieving in the field, a minus two micron clay fraction is separated in the lab. This clay size material is exploited as a natural adsorptive substrate in the soil. Using the clays allows the gas flux to be averaged over time and space, resulting in much lower variability than that achieved with “sniffer probe” techniques. Also, the clay separation greatly reduces the noise in the measurement, which largely derives from coarser fragments of organic material.

The second step in SDP analysis is to heat the clay separate to 450 °C, which drives off all the adsorbed gas. A single mass spectrum is rapidly determined for each sample, from which more than forty compounds are measured. The compounds used in SDP are a mixture of inorganics, hydrocarbons, sulphur gases and halogenated hydrocarbons. No metals are measured, only volatile compounds.

The final step is calibration. An orientation survey is used to find a “fingerprint” template which discriminates between ore and background. The template is essentially composed of many stacked compound ratios, and is derived using a proprietary, empirical, process. Once a satisfactory calibration has been developed, it can be applied to exploration samples.

Orientation and Calibration

Because SDP is an indirect measurement, a calibration is needed to interpret the survey results. The ideal case is to run a small orientation survey before exploring in a particular district, using a known mineralization example of the same style as the exploration target. Where this is not practicable, it may be possible to use a “generic” calibration, aimed at a

particular deposit style. For example, a single calibration can be defined which will distinguish most of the Australian massive sulphide deposits so far examined; likewise, a single calibration responds to two Chilean porphyry copper systems, a manto-style copper deposit, and the Osborne iron oxide Cu-Au deposit in North Queensland (fig 2). In this case, the deposits and their settings are sufficiently diverse that it is likely that the gas response relates to a simple common process such as bacterial oxidation of sulphides.

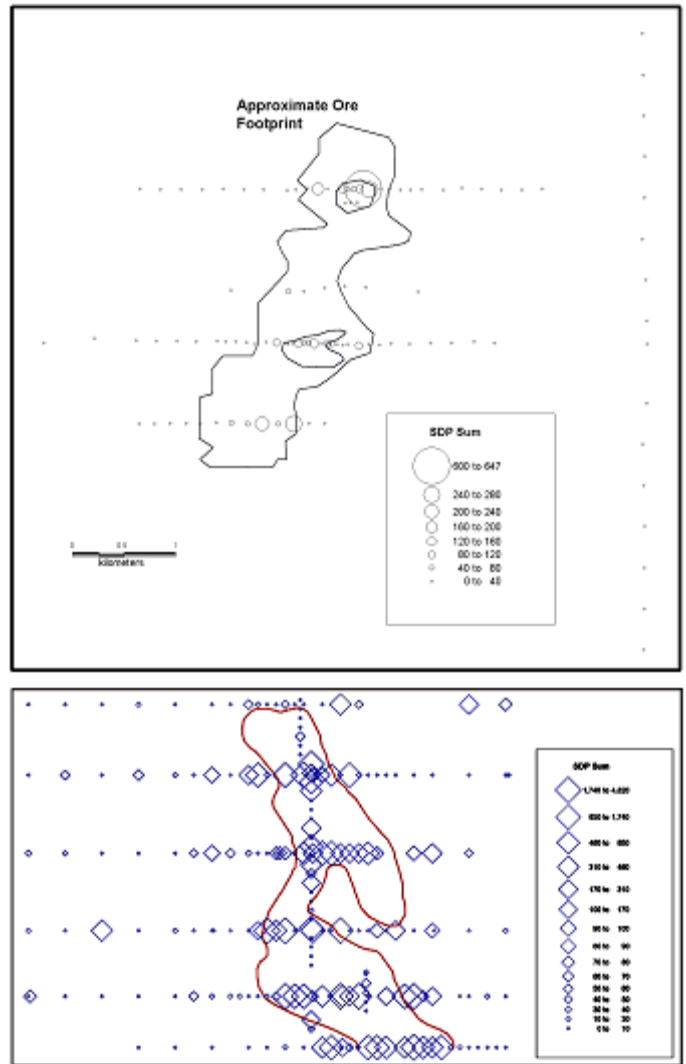


Figure 2: SDP response of a Chilean porphyry copper (top) and the Osborne iron oxide copper-gold deposit in NW Queensland. The same calibration is used in both surveys. Cover thickness is 100m of gravels in Chile, and at Osborne cover is 250m of Proterozoic volcanics plus 60m of Tertiary sediment. The surface projected ore footprint is shown in both cases. Clearly, the Osborne deposit would have been identified in an exploration survey using the Chilean calibration.

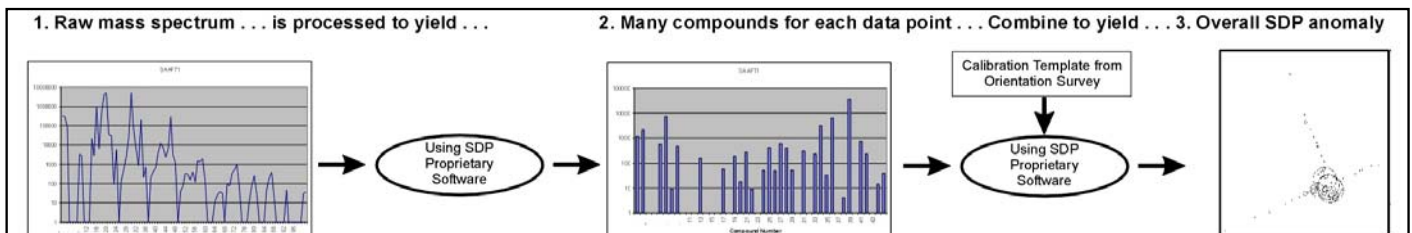


Figure 1: SDP Process overview

continued on page 25

Focus on: New Soil-Gas Chemistry...

continued from page 24



Carlin Style Gold

The pediments in the Basin and Range province of Nevada are a challenging geochemical environment. Debris shedding off the range fronts is often weakly mineralised, potentially obscuring signals from deeply buried mineralisation beneath the alluvium. Gas geochemistry is well suited to the area: the gravels are highly permeable, and the relatively rapid kinetics of gas transport and adsorption mean that even the young alluvium has had time to acquire a distinct soilgas signature above the deposit. The multivariate fingerprinting approach used by SDP is able to distinguish mineralisation from noise.

An orientation survey was made on a blind deposit in the middle of a pediment (unpublished data – details are confidential). The deposit is situated on a horst block of uplifted basement, resulting in a coverage of about 100m of alluvium over the deposit and much greater thicknesses in the background areas. A line of control samples was

collected across the range front fault to assess the effect of barren structure.

A collection of gas ratios has been defined which effectively discriminates between subcropping mineralisation and barren pediment. An extensive soil geochemical dataset in the same area was ineffective, with all the different strength leaches essentially responding to the provenance of the alluvium.

Application of SDP to other commodities

Recently, SDP has been applied to diamonds exploration with significant success. Work on distinguishing buried kimberlites from other barren geophysical targets was recently presented at the 23rd IGES in Dublin. Using a combination of SDP and partial leaches, BHPB has achieved 85% success rate in identifying kimberlite targets in blind tests, in terrain ranging from till in Canada to Kalahari sands in Botswana.

For other SDP news and information, see www.sdpsoilgas.com.



Call for Papers

International Conference on the Monitoring, Simulation and Remediation of the Geological Environment. 5 - 7 July 2004, Segovia, Spain. This conference aims to attract a multi-disciplinary audience of researchers, practitioners and government employees interested in the geological environment from diverse backgrounds, such as geologists, civil engineers, forest and agricultural engineers, geographers, biologists, ecologists, and hydrologists.

Papers are particularly being encouraged under the following topics:

EARTH'S MATERIALS AND RESOURCES

Sustainable exploitation of natural resources, Renewable energy, Surface and Groundwater resources, Soil and rock properties, Mineral resources, Geochemistry.

EARTH'S DYNAMICS

Earth's dynamic systems modelling and monitoring, Natural hazards and risks - assessment and mitigation, Oceans and coasts, Flow processes, Geo-indicators.

GEO-ENVIRONMENTAL PLANNING AND MANAGEMENT

Environmental impact assessment (EIA), Environmental planning and management, Geo-ecology and ecological surveys, Geo-technical and geo-environmental engineering, Scenery assessments and landscaping, Urban and regional planning issues, Geological and geomorphological heritage (geo-sites).

ENVIRONMENTAL REMEDIATION

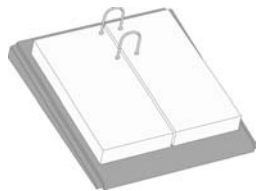
Environmental and ecological restoration of derelict areas, Waste management, treatment and disposal, Remediation and contaminated sites.

GEO-INFORMATION SOURCES

Remote sensing and GIS, Digital Terrain Models, Geo-statistics, Geo-databases.

Full conference details are available at:

<http://www.wessex.ac.uk/conferences/2004/geoenvironment04/index.html>
Karen Neal, Conference Marketing Manager, Email: kneal@wessex.ac.uk



CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry.

■ March 15-16, 2004, **GSA South-central section meeting**. College Station, Texas. INFORMATION: Chris Mathewson, gsa.aeg@geo.tamu.edu, (979) 845-2488.

■ March 25-27, 2004, **GSA Northeast/Southeast Section meeting**. Tysons Corner, Va. INFORMATION: George Stephens, (geoice@gwu.edu), George Washington University, 2029 G St NW, Washington, DC 20052-0001, Rick Diecchio, (rdiecchi@gmu.edu), George Mason University, Dept. of Environmental Science & Policy, MS 572, 4400 University Dr., Fairfax, VA 22030-4444

■ April 1-2, 2004, **GSA North-central section meeting**, St. Louis, Mo. INFORMATION: Joachim O. Dorsch, dorsch@eas.slu.edu.

■ April 21-23, 2004, **5th Biennial Interstate Technical Group on Abandoned Underground Mines Workshop**, Viscount Suite Hotel, 4855 East Broadway, Tuscon, Arizona, USA, by the Arizona Department of Transportation and Federal highway Administration. (Nick Priznar, 1221 North 21st Avenue, 068R, Phone: 602-712-8089 FAX: 602-712-8415 EMail: npriznar@dot.state.az.us Web: <http://www.fhwa.dot.gov/mine/minework.htm>)

■ May 3-5, 2004, **GSA Rocky Mountain/Cordilleran**, Boise, Idaho. INFORMATION: C.J. Northrup, Chair, (208) 426-1581, cjnorth@boisestate.edu

■ May 9- 12, 2004, EDMONTON 2004, Canadian Institute of Mining and Metallurgy - Annual General Meeting (CIM-AGM), Mining Industry Conference and Exhibition. More information: www.cim.org

■ May 17-20, 2004, **National Monitoring Conference: Building and Sustaining Successful Monitoring Programs**, Chattanooga Convention Center, Chattanooga, TN, by the National Water Quality Monitoring Council (NWQMC). (National Monitoring Conference Coordinator -, 10045 Red Run Blvd., Ste. 110, Owings Mills, MD 21117, Phone: 410-356-8993 FAX: 410-356-9005 EMail: nwqmc2004@tetrattech-ffx.com Web: <http://www.nwqmc.org>)

■ June 19-24, 2004 **Clay Minerals Society annual meeting**, Richland, WA, USA, by the Clay Minerals Society and Pacific Northwest National Laboratory. (Jim Amonette, Phone: 509-376-5565 FAX: 509-376-7972 EMail: jim.amonette@pnl.gov Web: <http://www.pnl.gov/cms/>)

■ June 27-July 2, 2004 **11th International Symposium on Water-Rock Interaction**, Saratoga Springs, New York, USA (Dr. Susan Brantley, Secretary General, Dept. of Geosciences, The Pennsylvania State University, 239 Deike Building, University Park PA USA 16802, Phone: 814-863-

1739 FAX: 814-863-8724 Web: <http://www.outreach.psu.edu/C&I/WRI/>)

■ August 20-28, 2004 **32nd Session of the International Geological Congress**, Florence, Italy (Chiara Manetti, Dipartimento di Scienze della Terra, Via La Pira, 4 - 50121 Firenze -ITALY, EMail: casaitalia@geo.unifi.it Web: <http://www.32igc.org>)

■ September 19-22, 2004, **8th International Congress on Applied Mineralogy (ICAM 2004)**, Aguas de Lindoia, Aguas de Lindoia, Sao Paulo, Brazil, by the International Council for Applied Mineralogy (ICAM); International Mineralogical Association - Commission on Applied Mineralogy (IMA-CAM). (Dogan Paktunc, 555 Booth Street, Phone: 613-947-7061 FAX: 613-996-9673 EMail: dpaktunc@nrca.gc.ca Web: <http://www.icam2004.org>)

■ Sep 27-Oct 01, 2004, **SEG 2004: Predictive Mineral Discovery Under Cover**, University of Western Australia, Perth, WA, Australia, by the Society of Economic Geologists (SEG), Geoconferences WA, and Society for Geology Applied to Mineral Deposits (SGA). (Susan Ho, P.O. Box 80, Bullcreek WA 6149, Australia, Phone: (61 8) 9332 7350 FAX: (61 8) 9310 6694 EMail: susanho@geol.uwa.edu.au Web: <http://www.cgm.uwa.edu.au/geoconferences/index.asp>)

■ October 10-15, 2004, **SEG International Exposition & 74th Annual Meeting**, Denver, Colorado, US, by the SEG. (Debbi Hyer, 8801 S. Yale, Tulsa OK 74137, Phone: (918) 497-5500 Email: dhyer@seg.org Web: <http://meeting.seg.org>)

■ November 7-10, 2004, **Annual Meeting of the Geological Society of America**, Seattle, Washington. INFORMATION: TEL 1-800-472-1988, meetings@geosociety.org.

■ November 25 – 27, 2004, **International Karakorum Conference** to be held at Islamabad, Pakistan. This meeting will cover a wide range of topics, including mineral exploration, metallogeny and geochemistry. Information: Prof. Dr. F. A. Shams, Lahore, Pakistan. pags@yahoo.com or telefax: 092-42-9230236.

■ February 28-March 2, 2005, **2005 SME Annual Meeting and Exhibit**, Denver, CO. INFORMATION: Meetings Department at 800-763-3132 or 303-973-9550. http://www.smenet.org/meetings/calendar/event_calendar.cfm

■ May 15 through May 18, 2005, **Geological Society of Nevada Symposium 2005** Sparks, Nevada USA, INFORMATION: Geological Society of Nevada (gsnsymp@unr.edu)

Please check this calendar before scheduling a meeting to avoid overlap problems. Let this column know of your events.

Virginia T. McLemore

New Mexico Bureau of Geology and Mineral Resources

New Mexico Institute of Mining and Technology

801 Leroy Place

Socorro, NM 87801 USA

TEL: 505-835-5521

FAX: 505-835-6333

e-mail: ginger@gis.nmt.edu



Association of Exploration Geochemists Publications

DISTINGUISHED LECTURER SERIES CD AND VIDEO TAPES

- No. 1: 2002 - The Kola Geochemistry Project: An environmental investigation in Arctic Europe.*
2002 Distinguished Lecture Series by Clemens Reimann, Norway. US\$20.
- No. 2: 2002 - Geochemical Provinces: Do they exist and what is their relation to regional Geology.*
2002 Distinguished Lecture Series by Clemens Reimann, Norway. US\$20.

SPECIAL VOLUMES

- Sp Vol. 4: *Application of Probability Plots in Mineral Exploration*, A.J. Sinclair. US\$12.
- Sp Vol. 14: *PROBLOT*, An Interactive Computer Program to Fit Mixtures of Normal (or Log Normal) Distributions with Maximum Likelihood Optimization Procedures. C.R. Stanley. On 3.5" diskette. US\$55.

OTHER PUBLICATIONS

- A Global Geochemical Database for Environmental and Resource Management, Recommendations for International Geochemical Mapping*, Final Report of IGCP Project 259, A.G. Darnley, A. Bjorkland, B. Bolviken, N. Gustavsson, P.V. Koval, J.A. Plant, A. Steinfeld, M. Tauchid and Xie Xuejing; with contributions by R. Garrett, and G.E.M. Hall. US\$20.
- Applied Biogeochemical Prospecting in Forested Terrain*, C.E. Dunn, G.E.M. Hall, and R. Scagel, short course notes. US\$50.
- Applied Biogeochemistry in Mineral Exploration and Environmental Studies*, C.E. Dunn, G.E.M. Hall, R. Scagel, D. Cohen, P. Catt, and M. Lintern, short course notes. US\$55.
- Biogeochemical Exploration, Simplified - with emphasis on arid terrains*, C.E. Dunn, J.A. Erdman, G.E.M. Hall, and S.C. Smith, short course notes. US\$50.
- Exploration Geochemistry; Design and Interpretation of Soil Surveys*, Reviews in Economic Geology Vol 3, ed. W.K. Fletcher. Co-sponsored by the SEG. US\$25.
- Geochemistry: Exploration, Environment, Analysis*, A one-year set of past issues US\$70.
- Journal of Geochemical Exploration*, in Subscription Years pre-1997, per year. US\$70.
- Practical Problems in Exploration Geochemistry*, 1987, A.A. Levinson, P.M.D. Bradshaw and I. Thomson, 269 p. US\$80.
- Writing Geochemical Reports*, Guidelines for Surficial Geochemical Surveys, 2nd Edition, Edited by L. Bloom. Free

AEG Member discounts apply for most publications. All payments must be made in US funds in one of the following formats: VISA, Master Card, American Express, personal cheque, International Money Order, UNESCO coupons, and International Postal Orders. For further information, verification of member discounts, and to place orders, contact:

ASSOCIATION OF EXPLORATION GEOCHEMISTS

Betty Arseneault, AEG Business Office

P.O. Box 26099, 72 Robertson Rd.

Nepean, Ontario, Canada K2H 9R0

Tel: 613-828-0199, Fax: 613-828-9288, email: AEG@synapse.net

Association of Exploration Geochemists APPLICATION FOR MEMBERSHIP*



Please complete only the relevant section for membership. See below for mailing instructions.

I, _____, wish to apply for election as a ___ Member / ___ Student Member of the Association of Exploration Geochemists. I have read the Code of Ethics of the Association and in the event of being elected a Member/ Student Member agree to honour and abide by them.

MEMBER: *State Employer and Employee title*

I am actively engaged in scientific or technological work related to geochemical exploration and have been so for the past two years.

_____ as a _____
(employer) (employment title)

STUDENT MEMBER: *Student status must be verified by a Professor of your institution or a Fellow of the AEG*

I certify that the applicant is a full-time student at _____ in pure or applied science.
(institution)

(Professor/ AEG Fellow Signature) (Printed Name and Title)

Witness my hand this _____ day of _____, 20_____. _____
(Signature of applicant)

NAME AND ADDRESS: PLEASE PRINT (to be completed by applicant)

Name: _____ Telephone bus: _____
Address: _____ fax: _____
_____ home: _____
_____ e-mail: _____

Annual Dues :

All applications must be accompanied by annual dues. All payments must be in US funds. Select one of the four listed below.

1 2004 member dues	US\$	70	_____
2 2004 student member dues		40	_____
- If receipt required, include a self-addressed envelope and add		2	_____
- If your check is not drawn from a U.S.A. or Canadian bank, add		15	_____
		TOTAL	_____

Payment by check, International Money Order, UNESCO Coupons, International Postal Orders, VISA, American Express and Master Card are acceptable. For credit cards users, minor variations in your billing may reflect currency exchange rate fluctuations at time of bank transaction.

Type: VISA ___ American Express ___ Master Card ___ Credit card account number: _____
Expiry date: _____ Name: _____ Signature: _____

***Application for voting membership requires the sponsorship of three voting members. Request a voting member application from the Association office.**

Please note: Your application form will be acknowledged upon receipt. The Admissions Committee reviews all applications and submits recommendations to Council, who will review these recommendations at the next Council Meeting or by correspondence. If no objection is raised the names, addresses and positions of candidates will be listed in the next issue of the AEG Newsletter. If after a minimum of 60 days have elapsed following submission of candidate information to the membership no signed letters objecting to candidates admission are received by the Secretary of the Association from any Member, the Candidate shall be deemed elected, subject to the receipt by the Association of payment of required dues. Send completed application, together with annual dues to:

Association of Exploration Geochemists
P.O. Box 26099, 72 Robertson Road, Ottawa, Ontario, CANADA K2H 9R0
TEL: (613) 828-0199, FAX: (613) 828-9288, email: aeg@synapse.net WEBSITE: <http://www.aeg.org>

THE ASSOCIATION OF EXPLORATION GEOCHEMISTS presents the
22ND INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM



22nd
IGES
2005

from Tropics to Tundra



**Perth, Western Australia
at the Sheraton Perth Hotel
19 - 23 September 2005**

Symposium Themes:

- Regolith - the continuum
- Discovery histories and geochemical exploration in tropical, temperate and glacial terrains
- Environmental geochemistry, analysis, data management, hydrothermal geochemistry
- Exploration in areas of transported overburden, biogeochemistry, isotope chemistry

Further Information

Secretariat: **Promaco Conventions Pty Ltd**
PO Box 890, Canning Bridge, WESTERN AUSTRALIA 6153
Tel: + 61 8 9332 2900 Fax: + 61 8 9332 2911
Email: promaco@promaco.com.au

Symposium website:

www.promaco.com.au/conference/2005/iges

Field Excursions:

- Mineral deposits of southwestern Western Australia (bauxite, gold, Sn-Ta and mineral sands)
- Mineral deposits and regolith evolution, Eastern Goldfields;
- Mineral deposits of the Pilbara.

PLUS pre- and post-conference excursions:

- Mineral deposits of eastern Australia (New South Wales);
- Geothermal systems: surface expression of epithermal mineralization in New Zealand.

Workshops

- related to field excursions (WA regolith - evolution and geochemistry, and WA mineral deposits - hard rock and regolith);
- general workshops (data management and processing, QC/QA; Lithogeochemistry)

EXPLORE

Newsletter No. 122 JANUARY 2004
 Editor: Mary E. Doherty (303) 278-6876 Fax: 303-215-0641
 MaryEDoherty@earthlink.net

Associate Editor:

Lloyd James (303) 741-5199 (l-njames@ecentral.com)

Assistant Editors:

Chris Benn (Chris.J.Benn@BHPBilliton.com)

Rob Howell (rhowell@srk.co.uk/srk003@aol.com)

Richard Carver (RichardCarver@gcexplore.com)

Patrick Highsmith (phighsmith@alschemex.com)

Robert Jackson (rgjackson@ctnis.com)

Allan Kelly (aj-kelly@bigpond.com)

Barry Smee (bwsme@attglobal.net)

Business Manager:

David Kelley (720) 554-8318 (dave.kelley@wmc.com)

David Seneshen, Associate Business Manager

Back Issues contact: Betty Arseneault (aeg@synapse.net)

EXPLORE is published quarterly by the Association of Exploration Geochemists, P.O. Box 150991, Lakewood, CO 80215-0991, USA.

EXPLORE is a trademark of the Association of Exploration Geochemists.

Type and layout of EXPLORE: Vivian Heggie, Heggie Enterprises, Thornton, CO (303) 288-6540; <vjmhggie@starband.net>

ADVERTISING RATES

Full page (Black & White)	241h x 190w mm	(9.5h x 7.5w in)	US \$ 970
Full page (Color)			US\$1165
Half page (Black & White)	241h x 89w mm	(9.5h x 3.5w in)	US \$ 530
or	124h x 190w mm	(4-7/8h x 7.5w in)	
Half page (Color)			US \$635
Third page (Black & White)	241h x 51w mm	(9.5h x 2w in)	US \$420
or	178h x 89w mm	(7h x 3.5w in)	
Third page (Color)			US \$505
Quarter page (B&W)	124h x 89w mm	(4-7/8h x 3.5w in)	US \$300
or	241h x 41w mm	(9.5h x 1-5/8w in)	
Quarter page (Color)			US \$360
Eighth page (Black & White)		60h x 89w mm(2-3/8h x 3.5w in)	US \$190
Eighth page (Color)			US \$230
Business Card (B&W)	51h x 89w mm	(2h x 3.5w in)	US \$ 50
Business Card (Color)			US \$ 60

Please direct advertising inquiries to:

DAVID KELLEY, WESTERN MINING CORP. (USA)
 8008 EAST ARAPAHOE COURT • ENGLEWOOD, CO 80112 • USA
 (720) 554-8318 Fax: (720) 554-8370 (dave.kelley@wmc.com)

LIST OF ADVERTISERS

Acme Analytical Laboratories, Ltd.	14
Activation Laboratories Ltd.	2
AEG Publications	27
ALS/Chemex	17
Becquerel Laboratories, Inc.-Canada	9
GCxplora	20
GeoPro Services, LLC	16
Geosoft	2
Karjeni	13
MEG Shea Clark Smith	7
MMI Technology	18
Robert G. Jackson	18
Rocklabs	15
SGS	32
22nd IGES 2005	29

THE ASSOCIATION OF EXPLORATION GEOCHEMISTS

P.O. Box 26099, 72 Robertson Road, Nepean,
 Ontario K2H 9R0 CANADA • Telephone (613) 828-0199

OFFICERS

January - December 2004

David Kelley, *President*

WMC Exploration
 8008 E. Arapahoe Ct., Suite 110
 Englewood, CO 80112 USA
 TEL: 720-554-8318
 FAX: 720-554-8370
 email: Dave.Kelley@wmc.com

Robert J. Howell, *Vice President*

SRK Consulting
 Windsor Court, 1 Windsor Place
 Cardiff, Wales CF10 3BX
 TEL: 442920348150
 FAX: 442920348199
 email: rhowell@srk.co.uk

David B. Smith, *Secretary*

U.S. Geological Survey
 Box 25046, MS 973
 Denver, CO 80225, USA
 TEL: (303) 236-1849
 FAX: (303) 236-3200
 email: dsmith@usgs.gov

Gwendy E.M. Hall, *Treasurer*

Geological Survey of Canada
 601 Booth Street, Room 561
 Ottawa, ON K1A 0E8, CANADA
 TEL: (613) 992-6425
 FAX: (613) 992-6425
 email: ghall@nrcan.gc.ca

COUNCILORS

Councilor Emeritus
 Sherman Marsh

2003-2005

Philippe Freyssinet (*ex-officio*)
 Robert Eppinger
 Allan Kelly
 Christopher Oates
 David Seneshen
 Cliff Stanley

2004-2006

Chris Benn
 William B. Coker
 Jeffrey Jaacks
 Robert Jackson
 Paul Morris

Australia

Leigh Bettenay
 Nigel Brand
 Mark Elliott

Brazil

Germano Melo Jr.

Chile

Alvaro Puig

China

Xueqiu Wang

Europe

J. B. De Smeth

Northern Countries

Vacant

Southeast Asia

Tawsaporn Nuchangong

Southern Africa

Charles Okujeni

UK and Republic

of Ireland

Deirdre M. A. Flight

COMMITTEES

Australian Geoscience Council

Representative
 David Garnett

Canadian Geoscience Council

Representative
 W. K. Fletcher

Awards and Medals Committee

Chair: Vacant
 William Coker
 Robert G. Garrett
 Jeff Jaacks
 Günter Matheis
 Barry W. Smee

Bibliography Committee

L. Graham Closs, *Chair*
 Robert G. Garrett
 Richard K. Glanzman
 Eric C. Grunsky
 Peter J. Rogers

Distinguished Lecturer Committee

Robert Howell, *Chair*

Election Official

Sherman Marsh

EXPLORE

Mary Doherty, Editor
 email: MaryEDoherty@earthlink.net
 Lloyd James, Assoc. Editor
 David Kelley, *Business Manager*
 David Seneshen, *Assoc. Bus. Manager*

Geochemistry: Exploration,

Environment, Analysis
 Gwendy E.M. Hall, *Editor-in-Chief*
 e-mail: GHall@nrcan.gc.ca

Admissions Committee

Nigel Radford, *Chair*
 Paul Morris
 Cliff Stanley

New Membership Committee

Robert Jackson, *Chair*

Publicity Committee

M. Beth McClenaghan, *Chair*
 Sherman P. Marsh
 J. Stevens Zuker
 R. Steve Friberg

Regional Councillor Coordinator

Philippe Freyssinet

Short Course Committee

Colin E. Dunn, *Co-Chair*
 Vlad Sopuck, *Co-Chair*

Student Paper Competition

Ian Robertson, *Chair*
 J.B. de Smeth
 Paul Morris
 Owen Lavin

Symposium Committee

Paul Morris, *Co-Chair*
 Nigel Radford, *Co-Chair*
 Eion Cameron
 Mario Desilets
 Philippe Freyssinet
 Gwendy Hall
 Virginia McLemore
 Barry W. Smee
 Graham F. Taylor

Web Site Committee

Richard Carver, *Chair*
 Rodrigo Vazquez, *Webmaster*
 email: galena@racsa.co.cr

Betty Arseneault, *Business Manager*

P.O. Box 26099, 72 Robertson Road, Nepean, ON K2H 9R0 CANADA,
 TEL: (613) 828-0199 FAX: (613) 828-9288, e-mail: aeg@synapse.net



Thank you!

The editors of the EXPLORE newsletter would like to thank all the Assistant Editors who contributed to the Focus Issues for the past two years:

*Chris Benn
Robert Howell
Richard Carver*

*Patrick Highsmith
Robert Jackson
Barry Smee*

Appreciation is also extended to the Graphic Artist, Vivian Heggie. Lloyd James assisted with editing each issue, and Steve Amor did a final grammatical check for the issues.

Thank you all for contributing to EXPLORE newsletter!

Chris Benn will be assuming the role of Editor for EXPLORE, and David Seneshen is now assisting as Associate Business Manager. Technical articles, letter to the editor, comments or suggestions for EXPLORE may now be forwarded to:

Chris Benn

Email: Chris.J.Benn@BHPBilliton.com

Phone: 1-604-632-1450

The Association of Exploration Gechemists Journal **Geochemistry: Exploration, Environment, Analysis**

Editor-in Chief

G.E.M. Hall

601 Booth St, Room 561, Ottawa, Ontario K1A 0E8 Canada

e-mail: GHall@NRCan.gc.ca

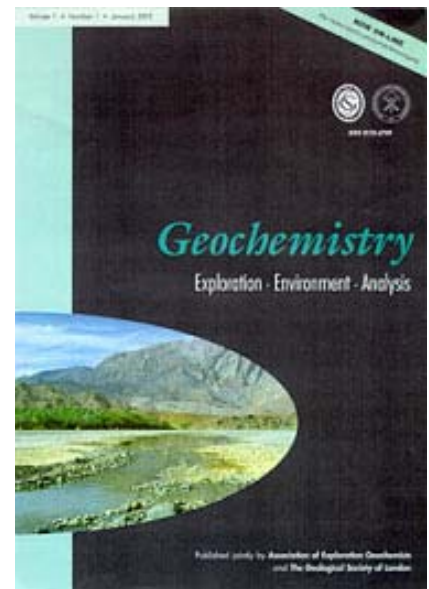
Associate Editors

C. R.M. Butt (Australia), P. Freyssinet (France), M. Leybourne (USA),
C. Reimann (Norway)

The GEEA Journal covers all aspects of the application of geochemistry to the exploration and study of mineral resources, and related fields, including the geochemistry of the environment. Topics include: the description and evaluation of new and improved methods of geochemical exploration; sampling and analytical techniques and methods of interpretation; geochemical distributions in and around mineralized environments; and processes of geochemical dispersion in rocks, soils, vegetation, water and the atmosphere. Papers that seek to integrate geological, geochemical and geophysical methods of exploration are particularly welcome. Given the many links between exploration and environmental geochemistry, the journal encourages the exchange of concepts and data; in particular, to develop mineral resources while protecting the environment.

GEEA is published in partnership with the Geological Society of London (<http://www.geolsoc.org.uk/>).

ASSOCIATION OF EXPLORATION GEOCHEMISTS



WHAT DOES IT MEAN TO BE COMPLETE?

It means delivering a full range of services to support you throughout your exploration program. As the world's leading verification, testing and certification company, we're committed to providing you with comprehensive solutions. That's why we've incorporated three outstanding organizations into our Minerals Services division. Using SGS to support your exploration projects now means that you get the expertise and capabilities that Analabs, Lakefield and XRAL contribute to the SGS Group.

To discuss how we can help you with your exploration programs, contact:
Africa/Australia/Asia • Ken Litjens, +61 (8) 9473 8100, ken_litjens@sgs.com
Americas, Rest of World • Russ Calow, +1 (705) 652 2018, russ_calow@sgs.com
www.sgs.com



SGS IS THE WORLD'S LEADING VERIFICATION, TESTING AND CERTIFICATION COMPANY

WHEN YOU NEED TO BE SURE



Paid Advertisement

EXPLORE

Newsletter for The Association of Exploration Geochemists

P.O. Box 150991, Lakewood, CO, 80215-0991, USA

Please send changes of address to:
Association of Exploration Geochemists

P.O. Box 26099, 72 Robertson Road, Nepean, Ontario, K2H 9R0, Canada • TEL: (613) 828-0199 FAX: (613) 828-9288
e-mail: aeg@synapse.net • <http://www.aeg.org/aeg/aeghome.htm>

PR SRT STD.
U.S. POSTAGE
PAID
DENVER, CO
PERMIT NO. 3550

AIR MAIL