

# EXPLORE

Newsletter for  
the Association  
of Exploration  
Geochemists

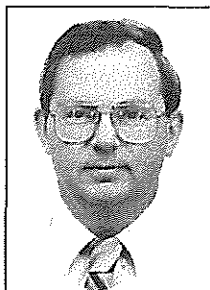


NUMBER 92

JULY 1996

## PRESIDENT'S MESSAGE

In Canada, we are just now finishing up our winter and spring drilling and once again moving out on the ground to start this summer's field work, including geochemical surveys of various kinds. Of much interest to many explorationists these days are a number of the recently developed selective extraction techniques such as "Enzyme Leach" and "MMI" (Mobile Metal Ion) as well as a number of older selective extraction techniques such as sodium pyrophosphate and hydroxylamine hydrochloride. Also, the increased use of ICP-MS by geochemical laboratories now allows detection of many metals at much lower levels, ppb and ppt, than was historically possible.



Bill Coker

It was during the 1970's that partial and/or selective extraction techniques were last heavily used in exploration. Interest, while still present, dropped off through the late 1970's and early 1980's, but was then rekindled in the late 1980's to early 1990's when scientists from the USSR introduced CHIM, MPF, and TMGM methods to the Western world. This prompted various organizations and individuals around the world into thinking about the possible mechanisms of metal transport to, and fixation within, surficial materials. Of particular interest was the potential of these selective extraction techniques to "see through" thick sequences of deeply weathered residual or transported exotic overburden covers to provide a tool which would allow the prioritization of geophysical targets in the search for "blind" mineralization. There are a number of articles in the recent literature describing the successful application of various selective extraction techniques in the discovery of "blind" mineralization. In most cases, the anomalous patterns from these selective extraction techniques tend to be very distinct, having generally high contrasts, but quite narrow, usually one to three closely spaced sample points.

From what I have seen, these techniques have the potential to offer a major breakthrough, on a world wide basis, in the successful use of geochemistry in the search for deeply buried mineralization. I applaud the initiative of the individuals and laboratories that have successfully developed and sold these techniques to the exploration industry. But, as with any geochemical method, caution must be taken. It is important to understand what form of the metal any particular selective extraction is going after. Care must be taken to collect the proper sample medium. Also, while ICP-MS allows us to detect much lower concentrations of many metals, one must be more aware of possible contamination and also that there is still work to be done to resolve matrix and/or instrumentation problems in the selective extraction

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## 50 YEARS AGO

### The birth of the USGS Geochemical Prospecting Unit

by Herb Hawkes

July 1996 marks the 50th anniversary of the Geochemical Prospecting Unit of the U.S. Geological Survey (USGS). [The Geochemical Prospecting Unit took on many other names over the next 50 years, including Branch of Exploration and Branch of Geochemistry, and in 1996 lost its name as a distinct entity. *Eds.*] This was the beginning of the Survey's involvement in exploration geochemistry, and was, in fact, the first concerted effort by any organization outside the Soviet Union to develop the idea of using trace elements as an aid in mineral exploration.

Of the small group of starry-eyed enthusiasts who took part in these early beginnings, I am one of only two survivors. Lyman Huff, Bert Lakin, and Pete Sokoloff are no longer with us. Since there is nobody else who remembers the dramatic events that took place during the first month or two, I guess I am sort of automatically delegated to tell about it.

Perhaps it is a bit excessive to say that the situation in July, 1946, was dramatic, but at the time it seemed that way. Three of us, Helen Canon, Lyman Huff, and I were thrown together with the common idea that maybe trace elements could be used as a guide in prospecting for ore deposits. Helen was a geobotanist, Lyman a hydrologist, and I was an ore-deposits type. We had just been told that we had \$125,000 to spend in one year on trying to develop our ideas—that was equal to more than a million in today's dollars. That was great, but we had no space allotted for the project, no laboratory, and no access to analytical services. None of us had more than a smattering of chemistry in our backgrounds. Furthermore, the chemists of the Survey were of no help at all. This whole thing was not their idea, and they wanted no part of it.

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## Information for Contributors to EXPLORE

**Scope** This Newsletter endeavors to become a forum for recent advances in exploration geochemistry and a key informational source. In addition to contributions on exploration geochemistry, we encourage material on multidisciplinary applications, environmental geochemistry, and analytical technology. Of particular interest are extended abstracts on new concepts for guides to ore, model improvements, exploration tools, unconventional case histories, and descriptions of recently discovered or developed deposits.

**Format** Manuscripts should be double-spaced and include camera-ready illustrations where possible. Meeting reports may have photographs, for example. Text is preferred on paper and 5- or 3-inch IBM-compatible computer diskettes with ASCII (DOS) format that can go directly to typesetting. Please use the metric system in technical material.

**Length** Extended abstracts may be up to approximately 1000 words or two newsletter pages including figures and tables.

**Quality** Submittals are copy-edited as necessary without re-examination by authors, who are asked to assure smooth writing style and accuracy of statement by thorough peer review. Contributions may be edited for clarity or space.

All contributions should be submitted to:

### EXPLORE

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## NOTES FROM THE EDITORS

*Sherman Marsh and Tom Nash*

Of particular interest in this issue is the short article by Herb Hawkes on the start of exploration geochemistry in the U.S. Geological Survey. When we received this article we were reminded of the wealth of anecdotal material that must exist concerning the early days of exploration geochemistry and the Association. We would be extremely interested in additional articles, especially from those of you who remember first hand the beginnings of our discipline and the Association. Alan Coope touched on this in his address at Townsville, Australia last year and we know there must be others who have recollections of the "early days".

We also would like to draw your attention to a new member service. We now have a web site and would encourage those of you with internet access to visit it. The address is:

<http://aeg.org/aeg/aeghome.html>

A major vote of thanks goes to Eric Grunsky for constructing the web site for us and putting in all the information. There are links to information on the 18<sup>th</sup> IGES in Jerusalem and the 4<sup>th</sup> ISEG in Vail, Colorado as well as general information about the Association. Please visit our home page and let us know what you think. We would appreciate suggestions for additional items and any changes or corrections you might have.

EXPLORE is always looking for articles, either as Technical Notes or as items of general interest. We can generally print your article in the next issue or certainly the one after that. So, please send us your contributions, they're what make EXPLORE one of the most highly regarded newsletters around.

*Sherm and Tom*



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## President's Message

*continued from page 1*

analyses of geological materials. Too often in geochemistry there has been a tendency for explorationists to want to "Black Box" geochemistry—just throw any material in a bag and send it to the laboratory. A technique becomes accepted as a universal panacea, is misapplied, then loses favor and disappears. Once again geochemistry rises in use only to tumble to depths. We all have seen this cycle before. I would not like to see this happen here. If these techniques are going to provide a real breakthrough, there needs to be an ongoing dialogue between the geologist/geochemists using these techniques in the field with the developers and laboratories providing these selective extraction methodologies. Furthermore, we must work towards understanding the processes of metal transport through thick covers over mineralization as well as the processes of metal fixation on near-surface surficial materials. Enough said! Please keep the dialogue going.

On another front, as time is fast approaching for the 18th IGES, I would urge all AEG members to take particular note of the announcement about the 18th IGES in Jerusalem, Israel, May 25-27, 1997 that appeared in EXPLORE 91. If you have any interest in attending, please take the time to contact the organizers to let them know your plans—as an attendee or as a presenter of a talk or poster or as a participant on a field trip.

My review of the By-laws of the AEG is progressing somewhat slower than I would like but is still underway. As I stated previously, anyone who has any suggestions or concerns regarding the By-laws is welcome to express such to me, or to any member of the Executive or Council. And, as I have stated before, please feel free to contact me or any member of the Executive or the Council on any matter to do with the AEG: we definitely seek your input and participation in your AEG.

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## 50 Years Ago...

*Continued from Page 1*

So there we were, three crazy nuts with nothing but a lot of half-baked ideas, and a lot of money.

How did we get into such a situation? For that we need to go back about two years to the latter part of WWII, when Bill Bradley, Chief Geologist of the Survey, circulated a memo to everybody to say that they could see the end of the War, and that management would like to have people submit ideas for possible post-war research projects. Each of us, Helen, Lyman, and I sent in our ideas. Helen's was that vegetation growing on soils that were poisoned with heavy metals might indicate the presence of metal-bearing deposits buried beneath the surface. Lyman's suggestion was that ground water circulating through a buried metalliferous deposit might dissolve traces of the metals that could be detected in spring or surface water down drainage from the deposit. My big idea was that weathering and erosion of the outcrop of a

deposit might leave a pattern of trace metals in either residual or glacial soils that could be used as a guide in prospecting.

Anyway, when the War ended in 1945 and all the suggestions were gathered together, the similarities in our three ideas were pretty obvious. I was asked to write up a project proposal with an itemized budget for Fiscal 1947. How much? Well, this was such a crazy idea that nobody would probably take it very seriously, but if we asked for a lot of money, the old Budget Bureau might not cut out the item entirely. So, how about \$125,000. And that was how it was set up.

After I wrote up our proposal, we all scattered to our various non-geochemical activities and awaited developments.

The announcement came in June, 1946. The Budget Bureau had approved the full amount of what we had "requested." In fact it was the only item in the entire Survey budget that was not cut at all. Panic set in. Nobody had a clue as to what to do with a project that had no traditional classification within the Survey structure. And who was going to run it? None of us had any experience, interest, or talent for the kind of administrative work needed to get such a thing started.

Anyway, they called the three of us together: Lyman from a ground-water project in Wisconsin, Helen from off in the boonocks somewhere, and me from Alaska. What to do now?

We couldn't have survived without the wholehearted collaboration and assistance from many other Survey

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## 50 Years Ago . . .

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geologists. Through the Washington grapevine, it was learned that a project at the Bureau of Plant Industry in Beltsville, Maryland involving minor-element nutrition in crops was being terminated and that they had a well-equipped laboratory and staff for trace-element analysis. And they would be delighted to collaborate with us. That really saved the day. Bert Lakin was in charge of that lab, and his tremendous contribution to the art of exploration geochemistry started when we joined forces with his lab.

What about field projects? Perhaps it was silly, but we all felt that we were on such tenuous ground that we needed some really spectacular demonstrations of the effectiveness of our screwball chemical prospecting methods if we were to continue to get appropriations for future years. So off we went into the field, for three frenetic research projects.

Helen's project was at a truck-farming tract in western New York where crops were being poisoned by zinc of unknown origin. She demonstrated very neatly that the zinc came from zinc mineralization in the underlying Lockport Dolomite. Lyman had been experimenting with the miracle colorimetric reagent dithizone, and had developed a field method for determining zinc in water. With his field kit, he was able to show the distribution of zinc in surface and ground water in the southeastern Wisconsin lead-zinc district. My own effort was to see if there was more zinc in the ground moraine south of the Edwards-Balmat zinc district in the northern Adirondacks than there was in the moraine north of the deposit. Luckily it turned out that there was! So we felt redeemed, justified, our dreams confirmed, our ideas no longer completely crazy.

From then on, things proceeded in a more orderly way. We never again had the strange empty feeling of facing a huge array of very practical problems armed with nothing but some raw ideas and a conviction that we were basically right about what we were doing, but had not been able to convince anyone else of it.

**Herb Hawkes**

*Kendall at Hanover*

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*Hanover, NH 03755-1229*



## LETTER TO THE EDITORS

The gold collector system described by Garnett and Butler (EXPLORE 91, p. 16) is really a gold recovery system akin to that used industrially and called *carbon-in-leach* (CIL) cyanidation. This technique has merits when trying to establish recovery of gold from large heterogeneous field samples using cyanide. Examples using several techniques, including CIL, with Alaskan ores were presented in 1987 (Treatment of Alaskan Refractory Gold Ores, by W.R. McDonald, J.L. Johnson, and R.G. Sandberg, Northwest Mining Association, Dec. 3-5, 1987) In this presentation it was demonstrated that proper gold extraction with cyanide needs first: freeing the gold from lock-up ores or encapsulation by fine grinding; second, removal of cyanicides, also called preg robs; and third, adequate oxygen source. Recently, I also studied the preg robs for gold cyanidation in more detail (E.L.

Kothny, 1994, Loss of Gold from Cyanide Solutions: Int. Calif. Mining Jour., v. 63, p. 65). Before reaching a definite conclusion about gold content using CIL, it is important to establish recovery in the presence of common contaminants. I noticed that AAS was used after ashing the activated carbon. Commercial charcoal often contains significant amounts of iron, calcium, and other metals and more of the same are added to the carbon during cyanidation. Most of these enhancers severely interfere with quantitation of gold by spectrographic methods.

**Evaldo L. Kothny**

*Walnut Creek, CA 94598*

*June 12, 1996*

## NEWS OF COUNCILORS

The role of AEG Regional Councilor for Western Australia has been taken over from Russell Birrell by Leigh Bettenay and Nigel Radford. Leigh is currently Principal Geochemist for Mount Isa Mines, based in Perth, and Nigel, also Perth-based, is Chief Geochemist for the Normandy Mining Group of companies. Bearing in mind the time requirements of both employers and families, it seemed like a good idea that they share the work and responsibilities of the Regional Councilor role.

Nigel may be contacted by FAX at (619) 480-3270 or TEL (619) 480-3232. Leigh can be reached at FAX (619) 321-2866 or E-mail: 100253.1020@compuserve.com.

## TECHNICAL NOTE

### Ferruginous Lag Geochemistry: Practical Aspects and Limitations

*by I.D.M. Robertson*

#### INTRODUCTION

Ferruginous lag, a surface veneer of ferruginous saprolite and/or lateritic nodules and pisoliths, left after removal of soil fines by wind and water, is common on mafic and ultramafic rocks on the Archaean Yilgarn Craton of Western Australia (Anand, 1995). Because it is rich in hematite, goethite and maghemite, which readily adsorb and incorporate indicator elements, it provides an excellent geochemical sampling medium for the detection of Au and base metal ore deposits where it has been shown to give a broader and stronger geochemical anomaly than equivalent soil fractions (Carver *et al.*, 1987).

The geochemistry, and other attributes, of lag-covered surfaces above the Bottle Creek, Beasley Creek and Lights of Israel gold deposits (Fig. 1) were studied prior to mining during CSIRO/AMIRA Projects 240, 241, 240A and 241A. The study sites provided a range of lag-covered regolith situations. Bottle Creek has a complex terrain with a relatively complete, though partly obscured, lateritic profile at the Emu gold deposit, grading to areas stripped to saprolite and buried beneath sheetflood colluvium-alluvium and fluvial gravels as at the VB-Boags deposits (Fig. 2a). A partly-truncated profile at Beasley Creek, complete with a partly preserved lateritic duricrust and upper saprolite,

## Technical Note

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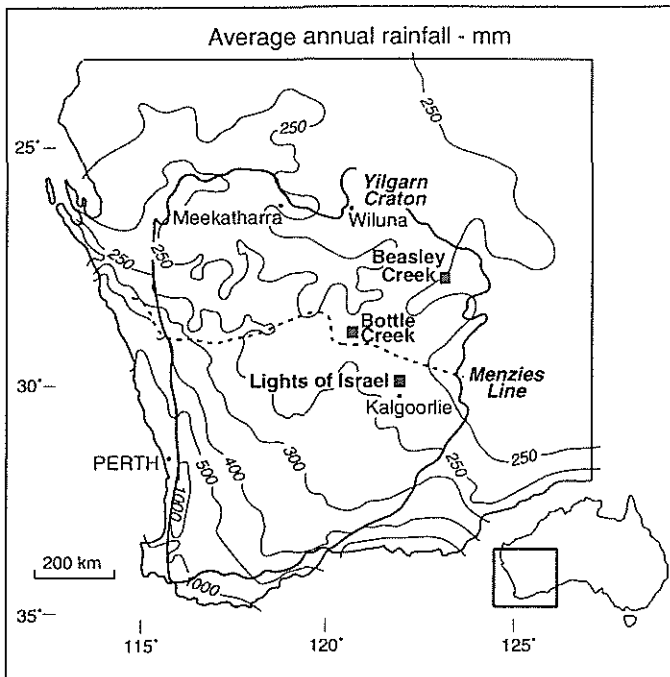


Figure 1. Location map of lag geochemistry orientation sites on the arid parts of the Yilgarn Craton of Western Australia showing contours of average annual rainfall (mm) and the Menzies Line.

protrudes through surrounding sheetwash colluvium-alluvium (Fig. 2b). Drilling and mining also revealed a palaeo-channel filled with Permian glacial debris. Most truncation has occurred at the Lights of Israel gold Deposit, where the lower saprolite is partly covered by fluvial gravels and all are mantled by a thin, calcareous soil (Fig. 2c). Beasley Creek lies well to the north of the Menzies Line, Bottle Creek lies very close to this important environmental dividing line and Lights of Israel is located to its south (Fig. 1).

### CLUES FROM EXTERNAL AND INTERNAL APPEARANCES

The outward appearance of lag gives clues to the nature of the underlying regolith. Where the lag consists of light brown to yellow-brown nodules and pisoliths, complete with cutans, the underlying regolith is probably lateritic duricrust. Where the lag consists of brown fragments of ferruginous saprolite, there is probably underlying saprolite. Both these lag types are monomictic, although they may contain some quartz fragments, and indicate relict and erosional regimes respectively. Where the lag is polymictic, containing lithic fragments from erosional regimes and worn pisoliths from relict environments, with cutans showing signs of extensive wear and other fragments such as quartz, the underlying regolith is probably transported (Anand, 1995), indicating a depositional regime. Understanding the distribution of these regimes is critical to sampling strategy.

Examination of internal fabrics of coarse lag fragments at all three sites has potential for recognition of the underlying rocks. Although interpretation of lag fabrics is complicated by saprolitic and pedogenic retexturing of various kinds, some primary fabrics remain, e.g., pseudomorphs of olivine

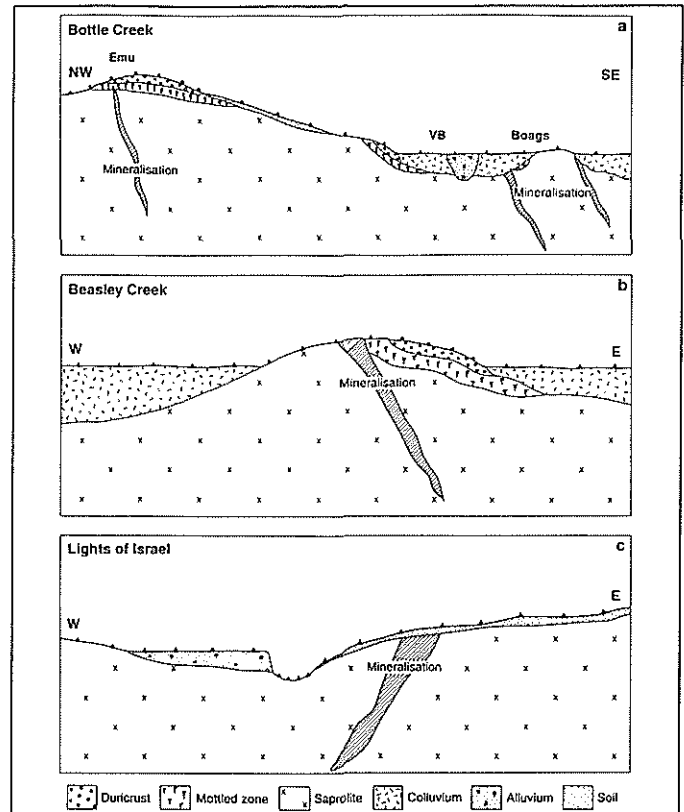


Figure 2. Regolith models for the (a) Bottle Creek, (b) Beasley Creek and (c) Lights of Israel study sites.

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## Technical Note

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and pyroxene and relics of chromite in peridotite, relics of mica pseudomorphing the fabric of phyllite, pseudomorphed Permian tillite, gossan, various pseudomorphed ore-zone sulfide fabrics and goethite pseudomorphed saprolitic clay fabrics (Robertson, 1996).

### LAG SAMPLING

Lag sampling is particularly simple. It can be swept from the surface, using a plastic dustpan and brush. Choice of the optimum size fraction is important and should be established by orientation. The sample may be sieved on site. It is advisable to take several samples from a 5-10 m radius around the sample site to ensure a site sample that is as representative as possible. At acceptable sites, the lag is evenly distributed and there is a wide variety of sizes. Incipient stream channels should be avoided; here, the lag is strongly size-sorted and is unlikely to have local relevance.

Both coarse (10-50 mm) and fine (0.5-10 mm) lag are effective sampling media but, with coarse lag, a representative sample would need to be very large (>>1 kg). Coarse lag tends to have less lateral dispersion due to its resistance to aeolian and sheetwash action, and hence targets mineralisation more accurately. If a representative sample can be obtained by collecting several kilograms of sample, which is tedious and may not be possible at all sites, coarse lag could be used for follow-up work. At Beasley Creek, spikes of up to 12 ppm Au closely defined the location of the

ore subcrop in the coarse lag; these samples undoubtedly contained fragments of gossan. Generally, fine lag is to be preferred as it gives a broader (more dispersed) but less intense anomaly. In some situations, the relatively coarse, ferruginous fraction (0.5-10 mm) of the soil may provide a material equivalent to fine lag. Much depends on what is available on site; this should be determined by a thorough orientation survey.

### MAGNETIC FRACTION

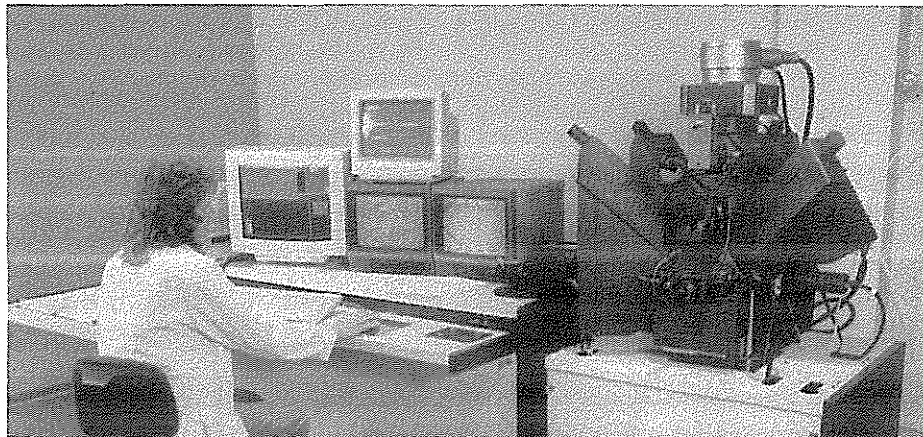
Some particles of fine lag are, in part, magnetic, due to a variable content of maghemite, largely generated by heating from bush fires. Magnetic separation of this material in the field or laboratory yields a very consistent ferruginous material which has analytical advantages by providing a consistent matrix. This practice was assessed to determine whether there were any exploration advantages in using complete, magnetic or non-magnetic lag samples.

Petrographic examination of material from Beasley Creek showed that the magnetic material, which makes up about 20-40% of the lag, consists of dark, glossy, compound granules of hematite, maghemite and goethite. The largely non-magnetic material also consists of similar, glossy haematite and goethite granules with additional, red-brown and yellow-brown granules of haematite- and goethite-stained clay, fragments of quartz and calcrete. Close to mineralisation, a very small (<1%) but geochemically most important component, consisting of cellular gossan, occurs in the lag; *this is entirely non-magnetic*. Petrographic examina-

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## Technical Note

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tion revealed goethite pseudomorphs after sulphides. Gossan fragments from Bottle Creek were also non-magnetic.

Geochemical analyses of materials from Beasley Creek showed that, for Au, there is little difference between the magnetic and the non-magnetic materials. However, for the important pathfinder elements (As, Sb, Cu, Se, Zn), the anomaly is contained almost exclusively in the non-magnetic fraction. The gossanous material contains these elements in elevated proportion. These elements showed a slightly improved signal to noise ratio in the non-magnetic samples compared to the complete lag. As the non-magnetic component made up about 60-80% of the total sample, only a slightly improved performance would be expected by analysing it separately. Thus, it seems there is nothing to be gained and much to lose by using magnetic lag fractions in geochemical exploration in the Yilgarn.

### INFLUENCE OF LANDSCAPE

Lag is an excellent geochemical medium, if used on the appropriate regolith-landform. It works well on relict and erosional regimes but is unlikely to represent the underlying Archaean geology under a depositional regime (Anand, 1995). An area around Bottle Creek, containing concealed, sulfide-rich gold mineralisation, provided a variety of regolith-landforms, including relict, erosional and depositional regimes (Fig. 2a), where sampling strategies were assessed.

Sampling on a 1 km triangular grid was effective in detecting a large (>300 m) As and a smaller (>150 m) Au anomaly in areas underlain by lateritic residuum and very thin colluvium around Emu. These anomalies are truncated by areas of colluvium- and alluvium- covered plains and alluvium-filled drainages, despite the presence of the VB-Boags deposits beneath these areas. Slightly more detailed sampling on a 0.5 km triangular grid produced very similar results. Detailed sampling on a 0.1 km pattern or less was needed to detect very small anomalies that occurred where the colluvial-alluvial cover was locally particularly thin (0.1-0.5 m) over VB-Boags (Wills, 1992). Very restricted Au anomalies were also found in lag at Lights of Israel, where there has been considerable stripping of the regolith.

Lag geochemistry is effective in relict regimes, particularly where the lateritic duricrust subcrops beneath a thin, stony soil (Fig. 3). In contrast, its effectiveness is severely limited in depositional areas, by the thickness of the transported veneer and the ability (or inability) of bioturbation to bring geochemically anomalous material to the surface. This is made more difficult where the layer of colluvial-alluvial sheetflood debris has been silicified. Sporadically, where this transported veneer is extremely thin, the lag shows a few indications of mineralisation. Where saprolite is overlain by narrow channels, filled with fluvial gravels, geochemical signals are completely prevented from becoming incorporated in the lag.

### PATHFINDER ELEMENTS

The success of multi-element lag geochemistry is very dependent on a useful pathfinder element suite characterising the primary mineralisation. Some sulfide-rich orebodies are very rich in pathfinder elements (Beasley Creek (As, Cd, Cu, Mo, Pb, Sb, W, Zn), Bottle Creek (As, Sb, Pb)); in contrast,

others are sulfide-poor and consequently have particularly low levels of chalcophile indicator elements.

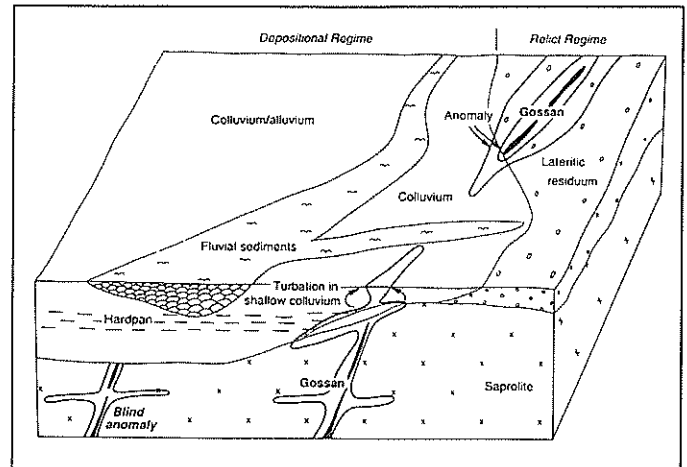


Figure 3. Model for lag geochemical exploration in different regolith-landforms, showing a significant dispersion halo in the relict regime but very limited dispersion in lag only where colluvium is very thin. Where colluvium is thick or there is a cover of alluvial sediments, geochemical dispersion is prevented from being recorded in the lag and subsurface sampling is necessary.

### CONCLUSIONS

The results of investigations on ferruginous lag at Bottle Creek, Beasley Creek and Lights of Israel have the following important implications for exploration in the Yilgarn of Western Australia.

- Lag sampling is very effective in areas of relict regimes, particularly where lateritic duricrust subcrops beneath a very thin soil. It is also effective where regolith has been stripped. The scale of a lag sampling pattern needs to be adjusted to suit the degree of regolith preservation; use broadly spaced samples (0.5 km) where the regolith profile is complete or nearly complete and close-spaced sampling (0.2-0.1 km) where regolith has been significantly stripped.
- The success of lag sampling in areas of colluvial cover is highly dependent on the cover being very thin and on the ability of soil turbation processes to bring anomalous material to the surface; therefore, it is not generally recommended and should be replaced by drilling or trenching.
- Fine lag may be swept from the surface or the equivalent coarse fraction of the soil may be sieved on site, where lag is not well developed. If coarse lag is used, sufficient sample needs to be collected to provide a representative sample; fine lag is preferred, particularly for reconnaissance.
- Multi-element analysis for at least As, Au, Bi, Cd, Cu, Mn, Pb, Sb, W and Zn of total lag is recommended for gold search. Use of only a magnetic fraction is not recommended, particularly if any reliance is to be placed on indicator elements other than Au which may be present in non-magnetic gossan chips. The total lag sample is preferred.
- Overall, mapping the distribution of lag types assists regolith-landform mapping and the planning of sampling programs. Internal fabric analysis of lag helps in identify-

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## Technical Note

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ing underlying rocks. Geochemical analysis of lag is an excellent prospecting method on relict and erosional landscapes. The need for such non-invasive, environmentally-conscious techniques is likely to increase.

### ACKNOWLEDGMENTS

The support of the sponsors of CSIRO/AMIRA projects 240, 240A, 241 and 241A is acknowledged with thanks. In particular, Aberfoyle Resources Ltd., Western Mining Corporation and North Exploration are thanked for access to their properties at Lights of Israel, Beasley Creek and Bottle Creek respectively.

This was presented as a paper at the 17th International Geochemical Exploration Symposium held in Townsville, May 1995; a more detailed version will appear in a forthcoming issue of the Journal of Geochemical Exploration.

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## BLEG SAMPLING IN GOLD EXPLORATION: an Australian View

by Nigel Radford

An aspect of everyday geochemistry which seems to be much used (and abused) in Australia, but seldom rates a mention overseas is the use of BLEG or BCL in reconnaissance sampling, stream sediments in particular. BLEG stands for Bulk Leach Extractable gold, whilst BCL stands for Bulk Cyanide Leach. Both acronyms refer to the same technique, although in detail various labs utilize somewhat different procedures. In essence, a large sample (usually 2 or 5 kg) of stream sediment or soil is leached in its entirety (actively or passively) in cold dilute sodium cyanide solution for a period ranging from one to several days depending on the lab concerned. The analytical finish varies, some labs using DIBK and the carbon rod AAS, others using a "sachet" of activated charcoal or zinc cementation to pre-concentrate the gold, and others relying on ICP-MS to provide a sensitive finish directly from the cyanide solution. The detection limits are usually 0.05 or 0.1 ppb Au in the original bulk sample.

This technique is not new. It was first offered commercially in Australia by its developer, Bill Griffin, as far back as 1981, following several years of development. A description of its application in northeastern Queensland is given in an appendix to a paper by Woods et al (1991, *Jour. Geochemical Exploration*, v. 36, p. 440-441).

Because detection limits in the range of 0.1 ppb Au or lower are now quite common in many commercial labs, one may ask why the additional trouble of collecting and analysing bulk samples is really necessary. They are, after all, heavy and awkward to carry out from remote terrain. Well, let's look at some sampling statistics. In the acronym BLEG, B is for BULK, but why is a large sample deemed to be essential? Consider the idealised situation of a 10 km<sup>2</sup> river catchment within which there is an exposed 1 million ounce gold ore body. If the entire catchment is lowered uniformly by erosion by 1 mm per year, 30,000 tons of sediment is generated. If the million ounce ore body has a 200 m vertical extent, there will be 150 g of gold per 1 mm, and that 150 g of gold will be diluted into the 30,000 t of sediment. The concentration therefore in the stream sediment at the 10 km<sup>2</sup> sampling point will be 5 parts per billion (ppb). This is highly idealised, but it gives an order of magnitude idea of the concentrations involved.

So if the commercial labs can achieve sub ppb detection limits, why bother with BLEG? Let's have a look at the particles of gold released into our 10 km<sup>2</sup> river system. Gold is normally present as flakes, so let's consider a flake 50 μm in diameter by 10 μm thick, which weighs 0.3 μg. Typically a 2 kg sample might be collected in the river, so one of our 50 x 10 μm flakes in 2 kg of sample constitutes a grade of 0.15 ppb.

We can see therefore that our stream sediment grading 5 ppb (from the 1 million ounce orebody), will have ONLY 33 gold flakes per 2 kg of sediment. Therefore the bigger the analytical sub-sample, the better. If we analyse the entire 2 kg as a BLEG sample, we will, of course, get the right answer, with all 33 flakes being digested. However, if we use conventional analysis of say a 20 g sub sample, things go wrong. The 20 g sub sample is one hundredth the size of the 2 kg sample. Therefore we have only a 33 divided by 100 or 33 percent

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## Technical Note

*Continued from Page 8*

probability of getting ONE gold flake in any particular 20 g sub sample. But even if we DO get one flake into the 20 g sub sample, it represents a grade of 15 ppb, not 5.0 ppb. We CANNOT get the right answer from such a small sub sample. The most likely results are: 2 out of 3 times we get zero gold and miss the 1 million ounce ore body, and the third time we get 15 ppb, not the correct value of 5 ppb. This creates highly erratic data, with true anomalies often being overlooked, and some true anomalies being over emphasised. If you collect less than 2 kg of sample, needless to say the statistics get even worse! Therefore BULK is important. BIG is BEAUTIFUL!!

Bearing in mind the high cost of putting the geologist on the ground to do a regional sampling programme (a recent helicopter supported programme in southeast Asia cost an average of \$US 1,200 per sample site), we, as geochemists, owe it to our employers and their shareholders, to collect the best sample we can. In the vast majority of cases, we will have no opportunity to re-visit the sample site. We have to do it right the first time. To be aware of these sampling statistics, and still only collect a few hundred grams of - 80 mesh for a 20 or 30 gram assay charge to a 1 ppb Au detection limit, is just not good enough!!

The table below shows a few deposits, large and small, where BLEG is known to have played a significant, but not necessarily exclusive, role in the discovery. This list is, of necessity, biased by the author's own experiences. Readers will note, however, that discoveries are restricted to Australia, SE Asia and the Western Pacific, and to areas where expatriate Australian geologists and mining companies have operated. Nevertheless, discoveries have been made over a wide range of climatic and regolith environments. Approximately 30 million ounces of gold resource is indicated by the deposits in this table. The author would be happy to add other deposits to the list, and if necessary, even remove some if their inclusion offends!

The photo below demonstrates the importance some companies attach to their BLEG sampling campaigns. The BLEG samples are so valuable that a soldier is assigned to guard each one individually!!



*BLEG samples are considered to valuable by some companies that an armed guard is assigned to each!! (Photo courtesy of Bruce Kay)*

*Continued on Page 10*



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## Technical Note

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Table 1. Some gold discoveries attributable in part to BLEG sampling programme

| DEPOSIT       | LOCATION         | COMPANY     | MEDIUM          |
|---------------|------------------|-------------|-----------------|
| Wirralie      | Queensland, Aus. | ACM         | Stream sediment |
| Tick Hill     | Queensland, Aus. | MIM         | Stream sediment |
| Toms Gully    | NT, Australia    | MIM         | Stream sediment |
| Granny Smith  | WA               | CSR         | Stream sediment |
| Neerambah     | WA               | ACM/BP Mins | Stream sediment |
| Dikili        | Turkey           | ACM         | Stream sediment |
| Mastira       | Turkey           | ACM/Norex   | Stream sediment |
| Batu Hijau    | Indonesia        | Newmont     | Stream sediment |
| Mesel         | Indonesia        | Newmont     | Stream sediment |
| Gosowong      | Indonesia        | Newcrest    | Stream sediment |
| Lerokis       | Indonesia        | CSR         | Stream sediment |
| Tolukuma      | PNG              | Newcrest    | Stream sediment |
| Mount Bini    | PNG              | BHP         | Stream sediment |
| Samphire      | WA               | Norex       | Soils           |
| Chalice       | WA               | Samantha    | Soils           |
| Griffins Find | WA               | Otter       | Soils           |
| Minjar MI     | WA               | Aztec       | Soils           |

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## BGS MEETING REPORT

### AEG - BGS Workshop on Environmental and Legislative Uses of Regional Geo- chemical Baseline Data for Sustainable Development

A very full one day Workshop was organised on the 27 March 1996, jointly by the AEG and the British Geological Survey (BGS). Sessions were held in the de la Beche Lecture Theatre at the Kingsley Dunham Centre, British Geological Survey Headquarters, Keyworth, Nottingham. The Workshop was organised in association with Global Geochemical Baselines IGCP Project 360 and with the BGS Minerals Industry Forum on the following day. The day preceding the AEG Workshop was taken up with a NERC-Institute of Terrestrial Ecology-BGS Workshop on Environmental Diagnostics. Hence those with professional, scientific, governmental and commercial interests in this rapidly evolving series of interrelated environmental geochemical fields were offered an excellent opportunity to get up to date on a broad spectrum of topical issues in an informal but stimulating environment.

The AEG Workshop delegates were welcomed by Dr. Peter Cook, Director of the British Geological Survey and the topic of the Workshop was briefly introduced by Professor Jane Plant, Assistant Director, Minerals and Geochemical Surveys Division. The first Session on 'Industrial Priorities

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## BGS Meeting Report...

*Continued from Page 10*

and Objectives' which was Chaired by Jane and Dr. Robert Garrett, Geological Survey of Canada was introduced by Claire Craig, herself an earth sciences graduate from Cambridge and Head of the Environment Group, Confederation of British Industry. Claire pointed out the need for fundamental reconsideration of industrial attitudes to science and development policy issues, especially in the light of the newfound power and strength of environmental groups. She was followed in this theme by Hugh B. Berridge of Hugh B. Berridge and Partners, Consulting Engineers and Scientists who indicated that the implications of the new UK Environment Act 1995 are far reaching and will require that much greater attention be paid in the future by consultants and their clients to the environmental applications of regional geochemical baseline data. This will particularly apply to systematically collected and interpreted data of the type maintained by geological surveys to international standards, developed by IGCP 360, under the leadership of Dr. Arthur Darnley of the Geological Survey of Canada who also attended the Workshop

The coffee break provided an opportunity for Dr. Peter Cook to officially launch and publicise to the press, the new BGS 1:625000 scale three part map series showing the Distribution of Areas with Above National Average Background Concentrations of Potentially Harmful Elements (As, Cd, Cu, Pb and Zn) - Radon Potential based on Solid Geology

- and Methane, Carbon Dioxide and Oil Susceptibility in the UK, all prepared by Dr. Don Appleton of the BGS with cooperation from Dr. Keith Ball, BGS, for the Department of the Environment and based in part on a combination of the BGS regional geochemical stream-sediment data and the Imperial College Wolfson Atlas. Eleven other posters on topical issues from international authors were also displayed.

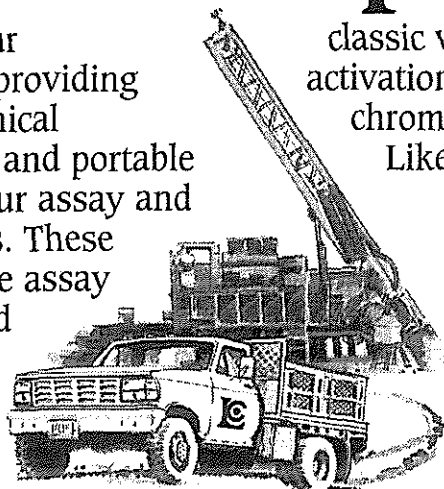
The next session addressed the Legal and Financial Framework and was led off by Dr. Charles Kirk of the Loss Prevention Council. Charles emphasised the need for access to geochemical baseline data with which to better inform clients, including the UK insurance industry. Next, Julian Kwolek FGS, a solicitor and a geologist, pointed out that the UK Environment Act 1995 is extremely significant because it represents the first comprehensive regime for identifying and then dealing with contaminated land. Julian highlighted the importance of the new contamination liabilities and the significance of migration of substances to adjacent or other land. It could be argued, for example, that an original polluter or current owner may be liable if he is aware of geogenic enrichment such as mineralisation on his land and knowingly permits it to escape to adjacent land thereby causing contamination. Julian therefore underlined the importance of geochemical baseline data in assisting with the interpretation and apportionment of the new liabilities and the remediation process.

The final session before lunch was chaired by Prof Iain Thornton of Imperial College Centre for Environmental Technology and Prof. Reijo Salminen, Geological Survey of

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## BGS Meeting Report

*Continued from Page 11*

Finland. They introduced Prof Fred Siegel, George Washington University, who spoke on Curative or Fix-it Modes in Sustainable Development--Importance of Baseline Geochemistry Data. Fred deployed a wide range of examples with financial, social and economic implications from global settings where baseline geochemical information, or the lack of it, played a significant role in the success or failure of a range of commercial enterprises. The cost of investment in baseline data and associated "preventative planning" usually forms only a small part of the project cost--less than 7%--which is sufficient to secure optimal use and yield in development, a small price to pay.

Following lunch a session chaired by Dr. Gwendy Hall, Geological Survey of Canada (and Past-President AEG) and Dr. Tony Bazley, Director of the Geological Survey of Northern Ireland addressed Case Studies on Soils. This session was designed to present an overview of the baseline data held by the principal research centres that are the main database holders and users of soil maps and soil chemistry in the UK and elsewhere. Dr. Peter Bullock, Director of the Soil Survey and Land Research Centre, discussed Sustainable Management Issues for English and Welsh Soils. For example, in parts of upland Wales remediation is required for very sensitive soils which are degraded and base deficient, partly due to continuous grazing by livestock. Regional and process geochemists could have a major role in devising and applying better land use strategies in such areas using geochemical

baseline data as the starting point. Dr. Ed Paterson from the Division of Soils, Macaulay Land Use Research Institute, provided a comparable perspective from north of the border. It is clear that there is much work to be done in the future by improved integration and interpretation of the regional geochemical data based on stream sediments at 1km<sup>2</sup> sample density with the lower sample densities usually used for soil mapping. Prof. Steve McGrath, Soil Science Department, Harpenden, and a co-author of the geochemical atlas of soils for England and Wales, discussed environmental applications of the soil-geochemical and stream-sediment data which are presently required, for example, in the development of sludge disposal strategies on agricultural land now that offshore dumping of sludge is no longer an option. The extent of Cd contamination in sludge relative to baseline Cd values in soils and stream sediments is one of the prime considerations. Dr. Richard God of the Geotechnical Institute, Vienna, provided an example of As contamination in Austrian soils and demonstrated the role of geogenic sources and baseline data from the Geochemical Atlas for Austria.

The final and longest session of the day commenced after tea with eight presentations on Case Studies based on Regional Geochemical Datasets. It was chaired by Ed Paterson and Dr. Miroslav Duris of the Czech Geological Survey. Bob Garrett and Gwendy Hall led off in a joint contribution based on a series of well illustrated maps of areas of geological and geochemical interest which demonstrate the power of the GSC's NGR data to distinguish and define the highly variable natural geochemical baselines in Canada. These data are increasingly used and uniquely valuable for defining geogenic versus anthropogenic contributions to the environment. Such definitions are a prerequisite for policy development because some parties presently tend to suggest that the presence of potentially harmful elements in the environment are essentially due to man's activities. The outcome will have major implications for the future of the minerals industry. Gwendy described environmental studies based on the deployment of ICP-MS for environmental and exploration studies of stream and lake waters.

Dr. Pavel Koval of the Vinogradov Institute of Geochemistry, Irkutsk, outlined the role of geochemical baselines in defining the local and regional impacts, especially on fresh snow, soil, water and biota from the urban-industrial-military complexes in eastern Siberia and the much more widespread historical (pre-Chernobyl) impact of <sup>137</sup>Cs throughout southern Russia from a wide range of experimental tests and other sources. Reijo Salminen provided a succinct account of the nationwide systematic geochemical databases for stream sediment, till and stream and lake water samples available for Finland with examples of their application to environmental studies.

Dr. Alecos Demetriades of Division of Geochemistry, IGME, Athens, showed how data originally collected as part of a mineral exploration programme from the early 1970s to the mid 1980s had been reused and reinterpreted since that time for the information they provide on environmental contamination and epidemiological studies. He strongly recommended further work in this area and outlined plans for the future analysis and production of multi-element stream sediment maps and atlases in Greece for use in planning and legislative activities. Jane Plant demonstrated the role and application of the BGS work on high resolution multi-element hydrogeochemical mapping in Wales, the

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## BGS Meeting Report...

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Welsh Borders and West Midlands areas of the UK. Baseline geochemical mapping of an essentially dynamic medium is facilitated by the high proportion of water in streams which is derived from the unsaturated zone. Jane described the large variation in water quality, ranging over three orders of magnitude in many cases, thus minimising the effects of short term variation. The close relationship between water quality, geology, geomorphology and land use was notable and complements information from stream sediments. Tony Bazley presented highlights from the new Geochemical Survey of Northern Ireland which is commissioned by a consortium of government departments in Northern Ireland for environmental and mineral-exploration purposes.

The new survey provides multielement high resolution geochemical maps of stream sediments and stream water samples using mainly local students for fieldwork and analytical facilities at the BGS. The Foyle and Erne catchments in the west are now largely completed and the data available from GSNi and BGS. Dr. James Baker of the Netherlands Geological Survey described his European Union-funded project on mine waste management of 200 million tons of pyritic ores and asbestos and chromite tailings, the analytical methods used and legislative aspects and environmental implications for Cyprus. He also summed up and thanked the organisers.

The workshop convener, Prof. Peter Simpson, thanked all the participants and closed the days' work with information on refereeing and publication of proceedings and submission of manuscripts to the JGE for release in a future Special Issue.

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## ANALYST'S COUGH

### Hydride generation: problematic- yes, but so powerful for low level detection of Se, Te and Bi

#### Introduction

This article builds upon the Technical Note by Steve Simpson and George Cartwright in the last issue of EXPLORE (#91, p. 13-16) where they warned geochemists about the pitfalls of determining Sb by acid digestion and hydride generation atomic absorption spectrometry (HG-AAS). I concur with their illustrations of problems such as incomplete digestion, possibility of hydrolysis for Sb and interferences in the measurement technique itself. In fact, I could cite more possible hazards. However, having produced over 100,000 analyses (for As, Sb, Se, Te and Bi) by this technique over the past 20 years, it would be remiss of me not to point out its advantages! In 1990 at the Geological Survey of Canada (GSC), we upgraded the method by switching from AAS as the measurement tool to the much more sensitive technique

of inductively coupled plasma mass spectrometry (ICP-MS). Although the higher abundance elements As and Sb can be determined by nebulisation (NEB) ICP-MS, Se, Te and Bi require the added detection power afforded by introduction of analyte as its hydride. For example, a 25 ppb Te solution yields a signal by NEB-ICP-MS of  $7166 \pm 240$  counts  $s^{-1}$  whereas 0.2 ppb Te introduced as the hydride produces  $25,850 \pm 900$  counts  $s^{-1}$ . This new method (HG-ICP-MS), described briefly below, not only provides much lower detection limits but negates many of the interferences encountered in HG-AAS.

The hydride is usually formed by addition of the strong reducing agent,  $NaBH_4$ , to an acidified (HCl) solution containing the analytes, derived conventionally from an aqua regia decomposition. The gaseous hydride (e.g.  $SbH_3$ ,  $H_2Te$ ) is then separated from solution (by a gas-liquid separator or membrane) and swept with an inert gas such as argon into the atomisation cell (heated quartz tube) of an AA spectrometer or directly into the central channel of an ICP. This process is fully automated with the use of peristaltic pumps and is computer-controlled. Interferences occur in various ways: (1) in the liquid phase, in the efficiency and kinetics of hydride generation; and (2) in the gaseous phase, both in transport (efficiency and kinetics) to the measurement cell and in the measurement cell itself. In the liquid phase, elements such as Cu, Ni and PGEs at elevated concentrations prevent the formation of the hydride or degrade it once formed. We routinely obviate this type of interference by separation of the analytes via precipitation with  $La(OH)_3$  and redissolution in HCl (PGEs can remain a problem). An alternate method, though sometimes not as reliable when dealing with widely ranging matrices, is to add masking agents (e.g. EDTA, tartrate, cysteine) on-line to minimise this liquid phase interference. It is in the area of *mutual* interferences in the measurement cell where we see a vast improvement using ICP-MS. For example, in the quartz cell of the AAS technique, the presence of As suppresses the atom populations of Te and Se, and hence causes low results. The high energy of the argon plasma at  $> 6000^\circ C$  drastically reduces vapour phase interference, as shown, for example, by Wickstrom et al. (1995) in the HG-ICP emission spectrometric determination of Se in Ni alloys.

Detection limits in solution by HG-ICP-MS are in the range 1-10 ppt ( $ng\ l^{-1}$ ) and therefore become about 0.4 ppb in the solid sample, assuming a dilution factor of 40 in the digestion procedure. Method detection limits are somewhat inferior to this, taking into account variability through the procedures, and are found to be in the order of several ppb. Typical detection limits by HG-AAS are in the range 0.1-0.5 ppm, inadequate for the measurement of Te and Se at background levels in geological materials. The method developed in our lab at the GSC is outlined below, together with data derived by application of both aqua regia and "4-acid" digestion to five standard reference materials (SRM).

#### Method

Optimum instrumental and operating parameters such as plasma power, carrier gas flow rate,  $NaBH_4$  concentration and HCl concentration are similar for all analytes. The ion lens settings on the mass spectrometer are optimised at the measurement isotope (130 amu) of the least abundant element, Te. A high acid strength in the analyte solution, 4 M HCl, is employed for two reasons: (1) to minimise the

*Continued on Page 14*

### Analyst's Couch

Continued from Page 13

washout time between samples (see Fig. 1 for 2 ppb Te); and (2) to reduce mutual interferences (see Fig. 2 for effect of Se on 0.2 ppb Te in 2 and 4 M HCl). Note in Fig. 2 that suppression of the Te intensity becomes significant at concentrations of Se greater than 500 ppb but this is at a tolerable ratio of 2500:1 of interferent:analyte, a ratio which is abnormally high in nature. In analysis by HG-AAS, where one is forced to work at higher concentrations ranges (e.g. 1-50 ppb), 500 ppb of Se reduces the signal for 5 ppb of Te by 44 %, using the GSC instrumentation. Lack of sensitivity by this technique negates the possibility of diluting out this interference from Se. The worst mutual interference in HG-ICP-MS is caused by excess Bi: at concentrations of Bi in solution greater than 500 ppb there is a progressively severe depression, especially on analytes Te and Se. The probable mechanism of this interference is decomposition of thermally unstable bismuthine ( $\text{BiH}_3$ ) within the tubing and torch and subsequent capture of the analyte hydride (Fujita and Takada, 1986).

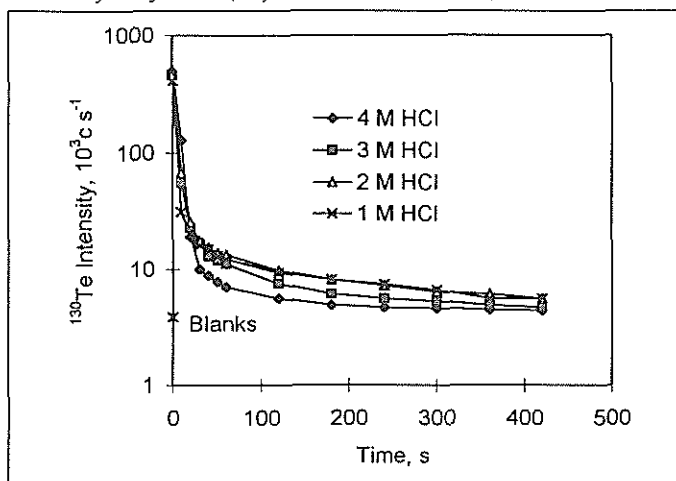


Figure 1. Effect of HCl molarity on wash-out time for 2 ppb Te

The hydride generation system is shown schematically in Fig. 3. The analysis is divided into two groups:  $^{78}\text{Se}$  is determined directly; while  $^{75}\text{As}$ ,  $^{209}\text{Bi}$ ,  $^{121}\text{Sb}$  and  $^{130}\text{Te}$  are determined simultaneously about 3-5 h after addition of 0.02 ml of 5 % KI to 10 ml of the sample solution in 4 M HCl. This

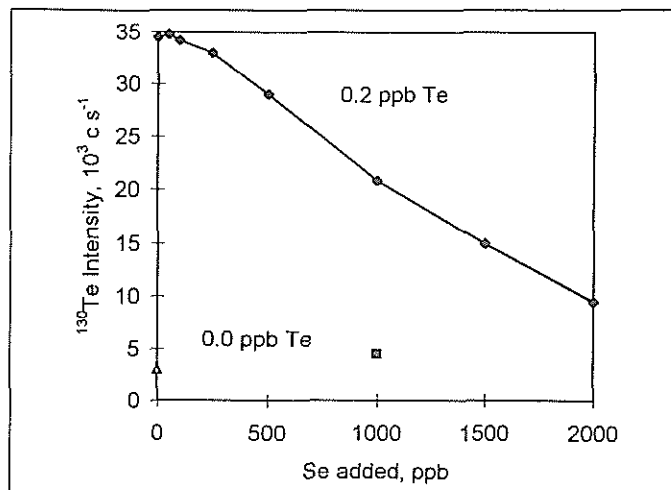


Figure 2a. Effect of Se on 0.2 ppb Te in 2 M HCl, bu HG-ICP-MS

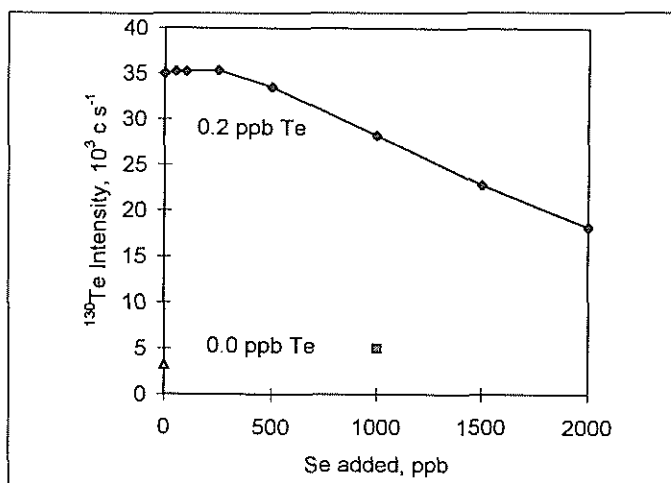


Figure 2b. Effect of Se on 0.2 ppb Te in 4 M HCl, bu HG-ICP-MS.

is done to pre-reduce the elements As, Sb and Bi to their III states. KI can be added off-line or on, the advantage of the former being that a smaller amount can be used which results in a much lower blank value for Bi. Unlike As and Sb, Se and Te are in their reduced states (IV) following the digestion.

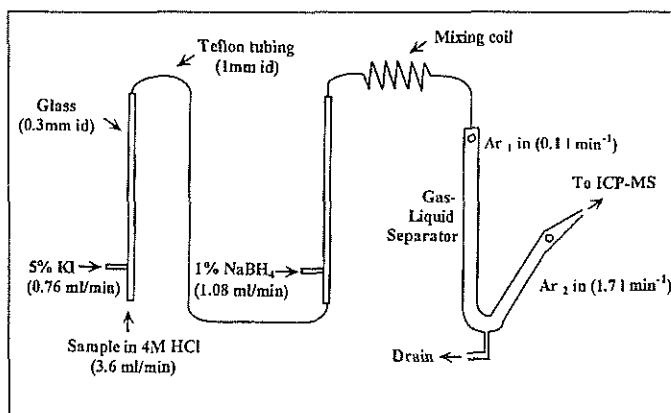


Figure 3. Schematic of hydride generation system used at the GSC.

*Shea Clark Smith*  
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## Analyst's Couch

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### Aqua regia digestion

1. To 0.5 g of sample in a test-tube, add 20 ml of aqua regia (HCl:HNO<sub>3</sub> of 3:1). Leave overnight. Heat for 3 h at 90°C.

2. Decant and make solution up to 20.0 ml. Take 15 ml for separation procedure.

### HF-HClO<sub>4</sub>-HNO<sub>3</sub>-HCl digestion

1. To 0.5 g of sample in a 50 ml polycarbonate ("pressure") tube, add 2 ml of 12 M HCl. Heat for 20 min at 90°C. [If the sample is highly organic, first add 2 ml of 16 M HNO<sub>3</sub> and take to insipient dryness].

2. Add 10 ml of HF-HClO<sub>4</sub>-HNO<sub>3</sub> (5:3:2) and cap tube. Heat 1 h. Shake twice during this period.

3. Transfer all contents to a Teflon beaker (with thorough rinsing) and evaporate to insipient dryness on a hot-plate.

4. Dissolve in 1 ml of 12 M HCl and 3 ml of 16 M HNO<sub>3</sub> with heat.

5. Transfer to calibrated test-tube and when cool make up to 20.0 ml with H<sub>2</sub>O.

### Separation with La(OH)<sub>3</sub>

1. Take 15 ml of leachate and add 4 ml of 2 % La(NO<sub>3</sub>)<sub>3</sub> solution. Add 20 ml of 1:1 NH<sub>4</sub>OH solution. Let stand for 20 min.

2. Cap test-tube, centrifuge (10 min at 2800 rpm) and decant.

3. Add 10 ml of 5 % NH<sub>4</sub>OH solution to precipitate. Cap, centrifuge and decant.

4. Dissolve precipitate in 4 M HCl and make up to 15.0 ml, ready for analysis.

## Results

Results for 5 SRMs taken through these procedures in triplicate are shown in Table 1 (see page 16). Note the excellent precision obtained, reflecting not only low variability in the method but also a high degree of homogeneity in the distribution of Sb, Bi, Se and Te in these SRMs. Relative standard deviations are in the range 1-10 % except at low

concentrations of analyte, at 12 ppb and below.

The difference in results obtained by the two decompositions can be interpreted as that portion of element bound as or encapsulated in a silicate matrix (e.g. Te in GSD-3 and LKSD-4; Se in LKSD-4 and MRG-1); unlike the other three analytes, Bi appears to be fully liberated by aqua regia in all these samples. Agreement between the 'HF' results and those recommended (underlined) by Govindaraju (1994) is only fair for: Sb in GSD-3 (5022 vs. 5400 ppb), GSR-4 (722 vs. 600 ppb) and LKSD-4 (1509 vs 1700 ppb); Se in GSD-3 (836 vs. 1060 ppb); and Te in GSR-1 (8 vs 21 ppb). However, upon examination of the original data used in the certification exercises, it is apparent that the range in values reported is large. For example, the standard deviation associated with 5400 ppb Sb in GSD-3 is 800 ppb, the range in the data being 3630 to 7400 ppb Sb (Xie et al., 1985). Similarly, the range in data for Sb in GSR-4 is 360 to 990 ppb (Xie et al., 1989). The low result for Te in GSR-1 is unexplained; the certification data of 17-31 ppb Te were obtained mostly by polarographic techniques (Xie et al., 1989).

Examination of the compiled SRM data provided in the special issue of *Geostandards Newsletter* (Govindaraju, 1994) shows that elements such as Se and Te lag far behind others like Cu and Zn in the degree of certainty associated with their values. For example, 227 of the 383 SRMs have recommended (highest degree of certainty) values for Cu compared to only 16 for Te. Clearly the reason for this is that cost-effective methods have not been available for their determination at natural levels. The next update of this special issue should reflect the growing influence of ICP-MS.

## Summary

Hydride generation ICP-MS offers a reasonably low cost method by which to measure low abundance elements Bi, Se and Te at ppb levels in geological media. Introduction of the analyte in ICP-MS as the gaseous hydride rather than in solution improves the sensitivity of measurement by a factor of 300 to 1000 which is required to obtain detection limits of

Continued on Page 16

Table 1

Results for Sb, Bi, Se and Te in 5 SRMs by HG-ICP-MS following digestion by aqua regia ("AR") and HF-HClO<sub>4</sub>-HNO<sub>3</sub>-HCl ("HF"). Shown in parentheses are the values from Govindaraju (1994): underlined = recommended; italics = proposed; "?" = informational only.

| SRM                   | Sb, ppb   |           | Bi, ppb |         | Se, ppb  |          | Te, ppb |         |
|-----------------------|-----------|-----------|---------|---------|----------|----------|---------|---------|
|                       | AR        | HF        | AR      | HF      | AR       | HF       | AR      | HF      |
| GSD-1<br>(stream sed) | 161± 6    | 251± 20   | 572± 2  | 622± 32 | 39± 2    | 35± 2    | 20± 1   | 19± 2   |
|                       |           | (220)     |         | (660)   |          | (110)    |         |         |
| GSD-3<br>(stream sed) | 5110± 181 | 5022± 126 | 807± 26 | 792± 52 | 878± 61  | 836± 45  | 98± 5   | 187± 17 |
|                       |           | (5400)    |         | (790)   |          | (1060)   |         | (150)   |
| GSR-1<br>(granite)    | 140± 5    | 221± 13   | 543± 8  | 542± 16 | 12± 2    | 10± 2    | 7± 2    | 8± 1    |
|                       |           | (210)     |         | (530)   |          | (59)     |         | (21)    |
| GSR-4<br>(sandstone)  | 539± 7    | 722± 4    | 172± 4  | 177± 4  | 52± 2    | 76± 4    | 35± 1   | 38± 1   |
|                       |           | (600)     |         | (180)   |          | (98)     |         | (38)    |
| LKSD-4<br>(lake sed)  | 972± 8    | 1509± 56  | 475± 3  | 520± 26 | 1623± 82 | 2165± 19 | 60± 8   | 185± 5  |
|                       |           | (1700)    |         |         |          |          |         |         |
| MRG-1<br>(gabbro)     | 449± 10   | 674± 56   | 138± 7  | 158± 12 | 131± 3   | 214± 9   | 9± 5    | 36± 2   |
|                       |           | (620)     |         | (130?)  |          | (194)    |         | (46?)   |

## Analyst's Couch

Continued from Page 15

several ppb in the sample. This improvement in sensitivity is not needed for higher abundance elements such as As and Sb. Attention *must* be paid to the different types of interferences in any hydride-based technique, the most severe being in AAS compared to ICP-ES or -MS. The need for digestion can be put to use in obtaining information on the speciation of the analyte, though again attention must be paid to stability of the element in solution and its valency state.

### References:

- Fujita, K. And Takada, T., 1986. Effect of temperature on generation and decomposition of the group Vb element hydrides and estimation of the kinetic stability of gaseous bismuth hydride by atomic-absorption spectrometry: *Talanta*, v. 33, p. 203-207.
- Govindaraju, K., 1994. 1994 Compilation of working values and sample description for 383 geostandards. *Geostand. Newsl.*, 18, 158 pp.
- Wickstrom, T., Lund, W. and Bye, R., 1995. Reduction of gaseous phase interference in hydride generation using inductively coupled plasma atomic emission instead of flame heated quartz tube atomic absorption spectrometry: determination of selenium in nickel alloys and low-alloy steels.: *J. Anal. At. Spectrom.*, v. 10, p. 809-813.
- Xie, X., Yan, M., Li, L., and Shen, H., 1985. Geochemical reference samples, drainage sediment GSD 1-8 from China. *Geostand. Newsl.*, v. 9, p. 83-160.
- Xie, X., Yan, M., Wang, C., and Shen, H., 1989. Geochemical standard reference samples GSD 9-12, GSS 1-8 and GSR 1-6: *Geostand. Newsl.*, v. 9, p. 83-160.

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NB This work will be published in detail in *J. Anal. At. Spectrom.* in 1996-97.



## NEWS NOTE

### Geoscientist Registration in Ontario

Geoscientists in Ontario are trying (once again) to achieve professional registration. This time, the chance of success appears to be significantly greater than in previous efforts. As of March 10, 1996, the Association of Geoscientists of Ontario was formed, following from the Committee for Professional Registration of Geoscientists in Ontario. The aim of this organization is to promote establishment of a system for geoscientist registration in Ontario and to provide a formal channel for communication with the geoscience community in Ontario as the registration process develops. The inaugural meeting, held to coincide with the PDAC, was attended by some 60 geoscientists. By the end of March 1996, over 300 geoscientists across Ontario have already joined. The aim is to have all Ontario geoscientists represented by the end of 1996.

The Association is now participating in a combined Task Force with the Professional Engineers in Ontario (PEO) to develop a licensure model for geoscientists within the PEO through an amendment to the Professional Engineers Act of Ontario. The intent is to develop a mechanism similar to that now available in BC, Alberta, Newfoundland and the NWT. The geoscientists on the Task Force committee are Bill Pearson, Andy Cooper, and John Bowlby. The Task Force is proceeding well and, at this time, both parties hope to be able to take a revised Act, incorporating geoscientists, to the Legislature in late 1996.

The Association is intended to be an interim organization whose principal objectives are identifying individual geoscientists in Ontario; facilitating discussion of the registration system; providing a formal organization to support the jointly prepared Assoc. Geoscientists of Ontario/PEO submission to the Ontario government; and providing a financial resource for this phase of the process.

Following the March meeting a Board of Directors was elected, and is comprised of Bill Pearson (President), John Bowlby (vice-president), Janet Haynes (Secretary-Treasurer), Linda Bloom, Andy Cooper, Mike Cosc, Brian MacKay, Bob Leech, Gary Pringle, and Bill Steibel. Committees have been struck to develop the Associations membership, disseminate information, and assist the Task Group discussions.

This association represents your profession and we urge you to join and support the registration process. Membership allows you to participate in the process and to keep well informed of the progress to advance registration and a professional status for geoscientists in Ontario. Don't assume that you will hear about it through other geoscientists - they may be assuming the same thing. Membership in the Association is open to all geoscientists in Ontario. Annual membership fee is \$25.00. A non-voting membership is available to full time students at the reduced rate of \$10.00 per year. For membership application and additional information, please contact: Mark Waychison, Membership Committee AGO, Consulting Geologist; Tel/FAX:(905) 847-6918; email 102252.720@compuserve.com.

## CALENDAR OF EVENTS

International, National and Regional Meetings of Interest to Colleagues Working in Exploration, Environmental, and other areas of Applied Geochemistry.

■ July 22-28 '96, *Geochemistry of the Earth's Surface*, int'l symp., Ilkley, Yorkshire, England (GES-IV Conference Secretariat, Dept. of Continuing Professional Education, Leeds University, Leeds LS2 9JT, England; TEL: 01132-333-241; FAX: 01132-333-240)

■ July 29-Aug. 2, '96, *Proterozoic Evolution in the North Atlantic Realm*, Goose Bay, Labrador, by Int'l Basement Tectonics Assn. (Charles F. Gower, Newfoundland Department of Natural Resources, P.O. Box 8700, St. John's, Newfoundland A1B 4J6, CANADA; TEL: (709) 729-2118; FAX: (709) 729-3493; E-mail: cfg@zeppo.geoserv.gov.nf.ca )

■ Aug. 4-14, '96, *30th International Geological Congress*,

Continued on Page 17

## News Note

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Beijing, China (Prof. Zhao Xun, Deputy Secretary General, 30th International Geological Congress, P.O. Box 823, Beijing 100037, P.R. China; TEL: 86-10-8327772; FAX: 86-10-8328928; E-mail: zhaox@bepc2.ihep.ac.cn)

■ Aug. 13-15, '96, **International Conference on Ground Control in Mining**, Golden, CO, by Colorado School of Mines and others (Colorado School of Mines, Office of Special Programs and Continuing Education, Golden, CO 80401; TEL: 800-446-9488, ext. 3321; FAX: (303) 273-3314)

■ Sept. 1-6, '96 **Brazilian Geological Congress**, int'l symp. Salvador, Bahia, Brazil (Eventus System Ltda., Rua Oito de Dezembro, 547, Grace - 40150000, Salvador, Bahia, Brazil; TEL: +55-71-245-3477; FAX: +55-71-237-3090; E-mail: 39cbg@pppg.ufba.br)

■ Sept. 4-11, '96, **Age and Isotopes of South American Metallogenic Provinces**, mtg., Salvador, Bahia, Brazil (M. Zentilli, Department of Earth Sciences, Dalhousie University, Halifax, B3H-3J5, Canada. TEL: (902) 494-3873; FAX: (902) 494-6889; E-mail: marcos.zentilli@dal.ca)

■ Sept. 15-20, '96, **Canadian Mineral Analysts**, 28th Ann. Conf., Peterborough, ON, Canada (Russ Calow, Lakefield Research Ltd., Lakefield, ON, TEL (705) 652-2018; FAX (705) 652-6441.

■ Sept. 17-19, '96, **Andean Geodynamics**, int'l mtg., St. Mrance (Denis Gapais, ISAG '96, Geosciences Rennes, Université Rennes 1, 35042 Rennes cedex, France; FAX: (33) 99 28 67 36; E-mail: isag96@seth.univ-rennes1.fr)

■ Sept. 22-25, '96, **The Interactions between Sediments and Water**, 7th Int'l Symp., Baveno (Stresa), Italy (Dr. E.D. Ongly, NWRI, 867 Lakeshore Rd., P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6; TEL: (416) 336-6439; FAX: 7th Int'l Symp. in Italy: 39-2-33220299)

■ Oct. 28-31, '96 **Geological Society of America**, Ann. Mtg., Denver (Becky Martin, GSA Meetings Dept., Box 9140, Boulder, CO 80301-9140; TEL: (303)447-2020, ext. 164; FAX: (303) 447-1133)

■ Nov. 10-14, '96 **Society of Exploration Geophysicists**, mtg., Denver (AAPG Convention Dept., Box 979, Tulsa, OK 74101; TEL: (918) 584-2555)

■ Nov. 18-21, '96, **Environmental Geochemistry in Tropical Countries**, 2nd Int'l Symp., Cartagena, Colombia (Ingeominas, Gloria Prieto R. and Luis E. Lesmes, Diagonal 53 #34-53 Santa Fe de Bogota D.C. Colombia, FAX:57(1) 222097; 57(1) 2220650; E-mail: ingeomin@hemeroteca.icfes.gov.co, or ingeomin2@hemeroteca.icfes.gov.co)

■ Mar. 23-26, '97, **SEGH 15th European Meeting**, Dublin, Geological Survey of Ireland

■ Mar. 24-27, '97, **4th All Portuguese Language Countries Geochemical Congress and the 10th Portuguese Geochemical Week**, Braga, Portugal (Prof. Graciete Dias, Dept. Ciencias da Terra, Univ. Minho, Campus de Gualtar, 4709 Braga Codex, Portugal; FAX: +351 53 604 304; TEL: +351 53 604 305; E-mail: geoquimica@ci.uminho.pt, URL <http://delta.ci.uminho.pt/ct/port/homepage.html>)

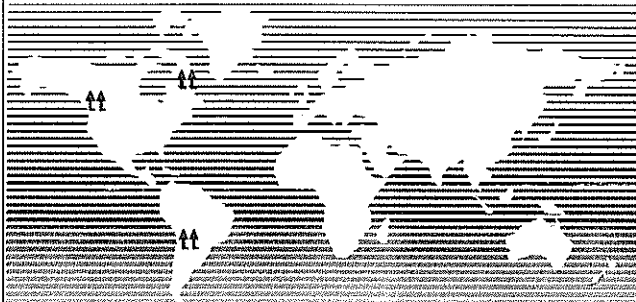
■ May 17-18, '97, **Volcanic-associated Massive Sulfide Deposits in Ancient and Modern Settings: Processes and Examples**, Short Course sponsored by SEG and GAC/MDD, preceding the '97 GAC-MAC Joint Annual Meeting, Ottawa, ONT, Canada (T. Barrie, GSC, 601 Booth St., Ottawa, ONT, Canada, K1A 0E8; TEL 613-947-2793, FAX (613)-996-9820, e-mail: barrie@gsc.emr.ca.

■ May 19-21, '97, **Geological Association of Canada/Mineralogical Association of Canada**, joint mtg., Ottawa, Ontario (Secretariat, Geological Survey of Canada, Room 757, 601 Booth St., Ottawa, K1A 0E8; TEL: (613) 947-7649; FAX: (613) 947-7650; E-mail: ottawa97@emr.ca)

■ May 25-29, '97, **18th International Geochemical Exploration Symposium**, Jerusalem, Israel (Organizing Committee, International Geochemical Exploration Symposium, P.O. Box 50006, Tel Aviv 61500, Israel; TEL: (972 3) 5140014; FAX: (972 3) 5175674/660325; E-mail: iges@mail.gsi.gov.il)

■ June 1-5, '97, **GEOANALYSIS 97**, 3rd Int'l Conf. on the Analysis of Geological and Environmental Materials, Vail, CO (Belinda Arbogast, U.S. Geological Survey, Federal Center, Box 25046, MS 973, Denver, CO 80225; TEL: (303) 236-2495; FAX: (303) 236-3200; E-mail: geo97@helios.cr.usgs.gov)

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## Calendar of Events

*Continued from Page 17*

■ June 23-26, '97, 4th International Conference on the **Biogeochemistry of Trace Metals**, Berkeley, CA (Dr. I.K. Iskandar, US Army Cold Regions, Res. & Eng. Lab, 72 Lyme Road, Hanover, NH 03755; TEL: (603) 646-4198; FAX: (603) 646-4561; E-mail: iskandar@crrel.usace.army.mil.

■ Sept. 14-18, '97, Fourth Decennial International Conference and Exhibition on **Mineral Exploration** with a theme of **Geophysics and geochemistry at the Millenium**, Toronto, Canada (Jon Baird, c/o CAMESE, 345 Renfrew Drive, Markham, Ontario, Canada, L3R 9S9; TEL: (905) 513-0046; FAX: (905) 513-1834; E-mail: 103214@compuserve.com )

■ Oct. 5-10, '97, 4th International Symposium on **Environmental Geochemistry**, Vail, Colorado (4th ISEG, c/o USGS/CEGG, Federal Center, Box 25046, MS 973, Denver, CO 80225; FAX: (303) 236-3200; E-mail: iseg@helios.cr.usgs.gov )

■ June 29-July 1, '98, **International Platinum Symposium**, IAGOD/CODMUR, Johannesburg, South Africa (C.A. Lee, Box 68108, Bryanston 2021, South Africa; TEL: (2711) 4112253; FAX: (2711) 6923693)

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

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## NEW MEMBERS

To All Voting Members:

Pursuant to Article Two of the Association's By-Law No.1, names of the following candidates, who have been recommended for membership by the Admissions Committee, are submitted for your consideration. If you have any comments, favorable or unfavorable, on any candidate, you should send them in writing to the Secretary within 60 days of this notice. If no objections are received by that date, these candidates will be declared elected to membership. Please address comments to Sherman P. Marsh, Secretary AEG, U.S. Geological Survey, Mail Stop 973, Box 25046, Federal Center, Denver, Colorado 80225, U.S.A. Editors note: Council has decided that all new applicants will receive the journal and newsletter upon application for membership. The process of application to the Nepean office, recommendation by the Admissions Committee, review by the Council, and publication of applicant's names in the newsletter remains unchanged.

**McLemore, Virginia T.**

Sr Economic Geologist

NM Bureau of Mines and Nat Res  
Socorro, NM, U.S.A.

### FELLOWS

**Manini, Antony J.**

**Principal Geologist**

CRA Exploration

Vientiane, LAOS

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Highlands Gold

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PAPUA NEW GUINEA

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**Dyer, Richard**

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Ontario Geological Survey

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**Green, Neville**

Exploration Geochemist

Golden Triangle Resources

Abbotsford, VIC, AUSTRALIA

**Hayes, Gerald**

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Acme Analytical Labs Chile

Santiago, CHILE

**Loader, Stephanie E.**

Exploration Geologist

CRA Exploration

Vientiane, LAOS

**Ruz Cid, Leonardo**

Geologist

WMC Chile

Las Condes, CHILE

**Stewart, Ronald W.,**

Exploration Manager

Placer (PNG) Exploration

Port Moresby, PAPUA NEW GUINEA

**Storre, B.**

Mineralogisch-Petrologisches Institut

Gottingen, GERMANY

**Swatton, Steve**

Mining Analyst

Yorkton Securities

Vancouver, BC, CANADA

**Thorsen Kenneth R.**

VP and General Manager

Teck Exploration

Vancouver, BC, CANADA

**Zhanlin, Gao**

Exploration Geochemist

## New Members

*Continued from Page 18*

Central Norseman Gold  
Norseman, WA, AUSTRALIA

### STUDENTS

Coolbaugh, Mark  
University of British Columbia  
Garibaldi Highlands, BC, CANADA

Guay, Mathieu  
University of Quebec, Chicoutimi  
Chicoutimi, PQ, CANADA



## RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in EXPLORE Number 91. Journals routinely covered and abbreviations used are as follows: Economic Geology (EG); *Geochimica et Cosmochimica Acta* (GCA); the USGS Circular (USGS Cir); and Open File Report (USGS OFR); Geological Survey of Canada Papers (GSC Paper); and Open File Report (GSC OFR); Bulletin of the Canadian Institute of Mining and Metallurgy (CIM Bull); Transactions of Institute of Mining and Metallurgy, Section B; Applied Earth Sciences (Trans IMM). Publications less frequently cited are identified in full. Compiled by L. Graham Closs, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, Chairman AEG Bibliography Committee. Please send references to Dr. Closs, not to EXPLORE.

Armitage, A.E., James, R.S., and Goff, S.P., 1996. Gold mineralization in Archean banded iron formation, Third Portage Lake area, Northwest Territories, Canada. *Explor. & Mining Geol.* **5**(1): 1-15.

Arora, M., Goril, P.K., Charan, S.N, Raj, B.U., Balaram, V., Manikyamba, C., Chatterjee, A.K., and Naqvi, S.M., 1995. Geochemistry and origin of Archean banded iron formation from the Bababudan Schist Belt, India. *EG* **90**(7): 2040-2057.

Barcelo, C., Pawlowsky, V., and Grunsky, E., 1996. Some aspects of transformations of compositional data and the identification of outliers. *Math. Geol.* **28**(4): 501-518.

Bartier, P.M. and Keller, C.P., 1996. Interpolation for geochemical surface reconstruction incorporating topographic catchment definitions. *Math. Geol.* **28**(3): 253-273.

Birrell, R., 1996. MMI geochemistry: mapping the depths. *Min. Mag.* May: 306-307.

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| <u>Issue</u> | <u>Publication date</u> | <u>Contributor's Deadline</u> |
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| 93           | October 1996            | August 31, 1996               |
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| 95           | April 1997              | February 28, 1997             |
| 96           | July 1997               | May 31, 1997                  |

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