

# EXPLORE

Newsletter for the Association of Exploration Geochemists

NUMBER 74

JANUARY 1992

## AN AUSTRALIAN PERSPECTIVE

Australian involvement in the Association of Exploration Geochemists received considerable impetus when the 6th IGES was held in Sydney during the 25th IGC in September 1976. Prior to this, some Australians had been early members of the fledgling Association and attended earlier symposia. The Australian membership has continued to grow with current membership of approximately 150, the highest national membership outside USA and Canada.

Geochemical exploration techniques are particularly suited to the Australian environment where deep (commonly 80-100m) weathering, transported overburden and highly conductive groundwater limit the application of geophysical techniques. In the past, many of the major exploration companies employed professional geochemists to conduct stream sediment, soil, weathered bedrock, lateritic pisolite and gossan geochemical surveys and interpret any anomalies. Some very prospective areas were delineated and a number of economic deposits discovered. Little emphasis was placed upon geochemical mapping by the national or state government instrumentalities. Unfortunately this is still the case. The companies are still reliant upon their own endeavours.

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Laterite profile developed on Archaean Yilgarn Block, Western Australia exemplifies deep weathering over much of Australia.

## 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 5¼- or 3½-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:

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# EXPLORE

Newsletter No. 74

JANUARY 1992

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## PRESIDENT'S MESSAGE



It gives me great pleasure to introduce this special issue of EXPLORE devoted to exploration geochemistry in Australia. There are enormous differences between the theory and practise of exploration geochemistry in Australia and theory and practices in the northern parts of Europe and North America. While the Australians typically face the complexities of 200 million years of postglacial regolith evolution under a variety of warm-wet to warm-dry climatic regimes, many of us working in the Northern Hemisphere face the very different complexities brought about by recent glaciation.

Nevertheless, there is a common message insofar as these very different extremes, and the exploration challenges they present, continually remind geochemists of the practical importance of landscape evolution and geomorphology. More specifically, Australian geochemists have made major contributions to our understanding of laterite geochemistry, gossan recognition and many related fields. It is interesting to speculate along what lines our geochemical laboratories might have evolved without the seminal work on atomic absorption by A. Walsh at CSIRO in the 1950's.

It is also appropriate to thank the Australian membership for its past, present and future participation in the activities of the AEG. Apart from their contribution of the steady flow of high quality scientific papers to the Journal of Geochemical Exploration, their involvement has included preparation of several special issues of the Journal and organization of the International Geochemical Exploration Symposium held in Sydney in 1976. Graham Taylor, as second Vice-President of the AEG and a former Regional Councillor for Australia, is working hard to make the activities and involvement of the AEG more international. This issue of EXPLORE is one step in that direction. Also, our new regional councillor in West Australia is Russell Birrell - welcome to Russ. For the future, Australia is preparing to host the 17th International Geochemical Exploration Symposium, to be held in Townsville in 1995.

Finally, on a more personal note, I wish to take this opportunity to thank everyone in Australia who made my tour as the AEG 1990 Distinguished Lecturer so memorable. I look forward to seeing you all again (and perhaps taking up some of the discussions where we left off) in Townsville in 1995.

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## NOTES FROM THE EDITOR

This issue of **EXPLORE** marks a first on two counts: 1) the first "regional" issue, and 2) four timely Technical Notes. Our thanks go to Graham Taylor (CSIRO) for attracting these articles and coordinating all of the Australian contributions. Hopefully, other regional, or "theme" issues will follow.

Readers are reminded that **EXPLORE** is not a reviewed publication. Potential articles are read by the editorial staff, and we are quite high-handed in our editorial modifications; however, articles are generally not rejected or revised simply because we do not agree with the view expressed by the author(s). For this reason, responsibility for the contents of an article lies primarily with the author(s). In this way we can be very nimble in our publication schedule and can publish information that may not otherwise be published in a timely manner.

Owen Lavin  
Editor, **EXPLORE**

## AEG COUNCIL MINUTES

It has been some time since I have had the opportunity to bring you up to date on the actions of Council. This has been primarily due to space limitations in **EXPLORE**; we have been filling each issue with technical articles and special features. With this issue I will catch up with some of the important decisions made by your Council that affect your Association.

### Actions of March 13, 1991

1. Council approved applications of 18 Affiliate and 2 Student Members.
2. Council agreed to co-sponsor a meeting with the Society for Mining, Metallurgy, and Exploration in Phoenix, AZ and decided to hold the 1992 Annual General Meeting at this event.
3. Council moved that all members who had NOT paid their membership dues for 1989-90 be dropped from the **EXPLORE** mailing list (PLEASE NOTE THIS!).
4. Council proposed that the Association inaugurate 2 medals; a Past Presidents Medal and a Gold Medal of the Association of Exploration Geochemists.

### Actions of April 28, 1991

1. Council approved applications of 20 Affiliate Members.
2. Graham F. Taylor was nominated and elected by Council to be the next Second Vice President.
3. Council approved the publication of the 1992 Directory.
4. Council approved the job description for the Association Business Manager.

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### Actions of June 26, 1991

1. Council approved applications of 12 Affiliate Members.
2. A committee was formed to select individuals to receive award certificates and medals.
3. A committee was formed (D. Runnells, Chairman) to liaise with environmental groups.
4. Council approved the Identity Committee report (**EXPLORE** No. 73).
5. Council agreed that **EXPLORE** No. 74 would focus on Australia.

### Actions of September 4, 1991

1. Council approved applications of 22 Affiliate and 4 Student Members.
2. Council approved the venue of the joint AEG-SEG-SExG-USGS meeting in Denver, CO in April 1993 for the 1993 Association Annual General Meeting.
3. Council approved the minting of the silver Past Presidents Medal and the gold plated Medal of the Association of Exploration Geochemists.
4. Council awarded a certificate to Hans Gundlach for his outstanding service to the science of geochemistry and the Association of Exploration Geochemistry.
5. Council approved the publication of one issue per year of **EXPLORE** with 4 pages in full color.
6. Council approved expenditure of funds to prepare a short course on biogeochemical exploration.

### Sherman P. Marsh

Secretary of the Association of Exploration Geochemists  
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## An Australian Perspective

Continued from Page 1

Today, with a few notable exceptions, geochemical exploration is left to geologists with little or no formal training in exploration geochemistry, a common but disturbing world-wide trend. Much of this so-called "geochemistry" is the sampling of drill material for Au analysis by commercial laboratories and the subsequent plotting of Au contours on a poorly-defined geological map. The companies that employ professional geochemists have had significant success and should be examples to those companies aspiring to survive into the 21st century. Others have turned to petroleum exploration and environmental geochemistry, two areas relatively new to Australian geochemists.

Exploration geochemistry receives only limited exposure at the undergraduate level with few universities having exploration geochemists on permanent staff. Post-graduate courses and research opportunities are offered more widely, often using expertise from industry and the Commonwealth Scientific and Industrial Research Organization (CSIRO). Each year the Australian Mineral Foundation offers an intensive course on exploration geochemistry, again utilizing the experience of consultant geochemists.

The Australian environment required modification of the techniques developed for the Northern Hemisphere. Some assistance was derived from the southern African experiences of John Webb, John Tooms and Ian Nichol at the Applied Geochemistry Research Group (AGRG), Imperial College, London. Several companies formed in-house research groups often structured around an AGRG graduate. A few of these groups survive today, and have been instrumental in the development of new techniques such as the bulk cyanide leach (BLEG) method widely used in gold exploration.

In the mid-1960's, CSIRO began an exploration geochemistry research program which has over many years received generous support from industry often through the Australian Mineral Industry Research Association (AMIRA). As a result, there have been major contributions to:

- gossan formation, characterization and evaluation
- application of Pb isotopes to exploration (and environmental geochemistry)
- laterite geochemistry, particularly multi-element geochemistry lateritic pisolites
- geochemistry of saline groundwater
- application of advanced analytical techniques to diamond exploration
- application of mercury geochemistry
- vapour geochemistry of hydrocarbons
- weathering and secondary dispersion in the regolith
- litho-geochemistry of volcanic massive sulphide deposits.

Surprisingly, there has been little effort in applying biogeochemistry in the Australian environment. Considerable effort into computer-aided presentation and interpretation of multi-element geochemical data by a number of companies, universities and CSIRO has been rewarding.

The Australian economy remains highly dependent on its mineral industry. Outcropping and near-surface mineralization, some of it formed by weathering processes, continues to be found. The future lies in discovering deposits concealed beneath the regolith. This will require techniques different from those used today and companies are showing renewed interest in geochemistry such as a research project sponsored by AMIRA into the adaption of Russian electrochemical techniques to the Australian environment.

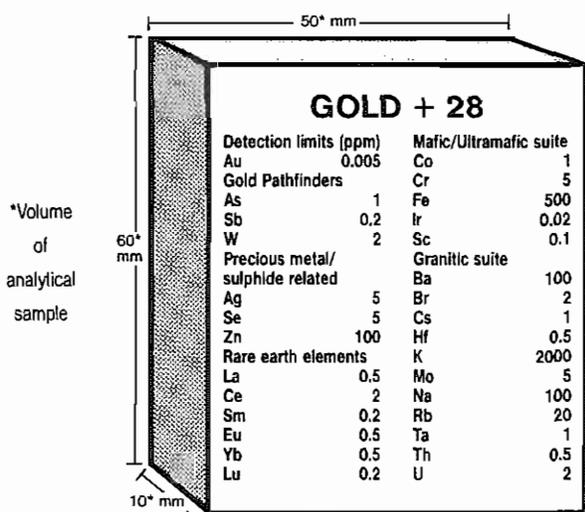
Council has agreed to the hosting of 17th IGES by Townsville in 1995. This will be a great opportunity to witness the application of a range of geochemical exploration techniques in a variety of geologic, geomorphic and climatic regimes.

Australian geochemists have made a significant and valuable contribution to the understanding and application of geochemical techniques. Much of this has been published in the Journal of Geochemical Exploration and details of some other techniques are included in this issue. An upcoming issue of the JGE will detail recent research and application of geochemical exploration in the regolith with emphasis on gold in lateritic terranes of the Yilgarn Block.

It is therefore a great privilege to be able to introduce this Australian issue of EXPLORE.

**Graham F. Taylor**  
Vice-President, AEG  
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## NOTES FROM THE BUSINESS MANAGER

- 1992 Dues Notice:** The 1992 dues notice was mailed to all members in late December, 1991. Members who have prepaid their dues (i.e. address label indicates PAID-92 or later) need not remit funds until the 1993 dues notice arrives. Please take the time to examine your dues notice and keep your membership status up to date. Specifically, ensure our information on your address, your affiliation, your postal code, telephone and FAX numbers are accurate (they will be used in the upcoming 1992 DIRECTORY). **US members, please include your ZIP + 4 postal code!**
- AEG Publications:** Publications available from the AEG are listed on the back side of the 1992 dues notice. You will note a new category labelled SPECIAL 1. The AEG has negotiated to market this well known text by Levinson et al. (1987) on Practical Problems in Exploration Geochemistry. Rose, Hawkes and Webb (1980) is being offered under a similar arrangement (see following note). Look for this and perhaps other special offers in future issues of EXPLORE.
- DIRECTORY:** Publication schedule requires receipt of membership information and service listings by January-February 1992. **All AEG members, please note:** You have the opportunity to list your consultancy or other business according to categories listed on page 75 of the 1990 DIRECTORY (up to 6 per company) at no charge. If you do not have page 75, the AEG office would be pleased to mail or FAX you a copy to you. Examine your 1990 DIRECTORY and let me know of any errors or omissions.
- Elsevier - Journal of Geochemical Exploration:** Our membership has received a letter from Elsevier Science Publishers concerning the expanded scope of the Journal and the subscription price for 1992. I believe Elsevier mistakenly sent AEG members a letter intended for their institutional subscribers. AEG membership continues to be accompanied by the Journal of Geochemical Exploration at a cost of \$US 50 for one year or \$US 85 for two years.
- Journal of Geochemical Exploration - Special Offer: EXPLORE 73,** page 15 listed volumes of the Journal of Geochemical Exploration which are available from Elsevier through the AEG (to members only). If you have lost issues or would like to complete your library, all volumes, except volume 15, are available. Volume 15, Geochemical Exploration 1980, is available separately as a hard covered book from the AEG (see Publications List). A popular issue out of print for many years, Conceptual Models in Exploration Geochemistry, the Canadian Cordillera and the Canadian Shield, JGE volume 4 (1975), has been reprinted and is also available.

Stan Hoffman  
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## BOOKS AVAILABLE

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The popular textbook *Geochemistry in Mineral Exploration* by Rose, A.W., Hawkes, H.E., and Webb, J.S., (1980) is now available to AEG members for US \$39.95. This textbook is a basic reference in the field of exploration geochemistry and is a must for your library. Non-member price is US \$49.95. The textbook can be ordered from the AEG Vancouver address.

## RESEARCH OPPORTUNITY

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## TECHNICAL NOTES

### The Status of Vapour Geochemistry in Australia

The employment of vapour methods in integrated exploration programs has not progressed to significant levels in Australia, and those methods are seldom used. Exploration companies have not been convinced that the methods offer advantage over conventional techniques and Australian research establishments have not devoted sufficient research effort to determine if vapour techniques can be employed reliably.

There is in general a poor understanding of how vapour techniques can be used and this results from a lack of understanding of how vapours are released from the target, and how they migrate through and are partially retained within the vadose zone. The impact on the flux of meteorological, bacterial, and other influences is also only partially understood. There are no definitive guidelines for sampling, analysis and interpretation of results.

As the search for deeper mineral and petroleum deposits intensifies, there will be the need to employ new methods to guide the use of geophysical methods and to rate targets defined by geophysical and geological methods. In several orientation studies carried out in Australia, some vapour techniques have been shown to reliably reflect the presence of accumulations of metals and petroleum at depth. There is, within the exploration industry, a failure to understand the limitations of vapour geochemistry — these techniques do not offer panaceas, and the results of surveys need to be interpreted in conjunction with geological and

geophysical results. Vapour techniques have a demonstrated potential for being part of future exploration programs, but much research remains to be completed before the methods can find routine application.

#### Mineral exploration

For mineral exploration, it seems surprising that more effort has not been applied to development of vapour techniques since many prospective regions of Australia are characterised by conditions such as deep weathering, saline groundwater, and exotic cover that provide difficulties for conventional exploration techniques. The failure to employ vapour methods also reflects the perceived success of present exploration methodology in the discovery of outcropping and near-surface mineralization using geological mapping and deduction, geophysical techniques and, for the most part, fairly crude surface geochemical methods. Of recent years, however, discoveries of important blind mineral deposits have been made in Australia following drilling to test innovative geological models, but it is clear that some methods, other than drilling, need to be developed to assist in discrimination or rating of potential targets.

*Mercury vapour methods* were promoted extensively in Australia during the period from the late 1960s to early 1980s for base and precious metal exploration, and again in the 1980s during the "gold boom." Many of the early analytical methods gave unreliable analyses, but reliable methods have been developed for the collection and analysis of nanogram quantities of mercury. Mercury vapour techniques, however, have generally fallen into disuse since it was shown that, in general, they had little or no advantage over the use of target elements in locating shallow mineralisation (Carr et al., 1986).

*Sulfur methods* have been used only sparingly in Australia, but the writer has been encouraged by results obtained over deeply weathered sulfide deposits in arid areas. In these case studies anomalous concentrations of one or a combination of sulfur dioxide, carbonyl sulfide, carbon disulfide and hydrogen sulfide were detected, in regions characterised by low background concentrations. The anomalous zones were generally narrow and confined to areas above the sub-cropping mineralisation. The presence of sulfur species is very dependent on moisture contents of soils. Instrumentation is now available to reliably analyse for sulfur species at the ultratrace levels required for exploration.

*Radon/helium* methods have been employed for uranium exploration in many regions of Australia. In general, radon methods have been preferred due to simplicity of operation. Both radon cups and radon pumps have been used and positive results have been reported over near-surface uranium mineralisation both by direct detection of radon in soil gas (Davy et al. 1978; Brownscombe et al., 1978) and by the use of radon cups, which employ an alpha particle-sensitive film (Pedersen et al., 1979).

*Continued on Page 8*

## SOILS ROCKS SEDIMENTS DRILL CORE MULTIELEMENT ANALYSIS

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Stan J. Hoffman, Ph.D., P.Geo.

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## Technical Notes

Continued from Page 6

Helium in soil gas was found to be ineffective as a pathfinder to concealed uranium and other mineralisation in five deposits surveyed in Western Australia and the Northern Territory by Butt and Gole (1985). The concentration of helium in groundwater was found to be in excess of the atmospheric equilibrium value around a number of Australian uranium deposits, but its concentration was also shown to be a function of the porosity, permeability and configuration of the aquifer so that helium in groundwater cannot be reliably employed in exploration (Butt and Gole, 1986).

Light alkanes (methane through butane) have been experimented with for exploration for epithermal gold and certain styles of base metal deposits which are known to be associated with elevated concentrations of hydrocarbons, such as sediment-hosted lead-zinc, and volcanic-associated gold deposits. The hydrocarbons may be original components of the mineralising fluids or may be produced by reaction with organic matter in wall rocks during or after the mineralising event. The light hydrocarbons can be easily and reliably analysed in the field and give the capability of rapid screening of large areas. The light hydrocarbons may also be used in some sedimentary environments to define the locations of structures, such as faults or anticlines, which may act as foci for ascending gases derived from the mineralisation or from deep within the basin.

Work carried out by the author in the Canning Basin for petroleum exploration showed a zone containing anomalous concentration of C1-4 alkanes in soils extending along the Admiral Bay Fault. Drilling of a subsequent petroleum exploration well encountered at a depth of about 1400 metres significant lead-zinc mineralisation, which is now being investigated by CRA Exploration Pty.

Direct metal detection in which metallic compounds or elements

are gathered on a polystyrene film collector buried in the ground and released for analysis by a proton beam generated by a particle accelerator have been attempted recently in several areas. Results of experimental surveys with the Swedish "Geogas" system remain confidential, but to date equivocal interpretations dominate. CSIRO Division of Exploration Geoscience have developed a variant of the technique, SIROGAS, which has been tested over the deeply buried Northern Lodes at the Elura minesite. The first trial yielded clear anomalous concentrations of copper and mercury over the orebody, but only very low concentrations of lead and zinc, which are the major base metals in the ore and in the soils. Research into the application of this technique is continuing.

### Petroleum exploration

Petroleum exploration in Australia is dominated by seismic geophysical methods, which of course have played an important part in nearly all Australian discoveries to date. However, these methods generally define only the structure of the sediments, and only in rare cases can they be used to directly infer the presence of oil or gas. Many of the seismically-defined structures when drilled are found to be dry, and methods are sought to determine if structures contain petroleum.

Before the advent of reliable seismic technology much of the world's petroleum reserves were discovered in proximity to seeps of oil or gas that could be seen with the unaided eye. These macroseeps have not been commonly recorded in the relatively old onshore basins that make up most of the prospective regions in Australia; however, it is becoming accepted that, even in unfaulted basins, trace quantities of light hydrocarbons leak from accumulations at depth and migrate upwards probably as microbubbles by buoyancy and capillary action along microfractures and fault zones. There can be no certainty that the light hydrocarbons will leak

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## Technical Notes

*Continued from Page 8*

vertically, and the signatures of these components at the surface will be determined by the presence of near-surface faults, aquifers, microbial activity, soil type, meteorological variables, etc.

In onshore petroleum exploration, surface geochemical methods have been experimented with for many years in Australia (Philip and Cris, 1982) but it is only over the past decade that real encouragement, engendered from correct predictions made before drilling, has led to some level of acceptance of the methods from the petroleum exploration industry. For example, in one exploration permit in Queensland with which the author has been associated, thirteen surface geochemical anomalous zones have been drilled for eleven oil discoveries. In some other parts of Australia, especially in temperate climates and having appreciable clay-rich soils, the surface techniques have not found such ready success.

Techniques in routine use in Australia include analysis of the light hydrocarbon contents of soil pore space gas and of hydrocarbon species adsorbed on soil components. The so-called "Petrex" technique, in which hydrocarbons are collected on a wire coated with activated charcoal and later released into a mass spectrometer for analysis, has been attempted at locations in Australia. The results of these surveys are not known to the author, but the method appears to offer no advantages over soil analyses for most climatic regions of Australia.

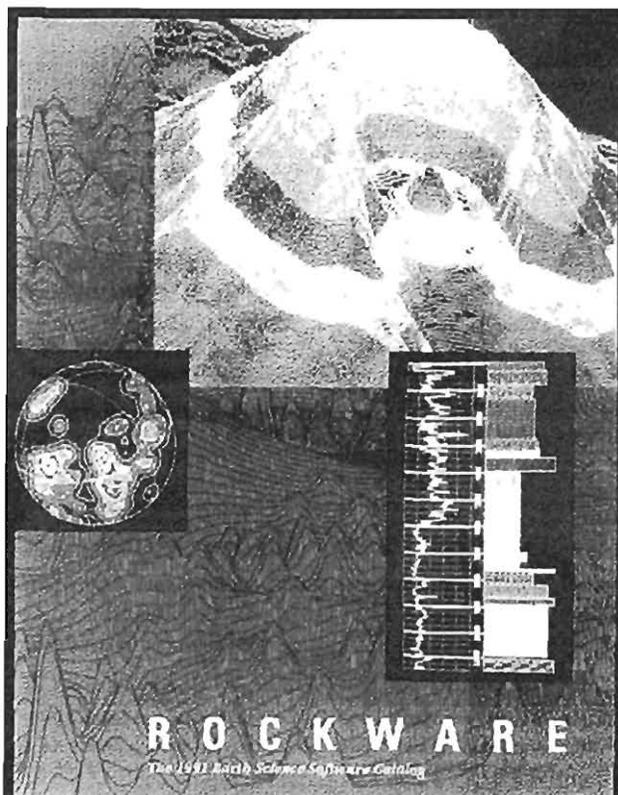
The analysis of light hydrocarbons in soils can be accomplished quickly in the field and this had led to their employment at reconnaissance scales to evaluate the petroleum potential of very large permit areas. Some of these surveys have located anomalous zones that on subsequent seismic survey have been shown to correspond to structurally high features.

In an attempt to explain some of the difficulties associated with surface prospecting methods, the author has participated in an investigation carried out by CSIRO Division of Exploration Geoscience in which the isotopic compositions of microseeps have been compared with the concentrations of the hydrocarbon gases in soils (Rigby et al., 1990; Rigby, 1991). This investigation showed that microbial oxidation was the major factor for the alteration of hydrocarbons in soil gas and has led to a strategy which focuses on the soil gas "residence time" which is used to select the sample type/s that is/are appropriate for given regions.

Vapour exploration techniques have been employed in Australian offshore exploration for several years. Generally, "sniffer" surveys have been carried out in which the light hydrocarbons in near-seafloor water are determined in real time in an onboard geochemical laboratory. The results to date from commercial operators have, however, been discouraging, but research into this method by the Bureau of Mineral Resources, from their research vessel "Rig Seismic" are showing some improvement in technique can be accomplished. Many of Australia's prospective offshore sedimentary basins are not well suited to application of sniffer surveys.

A better approach to offshore geochemical exploration is to acquire cores from below the oxidised and bioturbated zones, particularly from locations adjacent to near-surface faults which act as conduits for the leaking hydrocarbons. Samples from the cores are analyzed for light and heavy hydrocarbons that are present dissolved in pore water, or are adsorbed to mineral grains or are entrapped in carbonate cement. Results from offshore surveys carried out in Australian waters indicate that both gaseous and liquid hydrocarbons may leak through large thicknesses of apparently unfaulted Tertiary sediments (O'Brien and Heggie, 1989; Martin and Cawley, 1991).

*Continued on Page 10*



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## Technical Notes

Continued from Page 9

### Conclusion

Surveys completed to date show encouragement for employment of vapour surveys over many regions of Australia, but there is the need for reliable methods to be developed or at least for parameters to be defined to indicate when the methods can be employed optimally.

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## Application of Pb Isotopes to Environmental Geochemistry — Including a Case Study of a Wine Bottle

The Pb isotope fingerprinting method is an accepted approach in ore genesis and mineral exploration. In mineral exploration, the method is most commonly applied by comparing isotopic signatures of known deposits with signatures from the mineralization of interest and/or geochemical anomalies.

The same basic principles can be adopted for tracing the source of Pb in the environment whether the media are soils, vegetation, water, or biological media such as blood or urine.

The Commonwealth Scientific and Industrial Relations Organization (CSIRO) Division of Exploration Geoscience is currently involved in a number of major environmental and occupational health investigations. These include:

- Biokinetics of Pb in Human Pregnancy to determine the relative contribution of Pb in female blood from skeletal versus environmental sources (with Department of Community Medicines, University of Adelaide).

Initially, the consortium is determining the Pb isotope profiles in blood and urine of women of child-bearing age in Port Pirie, Adelaide and Hobart, and comparing them with the Pb isotope signatures found in samples of food, water, air, house dust and soil.

To answer the important question of whether Pb accumulated in pre-adult life is mobilized and transmitted to the foetus during pregnancy, it is necessary to be able to distinguish between Pb taken up during pregnancy and that from environmental sources and Pb previously absorbed and deposited in the bones.

- Testing groundwater for possible leakage from the Ranger uranium tailings dam (with the office of the Supervising Scientist).
- Source of metals in sediments and benthic fauna in the Torres Strait.
- Source of Pb in subjects from Broken Hill. Considerable publicity has arisen since:
  - 1) the discovery of Pb, at levels up to 3.6 percent, in ceiling dusts by a student from the University of Adelaide, and
  - 2) since the birth of three children with delayed visual maturation of the optic nerve (ie born blind).

These events have been attributed to Pb poisoning and the finger has been pointed at the extensive dumps in the centre of the city as the source of Pb in the population, especially in children.

Lead isotopes demonstrate that the ceiling dusts and the majority of vacuum cleaner and other surface dust are probably from the Broken Hill ore, but at least part of the Pb in the females of child-bearing age is derived from some other source. More importantly, no Pb isotope values indicative of Broken Hill ores have been found in children's blood, even in children purportedly suffering from Pb poisoning. We are trying to resolve this enigma from analyses of food, water, air and biological samples, including teeth, from more subjects.

Not only does this situation have important public health ramifications but, with the current state of

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## Technical Notes

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uncertainty, it could seriously jeopardise the future of the mines and/or incur massive costs for a decontamination program, as is being carried out at the Port Pirie smelter in South Australia.

- Role of Sn-Pb capsules as a potential source of Pb in wine. The wine project, commissioned and partly funded by the Australian Wine Research Institute, arose from concern that in bottles where there was obvious leakage of the wine through the cork and reaction with the Pb capsule, the Pb corrosion products would be drawn back through or around the cork.

The problem was elegantly solved using Pb isotopes based on the expectations that:

- 1) the Pb capsules were manufactured from Pb from different mines and would have a variable Pb isotope signature different from the wine, and
- 2) because of the low Pb concentration in the wine (usually <50 ppb), any Pb drawn back through the cork would be obviously identified by both the Pb content and isotopic value of the cork.

We analysed wines, corks, capsules and corrosion products from >50 bottles of Australian and some German wines, including bottles with and without capsules, the former with varying states of corrosion. We were able to demonstrate that the Pb isotopic composition of the wine was the same for bottles with and without Pb capsules even though the wine leaked out through the cork and reacted with the capsules. Furthermore, no Pb concentrations or Pb isotopic gradients were discernible from analyses of different segments of corks - except for the top 1-2mm (which illustrates that cork is a great filter for Pb?). However, for bottles with corroding Pb capsules, Pb can be introduced into the wine either by pouring, during which the wine dissolves the soluble Pb compounds on the neck of the bottle, or by entrainment of Pb through the cork if the bottom of the cork is pierced during its removal.

*A Word of Caution:* if there are any corrosion products on the top of the cork or bottle neck, scrub them well with water and a nylon pad, as the Pb acetate and carbonate easily dissolve and finish up in your glass! The only way to get rid of the Pb is with dilute nitric or hydrochloric acid, but not every restaurant is willing to provide these.

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## Ongoing Development and Application of Bulk Leach Technology in Exploration.

*Editor's Note:* The following article deals with the "Bulk Leach Extractable Gold (BLEG)" technique which may not be familiar to all of our readers. A short description is provided in this editor's note. BLEG refers to a wide spectrum of analytical techniques which employ large samples (200 to 20,000 g) exposed to cyanide solutions for various amounts of time and different styles of agitation. Using these procedures, it is at least theoretically possible to achieved high sensitivity at very low gold concentrations; however, it most certainly yields a "partial" analysis, as no occluded gold and only some of the gold from larger gold nuggets is dissolved. BLEG has been applied to just about every type of sample media; however, it is most popular with drainage sediment and soil samples.

The Bulk Leach or BLEG geochemical methodology was developed and applied extensively to gold exploration during the 1980's. In Australia it has been credited with a number of successes and for some time, stream and soil BLEG surveys became the dominant geochemical exploration technique employed.

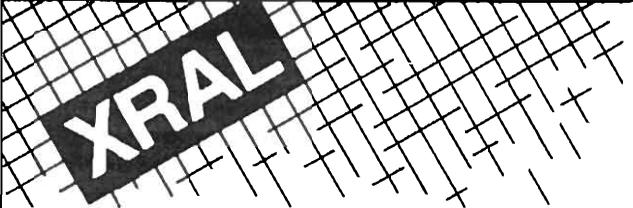
As with most new exploration techniques, until the industry had applied the method and established its limitations and more importantly, understood the factors that can significantly influence its performance as an effective exploration tool, the technology can be horribly abused through ignorance. Such has often been the case with BLEG surveys.

In more recent times, the BLEG technique has lost much of its previous popularity with some companies abandoning the method completely. The main criticism being poor precision (repeatability) and accuracy. The perceived advantages of BLEG surveys, particularly for gold exploration can be summarized as:

- 1) the technique claims low levels of detection providing increased sensitivity;
- 2) larger sample sizes can be collected making the samples statistically more meaningful or representative.
- 3) within well developed weathering environments, particularly deep lateritic profiles, gold is often an extremely mobile element which can be dispersed hydromorphically as well as mechanically. The low detection levels and larger sample size make BLEG surveys ideal for regional-scale stream and soil surveys, and therefore, cost effective.

The successful application of any BLEG survey, indeed any geochemical survey, relies upon an understanding and therefore control of a number of variables that include:

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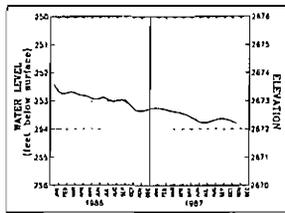
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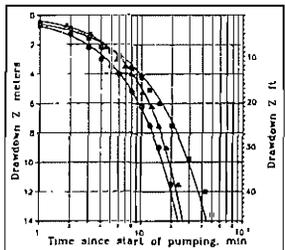
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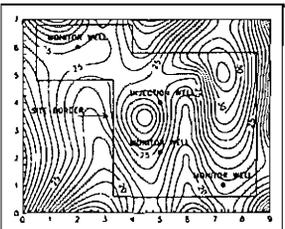
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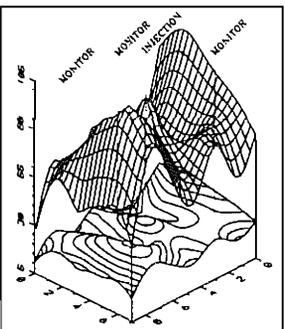
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## Technical Notes

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- 1) Regolith/Landform**  
 An understanding of the type of sample material (particularly its genesis) available for collection and categorizing it within a regolith/landform framework is necessary. This data is then used to define and control precisely the type of material to be collected, and later, for interpretation of analytical data.
- 2) Analytical Performance**  
 Quality analytical data with appropriate control and monitoring of laboratory performance is essential to ensure acceptable levels of precision and accuracy.
- 3) Interpretive Skills**  
 Sensible interpretation must be performed via the integration of 1 and 2 above with other available geotechnical information.

### Regolith/Landform Control

A major factor effecting the results available for interpretation from a BLEG survey is the influence of the regolith or landform, particularly on gold dispersion patterns. BLEG surveys have been overwhelmingly successful in mapping individual regolith units that do not necessarily reflect underlying mineralization. This has led to many wasted metres of drilling that provided no explanation for the impressive geochemical patterns shown by the soil survey. It is worthy of note that gold is not the only element which shows significant variation in concentration within differing regolith units. Thus, an understanding of the sample material, particularly its genesis and position within a complex weathering profile, can effect not only the material selected for collection, but also the size fraction taken.

The author uses regolith classification codes based on those developed by R.E. Smith's Laterite Geochemistry Group, CSIRO, Perth, which have been customized, where appropriate, for application to specific exploration programmes or environments. The geochemical patterns can then be interpreted within a controlled regolith/landform framework of reference.

### Analytical Performance

Although the BLEG analytical methodology appears simple enough, there are many variations promoted by individual commercial laboratories.

These include:

- 1) sample weight - from 0.5 to 20kg, exact weight or approximate weight samples;
- 2) concentration of the cyanide liquor;
- 3) period for digestion - 6hrs to 48hrs;
- 4) type of agitation - roll (continuous or intermittent) tumble or static (no agitation);
- 5) preconcentration techniques (stripping gold from the pregnant liquor) - activated carbon pads, zinc block, organic extraction or direct injection ICP;

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TABLE 1 Results of a BLEG Check Programme (Analyses in ppb)

SAMPLE No.	LABORATORY							Expected Response
	1	2	3	4	5	6	7	
1 - M	0.5	2.4	0.6	1.8	3.2	0.9	3.0	1.2
2 - M	2.1	6.3	2.4	3.6	7.4	2.3	6.0	4.6
3 - M	3.6	9.7	3.2	12.8	5.9	7.4	12.0	10.3
4 - M	0.4	5.3	0.9	4.2	4.6	2.1	1.0	2.3
5 - B	0.6	1.2	0.3	0.9	2.4	0.9	<1.0	<1.0
6 - SX	5.3	3.9	2.9	2.9	6.6	4.4	5.0	4.5
7 - SX	6.4	18.3	5.6	8.3	18.4	6.4	2.0	11.6
8 - B	0.7	1.9	0.2	0.5	1.5	0.8	<1.0	<1.0
9 - SX	8.3	42.3	15.3	21.4	42.4	15.4	24.0	20.2
10 - SX	10.4	2.4	5.1	8.3	10.9	2.4	8.0	5.3
11 - C	3.6	8.6	1.4	13.7	24.7	2.3	7.0	10.0
12 - C	15.8	25.7	5.6	23.2	13.2	8.4	18.0	20.0
13 - C	19.4	38.4	14.7	19.6	23.9	22.6	12.6	30.0
14 - CG	13.6	9.7	24.8	5.6	18.2	11.9	19.6	15.0
15 - CG	33.7	68.0	44.6	54.2	62.4	29.6	63.0	40.0
16 - B	1.9	1.6	1.2	0.5	1.3	0.5	<1.0	<1.0
17 - CG	7.4	10.1	2.9	1.9	6.8	1.4	12.3	6.2
18 - L	1.4	1.6	0.5	1.7	1.6	0.3	2.7	0.9
19 - L	3.4	1.2	1.8	3.7	4.1	2.8	<1.0	2.3
20 - L	2.3	5.3	7.6	2.9	8.8	7.4	2.5	5.5

M - Merredin SX - Southern Cross CG - Coolgardie  
 L - Laverton C - Control sample B - Blank sample

\* Based on control samples, blanks and previous data.

## Technical Notes

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- 6) analytical finish - AAS, AAS carbon rod, ICP-MS;
- 7) reported detection limits - 50, 100, 500, 1000 ppt.

Australian explorationists clearly have a number of analytical alternatives. A comparative check programme was initiated to evaluate the various commercial methods available in Perth, Western Australia. Samples of lateritic soil were sieved to minus 0.5 mm, homogenized and 2-kg samples split for analysis. Check and blank samples were also included. The results are shown in Table 1.

In order to identify and isolate the causes for the wide variations shown by the numerous BLEG methodologies, an applications/research group, In-Field Technology was established by R. Birrell and A. Mann (Chemtronics, Perth, W.A.). The group actively researched the chemistry and methodology of the BLEG techniques to identify those areas contributing to poor precision and accuracy.

Clearly, BLEG is only a partial extraction of free and available metals and will not access elements that are bound within rock. The research confirmed that at every step within the process metals available for final analysis will be lost. Also, the final analytical technique had little impact on results, rather, the handling, digestion and pre-concentration steps had the greatest effect on BLEG performance.

To address these problems, and that of operating in remote locations where analytical facilities are not available and sample freight is expensive, a field-based system was developed. This is currently being applied in Australia and trialed in South America, Africa, and the Middle East in an effort to improve the performance and cost effectiveness of BLEG surveys.

The field system involves:

- 1) a mobile field-facility contained and transported within a 7' x 4' box trailer;
- 2) collection of samples and transfer into leach bottles in the field (2 or 5kg) to avoid excess handling;
- 3) sample leaching at a field camp with 15 ml of pregnant liquor despatched for direct analysis by ICP-MS, thus alleviating excessive freight costs.

### Outlook

In-Field Technology's research activities are currently directed towards development of bulk leach technology for multi-commodity exploration application. Integral to this is the application of interactive sampling procedures in conjunction with field-based analytical methods and instrumentation.

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## The Nickel Thermometer: A New Tool for Diamond Exploration

Chrome-pyrope garnets are widely used as an indicator mineral in exploration for diamonds. Qualitatively, their occurrence in a heavy-mineral concentrate indicates the presence of mantle-derived material. The more quantitative use of these garnets in evaluation of prospects has until now mainly involved the search for low-Ca, high-Cr ("G10") harzburgitic garnets. However, some diamondiferous pipes, such as Argyle, contain few G10 garnets, while some barren pipes (e.g. Zero pipe; Shee et al. 1989) are rich in G10 garnets. Higher-Ca chrome pyropes ("G9" garnets) are typically much more abundant than G10 garnets in heavy-mineral concentrates from kimberlites and lamproites. They carry considerable information on the source of the host rocks, and thus on their diamond potential, but hitherto have been largely ignored in exploration.

Only 1-2% of kimberlites or lamproites contain economic concentrations of diamonds, and bulk testing is an expensive process. A rapid, inexpensive alternative therefore can save the industry millions of dollars annually, and decrease the exploration time invested in a new mine. The Division's Diamond Project has developed a simple technique for evaluating the diamond potential of a kimberlitic or lamproitic host rock, using proton-microprobe analysis of trace elements in a small number of garnet grains from a heavy-mineral concentrate.

Proton-microprobe analyses of garnet grains in concentrates from kimberlites and lamproites show large ranges in the concentrations of some key trace elements, such as Ni, Zn, Ga, Y and Zr. To understand these variations, we have analyzed the coexisting minerals in garnet peridotite nodules (the probable source of most of the garnets) from kimberlites. These xenoliths are important because their temperature of equilibration can be estimated from the compositions of their minerals.

This work found that the Ni content of the garnets in the xenoliths ranges from <10 to >150 ppm and is very sensitive to the equilibration temperature (Fig. 1). This is the result of two effects: the distribution of Ni between garnet and olivine is very temperature-sensitive, and the Ni content of olivine is large ( $\approx 3000$  ppm) and essentially constant in mantle peridotites. This allows us to construct a "nickel thermometer" based only on the Ni content of individual garnet grains. The thermometer has proved to be independent of garnet major-element composition and of pressure; the temperature estimates are probably accurate to  $\pm 50^\circ\text{C}$  (Griffin et al. 1989a).

Continued on Page 14

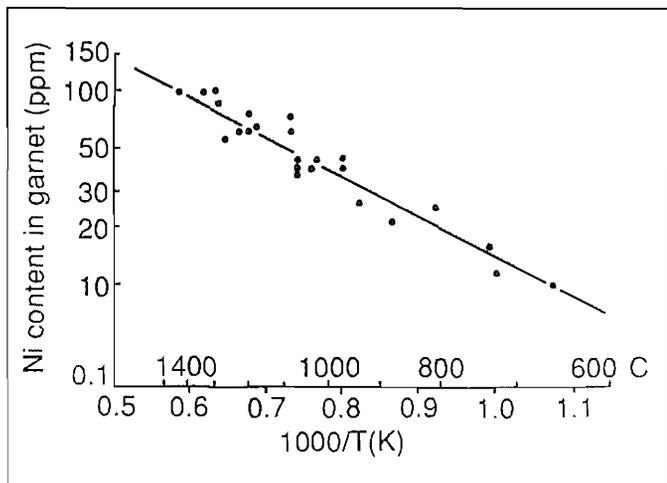


Fig. 1. Relation between temperature and Ni content of garnet in mantle-derived garnet peridotites, assuming Ni in olivine is 3000 ppm. Temperatures estimated by two-pyroxene or olivine-garnet thermometers (after Griffin et al. 1989a, with additional data).

**Technical Notes**

*Continued from Page 13*

The usefulness of the Ni thermometer in diamond exploration depends on the possibility of converting a temperature estimate to a depth estimate. Most temperature/pressure estimates for xenoliths from kimberlites cluster near a calculated "cratonic" geotherm, which crosses from the graphite stability field into the diamond stability field near 1000°C (Fig. 2; Finnerty and Boyd, 1987). From

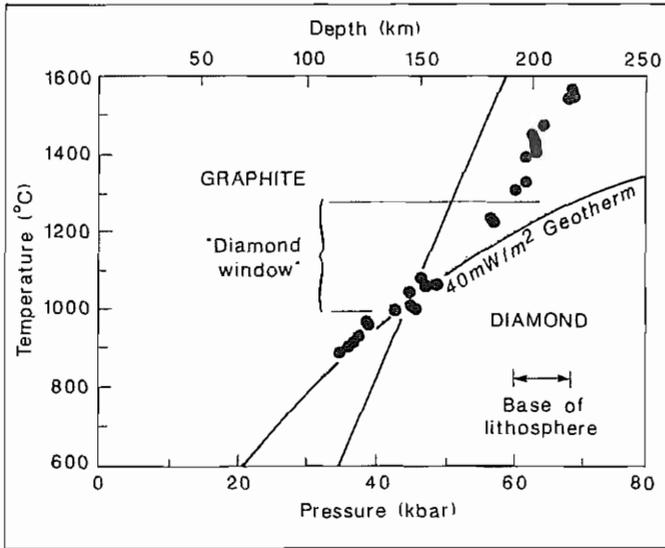


Fig. 2. Pressure (P) -temperature (T) plot showing the graphite-diamond stability curve, the 40 m W/m<sup>2</sup> "cratonic" geotherm and P-T estimates for peridotite xenoliths in Northern Lesotho kimberlites (after Finnerty and Boyd, 1987). The temperature ranges of the "diamond window" and the base of the lithosphere are indicated.

this, we can predict that garnets coexisting with diamonds should give Ni temperatures above about 950-1000°C; this has been confirmed by analysis of garnet inclusions in diamonds. Similarly, the base of the cratonic lithosphere (T ≈ 1250°C) may mark the deepest level from which diamonds commonly are derived. We have applied the Ni thermometer to garnet concentrates from about 50 kimberlites and lamproites, and found several very consistent patterns.

In areas with "cratonic" geotherms, diamond-rich kimberlites and lamproites contain high proportions of garnets with Ni temperatures in the range 950-1250°C. This range coincides with the main temperature distribution for garnet inclusions in diamonds and probably means that the concentrate garnets and the diamonds were derived from the same depths in the mantle. This region was preferentially sampled by diamondiferous kimberlites.

Diamond-poor kimberlites/lamproites in cratonic areas contain a high proportion of garnets with T < 950°C. This suggests they have mainly sampled shallower regions of the mantle, where graphite, rather than diamond, is the stable form of carbon. Many of these low-grade or barren pipes also contain many high-temperature garnets (T > 1250°C), which typically show high concentrations of Ti, Zr and Y. These garnets probably reflect reaction between magmas and their mantle wall-rocks (Griffin et al. 1989b, Smith et al. 1991). Our observations on many garnet concentrates suggest that reaction with high-temperature magmas has a negative effect on diamond preservation.

These principles are well illustrated by examples from Tanzania. The Tanzanian craton contains many kimberlite pipes, divided between an eastern and a western zone (Nixon and Condliffe, 1989; Griffin et al. 1991). All of the known diamondiferous pipes are in the western zone, including Mwadui, the world's largest diamond mine in terms of areal extent. Temperature relations for the kimberlites of the western zone are summarized in Fig. 3. The

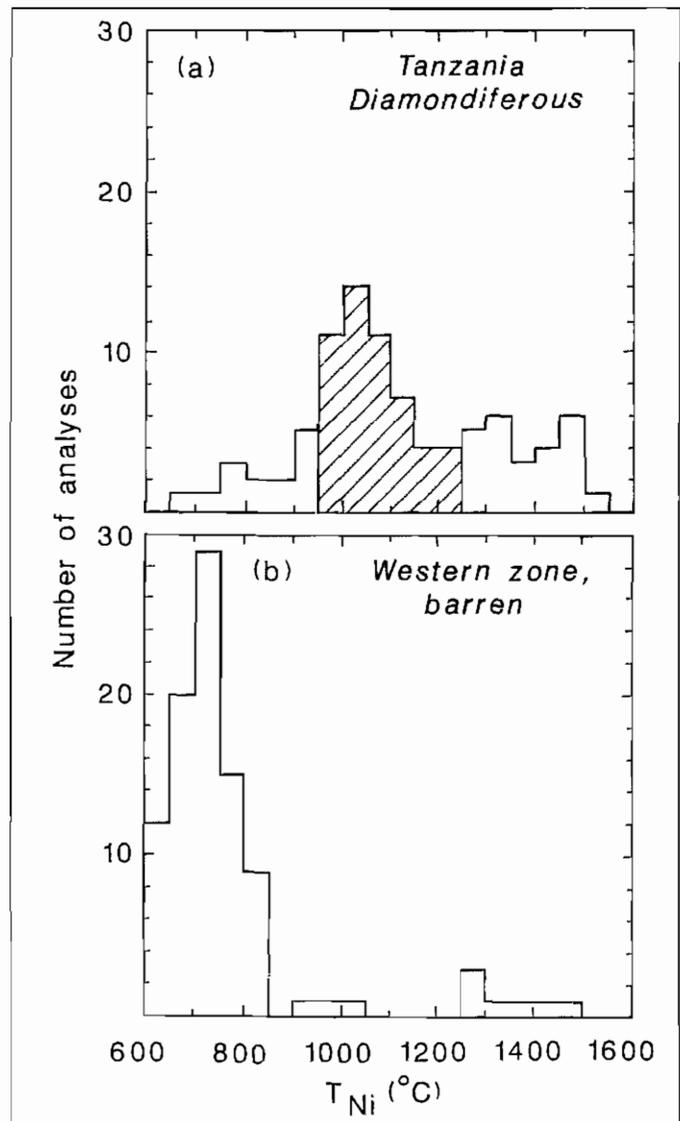


Fig. 3. Nickel-temperature histograms for garnet concentrates from kimberlites of the western zone of Tanzania, showing the differences between (a) diamondiferous and (b) barren kimberlites. The shaded region represents the "diamond window" of Fig. 2.

*Continued on Page 15*

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## Technical Notes

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barren pipes have abundant low-T garnets, some high-T ones and almost none in the 950-1100°C range. The diamondiferous pipes, in contrast, show large peaks in the 950-1100°C range and a significant high-T peak, but almost no low-T garnets. These differences are not reflected in the major-element chemistry of the garnets. In another example, the Skerring kimberlite (North Kimberley) was clearly identified as barren by the analysis of 20 garnets.

The data derived from nickel thermometry of garnet concentrates can also give a semi-quantitative estimate of potential grade. Fig. 4 plots diamond grade against a parameter  $\Omega$ , which is a weighted proportion of the garnets in the different temperature groups. It reflects both the degree of sampling of potentially diamond-bearing mantle and the detrimental effects of magma interaction on diamond preservation.

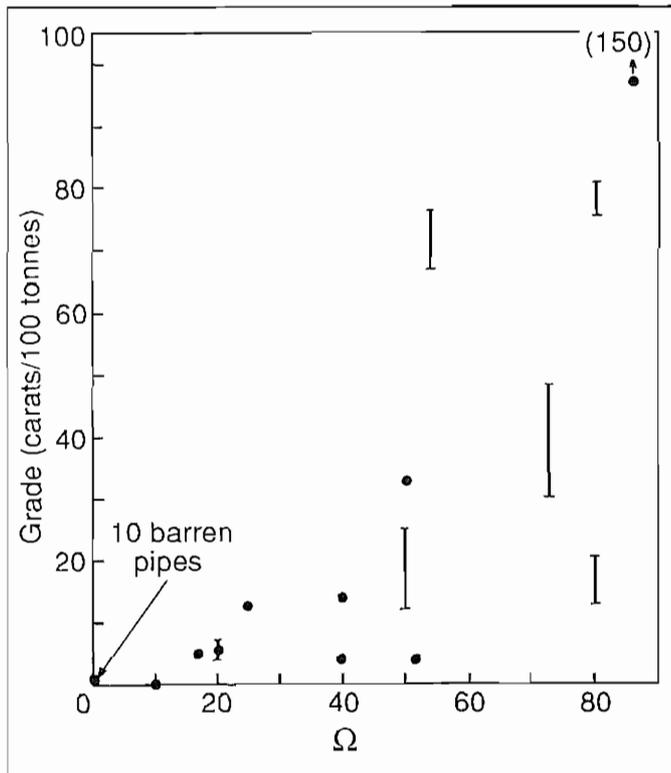


Fig. 4. Correlation between diamond grade (carats/100 tonnes) and  $\Omega$ , a parameter reflecting the relative proportions of garnets in different temperature ranges in a concentrate, for kimberlites and lamproites from Africa, Australia and North America.

The broad correlation between  $\Omega$  and maximum grade suggests that the grade of a pipe is in fact largely determined by the depth range it has sampled. Other factors can be expected to reduce the grade. A pipe could sample carbon-poor material within the diamond stability field, so that it has a high value of  $\Omega$  but a low diamond grade. The grade may also be lowered by dilution with country rock, without this being reflected in garnet chemistry. Several such points appear in Fig. 4. The project is now studying the use of other trace elements, such as Ga, Zr and Y, to identify garnets from carbon-poor mantle.

The use of "G10" garnets to evaluate diamond potential may be ambiguous, at least outside southern Africa. The nickel thermometer technique is independent of the presence or absence of G10 garnets and appears to be a robust and reliable indicator of potential diamond grade. This technique has the added advantage of requiring only a small number of garnets (30-50 grains), rather than a statistically large sample. It can therefore be applied to material

taken from stream or soil samples during exploration programs, as well as to concentrates taken from the primary source rocks.

The nickel thermometer offers a rapid, cheap and powerful tool for evaluating diamond prospects. The potential savings from avoiding bulk testing of barren or very low-grade prospects are very large, especially compared to the cost of the analyses (ca. \$2000 per locality).

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Australia

## THIRD GOLDSCHMIDT CONFERENCE

### SYMPOSIUM ON INTERNATIONAL GEOCHEMICAL MAPPING

Third Goldschmidt Conference,  
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#### Preliminary Program Outline

A full day of oral presentations covering a wide range of aspects related to Geochemical Mapping will be held, supplemented by posters and informal displays. A parallel symposium on Environmental Geochemistry and Health is being sponsored by the Society of Environmental Geochemistry and Health. The following is a preliminary list of presentations for the Geochemical Mapping Sessions, grouped into four main themes:

#### 1) INTRODUCTION AND PROGRESS WITH NATIONAL MAPPING PROGRAMS

Introductory remarks and overview of progress in geochemical mapping in continental North America - P.H. Davenport and J.M. McNeal

Geochemical mapping: progress in Greenland - A. Steenfelt

Continued on Page 16

## Third Goldschmidt Conference

Continued from Page 15

- Geochemical study and mapping of Quaternary deposits in Byelorussia - *V.K. Lukashév*
- Geochemical mapping in western Europe - *B. Bolviken, J. Bogen and R.T. Ottesen*
- Geochemical mapping: progress in Canada - *P.W.B. Friske*
- 2) GEOCHEMICAL MAPPING - APPLICATIONS
- Thematic mapping of southern British Columbia using regional geochemical data - *P.F. Matysek, E.C. Grunsky and W. Jackaman*
- Geochemical mapping: the Nova Scotia experience - *P.J. Rogers*
- Geochemical mapping as an aid in the interpretation of stream sediments from the upper Illinois River basin in Illinois, Indiana and Wisconsin - *S.M. Smith and R.F. Sanzolone*
- The role of geochemical mapping in establishing baselines for the measurement of environmental change; an example from Newfoundland, Canada - *P.H. Davenport and L.W. Nolan*
- 3) INTERNATIONAL MAPPING - DATA LEVELING AND MEDIA COMPARISONS
- A comparison of airborne gamma-ray spectrometry data with stream sediment and lake sediment geochemical data - *A.G. Darnley, P.H., Davenport and A. Steinfeld*
- Comparison of lithochemical and stream sediment geochemical data for granitic rocks in Northern Britain: Implications for petrogenetic, economic and environmental studies - *P.J. Henney, T.M. Williams, J.A. Plant and P.M. Green*
- Multi-media geochemical mapping employing active and overbank stream sediments, lake sediments, and surface water in two areas in Newfoundland - *J.W. McConnell, P.H. Davenport, C. Finch, G.E.M. Hall, S.E. Jackson, H.P. Longrich, and B.J. Fryer*
- Similarities and differences between the geochemical patterns obtained from different sample media collected in the Nordkalott Project in Scandinavia - *S. Steinfeld*
- 4) GEOCHEMICAL MAPPING - NEW METHODOLOGIES AND MEDIA
- Investigation into ultra-low density geochemical mapping using soils on the Canadian Prairies - *R.G. Garrett*
- Lateritic soil pattern above Late Proterozoic volcanic sequences in Nigeria: a geomathematical approach related to rare-metal mineralization - *A.M. Said and G. Matheis*
- Biogeochemical mapping in the maritime provinces of Canada - *C.E. Dunn*
- Stream and lake water as media for geochemical mapping in environmental studies and mineral exploration - *P.R. Simpson, G.E.M. Hall, W.M. Edmunds, C. Finch, D. Flight, N. Breward and T.R. Lister*
- The mapping of geochemical provinces in China based on Pb isotopes - *Bing-Quan Zhu*
- Variable sample density simulation of regional geochemical survey maps - *P.R. Simpson, F. Fordyce and C. McDermott*
- Experience in geochemical mapping using the Clarke Index-1 - *J.A.C. Fortescue and E.A. Vida*
- Fractals and geochemical exploration - *B. Bolviken and P.R. Stokke*

## PEARL HARBOR FILE

With renewed interest in base metal exploration, considerable attention will no doubt be devoted to records of previous exploration campaigns, now reposing in company and government archives. The *Balcooma geochemical drainage survey* provides an example of what may await the diligent investigator. It must be stressed that Balcooma *not* an example of one that got away, thanks to some careful geological work and astute field observation. However, a more appropriate statistical interpretation of the stream sediment geochemistry at an early stage in the project could have led to a more satisfactory outcome for the discoverers.

The Balcooma massive sulphide deposit was discovered by Carpentaria Exploration Co. Pty. Ltd. in 1978 by recognition of gossanous outcrops within an area selected on conceptual geological  
*Continued on Page 17*



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# Pearl Harbor File

Continued from Page 16

grounds (Harvey, 1984). A conventional drainage geochemical survey had been carried out over the area of interest some years before but response over the mineralization subsequently located was so weak that drainage geochemistry was regarded as essentially ineffective in exploration for this type of deposit.

Three occurrences of massive sulphides have so far been located over a 3km zone within a sequence of deformed metasediments of Early Paleozoic age. The northernmost Balcooma deposit contains some 3.5 Mt grading 3.0% Cu plus significant zinc-lead mineralization. Further to the south, the Surveyor 1 and Dry River South deposits aggregate at least 1.8 Mt grading 0.95% Cu, 5.0% Pb, 12.6% Zn, 112 g/t Ag, and 0.9 g/t Au, (Huston and Taylor, 1990). Ownership of these deposits is split between two different groups, a factor which has inhibited exploitation.

The interpretation of Cu and Zn analytical results on -80 mesh fraction stream sediments from the survey carried out in May 1971 is shown in Figs. 1 and 2. The way in which the background, threshold and anomaly categories are expressed on the map legends raises the suspicion that the various parameters have been based on a calculation which assumes the data set consists of a single population. This type of approach, which was common in the 1960s and 1970s, calculated threshold as the mean plus one or two standard deviations of the whole data set, and then used incremental multiples of the standard deviation to designate "possible", "probable" and "definite" anomaly categories.

Such calculations are statistically valid only if the calculation is carried out on a data set comprising samples from a single (background) population. Data sets arising from geochemical

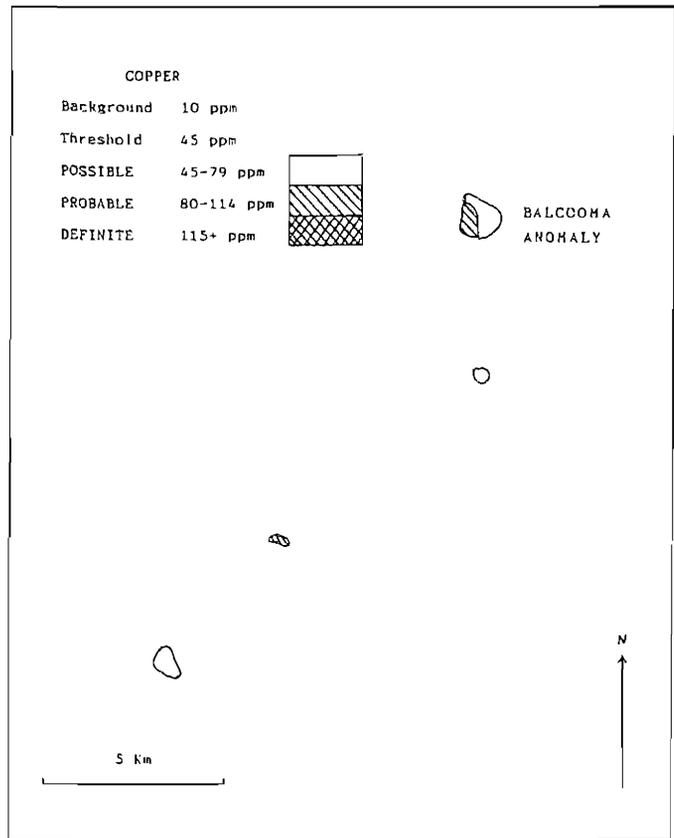


Figure 1. Copper in stream sediments, Balcooma area - 1971 Interpretation.

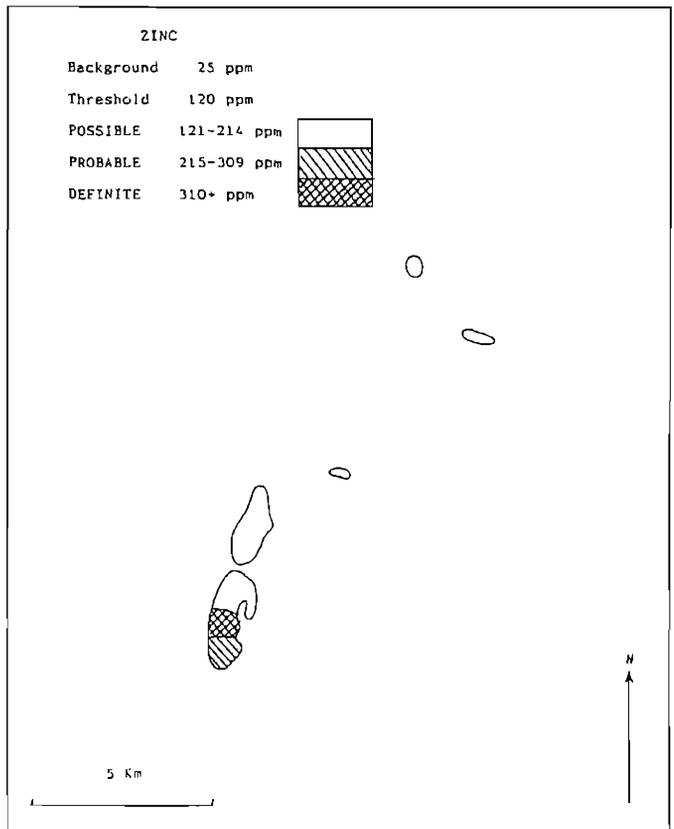


Figure 2. Zinc in stream sediments, Balcooma area - 1971 Interpretation.

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## Pearl Harbor File

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surveys usually consist of several populations. At least one population represents the background for the area. However if more than one rock type is present in the survey area with contrasting trace element characteristics, there may be two or more recognizable background populations. If mineralization is present this will be expressed as one or more additional population, with the target and pathfinder elements at relatively high concentration levels compared to background.

The use of a formula to calculate means and standard deviations on data sets consisting of mixed populations inevitably results in the setting of threshold and anomaly values at too high a level. This appears to have been the case with the original Balcooma interpretation. As a result, only one definite anomaly (for Zn) was recorded,

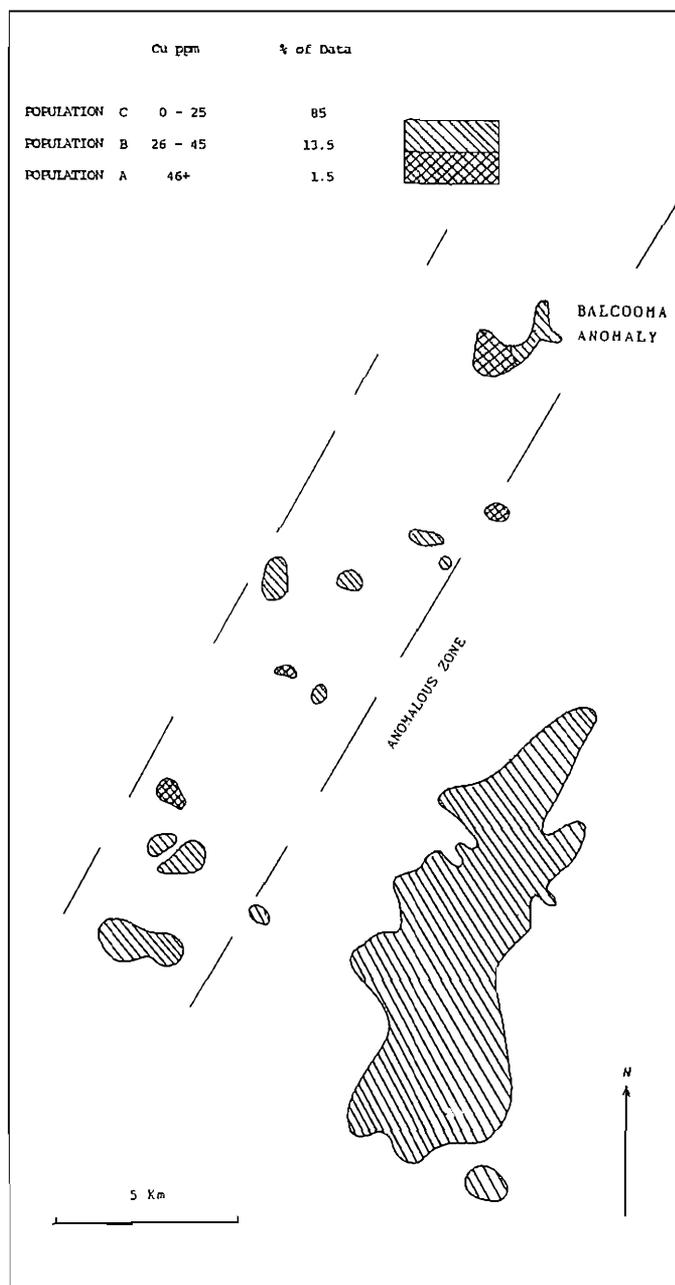


Figure 3. Copper in stream sediments, Balcooma area - Reinterpretation.

and this was found by follow-up to be of no significance. Copper response is particularly subdued. The Balcooma massive sulphide deposit is weakly expressed in the survey by a possible and a probable Cu anomaly (and a probable Pb anomaly) but was not rated as important in comparison with the Zn response to the southwest.

Methods of decomposing single element geochemical data sets into their component populations are well documented in the literature (Sinclair, 1976 and 1983, Rose, Hawkes and Webb, 1979). When applied to the Balcooma Cu and Zn data, they result in the data breakdown indicated in Figs. 3 and 4. The Cu plan (Fig 3) shows an extensive area of population B response in the south eastern segment of the survey, which correlates with a belt of Cainozoic alluvium and laterite overlying an intrusive ranging in composition from tonalite to gabbro (Huston and Taylor, 1990). The elevated Cu results could be related to a gabbroic phase within this batholith, possibly concentrated at the surface by lateritic weathering. Of greater interest are scattered groupings of samples from populations A and B occurring in a NNE-trending zone which passes through the Balcooma deposit. The strongest and most extensive of these anomalies coincides with the Balcooma mineralization.

The southeastern Cu anomaly is poorly expressed in the Zn data, supporting the concept that it is of lithological origin (Fig. 4). However, anomalous Zn is widespread within the NNE-trending belt through Balcooma, coincident and complementary to the Cu (and Pb, not shown) response. The immediate environs of the Balcooma massive sulphide deposit are marked by Pb and Zn values spanning populations A-C. Thus populations A, B and C for Pb and Zn appear to signify mineralization and favourable lithologies. The same can be said for populations A and B for Cu, but the

Continued on Page 19

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## Pearl Harbor File

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interpretation is complicated by a second background population with high Cu content which also generates population B Cu response in stream sediments.

The need for care in setting anomaly threshold parameters is greater in some geochemical contexts than in others. The geochemical dispersion patterns associated with small volcanogenic massive sulphide deposits might be expected to be subtle because of the relatively small surface area of enriched material exposed to weathering and erosion, compared to disseminated deposits e.g. porphyry coppers. This appears to be so for Balcooma, which gives rise to an anomaly of 3.1 sq km with peak values of only 50 ppm Cu, 110 ppm Pb and 115 ppm Zn.

The importance of correctly setting anomaly threshold values is most apparent in this situation. When threshold values are too high, there is the possibility that valid anomalies, such as that caused by Balcooma, will go unrecognized. If too low, valuable resources can be wasted in following up spurious anomalies. At Balcooma the main deposit was discovered by direct geological observation in spite of the apparent weak geochemical expression and could have been overlooked if reliance had been placed entirely on the geochemical survey.

A more rigorous setting of threshold values for the 1971 drainage survey may have led to earlier discovery of the mineralization at Balcooma and recognition of the significance of the NNE-trending zone of anomalous response. Detailed follow-up soil sampling within this zone would quite likely have led to subsequent discoveries, such as Surveyor 1.

Carpentaria Exploration Co Pty Ltd and, in particular, Mr. K.J. Harvey are thanked for providing the open file material which formed the basis of this submission, and for helpful comments.

### Annual Pacific Northwest Mining and Metals Conference MINING, EXPLORATION and the ENVIRONMENT '92

Bellevue, Hyatt Regency Washington April 6-10, 1992

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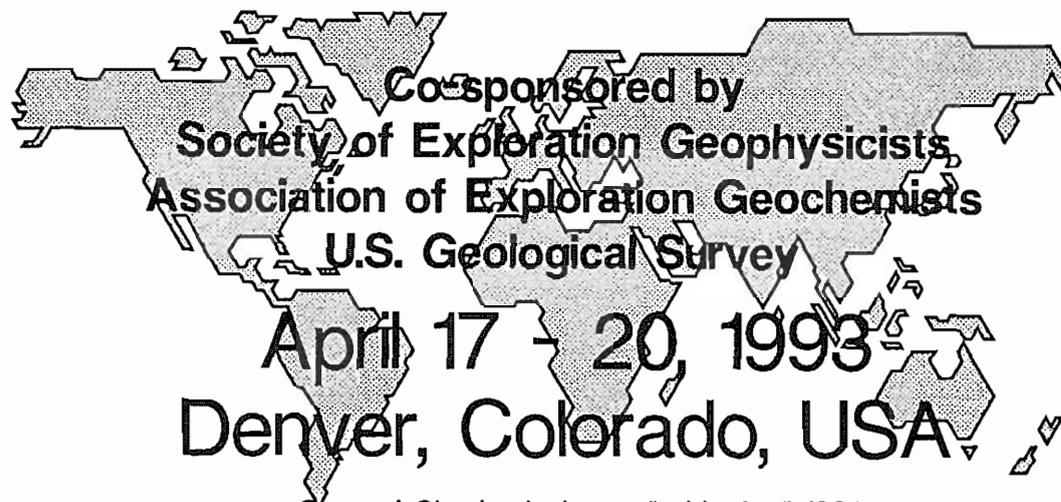


Figure 4. Zinc in stream sediments, Balcooma area - Reinterpretation.

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See progress report on page 21 of this issue of **EXPLORE**

## 16th INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM

The first circular for the 16th International Geochemical Exploration Symposium will be sent out at the beginning of 1992. The Symposium will take place September 3 - 5, 1993 in Beijing, PRC. It will be preceded on September 1 - 2 by the 5th Chinese Exploration Geochemistry Symposium and IGES workshops on:

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3. Geochemical exploration for gold and other precious metals
4. Geochemical exploration for oil, gas, and geothermal fields
5. Environmental and agricultural geochemistry
6. Regional geochemistry and international geochemical mapping
7. Analytical techniques
8. Data processing and interpretation of geochemical data
9. Integrated methods in exploration and discovery

## INTEGRATED METHODS IN EXPLORATION & DISCOVERY, 1993

Call for papers deadline - February 14th, 1992

Alan Coope reports that the response to the Conference Announcement of the SEG's 1993 Conference is very encouraging. The blue slips are still coming in and approximately 30 percent of all respondents are from outside North America. The meeting will, therefore, have that very important international input and atmosphere. By early December, 20 respondents had either submitted abstracts or indicated that summaries of proposed presentations will soon be forthcoming. The Technical Program Committee will be making the program selections immediately after the January 31st, 1992 receipt-of-abstracts deadline.

It is gratifying that the integrated exploration theme of the conference has apparently struck such a responsive chord among explorationists around the world. The organizing committee is looking forward to staging one of the more informative and memorable meetings of the early 1990's. Committee meetings are being held at approximately monthly intervals and planning is on track for the forums, poster sessions, workshops, short courses and related field excursions.

This newsletter article will be a last reminder for all potential authors to get their abstracts to the Technical Program Committee by January 31st, 1992. Please mail them to:

SEG CONFERENCE 93  
PO BOX 571  
GOLDEN CO 80402  
USA

Last minute completions can be faxed to (303) 279-3118.

## AEG ANNUAL GENERAL MEETING

The AEG's Annual General Meeting will be held in conjunction with the Society of Mining Engineers (SME) meeting in Phoenix, Arizona. The SME meeting is scheduled for February 24-27, 1992 at the Civic Plaza North in Phoenix. The Annual General Meeting will take place immediately following the Geochemistry session on Tuesday (24th) in the same room as the session. All AEG members are urged to attend.

## CALENDAR OF EVENTS

### International, National and Regional Meetings of Interest to Colleagues Working in Exploration and Other Areas of Applied Geochemistry

- Jan. 18-25, '92 **Earth Sciences, Computers and the Environment**, mtg., Victoria, Australia, by the Geological Society of Australia (Bloomsbury Conference Services Pty. Ltd., 232 Bridge Road, Richmond, Victoria 3121, Australia; TEL: 61-03-429-4322; FAX: 61-03-427-0715).
- Feb. 4-6, '92 **Minerals, Metals and the Environment**, mtg., Manchester, England (*Institution of Mining and Metallurgy*, 44 Portland Place, London, W1N 4BR).
- Feb. 18-20, '92 **McKelvey Forum on Energy Resources**, mtg., Houston, TX (Christine Turner, USGS, Box 25046, MS 939, Federal Center, Denver, CO 80225, TEL: (303) 236-1561).
- Feb. 22-23, '92 **Biogeochemistry Simplified Short Course** pre-Society for Mining, Metallurgy and Exploration Inc., Phoenix, AZ - see below (Tara Davis, SME, P.O. Box 625002, Littleton, CO 80162).
- Feb. 24-27, '92 **Mineral Resources**, ann. mtg., Phoenix, AZ (Society for Mining, Metallurgy and Exploration Inc., Meetings Department, Box 625002, Littleton, CO 80162; TEL: (303) 973-9550; FAX: (303) 979-3461).
- March 3-30, '92 **Computer-Simulated Mineral Exploration** workshop, Fontainebleau, France (L. Zanone, Ecole des Mines de Paris, Centre de Geologie General et Miniere and Informatique Gitologique et Miniere, 35, Rue Saint Honore, 77305 Fontainebleau Cedex, TEL: 33-1-64-69-49-30; FAX: 33-1-64-69-47-01; deadline for grant requests: Jan. 15, 1992).

Continued on Page 22



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## Calendar of Events

Continued from Page 21

■ March 9-12, '92 Circum-Pacific Council for Energy and Minerals Resources, mtg., Bangkok, Thailand (Mat Stewart, Circum-Pacific Council, Suite 500, 5100 Westheimer, Houston, TX 77056, TEL: (713) 622-1130; FAX: (713) 622-5360).

■ March 28, '92 Came 92 'CAD, From Mapping to Mining, Royal York Hotel, Toronto, Ontario.

■ March 29 - April 1, '92 Prospectors and Developers Association of Canada 1992 Annual Convention, Royal York Hotel, Toronto, Ontario (Dr. W.E. Urquhart, 74 Victoria Street., Suite 1002, Toronto, Ontario M5C 2A5).

■ Apr. 8-10, '92 Society for Mining, Metallurgy and Exploration Inc. Regional (Northwest Section) Symposium on Topical Exploration Interest in **Geology, Geochemistry and Geophysics**, Bellevue, Washington (Grant Newport, c/o Weyerhaeuser Co., PC2-31, Tacoma, WA 98477, TEL: (206) 924-2754, FAX: (206) 924-3862).

■ May 8-10, '92 **Goldschmidt Conference**, Reston, VA, by the Geochemical Society, the AEG, and other societies (Bruce R. Doe, USGS, 923 National Center, Reston, VA 22092, TEL: (703) 648-6205; FAX: (703) 648-6191). Includes Symposium in **International Geochemical Mapping** (P. H. Davenport, Geological Survey, Newfoundland Department of Mines and Energy, P.O. Box 8700, St. John's, Newfoundland A1B 4J6, Canada, TEL: (709) 729-2171; FAX: (709) 729-3493, abstract deadline, Dec. 1, 1991).

■ May 25-27, '92 GAC-MAC, ann. mtg., Wolfville, Nova Scotia (Aubrey Fricker, Atlantic Geoscience Centre, Bedford Institute of Oceanography, Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, TEL: (902) 426-6759).

■ Aug., '92 13th Caribbean Geological Conference, Pinar del Rio, Cuba (Sociedad Cubana de Geologia, Apartado 370, CH-10100, Habana, Cuba).

■ Aug. 23-28 '92 Symposium on **The Environmental Geochemistry of Sulfide Oxidation**, (American Chemical Society Meeting), Washington, D.C. (Charles N. Alpers, Dept. of Geological Sciences, McGill University, 3450 University St., Montreal, Quebec, H3A 2A7, Canada, TEL: (514) 398-3589; or David Blowes, Waterloo Center for Groundwater Research, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada, TEL: (519) 885-1211, ext. 6997).

■ Aug. 24-Sept. 3, '92 29th **International Geological Congress**, Kyoto, Japan (Secretary General, IGC-92 Office, P.O. Box 65, Tsukuba, Ibaraki 305, Japan, TEL: 81-298-54-3627; FAX: 81-298-54-3629).

■ Oct. 26-29, '92 Geological Society of America, ann. Mtg., Cincinnati (Vanessa George, GSA, Box 9140, Boulder, CO. 80301, TEL: (303) 447-2020).

■ Spring, '93 **Integrated Methods in Exploration & Discovery**, Society of Economic Geologists Conference, Denver, CO (Richard L. Nielsen, SEG, Box 571, Golden, CO 80402; TEL/FAX (303) 279-3118).

■ May 17-19, '93 GAC-MAC, ann. mtg., Edmonton, Alberta (J. W. Kramers, Alberta Geological Survey, Box 8330, Station F, Edmonton, AB, T6H 5X2, Canada; TEL: (403) 438-7644; FAX: (403) 438-3364).

■ Sept., '93 **16th International Geochemical Exploration Symposium**, and **5th Chinese Exploration Geochemistry Symposium**, Beijing, China (Dr. Xie Xuejing, Honorary Director, Institute of Geophysical & Geochemical Exploration, Langfang, Hebei 102849, China; TELEX: 22531 MGMRC CN; FAX: 86-1-4210628; and, Dr. Lin Cunshan, Deputy Director, Institute of Geophysical and Geochemical Exploration, Langfang, Hebei 102849, China; TELEX: 26296 LFPBL CN; FAX: 86-0316-212868).

■ Oct. 25-28, '93 Geological Society of America, ann. mtg., Boston, MA (Vanessa George, GSA, Box 9140, Boulder, CO 80301; TEL: (303) 447-2020).

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

Fred Siegel

The George Washington University  
Department of Geology  
Washington, D.C. 20052  
USA

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## SOFTWARE AVAILABLE

### Ternary Plots Using LOTUS 1-2-3

Triangle.WK1 is a LOTUS 1-2-3 template program which recalculates the values of three components into triangular coordinates, allowing plotting of the triangle graphs or ternary plots used in geological classification schemes. The graphic capabilities of LOTUS 1-2-3 are used to draw the diagram on which the data are plotted. The blank triangular diagram provided can be modified to include the field boundaries and apex labels of any classification scheme. Five are included: two for sandstone, one for felsic plutonic rocks, one for ultramafic rocks, and one for volcanic rocks. This program was originally published in *Geobyte* (Mustard and Richardson, 1990, Feb. 1990, pp.1-7).

As a service to potential clients and the geological community, this program and a *Geobyte* reprint are available from the Geoscience Laboratories, Ontario Geological Survey, Ministry of Northern Development and Mines for either LOTUS 1-2-3 (V2.01 or 3) upon submission of 5.25 or 3.5 inch, high or low density diskettes. There is no copying charge; however, the following conditions apply.

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## RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in EXPLORE Number 73. 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, Chairman AEG Bibliography Committee. Please send new references to Dr. Closs, not to EXPLORE.

Anthony, J.W., Bideaux, R.A., Bladh, K.N. and Nicols, M.C. 1990. Handbook of Mineralogy. V. I: Elements, Sulfides, and Sulfosalts. Min. Data Pub. (Tucson, AZ).

Ashley, R.P. et al. 1991. Geology and geochemistry of three sedimentary rock-hosted disseminated gold deposits in Guizhou province, People's Republic of China. Ore. Geol. Rev. 6: 133-152.

Bechtel, A. and Pattmann, W. 1991. The origin of the kupferschiefer-type mineralization in the Richelsdorf Hills, Germany, as deduced from stable isotope and organic geochemical studies. Chem. Geol. 91(1): 1-18.

Benvenuti, M. et al. 1991. Mineral chemistry of tourmalines from the Bottino mining district. Europ. J. Mineralogy. (3): 537-.

Berthelin, J. (Ed.) 1991. Diversity of Environmental Biogeochemistry. Elsevier. 538 p.

Bloom, H. 1991. Review of the exploration and development of the Mount Pleasant Mines, New Brunswick, Canada. in Hollister, V.F. (Ed.) Case Histories of Discoveries. V. 3: 185-188.

Blount, A.M. and Parkison, G.A. 1991. Hydrothermal alteration haloes and enlarged soil anomalies over concealed talc bodies, southwestern Montana. Ore. Geol. Rev. 6: 185-194.

Branthaven, J.F. and Filby, R.H. (Eds.) 1991. Special Issue: Trace Metals in Petroleum Geochemistry. Chem. Geol. 91(2): 83-206.

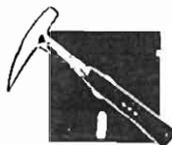
Bulnaye, K.B. and Kaperskaya, Y.N. 1991. Trends in REE distribution in fluorite from various types of deposits in Transbaykalia. Geochem. Intern. 28(7): 73-85.

Cerny, P. 1991a. Rare-element Granitic Pegmatites. Part I: Anatomy and internal evolution of pegmatite deposits. Geoscience Can. 18(2): 49-67.

Continued on Page 24

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## Recent Papers

Continued from Page 23

Cerny, P. 1991b. Rare-element Granitic Pegmatites. Part II: Regional to global environments and petrogenesis. *Geoscience Can.* 18(2): 68-81.

Cole, M.M. 1991. Remote sensing, geobotany and biogeochemistry in detection of Thalanga zinc-lead-copper deposit near Charters Towers, Queensland, Australia. *IMM 100*: B1-8.

Faure, G. 1991. Principles and Applications of Inorganic Geochemistry. Macmillian, 626 p.

Force, E.R. 1991. Geology of Titanium-Mineral Deposits. *Geol. Soc. Am. Sp. Paper* 259. 112 p.

Fujinuki, T. 1990. Determination of Nb and Ta in weathering soils from Brazilian carbonatite complexes. *Bull. Geol. Soc. Japan* 41(11): 627-630.

Hausen, D.M. and Odekirk, J.R. 1991. XRD mineralogic logging of drill samples from gold and copper mining. *Ore. Geol. Rev.* 6: 107-118.

Korobeynikov, A.F. et al. 1990. Endogenetic zoning of gold mineralization and sulfur isotopes in a black shale deposit. *Intern. Geol.* 32(10): 1008-1016.

Kribek, B. 1991. Metallogeny, structural, lithological and time controls of ore deposition in anoxic environments. *Min. Deposita.* 26(2): 122-131.

Kujansuu, R. and Saarnisto, M. (Eds.) 1990. Glacial Indicator Tracing. A.A. Balkema. 252 p.

Mardock, C.L. and Barker, J.C. 1991. Theories on the transport and deposition of gold and PGM minerals in offshore placers near Goodnews Bay, Alaska. *Ore. Geol. Rev.* 6: 211-228.

McEwan, C.J.A. and Rice, C.M. 1991. Trace-element geochemistry and alteration facies associated with epithermal gold-silver mineralization in an evolving volcanic centre, Rosita Hills, Colorado, USA. *IMM 100*: B19-27.

Middlemost, E.A.K. 1991. Towards a comprehensive classification of igneous rocks and magmas. *Earth-Sci. Rev.* 31(2): 73-87.

Min, K.W. 1991. A geochemical study of granitic rocks related to uranium deposits at the Midnite mine, Washington, USA. *J. Korean. Instit. Min. and Energy Res. Eng.* 28(2): 75-85.

Nahon, D.B. 1991. Introduction to the Petrology of Soils and Chemical Weathering. Wiley. 313 p.

Nelridge, R.A. and Blount, A.M. 1991. The use of soil anomalies to locate concealed talc bodies. *Ore. Geol. Rev.* 6: 195-210.

Nicilini, P. 1990. *Gitologie et Exploration Miniere*. Lavoisier. 589 p.

Paul, D.K. 1991. Indian kimberlites and lamprophyres: Mineralogical and chemical aspects. *J. Geol. Soc. India.* 37(3): 221-238.

Petts, G.E., Coats, J.S. and Hughes, N. 1991. Freeze-sampling method of collecting drainage sediments for gold exploration. *IMM 100*: B28-32.

Ramadorai, G., Hausen, D.M., and Bucknam, C.H. 1991. Metallurgical, analytical and mineralogical features of Carlin refractory ores. *Ore. Geol. Rev.* 6: 119-132.

Ramsden, A.R., Kinealy, K.M. and French, D.H. 1991. Gold grades and iron content of sphalerite-relationship of possible genetic significance from volcanogenic massive sulphide deposit of north-west Tasmania, Australia. *IMM 100*: B42-44.

Samoylov, A.G. and Sadikov, M.A. 1991. Geochemical data-based prognosis for ore deposits in the trapp regions. *Geologija Rudnykh. Mestorozhdenii.* 33(1): 69-76.

Smedley, P.L. 1991. The geochemistry of rare earth elements in groundwater from the Carnmenellis area, southwest England. *GCA* 55(10): 2767-2779.

Theyer, P. 1991. Petrography, chemistry and distribution of platinum and palladium in ultramafic rocks of the Bird River Sill, SE Manitoba, Canada. *Min. Deposita.* 26(3): 165-174.

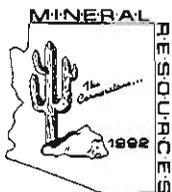
### SME SHORT COURSE

#### Biogeochemical Exploration - Simplified

February 22-23, 1992 Sheraton Hotel  
Phoenix, Arizona, USA

This course is designed for explorationists as an introduction to the concepts of biogeochemical methods applied to exploration programs for minerals and precious metals. Emphasis is placed on practical application of techniques. Course content includes: element requirements and tolerances of common plants; environmental controls on metal uptake; sampling methods, sample preparation, analytical methods, analytical controls, and data evaluation. Case histories from: arid, temperate, and boreal environments are presented, and a half day field trip is taken to demonstrate methods.

**INSTRUCTORS:** *Colin E. Dunn*, Biogeochemist, Geological Survey of Canada; *Gwendy E.M. Hall*, Analytical chemist, Geological Survey of Canada; *James A. Erdman*, Botanist, US Geological Survey; and *S. Clark Smith*, Geochemist, Minerals Exploration and Environmental Geochemistry.



**FEE:** Cost for Members of AIME, AEG, CIM, and SEG is US\$350, Nonmember cost is US\$475.

**CONTACT:** SME, Meetings Dept., PO Box 625002, Littleton, CO 80162 USA, TEL:(303)973-9550 FAX:(303)979-3461.

**DEADLINE** for registration is February 7, 1992

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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 Vancouver office, recommendation by the Admissions Committee, review by the council, and publication of applicant's names in the newsletter remains unchanged.*

### VOTING

**Baxter, Robert W.**

*Sr. Geologist  
Geopeko  
Kensington, WA, Australia*

**Eden, Peter**

*Researcher  
Abo Akademi University  
Abo, Finland*

**Garnett, David**

*General Manager  
Becquerel Labs  
Menai, NSW, Australia*

**McClenaghan, Beth**

*Quaternary Geol/Geochem  
Geol. Survey Canada  
Ottawa, ON, Canada*

**Sell, James D.**

*Manager SW Expl Div  
ASARCO  
Tucson, AZ, USA*

**Sibbick, Steve**

*Head Appl. Geochem Unit  
BC Geol Surv  
Victoria, BC, Canada*

**Zhovinsky, Edward Y.**

*Deputy Director  
Inst Geochem and Phys of Minerals  
Kiev, Ukraine SSR*

### AFFILIATE

**Bailey, David G.**

*Principal  
Bailey Geol Conslts  
Vancouver, BC, Canada*

**Barnes, Gordon J.**

*Project Geologist  
Normandy Poseidon  
Perth, WA, Australia*

**Camus, Francisco**

*VP Exploration  
Codelco-Chile  
Santiago, Chile*

**Marian, Ron**

*General Manager  
Australian Assay Labs  
Greenwood, WA, Australia*

**Medina, Cesar C.**

*Homestake Australia  
Aitkenvale, QLD, Australia*

**Money, David P.**

*Sr. Field Geologist  
Falconbridge  
Chelmsford, ON, Canada*

**Routledge, Richard E.**

*Teck Exploration  
Toronto, ON, Canada*

**Saric R., Nicolas**

*Exploration Manager  
Soc. Minera Pudahuel  
Santiago, Chile*

**Schell, Gary D.**

*USMX  
Tucson, AZ, USA*

**Silva M., J. Roberto**

*Expl Geologist  
Industrial Minera Mexico  
Parral, Mexico*

**Teale, Graham S.**

*Conslt Geologist  
Prospect, SA, Australia*

**Wetherill, James E.**

*Geologist  
BHP-Utah Mines  
Vancouver, BC, Canada*

### STUDENT

**Dower, Brendan J.**

*University of Tasmania  
Hobart, Australia*



## Symposium on International Geochemical Mapping

**Third Goldschmidt Conference  
Reston, Virginia  
May 8-10, 1992**

**Co-sponsored by  
The Association of Exploration Geochemists  
and IGCP Project 259**

As part of the Goldschmidt Conference, a one-day symposium will present the results of regional and continental scale geochemical mapping in North America and Greenland, and demonstrate its application to geological and environmental fields.

### Topics will include:

- the extent of coverage by systematic geochemical mapping
- airborne gamma-ray spectrometry
- sample media, sampling methods and designs; *establishing relevant geochemical baselines*
- analytical techniques; *element suites, instrumental methods, element speciation, standardization*
- data compilation and presentation
- applied/integrated case histories; *mineral exploration, geological correlation, health, agriculture, forestry...*

### For additional information, please contact:

Dr. Peter H. Davenport  
Geological Survey  
Nfld. Dept. of  
Mines & Energy  
P.O. Box 8700  
St. John's, Nfld.  
A1B 4J6  
Canada  
Tel: 709-729-2171  
Fax: 709-729-3493

Dr. James M. McNeal  
U.S. Geological Survey  
Mail Stop 913  
Reston  
Virginia 22092  
USA  
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**See list of titles on page 15.**

# AEG PUBLICATIONS

The following special volumes are available from the AEG on a post-paid basis (surface mail) to all.  
Both member and non-member prices are listed.

Sp. Vol. No.	Description	Member Price	Non-Member Price
4	Application of Probability Plots in Mineral Exploration (A.J. Sinclair)	US \$ 8.00	US \$ 12.00
7	Geochemical Exploration 1977 Proceedings of the Denver Geochemical Symposium (ed. J.R. Waterson and P.K. Theobald)	US \$ 20.00	US \$ 40.00
10	Gold-81, Precious Metals in the Northern Cordillera (ed. A.A. Levinson)	US \$ 7.50	US \$ 18.00
11	Exploration Geochemistry Bibliography to January 1981 (compiled by H.E. Hawkes)	US \$ 10.00	US \$ 20.00
11.1	Exploration Geochemistry Bibliography Supplement 1 to Oct. 1984 (compiled by H.E. Hawkes)	US \$ 10.00	US \$ 17.00
11.2	Exploration Geochemistry Bibliography Supplement 2 to Oct. 1987 (compiled by H.E. Hawkes)	US \$ 10.00	US \$ 17.00
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—	GEOEXPO/86, Proceedings of an exploration symposium focussing on Cordilleran environments held in Vancouver May 12-14, 1986 (ed. I.L. Elliot and B.W. Smee)	US \$ 37.00	US \$ 37.00
—	Reviews in Economic Geology Volume 3. Exploration Geochemistry; Design and Interpretation of Soil Surveys (ed. W.K. Fletcher) This volume was co-sponsored by the SEG.	TO U.S.A. US \$ 20.00 FOREIGN US \$ 23.00	TO U.S.A. US \$ 25.00 FOREIGN US \$ 28.00
—	1992 AEG Membership Listing and Directory of Exploration Geochemical and Environmental Services	US \$ 10.00	US \$ 20.00
—	Journal of Geochemical Exploration for 1991 (Volumes 39-41)	US \$ 50.00	N/A
—	for 1990 (Volumes 36-38)	US \$ 50.00	N/A
—	for 1989 (Volumes 34-35)	US \$ 50.00	N/A
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