

EXPLORE

Newsletter for the Association of Exploration Geochemists

NUMBER 76

JULY 1992

PRESIDENT'S MESSAGE

A Need for Volunteers

The Association of Exploration Geochemists was founded twenty-two years ago after members recognized the need for a professional organization to represent exploration geochemists. Our organization has been served over this period of time by a capable group of volunteers in the Executive, Council, **EXPLORE**, Journal of Geochemical Exploration (JGE), and various committees.



The AEG has reaffirmed its focus on exploration geochemistry but has also made the commitment to expand its contacts with professionals in related fields (e.g. environmental geochemistry) and to conduct activities which will serve the membership (e.g. education, professional registration, short courses, special publications). This taxes the limited time of existing volunteers.

As with any volunteer organization, there is a small active group of volunteers who carry out the vast majority of activities of the Association within the framework of several committees. In order to maintain the vitality of the organization, we need more members to participate in the endeavors of these committees.

The list of committees is included at the end of this column. The titles are, for the most part, self-explanatory and reflect the commitments and activities of the Association. The committees are of two types, those which were formed to address specific issues, such as the Bylaws Review, Elsevier Negotiations, and Membership Application forms. These committees are dissolved after their task has been accomplished. However, the vast majority of committees are ongoing. These committees need your input.

In the past, it has been difficult to determine who to contact to volunteer your assistance. For that reason, we are also including the corresponding addresses of the Committee Chairman. Contact the chairmen and volunteer your time to the Association.

A second way to participate is for members to upgrade their membership status to Voting Member. This gives you the opportunity to vote on matters concerning the Association and have a say in the direction of the Association. Applications may be obtained through the Association offices in Vancouver.

If you have any questions, comments, or suggestions for the Association, feel free to contact any of the Chairman listed starting on the next page.

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TECHNICAL NOTES

Detection of Bedrock-related Geochemical Anomalies at the Surface of Transported Overburden

Introduction

The chemistry performed before instrumental determinations are made is critical to the quality of the geochemical interpretations made from the resulting data. In the 1970's and 1980's much emphasis in exploration geochemistry was placed on new instrumental techniques. Many geochemists found that volumes of multi-element data could be generated by inductively-coupled plasma/atomic emission spectroscopy (ICP/AES) for a relatively low cost. Consequently, interest in data handling and manipulation using computers to assist in producing interpretations increased dramatically. During this period of "Black Box" analyses the importance of preparatory chemistry was largely ignored, and the usefulness of analytical chemistry for unraveling dispersion processes was frequently overlooked. Consequently, geochemical exploration data often have been interpreted with little regard for the strengths or weaknesses of the analytical techniques used to produce the data. Also, an adage that has often been quoted is that you can not do exploration geochemistry on transported overburden, because the material in the overburden is unrelated to the bedrock that it covers. This viewpoint exemplifies a lack of comprehension of chemical mobility, geochemical barriers, and how selective partial analysis can be used to enhance extremely subtle geochemical anomalies.

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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 1/4- or 3 1/2-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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C/O USGS

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Information for Advertisers

EXPLORE is the newsletter of the Association of Exploration Geochemists (AEG). Distribution is quarterly to the membership consisting of 1200 geologists, geophysicists, and geochemists. Additionally, 100 copies are sent to geoscience libraries. Complimentary copies are mailed to selected addresses from the rosters of other geoscience organizations and additional copies are distributed at key geoscience symposia. Approximately 20% of each issue is sent overseas.

EXPLORE is the most widely read newsletter in the world pertaining to exploration geochemistry. Geochemical laboratories, drilling, survey and sample collection, specialty geochemical services, consultants, environmental, field supply, and computer and geoscience data services are just a few of the areas available for advertisers. International as well as North American vendors will find markets through EXPLORE.

The EXPLORE newsletter is produced on a volunteer basis by the AEG membership and is a non-profit newsletter. The advertising rates are the lowest feasible with a break-even objective. Color is charged on a cost plus 10% basis. A discount of 15% is given to advertisers for an annual commitment (four issues). All advertising must be camera-ready PMT or negative. Business card advertising available for consultants only.* Color separation and typesetting services are available through our publisher, Network Graphics, Inc.

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EXPLORE

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President's Message

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President's Message

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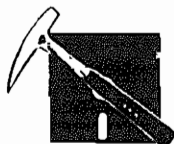
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NOTES FROM THE EDITOR

Interest in partial digestions appears to be on the rise, much to the joy of many geochemists. Bob Clark begins this issue by describing a selective leach for amorphous manganese oxides. In the *Analyst's Couch* column, Gwendy Hall describes the results of some additional experiments with the portable anodic stripping voltammeter, which is beginning to look like a robust, field portable method of gold analysis with the potential for high sensitivity.

Some readers will have noticed that the last issue of **EXPLORE** (Number 75) was delivered later than normal. This was due to a technical difficulty with the membership label list. We believe this problem has been remedied and expect to resume our quarterly publication schedule with this issue. Your patience is appreciated.

EXPLORE continues to service the AEG as a quick and efficient way to reach the membership with news and issues. It is also a good place to alert other members of items of interest and perhaps to *air out* your latest ideas on exploration geochemistry. All members should consider submitting to **EXPLORE**. It's quick, it's easy, and it keeps the Association current and healthy. Please join in.

Deadlines for the future issues of **EXPLORE**

Publication Date	Issue Number	Final date for submissions
October 1992	77	August 31, 1992
January 1993	78	November 30, 1992
April 1993	79	February 28, 1993

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NOTES FROM THE BUSINESS MANAGER

Membership Database: The AEG has processed about 3050 applications since the inception of the organization in 1970. During that time, record keeping has changed from manual recording in the early days, through the use of computer service bureaus in the late 1970's, to the use of RBASE in the 80's and DBASE in the 90's. At each stage, decisions were made to modernize but at the same time keep costs to the AEG low.

The latest change in procedure began in 1991 with the opening of the Vancouver office. It became apparent shortly thereafter that decades of compromise had introduced errors and omissions in the database. I believe these have been now identified and rectified to the point where verifications by the membership is the next step. We are presently developing a DBASE entry program to minimize data entry errors in the future.

Our new database will request members to provide both their home and business address (and applicable telephone/fax numbers), with an indication of which address they wish to use for mailing purposes. To help us update our database, we are requesting inclusion of a business card with all correspondence. This will serve several purposes. It will enable locating lost members more easily and it will minimize errors in recording addresses and affiliations. It will also facilitate merging of the AEG service DIRECTORY with the membership database, and minimize AEG costs in contacting prospective new members.

AEG Directory: Publication of the 1992 version of the DIRECTORY has been delayed as a consequence of the need to correct the membership database. This has now been

accomplished, and it is hoped the DIRECTORY will be on its way to members about the same time as this issue of EXPLORE reaches your hands.

Publicity - New Members: The AEG uses as its main method of promotion a complimentary copy of EXPLORE and a follow up letter from our President, along with an application form and publications list. We request address labels from sister non-profit organizations (such as the Northwest Mining Association, SEG, SME, IAGC). We also use the addresses in the AEG DIRECTORY.

Our costs for promotion are lowest when aimed at prospects in the USA because of our non-profit status and low mailing costs. Higher costs are incurred in Canada and highest costs characterize locations outside North America. The AEG has recognized its international membership by not adding a subscription price differential on membership to reflect costs, understanding that costs of AEG members in many "outside North American locations" represent a significant proportion of income and could not easily be afforded. Members living outside North America are not penalized.

Promotion, however, has focussed on the USA. This has led to duplication and in some cases regular receipt of EXPLORE even though the recipient is not an AEG member. This duplication will end shortly.

To avoid reoccurrence of duplication, the AEG needs your assistance. Send in your business cards so that the AEG is not sending you duplicate mailings at your work place. Send along lists of exploration offices of related companies (or the same company in different cities) so that they can be compiled in the DIRECTORY. This request is particularly directed at members outside North America. If you do receive a duplicate mailing, please pass it along to an interested colleague.

Biogeochemical Exploration - Simplified: The AEG has sponsored a biogeochemical-geobotanical prospecting short course with emphasis on arid terrains. A limited print run of 20 copies are available for sale from the AEG Vancouver office. See advertisement this issue.

Elsevier Special Books Offer: Elsevier has reduced the cost of a number of topical geological/geochemical texts. See advertisement this issue.

Lost Members: The AEG has compiled a list of recent members who have moved or whose addresses are inaccurate or incomplete. Please examine the list in this issue and if you recognize a name, please send the AEG Vancouver office an update of the address and telephone/fax of that member.

Dues Notice Reminders: These were sent out to members who are in arrears in payment of 1991 or 1992 dues (about 691 members). In addition, notices were also sent to 223 previous members who were last active in the Association in 1988, 1989 or 1990.

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LINDGREN AWARD NOMINATIONS

The Lindgren award is offered annually by the Society of Economic Geologists to a young geologist whose published research represents an outstanding contribution to economic geology. The award, which consists of a citation, dues-free membership in the Society, and travel to the fall meeting for the presentation, is not restricted as to the candidate's nationality, place of employment, or membership in the Society. The work for which the Lindgren Award is given must have been published as a single paper or series of papers in a recognized journal before the author's 35th birthday, and the awardee must be less than 37 years of age on January 1 of the year in which the award is presented.

The award can be given for contributions to economic geology from any subdiscipline of geology (including, among others, structural geology, mineralogy, petrology, geochemistry, stratigraphy, geophysics, and mine geology).

Any Society member in good standing may nominate candidates for the award. We are currently seeking nominations for the 1993 Award, for which nominees must have been born after January 1, 1956. Nominees who are not selected for 1993 but are still eligible will be considered for awards in following years. The deadline for nominations is October 30, 1992.

For more information please contact:

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Technical Notes

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In the Canadian Shield, large areas are covered by one or more sequences of glacial till and glaciolacustrine sediments. In the Basin and Range Province much of the bedrock has been buried by basin fill. Typically the overburden in these regions is exotic to the bedrock that it covers. A conventional chemical analysis would reveal only the composition of the overburden and would not give any indication of the underlying bedrock. Drilling has been the only means of collecting useful geochemical samples in areas of extensive overburden. An inexpensive technique was needed for gathering meaningful geochemical data from overburden that would provide some indication of the chemistry of the bedrock.

Small amounts of trace elements mobilized by oxidation of sulfide minerals in the bedrock or basal till can migrate through

overburden by various mechanisms, such as ground water flow, capillary action, or diffusion of volatile compounds. Oxides of manganese and iron, which form coatings on mineral grains in soils developed on overburden, are effective traps for mobilized elements. However, the proportion of a given element from a bedrock-related source that has been introduced into an overburden sample is typically very small compared to its total concentration in the overburden. Thus, it has been difficult to determine the amount of a trace element that has been added to the overburden rather than the total concentration. Selectively determining trace elements in oxide coatings can be an effective approach to mineral exploration in buried terrains. Chao (1984) thoroughly reviewed the principles and practices of partial analysis.

Analytical Problem

Amorphous manganese oxide, which is commonly a very small part of the total manganese oxides in soils, is one of the most efficient natural traps for trace elements mobilized in the surface/near-surface environment. The large surface area per unit mass and the random distribution of both positive and negative charges on the irregular surface of this material make it an ideal adsorber for a variety of cations, anions, and polar molecules. Anomalous concentrations of trace elements adsorbed by this material are often indicative of the chemistry of oxidizing minerals in the bedrock or basal till rather than the composition of the exotic overburden from which the soil formed. Previously, no partial leaches had been developed which were selective for amorphous manganese oxide.

Hydroxylamine hydrochloride has been used very effectively as a selective reducing agent for manganese oxide coatings (Canney and Nowlan, 1964; Chao, 1972). This reducing agent rapidly reacts with nearly all of the manganese oxide phases in a geological sample. It can be used along with other reagents in

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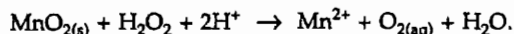
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Technical Notes

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such dilute concentrations that any chemical attack upon the mineral substrates of the coatings is very minor. However, the concentrations of many trace elements in these leach solutions could be so low that specialized instrumental techniques would be needed to make determinations. These techniques would likely be inductively-coupled plasma/mass spectrometry (ICP/MS) and graphite furnace atomic absorption (GFAA). The presence of chloride ions in the hydroxylamine hydrochloride-leach solutions can produce extreme interferences for many elements by both of these instrumental techniques. Therefore, hydroxylamine hydrochloride is not a viable leaching agent when seeking many extremely low-level trace-element signatures.

Hydrogen peroxide also acts as a reducing agent for MnO_2 . In an aqueous solution it will react with manganese dioxide, consuming hydrogen ions, and resulting in the manganese being reduced to the divalent state, which is soluble.



In this process, all the trace elements trapped in the manganese dioxide are released. Chao (1972) rejected the use of hydrogen peroxide as a selective leaching agent because, even at very high concentrations, it reacts very slowly with many crystalline phases of manganese dioxide (Taylor and McKenzie, 1966). However, even dilute concentrations of hydrogen peroxide vigorously react with amorphous manganese dioxide.

It would be possible to selectively leach for amorphous MnO_2 by adding H_2O_2 directly to the leach solution. However, the chemist would not know how much hydrogen peroxide should be used to leach each particular soil or sediment sample. If too much were added, there would be increased leaching of

crystalline manganese oxides, as well as leaching of organic matter, sulfide minerals, and other oxidizable phases in the soil sample. Also, with some samples too high a concentration of H_2O_2 in the leach solution could produce precipitation of insoluble metal peroxides. Alternatively, if too little reagent were added, the leaching of amorphous manganese oxide would be incomplete.

Enzyme Leach

An enzyme chemical reaction slowly generates very low concentrations of hydrogen peroxide in aqueous media. Glucose oxidase reacts with dextrose (D-glucose) to produce hydrogen peroxide and gluconic acid.



Dilute hydrogen peroxide readily reduces and dissolves amorphous manganese dioxide, releasing trace elements and polar molecules trapped in that material. Gluconic acid complexes the metals and holds them in solution. Once all the amorphous manganese dioxide has been dissolved, the products of the glucose oxidase-dextrose reaction are no longer being consumed at a rapid rate, and the enzyme reaction virtually stops. The hydrogen peroxide concentration probably never exceeds 40 $\mu g/ml$, and sufficient gluconic acid is produced to complex the metals solubilized by the process. This self-limiting characteristic of the process minimizes undesirable leaching of mineral substrates. Thus, the background concentrations for many elements determined are extremely low and the anomaly/background contrast is often dramatically enhanced.

Trace-element concentrations for many elements in the leach solutions are often in the mid-to-low picogram-per-liter range. The only current instrumental technique that can be effectively used to determine such low concentrations for large numbers of elements in a significant number of samples is ICP/MS. Nothing is added to the leach solution that would be detrimental to the ICP/MS technique, or which would produce a serious analytical blank problem. The leach solutions are also amenable to determination of many trace elements by GFAA and ICP/AES.

Results and Discussion

In an early experiment with the Enzyme leach, a relatively large quantity of amorphous MnO_2 precipitate was dissolved in only one hour (Clark, pending). Alternatively, in a set of soil samples from a regional mineral-resource assessment project in northern Minnesota, the Enzyme leach typically leached less than five percent of the total manganese oxides in the samples (Clark pending; Clark, in press). Based on the observations of Taylor and McKenzie (1966), it was expected that very dilute hydrogen peroxide concentrations would have minimal leaching effect on many crystalline manganese oxide phases. Thus, it appears that the Enzyme leach is somewhat selective for amorphous manganese dioxide.

Crystalline manganese oxides are known to be effective traps for such metals as Ba, Co, Ni, and Zn. Enzyme leach analyses of soil samples often reveal anomalies not only of these metals, but also a long list of other trace elements, some of which occur as cations and others that form anions in the surficial environment. The list includes Ag, As, Bi, Br, Cd, Cl, Cu, Ga, I, In, Mo, Pb, Re, Sb, Se, Tl, U, V, and W. Because the surface chemistry of amorphous MnO_2 allows it to trap a variety of cations, anions, and polar molecules, selectively leaching for that material provides distinct advantages.

In samples that are identified as being part of a background population with respect to a number of leachable trace elements, a correlation is often observed among leachable Ba, Co, Mn, Ni, and Zn. However, in samples that have concentrations above threshold values for one or more elements, no relationship has been found between leachable Mn and the leachable

Continued on Page 8

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Continued from Page 6

concentrations of the anomalous elements. Therefore, the Enzyme leach is not prone to generating false anomalies. **Glacially Buried Terrain as in Desert Sediments.**

A regional mineral-resource assessment project in the International Falls and Roseau 1°x2° quadrangle of Minnesota was the first large-scale application of the Enzyme leach. The bedrock in most of the region is buried by a minimum of two till sheets, and in most of the area these tills are capped by glaciolacustrine sediments from Glacial Lake Agassie. In the initial phase of that project, a pilot study revealed a relationship

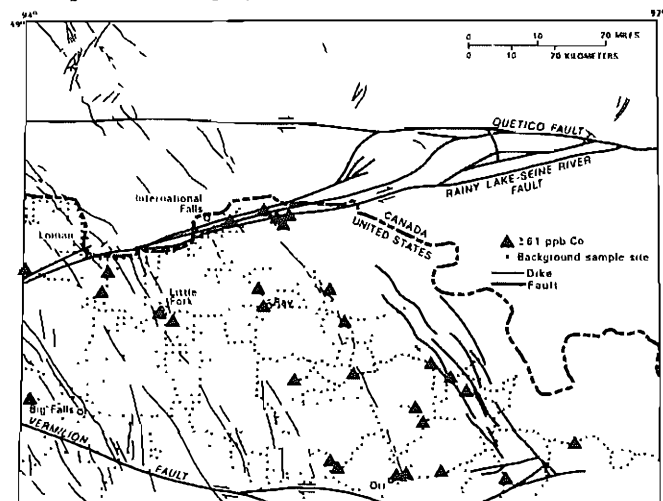


Fig. 1. Enzyme-leach Co anomalies in B-horizon soil samples of the International Fall 1°x2° quadrangle, Minnesota.

between Enzyme-leach anomalies in B-horizon soils and vegetation anomalies at the same sites. In effect, the B-horizon soils apparently have been acting as long-term integrators of vegetation anomalies (Clark, in press). Enzyme leaching of B-horizon soils proved to be the most cost-effective means of conducting a mineral-resource assessment of that region.

This geochemical study of northern Minnesota produced the first recognized evidence of potential for Proterozoic vein deposits in that region. A plot of cobalt anomalies in the International Falls 1°x2° quadrangle revealed an alignment of anomalous-sample sites along what appears to be northwest-striking structural trends (Fig. 1). Some of the trends coincided with diabase dikes, and the Co anomalies tended to occur within a short distance east or west of the termination of dike segments. Other trends appeared to be controlled by faults. Clark et al. (1990) observed that the diabase dikes could not be the sources of the Co, and plots of Ag and Tl revealed anomalous trends that either paralleled or coincided with the Co trends. The anomalous-sample sites tended to cluster in areas where structural trends evidently intersect in the covered basement. Stronger leaching methods did not perform as well as the Enzyme leach. An augmented version of the Enzyme leach (Clark et al. 1990) detected fewer anomalies. In a pilot study, the potassium iodide+ascorbic acid leach (Viets and others, 1984) and the oxalic acid leach (Alminas and Mosier, 1976; Church and others, 1987) failed to detect any of the anomalies along one of the trends southeast of International Falls.

Desert pediments. The first desert pediment study used soil samples collected along two traverses perpendicular to the mineralized structure that hosts the Sleeper ore body, in northwestern Nevada. A plot of Enzyme-leachable Re along traverse two (Fig. 2, 600 meters north of the pit) is one example of trace-element anomalies along that traverse. The overburden along traverse two (Fig. 2, 600 meters north of the pit) is one

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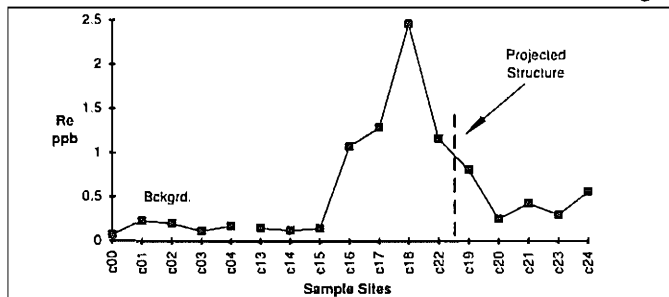


Fig. 2. Enzyme-leach Re anomaly in soil samples along a traverse 600 meters north of the Sleeper pit, Nevada. The vertical dashed line represents the approximate location of a buried mineralized structure. Sample site spacing along traverse 2 varies between 30 and 60 meters.

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example of trace element anomalies along that traverse. The overburden along traverse 2 (sample sites c13-c24) consisted of from 20 meters to 40 meters of basin fill. The background-soil sample sites (c00-c04) were collected on basin fill up slope from the mineralized structure.

Anomaly/background ratios show the dramatic contrast of the Enzyme-leach soil anomalies found near the Sleeper mine (Fig. 3). The elements with the highest anomaly contrasts are those that characteristically occur as anions in the surficial environment. By comparison, the stronger partial leaching methods, potassium iodide+ascorbic acid (Viets and others, 1984) and oxalic acid (Alminas and Mosier, 1976; Church and others 1987), produced much lower anomaly contrasts than the Enzyme leach (Fig. 3). Even higher anomaly contrasts were obtained by using the Enzyme leach on soil samples

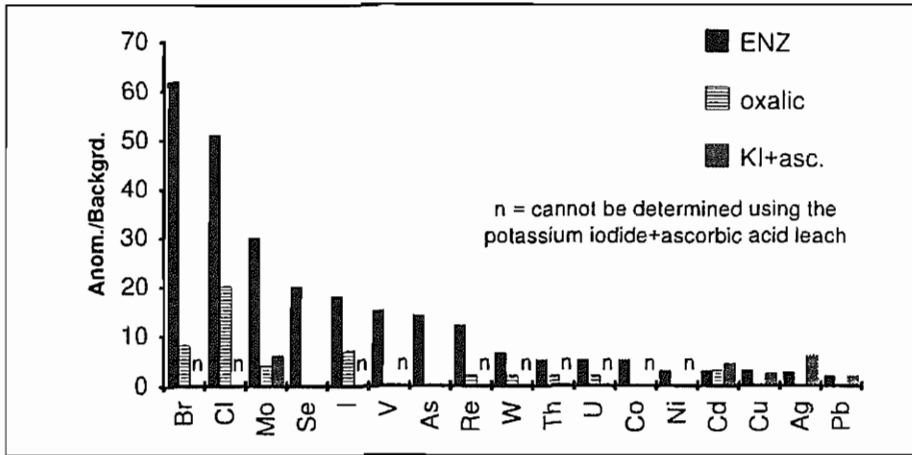


Fig. 3. Anomaly/background ratios for anomalous elements in soils over the mineralized structure at the Sleeper deposit, Nevada. The three analytical methods used were the Enzyme leach, the oxalic acid leach, and the potassium iodide + ascorbic acid leach.

collected over the Rabbit Creek deposit, in north central Nevada.

Enzyme leach analyses of soil samples from desert pediments at several localities have revealed strong correlations between anomalous concentrations of one or more halogens and other trace elements. The leachable concentrations of arsenic and iodine in the samples collected near the Sleeper mine show a nearly linear relationship (Fig. 4). Scatter plots of Mo and Cl and Re and Br also reveal similar relationships in the leach

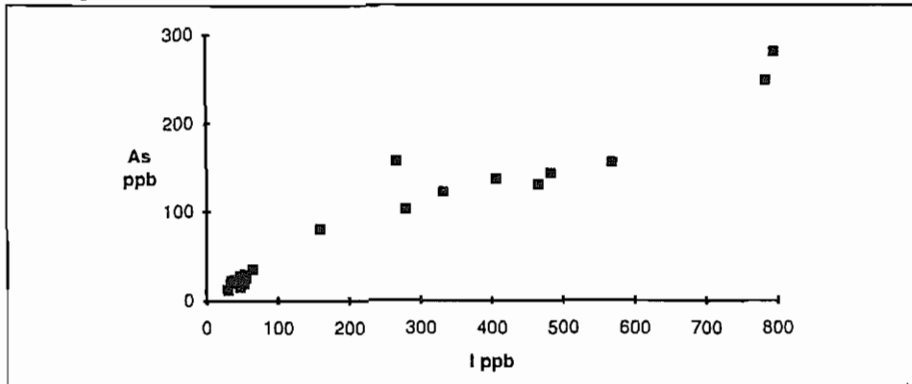


Fig. 4. Scatter plot of Enzyme-leach iodine and arsenic concentrations in soil samples collected near the Sleeper mine, Nevada.

data from the Sleeper samples. Figure 5 shows the nearly linear relationship between Sb and Br produced by Enzyme leaching of soils from another property in Nevada. The strong linear relationships between pairs of elements would seem to indicate that each pair is migrating together at that given location. Trace elements that correlate strongly with the halogens at various localities are those that tend to volatilize as halides under acid/oxidizing conditions used for chemical digestion of geological samples. Although the boiling points of halides and oxyhalides of these metals are 100°C to 300°C above

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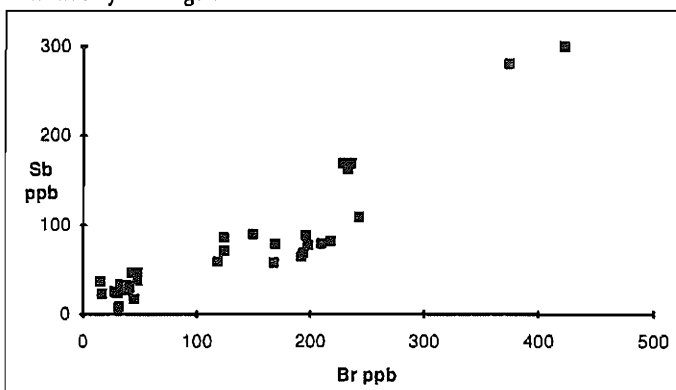


Fig. 5. Scatter plot of Enzyme-leach bromine and antimony concentrations in soil samples collected over a property in Nevada.

the ambient temperature, they would have moderate vapor pressure in localities where sulfide-rich bodies of rock were being oxidized. It seems that these halogen compounds are migrating very slowly through the overburden over extended periods of time and are being trapped by amorphous MnO₂ near the surface.

Limitations. The development of this new leaching technology does not diminish the need for performing pilot studies. In northern Minnesota it was essential to sample the B-horizon (Clark, in press). With desert soils, evidence suggests that the depth of collection can be of major importance. Where the overburden is generally less than 3 meters thick, stronger partial leaches usually produce greater anomaly contrasts. As an

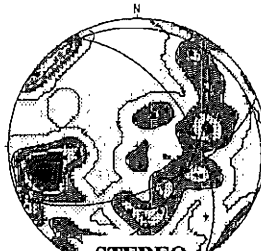
experiment, identical sample sets were sieved to minus 60 mesh in one case and pulverized in the other. The pulverized samples either failed to show any anomalies or the anomaly contrast was drastically reduced when compared to the sieved samples. Grinding may have caused this, because amorphous MnO₂ is a soft material that is readily reduced to a fine powder, which in turn may be dissipated by the air movement in and around the grinding apparatus. Alternatively, volatile compounds trapped in MnO₂ coatings could easily be lost due to the heat generated by the grinding process. Although the Enzyme leach performs extremely well for detecting currently active dispersal processes, in cases where barren oxide coatings have had time to accumulate on the surfaces of mineral grains, stronger leaching techniques produce more useful results.

Enzyme leaching of surficial geochemical samples is a relatively inexpensive technique that can be used to define overburden drilling targets. This new technology opens the door for cost-effective geochemical exploration for mineral deposits in many geographic areas where the bedrock is buried by overburden.

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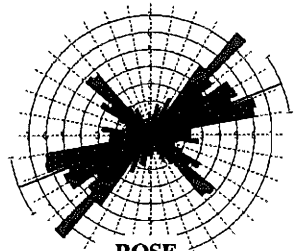
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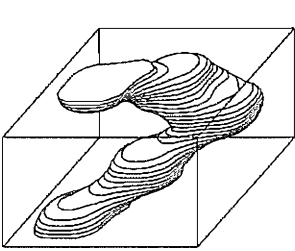
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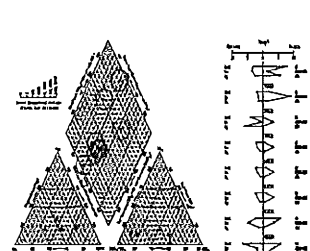
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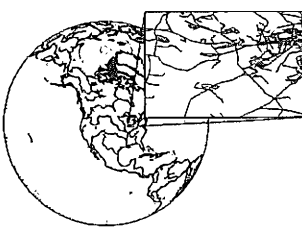
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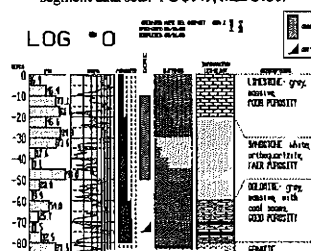
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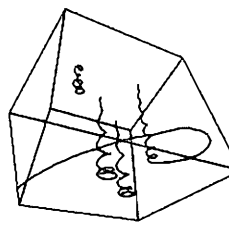
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GEOCHEMICAL MAPPING

Update on the International Geochemical Mapping Project

The International Geochemical Mapping (IGM) project, sponsored through UNESCO/IUGS as IGCP Project 259, distributes a newsletter in January each year to its 350 listed participants in 80 countries. The following is taken from the editorial in the latest edition, with updates from recent project meetings held in Keyworth U.K. April 22-24, and Reston, Virginia, May 8-10, 1992. For more background information about the project see Vol. 39 (1990) of the *Journal of Geochemical Exploration*.

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Sample Media

Applied geochemistry and, therefore, plans for geochemical mapping, are being driven increasingly by environmental considerations.

In 1991 it became clear from papers and discussions that the preferred sampling media for the IGM project are stream sediment, soil, and water, as and when analytical problems relating to low concentrations can be overcome. Support for overbank sampling seemed to weaken. Evidence presented by John Ridgway et al. in Uppsala seemed to confirm the opinions of others that for reliable interpretation they require, in general, more detailed site investigations than are practical for regional reconnaissance purposes.

The Uppsala Symposium on Environmental Geochemistry helped to clarify a number of issues. Water is becoming the most sought-after natural commodity and for obvious reasons attracts the greatest public interest. The Symposium underlined the need for baseline data on soils (*sensu lato*), as the almost-universal surface sampling media of general environmental significance. Stream sediments are complementary in providing enhanced sensitivity for some elements of economic importance, but this medium is of lesser interest to most scientists concerned with non-geological environmental questions. Lake sediments substitute for stream sediments in wet Shield areas with poorly developed drainage, and have the advantage that, with suitable sampling, long-term changes can be detected.

An important consideration in the selection of methods is that sample spacing for soil surveys, and to a lesser degree water, stream and lake sediment surveys, can be increased beyond that required for initial reconnaissance coverage to permit more detailed investigations for specific purposes. Since most countries have undertaken geochemical surveys and based their data on

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Geochemical Mapping

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stream sediments, it is highly desirable to relate existing data to a global database which uses the same medium. Note that seasonal compositional fluctuations must be considered in the planning of water surveys.

The increasing importance being given to soil sampling as a reconnaissance medium strengthens the argument for regarding airborne gamma ray spectrometry (AGRS) as a complementary technique. It can provide an inter-regional and intercontinental reference datum along continuous profiles. The method is readily standardised and provides the radioelement content of the upper 0.5m of land surface. (Approximately 66 per cent of the response is from within plough-depth (20cm)). In addition to providing a natural radioelement concentration profile, each flight-line can simultaneously identify and quantify fall-out. The continuing public apprehension about radioactivity in general may result in ready support for systematic surveys of this type.

Sample Spacing

Since the beginning of the IGM project there has been on-going debate about wide-spaced sampling. The concept is crucial because it appears to provide the only practical way to obtain an overview of global geochemistry within one decade. It offers speed, economy and relative simplicity in execution, which is a key factor in quality control. However, wide-spaced sampling must first be accepted as being useful. In 1991 in Reno, Edinburgh and Uppsala this aspect of the IGM project continued to cause the greatest hesitation amongst those whose working experience has been focused on detailed investigations. It seems that generalised overviews are instructive with respect to the moon or planets, but not for earth!

Regional overviews contribute to the understanding of large

scale processes and identification of areas deserving more detailed attention. Evidence presented in recent meetings has indicated that major geochemical features can be delineated by:

- 1 sample per 1600 km² (soil sampling, China; Xie, in press);
- 1 per 625 km² (lake sediment surveys, Labrador/Quebec; Garrett et al);
- 1 per 400 km² (do., Newfoundland; Davenport et al);
- 1 per 300 km² (till sampling, Finland; Koljonen et al).

It may be noted that in the 1970s several publications illustrated the resolution provided by airborne radiometric surveys at different line spacings. In the absence of other information, useful results were demonstrated for regional reconnaissance purposes at up to 25 km spacing. There is no doubt that wide-spaced sampling misses small features and distorts the shape of large ones. This was well demonstrated recently by Fordyce and Simpson in Keyworth and Reston, using detailed map data for Scotland as a starting point. However, when the alternative to wide-spaced data is no data at all for a long time into the future, priorities need to be carefully considered.

Post Script and Present Status

In 1991 the Global Mapping Committee proposed one composite drainage sample per 160 000 km² or one composite/40 000 km² for soils. This aroused considerable scepticism amongst many earth scientists and so this particular proposal became subject to much subsequent discussion. The debate has invited the question, what are the dimensions of the largest geochemical features that are of practical interest for geological, mineral exploration or environmental purposes (e.g. fragments of accreted terrane; metallogenic province identification; baseline levels in major drainage basins)? What examples can be demonstrated? In fact, as with geophysical phenomena, there are geochemical patterns at every scale, from microscopic to global.

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Considerable progress with this question was made in Keyworth and Reston. It was agreed that wide-spaced sampling is of highest priority in regions of the world where there is a low probability of obtaining conventional geochemical surveys in the near future. However, systematic and coherent quantitative baseline data are required over the whole of the earth's land surface. The inconsistencies in (and inadequacies of) existing surveys make it highly desirable to obtain coherent reference data across all areas. The minimum requirement would be to overlap the borders of existing coverage for the purpose of establishing comparability.

A substantially smaller maximum cell size is now recommended compared with previous proposals. At the Reston meeting the consensus was for basic 80 x 80 km cells, with a minimum of five sampling sites in each cell (effectively 1/1400 km²), evenly distributed where possible. All sample types would relate to these cells; AGRS line spacing would be 20 or 40 km. Robert Garrett (GSC) argued for the desirability of being able to establish a simple hierarchy of sampling densities in different areas (10 x 10, 20 x 20, 40 x 40, etc) and the convenience of relating to the 10 km grid drawn on many existing topographic maps. The question of sample density is moving in the direction of making recommendations which are more flexible, establishing a hierarchy for different purposes. Thus 80 x 80 could be recommended for a global geochemical map compilation, but closer spacing could be recommended for the purpose of establishing national baseline data in a small country, whilst a wider spacing (160 x 160) could be used for a global network of monitoring stations and the collection of standard reference materials. It may be noted that planning documents that are being issued in connection with the International Global Change Program often refer to a hierarchy of investigative sites for different types of monitoring and research, so IGM would be adopting a similar broad approach.

Very encouraging results relating to water analysis (i.e. low detection limits with good repeatability) were reported by G.E.M. Hall (GSC) at the Reston meeting, based on joint GSC/BGS work carried out during recent months. Sample storage appears to be less of a problem than previously supposed. As a result water sampling will almost certainly be included in recommendations for global mapping.


Opinion on overbank sampling continues to wax and wane. In the latest version of the draft recommendations, sampling of flood plain sediment (if present) is given as an option at suitable stream sediment sites. Proponents emphasize sampling the top and bottom of profiles; "bottom" being defined by practical accessibility). However, Xie made the important point in Reston

that the impressive and convincing geochemical maps of all of China, which have been shown at several recent meetings, are based on A-horizon samples, many of which were collected from flood-plains, i.e. overbank material.

Compositing of samples of a given type within each cell has been suggested to minimise analytical costs; but because sample collection is normally the principal expense, it is recommended to analyse individual samples to establish variance. With respect to each soil/regolith site, the following horizons should be sampled: 1) A, 2) B or pisolite (if present), 3) deep C, 4) 0-50 cm profile (P) for Critical Load evaluation and radiometric correlation.

None of the above recommendations are complete or should be considered as final at this stage. Also, readers should realize that this is only a partial list of highlights. For example, comprehensive recommendations concerning analytical methods and data management are not mentioned here. This report has been prepared for the information of interested AEG members to show the type of problems being discussed and to show that progress is being made. The long-term implications of the IGM project could be considerable. Further discussions will take place before a definitive report is prepared in October. Recent progress has been largely due to the hard work and persuasive powers of the following (in addition to those mentioned in the text): Bjorn Bolviken, Alf Bjorklund, Peter Davenport, John Fortescue, Eric Grunsky, Nils Gustavsson, Pavel Koval, Gunter Matheis, Jane Plant, Reijo Salminen, Agnete Steenfelt, Xie Xuejing. Any member of the Project's Technical Committee Leaders would be pleased to receive comments. These people can be contacted directly or through the Project Leader.

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Geochemical Mapping

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To conclude, the following news items are evidence of the growing acceptance of the concept of international geochemical mapping by the scientific community:

- the International Council of Scientific Unions has highlighted the project in background documentation submitted to delegates at the Rio "Earth Summit" (because of this, the project is the subject of a press release by "UNESCO Sources", Paris);

- there is to be a new Russian program for the Geochemical Mapping of Russia which will incorporate recommendations developed by the project for wide-spaced global sampling;

- IGCP 259 was one of the top three amongst the 50 currently active IGCP projects in 1991;

- the retiring Chairman of the IGCP Board (Tony Naldrett, President of the Society of Economic Geologists) cited the project at a recent International Conference of Geological Surveys as a model for future international collaboration.

Dr. A.G. Darnley

Project Leader

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ANALYST'S COUCH

Analysis for gold using a portable anodic stripping voltammeter

In issue Number 70 of **EXPLORE**, we described the application of the field portable PDV-2000 (Chemtronics, Perth, Australia) instrument, based on measurement by anodic stripping voltammetry (ASV), to the determination of Zn, Cu, Pb and Cd in sulphide-selective leaches and various types of waters. Further research at the Geological Survey of Canada, funded by industry, has proven the value of this unit in analysis for Au. The method designed is based on decomposition with aqua regia, separation from potential interferences by extraction into ethyl acetate and redissolution into a final electrolytic solution of 1% HCl and 2% HNO₃. Although aqua regia has been demonstrated to be only partially effective for some types of samples (Hall et al., 1989) and clearly is not sufficient to liberate Au encapsulated in a silicate matrix, its use throughout the exploration industry is widespread and may reflect the Au extracted in the refining process.

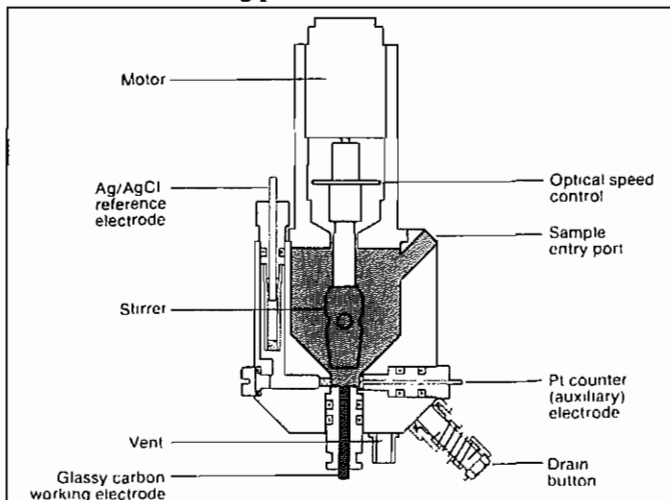


Fig. 1. Schematic diagram of the PDV-2000 electrolytic cell.

The operation of the PDV-2000 has been described in **EXPLORE** Number 70. A schematic diagram of the cell into which the analyte solution is pipetted is shown in Figure 1. The shaded area represents the space occupied by the 10 ml of analyte solution, the bottom of which is in contact with the glassy carbon working electrode. Gold is plated (i.e. reduced) directly onto the carbon surface, unlike the situation for the base metals which are deposited on a thin film of Hg previously plated onto the working electrode. The automated program begins with a 5 s circulation time to mix the 10 ml sample thoroughly after which a potential of -1200 mV is applied for 60-300 s to plate the metal onto the carbon electrode. During the 'hold' period of 15 s, the stirrer is turned off and a potential of 500 mV is applied to oxidise off those elements not required in the analysis. Gold is stripped back into solution at 900-1100 mV during the potential sweep to 1500 mV at a maximum rate of 999 mV s⁻¹. Prior to calibrating the cell response with known standard solutions, the system is primed by applying several plate (60 s duration) and strip cycles (at 375 mV s⁻¹) to a 1000 µg l⁻¹ (ppb) solution of Au in electrolyte (1 % HCl, 2 % HNO₃). This has the effect of conditioning the surface of the working electrode and creating reproducible signals and also serves as a

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check on sensitivity where a count of at least 10000 units is expected. We have found it necessary to connect a lap-top computer to the RS 232C port of the instrument in order to view the voltammograms generated rather than relying on the digital output which reflects the highest peak observed in the pre-programmed voltage window. This way, the occurrence of overlapping peaks in the vicinity of the Au oxidation potential or a change in the shape of the peak can be detected.

Lintern et al. (1988) first reported the application of the PDV-2000 to the determination of Au in synthetic solutions, achieving a detection limit in solution of 5 ppb for a 300 s plating period. Other electro-active elements which co-deposit with Au and cause interference in its measurement include Cu, Ag, Hg and Tl, and thus their separation is necessary. We attempted initially to use adsorption of Au onto activated charcoal but the amount of HCl required to re-solubilise Au was too high, leading to excessive evolution of Cl_2 and interference on the positive side of the Au peak. An attractive feature of ethyl acetate for extraction is its easy removal by evaporation prior to analysis (organics interfere in measurement by ASV). The methodology finally adopted is detailed as follows.

Proposed Procedure

- (1) If the sample is high in sulphur or carbon content, roast 10 g at 650 °C for 3 h in a muffle furnace.
- (2) Transfer the ash (or sample) to a beaker and add 6 ml of 16 M HNO_3 and 18 ml of 12 M HCl. Mix well and allow to reflux on a hot-plate for 1 h.
- (3) Increase the temperature and evaporate gradually to incipient dryness. Stir periodically.
- (4) Add 15 ml of 4 M HCl, warm and transfer to a centrifuge tube, rinsing with 4 M HCl.
- (5) Centrifuge at 2800 rpm for 5 min. Decant. Wash the residue twice more with 10 ml portions of 4 M HCl, adding together the solutions derived from centrifuging. Make up the volume to 50 ml in 4 M HCl.
- (6) Extract the sample solution with 25 ml of ethyl acetate on a shaker for 5 min. Carry out a second extraction with 10 ml of ethyl acetate, combining the two. Backwash the ethyl acetate twice with 10 ml of 0.5 M HCl to remove Fe.
- (7) Evaporate the ethyl acetate extract (bp. 77°C) to incipient dryness. Redissolve Au by addition of 0.4 ml of 6M HCl and 0.8 ml of 8 M HNO_3 . Transfer to a calibrated test tube with washings and make up to 20.0 ml with water.
- (8) Pipette 10 ml of this solution into the ASV cell, add the appropriate amount of Cu (see discussion below) and analyse using a plating voltage of -1200 mV for 120 s and a stripping rate of 999 mV s^{-1} . The dilution factor using this scheme is 2 (10 g to a final volume of 20 ml).

Sufficient sample solution remains for a replicate analysis.

Calibration graphs, constructed using electrolyte solutions spiked with known amounts of Au, are shown in Figures 2a and 2b, for the ranges 5-100 ppb ($\mu\text{g l}^{-1}$) Au and 100-1000 ppb Au, respectively. Much of the work developing this method dwelled upon ensuring freedom from interferences in the ASV step. Analysis by the conventional technique of graphite furnace atomic absorption spectrometry (GFAAS) was used to corroborate results (Hall and Vaive, submitted to Chem. Geol.).

Although the recovery of Cu through the extraction procedure was only 0.03-0.04%, it still caused interference. Thus, a sample containing 500 ppm Cu would yield a solution for analysis of about 200 ppb Cu. If the concentration of Au is also about 200 ppb in solution, the presence of Cu causes the Au peak to be enlarged and shifted to a less positive potential. Where the level of Au is significantly greater than that of Cu in the final solution,

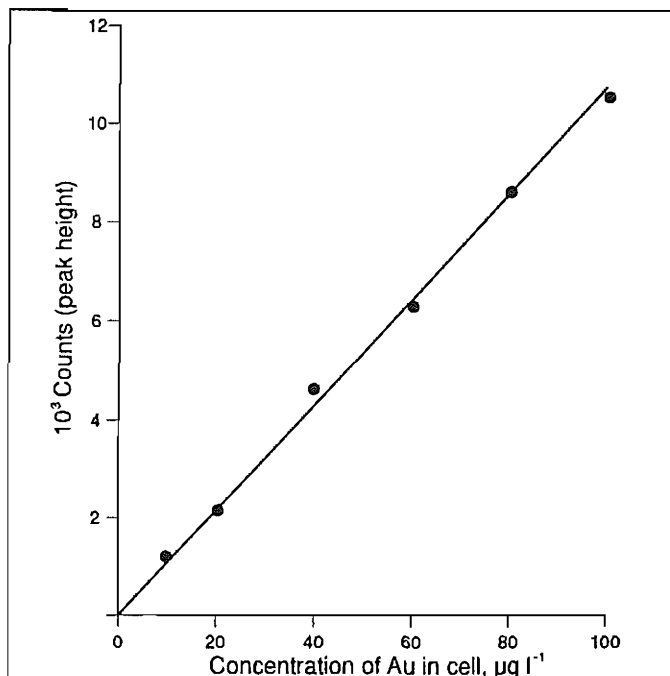



Fig. 2a. Calibration graph for Au up to 100 $\mu\text{g l}^{-1}$ in electrolyte containing 1 mg l^{-1} of Cu. Plating period: 120 s.

say a tenfold excess, this interference by intermetallic compound formation is not evident and single peaks at 1050 mV are observed. However, if Cu is in at least two-fold excess over Au, a stable peak is formed, about twice the amplitude of that for Au alone and unchanged by addition of

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Analysts Couch

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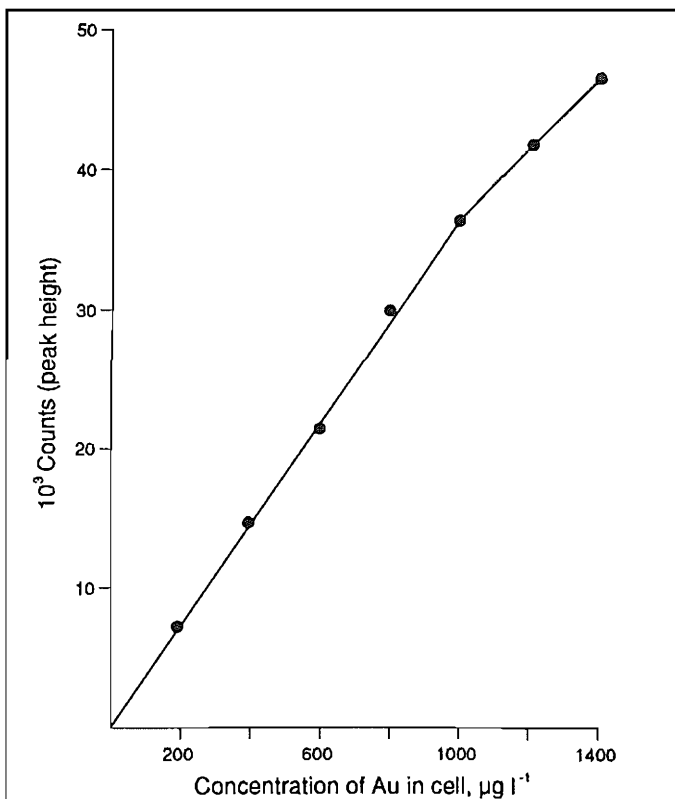


Fig. 2b. Calibration graph for Au up to $1400 \mu\text{g l}^{-1}$ in electrolyte containing 10 mg l^{-1} of Cu. Plating period: 60 s.

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greater amounts of Cu. Since Cu is normally present in geological materials at the $\mu\text{g g}^{-1}$ level while Au would be in the ng g^{-1} range, a recovery for Cu at about 0.05 % would result in approximately equal levels of the two elements. Therefore it was decided to add Cu, in at least a tenfold excess over Au, to all analyte and calibrating solutions. In the range 10-100 ppb ($\mu\text{g l}^{-1}$) of Au in solution, 1 ppm (mg l^{-1}) of Cu is added, while at a decade higher, 10 ppm of Cu are added. This scheme has the benefit of increasing sensitivity for Au (by deliberate co-deposition) as well as compensating for the interference. An approximate concentration of Au in an unknown solution can be estimated by one plating/stripping cycle in the absence of Cu.

The results of the analyses of various standard reference samples (from the Canadian Certified Reference Materials Project, CCRMP) and in-house samples are shown in Table 1. Each sample was decomposed in triplicate, thereby via compositing producing sufficient homogeneous solution for analysis by GFAAS (after extraction into MIBK) and by both ASV and GFAAS after ethylacetate extraction (i.e. the three results by ASV for each sample represent three different extractions from a composite decomposition, not three individual decompositions).

TABLE 1

Results of analyses by ASV and GFAAS following aqua regia decomposition for Standard reference materials and in-house control samples. Values in ppb (ng g^{-1}) Au.

Sample	Recommended		Without ethyl acetate extraction	After ethyl acetate extraction	
	Value	Reference	Au by GFAAS	Au by GFAAS	Au by ASV
CH-1 (Cu-Ag-Au bearing Fe sulphide)	240±20	Bowman, 1990	209, 207	198 204 203	186 231 207
CH-2 (composite CH-1 and MA-1, a siliceous ore)	1330±50	Bowman, 1990	1251, 1223	1234 1261 1269	1259 1286 1217
GTS-1 (composite of siliceous ore, Au in quartz)	346±16	Bowman, 1990	324, 321	307 320 288	298 315 280
PTC-1 (precious metal bearing Cu-Ni sulphide)	650±100	Bowman, 1990	566, 568	551 562 556	579 583 610
UMT-1 (silicate bearing Ni-Cu sulphide)	48±4	Certificate of Analysis, 1992	45, 44	42 42 39	46 44 40
G Au-7 (stream sediment)	82 ¹	Simpson et al., 1990	83, 83	76 82 78 70	86 72 70
MS-1 (Ni-Cu sulphide)	380 ¹		249, 251	235 233 218 205	239 251 205
MG-1 (mineralised gabbro)	138 ¹		119, 121	111 90 108 104	104 81 104
PR-1 (periodotite)	40 ¹		42, 42	42 47 42 47	52 47 47
Vivian (Nevada soil)	58±16 ²	Hall et al., 1989	41, 41	44 39 43 42	41 36 42
Blue Star (Nevada soil)	62±16 ²	Hall et al., 1989	51, 50	46 46 49 50	49 40 50
Genesis (Nevada soil)	143±14 ²	Hall et al., 1989	102, 104	102 95 90	105 97 101

¹ Analysis by Pb fire assay/inductively coupled plasma mass spectrometry

² Analysis by direct instrumental neutron activation (n=9)

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and extractions. These data indicate that the ethyl acetate extraction is efficient for Au. For the most part, values by ASV and GFAAS agree to within 5-10% of each other with the exception of a few outliers, namely two extractions of G Au-7 and two of PR-1. The accuracy demonstrated for samples such as CH-1 and CH-2 which contain over 25% Fe, 2.4% Cu and 25 ppm Ag, indicates the lack of interference in this method from other electroactive species which also plate at -1200 mV. The low results obtained for some samples (e.g., CH-1, Genesis, WS-1) by aqua regia decomposition in comparison to the recommended values shown in Table 1 was expected (Hall et al., 1989) and is not of concern in this application, as the objective was to design a field based method to determine leachable Au in a variety of matrices. The reproducibility of results by ethyl acetate extraction/GFAAS inferior to the excellent precision achieved in the duplicate analyses by direct extraction into MIBK and GFAAS. Results were degraded by the extra manipulations involved. The precision of analysis by ethyl acetate extraction/ASV varies from a low of 2.8% RSD for CH-2 at 1254 ppb (ng g^{-1}) Au to 13.8 % for the mineralised gabbro, MG-1 at 96 ppb Au and averages 7.9 % RSD over the suite of samples analysed in triplicate. The lowest concentration of Au deemed to yield an adequate count rate using the calibration graph shown in Figure 2a is $5 \mu\text{g l}^{-1}$, equivalent to a detection limit of 10 ppb in the solid sample by the proposed scheme.

This method has also been applied to mill cyanide solutions supplied to us by Inco Exploration Inc. Potassium permanganate was used to oxidise Au, present as $\text{Au}(\text{CN})_2^-$, to the trivalent state suitable for extraction into ethyl acetate. Agreement in results between ASV and GFAAS was good for three solutions (0.038 vs. 0.035, 4.03 vs. 4.15, and 18.4 vs. 17.3 ppm Au), but the result by ASV for the fourth solution was low by about 50 % (50 vs. 99 ppm). This discrepancy at the high end remains to be resolved.

About ten sample solutions per hour can be analysed by ASV, allowing for duplicate readings at a 120 s plating period. Overall productivity is difficult to estimate as the efficiency of decomposition and extraction depends upon the equipment available, such as hot plates and shakers. In fact, it is the instrumentation required for sample preparation, not the small 12 kg ASV unit for analysis, which necessitates a field laboratory of considerable size and complexity.

Acknowledgements

The authors are very grateful to the following companies for their support of this project: Echo Bay Mines, Inco Exploration Inc., Noranda Exploration, Placer Dome Inc., Teck Explorations Ltd., and Westmin Resources Ltd. We also thank Newmont Exploration Ltd. for their three soil control samples given to us in bulk for an earlier study.

Gwendy E.M. Hall and Judy E. Vaive
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Simpson, P.R., Robotham, H. and Hall, G.E.M., 1990. Regional geochemical orientation studies for platinum in Jamaica. *Trans. I.M.M. (Sect. B: Appl. earth sci.)*, 99: B183-187.

PEARL HARBOR FILE

In the Pearl Harbor file of *EXPLORE* Number 74, Richard Mazzuchelli presented a case history where the same geochemical data could be interpreted in strikingly different manners. In one fashion, useful information regarding the location of potential exploration targets was not apparent, in the second fashion targets were defined (albeit after the fact). Same data - strikingly different results.

In this Pearl Harbor file, I wish to discuss the concept of professional registration of geoscientists and how this relates to geochemical interpretation. It is well recognized that in the early years exploration geochemistry was developed by an elite group of experts. Over the past 20 years or so, practitioners controlling the decision making pertaining to all aspects of exploration geochemistry are, in overwhelming numbers, exploration geologists with limited geochemical training. Prior to professional registration, a geologist making a significant misjudgment which related to a major project might lose his/her job as a consequence of that project failing to define a target subsequently shown to be worthy of continued work.

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Pearl Harbor File

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Shareholders of the company paying for the work had no legal recourse (except for fraudulent use of funds). Professional registration sets the stage for making practitioners liable for their interpretations if it can be shown that those who make a serious mistake should have known better.

Recent discussions in Vancouver have indicated that many non-geochemists have felt very comfortable with their ability to plan, conduct and interpret geochemical surveys. In their opinion, to require a geochemist to sign a geochemical report is tantamount to establishing a closed shop, particularly in view of the low number of registered geochemists. I am sure spirited discussions of this subject will continue, particularly during the grandfathering period which is meant to allow current practitioners to continue to earn income from exploration activities into the future. Professional registration is intended to protect the public, not the explorationist who has to recognize his/her limitations to avoid, in the ultimate case, negative legal consequences.

Some examples are in order. Suppose a project geologist has a budget to conduct a 5000 sample soil survey. Prior to professional registration, the task might normally be conducted via sealed bid, with a contact awarded to the lowest bidder. Samples would be sent to a laboratory of choice, high results highlighted, and follow up undertaken on anomalies of merit. This scenario represents a relatively standard exploration approach. What possible deficiencies are inherent above which could cause the entire program to fail?

In previous Pearl Harbor files, quality of sampling was shown to be a fundamental factor promoting outstanding false anomalies at the expense of more subtle significant features.

What must the project geologist do or have in his background to mitigate sampling artifacts controlling survey results? In this example, if the geologist is to spend investor money wisely, he/she must have had training in (1) principles of exploration geochemistry, (2) principles of soil genesis, and (3) a course in the nature of surficial deposits. How many exploration geologist have such training? Analogous arguments can be made regarding selection of an analytical method for those samples, and interpretation of results.

An example regarding interpretation of results comes from a recent report in central British Columbia. An interpreter of a 1000 sample, 30 element survey came to the following conclusions:

- (1) The elements As, Zn and Mn followed a unimodal distribution, therefore there was no need to plot the data.
- (2) Strong positive correlation was seen between Ca and Sr which were strongly negatively correlated with Fe-V-Cr. The geochemical trend was fairly linear across a flat, broad valley bottom. Results were interpreted to be geological, caused by a geochemically distinctive geological unit lying beneath the overburden.

Readers of this column should be able to reinterpret the meaning of conclusion (2). I would be interested in hearing what you have to say, along with your comments on conclusion (1).

Serious misinterpretation is represented by the above two conclusions. For example, data for As, which is often a key pathfinder for Au, was not used because it is unimodally distributed. I will indicate what meaning the As, Zn and Mn data have in the next EXPLORE. Are there legal implications for the original report writer? I believe in this case the author may have exceeded his knowledge and/or training and could be subject to legal proceeding if he was a registered professional geoscientist. Such proceedings would be initiated if the property was allowed to lapse as a consequence of a faulty interpretation, and then acquired by a second company which then makes a significant discovery.

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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.

Kamilli, Robert J.
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Kilpatrick, Bruce
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Tucson, AZ, U.S.A.

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Krygsveld, Dawna E.
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McLeod, James W.
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Pevida, Luis R.
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Salas, Spain

Pinto-Vasquez, Jose
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Poulter, James E.
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Prescott, AZ, U.S.A.

Roberts, Paul
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Tucker, Robert E.
Fort Sheridan, IL, U.S.A.
Turnbull, Paul
Geologist
Placer Dome
Kamloops, BC, Canada

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Tech.
Rapid City, SD, U.S.A.

Furman, Francis C.
University of Missouri
Rolla, MO, U.S.A.
Minehane, Diane
University of Alaska
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Exploration Geochemistry

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 75. 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**.

Arehart, G.B., Kesler, S.E., O'Neil, J.R. and Foland, K.A. 1992. Evidence for the supergene origin of alunite in sediment-hosted micron gold deposits, Nevada. *EG* 87(2): 263-270.

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Bezmen, N.I., Brugmann, G.Y. and Naldrett, A.J. 1991. Mechanism of concentration of platinum-group elements: partitioning between silicate and sulfide melts. *Intern. Geol. Rev.* 33(8): 784-792.

Closs, L.G. 1992. Geochemistry - Annual Review. *Min. Eng.* 44(5): 426-427.

Doe, B.R. (Ed.) 1990. Proc. USGS Workshop on Environmental Geochemistry. USGS Cir. 1033. 194 p.

Doe, B.R. 1991. Source rocks and the genesis of metallic mineral deposits. *Global Tectonics and Metallogeny* 4(1/2): 13-20.

Dostal, J., Keppie, J.D. and Zhai, M. 1992. Geochemistry of mineralized and barren, Late Proterozoic felsic volcanic rocks in southeastern Cape Breton Island, Nova Scotia (Canada). *Precamb. Res.* 56(1/2): 33-49.

Giblin, A.M. and Dickson, B.L. 1992. Source, distribution and economic significance of trace elements in groundwaters from Lake Tyrrell, Victoria, Australia. *Chem. Geol.* 96(1/2): 133-149.

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Hollister, V., Hruska, D. and Moore, R. 1992. A mine-exposed hot spring deposit and related epithermal gold resource. *EG* 87(2): 421-424.

Hood, P.J. 1992. Mineral Exploration: Trends and developments in instrumentation and services in 1991. *Northern Miner Mag.* (Jan): 8-29.

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Jebrak, M. 1992. Les gisements d'or des tonalites archeennes (Abitibi, Quebec). *Min. Deposita*. 27(1): 1-9.

Knudsen, H.P. 1992. Blasthole samples - a source of bias! *Min. Eng.* 44(3): 251-253.

Mao, J.H. 1991. Occurrence and distribution of invisible gold in a Carlin-type gold deposit in China. *Am. Min.* 76(11/12): 1964-

Minko, A.E., Colin, F., Trescases, J.J., and Lecomte, P. 1992. Alteration lateritique du git aurifera d'Ovala (Gabon), et formation d'une anomalie superficielle de dispersion. *Min. Deposita* 27(2): 90-100.

Moh, G.H. 1991. Thallium and gold: Observations and experimental contributions to mineralogy, geochemistry and crystal chemistry. *Neus Jahrbuch. Fur Mineralogie* 163(2/3): 197-

Moulin, V. and Ouzounian, G. 1992. Role of colloids and humic substances in the transport of radioelements through the geosphere. *Applied Geochem. Supplem. Issue 1*: 179-186.

Pavlov, D.I., Gorzhevskiy, D.I., Goleva, G.A., Kalinko, M.K., Kartsev, A.A. and Lipayeva, A.V. 1991. Conjunction of ore- and oil-forming systems in sedimentary basins and the predictions of ore deposits. *Intern. Geol. Rev.* 33(8): 822-829.

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Rye, R.A., Bethke, P.M. and Wasserman, M.D. 1992. The stable isotope geochemistry of acid sulfate alteration. *EG* 87(2): 225-262.

Schlesinger, W.H. 1991. *Biogeochemistry: An Analysis of Global Change*. Academic Press. 441 p.

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Shapenko, V.V. and Smidel, P. 1991. Sn and W mineralization in skarn-greisen deposits at the northern margin of the Bohemian Massif. *Geochem. Intern.* 28(12): 107-115.

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Young, L.B. and Harvey, H.H. 1992. The relative importance of manganese and iron oxides and organic matter in the sorption of trace metals by surficial lake sediments. *GCA* 56(3): 1175-1186.

Yudintsev, S.V. and Simonova, L.I. 1992. Radiogeochemistry of tin-bearing lithium-fluorine granites. *Geochem. Intern.* 29(1): 48-55.

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Analytical Geochemistry

This column highlights analytical papers of geochemical interest published in major international journals. These include: Analytical Chemistry (Anal. Chem.), Analyst, Journal of Analytical Atomic Spectrometry (J. Anal. At. Spectrom.), Analytica Chimica Acta (Anal. Chim. Acta), Talanta, Applied Spectroscopy (Appl. Spectrosc.), Spectrochimica Acta Part B (Spectrochim. Acta), Atomic Spectroscopy (At. Spectrosc.) and Analytical Proceedings (Anal. Proc.).

Pertinent papers from Geostandards Newsletter, published in April and October yearly, are too numerous to cite. This journal is a "must" for the geochemist. This list covers those issues received by the author since those listed in EXPLORE Number 72.

Compiled by **Gwendy E.M. Hall**, Head of Analytical Methods Development, Geological Survey of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8. Please send new references to G.E.M. Hall, not to EXPLORE.

Adeloju, S.B., Bond, A.M., Tan, S.N. and Wei, G. 1990. Voltammetric determination of platinum in inorganic complexes and in water, geological and biological matrices using laboratory and field-based instrumentation. *Analyst* **115**: 1569-1576.

Agarwal, C., Shrivastava, M., Mishra, R.K. and Pastel, K.S. 1990. Extraction of gold(III) from low-grade ores with amidines followed by its spectrophotometric determination with methylene blue. *Anal. Chim. Acta* **237**: 491-496.

Asif, M. and Parry, S.J. 1991. Study of the digestion of chromite during nickel sulphide fire assay for the platinum group elements and gold. *Analyst* **116**: 1071-1073.

Baxter, D.C., Frech, W. and Berglund, I. 1991. Use of partial least squares modelling to compensate for spectral interferences in electrothermal atomic absorption spectrometry with continuum source background correction. Part 1. Determination of arsenic in marine sediments. *J. Anal. At. Spectrom.* **6**: 109-114.

Bergeron, M., Beaumier, M. and Hébert, A. 1991. Evaluation of a molecular recognition ligand for performing the extraction of palladium, platinum and rhodium from ion-charged solutions and its application to geochemical exploration techniques using electrothermal atomic absorption spectrometry. *Analyst* **116**: 1019-1024.

Bermejo-Barrera, P., Beceiro-Gonzalez, E. and Bermejo-Barrera, A. 1990. Determination of vanadium in water by atomic absorption spectrometry with electrothermal atomization and using hot injection and preconcentration on the graphite tube. *Anal. Chim. Acta* **236**(2): 475-477.

Bond, A.M., Hudson, H.A., Mosby, V., Tan, S.N. and Walter, F.L. 1990. Development and application of a fully automated, battery-operated, computerized field-based fluoride monitor. *Anal. Chim. Acta* **237**: 345-352.

Broadhead, M. 1991. Laser sampling ICP-MS: determination of rhenium in molybdenum concentrates, copper concentrates and other geological materials. *At. Spectrosc.* **12**(2): 45-57.

Bye, R. 1990. Considerations on the different oxidation states of antimony, arsenic and selenium in the determination of the elements by hydride generation-atomic spectrometry. *Talanta* **37**: 1029-1030.

Chattopadhyay, P. and Nathan, S.S. 1991. Determination of bismuth in geological materials by flame atomic absorption spectrometry using a selective extraction technique. *Analyst* **116**: 1145-1147.

Chekalin, N.V., Marunkov, A.G.M., Pavlutskaia, V.I. and Bachin, S.V. 1991. Determination of traces of Cs, Li and Rb in rocks by laser enhanced ionization spectrometry without preconcentration. *Spectrochim. Acta* **46B**: 551-558.

de la Calle Guntñas, B., Madrid, Y. and Cámara, C. 1991. Determination of total available antimony in marine sediments by slurry formation-hydride generation atomic absorption spectrometry. Applicability to the selective determination of antimony(III) and antimony(V). *Analyst* **116**: 1029-1032.

Diaz, J.M., Caballero, M., Pérez-Bustamante, J.A. and Cela, R. 1990. Multi-elemental separation of copper, cobalt, cadmium and nickel in natural waters by means of colloidal gas apheron co-flotation. *Analyst* **115**: 1201-1205.

Dmitriev, S.N., Krasnov, A.V. and Lebedev, V.Y. 1991. Isolation of gold from geological samples by microwave plasma for neutron activation analysis. *Anal. Chim. Acta* **248**: 579-582.

Dmitriev, S.N., Shishkina, T.V., Zhuravleva, E.L. and Chimeg, J. 1991. Determination of gold in geological samples by x-ray fluorescence spectrometry after extraction with tributyl phosphate. *Anal. Chim. Acta* **243**(1): 81-87.

Donaldson, E.M. Determination of antimony in ores and related materials by continuous hydride-generation atomic absorption spectrometry after separation by xanthate extraction. *Talanta* **37**: 955-964.

Dolinský, F., Štupar, J. and Vrščaj, V. 1991. Direct determination of cadmium and lead in geological and plant materials by electrothermal atomic absorption spectrometry. *J. Anal. At. Spectrom.* **6**: 653-660.

Elsheimer, H.N. and Fries, T.L. 1991. Determination of total tin in silicate rocks by graphite furnace atomic absorption spectrometry. *Anal. Chim. Acta* **239**: 145-149.

Fernando, A.R. and Plambeck, J.A. 1992. Digestion of soil samples for the determination of trace amounts of lead by differential-pulse anodic stripping voltammetry. *Analyst* **117**: 39-45.

Ficklin, W.H. 1990. Extraction and speciation of arsenic in lacustrine sediments. *Talanta* **37**: 831-834.

Garcia-Olalla, C. and Aller, A.J. 1990. Determination of gold in ores by flame and graphite furnace atomic absorption spectrometry using a vanadium chemical modifier. *Anal. Chim. Acta* **252**: 97-104.

Gowing, C.J.B. and Potts, P.J. 1991. Evaluation of a rapid technique for the determination of precious metals in geological samples based on a selective aqua regia. *Analyst* **116**: 775-779.

Hinkamp, S. and Schwedt, G. 1990. Determination of total phosphorous in waters with amperometric detection by coupling of flow-injection analysis with continuous microwave oven digestion. *Anal. Chim. Acta* **236**(2): 345-350.

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Bjorklund, A.J., Geochemical Exploration 1983	171.00	102.50	_____
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Garret, R.G., Geochemical Exploration 1985	348.00	209.00	_____
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Parslow, G.R., Geochemical Exploration 1982	159.00	95.50	_____
Rich, R.A., Hydrothermal Uranium Deposits	87.00	52.00	_____
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Recent Papers

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Waller, P.A. and Pickering, W.F. 1990. Evaluation of "labile" metal in sediments by anodic stripping voltammetry. *Talanta* **37**: 981-993.

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Zhanxia, Z., Bear, B.R. and Fassel, V.A. 1991. Determination of major, minor and trace constituents in meteorites by inductively coupled plasma-atomic emission spectroscopy. *Spectrochim. Acta* **46B**: 1771-1183.

CALENDAR OF EVENTS

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

■ July 13-22, '92 **Water/rock interaction mtg.**, Park City, Utah, by WRI Working Group of the International Association of Geochemistry and Cosmochemistry (Yousif Kharaka, USGS, MS 427, 345 Middlefield Road, Menlo Park, CA 94025 USA; TEL: (415) 329-4325; FAX: (415) 329-5110)

■ July 19-22, '92 **Second International Symposium on Mining in the Arctic**, Fairbanks, Alaska, by the Univ. of Alaska (Dr. Sukumar Vandopadhyay, Chairman, 108 Brooks Bldg., Univ. of Alaska, Fairbanks, AK 99775 USA, TEL: (907) 474-6876)

■ Aug. 3-4, '92 **The Society for Environmental Geochemistry and Health Annual Mtg.**, International Conference on Lead and other Trace Substances, Sheraton Imperial Hotel and Convention Center, Research Triangle Park, NC USA

Continued on Page 27

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- Aug. 10-14, '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, U.S. Geological Survey, 2800 Cottage Way, Room W-2235, Sacramento, CA 95825 USA TEL: (916) 978-4648; FAX: (916) 978-5529; or David Blowes, Waterloo Center for Groundwater Research, University of Waterloo, Waterloo, ON, N2L 3G1, Canada, TEL: (519) 885-1211, ext. 6997; abstract deadline is March 1, 1992, 200 words or less, on ACS forms)
- 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)
- Aug. 29-Sept. 1, '92 **GeoTech '92**, Geocomputing Conference, Denver, Colorado (Mark Cramer, GeoTech, Contract Station 19, P.O. Box 207, Denver, CO 80231-4952 USA; TEL: (303) 752-4951; FAX: (303) 752-4979)
- Sept. 2-4, '92 **Arctic Margins**, int'l mtg., Anchorage, Alaska, by Alaska Geological Society (David Steffy, U.S. Minerals Management Service, 949 E. 36th Ave., Anchorage, AK 99508 USA; TEL: (907) 271-6553; FAX: (907) 271-6805; abstracts deadline, Feb. 1)
- Sept. 8-11, '92 **Canadian Mineral Analysts 24th Annual Conference**, Val d'Or, Quebec (Jacques Martell, Chairman, Abilab Inc., 1905-3 Avenue, Val d'Or, PQ, J9P 4N7 CANADA; TEL: (819) 874-4723 FAX: (819) 874-0625)
- Sept. 11-13, '92 **Environmental Change**, mtg., Denver, by Association for Women Geoscientists (Leslie Anne Landefeld, Barranca Resources, 16150 W. 14th Place, Golden, CO 80401 USA; TEL: (303) 278-1292)
- Sept. 13-18, '92 **Geostatistics**, mtg., Troia, Portugal (Amilcar Soares, Centro de Valorizacao de Recursos Minerais, IST Av. Rovisco Pais, 1096 Lisbon, Portugal, FAX: (351) 1-8486935)
- Oct. 12-16, '92 **Energy, Environment and Technological Innovation**, int'l mtg., Rome, by Universidad Central de Venezuela, and Universita di Roma (Secretaria CPA, Comision de Promocion Academica, Facultad de Ingenieria, Universidad Central de Venezuela, Edf. Decanato, Caracas, 1050, Venezuela; TEL: (58) 2-6627538; FAX: (58) 2-6627327)
- Sept. 17-Oct. 1, '92 **American Institute of Professional Geologists**, ann. mtg., Lake Tahoe, NV (Jon Price, AIPG, Box 665, Carson City, NV 89702 USA; TEL: (702) 784-6691)
- Sept. 22-24, '92 **Ground-water Geochemistry**, short course, San Antonio, Texas (National Ground Water Association, Education Department, 6375 Riverside Drive, Dublin, OH 43017 USA; TEL: (614) 761-1711; FAX: (614) 761-3446)
- Oct. 2-6, '92 **Sudbury-Noril'sk Nickel Camps**, symposium, Sudbury, ON (A.J. Naldrett, Dept. of Geology, University of Toronto, ON, M5S 3B1 CANADA; FAX: (416) 978-3938)
- Oct. 5-7, '92 **Contaminant Remediation and Wellhead Protection**, short course, Burlington, VT (National Ground Water Association, 6375 Riverside Drive, Dublin, OH 43017 USA; TEL: (614) 761-1711; FAX: (614) 761-3446)
- Oct. 12-16, '92 **Energy, Environment and Technological Innovation**, int'l mtg., Rome, by Universidad Central de Venezuela and Universita di Roma (Secretaria CPA, Comision de Promocion Academica, Facultad de Ingenieria, Universidad Central de Venezuela, Edf. Decanato, Caracas, 1050, Venezuela; TEL: 58-2-6627538; FAX: 58-2-6627327)
- Oct. 19-21, '92 **Bio-leaching Minerals and Mineral Land Reclamation**, mtg. and workshop, Sacramento, CA (Yung Sam Kim, Nevada Institute of Technology, Box 8894, Campus Station, Reno, NV 89507 USA; TEL: (702) 673-4466)
- Oct. 25-30, '92 **In-situ Minerals Recovery**, mtg., Santa Barbara, CA (Engineering Foundation, 345 E. 47th St., New York, NY 10017 USA; TEL: (212) 705-7835; FAX: (212) 705-7441)
- Oct. 26-29, '92 **Geological Society of America**, ann. mtg., Cincinnati, OH (Vanessa George, GSA, Box 9140, Boulder, CO 80301 USA; TEL: (303) 447-2020)
- Nov. 23-25, '92 **Women Geoscientists in national planning and development**, mtg., New Dehli/Dehradun, India, by Association of Geoscientists for International Development and Indian Geological Congress (O.P. Varma, IGC, Dept. of Earth Sciences, University of Roorkee, Toorkee-247 667, India)
- Feb. 8-11, '93 **Geologic Remote Sensing**, mtg., Pasadena, CA (Nancy J. Wallman, ERIM, Box 134001, Ann Arbor, MI, 48113-4001 USA; TEL: (313) 994-1200, ext. 3234; FAX: (313) 994-5123)
- Apr. 13-16, '93 **The Environmental Geochemistry of Mineral Deposits**, short course and seminar, Denver, CO (G.S. Plumlee, U.S. Geological Survey, MS 973, Federal Center, Denver, CO 80225 USA; TEL: (303) 236-9224)
- Apr. 17-20, '93 **Integrated Methods in Exploration & Discovery**, Conference, by the Society of Economic Geologists, Association of Exploration Geochemists, Society of Exploration Geophysics, and others, Denver, CO (J. Alan Coope, SEG Conference '93, Box 571, Golden, CO 80402 USA; TEL/FAX: (303) 470-6289)
- May 4-7, '93 **Geofluids '93**, International Conference on Fluid Evolution, Migration and Interactions in Rocks, Torquay, England (Sally Cornford, IGI Ltd, Hallsannery, Bideford, Devon, EX39 5HE, England; TEL: 44 (0)237 471749; FAX: 44 (0)237 421700)
- 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)
- Aug. 1-3, '93 **Geochemistry of the Earth Surface**. Third International Symposium, University Park, PA (Dr. Lee R. Kump, Secretary General, GWDS-3, Department of Geosciences, The Pennsylvania State University, 210 Deike Building, University Park, PA 16802 USA; TEL: (814) 863-1274; FAX: (814) 865-3191)
- Sept. 3-5, '93 **16th International Geochemical Exploration Symposium**, and Sept. 1-2, '93 **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)
- Sept. 25 - Oct. 1, '93 **International Association of Volcanology and Chemistry of the Earth's Interior**, mtg., Canberra, AUSTRALIA (IAVCEI ACTS, GPO Box 2200, Canberra ACT 2601, AUSTRALIA, TEL: (61) 6-257-3299; FAX: (61) 6-257-3256)
- Oct. 25-28, '93 **Geological Society of America**, ann. mtg., Boston, MA (Vanessa George, GSA, Box 9140, Boulder, CO 80301 USA; TEL: (303) 447-2020)

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Calendar of Events

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- Summer, '94 Geoanalysis '94, UK (Doug Miles or Peter Simpson, British Geological Survey, Keyworth Nottingham NG12 5GG, UK; TEL: 44-36-602-3100; FAX: 44-602-36-3200)
- Aug. 28-Sept. 3, '94 European Association of Geochemistry Meeting and 4th Goldschmidt Conference, Edinburgh (Dr. B. Harte, Department of Geology and Geophysics, Grant Institute, University of Edinburgh, West Mains Road, Edinburgh, EH9 3JW UK)
- Sept., '94 Joint International Symposium on Exploration Geochemistry, Irkutsk: a tribute to Academician L.V. Tauson (Pavel Koval, Vinogradov Institute of Geochemistry, P.O.B. 701, 664033 Irkutsk, Russia; TELEX: 133 163 Taiga SU)

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