

EXPLORE

Newsletter for the Association of Exploration Geochemists

NUMBER 78

JANUARY 1993

PRESIDENT'S MESSAGE

This issue of **EXPLORE** reflects the changing role of the exploration geochemist. In the past, the primary role of the exploration geochemist was to assist the exploration staff in applying geochemical techniques to the discovery of mineral deposits. Today, more and more frequently, this same professional is also called upon for technical advice on environmental applications, whether it be performing baseline studies for properties going into production, dealing with mining contamination problems, or assisting with remediation issues after mine closure.

The Association recognizes this changing role and has formed an Environmental Committee chaired by Dick Glanzman, who like many members, is a former exploration geochemist now employed in the field of environmental geochemistry. The mandate of this committee is to expand the Association's contacts with environmentally oriented geochemical societies, developing a reciprocal exchange of benefits, co-sponsoring meetings, and providing assistance in the exchange of similar technology.

With the increased interest of the membership in mining-related environmental geochemical applications, the committee has organized this issue of **EXPLORE**. On behalf of the Association, I want to thank Dick Glanzman and the authors of these papers for their contributions.

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TECHNICAL NOTES

Exploration Geochemistry and the Environment

Mineral exploration and development professionals generating geochemical data, particularly geologists and geochemists, are in a unique position to develop geochemical background/baseline data. These data are important both for definition of target and indicator elements for use in mineral exploration and for identification of situations that may be potential threats to public health and the environment. Without comprehensive background/baseline data it may be difficult, if not impossible, to establish what is natural and what is anthropogenic (considered man-caused contamination). Documentation of elevated metal levels in toxic concentrations is best obtained at the initial property evaluation stage of exploration. It becomes critical at the development stage for both prudent development planning and for potential defence at later environmental assessment reviews.

This issue of **EXPLORE** presents four short papers which demonstrate that an appreciation of natural geochemical processes is the common, determining factor in the effective use of geochemistry in solving exploration and environmental problems. In the first paper, Dick Glanzman and Graham Closs present the minimum quality assurance and control procedures necessary for both exploration and environmental purposes. Next, Don Runnells points out the close association between geochemical tools used for exploration and environmental purposes, and how data can be generated that presents a case for a natural background/baseline in mineralized areas. Peter Davenport illustrates the general principles for establishing a geochemical background/baseline using lake sediments. Finally, Keith Nicholson documents the use of metal adsorption by manganese as both an exploration guide and an indication of control on metal mobility.

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Quality Assurance and Control Guidelines for Exploration and Environmental Geochemistry Investigations.

A few relatively simple quality assurance and control procedures produce data of sufficient known quality upon which to base informed decisions for mineral potential evaluation and environmental risk assessment. Consideration of these needs simultaneously permits elimination of costly duplication of effort. Although requirements for geochemical data quality are different for these individual applications, the differences are minimal. Further, the cost differential associated with meeting the various data quality requirements is often also minimal. Thus, it is commonly simpler, more efficient and appropriate to consistently obtain the high quality geochemical data which meets all anticipated requirements associated with the variety of potential applications.

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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 5/4- 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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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.

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NOTES FROM THE EDITOR

Anyone who has worked in geochemical exploration will have noticed the emergence of environmental concerns and environmental geochemistry over the past few years. Even as a passive observer it is difficult not to notice the parallels between environmental geochemistry and exploration geochemistry. What we may fail to fully appreciate, however, is that the general public does not have the training and experience of a practicing geologist, and they can be easily swayed by statements made by either side to appear *scientific*. With this in mind, it seems that geologists have an obligation to monitor and contribute to debates on environmental issues, not necessarily from the partisan position of their employer, but from the position of a fellow citizen and scientist who has a concern for the environment as well as the development of our economies. It is time that the debates on environmental issues be elevated from this current level to a scientific level.

This EXPLORE goes a step in this direction. Richard Glanzman has assembled the technical papers for this issue that concentrate on the relationship between environmental and exploration geochemistry. Our thanks to Richard and his colleagues.

Owen P. Lavin

Editor 

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LETTERS

August 31, 1992

Dear Pearl Harbor Editor,

I am commenting on the issues as they appeared in the Pearl Harbor File in **EXPLORE** #76.

A. Registration. This is not a guarantee for success or avoidance of failure, especially in exploration. There are just too many factors involved.

B. 5000 sample project awarded to the lowest bidder.

Mistakes in this approach are a few or all of the following:

1. Inherently inconsistent random sampling;
2. Sloppy sample preparation and subsampling;
3. Inadequate extraction method;
4. Improper analytical detection limits;
5. Misjudgment in interpretation of results;
6. Failure to do corrections (i.e., analytical contamination, soil background);
7. Inadequate statistics (i.e., failure to look at all possible combinations, correlations, graphics).

C. Example from 1000 samples in British Columbia.

1. All elements should have been treated statistically, i.e. moving cells with background correction; composite graphics.
2. Correlation Ca/Sr and anti-[pathetic] correlation Fe/V/Cr could be interpreted as stated (influenced by geological factors) or from alteration (geochemical). In this latter case, fluids (or decomposing pyrites) could have replaced Ca by Fe.

Conclusion: The misinterpretation is only negligence, since all the data were available for statistical manipulation. In my opinion, the company was negligent in allowing an improperly trained professional to pass judgement on the final, but unfinished work. In essence, they failed in asking a second (third, etc.) opinion before discarding all that costly work. Opinions, in this case, need not be formulated by registered professionals because these are suggestions for comparative use only.

Respectfully submitted,

Evaldo L. Kothny
Walnut Creek, CA ✎

ANNOUNCEMENTS

Abstracts with Program; 15th IGES

Abstracts with Program, 15th International Geochemical Exploration Symposium, Reno, Nevada is available from the Vancouver AEG office at US \$7.50 to AEG members and US\$ 15.00 to non-members, postage and handling included.

XRAL Acquires GFMC Assay Laboratory

Dr. Michael Hildon, President and CEO of Commercial Testing & Engineering Co. (CT&E), recently announced the purchase of Gold Fields Mining Company's assay laboratory, located in Golden, Colorado.

Concurrently with the purchase agreement, CT&E and Gold Fields entered into a service agreement under which CT&E will

provide assay services to Gold Fields in connection with their ongoing gold exploration programs.

The laboratory will offer commercial assay services to other mining companies and will operate as a division of CT&E under the name XRAL Laboratories. CT&E is a member of the Swiss SGS Group, the world's largest independent inspection and testing company. SGS operates a number of other mining exploration laboratories under the XRAL name in Canada, Mexico, South America, and Africa.

For more information contact Bob Gerteis (303) 277-1377, Dave McInnes (708) 953-9300 or Linda Bloom (416) 445-5755.




PROFESSIONAL REGISTRATION

Professional Registration Committee Report (USA)

In twenty of the United States, geochemists must register under the title of Professional or Registered Geologist. In most of these states, engineers, assayers, geologists and architects all fall under the same enacting legislation and rules of the registering board. To date, the regulations applying to geologists (and therefore geochemists) have been very state specific. This has caused problems with reciprocity and testing.

The Association of State Boards of Geology (ASBOG) was formed in 1991 to standardize testing of professional geologists and facilitate reciprocity between different State Boards. The effort to date has been very successful. Of the twenty states

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Professional Registration

Continued from Page 3

requiring registration of geologists, eight have committed to participate and all but two have indicated an intent to join upon successful legislation/rule changes. ASBOG has been working hard at developing a national test which was given for the first time in October in eight states (Arizona, Oregon, Wyoming, North Carolina, South Carolina, Arkansas, Georgia, and Virginia). The national exam consists of two, four-hour, multiple-choice exams (Fundamentals of Geology, and Principles and Practice of Geology). Member boards will have the option of constructing an additional examination section to test the applicant's knowledge regarding geologic conditions of particular importance to that state's protection of public health and welfare.

ASBOG is using the Arizona exam and content validity model to develop the national exam. I have been working with the Arizona Technical Board of Registration (through the AZ section of AIPG) for the past eight years in the development of the Arizona test. Arizona contracted Dr. Jack Warner, a psychometrician, to assist in the development of a content validity model for the Arizona exam. The validation process has been used for the past eight years to demonstrate that the questions and problems on the exam are representative of the important duties/tasks needed for competent practice in the profession.

To that end, a job analysis was conducted to determine the type of duties performed by geologists which are related to public protection and the underlying knowledge and skills

needed in order to perform those duties. A job analysis survey, consisting of 75 task statements, was developed and sent to registered and certified geologists in Arizona. The survey was distributed so that a large group of experts could provide information about how frequently they performed the 75 tasks, how important each task was in terms of protecting the health, welfare, or safety of the public, and to what extent it was necessary that a geologist be competent to perform each task at the time of initial licensure.

As a result of the survey, a "test blueprint" was developed in order to ensure that examination questions were linked to specific job tasks and knowledge statements. Once the "test blueprint" was established, a question bank was developed by a group of 20 registered geologists from Arizona. Multiple choice questions were developed in contrast to the previous essay format exam. This removed the subjectivity of the scorer when grading the exam. In addition, the applicant was no longer given a choice of questions to answer, but was required to answer all questions. These subtle changes greatly enhanced the validity of the exam.

The "test blueprint" includes the following areas under the Geochemistry content domain:

- 1) Establish analytical objectives and approaches.
- 2) Evaluate geochemical data.
- 3) Construct models based on results of geochemical analyses.
- 4) Make recommendations based upon results of geochemical analyses.

The remaining content domains include:

- 1) Research, field methods, and communications
- 2) Mineralogy
- 3) Petrography/Petrology
- 4) Stratigraphy/Historical Geology
- 5) Structural Geology
- 6) Paleontology
- 7) Geomorphology
- 8) Geophysics
- 9) Hydrogeology
- 10) Engineering Geology
- 11) Mining Geology
- 12) Petroleum Geology

One of the exciting features of the current testing format is that after the exams are computer graded, the results are reviewed by a group of registered geologists. This review is beneficial for both the integrity of the exam and for the applicants. During the review, questions that have been 'flagged' as being statistically anomalous are critically reviewed for completeness, accuracy, and fairness. For example, a question would be reviewed if those who took the exam and passed, did poorly on that question. A question may be credited; or may be removed from the test if the question was poorly worded, misleading, trivial, incorrectly keyed, or otherwise at fault. This dynamic process provides Arizona with a constantly evolving base of high quality questions. It is important to remember the purpose of the exam is to test MINIMUM COMPETENCY, not to be tricky, or overly difficult. This same process will be applied to the national test.

If you would like further information on ASBOG or the national geology test, please do not hesitate to contact me. I will let you know how the first national geology test fairs in the next EXPLORE.

E.F. Weiland
Co-Chairman
Professional Registration Committee of the AEG



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SPECIAL ISSUE

THE POCOS DE CALDAS PROJECT: NATURAL ANALOGUES OF PROCESSES IN A RADIOACTIVE WASTE REPOSITORY, PART 1

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Editorial

Preface

The Pocos de Caldas Project: an introduction and summary of its implications for radioactive waste disposal by N.A. Chapman (Melton Mowbray, UK) I.G. McKinley (Wettingen, Switzerland), E. Penna Franca (Rio de Janeiro, Brazil), M.E. Shea (Chicago, IL, USA) and J.A.T. Smellie (Uppsala, Sweden) 1

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Technical Notes

Continued from Page 1

Sample design, collection, handling, chemical analysis, and interpretation procedures need to be documented and kept as a permanent record. Data from outcrop, soils, drill core, and drill cuttings are typically obtained for exploration target areas. A record of who, when, how, and where samples were collected should be established in field notebooks and on maps.

Any groundwater encountered should be sampled and the water level measured. At the feasibility stage, if groundwater is encountered in a drill hole situated in a prime exploration area, consideration should be given to converting it into a monitoring well. Surface water, if present, should be included in the potential environmental samples. The minimum required field data include location, date, time, and approximate flow rate. All water samples should be kept in a cooler which maintains a constant temperature until the samples arrive at the laboratory, samples for metal analyses usually require a preservative as well. The laboratory should keep the samples cooled and samples should be analyzed within approximately 2 weeks.

Use of blank, reference or standard, and duplicate samples is required to establish data quality. A blank sample should be included per 40 exploration samples to assess laboratory contamination. If less than 40 samples are taken from an individual area, at least one blank sample should be included with the sample batch sent to the laboratory. One reference or standard sample per 20 routine exploration samples should be included to assess analytical accuracy. For smaller lots, a minimum of one reference sample per batch should be included in the laboratory job submission.

A suite of ten reference samples can be created from target

mineral deposit types. Alternatively, reference materials can be purchased from companies specializing in their preparation. In either case, materials selected for preparation should be of a comparable lithologic and mineralogic character to that of routine samples to standardize matrix effects. Finally, one split (homogenized and divided) and one field duplicate (a second sample taken in an identical manner adjacent to the first) per 20 exploration samples or one per batch of routine exploration samples completes the basic QA/QC sample suite.

A form that establishes a tracking system for sample shipments should be created. It should include the name of the person, date and mode of shipment. Copies of all shipping forms should be retained. A return receipt from the laboratory should be requested. This document should indicate the condition of the samples upon receipt by the laboratory. This procedure competes the "chain of custody" normally performed when shipping environmental samples. It also constitutes an appropriate procedure for transmittal of exploration samples from the field to the laboratory. The purpose is to be able to determine what happened or could have happened to the samples during shipment should problems arise.

Most laboratories currently include laboratory detection limits, and results from blank, internal reference and duplicate samples along with analytical data for the routine samples. These data should be retained with their corresponding batch of analytical data received from the laboratory. The laboratory should supply a description of the analytical methods used to obtain the data. The analytical schedule should consider the inclusion of the Priority Pollutant Metals (Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, and Zn). This is the suite of elements that should be available in the environmental suite when questions of natural or anthropogenic concentrations of potentially toxic metals are asked. Data from different laboratories need to be compared and evaluated before geochemical interpretation of additional data is initiated.

The above suite of minimal QA/QC procedures includes information and data we should be collecting on exploration samples. Decisions to continue working on the property depend upon these results. These procedures also include the essence of what is needed for the data to be useful in assessing the environmental conditions. Collection of this data *does not* guarantee that they will be considered of sufficient quality for inclusion in an environmental appraisal. It may not be of sufficient quality for exploration decisions! However, without such information, considerable potential liability may be unnecessarily assumed by the exploration company.

Richard K. Glanzman
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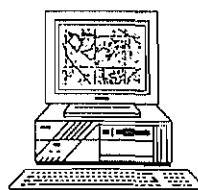
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Technical Notes

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Geochemical Baseline versus Background

All man-made chemical changes, regardless of their scale or origin, are superimposed upon a variable natural background. Natural abundances for trace elements typically range over two or more orders of magnitude in surficial materials directly influencing the chemistry of the biosphere. This variability in geochemical background is determined by approximately four billion years of natural geological processes. Major element (Si, Al, Fe, Mg, Ca, Na, and K) concentrations can be estimated from good geological maps and rock descriptions. However, even these maps offer little information on trace elements currently regarded either as essential to many forms of life (i.e. Cl, Co, Cu, F, I, Mn, Mo, P, S, Se, V, and Zn) or as toxic (As, Be, Cd, Hg, Ni, Pb, Sb, Tl, and U). Even essential elements can occur in sufficiently high concentrations to be toxic. Therefore, trace element concentrations and their spatial variations can be provided only by appropriately designed geochemical surveys.

Geochemical mapping based upon the chemical analysis of stream sediments has been employed successfully for mineral exploration for a broad range of commodities on a worldwide scale. These geochemical surveys may prove useful as well in establishing the natural geochemical characteristics of a region, especially if sampling relates the survey to an environmental assessment. Such sampling would be equivalent to the typical orientation sampling undertaken prior to the regional surveys for mineral exploration.

We usually assume that spatial variation in stream sediment survey data is essentially natural and, for the most part, geologically controlled. This assumption has been borne out by quantitative studies such as those of Bonham-Carter and Goodfellow (1986) and Bonham-Carter et al. (1978). Although highly disturbed sites are usually avoided and possible sources of contamination noted during sample collection, contamination due to human activities is seldom, if ever, quantified.

In Canada, lake sediments not only reflect spatial geochemical variations at the geosphere-biosphere interface similar to stream sediments, but they also contain a historical record of both natural and man-made changes over approximately the last 10,000 years. These chemical changes are preserved as a geochemical stratigraphy in sediment cores (Engstrom and Wright, 1984). Studies of geochemical change over time due to environmental factors, however, typically ignore geologically controlled variation and focus on change relative to the ambient local background of only a few sites instead of the whole exposed area.

Geologically controlled geochemical responses can be separated from subtle but pervasive anthropogenic modification of drainage sediments (Fortescue and Vida, 1991) by linking extensive regional surveys with detailed historical studies at a few selected lakes. Furthermore, studies comparing spatial elemental distribution patterns in sediments with patterns in media more commonly used for environmental investigations (i.e. water) will make geochemical surveys conducted for mineral exploration more relevant for baseline documentation.

Figure 1 shows this approach to evaluate the relevance of geochemical mapping, here using nickel, to establishing geochemical baselines in Newfoundland and Labrador. Geochemical surveys designed to stimulate and focus mineral exploration are based on "grab" samples from the upper 20 to 100 centimeters (cm) of organic lake sediments. Forty elements from over 40,000 sites throughout the provinces form part of Canada's National Geochemical Reconnaissance database, NGR (Friske and Hornbrook, 1991).

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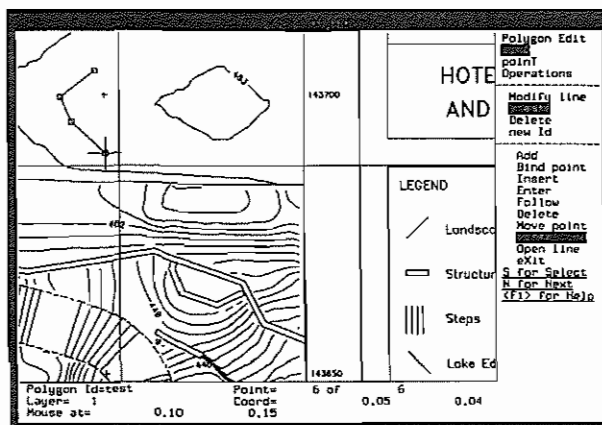
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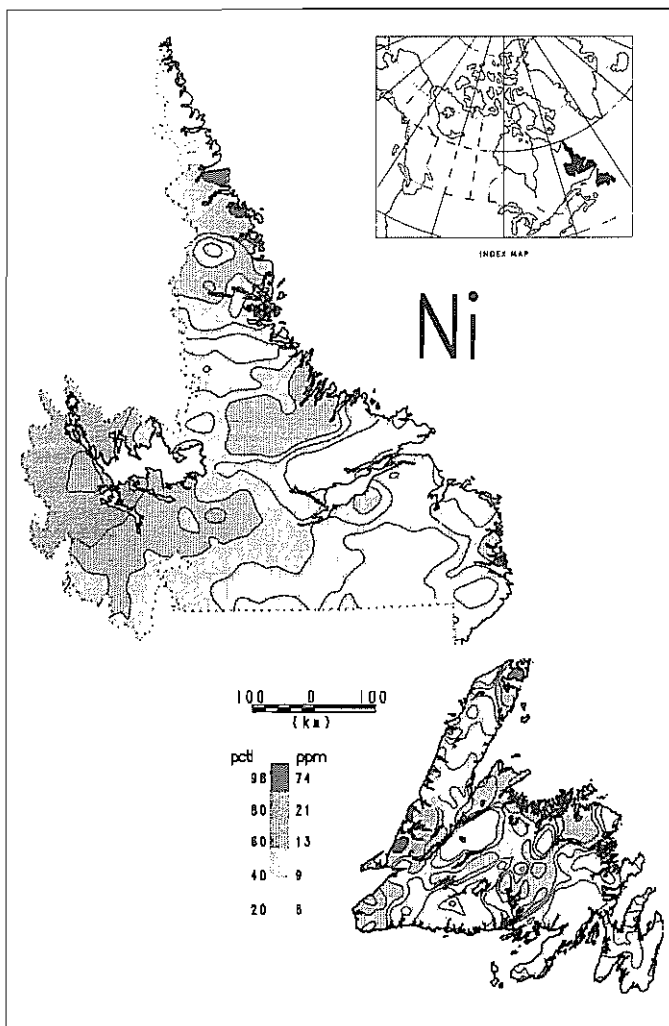


Figure 1. Nickel distribution in lake sediment in Newfoundland and Labrador.

The relative magnitudes of geologically-controlled, lake to lake geochemical variation compared to local variation in relatively undisturbed areas over time is illustrated in Figure 2. Arsenic data illustrate what most elements show, geological variation is much more important than local variation. The lack of arsenic concentration variation over the upper 10 to 20 cm of the cores indicate that anthropogenic sources are probably not important for arsenic in most of rural Newfoundland. Acid-soluble lead, on the other hand, indicates a two-fold enrichment at the top of three sediment profiles suggesting anthropogenic sources are contributing lead.

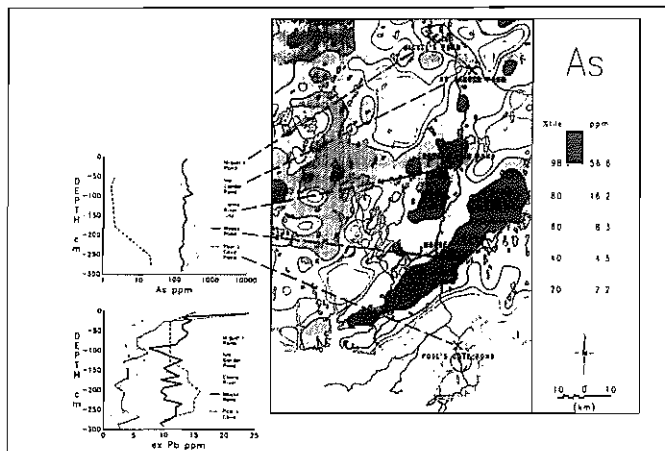


Figure 2. Arsenic and lead distribution in lake sediment, areal distribution and distribution with depth (used as a surrogate for time).

A section of core represents an average composition over a period of several years. Water analyses, however are more ephemeral in nature. Water composition has a more direct relevance to uptake by aquatic organisms above the sediment surface. The degree of correspondence between trace element concentrations in sediments and water in lakes has been studied in undisturbed (Finch, et al., 1992) and disturbed areas (Blake, 1992).

Arsenic is one of the elements showing good correlation between the two media. Figure 3 shows the arsenic concentration in Moose Pond (Baie d'Espoir area, Figure 3). Moose Lake is surrounded by sources of high arsenic and from the depth consistency of the arsenic concentration, it is concluded that the arsenic concentration in water has been around 2 parts per billion (ppb) for about 8,000 years. Similar inferences can be made for Ba, F, Ni, Sb, V, and several rare-earth element paleo-water concentrations (McConnell, et al., in prep.). These results are consistent with acid-leaching studies that show that Co, Cu, Zn, Ni, Mo, Mn, La, Ce, Y, Dy, Fe, Be, Cd, Ba, Cr, Li, Pb, and V are readily extracted from lake sediments by weak acids (Davenport, in prep.).

Christopher (1991) extended regional surveys into the City of St. John's and suburbs to measure the nature, extent, and intensity of geochemical changes in lake sediments due to anthropogenic sources (urban development in this case). Evidence of pollution is clear. For example, peak lead concentrations in grab samples of lake sediment are up to 10 times higher than the natural background for this area and above the 99th percentile for all of Newfoundland (Figure 4). Silver, Au, Ba, Cd, Cs, Cu, F, Hf, Rb, Sc, Ta, Th, U, V, W, Yb, and Zn are likewise apparently elevated in city core sediment but not above background in all cases. Christopher is continuing to examine the chronology of the chemical changes in sediment cores from several lakes in St. John's. A comprehensive picture of these changes in space and time is being established by relating the

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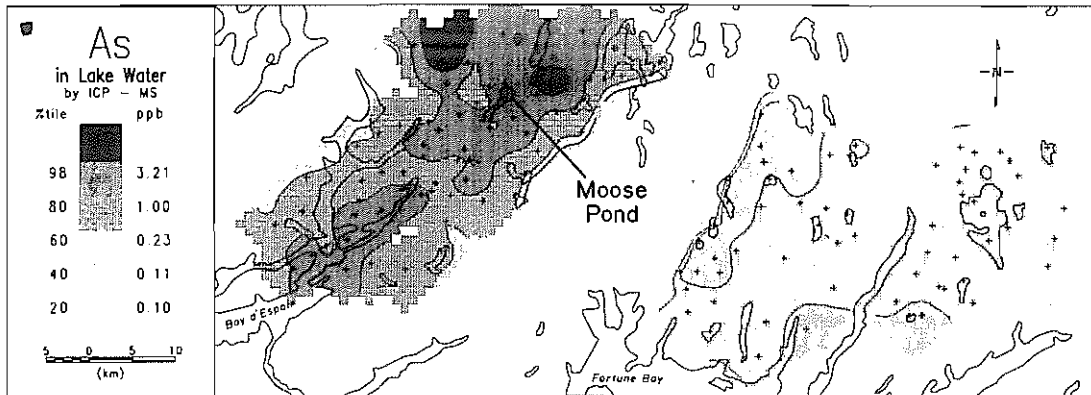
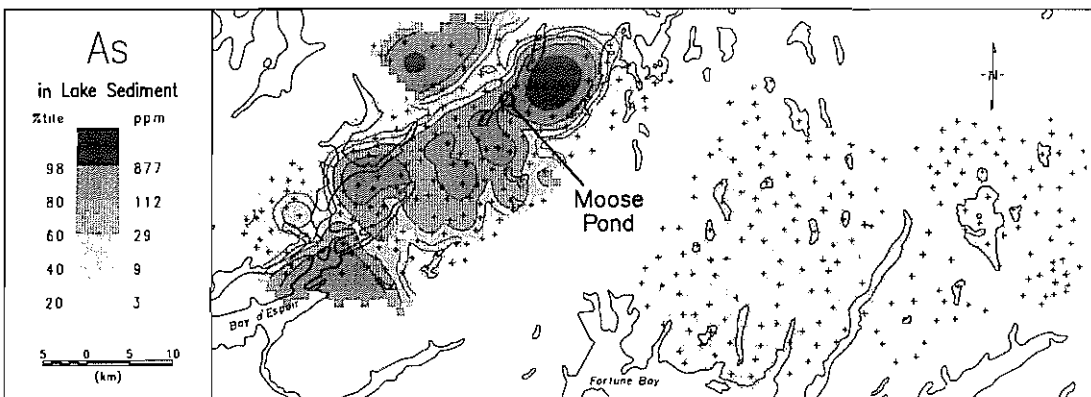
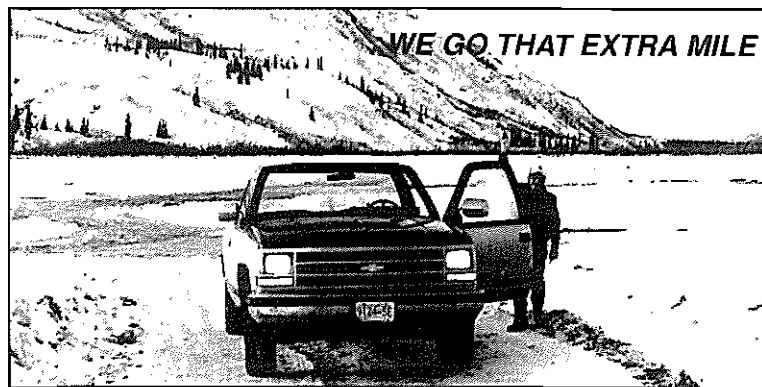


Figure 3. Comparison of arsenic in lake water and in lake sediment in the Baie d'Espoir area, southern Newfoundland (from Finch, et al., 1992).



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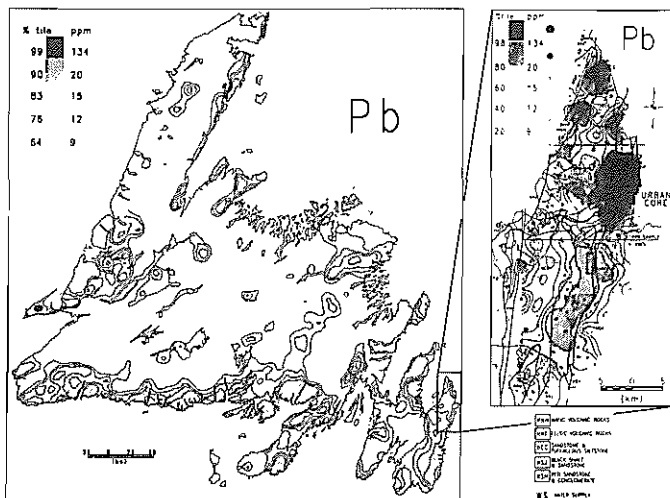


Figure 4. Regional distribution of lead in lake sediment from 16,000 sites throughout Newfoundland (left) and, from 246 sites on the northeast Avalon Peninsula, in more detail, including the St. John's urban region (right).

historical record to multi-element and isotopic signatures of geochemical changes dated by pollen sequences, radiometric dating, and the occurrence of physical micro-artifacts like soot particles.

Existing NGR style geochemical databases, like those for Newfoundland and Labrador, provide useful and reliable geochemical baselines. Only surveys based upon grab samples of organic lake sediments are validated. Similar retrospective studies in other areas and employing other media are necessary to establish their applicability as geochemical baselines documenting environmental changes. These studies extend the range of application for existing geochemical maps and contribute to the more complete understanding of geochemical processes in the surface environment, and allow more scientifically rigorous interpretations of geochemical survey data applied to both exploration and the environment.

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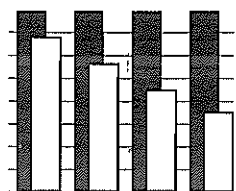
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Manganese Oxide — Metal Adsorption: Exploration Guide and Environmental Control

The inter-relationship between geochemical exploration and environmental geochemistry, and particularly the commonality of geochemical processes upon which both are based, is appreciated by geochemists active in both areas. The adsorption of metals by manganese oxides is a good illustration of this commonality. Manganese oxide adsorption is a natural geochemical process producing a guide in mineral exploration and acts as a control on metal transport in the environment.

Freshly deposited, amorphous manganese oxides have an isoelectric point between a pH of 1.5 and 2.0. This means that,

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at the pH of most depositional environments, amorphous manganese-oxides have a net-negative surface charge and, therefore, adsorb cations. As the amorphous oxides crystallize, some to all of the adsorbed cations may become incorporated into the crystal lattice, thereby governing which mineral will form. Upon crystallization, the isoelectric point moves to a higher pH approaching a neutral pH (7). The precise pH value is variable and dependent upon the mineral formed. Following crystallization, the oxide may continue to adsorb metals depending upon the pH of the environment. Both amorphous and crystalline manganese oxides therefore develop a chemical signature which, in crystalline minerals may be regarded as a two-stage, dynamic natural process.

Manganese oxides can be a valuable guide to mineralization, but their application is often overlooked. Too often they are seen as ubiquitous weathering products of negligible significance or even a nuisance. Yet, manganese oxides act as natural preconcentration agents, enhancing geochemical signatures which would otherwise go unnoticed. The key to interpretation lies in understanding the natural adsorption process.

The adsorbed species forming the geochemical signature on manganese oxides reflect the composition of the depositional aqueous environment. This useful property enables the element enrichments of ancient deposits to be used to determine the genetic origin of manganese oxides (Nicholson, 1992a,b). Recognizing enrichments of these oxides can also be employed, to avoid misleading interpretations. The significance of manganese oxides should not be evaluated on criteria used with silicate lithologies. The strong adsorption capacity of these oxides and their predominance on an outcrop means that any trace element signature is partially dependent upon the concentration of exposed manganese oxides, a position not parallel in the interpretation of silicate rock geochemistry. This property can lead to misinterpretation when comparing the chemistry of manganiferous deposits with the typical situation of varying amounts of manganese oxides within the occurrence. Normalization of the data to the manganese concentration is one way to overcome the problem (Nicholson, 1992a).

Manganese oxides can be separated into three genetic types:

- stream sediment coatings,
- exhalites, and
- dubhites.

The use of manganese oxide coatings on *stream sediments* in exploration for base metal deposits is well established. The oxides concentrate pathfinder elements from groundwater entering the stream, enabling otherwise undetectable hydrogeochemical anomalies to be identified. Zinc, for example can attain concentrations in excess of 2,500 parts per million (ppm) in the oxides (Carpenter, et al., 1975).

Manganese *exhalites* can be recognized by geochemical enrichments in some or all of the following elements: As, Ba, Cu, Li, Mo, Pb, Sb, Sr, V, and Zn. Diagnostic geochemical signatures can be ascertained by plotting combinations of these elements. For example, Nicholson, 1992a,b, uses plots of $Fe-Mn-10(Co+Cu+Ni)$; $Si-Al$; $Fe/Ti-Al/(Al+Mn+Fe)$ as diagnostic criteria. Exhalitive manganiferous sediments identify areas of hydrothermal activity and may be the distal expression of sulfide-bearing stratiform mineralization.

Distinctive manganese oxide deposits may be formed from the oxidation of both Au-Ag and Pb-Zn mineralized sequences and are a reliable guide to ore. Accumulation of manganese oxides formed in this way (*dubhites*) typically show high levels of lead and zinc and are readily identified on a Pb-Zn plot (Nicholson, 1992a). However, some caution has to be exercised in the analysis of heterogeneous manganiferous ironstones. The adsorptive capacity of manganese oxides will raise the threshold of

significance for many elements, such that what would be an anomalous concentration of a target or pathfinder element in a silicate rock or ironstone may be only within the background range for manganese oxides. In such circumstances, selective separation and analysis of the manganese oxides can be more revealing than attempts to interpret the bulk geochemistry of the mixture.

Since manganese oxides lock up metals from aquatic and soil environments, they also affect fate and transport of many metals which can impact the environment, and have a beneficial effect on *water quality*. Deposition of amorphous oxides on sand filtration beds of a water treatment plant in northeastern Scotland occurs as a consequence of the treatment process. The oxides deposit as uniform coatings on the individual sand grains, effectively forming a metal adsorption bed. Manganese oxides constitute 20 to 33 weight percent of the sand grains and adsorb metals from the treated water. Up to 55 ppm Fe, 50 ppm Ca, 7 ppm Zn, and 5 ppm Mg have been measured on the coatings (Eley and Nicholson, in press) representing enrichments relative to the incoming water of approximately 1,000 percent. Initially considered a nuisance by the water treatment engineers, the deposition of manganese oxides on the filtration beds aids water treatment and further improves the water quality.

The ability to remove metals from the environmental cycle, however, is not always beneficial. For example, the presence of significant quantities of oxides in soils can have a detrimental effect on the *plant-animal nutrition*. Removal of key trace metals from the soil solution can result in deficiencies in crops grown on such soils, and grazing livestock, as the bio-availability of essential metals is reduced. Rae et al. (1992) demonstrated such an instance in Devon, England, where the manganese oxides reduced the plant-available Co and Cu. The reduction in bio-availability of these metals created deficiency problems in livestock grazing affected areas.

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Finally, metals adsorption can result in unusually high concentrations resulting in potential sources of pollution/toxicity. Should manganese oxides become reduced or otherwise become soluble (for example, flooding of a soil horizon (Patrick and Henderson, 1981), the adsorbed metals can be returned to aqueous solution at concentrations sufficiently high to produce a "toxic flush."

In summary, the surface chemistry of manganese oxides allows for a distinctive geochemical signatures and thereby plays a unique role in both exploration and environmental sciences. In the hands of an exploration professional, these are diagnostic tools which act as guides to mineralization, aiding in recognition of the depositional/formational environment, and permit estimates of paleo-oceanic spreading rates. Manganese oxides also form metal sinks which can be important to environmental understanding.

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Application of Exploration Geochemistry Tools to Environmental Purposes

Remarkably close relationships exist between exploration and environmental geochemistry. Geochemists trained in exploration easily make the transition to environmental geochemistry. An important reason for this is that a geochemist trained in mineral exploration understands the natural processes involved in the weathering, transport, and fate of metals and associated components from ore deposits. Indeed, the use of hydrogeochemistry in mineral exploration is based on the concept that water in contact with mineral deposits will have a different geochemical signature than that in contact with unmineralized rocks. Agricola long ago recognized this phenomenon and describes the natural contamination of water by contact with metallic ores (Levinson, 1974):

"Now I will discuss that kind of minerals for which it is not necessary to dig, because the force of water carries them out of the veins. Of these there are two kinds, minerals - and their fragments - and juices...If the springs discharge water containing some juice, this also should be collected; the further (sic) such a stream has flowed from the source, the more it receives plain water and the more diluted it does become..."

Surprising, many neophyte environmental scientists fail to recognize that "natural contamination" of the environment does occur, especially in mineralized regions. Runnells et al. (1992) demonstrates that natural weathering of ore deposits can result in concentrations of metals in surface and ground waters that exceed regulatory drinking standards.

In comparing the specific techniques of exploration and environmental geochemistry, it is clear that many aspects are almost identical. Not only are the media identical but also the analytical methodologies and the statistical methods of interpreting the data. However, environmental data usually involves more rigorous quality control/quality assurance (QA/QC) than exploration data.

Perhaps one of the most significant differences between the two fields lies in the direction of movement of the dissolved components. Anomalies in exploration are almost always formed by components moving *upward* from sources at depth, whereas, in environmental contamination, *downward* movement is usually very important.

Defining the natural background metal concentrations is an important aspect in both exploration and environmental geochemistry. A meaningful contribution to the base of knowledge in both areas can come from the exploration data from mineral deposits before they are mined, information readily accessible to exploration professionals. Runnells et al. (1992) presents a compilation of water chemistry analyses from mineralized areas that have not been impacted from mining. Table 1 shows that naturally low pH values and elevated metals concentrations occur in natural waters. It is important to document such data before any mining activities are started at a property.

Table 1. Chemical analyses of mineralized spring waters from areas that have not been mined (from Kepler, 1980), concentrations in milligrams per liter (mg/L), except pH.

NON-DISTURBED SPRING WATER BACKGROUND				
Location	pH	Fe	Cu	Zn
Spring, Howard's Fork, San Miguel River, CO.	3.9	1.5	0.27	0.40
Alum and Bitter Creeks, San Juan Mtns., CO.	2.7-3.3	17	0.27	0.94

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Modern methods of geochemical computer modeling, potentially useful in mineral exploration, are of great value in environmental work. Runnells and Lindberg (1981) demonstrated the application of the WATEQF geochemical model to hydrogeochemical exploration for uranium deposits. More recently, similar models have been used to predict the natural dissolved metals concentrations that can result from exposure and weathering of base-metal ore deposits. Table 2 shows the results of one such application in the Kansas part of the old Tri-State Mining District.

Table 2. Computed dissolved concentrations in surface water in the Tri-State Mining District, U.S.A. Equilibrating "non-contaminated" surface water with mineral assemblages. All concentrations in mg/L except pH.

Dissolved Component	CONCENTRATION IN SURFACE WATER			Short Creek 2 mi. W. of Galena Kansas
	Slightly Predicted	Moderately Predicted	Highly Predicted	
pH	7.0	6.3	7.2	6.0
Barium	0.0059	0.2	0.0092	0.00
Calcium	750	210	41	240
Magnesium	ns	23	ns	4.5
Sulfate	1900	50	540	71
Lead	0.45	0.45	0.57	0.00
Zinc	104	18	180	25
Iron	0.02	2.4	0.00077	0.01
Manganese	12.3	ns	1.6	1.7
Cadmium	0.01	1.2	0.028	0.17

Slightly oxidized suite:
barite (BaSO_4), greenockite (CdS), sphalerite (ZnS), galena (PbS), calcite (CaCO_3), cerussite (PbCO_3), and rhodochrosite (MnCO_3).

Moderately oxidized suite:
barite, otavite (CdCO_3), siderite (FeCO_3), smithsonite (ZnCO_3), cerussite, calcite, and dolomite ($\text{CaMg}(\text{CO}_3)_2$).

Highly oxidized suite:
barite, jarosite ($\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$), otavite, cerussite, manganite (MnOOH), ferric hydroxide ($\text{Fe}(\text{OH})_3$), and zinc hydroxide precipitate ($\text{Zn}(\text{OH})_2$).

Reasonable mineral assemblages were equilibrated with stream water up-gradient of the mining activity. The results of the predicted surface water composition are compared with the actual observed down-gradient composition in Table 2. The comparison shows that reasonable values of lowered pH and elevated metals concentrations can be calculated to result from the natural weathering process acting upon metallic minerals. Furthermore, the predicted metals concentrations are remarkably similar to the measured concentrations in the stream water. Many important assumptions are involved in such modeling (e.g. equilibrium is assumed) and a valid argument can be made that the exact results are suspect. However, the single most important point is that natural weathering of ore deposits is potentially capable of causing significant degradation of natural waters. Surprisingly, this is a point not widely recognized outside of exploration geochemistry.

In summary, it is obvious that exploration professionals, particularly geochemists, have specialized knowledge and skills that can be of great value in the characterization and remediation of some of the difficult environmental issues that face the mining industry. It is logical to apply many of the skills and techniques of exploration geochemistry to solving environmental problems.

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

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RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 77. 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**.

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Continued on Page 16

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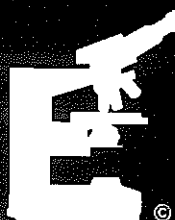
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CALL FOR PAPERS

Geochemistry Session of 1994 SME Annual Meeting, Feb 14-17, Albuquerque, New Mexico

The title for the geochemistry session is "Geochemical Exploration for Au: Using Old (proven) Techniques for New Discoveries." In the past few years, exploration companies have moved away from the experimental/research methods of the late 1980's to geologically driven geochemical methods that have proven successful in the past. To reflect this change, the 1994 geochemistry session seeks papers dealing with the effective use of proven geochemical methods/techniques towards discovery. Please submit preliminary abstracts (100 words) for consideration to: Todd Wakefield, Newmont Exploration Ltd., PO Box 669, Carlin, NV 89822 USA; TEL: (702) 778-4031; FAX: (702) 778-4038.



Structural and Stratigraphic Relationships of Devonian Reservoir Rocks, East Central Nevada

The Nevada Petroleum Society is soliciting quality papers which address the relationship of Devonian reservoir rocks to the structural framework of the Nevada portion of the Great Basin. The papers will be published in a guidebook to be associated with a 1993 field trip. Questions and papers should be submitted to Charles W. Gillespie, Guidebook Editor, PO Box 10350, Reno, NV, 89509; TEL: (702) 786-4000, FAX: (702) 786-4888. Anyone interested in the field trip should contact Neal Brecheisen, Field Trip Committee Chairman, 1030 Gentry Way, #5, Reno, NV., 89502; TEL: (702) 785-6574.



INTEGRATED METHODS

Integrated Methods in Exploration and Discovery, April 17-20, 1993, Denver, Colorado, USA

The organization and planning for this conference continues to proceed very smoothly. Co-sponsors for the meeting are the: Society of Economic Geologists, Society of Exploration Geophysicists, Association of Exploration Geochemists, and the US Geological Survey.

At the time of writing, extended abstracts are being received from all over the world. The response to the fund-raising campaign has been very gratifying. Companies in North America,

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Australia and elsewhere have endorsed the focussed themes and objectives of the conference with generous cash contributions. These monies will be used primarily to lower registration and other delegate costs, and subsidize student enrollment and involvement in the workings of the conference.

The expression of interest in the field trips, short courses, and workshops is very strong. Over 250 people (= 40% from outside North America) responded and the majority of these events have been filled. Those included in these events have been advised by first class mail and reminded that their reservations will only be confirmed on receipt of required fees prior to March 1, 1993. These payments should accompany the completed conference registration forms, which will be mailed as part of the final circular in December 1992.

The Conference Committee, representing the four co-sponsors, is optimistic that the April '93 meeting will become the first in a series reflecting progress in exploration practice with time. It is clear from the response to the planned conference that integration is viewed as a promising direction for exploration success.

Copies of the final circular (including registration forms and information) can be obtained by writing or calling:

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CALENDAR OF EVENTS

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

■ 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)

■ Feb. 15-17, '93 **Society for Mining, Metallurgy, and Exploration**, ann. mtg., Reno, NV (SME, Meetings Dept., Box 625002, Littleton, CO 80162-5002; TEL: (303) 973-9550; FAX: (303) 979-3461)

■ Mar. 16-18, '93 **Biennial Finnish Symposium 'Geochemistry '93'**, with status of geochemical mapping and interpretation, data availability, and exploration case studies, Abo, Finland, by Finnish Society of Mining; a change in the mining law gives full rights for exploration and mining to foreign companies which are invited to send representatives to this symposium (Dr. Alf Bjorklund, Department of Geology, Abo Akademi University, SF-20500 Abo, Finland, FAX: +358 21 654818)

■ Mar. 28-31, '93 **Prospector's and Developer's Association of Canada**, Toronto, ON, Canada, abstracts by Jan 29, '93 (Mrs. Saley Lawton, Co-coordinator, open forum, PDAC, 74 Victoria Street, Suite 1002, Toronto, ON, M5C 2A5)

■ Apr. 1-3, '93 **Computer-simulated Mineral Exploration**, workshop, Fontainebleau, France, by UNESCO's Earth Sciences Division and French National Commission (L. Zanona, Ecole des Mines de Paris, CGGM-IGM, 35, rue Saint-Honor, 77305 Fontainebleau Cedex, France; TEL: (33 1) 64 69 49 30; FAX: (33 1) 64 69 47 01)

■ 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)

Continued on Page 19

Calendar of Events

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■ 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)

■ Apr. 20-24, '93 International Conference on Geoscience Education and Training, South Hampton University, England (Dr. Dorrik A.V. Stow, Dept. of Geology, University of South Hampton, South Hampton, SO9 5NH, England, TEL: (0703) 593049, FAX: (0703) 593052)

■ Apr. 25-30, '93 Geology of Industrial Minerals, symposium, Long Beach, CA (Dave Beeby, Division of Mines and Geology, MS 8-38, 801 K St., Sacramento, CA 95814; TEL: (916) 323-8562)

■ 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)

■ May 31-June 2, '93 Applied Mineralogy, int'l. mtg., Perth, Western Australia (Jim Graham, ICAM '93, Private Bag, P.O. Wembley 6014, Australia; TEL: (619) 387-0371)

■ June '93 Intl. Precious Metals Institute, Newport, Rhode Island (IPMI, 4905 Tilghman St., Suite 160, Allentown, PA 18104, TEL: (215) 395-5855)

■ July 24-29, '93 Society for Environmental Geochemistry and Health mtg., New Orleans, LA (Dr. Howard Mielke, College of Pharmacy, Xavier University of Louisiana, New Orleans, LA 70215; TEL: (504) 483-7523)

■ Aug. 1-3, '93 Geochemistry of the Earth Surface. Third International Symposium on Geochemistry of Weathering and Diagenesis of Sediments, 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. 1-3, '93 International Symposium on Mineralization Related to Mafic and Ultramafic Rocks (IAGOD, Symposium Secretary/D. Ohenstetter, CRSCM, La rue de la Feqrollerre, 45071 Orleans, Cedex 2, France; TEL: 33-38-51-54-01, FAX: 33-38-63-64-88)

■ 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. 5-10, '93 Trace Elements, 2nd Int'l Conference on Biogeochemistry of Trace Elements, Taiwan, ROC (Dr. D.C. Adriano, University of Georgia, Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29802)

■ Sept. 21-23, '93 Andean Geodynamics, int'l symposium, Oxford, England, by University of Oxford and Institut Français de Recherche Scientifique pour le Développement en Coopération (Orstrom). (Pierre Soler, Orstrom, CS1, 213 rue Lafayette, 75480

Paris Cedex 10, France; FAX: 33-1-48 03 08 29)

■ 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)

■ Sept. 26 - Oct. 1, '93, Analytical Environmental Chemistry, Symposium on Analytical Chemistry incorporating the 3rd Environmental Chemistry Conference, Perth, Western Australia (12 AC, The Conference Office, University of Western Australia, Nedlands, WA, Australia 6009)

■ Sept. 28 - Oct. 1, '93 Environmental Pollution, int'l mtg., Barcelona, Spain, by European Centre for Pollution Research and others (ICEP Conference Office, ICTR Secretariat, 11-12 Pall Mall, London SW1Y 5LU, England; TEL: 44 71 930 6825; FAX: 44 71 976 1587)

■ 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)

■ Feb. 14-17, '94 Integrating Mining and the Environment, SME Annual Meeting, Albuquerque, NM (Meetings Dept., SME, PO Box 625002, Littleton, CO 80162-5002 USA; TEL: (303) 973-9550; FAX: (303) 979-3461)

■ 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. *Continued on Page 21*)

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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)

■ Oct. 25-27, '94 Geological Society of America, annual mtg., Boston, MA (Vanessa George, G.S.A., Box 9140, Boulder, CO 80301; TEL: (303) 447-2020)

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