EXPLORE

Newsletter for the Association of Exploration Geochemists

NUMBER 72 JULY 1991

TECHNICAL NOTES

Using Silt-Sized Visible Gold Grains to Explore for Gold Deposits Concealed by Quaternary Overburden: Nevada vs. Canada

Introduction

In Canada and northern USA, heavy mineral geochemical sampling of till is widely used to explore Archean, Proterozoic and Paleozoic fold belts for gold deposits concealed by Quaternary glacigenic overburden. An important aspect of these heavy mineral till geochemistry programs is the temporary separation and visual inspection of any native gold grains before the concentrate is chemically analyzed. In this way, geochemical anomalies caused by dispersal of gold from significant bedrock sources are screened from anomalies of similar strength caused by common background gold grain noise. As well, the concentration, size, habit and chemistry of the dispersal train gold grains can be employed to predict the size, grade and character of the bedrock source mineralization, and the degree of gold grain modification by glacial processes can be used to estimate the up-ice distance to the source. The large Casa-Berardi gold deposits in Quebec (Fig. 1) were discovered using these parameters (Sauerbrei et al., 1987).

Gold grains in most Canadian gold deposits are silt-sized (<63 microns wide). Gold grains in the dispersal trains of these deposits are also silt-sized because gold, being very malleable, is deformed rather than comminuted during glacial transport. The need to recover and observe these silt-sized gold grains has led to improved laboratory technology, and grains of 5 to

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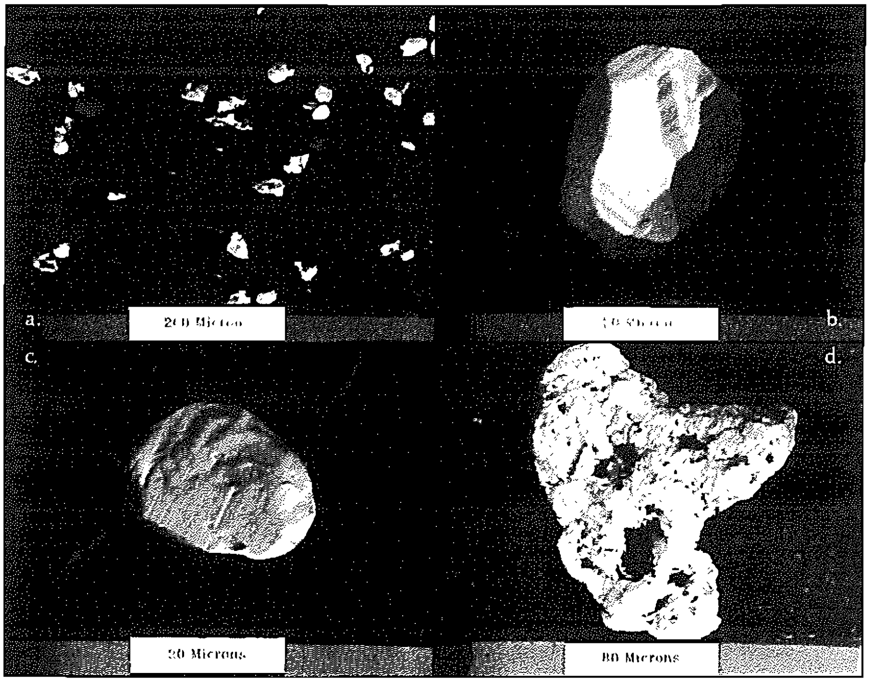

Plates a-d: Photomicrographs of silt-sized gold grains from till in Canada: a) dispersal train population; b) pristine crystal showing parallel growth; c) modified grain with glacially striated facet; d) reshaped background grain.

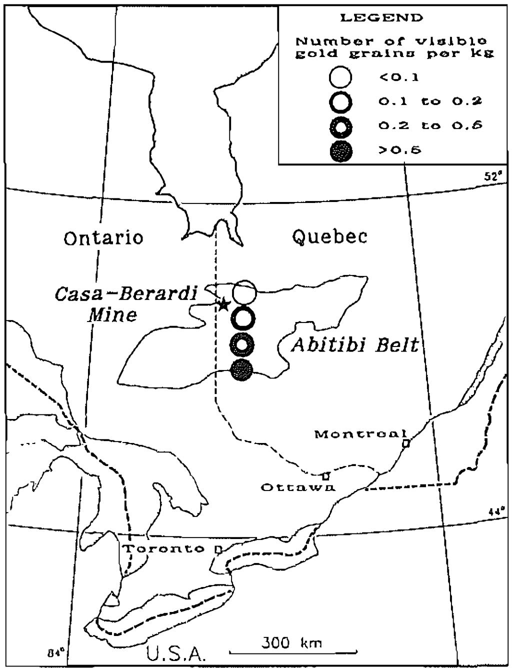

Fig. 1 — Background concentration of native gold in till, Abitibi Greenstone Belt, Canada.

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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* 5¼- or 3½-inch IBM-compatible computer diskettes with ASCII (DOS) format that can go directly to typesetting. Please use the metric system in technical material.

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

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

EXPLORE

Newsletter No. 72 JULY 1991

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NOTES FROM THE EDITOR

This issue of **EXPLORE** follows in the wake of the successful 15th IGES in Reno, Nevada, the installation of a new AEG executive and the election of new councilors. By now, as the North American field season heats up, things should be settling down as we all attempt to apply what we have learned.

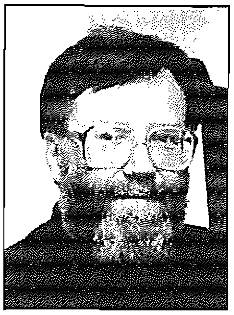
This issue of **EXPLORE** contains two technical notes pointing out *non traditional* types of information which may be of interest to us in exploration. Stu Averill discusses the value of examining gold grains, even when you think all of your gold is "invisible" and Dave Leach draws our attention to the potential value of fluid inclusions in exploration. In the **Special Notes** section, Betty Gibbs provides a discussion and compilation of sources for inexpensive software. As promised, Russ Calow discusses, in the **Analyst's Couch** section, analytical quality control in a commercial laboratory.

This issue also reflects a growing trend towards letters, discussions, replies and other forms of heated debates. By now the readership must realize that *if you write it, we will try to find a way to print it*; however, in future editions we expect to restrict the subject matter of such debates to geochemical issues.

EXPLORE Number 74 (January 1992) will be an ***all Australian*** issue, to be organized by Graham Taylor (CSIRO) and other Australian AEG members. *Hold onto your hats.* This is shaping up to be a particularly interesting issue.

Owen P. Lavin
Editor, **EXPLORE**

PRESIDENT'S MESSAGE



There were approximately 500 participants at the 15th International Geochemical Exploration Symposium in Reno. Some excellent papers and posters were presented at the meeting and I look forward to their publication in the Journal of Exploration Geochemistry. My congratulations and thanks to Hal Bonham and all the organizers for their hospitality and efforts in making the meeting both enjoyable and successful.

Don Runnells, in his outgoing Presidential Address at the 15th IGES, gave examples of the application of geochemical principles to environmental decision-making in the mining industry. This brings me back to some of the thoughts I raised in the last issue of **EXPLORE** about the education of the exploration geochemist. Clearly the fundamental laws of chemistry and basic concepts of geochemistry are common to both environmental and exploration geochemistry, or to any other application of geochemistry. A further similarity is that, although the emphasis may differ, both activities focus much of their attention on distribution and trace element behavior in soils, sediments and waters; that is, in the near-surface environment of weathering and landscape development. In this regime, depending on the location and geomorphic setting, element dispersion is largely dependent on physical movement of materials by mass wasting, glacial or fluviatile processes, or by the flow of water through porous or fractured media. Our ability to interpret exploration geochemical data or make rational environmental decisions is thus dependent on our understanding of the interaction of geochemical and physical processes.

Where is this polemic leading? In brief, I conclude that the education of the exploration geochemist requires exposure to modern concepts of both geochemistry and geomorphic processes. This is equally true for the environmental geochemist. Unfortunately in traditional geoscience programs the teaching of geochemical and physical processes tends to diverge - to the extent that the latter, as Physical Geography and some aspects of Soil Science, may be taught in a different department from geology and geochemistry. Insofar as the success or failure of exploration geochemical programmes often depends on our ability to interpret geochemical patterns in soils and sediments, I believe it is in our interest to encourage both students and research to cross these artificial barriers.

A starting point is to find out how the geosciences are organized at the campus near you. I would be interested in hearing your comments, either directly or through these pages, on how exploration geochemists are or should be educated. I will return to the topic in future issues.

Turning to the operation of your Association, we are in the process of simplifying the organization by centralizing various activities through a new office in Vancouver. Applications for or about membership, journal subscriptions and similar queries can now be addressed to:

Association of Exploration Geochemists
PO Box 48270
Bentall Centre
Vancouver, BC
Canada, V7X 1A1
TEL: (604) 685-4767
FAX: (604) 684-5592

where Mrs. L. Kluber will be the Association's office manager.

As the new office is phased in, I wish to take this opportunity to thank Mrs. I. Filicetti for all her work over many years in the Toronto office. During the transfer period she will continue to run the Toronto office.

W.K. Fletcher
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University of British Columbia
Vancouver, BC, Canada
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AEG ANNUAL GENERAL MEETING

On April 29, 1991 the Association of Exploration Geochemists held its Annual General Meeting (AGM) at Bally's Hotel in Reno, Nevada, USA in conjunction with the 15th International Geochemical Exploration Symposium (IGES). Due to the luncheon venue of the meeting, the President of the Association gave his Presidential Address just prior to the AGM, at the end of the luncheon. *This address will be published in a forthcoming issue of* the Journal of Geochemical Exploration.

1. Call to Order

The President called the meeting to order at 1:05 PM, local time, and established that a quorum of voting members was present.

2. Minutes of the 1990 Annual General Meeting

The President asked if there were any matters arising from the minutes of the 1990 AGM, as published in **EXPLORE** Number 68. There were no matters arising.

A motion was made that the minutes of the 1990 Annual General Meeting of the Association of Exploration Geochemists, as published *in EXPLORE Number 68 and filed with the Secretary, be ap-*proved. The President asked for a vote on the motion. The motion passed unanimously.

3. President's Report

The President expressed appreciation on behalf of the Council and Executive to the Organizing Committee of the 15th IGES for all their efforts. He went on to list some of the more important Association events that had occurred since the last AGM:

(1) The Association, which is now 21 years old, is stable at about 1200 members, an increase over the last year. The Association is working hard to increase the number of members, especially in countries where we have very few members. As an example, there are very few members in Chile, a country where there should be many members.

(2) The Association has a positive financial position and has sufficient funds to move forward with all planned activities.

(3) The Association has many committees and some of the major committees are:

(a) **Symposium Committee** (C. Dunn, outgoing Chairman, F. Siegel, incoming Chairman) - this committee helps organize future symposia and regional meetings. Plans are being made as far ahead as 1995 at this time. This planning requires a constant exchange of communications throughout the world.

(b) **Awards and Medals Committee** (A. Soregaroli and R. Garrett, Chairmen) - This committee has been very active in 1991 and the Association now has Certificates of Achievement that will be awarded to members for recognition of their achievements. The Association will also strike two medals; (1) a "Past President's Medal" for outstanding contributions to the Association and (2) a "Gold Medal of the Association of Exploration Geochemists" for outstanding achievement in the field of exploration geochemistry.

(c) **Future Directions Committee** (J. A. Coope) - This committee is working on defining the directions for the Association for the future. Results from this committee have been published in **EXPLORE** Number 71. (*Editor's Note: This ad hoc committee was dissolved during the June 26 Council meeting, after its final report was accepted. The final report is scheduled to be publishjed in EXPLORE Number 73.)*

(d) **Voting Membership Committee** (J. Jaacks) - This committee is working on how to get Affiliate members to upgrade their membership to Voting members. Results from this committee have been published in **EXPLORE** Number 71.

(4) The Association newsletter **EXPLORE** was started in Reno by C. Nichols, S.C. Smith, and several others and has had remarkable success. The publication of **EXPLORE** has now been moved to Denver and O. Lavin is the new Editor. **EXPLORE** is being published quarterly by Network Graphics, Inc.

(5) There are some important symposia scheduled for the future. In 1992 the AGM will be held in conjunction with the Society of Mining Engineers (SME) meeting, February 24-27, in Phoenix, AZ, and there will be a half day session on exploration geochemistry. Also in 1992, in May, the AEG is participating in the Goldschmidt Conference in Reston, VA with the theme "Regional Geochemical Mapping." The AEG association with the Goldschmidt Conference has been ongoing for a number of years. In the spring of 1993, the AEG will participate in a symposium with the Society of Economic Geology and the Society of Exploration Geophysisists in Denver, CO. Finally, in September of 1993, the AEG will hold the 16th IGES in Beijing, China.

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AEG Annual General Meeting

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(6) The move of the headquarters of the AEG from Toronto to Vancouver is continuing. It is hoped that this move will improve the response of the Association to the concerns of members. Much of the difficulty with communication has resulted from having the business of the Association scattered over many locations. Consolidating the business of the Association in Vancouver will, hopefully, alleviate this problem. It will take about a year to complete this process.

4. Secretary's Report

The Secretary reported that the Association was in good financial health and that an election of Council and Executive had just been held. The Secretary said that an item on the election ballot had been to solicit the opinion of the Voting Membership on whether or not a new class of membership should be offered. This class of membership would include **EXPLORE** but not the Journal of Geochemical Exploration and would be offered at a reduced rate. The Voting Membership has responded favorably with 52% of those responding approving of the idea. Council will pursue this issue and report to the membership in a future issue of **EXPLORE**.

The 1991 AEG membership is 969 to date and consists of Voting, Affiliate, and Student Members. It is hoped that by the end of the membership year in June, 1991 the Association will have over 1100 members for 1991. The membership base seems to be increasing with a small increase in Voting Members. The Association would like to extend an invitation to all interested Affiliate Members to upgrade their membership to Voting.

The By-laws Committee (D. Runnells) has completed a major revision of the By-laws of the AEG. This revision has been a major effort for the last year and the final version is being reviewed by Council. The revised By-laws will be sent to the membership for final approval.

The Association hopes to continue to grow in the coming year and plans to actively solicit members in developing countries in the southern hemisphere, eastern Europe, and Asia.

5. Treasurer's Report

In the absence of the Treasurer, S.P. Marsh gave the Treasurer's Report. He announced that a copy of the audited Treasurer's Report for 1990 was available to attending members. The assets of the AEG in 1989 were $170,240 and in 1990 the assets were $196,763. The liabilities for 1989 were $34,831 and the liabilities for 1990 were $36,617. The Association had revenues of $115,308 in 1989 and revenues of $129,854 in 1990. Offsetting this were expenses of $88,031 in 1989 and expenses of $105,126 in 1990. This all resulted in net revenues of $27,277 in 1989 and $24,728 in 1990. The AEG is in sound financial condition and this should continue into the future.

6. Introduction of the 1991 Executive

The President announced that the incoming President for 1991 would be W. Kay Fletcher, the First Vice President would be Jeffrey A. Jaacks, the Second Vice President would be Graham F. Taylor, the Secretary would remain Sherman Marsh, and the Treasurer would remain David M. Jenkins.

7. Announcement of the 1991-93 Ordinary Councilors

The President announced that, as a result of a general election, Frederick R. Siegel and Owen Lavin had been elected as new Ordinary Councilors. Gwendy M. Hall, Peter H. Davenport, and J. Alan Coope were re-elected to a second term and Donald D. Runnells would serve as an Ordinary Councilor in his *ex officio* status. There were two outgoing members of Council, Colin E. Dunn and Erick F. Weiland. These Council members were thanked for their efforts in helping to run the affairs of the Association and were invited to remain active participants.

8. Motion to Destroy Ballots

It was moved (I. Elliott) and seconded (R. Klusman) that the accountants, Nemoth Thody and Associates, be instructed to destroy the ballots for Ordinary Councilor. The President asked for a vote on the motion. The motion passed unanimously.

9. Appointment of Auditors

The President proposed that the Treasurer be given permission to reappoint the existing accounting firm of Nemeth Thody and Associates as auditors for the Association of Exploration Geochemistry for the year 1991. There were no objections from the floor.

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AEG Annual General Meeting

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10. Transfer of Meeting

Before transferring the meeting the out-going President gave a special thanks to his wife, Erica Runnells for her patience with him during his Presidency. The out-going President then transferred the meeting to the in-coming president, W. Kay Fletcher.

On behalf of the Association, W. Kay Fletcher thanked the out-going President, Secretary, and Councilors and welcomed the in-coming Councilors. The new President also thanked the organizers of the 15th IGES, especially H. Bonham and the Organizing Committee. He hoped that all attendees would take advantage of the meeting to communicate with each other.

11. Other Business

One member asked what the difference was between Affiliate and Voting Membership. The President said that this would be clearly explained in the new By-laws. No further business was brought before the Executive.

12. Adjournment

It was moved (F. Siegel) and seconded (J. Jaacks) that the Annual General Meeting of the Association of Exploration Geochemists be adjourned. The President asked for a vote on the motion. The motion passed unanimously.

The 1991 Annual General Meeting of the Association of Exploration Geochemists was adjourned at 1:46 PM local time.

Sherman P. Marsh
Secretary, AEG

NOTES FROM THE BUSINESS MANAGER

1991 Dues Reminder

A reminder regarding members who were in arrears of the 1991 (or earlier) dues was recently distributed. Several members have noted that the notice erroneously indicated 1990 dues were in arrears, in conflict with their label which indicated PAID- 90. Apologies are in order if this error in the form letter was not recognized. Please check the address label affixed to this **EXPLORE** to determine if the error has been rectified and/or your membership status is up to date. The notice also brought discrepancies regarding our records into focus, hopefully eliminating cases of non receipt of the Journal of Geochemical Exploration. This mailing also helped to identify members whose mail is being returned. The names of these individuals are listed below as *lost members*. Members who have the current address of lost members are requested to forward corrections to the Association's new office in Vancouver.

Lost Members

D.S. Andrews Sarmiento Ecuador	Daniel E. Robertson Reno, NV USA	Jim E. Newman Victoria, BC Canada
James R. Dobbs Denver, CO USA	Ahmed M. Behi Lakewood, CO USA	Douglas W. Alley Saint John, NB Canada
R.H. Olsen Denver, CO USA	Daniel Boamah Delft The Netherlands	M. Ajmal Ansari Nepean, ON Canada
Bernard C. Koch Lakewood, CO USA	P.C. Masterman Duberger, PQ Canada	James Chapman Vancouver, BC Canada
Purusotan Lal Shrestha Socorro, NM USA	Donald Nicholson Vancouver, BC Canada	M. Fukuda formerly of Dhaka, Bangladesh
	D. Craig Victoria, BC Canada	Mark W. Osterberg Tucson, AZ USA

AEG Directory

During a trip to Australia earlier this year I had numerous occasions to use the AEG directory. Valuable as the directory is, I found many entries with missing or faulty information. Check your listing to insure that all information is correct and advise the Vancouver office of the AEG of any corrections or updates. Preparation of a new directory is under way and we would like to make the next edition even better.

AEG Membership

I also noted during my travels that many more exploration companies are listed in the telephone book yellow pages than comprise our AEG Australian membership. Recognizing that not all companies seek to pay for listing in a telephone book, the potential for increased AEG membership in Australia is great, provided the AEG reach this audience with its Journal, newsletter and other exposure. The same situation exists in many other contries, including Canada and the United States. For this reason, the following appeal is issued to our membership world-wide.

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Notes from the Business Manager

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(1) Review listings in your local telephone book yellow pages, under the headings of Mining Exploration, Mineral Exploration, Mining Companies, Geologists, Geochemists, Consultants-geologists, Consultants-geochemists. **Photocopy these pages.**
(2) Search the telephone book or inquire elsewhere about corresponding postal codes.

Send a photocopy of the appropriate yellow pages and postal codes, to the AEG Business Manager at the AEG office in Vancouver. In the past, response to these requests have been poor, so please make an exceptional effort in this case. An increased membership will lead to more contributions and opinions which may benefit your efforts. **Please help!**

Stan Hoffman
Business Manager, AEG

LETTERS

Letter to the Editor;

In **EXPLORE** Number 71 (April 1991, page 14) a technical note about results of moss-mat stream sediment sampling was published. The sampling and analysis of moss under the circumstances explained in the note, appears to be a combination of old time prospecting with high tech analysis. Exactly this combination of techniques is what caused the erratic results for many of the elements. Moss absorbs biologically needed and non-biological elements, and a portion is retained mechanically. Substances retained by the moss are not only gold grains, but also decay products from the rock surface where the moss is anchored. Among the hydrolysis products, the most prevalent are hydrous iron and manganese oxides which absorb some of the elements carried in solution in the stream. From the sampling description it is understandable that gold shows wide variations due to the nugget effect in the moss. Other elements are retained in the sediment as fine dispersion. If the aim is finding the source of the gold, old-time prospecting alone would be sufficient. For this, moss sampling must be done carefully, with the moss being removed from preferably horizontal rock surfaces and collected dry in a bucket. Next, using a spoon and a brush, clean the surface from where the moss was taken and add this dry sediment to the bucket. Repeat the procedure a few times around the immediate area. The location of the samples should be standardized as it makes a difference whether it is taken around or before a bend of the stream, or if it is taken above, at or below the winter water level. The indicated procedure explained in the published note can be followed if the sediment is going to be analyzed whole, otherwise pan off the light sediment into another container and save the heavy concentrate. Use the relative amount of heavy concentrate (predominantly black sand) vs. total sediment for standardization. A panning of the concentrate can be used to observe and count gold colors.

For measuring the trace elements originating from sources upstream, a partial extraction of the hydrous iron and manganese oxides rather than a total dissolution of the sediment is advisable for avoiding anomalies diluted by local rock substances.

Respectfully submitted,

EVALDO L. KOTHNY
3016 Stinson Circle
WALNUT CREEK
CA 94598, USA

Letter to the Editor;

In **EXPLORE** Number 71 (April 1991, page 17) a technical note about INAA Applications to Geochemistry was published. What follows, challenges the notion about the infallibility of fire assay which was mentioned in a reply from Russ Calow (paragraph 1, page 21) to an earlier issue of the Pearl Harbor File.

Years ago I was confronted with a soil sample which assayed <0.1 ppm Au by HCl-BrCl attack at 100°C under pressure for one hour, but yielded >2 ppm when the clay matrix was dissolved by HF. This same material was analyzed by fire assay by many other laboratories and yielded <0.2 ppm Au on the first as well as on any subsequent assay of the resulting slag. Since the owner knew that in South Africa it is standard practice to do two additional fire assays of the slag, he ordered up to 8 or more additional fire assays of the resulting slag (ending up with an enormous bulk of slag!). With this procedure, he invariably obtained nearly 3 ppm Au. To confirm the concentration of gold in the sample, it was analyzed by INAA by a commercial laboratory. In two instances the value came out nil. Later I learned that the laboratory did a single fire assay before INAA, a case of bad fluxing and low accuracy. Later, determinations using an industrial electrolytic process yielded 2.4 and 2.8 ppm Au.

Respectfully submitted,

EVALDO L. KOTHNY
3016 Stinson Circle
WALNUT CREEK
CA 94598, USA

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Letters

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Letter to the Editor:

RE: *Rebuttal to Mr. Robert Tubbs, Jr.'s Letter*

Mr. Tubbs letter (**EXPLORE** Number 71) demonstrates *why* the Wilderness impact Research Foundation (WIRF) was formed in the first place. Before more land is taken from multiple use, we must gather much more information on the impacts that Wilderness designations are having on the nation—including its economy, jobs, rural tax base, and even potentially adverse impacts upon the environment.

Unlike the many organizations promoting more and more wilderness designations, WIRF believes that sound policy dictates that we examine *all* the potential consequences of wilderness designations *before* tens of millions of acres of additional wilderness is designated on the public lands now open to multiple uses.

The *only* extensive economic studies prepared to date on wilderness proposals demonstrate that there will be huge economic dislocations—which will be primarily but not exclusively felt in rural communities. These studies, prepared by Dr. George Leaming of the Western Economic Analysis Center, examined the costs of wilderness—everything from the minerals that will not be mined, timber that will not be cut, oil that will not be pumped, to reductions in livestock grazing. The conclusions are startling—billions of dollars will be lost to the western states and rural economics in the coming decades.

Mr. Tubbs criticizes the studies as being "bad science" based on criticisms from unnamed "university economists." However, I stress that these are the *only*, and therefore the best, studies available. Other economists have examined Dr. Leaming's work and have called it too conservative. A recent Leaming study in Utah, that was commissioned by the Utah Association of Counties, states that the wilderness bill for 5.1 million acres, proposed by Congressman Wayne Owens, will cost the Utah economy 13.2 billion dollars annually. After reviewing the Utah study, we concluded to have Dr. Leaming's work reviewed by some independent economists. We commissioned Dr. Tom Harris and Dr. Anthony Lesperance to review Dr. Leaming's work and give us an opinion regarding the methodology and the accuracy of the work. Their conclusion was he was too conservative and that the actual losses would be considerably greater.

The position of the Foundation has been to encourage economic, wildlife, social and recreational studies to determine the actual impact of federal wilderness. Prior to the establishment of the Foundation the entire wilderness debate revolved around philosophy and emotional arguments. At a national symposium in 1989, at the University of New Mexico, I debated George Frampton, President of the Wilderness Society. I challenged him to produce any studies completed by the Wilderness Society, or any other preservationist group, that demonstrated the benefits of additional wilderness designations. I knew I was safe because the preservationists have not produced any studies demonstrating the benefits of wilderness to wildlife, vegetation, or people. At the Foundation we would welcome written criticisms of Dr. Leaming's studies, and would encourage additional studies. If Dr. Leaming's studies are too high, then those making the criticisms should conduct studies to demonstrate the actual costs of wilderness.

Hopefully, by having WIRF continue to promote research on the wilderness issue, it will create a climate of controversy in this area that will then result in a proliferation of studies being completed. Based on the research completed to date, it appears the preservationists claims are false and that wilderness is bad for wildlife, people, and the land.

There are already nearly 90 million acres of wilderness on the federal lands. According to the Congressional Research Service, 126 million acres of federal land are under study as wilderness. Wilderness proposals by the Sierra Club and Wilderness Society routinely exceed study recommendations. Adding in additional designations proposed on state lands, the 150 million figure is conservative. Mr. Tubbs accuses WIRF of using figures from Earth First! However, Earth First! proposes 758 million acres (one third of the nation's landmass) as wilderness. Earth First's demands are now used by the Sierra Club and other preservationist groups as a stalking horse, so that they may then make far greater demands without appearing to be radical. I have already referred to the Utah situation where the BLM was only studying 3.2 million acres. Earth First! demanded 15 million acres, and the Sierra Club succeeded in getting Congressman Owens to introduce their proposal of 5.1 million acres, or 60 percent more than the BLM was even studying as potentially qualifying for wilderness.

Finally, Mr. Tubbs questions whether wilderness designations will have much impact on ranching, recreation, or wildlife management. WIRF has on file numerous affidavits from ranchers outlining precisely these adverse wilderness impacts. WIRF has sponsored several documentary films on the same subjects.

There are numerous examples of once passable roads being ditched and bermed to prevent access once areas become designated as wilderness. Cattle ranchers have given up trying to run livestock in many wilderness areas because of restrictions on access and maintenance. Wildlife enhancement programs, such as water guzzlers for bighorn sheep and trout ponds are precluded in wilderness areas. Perhaps Mr. Tubbs has not experienced these impacts in Texas, but they are very real in those states which have already experienced massive wilderness withdrawals.

There may be room for debate—but there must at least be study and debate *before* we permanently set aside more land from productive multiple use. We encourage anyone interested to contact WIRF and become part of the debate.

Sincerely,

A. GRANT GERBER
Chairman, Wilderness Impact Research Foundation
5555 Sixth St.
Elko, NV 89801
USA

Technical Notes

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10 microns are now regularly observed. This breakthrough suggests that visible gold geochemistry may be adaptable to exploration for sediment-hosted, Basin and Range gold deposits in Nevada where the gold typically is very fine-grained and some of the most prospective areas (pediment) are concealed by thick Quaternary basin fill alluvium. Many of the papers presented at the recent AEG Symposium in Reno focussed on efforts to adapt methods such as biogeochemistry, soil gas chemistry, electrogeochemistry and selective ion leaching to Nevada conditions. The extraction of fine particulate gold from the alluvium, if successful, would be a more direct geochemical approach capable of fingerprinting new deposits in areas of interference from known deposits. As well, visible gold geochemistry offers a longer exploration "reach" than many geochemical methods.

The purpose of this article is to compare gold grains from Canada and Nevada and thereby outline a framework within which gold grains dispersed in alluvium may be used to search for concealed deposits in Nevada. Except where indicated, the gold grain data cited were obtained from the laboratory of Overburden Drilling Management Limited in Ottawa and the observations made are those of the authors. The Nevada samples were collected on the Battle Mountain - Eureka field trip of the recent AEG Reno Symposium. Cited background information on Nevada gold deposits was obtained mainly from the field trip guidebook (Wotruba and Foo, 1991) or verbally from the guides.

Visible Gold in Till

Comminution of bedrock during glaciation occurs by plucking and grinding, producing till that is bimodal in clasts and silt. The rapid generation of silt results in very rapid liberation of gold particles. When liberated, the gold is pristine (Plates a and b). It then becomes progressively modified (Plate c), and unless deposited within 1 km of source, reaches a stable, reshaped form (Plate d). As explained by DiLabio (1990), the reshaping occurs through progressive blunting and folding of the grain edges; the original mass of the grain is not diminished. Furthermore, no significant dissolution of gold from the surfaces of the grains occurred during the +10 Ka interglacial and postglacial periods. Consequently all till, even in unmineralized regions, contains some gold grains. The background concentration in various parts of Canada, based on 50,000 samples, ranges from <0.1 to about 1.5 grains/kg of -2 mm matrix with the highest buildup occurring on the down-ice edge of very large fold belts (e.g. the Abitibi Greenstone Belt of Ontario-Quebec; Fig. 1).

Although the background abundance of visible gold may seem high, the grains are actually very sparsely distributed through the till and about 20 percent sand-sized nuggets are intermixed with the dominant silt-sized population. Consequently a huge sample would be required to obtain a representative gold grain count and gold assay under background conditions (Clifton et al., 1967). As this is impractical, the sample size is geared toward obtaining representative values under dispersal train conditions and the background nugget noise is rejected by direct observation of the gold grains. Samples weighing 8 to 10 kg and containing about 7 kg of -2 mm matrix material are generally used. At a distance of 500 to 1000 m down-ice from source, depending on the orientation of the deposit relative to ice flow, these samples will normally yield a minimum of 10 gold grains of similar size and shape, fingerprinting the source mineralization. Using smaller samples or analyzing raw till instead of a concentrate would effectively shrink the dispersal train (Fig. 2) and a tighter sampling pattern would be required to detect it, increasing costs.

The bulk till samples are obtained from surface pits in areas of thin overburden or by reverse circulation drilling in areas of thick cover. To allow drilling in soggy terrain, the drill rigs are much lighter than those employed for testing bedrock in Nevada and the hole diameter is smaller (7.5 cm). The till is sampled as a wet slurry.

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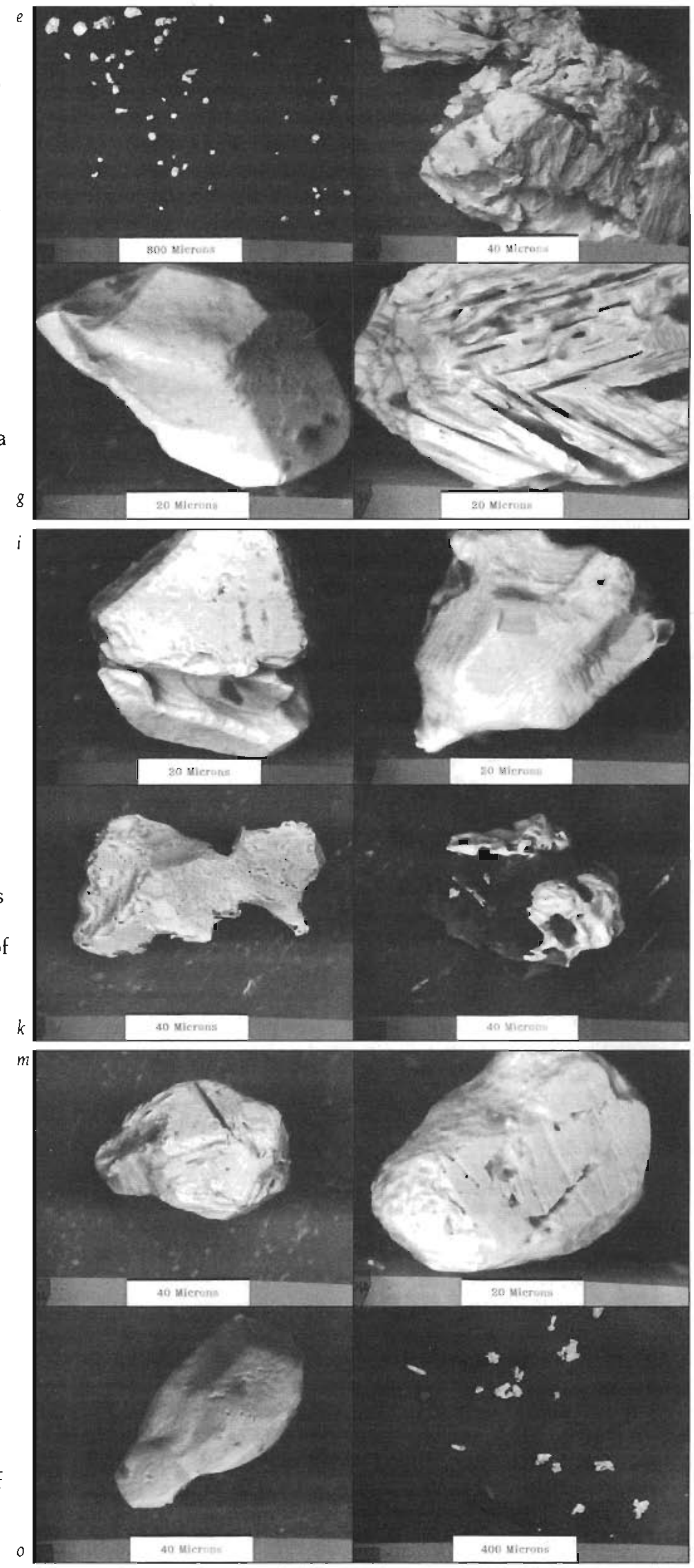

Plates e-p: Photomicrographs of gold!grains from Western US: e) largest grains of Fortitude population; f) severely damaged (smeared and crumpled) grain, Fortitude; g) subhedral crystal, Fortitude; h) subhedral crystal with leached compositional (silver?) zones, Fortitude; i) euhedral octahedral crystal, Surprise; j) subhedral crystal showing parallel growth and two pyrite molds, Surprise; k) grain with leached, leathery surface and flat, damaged areas, Surprise; l) grain with inclusions, Surprise; m) slightly damaged subhedral crystal, Gold Bar; n) grain with leached, leathery surface and damaged flat surface, Elder Creek; o) subhedral crystal with leached, pitted surface, Cove; p) dispersal train population from alluvium, California.

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SEM microscopy indicates that the gold grains are not normally damaged during drilling.

Rough heavy mineral concentrates are prepared using improved shaking tables that ensure good recovery and observation of both silt-sized and sand-sized gold. Any hidden grains can be observed later by micropanning. The rough concentrate is refined by heavy liquid separation (SG 3.3), and drill steel and magnetite are removed magnetically. The final concentration ratio of total till to heavy mineral concentrate averages about 200:1. Conveniently, this is about the same as the glacial dilution factor, making the gold grade of the concentrates approximately the same as the grade of the source. Concentrates from significant dispersal trains typically contain 10 to 200 gold grains and assay 1 to 20 g/t Au. Ideally the assay is obtained by the non-destructive Instrumental Neutron Activation Analysis (INAA) method which allows follow-up examination of the concentrate if an anomaly is unexpectedly obtained. A visible gold value is also calculated from the observed grains. Good agreement between the two values indicates that all of the gold in the concentrate is native gold and all grains were observed during processing.

Visible Gold in Nevada

Gold in Nevada deposits variably occurs as silt-sized native particles, both free and encapsulated in pyrite and silica, or as submicron particles. Visible native gold is dominant in skarnified deposits such as Fortitude, and submicron gold in Carlin-type deposits and carbonized ores such as Gold Acres. Concrete data are seldom available on the proportion of each type of gold in a deposit. Most deposits are deeply weathered but native gold particles are well preserved due to the arid climate and the high ground water pH maintained by the carbonate host rocks.

The Battle Mountain - Eureka field trip afforded the senior author an opportunity to collect samples from six mines (Fig. 3) representing a series from strictly visible gold (Fortitude) to strictly submicron gold (Gold Bar). Other deposits visited were Cove, Elder Creek, Gold Acres and Surprise. Eight samples representing oxide, sulphide and carbon ore and wallrock were collected. INAA indicates gold contents range from <5 ppb in Gold Bar wallrock to 7930 ppb in Fortitude sulphide ore (Table 1).

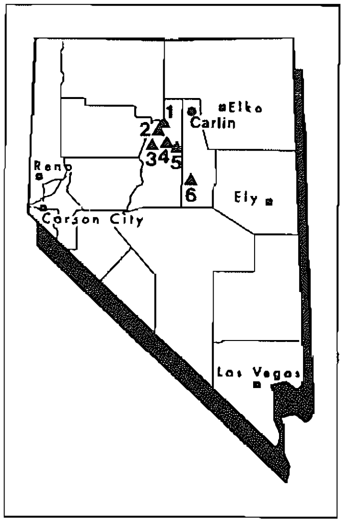

Fig. 3 — Location of Nevada mines sampled in study. 1—Surprise; 2—Fortitude; 3—Cove; 4—Elder Creek; 5—Gold Acres; 6—Gold Bar.

To determine the abundance of fine-grained visible gold, concentration tests were performed on at least 50 grams of -100 micron material, this being the weight of ore expected in 10 kg of alluvium after 200:1 dilution. The Cove oxide ore had decomposed naturally to -100 microns, but for the other seven samples it was necessary to perform some grinding. This caused considerable damage to the gold grains (Plates e to o) but no reduction in their size, and features such as euhedral to subhedral crystal forms (Plates g, i, m and o), parallel growth lines (Plates h and j), inclusions (Plate l) and leached surfaces (oxide ores only; Plates k, n and o) are often well preserved. Gold grains were recovered from all of the oxide and sulphide samples but not from the carbon wallrock at Gold Bar or carbon ore at Gold Acres. The coarsest grains — up to 75 microns — are in Fortitude sulphide ore (Plate e). Samples from most deposits contain grains as fine as 5 to 10 microns. The gold grain concentrations are normalized to a 50 gram sample in Table 1. They range from 2 grains in Gold Bar oxide wallrock assaying <5 ppb Au to 262 grains in Surprise oxide ore assaying 2240 ppb Au. The Gold Bar wallrock results are unexpected considering that even the ore is said to contain no visible gold. In general, 50 g of typical oxide or sulphide ore grading 2 g/t translates into 10 to 200 gold grains. Cove oxide ore is an exception with only 3 gold grains; however the orebody is not noted for visible gold but electrum, and leach pits present on the surfaces of the recovered gold grains (Plate o) suggest that any electrum in this part of the orebody has decomposed. Tin is also common in Cove ore and many grains of native tin were recovered from the test sample.

Sample No.	Deposit	Description	ppb Au	Grains VG/50 g
NV-91-01	Gold Bar	Oxide wallrock	<5	2
02	Gold Bar	Carbon wallrock	<5	0
03	Elder Creek	Oxide fault	390	4
04	Cove	Oxide ore	2870	3
05	Gold Acres	Oxide wallrock	360	3
06	Gold Acres	Carbon ore	2110	0
07	Surprise	Oxide ore	2240	262
08	Fortitude	Sulphide ore	7930	213

Table 1 — Gold data for Nevada samples

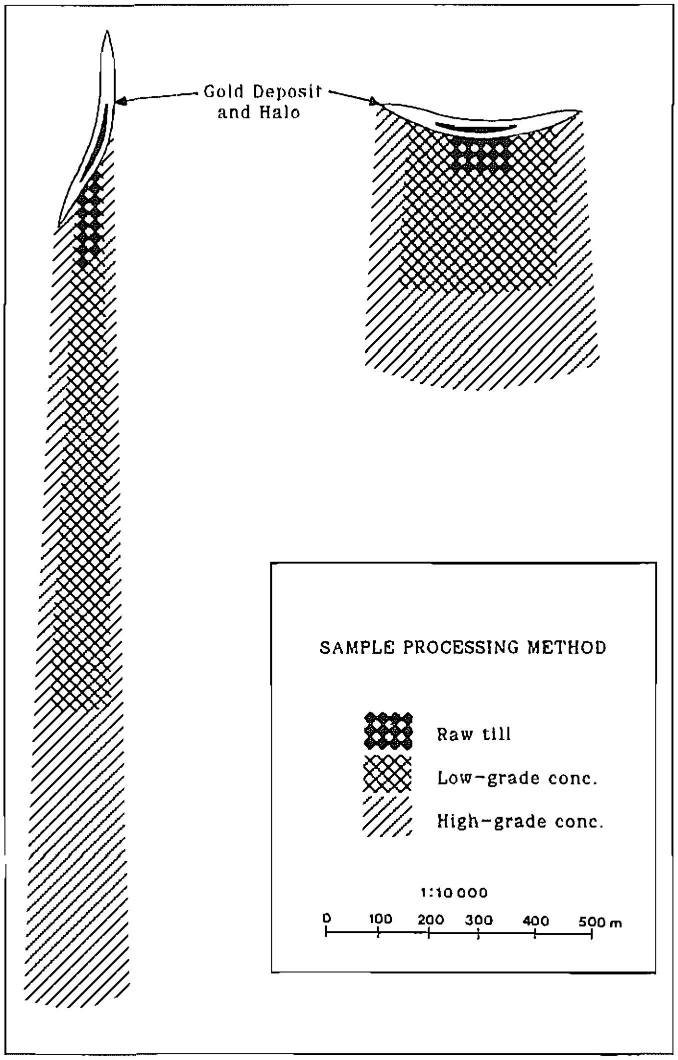

Fig. 2 — Typical sizes and shapes of till-hosted gold dispersal trains produced by different sample processing methods.

Conclusions

The gold grain test results suggest that many Nevada gold

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deposits, including some such as Gold Bar, which are thought to contain only submicron gold, contain a sufficient proportion of silt-sized native gold to generate a readily detectable dispersal train in the alluvium. With 200:1 dilution, a typical deposit grading 2 g/t would yield 10 to 200 gold grains in a 10 kg sample — similar to the concentration found in till-hosted gold dispersal trains in Canada. Using modern technology, recovery of these gold grains is no longer a problem but important questions that affect the dispersion, and therefore practicality, of visible gold geochemistry have not been addressed. These include: 1) the transport history of alluvium vs. till; 2) the ratio of silt to gravel in near-source alluvium, and of primary to secondary silt; 3) the rates of gold grain reshaping and dilution in alluvium, and 4) possible interference from pristine gold grains weathered in situ from the gravel clasts. Preliminary surface sampling of alluvium on one property in California has revealed high concentrations of pristine gold grains where visible gold had not previously been observed (Plate p). Much additional research data — and potentially important exploration data — could be obtained very economically by sampling the alluvium in reverse circulation holes that are presently being drilled to test bedrock around known gold deposits. The ultimate goal of visible gold geochemistry is to extend the exploration reach of these drill holes, lowering the cost and raising the probability of discovery of concealed gold deposits in Nevada.

Acknowledgements

The authors thank D. Heyl of Alta Gold Mines, J. McCormack of Cortez Gold Mines, R. Parker of Atlas Gold Mining Inc., J. Witner of Echo Bay Mines Ltd. and P. Wotruba of Battle Mountain Gold Company for permission to visit and sample their mines.

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Application of Fluid Inclusions to Minerals Exploration

Introduction

The formation of most ore deposits involves aqueous fluids at elevated temperatures. Small volumes of these fluids are trapped in ore and gangue minerals as fluid inclusions. Primary fluid inclusions are samples of the fluids present during mineral growth and can provide geologists with direct evidence of the nature of the ore fluids and constraints on ore transport and deposition. Fluids that later bathed the minerals are often trapped as secondary inclusions and in some instances, provide valuable information on evolution of ore fluids through time. Fluid inclusion studies have traditionally provided critical information for development of ore models and it is through these models that fluid inclusion studies have made the greatest contribution to exploration geologists. Recently, there has been a growing use of fluid inclusions as an exploration tool in the search for blind ore bodies, as guides to extensions of known ore deposits, and to clarify or interpret other kinds of geological observations. The kinds of information obtainable from fluid inclusions and potential applications are briefly discussed here.

The increased application of fluid inclusion studies in minerals exploration is due in part to significant advances in the analytical techniques and instrumentation that allow for rapid collection of data. For example, new designs of gas-flow heating and cooling microscope stages with low thermal mass, rapid temperature response, and low thermal gradients allow microthermometric determinations of phase changes in fluid inclusions in a matter of minutes. New experimental data on various multicomponent systems and synthetic fluid inclusions have increased our ability to estimate fluid compositions obtained from microthermometric data. Recent development in mass spectrometry, gas chromatography, and Raman spectrometry now permit the quantitative analysis of gases in fluid inclusions. A variety of microchemical techniques are available to obtain quantitative chemical and isotopic composition of fluid inclusions.

Although it is now easier to collect precise fluid inclusion data, there will always be fundamental concerns regarding the nature of the fluid inclusions (whether primary or secondary in origin), whether there have been changes in fluid composition or density since trapping, how these data relate to the problem being addressed, and the degree of uncertainty in the data. Collecting accurate fluid inclusion data requires an experienced operator and every person interpreting fluid inclusion data must be familiar with the basic principals as discussed in Roedder (1984). As Ed Roedder pointed out (1984, p. 464), the study of fluid inclusions is no panacea but should be considered a potentially useful tool in exploration, particularly when interpreted in conjunction with careful geologic and paragenetic studies.

Types of Information Available from Fluid Inclusions

Composition: The most commonly used technique for evaluating compositions of fluid inclusions is microthermometry. A microscope freezing stage permits the quantitative measure of the temperature of phase changes which relate to the composition of the included fluids. The most commonly measured parameter is the depression of the freezing point of the aqueous phase, which is an estimate of the total solutes in the fluid. The temperature of other phase changes permit, within limitations discussed by Roedder (1984), estimations of concentrations of other components. Analysis of extracted fluid inclusions has long been conducted to determine concentrations and atomic ratios of solutes and isotopic compositions. Advances in microanalytical techniques that include ICP-AES, ICP-MS, and ion chromatography allow for enhanced detection and quantitative determinations of extracted fluid inclusions. Estimation of atomic ratios of electrolytes in individual fluid inclusions are possible with scanning electron microscopy and energy dispersive analysis of inclusion decrepitates. Quantitative analysis of fluid inclusion gases is

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possible using mass spectrometry, laser Raman microprobes, and gas chromatography. Identification of daughter minerals in fluid inclusions provides valuable information on fluid compositions and can be accomplished by optical microscopy as well as a variety of microbeam techniques.

Temperature and Pressure: The most widely used geothermometry is the temperature of homogenization obtained on the microscope heating stage. This techniques gives a minimum value for the temperature of fluid inclusion entrapment. Because fluids are compressible, a pressure correction to the homogenization is generally needed to obtain accurate trapping temperatures. Typically this is accomplished through estimation of the pressure at time of mineral deposition through geological considerations or various geobarometric methods. Seldom can the pressure at the time of mineral formation be directly determined from fluid inclusions; however, fluid inclusions can provide valuable constraints on pressure as discussed by Roedder (1984). Both pressure and temperature can be determined if the fluid was boiling during fluid entrapment and if the presence of other volatiles in the fluid inclusion are known. Decrepitation temperatures are widely used in the Soviet Union as an exploration tool and to estimate temperature of formation. As Roedder (1984) points out, decrepitation studies have serious problems, both in theory and practice.

Density: Fluid inclusions can provide estimates of the density of the ore fluids which are unobtainable from other sources. Estimation of fluid density can be accomplished with information on the composition and volumetric properties of the inclusion fluids, and estimates of the relative volumes of gas and liquid phases at room temperature.

Petrographic Observations: Petrographic observations of fluid inclusions can provide inexpensive but valuable diagnostic information about the environment of mineral deposition. For example, fluid inclusion textures in quartz from epithermal environments vary systematically and allow for prediction of general thermal conditions (Bodnar et al., 1985). Petrographic evidence for boiling, the simultaneous trapping of vapor- and water-inclusions, can be guides to ore. The presence of condensable gas in fluid inclusions places constraints on ore depositional environments. Estimates of fluid inclusion density and composition in the CO_2-H_2O system can readily be estimated from phase relations at room temperature (Roedder, 1984, p. 288). A microscope fluid-inclusion crushing stage can rapidly be used as a semiquantitative measure of vapor pressure and composition of noncondensable gases in fluid inclusions.

Applications to Exploration

Hydrothermal ore deposits are geologically rather small features that have been produced through changes in mineral stability brought about by changes in temperature, pressure, composition, oxidation state, or pH of the ore fluid. These changes in the ore fluid result from processes such as fluid boiling and loss of volatiles, reaction with wall rocks, fluid mixing, and migration of ore fluids along pressure-temperature gradients. Fluid inclusions, as samples of the ore fluid, provide a direct measure of these ore fluid parameters and when constrained by paragenetic and field studies, reflect changes in fluid parameters through time and space. Therefore, fluid inclusion studies can potentially be used in the search for ore. There are so many examples where fluid inclusion studies have been successfully used in minerals exploration that it is not practical to present but a few general applications here. Rather, I refer the reader to examples discussed by Roedder (1984) and to abstracts of fluid inclusion research published yearly in *Fluid Inclusion Research.* Some general applications are discussed below.

Clarification of Geological Environments : Ore deposits tend to occur within geologically complex regions and it is important in exploration to identify which event or events led to ore deposition. Fluid inclusion studies can contribute to this understanding in a variety of ways. For example, fluid inclusion data can provide a means to characterize structurally complex quartz veins and identify which generation of veins may reflect ore depositional processes or to distinguish which veins relate to known ore-hosting igneous intrusives or structures. Temperature, pressure, and composition of ore-forming fluids are typically integral parts of ore models; therefore, fluid inclusion data can help identify which ore model might be most applicable to a mineral occurrence in a region. For example, the presence of dense and gas-rich inclusions in gold-bearing quartz veins clearly eliminates formation in a shallow epithermal environment but is suggestive of a mesothermal environment. Low temperature, highly saline fluid inclusions in sphalerite hosted in carbonate rocks are consistent with Mississippi Valley-type mineralization and unlikely related to magmatically-driven, shallow crustal-fluids. The composition of fluid inclusion gases can potentially determine whether minerals formed from fluids associated with metamorphic, volcanic, or magmatic processes. Compositions of fluid inclusions can help interpret rock alteration patterns related to ore deposition.

Search for Blind Ore Bodies: Since many hydrothermal ore deposits are produced by convecting hydrothermal cells, many studies have mapped fluid inclusion data in order to identify gradients (or halos) in temperature, pressure (or density) and composition of fluid inclusions in vein minerals in the search for blind ore bodies. In exploration for porphyry copper deposits, the presence of high temperature, vapor dominant, and very saline fluid inclusions with halite or chalcopyrite daughter crystals in quartz veins are a favorable indication for undiscovered ore. Many studies report an increase in abundance of fluid inclusions in vein quartz near hydrothermal ore deposits. Quartz veins with fluid inclusions trapped during fluid boiling, particularly if there is a corresponding geochemical anomaly, would warrant further investigations (e.g., tin and epithermal gold deposits are commonly associated with fluid boiling). Variations in fluid inclusion gas chemistry may indicate local upwelling plumes of magmatic-derived volatiles, boiling zones, and regions of fluid mixing. Because mesothermal gold-bearing quartz veins characteristically contain CO_2-rich fluid inclusions, fluid inclusion gas studies in quartz veins may be a valuable reconnaissance tool in greenstone belts.

Extensions of Known Ore Deposits: Fluid inclusions can be useful in identifying possible vertical or lateral gradients in temperature, pressure (density) and composition within a deposit, particularly when constrained by good paragenetic control. Fluid inclusion studies can identify fluid feeder-zones and pathways and place constraints on the thermal and hydrological regime during ore formation. Evidence for boiling, particularly in the epithermal gold environment, can potentially define boiling zones as guides to exploration drilling. The composition of solutes and gases is also a potential ore guide. For example, in the Coeur d'Alene district in Idaho, fluid inclusions in gangue quartz associated with precious metals are CO_2-rich in contrast to base-metal rich veins that contain more hydrocarbon gases. Many ore deposits form as a consequence of fluid mixing. Fluid inclusion temperatures and salinities can potentially determine favorable areas for extensions of ore trends or provide optimum depths for exploration drilling.

Exploration in Highly Weathered Rocks or an Aid in Sediment and Soil Geochemical Studies: Roedder (1984) states that several Russian studies report success in the use of decrepitation of quartz and other detrital minerals from stream sediment to recognize the presence of ore in the stream catchment. It is likely that more reliable fluid inclusion studies on minerals from a variety of sediments could provide new insights into exploration, particularly when combined with other geochemical studies. A simple inspection of fluid inclusions in detrital quartz grains for evidence of boiling or other fluid inclusion characteristics indicative of ore formation can be an important guide to ore or an aid in interpreting geochemical anomalies. Similarly, in areas of lateritic weathering, studies of fluid inclusions in resistate minerals and quartz grains may be useful ore

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guides. In glaciated regions or areas of poorly exposed outcrops, fluid inclusion studies of quartz grains may provide broad targets for exploration. In the US midcontinent, insoluble residues obtained from acid digestion of carbonate rocks from drill core provide samples of Mississippi Valley-type minerals suitable for fluid inclusion study. These samples are currently being used by the US Geological Survey to delineate pathways for migration of regional brines.

Conclusions

Fluid inclusion studies have a long-standing tradition of providing invaluable information to the study of ore forming processes. Fluid inclusions can and should be important tools for the exploration geologists. The greatest potential is achieved when integrated with other geological and geochemical studies. The reliability of fluid inclusion data is dependent, to a large degree, on the experience of the operator. Interpretations must be based on sound principles, being careful not to over interpret the data but yet sufficiently knowledgeable to recognize useful information.

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MEETING REPORTS

Gold '91, Belo Horizonte, Brazil

Editor's note: The following is a distillation of offerings by O.D. Chistensen of Newmont Gold, Carlin, NV, USA, and Bob Morrow, of Western Mining Corporation, Goias, Brazil.

Gold '91 was truly an international meeting, hosting approximately 300 delegates from six continents. The program offered some 70 oral presentations and 56 poster presentations. The venue was Brazil, with appropriate emphasis upon Brazilian deposits, but the papers covered the globe.

There were few papers related to "pure" exploration geochemistry. Results from some of the regional geochemical sampling in Finland were presented and a number of papers considered the behavior of gold in tropical weathering profiles. In addition, many integrated studies were presented that contained geochemical components, including fluid inclusions and isotopes.

Of note is an apparent shift in the genetic model for Archean banded iron formation-hosted gold deposits. Whereas a few years ago these were generally considered syngenetic, the authors presenting at Brazil 91 clearly favored epigenetic models with a strong emphasis upon structural controls.

The proceedings volume was assembled in advance and distributed at the meeting, a procedure that is always helpful to participants. For details see: **Ladeira, E.A.,** (ed.), *Proceedings of Brazil Gold '91, An international Symposium on the Geology of gold; Belo Horizonte, 1991. A.A.Balkema, Rotterdam, 823 p.*

SPECIAL NOTES

Are Sample Rejects Hazardous Waste?

With increasing attention to the environment and the accompanying regulations, we are often surprised at what materials are considered hazardous waste. With this in mind, Barringer Laboratories Inc. wondered if rejects from ordinary geochemical samples would be considered hazardous waste under current laws, and as such would require special procedures for disposal. Rather than ignore the question and hope that it would go away, Barringer contracted the law offices of J. Kemper Will of Englewood, CO, USA to investigate the question.

The conclusions of the opinion, based on the fact that the sample rejects had not been chemically treated during analysis, are as follows: *"These core samples or drill cuttings are not subject to regulations under RCRA and are not subject to 40 C.F.R. 261.4(d) dealing with samples"*. We thank Barringer Laboratories for sharing this information with us. Anyone wishing further details of the opinion should contact: Vern Peterson, V.P. Minerals Division, Barringer Laboratories Inc., 5301 Longley Lane, Bldg. E, Reno, NV, USA 89511 TEL: (702) 828-1158.

Canadian Geoscience Council Rethinks its Mission

The Canadian Geoscience Council (CGC) is a focal point for coordination and communication of the earth sciences in Canada and for Canadian participation in international geoscientific programs. The Council consists primarily of delegates from the national scientific and technical societies in the earth sciences, as well as scientists from industry, universities and government.

The Association of Exploration Geochemists is a member society of the CGC and Dr. Colin Dunn of the Geological Survey of Canada (GSC) normally attends CGC meetings on behalf of the AEG. The AEG has provided support to the CGC, in particular to the *EdGeo* Program. The EdGeo Program stimulates and subsidizes regional workshops through which science teachers can gain local knowledge and help from friendly earth scientists.

The CGC has recently issued an official *MISSION STATEMENT*, which is too lengthy to publish here. Interested parties are urged to contact Colin Dunn (GSC Ottawa) or the President of the CGC, Brian Norform (GSC Calgary).

Short Course on GIS for Mineral Potential Mapping

A 5-day Short Course entitled GIS for Mineral Potential Mapping will be offered at the University of Ottawa, November 11-15, 1991. The principal lecturers will be Drs. Graeme Bonham-Carter and Frits Agterberg from the Geological Survey of Canada, both Adjunct Professors in the Geology Department.

The Course will cover methods of using Geographic Information Systems to integrate regional datasets for assessing mineral potential. The emphasis will be on the use of models for combining maps and the implementation of these models in a GIS environment.

Some of the approaches to be discussed include:

- Subjective weighting
- Bayesian weights of evidence
- Weighted logistic regression
- Prospector-type inference networks

An important feature of the course will be the computer exercises that will be interspersed with each lecture. SPANS GIS (Version 5) running on 386 and 486 PCs under OS/2 will be used, with no more than 4 participants assigned to each system. Applications will mainly be to gold mineralization in Nova Scotia and base-metals in Manitoba.

The principal focus will be metallic mineral assessment, of interest to managers, geologists and computer specialists working in the field of mineral exploration or resource assessment. The methods may also be of interest for oil exploration, environmental impact and hazard assessment.

Participants are invited to bring digital data sets of their own. Although a background in digital mapping and quantitative methods will be an advantage, no prior GIS experience will be assumed. The course costs $1500 Canadian. For further information and registration, write to GIS Short Course, Department of Geology, University of Ottawa, 770 King Edward, Ottawa, Ontario K1N 6N5, Canada, TEL: (613) 564-3480, FAX: (613) 564-9916.

Public Domain Software for the Earth Sciences

Introduction

Universities and government agencies in the United States began developing computer programs for mining applications in the early 1960s on main frame computers. Government agencies develop software as well as provide grants to universities to do basic research.

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Computer programs are (and were) developed with public funds as part of the research work in the agencies and at the universities and are therefore available to the public in the form of reports and sometimes as computer readable media.

Other sources of public domain software are from individuals who write programs for work they are doing and then donate the programs to the public domain. Many such programs are available from PC user groups and other sources of inexpensive software. This class of software is developed by individuals who are not particularly interested in commercial marketing but want to offer a program as a service to others. An extension of the individual software offerings is the shareware concept where a version of a program is offered at no more than copying cost. If someone finds a program useful, a fee is sent to the author.

Since microcomputers have become so widespread in business and for personal use, computer-based bulletin boards have been established which offer a wide variety of public domain software for general applications. Some bulletin boards specialize in earth science, mining and geology software. These services are usually free and offer a forum for expressing ideas as well as a source of public domain programs which can be loaded onto a personal computer.

Pros and Cons of Using Public Domain Software

Public domain software is defined as computer programs which:

- are developed with public funds.
- are accessible to the general public at low cost.
- can be used for whatever purpose the user wishes.

Many public domain programs are written originally for specific projects and may have limited applications; however, other programs such as contouring, coordinate conversion, and similar programs have general application and a wider range of possible uses.

The old adage, "You get what you pay for" is especially true for public domain software. One of the attractions is the low cost of the software, but you must also be prepared to be a programmer yourself or have someone who can help you. When you obtain public domain software, you may have to learn how to run and revise the software with no help from the author(s). You are not always completely on your own, but you must be ready to assume responsibility for the correct operation of the program.

Pros: Some reasons to use public domain software are:

- Programs are free or low cost to acquire. Usually you will be asked to pay a fee for the media of transfer, such as disks, tapes, and documentation. Not all programs are low cost, but the cost is usually lower than a similar program provided by a commercial vendor. Programs from universities are sometimes high priced.
- You can do anything with the program that you want to, including making changes and selling the program yourself. This is not true for "shareware."
- Source code is often available for public domain software, so you can make changes to the program as your needs require.

Software vendors acquire public domain programs and incorporate the code into systems which they market to the industry. For example, contouring and mapping programs developed at NOAA have been used often as the basis for several commercial mapping programs. Another example of public domain software in commercial programs is geostatistics software developed at government agencies and universities. Using code from public programs saves a vendor significant development time, and carefully selected programs and/or algorithms allow a vendor to offer higher quality software at a reasonable price.

Cons: The other side of public domain software is of varying importance depending on your perspective. If you are an accomplished programmer and have time to work with a program, you will have a different perspective than an operations engineer who just needs a tool for engineering applications.

These are some things you must be aware of when considering public domain software:

- Support may be uncertain or non-existent.
- Program(s) may not work properly.
- The techniques used in the program may be obscure or very difficult to understand.
- You may have to configure the program to work on your computer.
- Documentation is often poor and sometimes non-existent; however, sometimes the documentation is excellent and may be like a textbook for the particular application.
- Getting a program to run on your computer (or at all) will likely require some programming knowledge.
- Programs are usually not very user oriented, and you may have to create cryptic parameter run files.
- Programs may be written for an odd computer (one not commonly used). A prospective user will have to manually enter code and possibly have to make program changes for the program to work on other systems.

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Special Notes

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- Programs may use proprietary graphics or other subroutines which are not provided with the public domain software.
- Before you use a public domain program for a critical calculation, it is best to run the program on as many test data sets as possible. This approach is a good policy, no matter where the program originates.

All the above conditions are not true for all public domain software, but if you plan to use public domain programs, you must be prepared to encounter some or all of the conditions. When you talk to people who are involved with public domain software development and support, you can also expect to find dedicated scientists who are providing a valuable service.

Sometimes test data will be supplied with the program in the documentation, and this is the first data to try in the program. When the test data produces the expected result, you can feel assured that the program you have runs as the original author(s) intended. The programs may be designed for very specific situations, *so the next step is to run some of your own data for which you* know the answers. You will then be able to determine whether the program will work for your specific application. An advantage of having the source code available is that if a program does not do everything needed, the source code can be modified.

How to Find Public Domain Programs

Some public domain software is easy to find, but certain specific applications can be very difficult to track down. A few organizations specialize in offering public domain information, including software (Table 1).

TABLE 1. Some North American organizations which supply public domain software and related information.

Arizona Computer Oriented Geological Society (ACOGS)
(602) 323-9170
Selection of software, bulletin board.

Computer Oriented Geological Society (COGS)
(303) 751-8553
16 Disks with programs, bulletin board. PC and Mac programs

Geologic Software
Rt. 10, Box 65, Spokane, WA 99206
Selection of earth science and general software. Free catalog.

Geological Association of Canada
(709) 737-7660
Workshops, course notes available.

Geological Survey of Canada
(613) 995-4142
Retrievals of paper and report titles.

Gibbs Associates
(303) 444-6032
Handbook of Public Domain Software for Earth Scientists and other publications about commercial software.

National Technical Information Service
(703) 487-4650
Reports on research projects and some USGS data sets. Wide range of categories available. Also on-line services.

U.S. Bureau of Mines
Many different offices. They are working on centralizing.

U.S. Geological Survey
(303) 236-7476
USGA libraries, including open file sections.

When research is done by a university, you can usually go to the university to find out the latest updates in a particular field such as statistics related to earth sciences. Programs developed at government agencies are usually harder to find, but can be well worth the time searching. Individuals in government agencies sometimes present papers or workshops about the work they are doing and programs they are developing. The papers may be included in conference proceedings or mining magazines. Some government agencies are effective in letting the public know about developing technology.

Theses and other programs developed for classes from universities are another source of programs. Some schools have organized software distribution systems, but others are reluctant to get into the business. Professors work with students who are developing software and are not usually willing to put in additional time to make the public aware of the work done. In some cases, professors develop programs for classes or consulting work and will supply programs as public domain or shareware.

Programs are often published as part of thesis work done by graduate students. Unless you can find someone willing to give you a computer media copy of the program, you must go through the process of entering the program into a computer, checking the results, and getting the program to run properly. It is always a good idea to check to make sure you can freely use and distribute a program you are interested in. Programs developed at universities may be copyrighted, so that use is limited, but the software may be available at little or no cost.

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Special Notes

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Other Source of Inexpensive Programs

Another related type of software called "shareware" is available from bulletin boards, computer user groups, and companies which specialize in marketing shareware. A copy of an executable version of a program - but not source code - can be obtained from either disks or a bulletin board or one of the distributors, and used by anyone. If a program is useful, then the user is asked to send the developer a small fee - usually $15 to $100. Sometimes the developer will send the program source code when the fee is paid. The developer may also send printed documentation, the most recent update of the program, and future updates. Sending the fee to the developer encourages program updates. The developer continues making updates because users are supporting the effort. Shareware software is not exactly "public domain," but is a hybrid because it can be used by anyone (at least on a trial basis), but cannot be incorporated in a privately developed computer program.

Many shareware programs are useful as they are and also may be high quality. An example is a spreadsheet program called PC-CALC which is similar to Lotus in many ways. The developer expects you to pay the registration fee if you continue to use it. PC user's groups have traditionally provided a service for distribution of public domain software. If you attend a PC user's group, someone will show up with several boxes full of disks which you can purchase on site. Some of the larger user's groups also offer software by mail. The disks are sold for $4-$5 per disk. Several commercial companies offer public domain and shareware disks at similar prices. Look for *ads in the computer magazines.*

The types of software available includes DOS utilities, games, general business applications, language, tutorials (Basic, DOS, math, language, etc.), graphics, spreadsheets, word processors, data base management, communications, and many other types of programs. Even though these are general programs, many are useful in the mining and petroleum world.

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PEARL HARBOR FILE

Editor's Note: This issue of the Pearl Harbor file is primarily a response to a letter from Russ Calow which appeared in the last edition of **EXPLORE** (Number 71). Following the Pearl Harbor file in this issue are two letters refering to earlier Pearl Harbor Files.

Russ Calow raised many interesting points in his letter of **EXPLORE** Number 71. His concerns represent only the tip of the proverbial iceberg regarding geochemical analysis, indicating a degree of complexity inherent in geochemical results returned from the laboratory which may not be appreciated by all explorationists. To be able to fully understand the significance and meaning of geochemical data requires training, experience, and many discussions with analysts.

Aqua regia-MIBK technique versus Fire Assay gold determination

Most North America mineral laboratories recommend the fire assay (FA) preconcentration method and either offer the aqua regia (AR) digestion as an alternative procedure, or not at all. At the same time, many of the same laboratories have begun to offer bulk leach extractable gold (BLEG) determinations utilizing a cyanide leach in a timed bottle roll. This technique has been used by metallurgical laboratories in North America for many years, but recently has been used in Australia and the western United States as a routine exploration tool. Both AR and BLEG are chemical leaches, relying on the powerful solubilizing action of AR or cyanide reagents, respectively, to liberate Au. Neither reagent dissolves much of the silicate host matrix, and thus they both represent partial extractions. In addition, the cyanide technique is time dependant and has the potential to not fully solubilize "coarse" Au grains. The current favour shown for BLEG determinations, particularly in the western United States, indicates that a partial extraction of Au by cyanide can be acceptable for exploration purposes. One must wonder why AR is not given the same weight. In part, this may be due to the similarity of the BLEG method to metallurgical test work performed to determine the "cyanide availability" of Au ore. BLEG also offers a supposed advantage of allowing very large samples to be analyzed, supposedly (!) overcoming Au particle sparsity problem.

Calow indicates the possibility of a bias in comparisons between sets of AR and FA determinations of Au on the same soil samples. This is to be expected. In addition, he raises concerns about variability and the low bias of AR leading to missed anomalies. Au encapsulated in an insoluble material, such as silica, or certain Au/Ag alloys, is unavailable for extraction with AR. Thus, the FA-Au determination would be superior in this instance. The partial AR extraction Au data can be treated similarly to partial AR data for other elements (i.e. Cu, Zn, Pb, Mn, etc.), and should not prove overly detrimental to the exploration process. If the absolute abundance of Au is important FA or INAA would be appropriate analytical techniques.

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Does mineral exploration require the absolute abundance of Au to be successful? If a program is at an advanced evaluation stage, the answer is "yes" (although recoverable Au (BLEG) may be what is actually required). If the application is a soil, or preliminary lithogeochemical study (bedrock chip, or the first few drill holes), provided Au is not encapsulated, (i.e., unavailable for extraction), or the matrix is not one which consumes the acids, many geochemist would probably say "no." Stanley and Smee (1988, 1989) indicated geochemists rely on patterns rather than absolute abundance to interpret the significance of Au distributions. This is a function of sampling density versus anomaly size. For situations in which only one (or two) samples are likely to be within the anomaly (e.g. reconnaissance heavy mineral or overburden drilling surveys), results of these one or two samples *must* be reliable and the explorationist cannot rely on other samples to provide a pattern, as would be expected for a soil survey grid.

Spirited discussion might accompany the above remarks. An example of a comparison between AR and INAA results for Au in soils, bedrock chips, and diamond drill data from Cat Mountain (see **EXPLORE** Number 69, page 7) will be found in a future issue of **EXPLORE**.

An orientation study looking at exploration effectiveness, and cost effectiveness, is required for any proposed exploration project prior to start-up. This study should include sample media, analytical methodology and laboratory studies. Explorationists must satisfy themselves on the applicability of any technique/laboratory to their project.

ICP-ES

All major laboratories in the Vancouver area have now acquired one or more ICP units. ICP is now one of the standard measurement techniques for all geochemical laboratories in North America. Acquisition of instrumentation, costing Cdn. $200,000 or more is but the first step. It is typical for a laboratory to invest two or more man years in set up. Commercial laboratories, like most small businesses, require rapid return on their investment. In a competitive environment, it is not unusual to see an understating of detection limits (the concentration value where the reproductibility is $\pm$ 100%) of elements offered in the multielement suite, not only for Bi and Sb but for many elements. This practice is common and usually readily apparent on maps by systematic shifts in background levels. Elements such as Tl or Hg, for example, are often offered in a multielement package, even though their stated detection limits are too high to enable reliable detection except, perhaps, in ore samples.

Aqua Regia Partial Extraction versus Total Determinations

A wide variety of analytical methods are available for determination of any one element. Each technique will provide different analytical results. For example, Mg values determined utilizing an AR extraction-ICP, will be lower than those for Mg determined utilizing a HCl-HNO_3-HF-$HClO_4$ decomposition-ICP, which in turn will be lower than Mg determined utilizing a metaborate fusion-ICP. Each technique produces different, but analytically correct data. Representatives of several laboratories have informed me that many of their customers, when in receipt of concentration values for elements like Ba, Cr, Mg, Na, Al, K, etc., expect to see total values, despite the fact the samples have been processed using AR-ICP with less than complete decomposition procedures. If these clients cross check results at a second laboratory and find much higher values (utilizing analytical methods providing a more total determination) their tendency is to assume that the original lab was in error and abandon it. Consequently, some laboratories refuse to provide AR values for such elements. Obviously, situations like this display the poor communication and trust that apparently exists between mineral analytical laboratories and explorationists.

Calow indicated that Al, Ba, Sb, and W should not be determined using an AR dissolution due to precipitation during and following digestion. If this occurred, elemental distribution would not be geologically controlled. Precipitation phemonema have been reported previously, for example in the determination of Ag and Pb utilizing a HNO_3-$HClO_4$ extraction (Fletcher, 1986). I believe, and can demonstrate using a number of case histories, that partial extraction data can assist in the interpretation of geochemical data for base and pathfinder elements.

Calow indicated that AR-Al data may reflect extraction quality. Batch errors of this type should be immediately obvious when AR-Al data are plotted. The problem can then be mitigated by reanalysis. AR-Ba and AR-Al data determined by two different commercial laboratories (Table 1) indicates correspondence can be relatively close, although some of the samples do demonstrate significant differences.

Systematic variation of AR-Al backgrounds is not common, but can occur. Absence of systematic variations promotes review of the AR-Al data for geological implications. In such cases, AR-Al can monitor compositional variability, for example, drainage and moss mat samples, and identify likely false anomalies (i.e., enhanced base metal values associated with fine textured (clay-rich?) sediments). Anomalous characteristics of the Al distribution may also suggest proximity of a sampling site to a VMS, or alkalic Au-Cu porphyry occurrence. Similar observational anecdotes can be offered for other elements. A W example will be presented in a future issue of **EXPLORE** for Cat Mountain soils and drill core.

Distribution of elements determined by total methods or by partial extractions both have a place in the exploration process. Each can tell a story which will aid the exploration process. The routine AR-ICP determination of 30 or more elements is selected first because it is the most inexpensive method to determine concentrations of base metals reliably. Once the analysis is completed, data for other elements are in hand, and they should be examined, recognizing the caveats issued by Calow. Never allocate large sums of money to follow up an anomalous concentration of an element which has an uncertain meaning. Always look for methods to employ all available data to solve the exploration problem at hand.

Spirited discussion might accompany a recommendation to examine partially extracted Mg, Al, Na, Ti, etc. (i.e. whole rock element) data before undertaking a whole rock analysis. Goodfellow and Wahl (1976) for example, suggested water extraction - major element lithogeochemistry to assist exploration at the Brunswick No. 12 massive sulphide deposit. Most explorationists are familiar with ramifications of whole rock data, for example, soda depletion. Guidelines and alteration indices are well known in searching for VMS occurrences. Why look at AR-major element results? The reason is straightforward. The AR leachable data would already be in hand and it is unlikely a large number of samples would be routinely analyzed using whole rock methods by a majority of exploration companies. Therefore, it makes sense to determine if, *a priori*, there is information in AR leachable distributions of the

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whole rock and other reported elements. If affirmative, put these to work in formulating followup plans. If partial extraction results for Ba, K, Al, Ti, W, etc. are exceptionally exciting promoting a followup program, confirm them by using more traditional methods of analysis. Those explorationists who only rely on distribution maps for a few elements from a multielement exploration package are short-changing themselves. Cost of analysis and cost of plotting maps are too low to be considered an impediment to full use of available data.

Recent travels in Australia reveal an analytical philosophy different from above, where total determinations represent a keystone to a routine exploration survey. This appears to be due to two factors: (1) the iron-rich samples selected for analysis, many in the 30% to 60% range, result in severe spectral interference on an AR-ICP determination and (2) the extractability of many of the pathfinders, such as As, from such Fe-rich material may not be effective. Perhaps Australian members will provide additional comments for a future issue of **EXPLORE**.

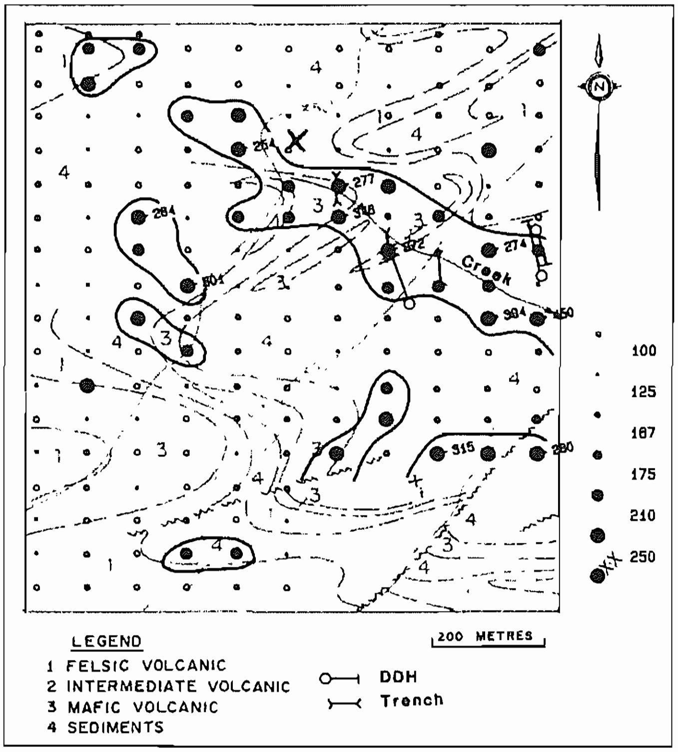

Fig. 1: X marks the location of the VMS prospect lying beneath a soil sample containing less than 100 ppm Zn.

Changing the subject; Figure 1 illustrates the location of the VMS occurrence requested on Figure 3 of **EXPLORE** Number 71. Discovery was based on a program of effective soil sampling followed by deep overburden drilling and diamond drill testing of the deep overburden anomaly. The case history involved contributions from three geochemists, three geologists, three managers, and one lonely project geologist. One might question how the massive sulphide lens was discovered under a sample site grading less than 100 ppm Zn and could still be considered a geochemical find. The full story will shortly be published in the Journal of Geochemical Exploration, *Rio de Janeiro symposium volume. But comments are in order here* on Figure. 1.

The map shows (1) trenches and (2) diamond drill holes. Undoubtedly, these represent the culmination of an interpretive process which did not lead to discovery. The trenches appear positioned in

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DISTINGUISHED LECTURER

Call for Nominations

The 1989-1991 distinguished lecture series was successfully completed early this year. Dr. Kay Fletcher, the current Distinguished Lecturer, presented a series of well received lectures and seminars in each of North America, Brazil, Australia and Europe. A combination of new financial support from local organizing committees and a concerted effort by the AEG Distinguished Lecturer Committee allowed the Distinguished Lecturer Series to be presented at sites outside of North America for the first time. The Distinguished Lecturer Committee intends to continue with this format during the next lecture series and seeks participation by regions which wish to be visited by the Distinguished Lecturer.

The Distinguished Lecturer Committee now invites nominations for the next Distinguished Lecturer. The Committee, in particular, extends an invitation for nominations of qualified scientists working in regions other than North America. Membership in the A.E.G. is not a requirement for the nominee. To nominate a person for election to the Distinguished Lecturer position, please complete the following form and return it as soon as possible to: Association of Exploration Geochemists, Distinguished Lecturer Series, P.O. Box 48270, Bentall Centre, Vancouver, BC, V7X 1A1, Canada.

I nominate:

Name ______________________

Address ______________________

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Phone (______) ______________________

for the honor of AEG Distinguished Lecturer. The nominee is worthy of this honor because:

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Signature ______________________

Name (please print) ______________________

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the middle of the anomaly, a relationship suggesting ore was anticipated beneath the heart of the Zn-rich zone. Drill holes appear located at the edges of the Zn anomaly, and it is likely they test the nearest conductors to the soil feature. Neither intersected ore. Interest waned and the property was subsequently acquired by an unrelated company for the cost of staking.

What procedure(s) can you suggest to facilitate discovery without additional sampling?

References:

Fletcher, W.K., 1986. *Analysis of soil samples.* In: Fletcher, W.K., Hoffman, S.J., Mehrtens, M.B., Sinclair A.J., and Thomson, Ian (eds.) Reviews in Economic Geology, 3: 79-96.

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Stanley, C.R. and Smee, B.W., 1989. *A test in pattern recognition: Defining anomalous patterns in surficial samples which exhibit severe nugget effects - II:* **EXPLORE** Number 65: 12-14.

Stanley J. Hoffman
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FAX: (604) 682-7354

Table 1. Aqua Regia Leach Comparison — Ba & Al determined by ICP at two commercial laboratories.

Sample	Ba-1	Ba-2	Ba-3	Al-1	Al-2	Al-3
1	134	134	150	4.22	4.74	4.67
2	60	55	70	4.44	4.80	5.12
3	75	72	80	3.30	3.22	3.36
4	75	71	80	3.46	3.37	3.79
5	71	71	80	3.85	3.80	3.94
6	87	84	100	3.18	3.30	3.60
7	36	34	40	3.34	3.34	3.86
8	51	45	60	4.37	4.33	4.78
9	59	54	60	3.89	4.05	4.16
10	57	51	60	5.80	6.67	6.63
11	61	65	70	4.23	4.68	4.48
12	99	98	120	4.22	4.36	4.36
13	61	52	60	3.12	2.95	3.30
14	48	42	50	3.64	3.60	3.89
15	65	53	60	4.97	5.60	5.82

Ba-1, Ba-2; Al-1, Al-2: Both determined at the same laboratory, 6 months between analysis, same analytical procedure.

Ba-3; Al-3: Check analysis at a different laboratory. Analytical procedures similar but not the same.

Dear Dr. Hoffman;

I note your comments on determing Ba as the sulphate, barite (Pearl Harbor file: **EXPLORE** Number 70).

While working in Africa for three years, I used an effective selective extraction for $BaSO_4$ developed by the Hunting Group's laboratory in Johannesburg in the early 70's. This extraction simply involves heating the sample in K-EDTA at 90 deg. C. The Anglovaal Group encouraged the development of this method and used Ba in roadside soil samples to help discover the Prieska Zn-Cu mine in NW Cape, South Africa. Feldspar Ba and other non-sulphate Ba are obviously excluded from the analysis.

Because the method is not ideal for high volume throughput, commercial laboratories which have adopted the method for me have charged a high unit cost per determination. However, if this method is not widely known, it may be worth bringing to the attention of **EXPLORE** readers.

Yours sincerely,

Dr. R.L. Andrew
Chief Geologist - Overseas
CRA Exploration Pty. Ltd.
Private Bag 509, 826 Whitehorse Road,
Box Hill, Australia 3128

Dear Stan:

In reference to the Pearl Harbor File in **EXPLORE**, Number 71 (April, 91) page 22 and following, figures 1 and 2 are presented with a different range of size coded symbols. This creates an illusion (for the shorter range representation) of higher anomalies especially when selecting larger symbols for similar values. To be of value, data of different years, seasons, or laboratories could be normalized before presentation on the same map. Different ranges for element concentration representation, or symbol shape and size for the same study area, is not germane in comparisons.

Figure 3 is barely acceptable. Too many details increase clutter and confusion, and this is not practical. I like to suggest using only a few geographical reference points, i.e. streamcourses and ridges. All other details including streamcourses and ridges could be presented at the same scale in an adjoining map.

Sincerely yours,

EVALDO L. KOTHNY
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ANALYST'S COUCH

Quality Control/Quality Assurance in Geochemical Laboratories

A good part of the success of most mineral exploration programs in North America rests on the data produced by independent laboratories; yet, the mineral laboratory industry is not subject to government certification, or monitoring for quality. Thus, the principle of "buyer beware" must be the rule when dealing with mineral laboratories. The explorationist is forced to put on his "chemist hat" and determine if the sales agent sitting in front of him represents an organization that really can provide fast, quality analytical determinations at a reasonable price. One of the evaluations that should be made of any laboratory is the effectiveness of their Quality Control/Quality Assurance (QC/QA) program.

In modern geochemical analytical laboratories, an elemental determination is usually the culmination of numerous steps and the efforts of many technicians. The quality of the determination depends on the quality of the work carried out at each step. Since the variance introduced at each step is cumulative, the tolerance for error at every individual step must be much more stringent than that for the final product. Explorationist's must take the time to confirm that the laboratory being considered has a QC/QA program effective enough to ensure that the analytical determinations produced are of the required quality for the proposed exploration program.

QC/QA Program Components

Quality is a subjective and a relative term. What is high quality in one situation may be unacceptable in another case, eg., the quality control required for a geochemical Cu determination will be less stringent than that required for an assay Cu determination. The quality required is dictated by the needs of the user and is also subject to the nature of the sample and the analytical technology applied. A good QC/QA program will be able to respond to these situations.

An effective laboratory QC/QA Program will have the following five components; 1) a rigorous, well defined employee training and re-training program; 2) documented methodology protocols; 3) clear, easily accessed, responsibility tracking system; 4) routine use of geostandards, round robin participation and an independent audit program; and 5) well defined and documented analytical data acceptance/data rejection control measures.

Employee Training and Re-training Program

The single most important factor in reducing the occurrence of laboratory error is professional competence. This requirement has become even more critical as the mineral laboratories in North America increasingly adopt computerized automation and expert systems. There is no question that the number of people required to run a mineral laboratory has gone down, but the training and technical ability of the remaining work force has increased.

Documented Methodology Protocols

An important aspect of any laboratory QC/QA program is to ensure control of the methodology applied in the laboratory. All methods must be documented and regularly up-dated to ensure that "gradual method creep" does not occur as each generation of new employees is trained. This is particularly important for sample digestion and calibration protocols. Slight variances in technique can create very different analytical data.

Responsibility Tracking System

In order for any laboratory to ensure "analytical control" an extensive responsibility tracking system is required. Complete work records must be kept, so that the exact sequence of processing can be determined. Technicians must "sign off" their work, thereby assuming responsibility for their actions. It is also very important that someone accept over-all responsibility for the work performed in laboratory sections. In addition, the increasing dependence on computers and "smart systems" has demanded new ways to track work history. Electronic data movement must be documented in order to prevent abuse and gross errors from occurring.

Geostandards, Round Robins and QC Audit Programs

The routine introduction of reference samples and participation in round robin studies is essential in order to ensure that a laboratory is producing analytical determinations that are free of bias. These studies also serve to point out gross errors, e.g. equipment malfunctions, improper standards, etc. The round robin study is the best tool available to effectively evaluate laboratory performance.

A QC Audit program usually involves surprise inspections of laboratory operations by senior personnel, or outside experts. The QC Audit's purpose is to ensure adherence to exact methodology and general good laboratory practice.

Analytical Data Acceptance Control Measures

To guide the acceptance or rejection of analytical data, a monitoring measure should be built into each operational system. This is accomplished by including control samples, weighed replicates, sample preparation replicates, standardized pulps and reagent blanks. The accumulated quality control data is then analyzed statistically and outliers are highlighted. The most common technique for visual monitoring of quality control data is a control chart. Data for all control samples, replicates and sample preparation duplicates are monitored and evaluated against established criteria during the measurement process.

Use of Control Charts

A control chart has time along the horizontal axis and concentration units along the vertical axis. The maximum, minimum and mean observed values of an analytical standard are plotted on the chart for successive time intervals. The central line is the established reference value, X. The lines above and below are the upper and lower warning and control limits, UWL, UCL and LWL, LCL, respectively. As data accumulates, any significant trends plotting above, or below X will become visible. This visual representation of the control of techniques allows the technician to respond to problems that may not have been discernable without the chart.

Data Acceptance/Rejection Criteria

There is no universally recognized criteria for data acceptance/rejection in the fields of geochemical analysis and assaying; however, in the late 1970's, the Geological Survey of Canada (GSC), Standards and Data Services Section, began compiling a guide to control the quality of analytical work performed by outside contractors. The GSC guideline applies a system that monitors and controls short and long term precision, as well as accuracy. Essentially,

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Analyst's Couch

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reference values for a control sample are established by compiling *20 to 40 results from different analytical runs and calculating the* mean and standard deviation. A tolerance limit for the standard is then set at ± 2.5 standard deviations from the mean.

Quality Control data can be of considerable value to the explorationist, yet, not all mineral laboratories will provide these data. Calculated variance data enable the explorationist to determine the overall laboratory variance for any given project. In addition, the variance determined from sample preparation duplicate data can be separated from the total laboratory variance leaving the variance *created during the sample preparation process. One now has a tool* that can be used to determine the appropriateness of the sample preparation procedure. If duplicate samples are taken in the field, qualitative variance information will be available for the entire project. By simple subtraction, the laboratory variance can be removed from the total project variance leaving the variation introduced during the field sampling stage.

Common Laboratory Errors and Mistakes

The major sources of error in a mineral laboratory can be classed using the following general categories:

A) Incorrect identification of samples.
B) Contamination.
C) Improper, or inappropriate sample preparation.
D) Inaccuracy of sample weights, or volumes.
E) Improper, or inappropriate sample dissolution/treatment.
F) Chemical and physical interferences.
G) Improper, or inappropriate instrumentation/inaccurate measurement.
H) Calculation errors.
I) Incorrect data handling/reporting.

In this list of possible errors and mistakes, all of them except one, chemical and physical interferences, have a "human component." That is why the single most important requirement in any QC/QA program is the ability to effectively train and re-train laboratory staff. The movement of mineral laboratories to automation and expert systems has reduced the number of people required, but it has also increased the requirement for trained, competent people, who can respond to situations and effectively trouble shoot and problem solve.

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RECENT PAPERS

Exploration Geochemistry

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 71. 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 (GCS Paper) and Open File Report (GCS 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, Colorado 80401, Chairman AEG Bibliography Committee. Please send new references to Dr. Closs, *not* to **EXPLORE**.

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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 70. Compiled by Gwendy E.M. Hall, Head of Analytical Methods Development,

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Recent Papers

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Geological Survey of Canada, 601 Booth Street, Ottawa, Canada K1A 0E8. Please send new references to G.E.M. Hall, *not* to EXPLORE.

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NEW MEMBERS

To All Voting Members:

Pursuant to Article Two of the Association's By-Law No.1, names of the following candidates, who have been recommended for membership by the Admissions Committee, are submitted for your consideration. If you have any comments, favorable or unfavorable, on any candidate, you should send them in writing to the Secretary within 60 days of this notice.If no objections are received by that date, these candidates will be declared elected to membership. Please address comments to Sherman P. Marsh, Secretary AEG, U.S. Geological Survey, Mail Stop 973, Box 25046, Federal Center, Denver, CO 80225, USA.

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.

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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

■July 29-31, '91 **Environmental site assessments**, mtg., Columbus, OH (Program Coordinator, National Water Well Association, 6375 Riverside Drive, Dublin, OH 43017)

■Aug. 11-24, '91 **XX General Assembly IUGG**, Vienna, Austria (IUGG Organizing Committee, c/o ZAMG Hohe Warte 38, A-1190 Vienna, Australia, EUROPE, TEL: (43) 222-36 4453 ext. 2001)

■Aug. 18-25, '91 **Tenth International Symposium on Environmental Biogeochemistry**, San Diego, CA (R. S. Oremland, USGS, 345 Middlefield Road, MS 465, Menlo Park, CA 94025; TEL: (415) 329-4482; FAX: (415) 329-4463)

■Aug. 30-Sept. 3, '91 **Metals**, mtg., Nancy, France (Societe de Geologic, CREGU, BP 23, 54501 - Vandoeuvre-les-Nancy Cedex, France, TEL: (33) 83441900, FAX: (33) 83440029)

■Sept. 2-4, '91 **Exploration and the Environment (9th Prospecting in Areas of Glaciated Terrain**, mtg., Edinburgh, Scotland (Conference Office, Institution of Mining and Metallurgy, 44 Portland place, London, W1N 4BR)

■Sept. 9-11, '91 **Mineral deposits and exploration methods**, mtg., Saskatoon, Saskatchewan, by the Canadian Institute of Mining (Len Homeniuk, Box 8201, Saskatoon, S7K 6G5, Canada; TEL: (306) *956-6380)*

■Sept. 11-13, '91 **Gold and Platinum in Central Africa**, Bujumbura, Burundi (W. Pohl, Institute of Geosciences, Technical University, P.O. *Box 3329, D-33 Braunschweig, Federal Republic of Germany)*

■Sept. 16-18, '91, Mineral resources **of Wyoming**, ann. mtg., Laramie, WY (G. A. Winter, Wyoming Geological Association, Box 545, Casper, WY 82602; TEL: (307) 261-5463)

■Sept. 16-19, '91 **2nd International Symposium on Environmental Geochemistry**, Uppsala, Sweden (Prof. Dr. Mats Olsson, Department of Forest Soils, Swedish University of Agricultural Sciences, Box 7001, S-750 07 Uppsala, Sweden, TEL: (46)18-672212, FAX: (46) 18-300831)

■Sept. 21-24, '91 **Denver GeoTech/Geochautauqua '91**, Lakewood, CO (Expomasters, 11100 E. Dartmouth Ave. #190, Aurora, CO 80014, TEL: (303) 752-4951)

■Oct. 21-24, '91 **Geological Society of America**, ann. mtg., San Diego, California (Vanessa George, GSA, Box 9140, Boulder, CO 80301, USA, TEL: (303) 447-2020)

■Nov. 4-8, '91 **Alaska Miners Association**, ann. mtg., Anchorage, Alaska (AMA, Suite 203, 501 W. Northern Lights Blvd., Anchorage, Alaska 99503; TEL: (907) 276-0347; FAX: (907) 278-7997)

■Nov. 11-13, '91 **Alluvial mining**, intl. mtg., London (Institution of Mining and Metallurgy, 44 Portland Place, London, W1N 4BR)

■Nov. 11-14, '91 **Circum-Pacific Council for Energy and Mineral Resources**, mtg., Bangkok, Thailand (Mary Stewart, Circum Pacific Council, Suite 500, 5100 Westheimer, Houston, TX 77056; TEL: (713) 622-1130; FAX: (713) 622-5360)

■Nov. 11-28, '91 **5th International Circum-Pacific Terrane Conference**, Santiago, Chile (D.G. Howell, U.S. Geological Survey, MS 902, 345 Middlefield Road, Menlo Park, CA 94025, TEL: (415) 329-5430)

■Nov. 19-21, '91 **International Symposium on Applied Geochemistry**, Hyderabad, India (Prof. K. S. P. Rao, Applied Geochemistry, Osmania University, Hyderabad 500007 (AP) India

■Feb. 4-6, '92 **Minerals, metals and the environment**, mtg., Manchester, England (Institution of Mining and Metllurgy, 44 Portland Place, London, W1N 4BR)

■Feb. 24-27, '92 **SME Annual Meeting and Exhibit**, Phoenix, AZ (Society for Mining, Metallurgy and Exploration Inc., Meetings Department, Box 625002, Littleton, CO 80162; TEL: (303) 973-9550; FAX: (303) 979-3461)

■April 26-30 '92 **CIM Annual General Meeting**, Montreal PQ.

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

■May 8-10 '92 **Third Goldschmidt Conference**, Reston VA (Bruce R. Doe, US Geological Survey, 923 National Center, Reston, VA)

■May 25-27 '92 **Sixth Congress of the Geological Society of Greece**, (Assoc. Prof. Dr. D. Papanikolaou, Department of Geology, University of Athens, Panepistimioupoi, Zografou, 157 84 Athens, Greece, TEL: (01) 72 42 743

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

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

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

■*April (late)* '93 ***SEG Integrated Exploration Conference***, Denver, CO (Richard L. Nielsen, SEG, Box 571, Golden, CO 80402; TEL/FAX (303) 279-3118)

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

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

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

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