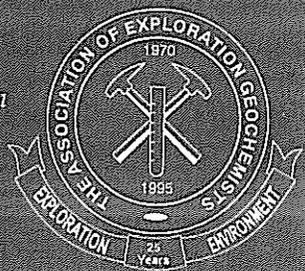


EXPLORE

Newsletter for
the Association
of Exploration
Geochemists



NUMBER 86

JANUARY 1995

PAST PRESIDENT'S MESSAGE

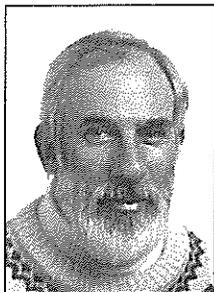
After 18 years as a Member (Fellow) and 18 months as President of the Association of Exploration Geochemists, I will use this opportunity for a little reflection.

I am, or have been, a member of a number of scientific associations/societies and without doubt, AEG is the best of them. This is not to imply that there are none better or that there is no room for improvement. Why do I make this assertion?

Firstly, AEG is comprehensive, with emphasis on both research and application, catering for the needs of universities, government instrumentalities, industry and consultants. It is international in scope and, although servicing mainly the mineral exploration industry, there have been encouraging moves recently into environmental geochemistry and ore genesis. An emphasis on the search for fossil fuels using organic geochemistry is one possible avenue to be explored. We are also extremely fortunate to have two excellent means of communicating our science: the *Journal of Geochemical Exploration* and EXPLORE.

Secondly, previous Councils have made some innovative changes which will ensure the vitality of AEG as we start on our second quarter century. We now have two prestigious medals for outstanding contributions to exploration geochemistry and to the Association. The student paper prize, although not as keenly contested as had been hoped, is aimed at encouraging our younger members. Another great success has been the Distinguished Lecturer tour which allows geochemists in a number of countries to meet with the visiting lecturer and discuss the latest techniques and methods. The number of Regional Councillors has been expanded to give our members in all parts of the globe a local point of contact. Many of our Committees have been very busy, e.g. the Elsevier negotiations have resulted in a new 5-year contract which is now acceptable to both parties; we have new membership application forms; there are new and improved ways to publicise the Association; and we should have a new comprehensive bibliography by 17th IGES. Of greatest importance are the successful efforts to get the business affairs of the Association running smoothly.

Finally, AEG is successful because of the friendships which are made through scientific contacts, meetings and exchange of ideas and knowledge. I have been privileged to meet and often stay with many very friendly people and I am sure that this applies to us all.



Graham Taylor

Continued on Page 3

PRESIDENT'S MESSAGE

My congratulations to Graham on his very successful term as President, during a period of challenge and change for the Association when numerous decisions had to be made. I was surprised that Graham was the first "non North American" to hold this office and am delighted that David Garnett, also from Down Under, will assume the position in 1997. David, incidentally, has been extremely active this past year in updating the

Australian section of the database (otherwise known as troubleshooting!) and in representing us so well at Geoanalysis '94 in the UK. The Australian influence continues this year with the 17th IGES in Townsville, Queensland, a meeting which many of us are striving to attend. It is the official venue for the celebration of the 25th birthday of the AEG and I hope attendees will range from those with membership numbers below 100 (e.g. Al Archer is #1, John Barakso #4) to those newcomers in the 3000 series. I feel particularly privileged to be President of AEG during this jubilee year, an event which naturally fosters assessment of the status quo and contemplation of new directions.

We are adopting a higher profile at both international and national meetings; to this end we have purchased a portable booth to advertise our activities and products. Andrew Bourque, now in Nevada, has kindly volunteered to assume responsibility for publicity and is open to new ideas and suggestions from our members. The first venue for our booth will be the Prospectors and Developers Convention in

Continued on Page 3



Gwendy Hall

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Information for Contributors to EXPLORE

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

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

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

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

All contributions should be submitted to:

EXPLORE

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Denver, CO 80225, USA

Information for Advertisers

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

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

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

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EXPLORE

Newsletter No. 86

JANUARY 1995

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NOTES FROM THE EDITOR

Owen Lavin

EXPLORE No. 86 is the first issue of 1995 which is the AEG's 25th year. We all eagerly await the 17th IGES in Townsville, Queensland and other celebrations associated with this significant milestone. Although the AEG has changed in the past 25 years, and is changing now, it remains one of the premier organization for those involved in mineral exploration. Let us commit ourselves to another 25 years of leadership.

This issue of EXPLORE is packed with technical information. A timely and comprehensive treatment of moss mat geochemistry, which is often used in stream sediment surveys where high energy environments prevent the deposition of fine-grained sediment, is provided by geologists from the British Columbia Geological Survey. In addition, Gwendy Hall et al. propose a method of determining all PGEs together with gold using laser ablation ICP-MS on a small Pb button resulting from fire assay.

EXPLORE is distributed at virtually no cost to AEG members because advertising revenues cover most of the production expenses. With this in mind, readers are asked to consider our loyal advertisers when contracting services or supplies. Potential advertisers are asked to consider EXPLORE, as we believe we are the most direct link to the geochemical exploration community, worldwide.

Contributor's deadlines for the next four issues of EXPLORE are as follows:

Issue	Publication date	Contributor's deadline
87	April 1995	February 28, 1995
88	July 1995	May 31, 1995
89	October 1995	August 31, 1995
90	January 1996	November 30, 1995

Owen Lavin
Editor EXPLORE



Past President's Message

Continued from Page 1

The success which we now enjoy has been due to the efforts of many people. I would particularly thank Gwendy Hall on whose shoulders have fallen many of the business management matters in the last 18 months and who with Eion Cameron successfully negotiated the Elsevier contract. Sherman Marsh has been a tower of strength as Secretary, and always seems to know the right answer. Alan Coope and Peter Rogers have both contributed to Committees which have made valuable contributions. Our two editors, Eion Cameron and Owen Lavin, maintain an excellent standard in our two publications. To each of these and the many others, I extend on your behalf, sincere thanks.

Gwendy Hall has the best wishes of us all as she starts her term of office as President. Her knowledge of the Association and her great energy and enthusiasm will ensure the continued success of AEG.

Graham F. Taylor

President's Message

Continued from Page 1

Toronto in March. Schedules permitting, it will be "manned" by our business manager, Betty Arseneault and by myself. Also at this meeting, the AEG will have a hospitality suite and a Past-Presidents table at the banquet (PPs - please contact me if you are planning on attending). The AEG is sponsoring sessions at the SME conference in Bellevue, Washington in May and is co-sponsoring the SEG symposium on carbonate-hosted Pb-Zn deposits in St. Louis, Missouri in June. The SEG is also celebrating a birthday this year; it has 50 years on us!

Jan. 1, 1995 marks another event -- a new 5 year contract with Elsevier. This differs significantly from the previous one, specifically in the formula by which royalties are calculated and in a more flexible arrangement for colour reproduction. Charges for colour are DFL. 1250 (ca 1.85 Dfl. = US\$1.00) for the first page and Dfl. 750 for the second. However, if separation is carried out by the author according to Elsevier's instructions (to be printed in the Journal and EXPLORE), these costs fall to Dfl. 850 and 500, respectively.

The Journal size is larger, at 19 by 26 cm. in common with the majority of such publications. As before, there will be no page charges but we may be subject to Value Added Tax (VAT) in the future. This decision rests in Brussels and seems to be beyond our influence (or Elsevier's). We are contacting other societies similarly affected and perhaps together we can lodge a protest.

As you know, delivery of journals to some members was not always smooth last year. If you find that yours is late or missing (remember issues dates are printed in Explore), don't hesitate to contact Betty Arseneault in the business office and she will take immediate action.

I am greatly looking forward to this year and welcome lots of input from members. We are seeking regional councilors in Africa and Europe and more volunteers for various duties, more on that in a future issue.

Gwendy Hall

TREASURER'S REPORT

Eion M. Cameron

Following the transfer of the business office to Ottawa, I took on the position of Treasurer in mid-1994 for a limited term. I append a summary of the auditor's report for 1993. It records a very unsatisfactory year for the Association's finances, a situation which prompted a reorganization of the AEG office. After the appointment of a Business Manager at the Vancouver office in 1993, the administration of the Association's affairs deteriorated. The records for 1993 were in poor shape, which led to a delay in preparing the audit and an increase in its cost. The audit revealed an unexpected fall in our dues revenue. Dues receipts per member were \$54 in 1990, \$42 in 1991, \$50 in 1992, \$28 in 1993 and \$62 in 1994. Some of the year to year variation is caused by the option provided to members to pay dues for two years, but this is not the sole cause of the sharp drop in 1993. It is the conclusion of the auditors, substantiated by examination of the bank records for 1993 by the Ottawa office, that the credit cards of a large group of members were not debited for their annual dues. This has since been discussed by Council, who agree that it would not be appropriate at this late date to ask the affected members for payment. On a purely voluntary basis, members may wish to check their records and, if no payments were debited for 1993, send in an authorization for payment. In examining the financial records from the

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Treasurer's Report

Continued from Page 3

Vancouver office we were impressed by the exemplary nature of those prepared by Lorraine Kluber in the early part of 1993.

The second item that had a negative effect on our finances for 1993 was a re-adjustment in the royalties payable by Elsevier to the AEG from sales of the Journal of Geochemical Exploration. The amount of the royalty is formally defined in our contract with Elsevier Science and is calculated each year by that company. Elsevier has informed us that they miscalculated the royalty payments for 1990, 1991 and 1992. We have confirmed that the revised royalty payments are correct. For 1990 the amounts decrease from US \$28909 to \$28096; for 1991 from US\$ 33303 to \$25666 and for 1992 from US \$29788 to \$21987. The AEG has made a strong representation to Elsevier that the Association should not bear the whole cost of this re-adjustment. However, waiting resolution of the matter, the entire re-adjustment cost has been applied to our 1993 financial statement, causing the substantial drop in royalty revenue for that year.

During 1994 we have undertaken a number of steps to improve the administration and use of our financial assets. The first was to implement a computer-based accounting package to record all transactions. The second was a decision to maintain all of our financial assets in US\$, apart from a small amount of working capital in Can\$. Most of our expenditures are in US\$. Although dues payments are

nominally in US\$, Canadian banks require that credit card payments be received in Can\$, which are now rapidly changed into US\$ to avoid the effects of devaluation in the Canadian currency. Formerly, most of our assets were held in bank accounts and Certificates of Deposit, which return relatively low rates of interest. In 1994 we adopted a more proactive, but conservative, investment policy. At this time these funds are mostly invested in 6 to 10 year bonds of A grade US corporations yielding higher rates of return. The new Business Manager, Betty Arseneault, and Al Arseneault, have made great efforts to return our financial affairs to steady ground. Gwendy Hall and her husband, Graeme Bonham-Carter, who live (perhaps unfortunately) only a few steps from the business office, have both contributed a very large number of hours to putting our affairs into shape. I also thank our auditor, Bruce Anderson.

Summary of Audited Financial Statements (in Canadian \$)

	1993	1992
Current Assets		
Current Assets:	176,957	202,193
Capital Assets:	<u>3,080</u>	<u>4,078</u>
Total current assets:	180,037	206,271
Current Liabilities		
Accounts Payable:	11,619	5,272
Members Equity:		
Balance, Beginning of year:	200,999	177,375
(Excess expenditures over revenue)	(24,551)	39,337
Foreign exchange adjustment:	<u>(8,030)</u>	<u>(15,713)</u>
Balance, end of year:	168,418	200,999
Revenue:		
Dues:	26,904	60,117
Royalties	13,459	43,250
Reno Symposium:	-	56,524
Other:	<u>10,996</u>	<u>31,649</u>
Total revenue:	51,359	191,540
Expenditures:		
General and Administrative:	54,201	49,966
Publications and Newsletter:	19,331	84,187
Special Projects:	<u>2,378</u>	<u>18,050</u>
Total expenditure:	75,910	152,203
Eion M. Cameron AEG Treasurer		

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Geochem fire Au, Pt, Pd (30 g)	\$10.90	\$ 8.40
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NEWS RELEASES

Drift Exploration in Mountainous Terrain, edited by P.T. Bobrowsky, S.J. Sibbick, J. Newell and P.F. Matysec

The British Columbia Geological Survey Branch will be releasing at Roundup 1995 (February 7 to 10, Vancouver, B.C.) the publication *Drift Exploration in Mountainous Terrain* (Paper 1995-2). Twenty-six contributions by leading specialists in the field of drift exploration provide reviews, case studies and new descriptive works of interest to geochemists, geologists and prospectors. Contributions from Canadian federal and provincial geological surveys, academia and the consulting community have combined their expertise to produce an essential asset to Cordilleran mineral exploration. This volume is an expansion of a short-course offered at Roundup 1994 which emphasized the integration of interdisciplinary methods in the search for drift-concealed mineralization. Primarily devoted to mineral exploration in glaciated mountainous terrain, the papers are arranged by topics including: basic surficial mapping methods (such as airphotographic studies and drilling/sampling techniques), drift exploration practices (including pebble lithological analysis, till geochemistry studies and application of lake sediment geochemistry) and geophysical techniques (such as shallow seismic, borehole and electromagnetic methods). Numerous illustrations, figures, tables and references accompany the text in this state-of-the-art publication, which will be available for CAN\$ 40.00 from Crown Publications (521 Fort St., Victoria, B.C., V8V 1E7). For more information on ordering, call Crown Publications at (604) 386-4636.

IGCP 259 Final Report: A Global Geochemical Database for Environmental and Resource Management Recommendations for International Geochemical Mapping by A.G. Darnley, A. Björklund, B. Bølviken, N. Gustavasson, P.V. Koval, J.A. Plant, A. Steinfeldt, M. Tauchid, Xie Xuejing, with contributions by R.G. Garrett and G.E.M. Hall.

This long-awaited report, describing the "why and how" of geochemical mapping, the reasons why a comprehensive quantitative database is urgently required, and why a global reference network is a necessary foundation, will be published in January 1995 by UNESCO, Paris, as Earth Science Report No. 19. It contains 130 pages, with 10 colour plates.

Arrangements for the distribution of the report are now being made. Copies will automatically be distributed by UNESCO to: listed participants in IGCP 259 and IGCP 360, science libraries, as well as national and international organizations. Copies will also be available for purchase at booksellers which specialize in government and UN agency publications.

A.G. Darnley
Geological Survey of Canada



NEWS OF MEMBERS

Alan Coope relocated to Tucson, Arizona during October 1994. His new address is 11060 North Canada Ridge Drive, Tucson, Arizona 85737-8559, U.S.A. (Phone/FAX 602-742-0250). He will be continuing his consulting and other professional activities from this new location.



UPCOMING JGE

VOLUME 52, NOS. 1 AND 2

Heavy Metals Aspects of Mining Pollution and its Remediation

R. Allan and W. Salomons (Editors)

CONTENTS

Preface

Introduction: sustainable mining in the future
R. Allan

Environmental impact of metals derived from mining activities: Processes, predictions, prevention
W. Salomons

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The effect of nickel mining and metallurgical activities on the distribution of heavy metals in Levisa Bay, Cuba

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Contamination of riparian wetlands from past copper mining and smelting in the headwaters region of the Clark Fork River, Montana, U.S.A.

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Development of proposed Canadian Environmental Quality Guidelines for cadmium

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Ecological impact and remediation of contaminated sites around lead smelters in Poland

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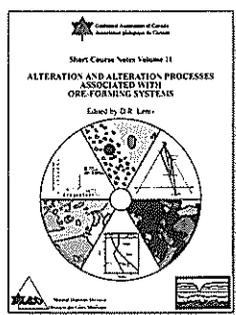


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Alteration and Alteration Processes
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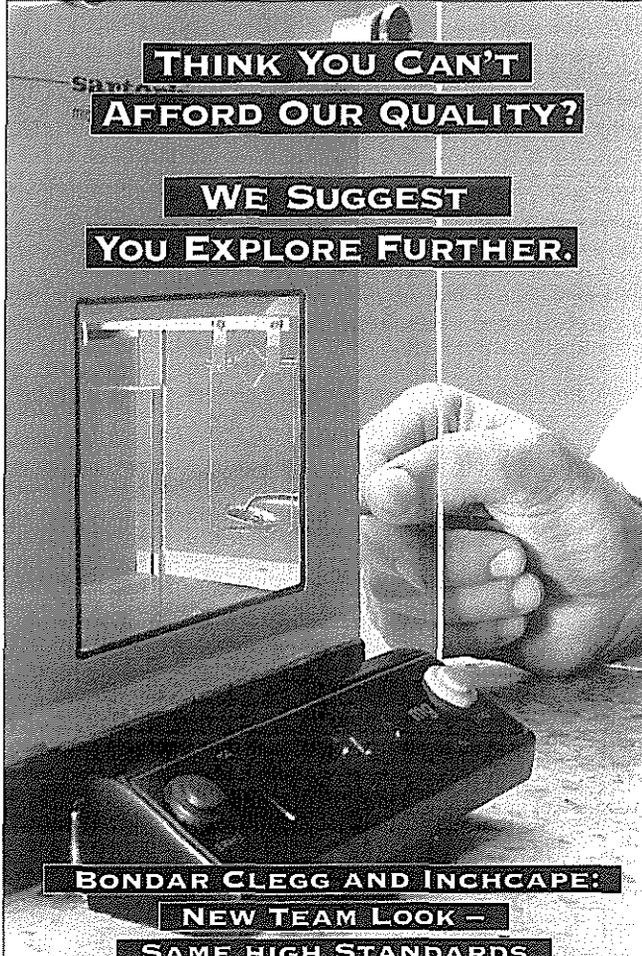
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TECHNICAL NOTES

Accumulation of gold and heavy minerals by moss mats: An example from northern Vancouver Island, British Columbia

Steve Sibbick and Kathy Laurus

Introduction

The British Columbia Regional Geochemical Survey (RGS) has extensively employed moss-mat (aquatic bryophyte) sediment as a sample medium. RGS programs conducted on Vancouver Island utilized moss-mat sediments exclusively. In total, over 3,700 moss-mat samples were collected on the island during 1987 and 1988. Moss mats, collected from the active stream channel, have proven to be a highly effective sampling media. Acting as a natural riffle, they accumulate sediment by trapping particulate matter entrained in the streamflow, making them particularly effective in stream environments where fine grained streambed sediment is absent. Moss mats are widely available, easy to collect and contain, on average, five times as much fine grained sediment as a conventional stream sediment (Gravel et al., 1990).

Based on results of orientation studies, Matysek and Day (1988) and Gravel et al. (1990) proposed that moss mats preferentially concentrate heavy minerals relative to conventional stream sediments. This process has been used to explain higher, more reproducible gold concentrations found within moss-mat sediment relative to stream sediment. As a test of this hypothesis, a sampling program was conducted on a stream draining the Red Dog copper-molybdenum-gold porphyry deposit on northern Vancouver Island. The deposit is hosted mainly within a quartz-magnetite breccia within a medium grained dioritic to monzonitic pluton that is approximately 2 kilometres in diameter. Primary sulphides are chalcopyrite and molybdenite with minor bornite and covellite. Pyrite is ubiquitous within the deposit and surrounding argillic alteration halo. This stream has been the site of previous orientation work by Matysek and Day (1988), who studied the downstream dispersion of elements from the deposit in both moss-mat and conventional stream

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sediments. They found that copper, molybdenum, silver, gold, arsenic, antimony, bismuth, selenium, and tellurium were anomalous in both types of sediment. The flat dispersal curves identified for anomalous elements were attributed to a relatively constant influx of mineralized material along the length of the stream from glacial sediments derived from the Red Dog deposit. Gold concentrations within stream sediments are highly reproducible, suggesting that much of the gold is fine grained (Matysek and Day, 1988).

Methods

Conventional stream sediment and moss-mat samples were collected at six sites, spaced 500 metres apart. Moss-mat samples were collected from boulders or logs within the active stream channel. Stream sediments were collected from sites containing abundant fine grained material and located within two metres of the moss-mat sample site. One to two kilogram samples of each sample type were collected. The samples were wet sieved to obtain the -177+62.5 micron (-80+230 mesh) fraction. A representative 50 gram split was separated into heavy and light mineral fractions using methylene iodide (specific gravity 3.3 g/cm³). Magnetite was removed from the heavy mineral fraction using a hand magnet. The resulting non-magnetic heavy mineral fractions and representative 30 gram splits of the light mineral fraction were analyzed at a commercial laboratory by instrumental

neutron activation analysis for 34 elements. Mean weight of analyzed non-magnetic heavy mineral fractions was 5.0 grams (range 2.1 to 8.4 grams).

Results and Discussion

Figure 1 shows the proportion of heavy minerals (SG>3.3) present in conventional stream sediments and moss-mat sediments. Moss-mat sediments contain 13 to 25 per cent

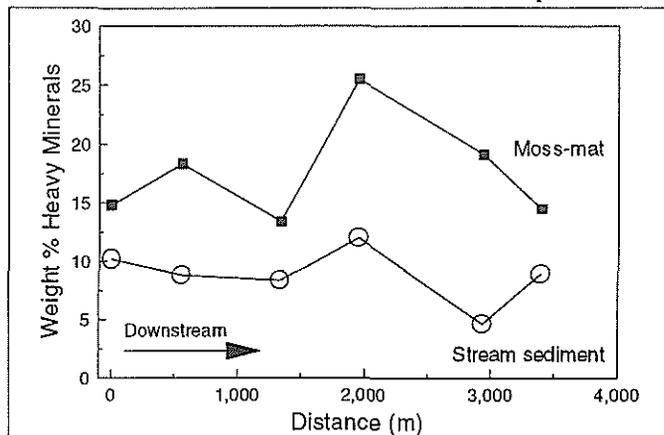


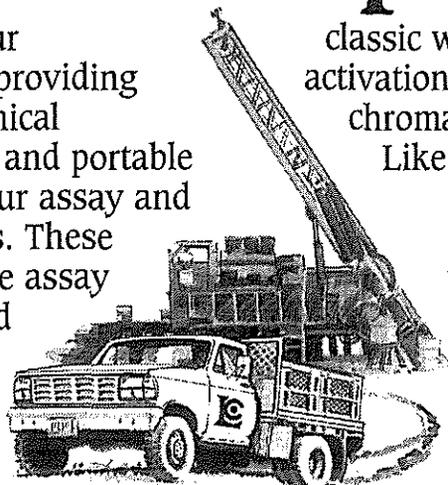
Figure 1. Proportion of heavy minerals in moss-mat sediment and stream sediments.

heavy minerals whereas stream sediments contain lesser amounts, ranging from 4 to 12 per cent. The higher proportion of heavy minerals supports the Matysek and Day (1988) hypothesis that moss mats preferentially concentrate heavy minerals.

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Magnetite abundances in the moss-mat heavy mineral fractions are, on average, double those in adjacent stream sediments (Fig. 2a). Hafnium, a trace element found almost exclusively in zircon, has much higher concentrations in moss-mat heavy mineral fractions (Fig. 2b). Moss-mat heavy minerals contain approximately three times the stream sediment hafnium concentrations, whereas the moss-mat and stream sediment light mineral fractions return detection limit values. Like magnetite, zircons appear to be preferentially accumulated within moss mats. Similar patterns for the heavy mineral fraction magnetite and hafnium abundances and their comparable densities (magnetite 5.2, zircon 4.7) suggest that these minerals behave in a hydraulically similar fashion.

Gold contents of the heavy mineral fractions are an order of magnitude higher than the light mineral fractions (Fig. 3). There is relatively good correlation between moss mat and stream sediment heavy mineral fraction gold values. The exception to this is one moss-mat sample with a gold content of 6860 ppb. This anomalous value is likely the result of the nugget effect; a single 150 micron gold grain (density = 18 g/cm³) will increase the gold concentration of a 5 gram sample by approximately 6300 ppb. Gold concentrations in moss and stream light density fractions are highly coincident and average approximately 50 ppb, suggesting that a

significant proportion of the gold is retained as fine particles within lower density grains.

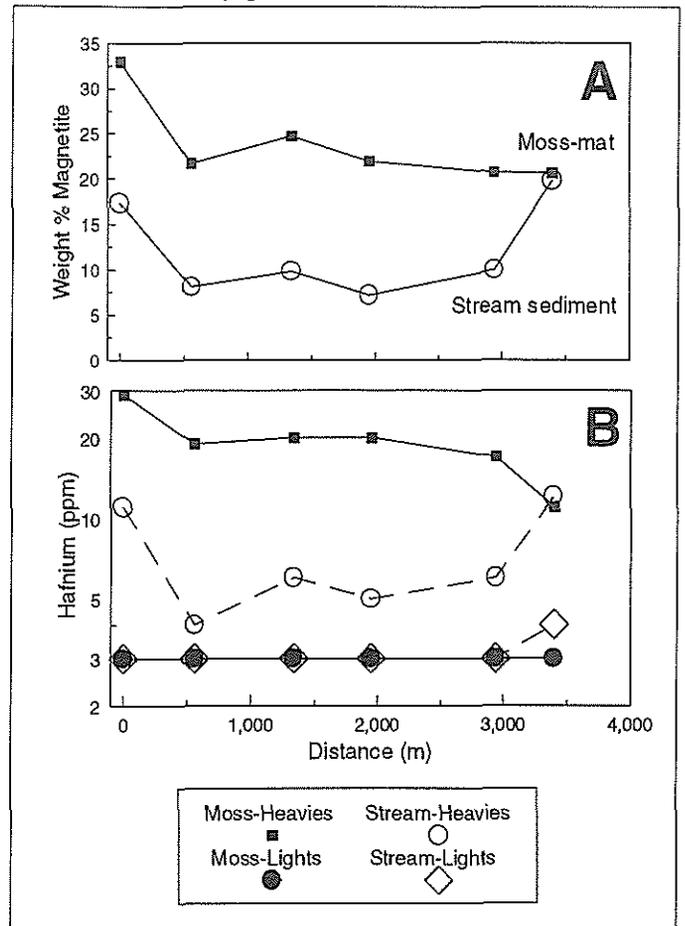


Figure 2.a) Weight percent magnetite in moss mats and stream sediments. b) Concentrations of hafnium in moss mat and stream sediment light and heavy mineral fractions.

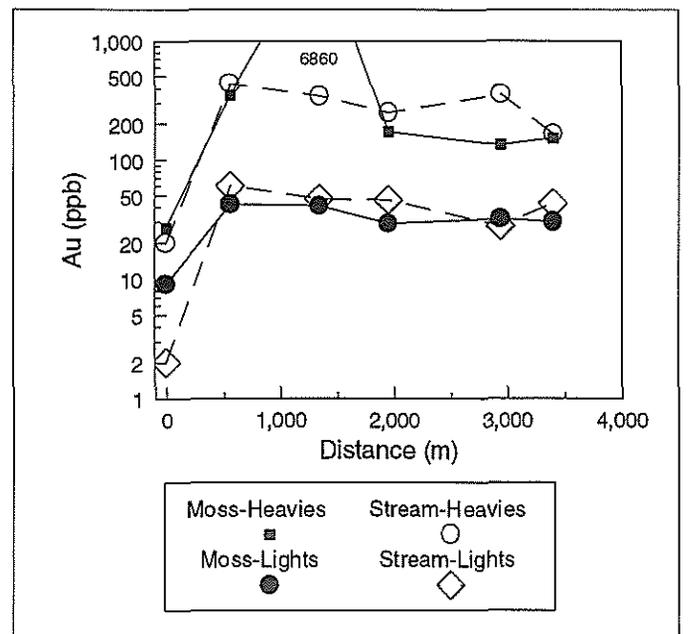


Figure 3. Concentrations of gold in light and heavy mineral fractions of moss mats and stream sediments.

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Based on observed concentrations within the heavy mineral fraction, magnetite and zircon (hafnium) are preferentially concentrated within moss mats compared to stream sediments, while gold is not. Concentration ratios ($\text{concentration}_{\text{moss}}/\text{concentration}_{\text{stream sed.}}$) for hafnium, magnetite and gold in moss mat and stream sediment heavy minerals emphasize this feature (Fig. 4). The similarity in heavy mineral fraction concentrations for gold in stream sediments and moss-mat sediment (Fig. 5, median concentration ratio = 0.9) suggest that gold particles in both sediments are accumulated in near equal amounts. Gold particles are not preferentially accumulated by moss mats.

Comparison of mineral densities versus their enrichment in moss mats shows a distinctive trend (Fig. 4). Enrichment of a mineral in moss-mat sediment increases with decreasing

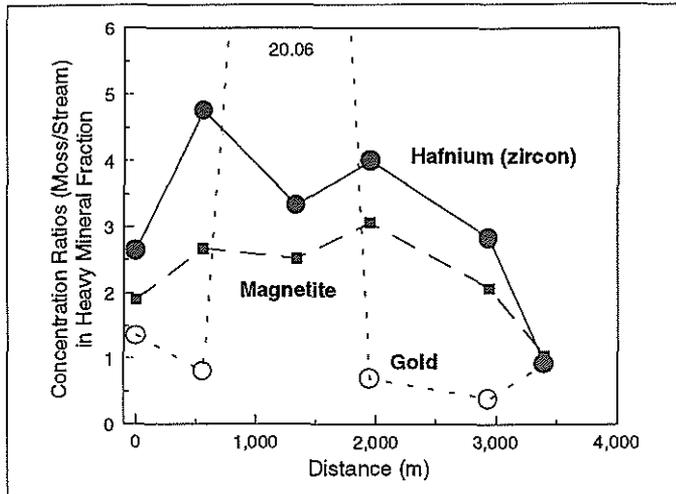


Figure 4. Heavy mineral concentration ratios ($\text{concentration}_{\text{moss}}/\text{concentration}_{\text{stream sed.}}$) for hafnium, magnetite and gold.

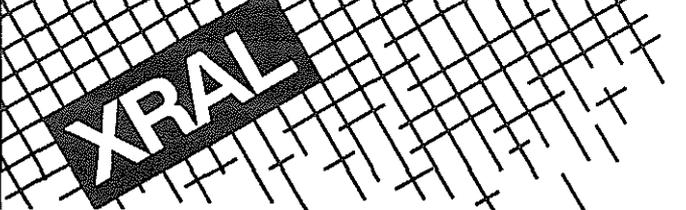
density. The correlation between degree of enrichment and density suggests that the accumulation of minerals by moss-mats is a function of their hydraulic equivalency. Only high energy stream flows are capable of entraining higher density grains and carrying them high enough in the streamflow to be trapped by moss mats. Lower density minerals will be transported in the stream flow more readily. This will result in lower density grains being trapped within mosses more frequently than equivalent-sized, higher density particles. Further evidence is provided by the fact that fine grained sediment, easily entrained within streamflow, is preferentially accumulated in moss mats relative to stream sediments (Gravel et al., 1990).

An additional limitation on sediment accumulation by moss mats may be their inability to trap and retain hydraulically equivalent sediment above a certain streamflow velocity. Sediment entrained within higher velocity flows will pass through the moss. Therefore a narrow stream velocity range may exist which permits gold to be entrained from the streambed, then trapped by the moss. Lower density minerals such as magnetite or zircon could be transported over a wider range of stream velocities, thereby increasing their opportunities to be trapped by moss mats. Fletcher and

Wolcott (1991) reported that the seasonal rate of magnetite transport was relatively uniform except for a rapid increase during a single high stream discharge in the spring. Gold particles were only transported during this high stream discharge. It is possible that while the trapping of fine sediment and low density heavy minerals by moss mats occurs regularly, gold accumulation by moss mats may occur infrequently, perhaps only once per year. These results seem contradictory to studies which report that moss mats have higher gold concentrations than stream sediments. The explanation may be that moss mats contain a higher proportion of fine grained sediment, thereby providing a more representative sample and reducing nugget effect. Sediment in the moss mat may represent several years of accumulation, whereas stream sediments likely represent a single depositional event. Another factor is that gold in the Red Dog deposit is generally fine grained, hence most of the gold may be unaffected by hydraulic sorting. Further, the processes observed on this stream may not apply to the entire region. Ongoing research will continue to study the process of sediment accumulation by moss mats. Analysis of larger heavy mineral samples in narrower size fraction ranges would provide a more accurate estimate of the behavior of heavy minerals in the stream environment.

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Steve Sibbick

Kathy Laurus

British Columbia Geological Survey

Preliminary investigation of a new analytical methodology for the PGEs: laser ablation ICP-MS analysis of partially cupelled lead buttons

Gwendy E.M. Hall, J.C. Pelchat, and Brenda Caughlin

Introduction

Methods used for the determination of gold and the platinum group elements (PGEs) in geological samples are commonly based on two fire assay preparations, Pb and NiS (Hall et al., 1988). These procedures serve to separate and preconcentrate the analytes from their sample matrix. A variety of analytical techniques can be then employed for the measurement step, including instrumental neutron activation analysis (INAA, as described by Hoffman et al., 1978), inductively coupled plasma emission spectrometry (ICP-ES) and ICP mass spectrometry (ICP-MS, as described by Jackson et al., 1990). The widespread Pb fire assay method has been designed for efficient high-volume production at relatively low cost (ca \$10). However, it has the disadvantage, compared to NiS, that only Au, Pt and Pd are reported as the other PGEs are lost (volatilisation) to varying degrees during the cupellation step. The much higher charges (ca. \$100) demanded by commercial labs for the NiS based method are due largely to such drawbacks as the large volume of acid needed to dissolve the NiS bead, the time required to do so and the copious quantities of noxious H₂S fumes formed.

Dissatisfied with the performance of the NiS fire assay, for Au and Pt in particular, Diamantatos (1977) designed an integrated scheme for the recovery of all 6 PGEs and Au immediately after Pb fusion (i.e. without cupellation). Though results are impressive, the manipulations involved are numerous and complex, and not conducive to commercial application. However, his work has shown that all PGEs are present quantitatively in the Pb buttons (of 20-25 g weight). Kolosova and colleagues in St. Petersburg have published extensively on the use of *partial Pb cupellation* for collection of Au and PGEs in buttons weighing 10-100 mg (Kolosova, 1982; Kolosova et al., 1984). This research showed that, when the weight of the Pb button is reduced by partial cupellation from ca. 20 g to 10 mg (without a silver inquant), the analyte losses are minimal. It appears that the easily soluble elements (Au, Pt, Pd, Rh) alloy with Pb while Ir and Ru remain in the form of suspensions or of intermetallic compounds with each other. We adopted this approach of

partial cupellation and combined it with analysis of the small Pb button by laser ablation ICP-MS. This report presents preliminary data using this methodology on five standard reference materials (SRMs) produced by the Geological Survey of Canada and marketed under the Canadian Certified Reference Materials Program (CCRMP).

Experimental

Chemex Laboratories in Vancouver carried out the Pb fire assay and partial cupellation procedure on four samples (2 at 10 g and 2 at 30 g) each of the following SRMs: TDB-1, a diabase from Tremblay Lake, Saskatchewan; WGB-1, a gabbro; WPR-1, a peridotite; WMG-1, a mineralised gabbro; and WMS-1, a massive sulphide. All four SRMs prefixed with 'W' were collected from the Wellgreen Complex, Yukon Territory and all SRMs had been sieved to <74 µm. Final bead weights were in the range 25-50 mg and were flattened between pliers to measure about 1.5-2 mm in diameter. Each bead was weighed to an accuracy of 0.1 mg before analysis. The fire assay/cupellation procedure is effecting a preconcentration factor of about a thousand-fold.

A commercially available VG LaserProbe system was used coupled to the PlasmaQuad II+ ICP mass spectrometer. The Nd-YAG laser was operated at 1064 nm in the Q-switched mode with a 5 ns half pulse duration. The beam was focused onto the surface of the bead through the window of a quartz sample cell, flushed by argon carrier gas at a flow of 1.1 l min⁻¹. Ablated aerosol was swept through Tygon tubing (ca. 2.5 m) to the injector inlet of the ICP torch. A high resolution CCD video camera with colour monitor, capable of x250 magnification, was used to view the sample. The location of the target and focussing of the laser beam were controlled by motorised X, Y and Z stages. The hardware could be controlled manually with an electronic console or remotely via the PQ software. The ion lenses were tuned to give a good elemental response for the ablation of the well characterised solid glass SRM 612 from the National Institute of Standards and Technology and the element response curve (i.e. expected counts s⁻¹ per ppm of each element across whole mass range) was stored for the semi-quantitative measurement mode. The glass standard was preablated for 1-2 min. prior to acquiring data. Operating parameters are shown in Table 1. The isotopes measured were:

Table 1. LA-ICP-MS operating conditions.

ICP forward power	1350 W
Carrier gas flow	1.1 l min ⁻¹
Auxiliary gas flow	0.75 l min ⁻¹
Coolant gas flow	1.1 l min ⁻¹
No. of sweeps	100
Dwell time	10 ms per channel
Acquisition mode	Peak jumping
Detector mode	Pulse counting and analog
Laser energy	2 mJ per shot
Shots per position	3
Repetition rate	2 Hz
Distance between positions	70 µm
Raster positions	5 x 5 grid
Integration time per raster	50 s

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Ru-101, Pd-105, Pd-106, Pd-108, Os-190, Ir-191, Ir-193, Pt-194, Pt-195, Au-197 and Pb-204. The analytes were measured in the pulse counting detector mode while Pb-204, used as the internal standard, was so intense that it necessitated measurement in the analog detector mode. The function of the internal standard is to compensate for the variability in the amount of material ablated by each shot. Signals resulting from a 5 x 5 position computer controlled raster with three ablations per position were integrated over a 50 s period to give an overall ICP-MS intensity value for that isotope. A preablation raster was performed initially without acquiring data. Two to four rasters were performed on each Pb bead, depending on the size of the bead.

Laser ablation processes are as yet poorly understood. The amount of material ablated will depend on factors such as the flashlamp power and repetition rate, the point of beam focus, and the absorption characteristics of the material. Naturally it is mandatory for accurate analysis that the composition of the ablated products is representative of the target itself, i.e. that there is minimal fractionation of one element relative to another during the ablation process. It is reasonable to expect vapour phase enrichment of the more volatile elements during the initial stages of ablation and Pb could certainly behave quite differently from the PGEs. A

major drawback to using Pb-204 as internal standard is that the analog detector mode is selected and count intensity for Pb is actually acquired at different times of ablation from the analytes which are being measured in a pulse counting mode.

Results and Discussion

The integrated normalised intensities for each raster on each of the 10 beads, derived from the 30 g sampling weights (in duplicate) of the five SRMs, were plotted against known concentration for each element. A line of best fit was drawn on each of these plots, the concentrations equivalent to these intensities then calculated and the found versus known concentration graph produced, as seen in Figure 1. The variable weight of the Pb bead was taken into account in this computation. Each star in Figure 1 represents the result for one raster (i.e. 5 x 5 grid). This was also carried out for the 10 g set of SRM beads and, as the data were similar to those obtained for the 30 g set, it is redundant to present them here. Unfortunately, intensities for Rh were acquired with only one set of beads. The certified concentrations of Au and PGEs in the five SRMs are given in Table 2 and the results obtained from the lines of best fit in Table 3. The values for

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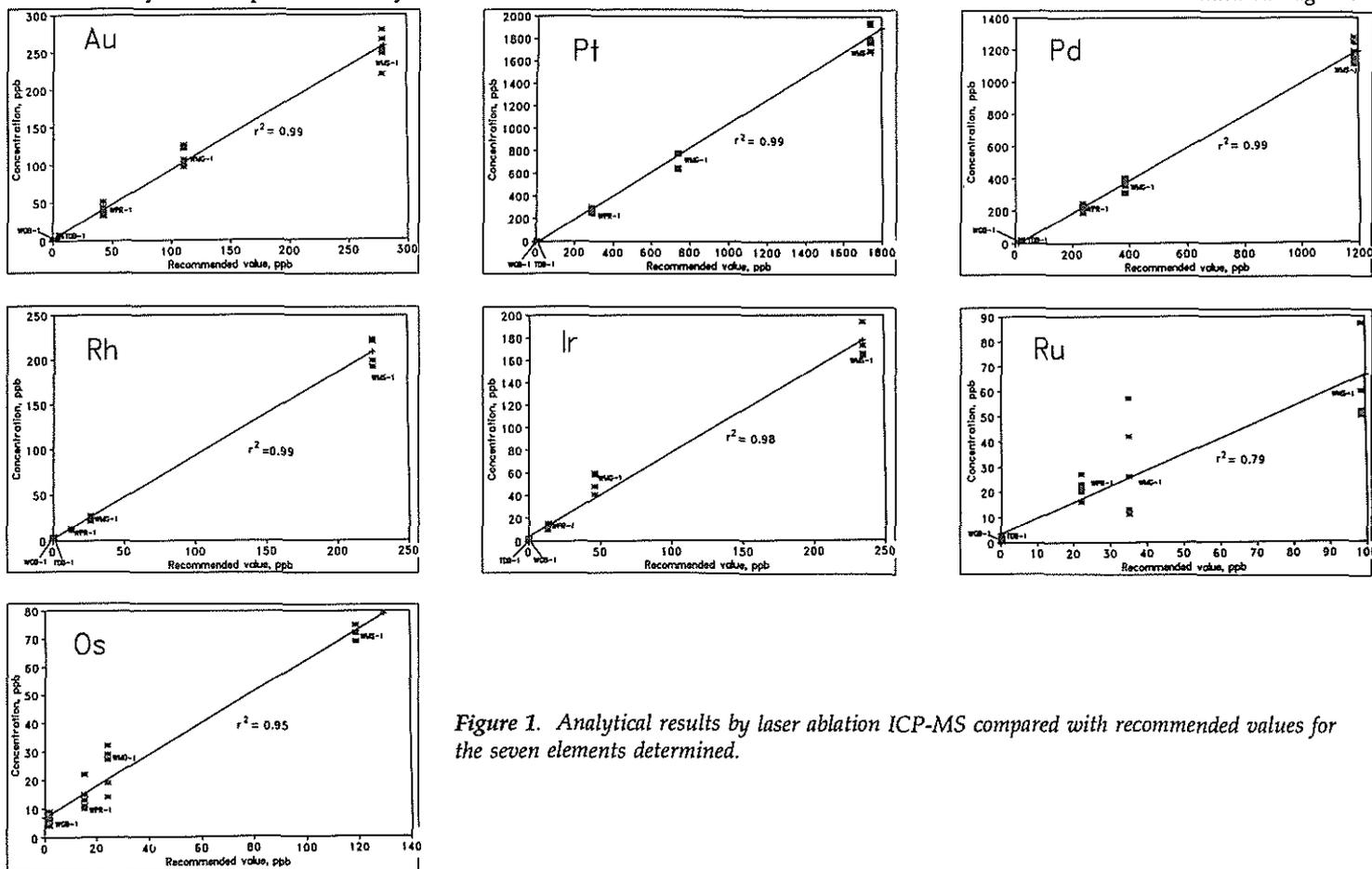


Figure 1. Analytical results by laser ablation ICP-MS compared with recommended values for the seven elements determined.

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Table 2. Certified precious metal concentrations (in ng/g) in Standard Reference Materials (SRMs) issued by the CCRMP.

SRM	Au	Pt	Pd	Rh	Ir	Ru	Os
TDB-1	6.3 ± 1.0	5.8 ± 1.1	22.4 ± 1.4	0.7*	0.15*	(0.3)	
WGB-1	2.9 ± 1.1	6.1 ± 1.6	13.9 ± 2.1	0.32*	0.33*	(0.3)	
WPR-1	42 ± 3	285 ± 12	235 ± 9	13.4 ± 0.9	13.5 ± 1.8	22 ± 4	13*
WMG-1	110 ± 11	731 ± 35	382 ± 13	26 ± 2	46 ± 4	35 ± 5	24*
WMS-1	279 ± 33	1741 ± 142	1185 ± 44	225 ± 16	235 ± 25	99 ± 16	119*

*: indicates provisional value rather than 'certified'

(): indicates informational value only

Table 3. Precious metal concentrations in ppb obtained by LA-ICP-MS calculated from the line of best fit.

	Au	Pt	Pd	Rh	Ir	Ru	Os
TDB-1							
Both beads	6.90 ± 0.83	5.90 ± 0.24	21.5 ± 2.4		0.10 ± 0.01	0.74 ± 0.17	<DL
Bead 3 (23 mg)	7.23 ± 1.15	6.05 ± 0.05	19.4 ± 2.2	0.68 ± 0.05	0.10 ± 0.01	0.73 ± 0.15	<DL
Bead 4 (24 mg)	6.65 ± 0.54	5.82 ± 0.26	23.3 ± 0.4		0.10 ± 0.01	0.75 ± 0.21	<DL
RSDs, %	12/16, 8.1	4.0/1.0, 4.8	11/11, 1.8	7.5	9.1/10, 8.1	23/21, 28	
WGB-1							
Both beads	1.90 ± 0.23	4.98 ± 0.49	11.3 ± 1.9		0.20 ± 0.04	1.27 ± 0.80	6.6 ± 1.8
Bead 7 (26 mg)	2.10 ± 0.17	4.50 ± 0.12	11.0 ± 1.6	0.38 ± 0.03	0.20 ± 0.06	2.03 ± 0.61	5.5 ± 2.1
Bead 8 (27 mg)	1.75 ± 0.13	5.08 ± 0.10	11.4 ± 1.0		0.20 ± 0.03	0.70 ± 0.08	7.3 ± 1.5
RSDs, %	12/8.2, 7.3	10/4.4, 1.9	11/14, 9.1	8.4	19/28, 15	62/30, 12	27/39, 21
WPR-1							
Both beads	39.7 ± 6.5	268 ± 19	212 ± 21		12.9 ± 2.6	21.7 ± 3.3	14.0 ± 4.3
Bead 11 (24 mg)	41.7 ± 8.6	264 ± 7	212 ± 30	12.5 ± 1.0	15.0 ± 0.8	22.7 ± 0.60	15.0 ± 6.2
Bead 12 (15 mg)	38.3 ± 5.3	270 ± 25	211 ± 17		10.8 ± 1.9	21.0 ± 4.5	13.0 ± 2.0
RSDs, %	16/21, 14	7.2/2.6, 9.1	9.8/14, 7.9	8.0	20/5.6, 18	15/2.5, 22	30/41, 15
WMG-1							
Both beads	113 ± 12	719 ± 72	351 ± 43		53 ± 8	29.8 ± 19.6	22.7 ± 6.6
Bead 15 (20 mg)	123 ± 2.5	694 ± 79	321 ± 25	24.5 ± 2.5	41	16.7 ± 8.1	17.3 ± 2.9
Bead 16 (16 mg)	102 ± 5	738 ± 71	373 ± 42		56 ± 5	49.5 ± 10.6	26.8 ± 5.6
RSDs, %	10/2.2, 4.9	10/11, 9.7	12/7.8, 11	10	15/9.7	66/48, 21	29/17, 21
WMS-1							
Both beads	254 ± 23	1816 ± 99	1182 ± 65		175 ± 14		
Bead 19 (26 mg)	247 ± 24	1784 ± 23	1120 ± 22	209 ± 16	175 ± 17	54 ± 5.3	
Bead 20 (37 mg)	264 ± 23	1831 ± 123	1213 ± 56		173		72 ± 3
RSDs, %	8.8/9.7, 8.5	5.4/1.3, 6.7	5.5/2.0, 4.6	7.4	7.8/9.6	10	4.2

RSDs given in the order of <all rasters over both beads>/<rasters over first bead>, <rasters over second bead>

each bead represent the mean obtained from 2-4 rasters carried out on each and the first relative standard deviation (RSD) given represents the variability over both beads for all rasters. Different isotopes of the same element gave essentially identical results, indicating an absence of isobaric interferences. Gold and PGEs in blank Pb beads (i.e. flux only) measured less than the equivalent of 0.5 ppb for Au, Pt, Pd, Ru and Os and less than 0.05 ppb for Rh and Ir. The system blank was monitored constantly; this involves acquisition of counts with the same protocol as that for sample beads but with the laser off and argon flowing through the cell to the ICP.

On an elemental basis:
GOLD: Results are excellent, with RSDs which are not dependent on concentration over this range. Bead 3, for example, produced from TDB-1 with a known concentration of 6.3 ppb Au, gives about 1400 counts s⁻¹ for each raster, well above the system blank of 21 ± 3 counts s⁻¹. The good precision within each bead for WMG-1 (2.2 and 4.9 % RSD) implies that the efficiency of collection of Au is different between the two beads, to give significantly different mean concentrations of 123 and 103 ppb. Alternatively, sampling variability could be the cause (though doubtful at 30 g for this SRM).

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Technical Notes

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PLATINUM: Precision for Pt is excellent, ranging from 4% RSD over all rasters (two beads) for TDB-1 to 10% for WMG-1. The distinct grouping of stars in Fig. 1b for Pt in WMG-1 suggests that these represent the two separate beads. However, one raster on bead 15 gave a comparatively low intensity while another on bead 16 gave a higher intensity than the rest. Data for beads 7 and 8 suggest the different mean values of 4.5 and 5.1 ppb Pt in WGB-1 to be due to sampling and/or assay preparation variability rather than analysis. Typical intensities are 600 and 53,000 counts s^{-1} , respectively, for TDB-1 and WMG-1 at 5.8 and 731 ppb Pt, with a system background of 21 ± 4 counts s^{-1} .

PALLADIUM: Precision across all rasters on both beads is in the range 6-12% RSD, slightly inferior to that for Pt but still good. Using the line of best fit, results for WGB-1 and WPR-1 are consistently low at 11.3 ppb (cf. 13.9 certified) and 212 ppb (cf. 235 certified), respectively. This may suggest that calibration should be divided into low and high concentrations of Pd. Sample TDB-1, at 22 ppb Pd, gave about 2000 counts s^{-1} at Pd-108, over a system blank of 29 ± 5 counts s^{-1} .

RHODIUM: There is an isobaric interference on the only isotope of Rh (103), originating from doubly ionised Pb-206. Hence subtraction of counts obtained for the Pb bead blank is critical, particularly at low concentrations of Rh. The absence of Rh in the original test data precludes estimation of bead-to-bead precision but the within-bead precision is excellent, at 7-10% over the concentration range of 0.3-209 ppb.

IRIDIUM: Precision between and within beads for Ir at the low levels in TDB-1 and WGB-1 is extremely good, at 9-19% RSD. When only these SRMs and WPR-1 are used for calibration, the line of best fit then goes through the origin (cf. Fig. 1). Signal intensity is quite low at levels below 1 ppb, WGB-1, for example, producing about 120 counts s^{-1} at Ir-193. Mean values for Ir in the two beads of WPR-1 are significantly different, at 15.0 and 10.8 ppb, indicating different efficiencies of recovery through the assay/cupellation procedure. Only one of the three raster values was taken for beads 15 and 20 of the mineralised samples, WMG-1 and WMS-1. Distribution of Ir in these two beads was clearly heterogeneous, as evidenced by count rates differing by factors of 2 to 5. This may be a reflection of the intermetallic compound formation referred to by Kolosova (1982). It is interesting to note that the precision within the other beads 16 and 19 was good, at 10%. Perhaps these particular

samples were inadvertently treated differently during preparation. Certainly this requires further investigation, as does the behaviour of the calibration at higher concentrations where a curve rather than a straight line is indicated by the data (Fig. 1). Is Ir collected less efficiently in the preparation of WMS-1 or is the lower intensity due to losses in the ablation and transport steps?

RUTHENIUM: Fig. 1 indicates a similarly curved fit to the data rather than a straight line for Ru and hence results taken from the line for WMS-1 are very low. It is unfortunate that there is no SRM with concentrations intermediate between those of WMG-1 and WMS-1. Again, beads 15 and 20 were extremely heterogeneous; where one raster was particularly low or high in Ru counts, so it was in Ir. This suggests intermetallic compound formation.

OSMIUM: The small number of counts obtained for Os on all sample beads indicated volatilisation loss during partial cupellation. The count rate for WPR-1, for example, is only about 60 counts s^{-1} . Precision values are poor, averaging 30% RSD, except for bead 20 of WMS-1. Interestingly, it is bead 19 of WMS-1 which produces extremely noisy raster data (too noisy to plot), suggesting quite different distributions and associations within the Pb bead compared to Ir and Ru.

Once the procedure is optimised, several of these SRMs will be selected for calibration against which unknown sample beads will be measured. They would be processed through the fire assay procedure with the suite of samples to be analysed.

Continued on Page 16

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Conclusions

Results for the easier elements Au, Pt, Pd and Rh are excellent. Inevitably it is the rarer PGEs which are most challenging. Many parameters, both in bead preparation and in analysis, remain to be optimised. We have not yet investigated loss of analytes to the cupel or through volatilisation during the final stages of Pb reduction, clearly an important factor for Os. Intermetallic formation of Ir and Ru and its effect on homogeneity in the Pb bead requires further study of the preparation methodology. Results for at least one of each bead for the five SRMs are encouraging and suggest that this drawback can be overcome. Though within this bead size range of 15-40 mg, there does not appear to be any trend in the results, different weights need to be investigated. An alternative internal standard to Pb-204 which could be read in pulse counting mode would certainly improve accuracy and precision. This element or isotope would have to be collected efficiently in the Pb bead. Polishing the surface of the beads does not appear to produce superior results to those generated by simply flattening them between pliers but this rather coarse approach needs review. New software is imminent from VG/Fisons which will allow us to traverse the bead at a predetermined constant rate and view the ablation signals of the analytes essentially simultaneously (i.e. element mapping). At least 20 beads can be mounted in the cell at one time and

the program of ablation and data acquisition carried out automatically. Thus the analytical step will prove to be very rapid, at several minutes a sample. The potential impact of this method is indeed exciting: its cost will be less than half that of current NiS prices, it is environmentally safer and its detection power is remarkable, having preconcentrated the analytes by about a thousand-fold. As with many analytical methods, sample preparation is critical to good accuracy and precision and thus the need for experienced fire assayers continues!

Gwendy E.M. Hall and J.C. Pelchat

Geological Survey of Canada

Brenda Caughlin

Chemex Laboratories, Vancouver

This project is being carried out under an Industrial Partners Program (IPP) between the GSC and Chemex Laboratories.

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Continued on Page 17

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Technical Notes

Continued from Page 16

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SOFTWARE REVIEW

Brian Krzys

RockWare Utilities Version 1.5

The RockWare Utilities (Version 1.5) are a new set of Windows-based programs that neatly combine various common geochemical, geological, and hydrologic applications. There are 14 programs in the initial release:

Geological Applications

- Rose diagrams
- Stereonets
- Ternary diagrams
- Calculate the volume of a 3-d geologic unit
- Plot an isopach and control point map
- 3 Point calculations
- Formation attitude calculations

Geochemical/Hydrological Applications

- Hydrographs for water level and precipitation measurements
- Piper diagrams for groundwater ion concentrations
- Stiff diagrams for groundwater ion concentrations

Miscellaneous

- Calculated XYZ points and base maps from survey data
- Convert between UTM and latitude/longitude coordinates
- Convert graphic files to/from various formats

All of the programs have been written to take advantage of the Windows environment, and present a clean, typically straightforward interface for the user. Individual programs that require extensive data input store data in ASCII files that can be modified through on-screen spreadsheet style data entry, or for many applications, imported from delimited ASCII files. The stereonet program is the one anomaly here, and relies on basic ASCII file editing for its data input. The

file formats are described both in the on-line and printed documentation.

The plotting programs produce clean, easy to read diagrams; however, the programs contain little or no options for changing font, line style, color, size, and layout. All diagrams can be written to any supported Windows output device, or saved to a variety of common graphic file formats. The saved diagrams can then be modified with other Windows-based programs or potentially combined with other types of information (i.e. written documents).

Two mysterious aspects of the on-screen plot previewing are the Contrast, Brightness, and Gamma controls that are used to change the colors on the diagrams, and the <shift> + mouse double click combination that must be used to zoom into an area of the plot. The colors are somewhat annoying since they must be changed to get a good black plot on a standard laser printer.

The RockWare programs are arranged nicely into the Windows interface, but expect to run them on fast computers or spend time waiting on slow computers. For example, the time required to generate a rose diagram with 158 measurements on a 486/25Mhz notebook with 8Mb of RAM was 32 seconds as opposed to 4 seconds on a 90Mhz Pentium with 16Mb of RAM.

Windows and its successors are becoming the preferred PC operating environments, and these utilities are good, practical geologic programs that are the first of many similar planned releases from RockWare. A demonstration disk can be requested for more information, or the RockWare Utilities 1.5 can be ordered directly for \$US 249.

In summary, the RockWare Utilities provide a useful combination of utilities with common geological applications, all under a consistent Windows interface. RockWare intends to expand the number of utilities, which could make this an indispensable package for those working in the geological sciences. For more information contact:

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CALENDAR OF EVENTS

International, national and regional meetings of interest to colleagues working in exploration and other areas of applied geochemistry.

■ Feb. 13-15, '95, U.S.G.S. McKelvey Forum, Energy and the Environment, Washington, D.C. (Dudley D. Rice, USGS, MS971, Box 25046, Denver, CO 80225, TEL: (303) 236-5711; FAX: (303)236-8822; e-mail: rice@bpgsvr.cr.usgs.gov)

■ Feb. 20-22, '95, Mineral Resources of Venezuela, conf., Caracas, Venezuela by Institution of Mining and Metallurgy and Camara Minera de Venezuela (Conference Office, Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR; TEL: +44 71 580 3802; FAX: +44 71 436 5388)

■ Feb. 20-25, '95, South Asia Geological Congress, Colombo, Sri Lanka (N.P. Wijayananda, GEOSAS II Secretariat, NARA, Crow Island, Mattakkuliya, Colombo 15, TEL: 941-522008; FAX: 941-522932)

■ Mar. 6-9, '95, Society for Mining, Metallurgy and Exploration, ann. mtg., Denver (SME, Box 625002, Littleton, CO, 80162-5002, TEL: (303) 973-9550; FAX: (303) 979-3461)

■ Apr. 3-7, '95, Centennial Geocongress 1995, Johannesburg, The Geological Society of South Africa (The Congress Secretariat, Centennial Geocongress, PO Box 36815, Johannesburg 0102, South Africa; TEL/FAX: 27 12 47 3398)

■ Apr. 10-13, '95, Geology and Ore Deposits of the American Cordillera, Geological Society of Nevada Symposium III (Bob Hatch, Geological Society of Nevada, P.O. Box 12021, Reno NV 89510; TEL: (702) 323-4569; FAX: (702) 323-3599)

■ Apr. 11-13, '95, European Environmental Geochemistry & Health Conference: Energy and the Environment (Dr. Keith Nicholson, Environmental Division, School of Applied Sciences, The Robert Gordon University, St. Andrew Street, Aberdeen, AB1 1HG, Scotland; TE: (0224) 262821 or 262802; FAX (0224) 262828)

■ Apr. 23-26, '95, Geology of Industrial Minerals, ann. mtg., El Paso, TX (Gretchen Hoffman, New Mexico Bureau of Mines and Mineral Resources, Campus Station, Socorro, NM 87801, TEL: (505) 835-5640; FAX: (505) 835-6333; e-mail: gretchen@gis.nmt.edu; pre-and post-meeting field trips)

✧ ■ May 15-19, '95, 17th International Geochemical Exploration Symposium, Exploring the Tropics, Townsville, Queensland, Australia (Russell Myers, 17 IGES, National Key Centre in Economic Geology, James Cook University, Townsville, Queensland 4814, Australia; TEL: 61 77-814486; FAX: (61) 77-815522)

■ May 24-26, '95, 5th V.M. Goldschmidt Conference, University Park, PA, USA (Technical Program Chair, Mike McKibben, TEL: (909) 787-3444; FAX: (909) 787-4324; E-mail: McKibben@UCRAC1.UCR.EDU)

■ June 3-6, '95, International Field Conference on Carbonate-hosted Lead Zinc Deposits, int'l mtg., SEG Anniversary Field Conference (David Leach or Martin Goldhaber, USGS, Branch of Geochemistry, MS 973, PO Box 25046, Federal Center, Denver, CO 80225, USA, FAX: (303) 236-3200; e-mail: dleach@helios.cr.usgs.gov)

■ June 7-9, '95, African Mining '95, Windhoek, Namibia (IMM, 44 Portland Place, London W1N 4BR, UK; TEL: (071) 580-3802; FAX: (071) 436-5388)

■ June 12-14, '95, Second International Conference on Arsenic Exposure and Health Effects, San Diego, CA (Dr. Willard R. Chappell, Campus Box 136, University of Colorado at Denver, Denver, CO 80217-3364; TEL: (303) 556-4520; FAX: (303) 556-4292; e-mail: rwormington@castle.cudenver.edu)

■ Aug. 28-Sept. 2, '95 Tectonics and Metallogeny of Early/Mid Precambrian Orogenic Belts, Montreal, Canada (J.A. Percival, Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8, Canada, TEL: (613) 995-4723; Fax: (613) 995-9723; e-mail: jpercival@601.C.gsc.emr.ca)

■ Sept. 4-8, '95, International Symposium on Environmental Biogeochemistry, Rio de Janeiro, Brazil (Symposium Secretariat, Prof. Luis Henrique Melges, FAX: 55-(0)21-248-4870; E-mail: iseb@bruerj)

■ Nov. 6-9, '95, Geological Society of America, Ann. Mtg., New Orleans, LA (Vanessa George, 3300 Penrose Place, Boulder, CO 80301; TEL: (303) 447-2020; FAX: (303) 447-1133)

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

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Editors note: Council has decided that all new applicants will receive the journal and newsletter upon application for

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Aveiro, Portugal

Osae, Shiloh

Okayama University
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RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in EXPLORE Number 85. Journals routinely covered and abbreviations used are as follows: Economic Geology (EG); Geochimica et Cosmochimica Acta (GCA); the USGS Circular (USGS Cir); and Open File Report (USGS OFR); Geological Survey of Canada Papers (GSC Paper) and Open File Report (GSC OFR); Bulletin of the Canadian Institute of Mining and Metallurgy (CIM Bull); Transactions of Institute of Mining and Metallurgy, Section B: Applied Earth Sciences (Trans. IMM). Publications less frequently cited are identified in full. Compiled by L. Graham Closs, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, Chairman AEG Bibliography Committee. Please send new references to Dr. Closs, not to EXPLORE.

Albino, G.V., 1994. Geology and litho geochemistry of the Ren gold prospect, Elko County, Nevada - the role of rock sampling in exploration for deep Carlin-type deposits. *J. Geochem. Explor.*, 51(1): 37-58.

Bellehumeur, C., Marcotte, D. and Jebrak, M., 1994. Multi-element relationships and spatial structures of regional geochemical data for stream sediment, southwestern Quebec, Canada. *J. Geochem. Explor.*, 51(1): 11-35.

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Blackburn, W.H., Metcalf, R.V. and Ragland, P.C., 1994. Geochemical evolution of the Precambrian Old Rag Granite, Virginia, USA: testing a U-Th exploration model. *Chem. Geol.*, 111(1/4): 177-206.

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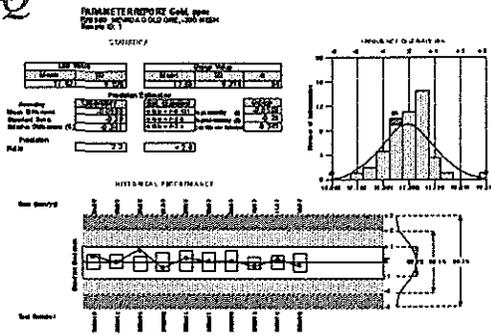
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 SME Pacific Northwest Mining and Metals Conf. 24-25
 Society for Environmental Geochemistry and Health 16
 XRAL - X-Ray Assay Labs 11
 XRAL Heavy Liquids 5



*Newsletter for The Association of
 Exploration Geochemists*

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