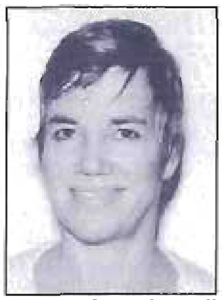
EXPLORE

Newsletter for the Association of Exploration Geochemists

NUMBER 87 APRIL 1995

PRESIDENT'S MESSAGE


Gwendy Hall

We began our 25th anniversary celebrations at the Prospectors and Developers Convention at the Royal York in Toronto during the week of March 5th. The P&D Association of Canada kindly provided us with a hospitality suite on Sunday and Monday nights and XRAL Laboratories of Toronto, at the suggestion of Lynda Bloom, generously sponsored the wine. Our booth was well positioned in the ballroom and we enjoyed a constant stream of interested people. Betty Arseneault "manned" the booth, equipped with database and computer ready to sign up new members (40 actually). Eion Cameron, Bill Coker, Colin Dunn, Bob Garrett and I took it in turns to help her. John Hansuld, current President of the PDAC and second President of the AEG, hosted a most enjoyable cocktail hour, prior to the Awards Banquet, for those sitting at specially designated tables. Past and present executive were invited to the AEG table, namely: Lynda Bloom, Peter Bradshaw, Eion Cameron, Bill Coker, Ivor Elliott, Bob Garrett, Chris Gleeson, Ian Nichol, Ian Thomson and Betty Arseneault. I had the honour of sitting at the High Table — thank you, John. In his speech, John Hansuld singled out Eion Cameron for special mention of his 25 years of dedicated editorial service to the Journal, a sentiment which we all echo. Pat Sheahan organised her annual day of talks devoted to diamond

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SOFTWARE REVIEW

Geographic Information Systems in Geochemistry

By Greg Lee

Geographic information systems (GIS) technology has been effectively applied over the past several years to geoscience programs that require spatial display or mapping of multivariate datasets. As a member of the USGS Branch of Geochemistry, I have enjoyed opportunities to utilize

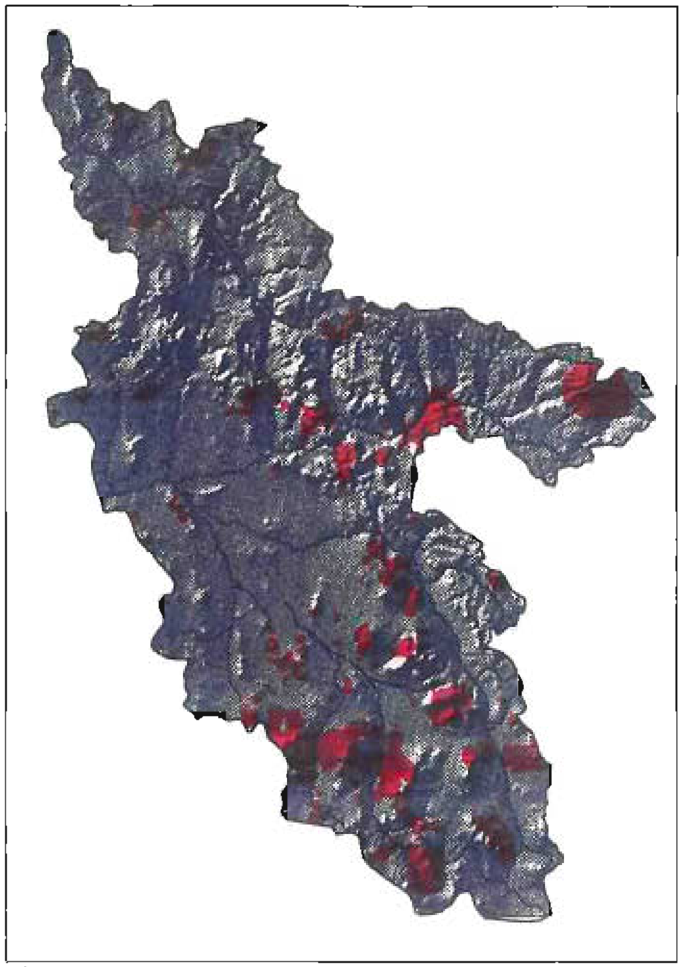

Figure 1. Example of Erdas, Inc. IMAGINE map composition showing overlay of raster images and vector coverages.

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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
c/o J.T. Nash, Box 25046, MS973, Denver Federal Center
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

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NOTES FROM THE EDITOR

Owen Lavin

This issue of **EXPLORE** will be published just before the 17th IGES in Townsville, Australia. The Townsville meeting is shaping up to be a timely and an important one. As mineral exploration moves away from the more developed countries we find ourselves increasingly in the tropics, and commonly on unfamiliar ground. The meeting should be an efficient way for members to learn more and catch-up on the very different challenges and problems of exploration in the Tropics.

On a personal note, approximately five years ago, I was honored with the opportunity to serve as editor of **EXPLORE**. I rapidly accepted the position and attempted to make my mark on this well established and respected Newsletter. With the able assistance of Sherman Marsh, Steve Zuker and a cast of assistant editors, I believe that we were at least partially successful in that goal. At the time, I felt a five year stint as editor would be about right. After that I thought that I may grow tired of the obligation and begin to run out of ideas and enthusiasm. I was correct. It is now time to step aside and let others have their impact on the Newsletter. Luckily, we have found two capable and dedicated members to assume the responsibility. Tom Nash and Sherman Marsh will be co-editors of **EXPLORE**. We expect the transition to be orderly and gradual, although they are already doing most of the work for this issue. I will continue to serve as business manager for **EXPLORE**. With that notification, I would like to thank the readership and the AEG council for allowing me such broad editorial freedom. It has been a pleasure serving as editor of **EXPLORE**. Please give Tom and Sherm your assistance and support, as you did for me.

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

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

Owen Lavin
Editor **EXPLORE**

President's Message

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exploration so we took the opportunity to promote the Journal's first issue of 1995, "Diamond Exploration: Into the 21st Century", edited by W.L. Griffin. Betty and I put fliers on every seat in the main hall and we are now reaping the rewards as faxes for membership come in. The mood of industry was noticeably optimistic at the P&D, with interest in various commodities (base metals, gold, diamonds) and representation from companies and agencies worldwide. The new membership gained to date almost offsets our costs, save several hundred dollars, which is well worth the exposure for the Association.

Eion Cameron and Betty Arsemeault doing a sterling job of representing the AEG at the P&D, Toronto.

I made ten copies of the laminated poster and title you see on our display unit in the photograph and have shipped them to regional councillors and to those offering to promote the AEG at meetings this year. The poster is rather 'wordy' in that it describes the benefits of the AEG, the regular and special issues of the Journal, and the nature of the contents of Explore. This is intentional so that it is a stand-alone, comprehensive 'document' from which readers can extract the information they are seeking. It will be accompanied by brochures and membership forms and be on display at these meeetings (amongst others): "Geology and Ore Deposits of the America Cordillera", Reno; "Mining, Exploration and the Environment '95", Washington; and the "International Field Conference on Carbonate-hosted Lead Zinc Deposits", St. Louis. Andrew Bourque, our publicity chairman, is busy devising schemes to increase our profile with the minimum in financial expenditure, so send any ideas or offers to him.

As a footnote, some confusion has arisen with regard to the costs of purchasing back issues of the Journal. Part of this is due to the fact that we have to order from two sources, Elsevier and Swets. In the terms of the new contract with Elsevier, a back issue becomes such six months after completion of the subscription year (the 1994 subscription year will be complete with Volume 52 due out in April). An AEG member can order a back issue for the usual cost of $50 for pre-1994 issues, or $70 for 1995 when it becomes back-issued. The member is entitled to receive all the issues in that subscription year for that price, not just the one issue of particular interest. To order extra copies of an issue or volume in the current year is very expensive; Elsevier normally pro-rates the institutional price and will provide us with a quote. Contact Betty for further information if I have not cleared this up!

Russell Myers tells me that registration is very healthy for the 17th IGES in Townsville and approximately 500 delegates are expected. The next issue of Explore will tell the tales from Down-Under. Looking forward to seeing and chatting with you there!

Gwendy Hall

*The AEG extends its sincere appreciation to **John A. Hansuld,** President of the P.D.A.C., for all the hospitality and encouragement received in celebrating its 25th anniversary at the Prospectors and Developers Convention in Toronto, March, 1995.*

AEG BIBLIOGRAPHY ON DISKETTE

Those of you who are paid 1995 members will find a bonus inside this issue of EXPLORE. We have included a 3.5" diskette which contains the latest version of the Exploration Geochemistry bibliography. For the last two years members of the Bibliography Committee have been converting all the previously published versions of the Exploration Geochemistry Bibliography into digital format and have added new references from the last bibliography (1984) through 1994.

Through the years the AEG has published five bibliographies, four in soft cover and one hard cover edition that contained all the previously published references from 1965-1981. In the original bibliographic efforts Herb Hawkes was the motivating force and it was through these early efforts that the present Bibliographic Committee was able to compile the references onto this diskette. All the earlier references were scanned into a database from the original printed copies and then edited by Dorthe Jakobsen. References from 1981 to 1994 were added by Graham Closs, who has been compiling references for **EXPLORE** on a quarterly basis. The resulting diskette has over 11,000 references in DBF, DOS format. This format was choosen as being one of the most commonly used in databases and word processors. We hope that everyone will be able to use it in their applications. For those of you that require Apple formats and can't convert the bibliography file, please contact the Secretary and we will try to get you an acceptable format. Included on the diskette is a "readme" file that explains how to install the bibliography on your computer.

Many members have requested an updated membership listing and in response we have also included the latest (March, 1995) membership listing, giving current members names and addresses and telephone and FAX numbers.

We hope that these databases will prove useful to you and we plan to issue yearly updates to members at a discount. For those of you who haven't renewed your 1995 dues yet, we will include a copy of the bibliography if you pay your 1995 dues by June 30.

Sherman P. Marsh, Secretary

NEWS OF MEMBERS

Ken Lovstrom has relocated to Tucson, AZ, where he will continue his geochemical consulting activities. Dick Horsenail has left AMAX Exploration and joined Ken in Lovstrom, Horsnail and Associates. Dick remains in the Denver area and is also Executive Director of the Minerals Exploration Coalition (MEC). Ken's new address is: 1770 E. Ganymeade Drive, Tucson, AZ 85737, USA; TEL: 602-797-4111; FAX: 602-797-2571. Dick can be reached at 9160 W. 73rd Place, Arvada, CO 80005; TEL: 303-422-8886; FAX: 303-422-0788.

LETTERS TO THE EDITOR

In **EXPLORE** No. 82 Lynda Bloom presented data on levels of cross-contamination from laboratory pulverizers and suggested that a silica cleaner be pulverized between samples. Neither this article nor the letter from Ian Devereux published in **EXPLORE** No. 84, which replied to Lynda's article, commented on the type of pulverizers used to obtain the test data. Disc and ring pulverizers are contrite and operate differently, which could lead to different problems of varying magnitude. For example, shredding, smearing, and cross-contamination of gold with reduced nugget effects may be more pronounced with disc pulverizers, versus flattening and reduced cross-contamination of gold, with larger nugget effects for ring pulverizers. I have heard many comments on these problems; however, they are more conjectural than empirical. Any comments from readers, based on hard data, would be interesting to hear.

Dale A. Sketchley
Placer Dome Canada Limited
1440 Hugh Allan Drive
Kamloops, B.C., V1S 1L8 Canada

Dear Sir;

XRAL's advertisement in **EXPLORE** No. 86 implies that laboratories are currently using carcinogenic heavy liquids for mineral separations. I have not seen warning labels on any of the commonly used heavy liquids sold by other

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Letters

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vendors. If XRAL's information is factual, readers of **EXPLORE** should be advised of the offending products and the time and place of their carcinogenic designation.

Stu Averill
President
Overburden Drilling Management Ltd.
Nepean, Ontario K2E 7X1 Canada

Editor's note: *Do readers have any advice regarding poorly advertised health hazards from chemicals in common use in geochemical laboratories?*

Software Review

Continued from Page 1

GIS in multidisciplinary projects that have focused on mineral resource and geo-environmental assessments. The study areas have ranged in size from individual mining districts to entire states. In the following, I offer both encouragement and realism to those sitting on the GIS sidelines. Although the emphasis of my own experience has been assessments, I hasten to stress that GIS may be advantageously employed in a wide range of geochemical investigations such as exploration, mine studies, university research, modeling, environmental studies, hazards identification, and more. A striking general aspect of GIS is the applicability of the technology to a broad scope of spatially-referenced studies.

There are, however, barriers to implementation of GIS. These may include general confusion, learning curve intimidation, system costs, evaluation and selection, and setup and training time. Confusion comes in various forms, starting with questions about the nature and applicability of GIS, the myriad choices of commercial and public domain systems, how to get data into a system, and vector versus raster systems. I sympathize. Perspective on these can be gained from the following a sketch of GIS implementation in the Branch of Geochemistry. Motivation for establishing GIS capabilities in the Branch included needs for (1) increased ability to interpret extensive, multivariate geochemical data; (2) enhanced capacity for graphically displaying geochemical and other geoscientific information and interpretations; (3) incorporating data in various digital formats; (4) data transfer to and from other GIS users; and (5) high quality color map production.

First, as a brief aside, some uncertainty may linger regarding the differences between computer graphics, computer-aided design/drafting/mapping (CADD) and GIS. In fact, there is some overlap between these general categories, but there are also many important differences. A GIS is designed to enhance, combine, and analyze layers of spatially-referenced data to produce interpretable results, whereas the purpose of CADD programs is to produce drawings or map illustrations. It is true that many GISs have substantial map composition tools, and it is not unusual to find GIS packages being used primarily for the purpose of map production, but a notable distinction is that while CADD programs create drawings and may even place drawings on top of each other, there is no ability to analyze relationships among multiple layers of data. A hallmark of GIS functionality, on the other hand, is the ability to logically analyze, transform, and combine multiple layers to create new layers. Another important difference is that CADD programs do not usually deal with geographic map projection information, so that accurate locational relationships between graphical elements and the earth's surface are not maintained. This limitation is not always the case, however, and GS-MAP, for example, by Gary Selner and Richard Taylor of the USGS, is public domain software for geographically-projected map production. This software is available from the U.S. Geological Survey as Open-File Report 93-11.

Although most GIS software packages include facilities for incorporating and displaying both vector (points, lines, and polygons) and raster (grid cell) data, the GIS processing functions of a particular system normally reside in one or the other, but not both domains. In other words, GIS packages tend to emphasize either raster or vector processing. Both sides of the coin may boast relative advantages, such as smaller data storage requirements for vectors versus greater processing speed for rasters, but these types of issues were, in my evaluations, less important than considering the types of data that I wanted to analyze using GIS. Put simply, vector GIS is well suited for thematic data such as geologic

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maps, composed of discrete types of information, whereas continuously variable data, in contrast, is best suited for raster GIS and image processing. The GIS projects in which I have participated have utilized data generated from various scientific disciplines: geologic (vector), geochemical (raster), geophysical (raster), remotely sensed (raster), linear features (vector), digital line graphs (vector), digital elevation (raster), mineral occurrence (vector), and land use (vector). This experience exemplifies the fact that any interdisciplinary GIS effort will likely involve both raster- and vector-based information and an evaluation of alternatives for implementation should include consideration of types of data that will be emphasized and facilities for data translation between systems.

Geochemical data, while generally site-based in nature, are usually projected into areal expressions or interpretations. The task of reasonably extending site-specific observations to areas has historically been effected in various ways. These range from scientists' judgements, exercised by manually drawing boundaries around areas thought to be geochemically similar; to assigning chemical values to stream drainage basins; to computer-generated mathematical interpolations of variables used to provide spatially continuous gridded "surfaces" or contours to represent the data. Those who blanch at the notion of interpolating point data through areas in which no "real" data exists should keep in mind that this has always been done *intuitively* when using the more traditional method of "eyeballing" data value distributions and hand drawing boundaries around areas. Similarly, geologists routinely use intuitive interpolation to extend "real" site-based observations to "fill in" mapped fault lines and lithologic polygons in areas between points where they have actually stood. I will not launch into a full scale promotion of interpolation here, except to say that I have had success with the approach and regularly use it to produce geochemical layers for use in GIS applications.

The algorithms used to create spatially continuous characterizations of point data vary considerably in type, complexity, and cost. The subject of interpolation is worthy of expanded separate treatment, but I will limit my comments here to a surface modeling package that I currently (happily) use.

In the discussion that follows, my use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

EARTHVISION

The Branch of Geochemistry has been successfully using EarthVision software, by Dynamic Graphics, Inc., to interpolate geochemical data for a variety of projects. This UNIX-based package incorporates what I consider to be the "cat's meow" of interpolators, although the price tag reflects its power — $12,500 for the basic 2-D package, with 3-D gridding and other module options available at additional cost. The algorithms used in the robust surface modeling part of the package have yielded excellent results, and functions are included which allow a scientist to impose faults or other desired gridding boundaries, such as lithologic terrane outlines, on the data, so that separate interpolations are performed on opposite sides of these boundaries. Further, the software incorporates visualization and graphical editing features that allow users to view and fine-tune the results of gridding. All popular map projections are supported. EarthVision also provides good map composition capabilities and produces excellent output on various color hardcopy devices. Getting geochemical data into EarthVision has been easily accomplished, whether coming from our in-house STATPAC format, from spreadsheets such as Quattro or Lotus, from databases such as Paradox or dBase, or even as text files created or edited with word processors. Grids produced by EarthVision can be exported to an ASCII format so that they may be imported by other applications. For more information, contact Dynamic Graphics, Inc., 1015 Atlantic Ave., Alameda, CA 94501, TEL: 510-522-0700.

After creating spatially continuous characterizations of geochemical data, it can be argued that a GIS which emphasizes raster-based/image processing functions is particularly well suited for geochemical applications. We conducted evaluations that stressed functionality, user community, and price, then installed two separate GIS packages. The first was IDRISI, obtained as a low cost, yet quite comprehensive raster GIS/image processing system which could operate using typical personal computer hardware configurations already found in many scientists' offices. IDRISI is very easy to install and serves as a

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relatively easy-to-use, readily available GIS resource for geochemical applications and training.

IDRISI

IDRISI is packaged as a comprehensive set of over 100 DOS-based (soon to be available in Windows version) program modules. This GIS is well-documented, menu and/or command driven, and runs on typically-equipped IBM-compatible machines. Minimum requirements are listed as an Intel 80xxx processor, MS-DOS 2.11 or later, 512 Kb of free RAM, and EGA or better graphics adaptor, and, for hardcopy output, a dot-matrix, inkjet, or laser printer. Recommended are a math coprocessor, an 80386 or later CPU with a processing speed of at least 25 Mhz, an 80 Mb or larger hard disk drive, and a super VGA graphics adaptor.

IDRISI is a raster (grid cell) based GIS and image processing system and was designed to provide geographic research tools on a low-cost non-profit basis. According to IDRISI project director Ron Eastman, "since its introduction in 1987, IDRISI has grown to become the largest raster-based microcomputer GIS and image processing system on the market. It is used in over 80 countries around the world by a wide range of research, government, local planning, resource management, and educational institutions. Today the project maintains a permanent staff and a long-term development plan. It is run within the Graduate School of Geography at Clark University as a non-profit project and maintains close links with the United Nations Institute for Training and Research (UNITAR) and the United Nations Environment Programme Global Resource Information Database (UNEP/GRID), both of whom have helped substantially in underwriting the development of the project."

IDRISI has numerous input/output filters which facilitate data transfer, and in-house software has been formulated to provide data conversion from our STATPAC and GS-MAP formats. The cost of IDRISI is $640, with student and government discounts available. For more information, contact The IDRISI Project, Clark University, Graduate School of Geography, 950 Main St., Worcester, MA 01610, (508) 793-7526.

Two important needs remained after the procurement of IDRISI, however. One was to be able to easily create and edit high quality, large format projected map compositions using the GIS software, and the other was to be able to directly (natively) communicate, data-wise, with collaborators using ARC/INFO as their GIS.

ARC/INFO, by Environmental Science Research Institute (ESRI), has emerged as an industry standard in the vector GIS domain, and is widely used for digital geology and other thematic data. It was felt, therefore, that our GIS efforts would be best served by having native ARC/INFO functionality included in our system to expedite data interchange with those using ARC/INFO.

IMAGINE, by ERDAS, Inc., was selected to fill both these needs. I predict that we will use IDRISI to ask "what if" types of questions to create desired geochemical models, and then bring this information into IMAGINE for final

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modification and combination with ARC vector layers to produce final output maps.

IMAGINE

ERDAS, Inc., founded in 1978, has thousands of licenses in over 80 countries worldwide. ERDAS IMAGINE incorporates many features which are ideally suited for geochemical and multidisciplinary geoscience applications. IMAGINE is a GIS/image processing package that has comprehensive raster-based functionality as well as vector functions that are a licensed subset of ARC/INFO by ESRI. This is proving to be a very useful system that allows seamless transfer of data to and from other ARC users as well as utilization of image processing and GIS techniques to process gridded geochemical surfaces created with EarthVision. I can directly import the native binary form of EarthVision grids into IMAGINE and also easily import maps created with GS-MAP. The powerful image processing functions in IMAGINE, such as supervised and unsupervised classification techniques, are useful for identifying areas with geochemical signatures that are significant in an investigation. Easy-to-use modeling functions allow complex operations to be invoked with minimum effort by the user. The import/export filters are quite extensive, and I have found the "generic binary" option, which allows the user to specify parameters, to be extremely useful. The software also supports many hardcopy output devices for map production.

IMAGINE runs on several platforms, primarily UNIX, but also includes Windows NT; here it has been implemented on a SUN SPARC 670 server using SUN-OS version 4.1.3. I access the software both by SUN workstations and by a personal computer operating as an X-terminal using Hummingbird Exceed for Windows. The IMAGINE software comes packaged in several modules and the provided functionality is quite comprehensive. The cost for the basic package starts at $11,000. The configuration I use includes Vector (ARC/INFO), Map Composer, Spatial Modeler, Image Enhancement, Import/Export, Perspective View, Image Catalog, and Radar modules. Images displayed in different viewers may be linked together and simultaneously roamed and queried. For more information, contact ERDAS, Inc., 2801 Buford Highway, NE, Suite 300, Atlanta, GA, 30329-2137, TEL: 404-249-9000.

For production of high quality color hardcopy maps, IMAGINE incorporates an easy-to-use Map Composer module that provides WYSIWYG ("what-you-see-is-what-you-get") map creation. These maps can include raster images together with ARC/INFO vector coverages, and opacity can be varied to let underlying images show through overlying layers. An example is shown in figure 1 which is composed of a shaded relief image derived from digital elevation data overlain by translucent red polygons which represent a range of concentration of an element in a geochemical surface, which was imported as a binary grid file from EarthVision. This combination of images is, in turn, overlain by ARC/INFO vector coverages of the study area boundary and streams and rivers.

I am currently using two color output devices to produce hardcopy from IMAGINE — a Tektronix Phaser III thermal wax printer that can generate graphics output of up to 11" by 17" in size, and a Hewlett-Packard DesignJet 650C, a color inkjet plotter/printer that produces maps of up to 36 in. width and semi-unlimited (roll feed) length. If larger sheets are required, IMAGINE produces panels that can be combined as mosaics. Both devices produce 300 dots-per-inch resolution output and the results have been excellent. The DesignJet has been particularly heavily used for IMAGINE map compositions and has shown to be quiet, easy and inexpensive to operate, insensitive to operating environment variables, and reliable. The maps that have been produced have been enthusiastically received. The Phaser printer has also been heavily used and, although the output has been very good, the device is considerably slower than the DesignJet and has also shown to be fairly expensive to operate, due to the cost of the color waxes used.

Although I am enthusiastic about geographic information systems applications in geochemistry and other earth science investigations, my zeal is not unqualified. First, it is naive to assume that procurement and installation of a GIS constitutes implementation. Training and considerable personal learning time are necessary ingredients. Second, I have likened GIS applications to Oriental stir-fry: the cooking part is fun, quick, and easy, but the preparation part is time consuming, tedious, and possibly frustrating. In other words, getting all the data together and in suitable form as digital information layers for the actual GIS processing really constitutes the lion's share of the effort. And this preparation may consume

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considerable time, particularly if geology is to be used but has not yet been digitized.

Despite potential problems, I encourage geochemists to utilize GIS tools in their work. GIS is becoming easier to use, decreasing in cost, and gaining widespread application in geoscience. I see my own continuing efforts as a growing experience, akin to learning more and more about how to use the word processing, database, spreadsheet, and statistical software packages that intimidated me not very long ago. Advances in GIS technology and user interfaces are helping to ease the pain of getting started and, as in other ventures into computer applications, once there, users are usually glad they made the trip.

Greg Lee
U.S. Geological Survey
Denver, CO 80225

NEWS RELEASES

IUGS Gros Morne Declaration: Assessing Rapid Environmental Change

Earth scientists at the International Workshop on Geological Indicators of Rapid Environmental Change, held July 11-14, 1994 at Gros Morne National Park, Newfoundland, Canada, issued a declaration on the importance of assessing rapid natural changes and of human-induced environmental changes. The declaration stressed the importance of documenting geological processes and geoindicators by collecting systematic, long-term datasets. Geochemical monitoring of topics such as water quality, CO_2 and ozone in the atmosphere, and ocean salinity is recommended, but the statement does not mention topics of concern to the AEG, such as continental geochemical mapping, monitoring of long-term effects of remediation, or natural contamination by volcanoes and unmined mineral systems. The full statement was published in **Episodes**, v.17, no. 1-2, p. 2, 1994. *JTN*

Co-Operative Research Centre for Landscape Evolution and Mineral Exploration

The Australian Government CRC Program has awarded funds for the this centre in Wembley, WA. The centre seeks to generate new knowledge of regolith-landscape evolution, to identify the resulting implications for mineral exploration and mining, to develop new exploration models, and to devise new or improved geochemical exploration methods. The centre will emphasize transfer of this knowledge to the mineral industry, geological surveys and universities. Some

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News Release

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A$16M new funding is provided by the grant over seven years. This is supported by a similar level of funding from industry and government research users, as well as secondment of staff from the core organizations (Australian National University, University of Canberra, Australian Geological Survey Organization, and CSIRO Division of Exploration and Mining. AEG members in the CRC LME include Raymond E. Smith, (Director), Charles Butt, Ravi Anand, and Ian Robertson. Smith and others can be reached c/o CSIRO Div. of Exploration and Mining, PMB PO, Wembley, WA 6014, Australia; TEL:. (619) 387-0272; FAX (619) 387-0146.

New Gold Standards

A series of 17 certified gold standards are available from LQSi. The new standard are an outgrowth of 20 years of experience with round robin analyses of rock and mineralized samples, including a two year round robin on gold ores that has 59 participants. Data for elements in addition to gold are reported but not certified. Most of the gold reference material have concentrations lower than 10 g/t and come from Nevada. For information contact Stephen Ivy, LQSI TEL:. (708) 331-3249, or Lynda Bloom, XRAL, in Toronto.TEL:. (416) 445-5755.

Keevil Chair in Mineral Exploration, U.B.C.

The University of British Columbia announces the Norman B. Keevil Chair in Mineral Exploration, established by the Teck Corporation to stimulate research in mineral exploration and to transfer the resulting technology to industry. The University is searching for an appointee who has established an international research reputation, or who has the clear potential to do so. Applications and nominations for this chair will be considered at all professorial levels.

The appointee is expected to develop an active research program in state-of-the-art methods of mineral exploration using techniques which could range from field to experimental to theoretical, and from disciplines as diverse as geology, geophysics, geochemistry, remote sensing, biogeochemistry, or hydrology. They seek a person who will maximize the interactions between the Departments of Geological Sciences, including the Mineral Deposit Research Unit, Geophysics and Astronomy, and the mineral exploration community. Innovative teaching at both the undergraduate and graduate level will be expected. Applicants must posses a Ph.D. Salary and rank will be commensurate with qualifications.

In accordance with Canadian immigration policy, priority will be given to Canadian citizens and permanent residents of Canada. The University of British Columbia welcomes all qualified applicants, especially women, aboriginal people, visible minorities and persons with disabilities.

Applications including a resume, a statement of research interests, and the names of three referees, should be sent by 31 July 1995 to Dr. Rosemary Knight, Chair of the Keevil Chair Search Committee, Department of Geophysics and Astronomy, 129-2219 Main Hall, University of British Columbia, Vancouver, B.C., V6T 1Z4, Canada.

TECHNICAL NOTE

Geochemistry and mineralogy of acid mine drainage at the Holden mine, Chelan County, Washington

by J.E. Kilburn, S.J. Sutley, and G.C. Whitney

INTRODUCTION

The large amounts of pyrite and other sulfide minerals in massive sulfide deposits (such as Holden) give them an unusually high acid-generating capacity that can cause environmental problems. Under oxidizing conditions, water draining these deposits can dissolve and transport high concentrations of metals (Smith and others, 1994) and can potentially release these acidic and metal-rich discharges into the environment, adversely affecting not only the local water quality but the biota as well (Plumlee and Edelmann, 1995). Recent geochemical studies, however, indicate that despite the ugly appearance of mine dumps and secondary encrusta-

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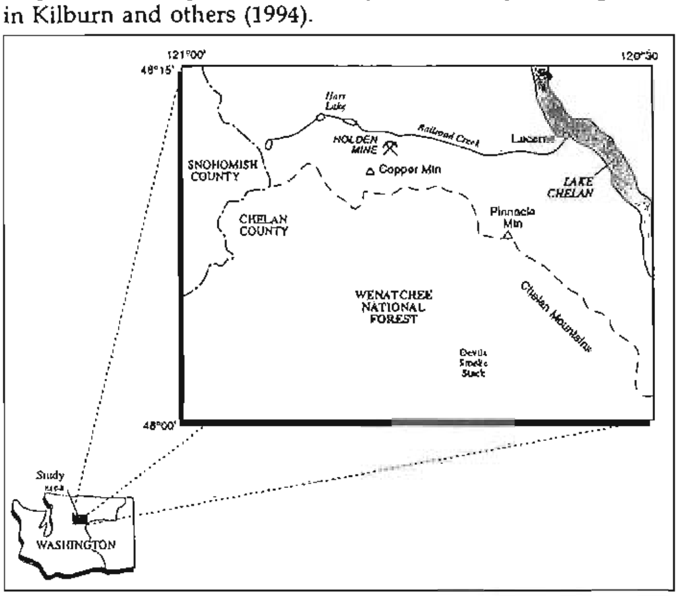
tions, the metal content of acid-mine drainage at the Holden site is relatively moderate in comparison to other mine waters (Ficklin and others, 1992; Plumlee and others, 1993) and appears to be naturally mediated with little impact on the local environment.

The Holden orebody is a relatively low-grade copper-zinc-silver-gold volcanogenic massive sulfide deposit (VMS) located within the crystalline core of the northern Cascade Range, north-central Washington (see Fig. 1) (Nold, 1983; Dragovich and Derkey, 1994). The mine, which began production in 1938, ceased operations in 1957 because of high production costs and a drop in the copper market. While operating, over 212 million pounds of copper, 40 million pounds of zinc, 2 million ounces of silver, and 600 thousand ounces of gold were extracted from 10 million tons of ore (McWilliams, 1958). At present, the mine site consists largely of mill tailings, waste dumps, portals and shafts, dismantled mill, and other abandoned surface structures.

The U.S. Geological Survey, in cooperation with the U.S. Forest Service, is currently conducting geochemical studies at the Holden mine as part of an integrated mineral-resource and mineral-environmental assessment of Wenatchee National Forest. The study at Holden was designed to rapidly identify, at a relatively low cost, possible contaminating effects of waters draining the sulfide-rich mill tailings, underground workings, and unmined ore zones at the deserted mine site. Sample media for this investigation included water:, effluent-related secondary sulfate salts, iron-oxide and hydrous metal oxide precipitates, and mill tailings. A complete listing of the analytical results, sample locality maps, and description of the analytical techniques are given in Kilburn and others (1994).



Location of Holden mine.

Results and Discussion

Two major sources of contaminated water flowing directly into nearby Railroad Creek were identified. The first source consists of a series of highly acidic metal-rich seeps located at the base of the mill tailings. Water from these seeps issues immediately into Railroad Creek or accumulates in numerous standing pools at the foot of the tailing impoundment. The second source is acidic, metal-rich water emerging from the mine portal. In addition to acid drainage, a less conspicuous source of contamination shows up at the base of the mill tailings in the form of various soluble efflorescent salts derived from sulfide weathering and related acid-generation.

Seep Water

A sample of active seep water collected at the base of the mill tailings had a pH of 2.9, conductivity of 1250 μS/cm, and contained 690 mg/L SO_4, as well as concentrations (in μg/L) of >6,000 Al, 6.8 Cd, 53 Cu, 50,000 Fe, 1,000 Mn, and 3,800 Zn. Quiescent or inactive seep water collected from a standing pool also at the foot of the tailings had a pH of 2.8, conductivity of 1110 μS/cm, and contained 456 mg/L SO_4. Dissolved metals included (in μg/L) 1,500 Al, 21 Cu, 23,000 Fe, 140 Mn, and 130 Zn (Kilburn and others, 1994). Applying the pH-metal classification of Ficklin and others (1992), whereby drainage water are classified according to pH and the sum of base metals (Cu+Zn+Cd+Co+Ni+Pb) in solution, the active seep discharge can be interpreted as a high acid-high metal solution, whereas the dormant pool water can be regarded as high acid-low metal. The concentrations of some metals in the two samples are lower than anticipated, considering the nature of the deposit and source of the samples (base of the tailings). Of particular interest are the comparatively low concentrations of Cu and Zn in solution. The geologic, geochemical, and external controls for high acid-extreme metal drainage discussed by Plumlee and others (1992;1993) are clearly in place at the Holden deposit where mining of massive sulfide ore has afforded oxygenated water easy access to tremendous volumes of highly permeable, fine-grained, sulfide-rich tailings. The geochemical metal-partitioning processes of sorption and mineral precipitation do not appear to exert much of a diluting influence or control with regard to the dissolved metal species (other than Fe). The pH is far too low for significant sorption reactions to take place (Smith and others, 1994), and chemical analysis of highly oxidized precipitates associated with the actively flowing seep water contained, not surprisingly, 32 percent Fe, but only moderate concentrations of 160 ppm Cu and 130 ppm Zn (Kilburn and others, 1994). *Continued on Page 12*

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The preponderance of Fe detected in the water and oxidized precipitates is consistent with a pyrite-dominated system, while the rather low Cu and Zn concentrations suggest a lack of significant chalcopyrite and sphalerite in the tailings, apparently an indication of efficient milling procedures at the Holden mine. Analytical data for mill tailings seem to corroborate this line of reasoning, showing 5 percent Fe, 0.6 ppm Au and only moderate amounts of Cu (110 ppm) and Zn (190 ppm) (Kilburn and others, 1994). The tailing sample, however, may not be representative because it consisted of a single grab sample collected at the surface. Moreover, surface tailings would be the first material to face dissolution by oxidation and weathering processes, liberating trace metals and concentrating the immobile Au.

Portal water

Effluent water emerging from the mine portal rapidly flows downhill nearly a quarter mile before discharging directly into Railroad Creek. A thick, milky-white, flocculent material, later identified as amorphous Al and Fe hydroxides, is suspended in the water or adhered to rocks and debris along the length of the mine drainage. Water collected at the mine portal had a pH of 5.2, conductivity of 760 μS/cm, and contained 410 mg/L SO_4, in addition to concentrations (in μg/L) of 1,000 Al, 21 Cd, 570 Cu, 580 Fe, 350 Mn, and 4,800 Zn. Chemistry of portal water remained remarkably uniform while flowing down the hillside prior to entering Railroad Creek. A sample of the effluent discharge taken just above its confluence with Railroad Creek had a pH of 5.0, conductivity of 800 μS/cm, and carried 406 mg/L SO_4, as well as (in μg/L) 940 Al, 21 Cd, 580 Cu, 370 Fe, 350 Mn, and 4,9OO Zn (Kilburn, and others, 1994). The drop in dissolved Fe is attributed to the continued hydrolysis of Fe and precipitation of Fe-hydroxides. According to the classification of Ficklin and others (1992), the effluent water are considered an acid-high metal solution; the high metal rating is based almost entirely on the very high Zn content. This is not surprising since Zn, which is the major base metal component in mine drainage, is highly mobile and resists sorption reactions within the pH range of the Holden portal water (Plumlee and others, 1993; Smith and others, 1994).

The flocculated Al and Fe hydroxides, which are amorphous and were identified by chemical evidence, probably precipitated as a result of pH-dependent solubility reactions (Smith and others, 1989). The development of the metal hydroxides and corresponding acidic, metal-rich adit water is attributed to many complex, and sometimes indistinct geochemical and geologic mechanisms (Plumlee and others, 1994). Although these interacting processes or controls are unique to each deposit, certain general inferences can be made regarding the evolution of the Holden adit water.

Ground water flowing along faults, fractures, or other permeable zones within the abandoned underground workings reacts with, and readily oxidizes and dissolves pyrite and other sulfides, liberating H^+, Fe^{2+}, SO_4^{2-}, trace metals (such as Zn, Cu, Pb, and Mo) and high concentrations of acid to the migrating water. The ensuing acidic water are highly corrosive and aggressively attack not only sulfide minerals but the enclosing wallrock as well, prompting the acid dissolution of resistive minerals such as the aluminosilicates (releasing major elements such as Al, Ca, K, Na, and Mg) while consuming acid in the process. Influenced by various buffering reactions such as the wallrock interaction described above and/or dilution by divergent ground and mine water, the pH of the solution rises causing precipitation of Al and Fe hydroxides and sorption or coprecipitation of the dissolved trace metals with these same hydrous metal oxides (Smith and others, 1994). Chemical analysis of the metal hydroxides confirms their affinity for attracting and scavenging trace metals, in particular Ag (1.6 ppm), Cu (710 ppm), Mo (19 ppm), Pb (160 ppm), and to a lesser extent Cd (0.63 ppm) and Zn (200 ppm) (Kilburn and others, 1994). How long the sorbed metals remain immobile within the solid phase is subject to the capacity of the scavenging metal hydroxides to resist dissolution (Smith and others, 1993).

Secondary sulfate salts

A less obvious source of contamination at the Holden site is secondary sulfate salt encrustations. The soluble salts form thin coatings on basal tailing material and other debris as seepage at the base of the mill tailings evaporates during intervals of dry weather. These encrustations store acid and metals in soluble salts that quickly dissolve during contact with rain or snow melt, releasing their toxic constituents to the environment.

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Samples of the sulfate-rich coatings were collected along the periphery of the tailings pile near the base. Ensuing XRD analysis of the salts revealed an extremely complex mineralogy, accommodating numerous interrelated secondary sulfates as well as minor amounts of relict primary minerals. Magnesium and aluminum sulfates were the common constituents in all the samples, with crusts gathered along the western fringe of the tailings pile exhibiting the most complex sulfate suites, including Fe, Cu, and Zn phases. Most of the salts contain relatively low to moderate metal concentrations, with some notable enrichments in Cd (3 to 16 ppm), Cu (94 to 5,800 ppm), and Zn (320 to 15,000 ppm). Especially high metal accumulations were detected in coatings from the western lip of the tailings pile where metal levels reached 13 ppm Ag, 370 ppm Cd, 43,000 ppm Cu, 280 ppm Mo, 120 ppm Pb, and 40,000 ppm Zn (Kilburn and others, 1994). These extreme metal concentrations are associated with the multiple or complex sulfate phases previously alluded to and include: pickeringite [$MgAl_2(SO_4)_4 \cdot 22H_2O$], halotrichite [$Al_2Fe(SO_4)_4 \cdot 22H_2O$, kalinite [$KAl(SO_4)_2 \cdot 11H_2O$], alunogen [$Al_2(SO_4)_3 \cdot 17H_2O$, siderotil [$FeSO_4 \cdot 5H_2O$], antlerite [$Cu_3(SO_4)(OH)_4$, gunningite [$ZnSO_4 \cdot H_2O$], chalcanthite [$CuSO_4 \cdot 5H_2O$], and bonattite [$CuSO_4 \cdot 3H_2O$].

The underlying cause of the growth of efflorescent sulfate minerals in company with exceptionally high metal concentrations is obvious: local highly-acidic water transporting high to extreme levels of Fe, Al, Cu, Zn, and other metals. The details, however, remain problematic. A plausible explanation comes from the sample locality itself, positioned immediately below the dismantled mill and related waste dumps — likely areas of sulfide weathering. Acidic, metalliferous runoff from these sites, on their descent to Railroad Creek , would inevitably advance directly over the metal-rich salt flats, causing seasonal precipitation of metal-rich sulfate salts.

Conclusions

From these reconnaissance data, it remains uncertain whether the acidic, metalliferous seep and portal water pose an environmental threat to Railroad Creek. Diverse sorption and metal-partitioning reactions play a dominant role in controlling and mediating the dissolved metal content of portal water prior to entering Railroad Creek. Compositions of water samples taken from Railroad Creek immediately above and below the mill tailings showed very little variance and compare favorably with background levels noted elsewhere along Railroad Creek and its tributaries. Given the relatively low discharge volumes from the seeps and portal and the high flow in Railroad Creek, it appears that metal concentrations and pH in the contaminated water are quickly diluted to background levels or the metals are precipitated. The impact of seasonal variation, however, was not addressed and could be significant.

The extreme metal contents of secondary salts in the Holden mine area could be sources of contamination and are cause for some concern. The dissolution and aqueous dispersion of these salts following storms could possibly lead to short-term spikes or increases in the acidity and dissolved metal content of nearby Railroad Creek. If, and to what extent, this represents an environmental hazard, or is in anyway harmful to creek biota, however, is unknown at this time.

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J.E. Kilburn, S.J. Sutley, and G.C. Whitney
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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.

■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. 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)

■Sept. 11-14, '95, **Canadian Mineral Analysts** 27th Annual Conf., Kelowna, B.C. (Wes Johnson, Chemistry Dept., Okanagan Univ. College, Kelowna, B.C V1V 1V7, Canada (604-762-5445; FAX: 604-470-6005).

■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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NEW MEMBERS

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

Editors note: Council has decided that all new applicants will receive the journal and newsletter upon application for membership. The process of application to the Nepean 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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Bangkok, THAILAND

SHORT COURSES

Pacific Northwest Mining and Metals Conference
"Mining, Exploration and the Environment '95"
Bellevue, Washington, May 1-2, 1995

Diamond Exploration: "Physical and Chemical Evaluation of Kimberlite Indicator Minerals" (Use of Heavy Mineral Concentrates in Diamond Exploration). Course Leaders: Dr. Tom McCandless and Dan Sculze.
2 days - cost US$300.00.

New Lithogeochemical Exploration Techniques: "Quantitative Analysis of Hydrothermal Alteration: Applications in Mineral Exploration." Course Leader: Hans E. Madeisky.
1 day - cost US$200.00 per participant (includes manual and diskette)

Alkalic Mineral Systems: Course Leader: Dr. Felix Mutschler
1 day - cost US$200.00.

Bioremediation: Course details being determined. Course Presenter: Jeff Campos of Envirotech.
1 day - cost US$200.00.

Introduction to Enzyme Leach Geochemistry.
Half Day - cost US$100.00.

For further information or to receive conference announcements contact:
Pacific Northwest Mining and Metals Conference
c/o GeoConstrux
6401 - 106th Ave. NE, Kirkland, WA 98033 USA

RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 86. 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**.

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Recent Papers

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Cheng, Q., Hattori, K., Fan, J. and Wang, S., 1994. Exploration history and geology of disseminated gold deposit at Maoling in Proterozoic sedimentary rocks in North China Platform. J. Geochem. Explor. 51(1): 93-108.

Church, S.E., Riehle, J.R. and Goldfarb, R.J., 1994. Interpretation of exploration geochemical data for the Mount Katmai Quadrangle and adjacent parts of the Afognak and Naknek Quadrangles, Alaska. USGS Bull. 2020. 67 p.

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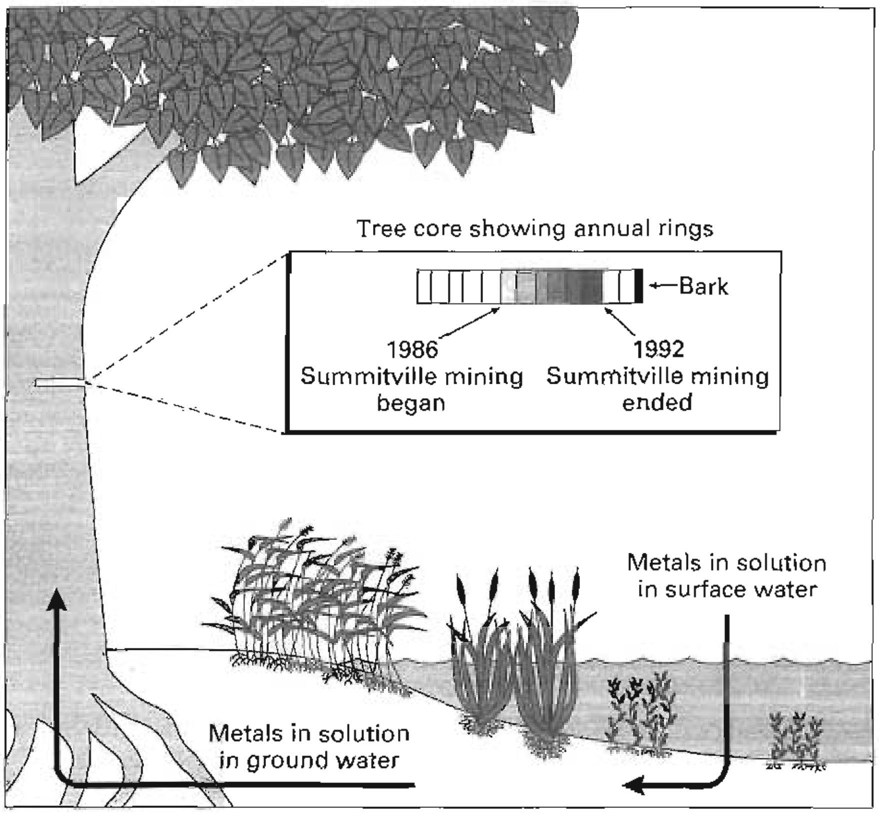

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