EXPLORE

Newsletter for the Association of Exploration Geochemists

NUMBER 100 AUGUST 1998

PRESIDENT'S MESSAGE

Peter Simpson

The Association of Exploration Geochemists (AEG) is now in the final stages of selecting a new title and publication arrangements for the new AEG journal to replace the Journal of Geochemical Exploration, to commence on 1 January, 2000. This has stimulated great interest with many discussions on the development of the Association and its publications and bodes well for the future.

One of the other continuing themes currently pursued by the AEG is the need to identify new scientific, technical, professional and business developments and opportunities for the application of geochemistry in support of economic and related environmental goals. Our members, with their professional experience, specialised knowledge and concern for the development and dissemination of the science of geochemical exploration are continually seeking new outlets and opportunities for the application of tools and concepts developed primarily for the mineral exploration industry.

For example, major governmental geoscientific research organisations, who are in the forefront of geochemical research and development, are now within a year of electronic release of geochemical data against payment by credit card. This increased accessibility should help to stimulate interest in the application of regional geochemical datasets to mineral exploration.

This activity is, however, taking place against a global economic background where a significant correction is underway. This is attributed to many factors, which include financial retrenchment and loss of public confidence in the junior mining sector due to the Bre-X fiasco. As a result, even major mining and exploration companies may no longer have geochemically trained, in-house staff, who are able to take advantage of opportunities for enhanced information availability for exploration geochemistry.

However, in spite of all these difficulties, major investments in geochemical methods are currently underway which involve evaluation of the use and application of exploration geochemistry, from the regional to drill hole scale. These test sites have been evaluated with combinations of sample media and analytical techniques, followed up by test drilling on the geochemical targets identified. Some of the methodology used is the subject of vigorous scientific debate and may help to elucidate conflicts in the understanding and interpretation of the geological and scientific principles involved in the detection of deeply buried mineralisation by geochemical methods. These studies involve the analytical service laboratories and their mineral industry clients, with input from in-house or independent geochemical exploration professionals.

Future corporate policy for the application of geochemistry in support of mineral exploration may therefore reflect the

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TECHNICAL NOTE

Kimberlite Indicator Minerals in Till, Lac de Gras Area, Northwest Territories, Canada

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INTRODUCTION

Since 1991, the Lac de Gras area of Canada's Northwest Territories has been the site of one of the most successful phases of diamond exploration and discovery in world history. With respect to number of kimberlites, the grade and quality of the diamonds, and the prospects for mining, the Lac de Gras area now rivals such legendary camps as the Kimberley district of South Africa, or the kimberlites of Russia. As of mid-1998, construction at the Ekati Diamond Mine of BHP Diamonds Inc. and Dia Met Minerals is nearing completion, and production is expected later this year. The Ekati Mine will rank among the most productive diamond mines in the world, with an initial production rate of about 4 million carats of high value diamonds, over 3% of world production by carat weight. A second mine, the Diavik project of Rio Tinto and Aber Resources Ltd., has entered regulatory review, and promises to be a mine on a scale similar to the Ekati. Evaluation of diamondiferous kimberlites continues at several other properties, and exploration remains active. Mountain Province Mining is now working with Monopros Ltd., the Canadian exploration subsidiary of De Beers, and other partners on the AK property, where prospects for grade and tonnage have recently been substantially enhanced. Near the Echo Bay Lupin Mine, Lytton Minerals Ltd. has continued work on their high-grade Jericho pipes. Several other companies, such as Winspear Resources Ltd., Ashton Mining of Canada, and SouthernEra Resources Ltd., are also active, and prospecrs for additional discoveries are good.

The key diamond exploration method in narrowing down the search to an area suitable for geophysical surveys has been indicator mineral tracing, using glacial sediments as the

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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:

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President's Message

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apparent local success or failure of sampling and analytical campaigns based on local definition of goals and understanding of the methodology being used. Minerals industry managers are prepared to seek a broader range of professional advice and opinions rather than relying entirely on generally optimistic claims for the successful application of currently fashionable geochemical exploration tools.

Geochemistry can be deployed effectively at many stages in the exploration and targeting of mineral deposits and is a particularly powerful tool when used constructively in conjunction with allied exploration disciplines. In addition, exploration geochemistry in undisturbed terrain often helps to establish a local geochemical baseline. This is increasingly required to help establish criteria for planning to meet the increasingly stringent initial regulatory standards prior to opening, during the life of the mine operation and ultimately, its closure. It is in these closely related areas that the environmental aspects of our work come to the fore. Since without such important and detailed studies, exploration targets, and potential mines may remain undeveloped, rather than contributing to the economic benefit of mankind.

How can the AEG and its members help? The AEG membership is very interested in the educational and learned society aspects of our work. The AEG is presently very active in the development and sponsorship of meetings and workshops of many different types, such as the 19th International Geochemical Exploration Symposium in Vancouver 11-16 April 1999, which will be a focal activity for the industry leaders and professionals. However there also is a clearly identifiable need for the AEG to develop a new range of onsite workshops which are more directly addressed at the special and particular requirements of the mineral industry.

Mine managers have responsibility for the mine exploration budget, which is not trivial expenditure, and generally appreciate any opportunity for greater informed contact with exploration geochemistry professionals. These workshops could be developed for the presentation to exploration staff and managers at the workplace, since they may be unable to attend the more scientifically oriented meetings organised by the AEG. This will involve greater effort on the part of our members;

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sampling medium. As part of the Geological Survey of Canada's (GSC) National Geoscience Mapping Program (NATMAP), the Terrain Sciences Division of GSC recently mapped the surficial geology, and carried out till sampling and ice flow studies in six 1:250 000 map sheet areas including Winter Lake, Point Lake, Napaktulik Lake, Aylmer Lake, Lac de Gras, and Contwoyto Lake (south half) (Fig. 1). The objectives of this survey were: a)

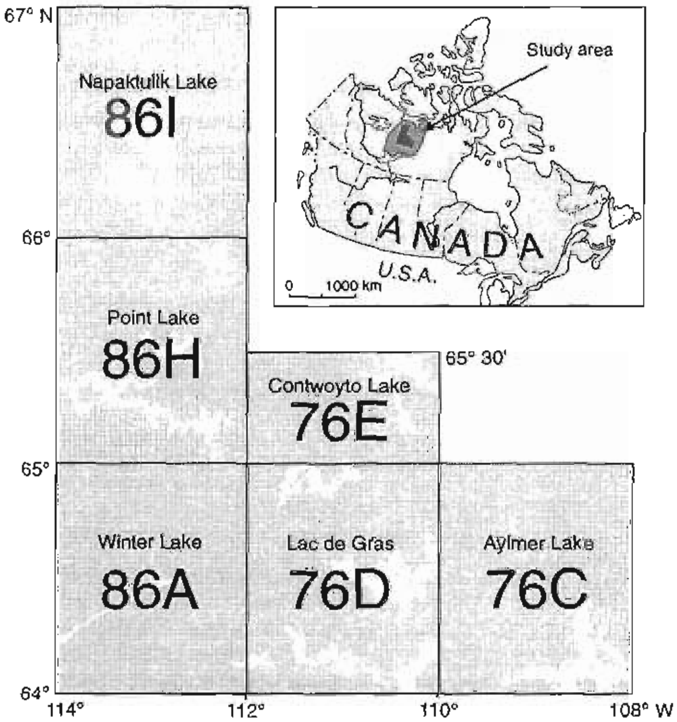

Fig. 1 – Location of the Lac de Gras area, with NTS topographic map sheet designations. Inset shows the Slave Geological Province shaded in light grey and the GSC study area shaded in black.

to determine which size fraction of glacial sediments was optimal for recovery of kimberlite indicator minerals and indicating the presence of kimberlites; b) to determine the regional distribution and background concentrations of kimberlite indicator minerals in till; and c) relate this distribution to regional ice flow patterns so that directions and distances of glacial transport from source kimberlite bodies can be evaluated. Because of a lack of published kimberlite indicator mineral data relating to diamond exploration in the Lac de Gras region, it is hoped that results presented here can be used as a guide for diamond exploration in other glaciated terrains, by way of illustrating the usefulness and benefits of till sampling, and providing potential background and anomalous concentrations of various kimberlite indicator minerals.

Certain minerals, when found in glacial sediments, are useful indicators of the presence of kimberlite, and to a certain extent, in evaluation of the diamond potential of kimberlite. Several features make these minerals ideal kimberlite indicator minerals; they are far more abundant in kimberlite than diamonds, they occur almost exclusively in kimberlite, they can withstand extreme crushing and grinding during glacial transport, and they are visually and chemically distinct. The most commonly used kimberlite indicator minerals are Cr-pyrope (purple colour, kelyphitic rims), eclogitic garnet (orange-red), Cr-diopside (pale to emerald green), Mg-ilmenite (black, conchoidal fracture), and chromite (reddish-black, irregular to octahedral crystal shape), although in rare cases, diamond is abundant enough to be its own indicator.

REGIONAL GEOLOGICAL SETTING

The Lac de Gras area is in the central Slave Geological Province and is underlain mainly by granite, gneiss, metavolcanics and metasediments of Archean age. Numerous diamondiferous kimberlite pipes, approximately 97 Ma to 52 Ma in age (Pell, 1995), have intruded these rocks. Pipes in the northern Contwoyto Lake map area are somewhat older (172 Ma; Cookenboo, 1997). Most pipes typically form circular depressions, and are glacially eroded deeper than the more resistant surrounding country rock. Kimberlite outcrops are rare, as some occur beneath lakes and most are overlain by glacial sediments. The exact number and locations of all known kimberlite pipes in the Slave Province have not been published yet (G.N.W.T., 1997), but it is estimated that there are some 200 kimberlites discovered to date.

The Lac de Gras area is a glaciated landscape, with glacial deposits constituting the most prevalent surface material. All glacial features are related to the Late Wisconsinan glaciation. To understand the direction and distance of dispersal of kimberlite indicator minerals, knowledge of ice flow history and till types is essential. Ice flow patterns are complex and record several different events (Fig. 2). Ice flowed initially southwestward

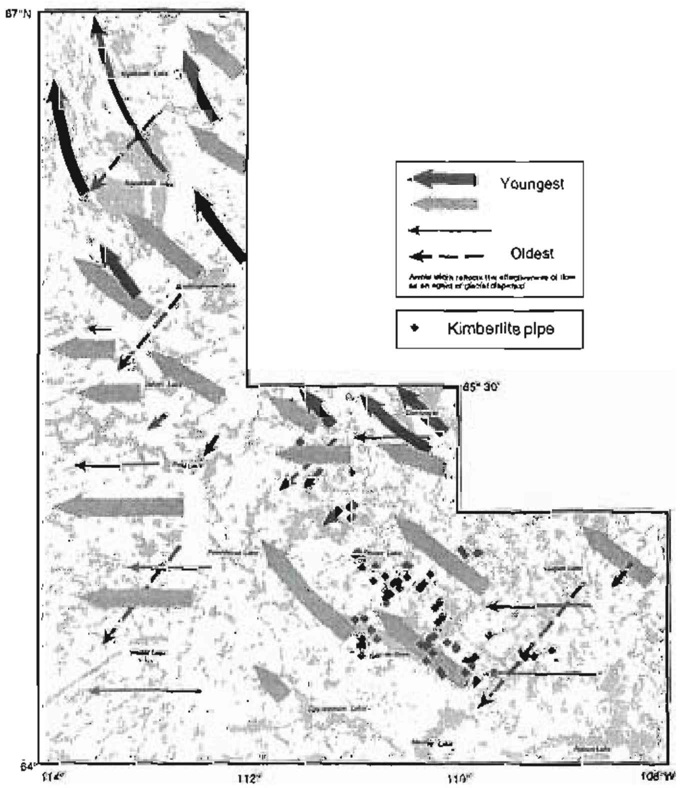

Fig. 2 - Summary of regional ice flow patterns and location of known kimberlite pipes in the Lac de Gras area.

across the entire study area, then westward in the southern and central regions, followed by northwestward in the southern and northern regions with a shift to west northwestward and

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westward in the central and western regions, and finally northwestward to north northwestward in the central and northern regions, at the end of glaciation. A young, very localized, southwestward ice flow was also recorded in a few isolated localities in the central study area. However, the dominant ice flow most responsible for transport of kimberlitic debris was the northwestward and westward flows as evidenced by striae, as well as large scale ice flow landforms such a s drumlins, and individual kimberlite dispersal trains.

METHODS

A total of 300 10-kg till samples were collected from shallow hand-dug pits, with a sampling density of one sample per 180 km^2. One single till sheet was sampled. Till sample processing included disaggregation, sieving, tabling and separation in heavy liquid, as summarized in McClenaghan et al., (1997). Non-ferromagnetic heavy mineral fractions were sieved to 0.25 to 0.5 and 0.5 to 1.0 mm to recover kimberlite indicator minerals. The 0.25 to 0.5 mm fraction was picked for potential kimberlite indicator minerals including pyrope garnet, eclogitic garnet, Cr-diopside, Mg-ilmenite and chromite. The 0.5 to 1.0 mm fraction was picked for potential indicator minerals only for those samples that contained 5 or more suspected pyropes in the 0.25 to 0.5 mm fraction.

Potential indicator mineral grains were mounted in 25 mm epoxy mounts and analyzed using the electron microprobe facilities at the Geological Survey of Canada, using operating conditions described by Ward et al., (1995), McClenaghan et al., (1996), and Stirling and Pringle (1996). More detailed information on sample processing, as well as a complete listing of Geological Survey of Canada kimberlite indicator mineral and till geochemistry reports, surficial geology maps and papers are listed in Dredge et al., (1997). Analyses were completed using a four spectrometer Cameca SX50 electron microprobe and all grains were analyzed using the "GARNET" routine. This routine was developed by the GSC to analyze for the major elements required to identify the potential mineral species using a minimum of probe time. Enlarged colour prints and scanning electron microprobe (SEM) backscatter images of the grain mounts were used to aid mineral identification and to recognize possible inhomogeneities, intergrowths or exsolutions within individual grains. Mineral chemistry and mineral color, specific gravity, and magnetic susceptibility were used to confirm identification of kimberlite indicator minerals.

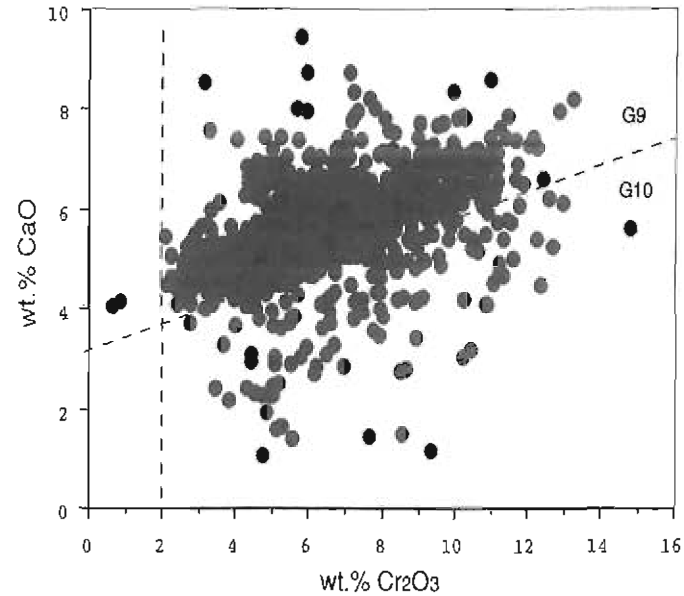

Fig. 3 – CaO versus Cr_2O_3 plot for all garnets in 10-kg till samples from the Lac de Gras area.

Kimberlite indicator minerals identified in till samples were primarily pyrope (garnet), Cr-diopside, chromite, and Mg-ilmenite.

INDICATOR MINERALS

Garnet

Subcalcic harzburgitic garnets are associated with diamondiferous kimberlites (Sobolev et al., 1973, 1993; Gurney, 1984, 1989; Gurney and Zweistra, 1995). They have a distinctive lilac purple to reddish purple colour (Plate I, Fig. A) and can be differentiated chemically from other pyrope garnets from lherzolite, harzburgite or dunite by their low CaO and high Cr_2O_3 content (Fig. 3). The diagonal line separating lherzolitic and harzburgitic garnets is the 85% line defined by Gurney (1984). Garnets that fall below the 85% line, i.e. low-Ca Cr-pyropes, are "subcalcic" or G10 garnets derived from harzburgite. The high chrome content gives these garnets a distinct lilac purple colour. The vertical line separates Cr-poor, orange-red garnets having <2 wt. % Cr_2O_3 from the purple peridotitic garnets. Garnets from till samples in the Lac de Gras area are mostly G9 (lherzolitic), and only a few are subcalcic-G10 garnets. Eclogitic garnets are orange pyrope-almandines containing <2 wt. % Cr_2O_3 and significant trace amounts of Ti

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and Na (Fipke et al., 1995).

Cr-diopside

Kimberlites contain diopsides with a wide range of Cr_2O_3 content (Stevens and Dawson, 1977) which overlap at the lower end of the Cr_2O_3 *spectrum* with diopside compositions in other ultrabasic rocks, making discrimination between kimberlitic and other diopsides on the basis of chrome content difficult. Cr-rich (>0.5 wt.% Cr_2O_3) diopside is easily identified by its distinctive emerald green colour (Plate I, Fig. B). It indicates the presence of kimberlite but provides little information on the diamond grade of kimberlite.

Chromite

Black (magnesio) chromite associated with diamonds has a high Cr_2O_3 content (>60 wt. %) and moderate to high level (12 to17 wt.%) of MgO (Fipke et al., 1989, 1995; Gurney and Moore, 1993). They occur as octahedral crystals or more commonly as resorbed, irregular shaped crystals. They appear as black grains but are reddish-brown when examined along thin edges.

Mg-ilmenite

Kimberlitic ilmenites can be distinguished from ilmenites from other rocks by their high MgO content, typically containing >6 wt.% MgO (Mitchell, 1973; Haggerty, 1975). Mg-ilmenite (also known as picro-ilmenite) is metallic black with conchoidal fractures on broken surfaces (Plate I, Fig. C). Unbroken grains are commonly rounded and may have whitish coatings of leucoxene or overgrowths of perovskite.

REGIONAL PATTERNS

For this regional study of the Lac de Gras area, four kimberlite indicator minerals were picked from two size fractions: the 0.25 to 0.5 mm and 0.5 to 1.0 mm non-ferromagnetic heavy mineral concentrates. Total concentrations of kimberlite indicator minerals ranged from 0 to 676 grains per 10 kg till sample (Fig. 4). The majority of the indicator minerals were found in the 0.25 to 0.5 mm fraction (Fig. 5).

In this fraction, 91 of the 300 samples contained indicator minerals, with the majority of these samples containing <5 indicator minerals. Of the samples examined for indicators in the 0.5 to 1.0 mm fraction, only 20 samples contained indicator minerals. These data indicate that for smaller samples (~10 kg), the finer grain size should be picked, or more subtle anomalies might be missed. The overall relative proportion of indicator minerals in the 0.25-0.5 size fraction of till in the Lac de Gras area is ~75% pyropes, ~22% Cr-diopsides, ~2% Mg-ilmenites, ~1% chromites and <<1% eclogitic garnets. Almost every sample with > 5 pyropes contains "G10" or sub-calcic garnets. These indicators suggest that most of the kimberlites in the area

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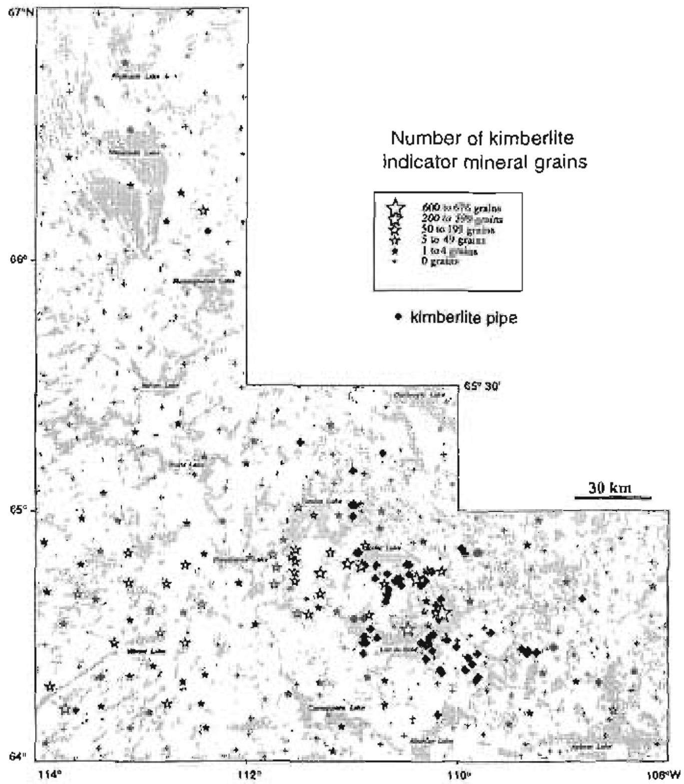

Fig. 4 – Regional distribution of total number of kimberlite indicator minerals in 10-kg till samples from the Lac de Gras area.

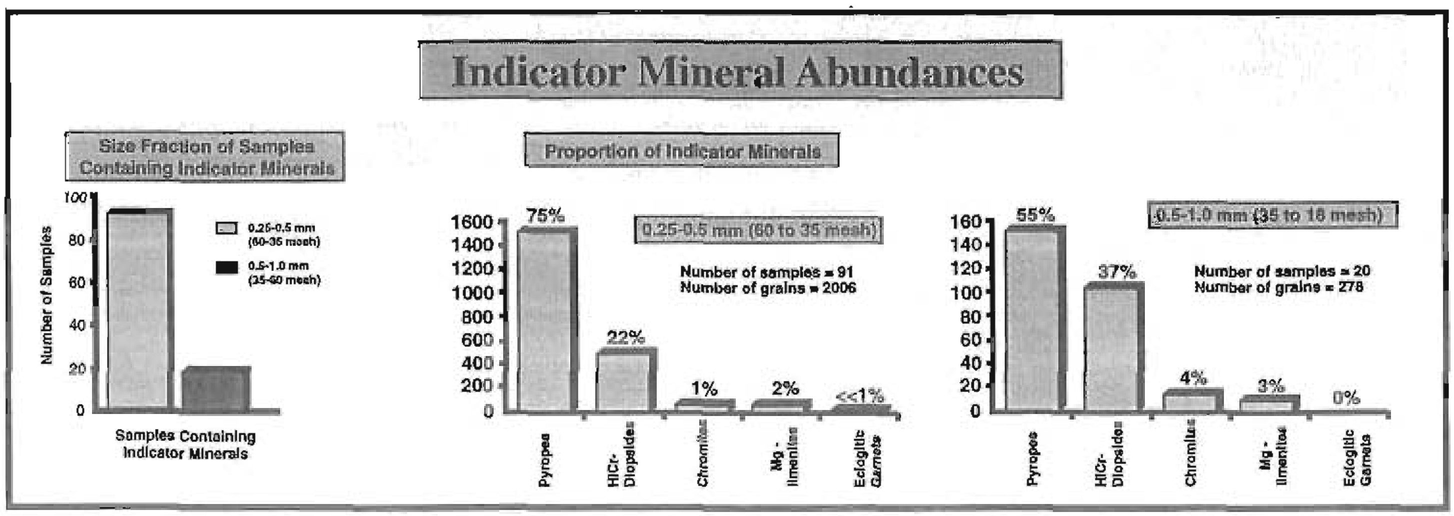

Fig. 5 – Indicator mineral abundances by grain size fraction.

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have sampled potentially diamondiferous harzburgitic mantle. The lack of eclogitic garnets precludes a significant source of diamond from eclogite. *Mckinlay et al., (1997) also have found* that in till samples taken at 1 km intervals in the Hardy Lake area northeast of Lac de Gras, pyropes were the most abundant indicator mineral in dispersal trains.

Pebble lithology and sand mineralogy of the regional till samples in the Lac de Gras area indicate that pebble-sized clasts have been glacially transported at least 40 km down-ice, and sand grains at least 75 to 100 km from bedrock sources. This indicates bedrock debris, including kimberlites, has been transported a significant distance, and that pebbles in till are reliable indicators of transport distance and direction.

Samples with the highest concentration of indicator minerals were found adjacent to and down-ice from the Lac de Gras kimberlite cluster in the northern half of the Lac de Gras map area (Fig. 4), where more than 200 kimberlite pipes have been reported. Samples containing >15 indicator minerals in number are common for this area. This zone is informally termed the Lac de Gras dispersal plume and represents the combined signature of the kimberlite field just north of Lac de Gras. Several samples with low concentrations of indicator minerals (up to 7 grains) occur westward/northwestward (down-ice) of the kimberlite field. This distribution forms the distal part of the dispersal plume. There are also a number of sites with low concentrations of grains west-southwest of the Lac de Gras kimberlite cluster.

The combination of earlier phases of southwestward and westward flow and the subsequent dominant northwestward flow over the principal zone of kimberlites in the Lac de Gras area and dominant westward flow in the Winter Lake area, could account for the presence of indicator minerals at some of the sites. However, because of high quantities of indicators at some sites and a lack of indicators directly southwest of the Lac de Gras pipes, it is more probable that there are additional unmapped kimberlites in the Winter Lake area.

Very few kimberlite indicator minerals occur up-ice (east) of the Lac de Gras kimberlite cluster, in the Aylmer Lake area, so that the presence of even one indicator mineral in that area would be considered anomalous. There is also a paucity of indicator minerals north of the Lac de Gras kimberlite field. Isolated samples with variable concentrations of indicator minerals in the Point Lake and Napaktulik Lake map areas may be related to a few known kimberlite pipes in the southeastern Napaktulik Lake and Contwoyto Lake map areas or possibly the Rockinghorse Lake area, as they occur down-ice of these potential source areas. Till geochemical analysis (Dredge et al., 1997) of rare earth and other elements (Ni, Cr, Be, Ba, La, Nd, Rb, Th, U) for till samples from the southern part of the Point Lake map area indicate that the kimberlite indicators found there have been dispersed from an unidentified source to the east, not from the Lac de Gras cluster. A small number of other sites with low concentrations of indicator minerals do not relate to any known source pipes, and are not part of the Lac de Gras dispersal train. Such localities with 1 or more indicator grains warrant further investigation.

Individual types of indicator minerals also show strong regional differences. The distribution of pyropes strongly reflects the Lac de Gras dispersal plume (Plate II), with the highest concentrations over the kimberlite field, decreasing in concentration down-ice (westward) into the Winter Lake map area and southern Point Lake area. Cr-diopsides have similar geographic distributions. Chromites and Mg-ilmenites are generally associated with the main plume in the northern Lac de Gras map area. The southeastern Napaktulik Lake map area and the northeastern Point Lake map area have 3 to 4 samples with relatively high concentrations of Cr-diopside, Mg-ilmenite, and rare pyrope and chromite. Kimberlites in the southeastern Lac de Gras map area and eastern Aylmer Lake map area were not detected in the samples collected in this study. There are several possible explanations for this.

Because of the low sampling density and small number of known pipes, the individual dispersal plumes for these pipes may not have been identified. More likely, these kimberlites have different heavy mineral signatures from those in other areas. The small abundances of Cr-diopsides and lack of pyropes in the Aylmer Lake map area suggests that there are regional

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This symposium will be the last major Geochemical Exploration meeting of this Century. In keeping with the theme, *Exploration Geochemistry into the 21st Century,* the conference will aim to stimulate and disseminate new ideas and innovations.

If you would like to receive more information, please complete the Reply Form and mail or fax the IGES Secretariat Office.

TECHNICAL SESSIONS

Technical Sessions will be held on April 12-13, 15-16. April 14th will be a mid symposium break to give delegates and guests the opportunity of enjoying the many attractions offered by Vancouver and the surrounding area.

Topics include:

- Integrated exploration case histories - discoveries and disappointments
- Search for concealed deposits (including diamonds)
- New sampling methodologies at all scales
- Data presentation & interpretation
- Analytical methods (including quality control)
- Lithogeochemistry
- Envirogeochemistry related to the minerals industry

Anyone interested in submitting a paper for the 19th IGES should complete the Reply Form for more information.

Deadline for Abstracts is October 1, 1998

SHORT COURSES

Short Courses will take place April 10 - 11th before the symposium.

FIELD TRIPS

Field trips will take place after the meeting, starting April 17th. The field trips are intended to complement short course and technical session themes by providing applied demonstration of methods and interpretation.

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differences in kimberlite heavy mineral suites. Relatively high Mg-ilmenite grain counts relative to pyrope at a site east of Winter Lake suggests that any pipes in that area also have a different indicator assemblage than the kimberlites of the Lac de Gras cluster.

CONCLUSIONS AND IMPLICATIONS

Important implications with respect to mineral exploration methodology result from this regional study. Despite the fact that many kimberlite pipes are recessive and occur under lakes, till sampling is an effective mineral exploration technique. A 10-kg till sample is sufficient weight to detect indicator minerals dispersed from the Lac de Gras kimberlite pipes. Kimberlite indicator minerals in the medium sand grain size fraction (0.25 to 0.5 mm) of non-ferromagnetic heavy mineral concentrates of kimberlites and glacial sediments should be picked, so that subtle anomalies are not missed. The relative abundance of kimberlite indicator minerals in the Lac de Gras dispersal train from the kimberlite cluster is: pyrope > Cr-diopside > Mg-ilmenite > chromite. Regional distribution of indicator minerals displays wide variability which can be explained by the ice flow history and the location of the principal zone of known kimberlites for the area.

The area with the highest concentration of indicator minerals occurs in the northern half of the Lac de Gras map area, either adjacent to or down-ice from most of the known kimberlites. The areas with the lowest concentrations of indicator minerals are the Aylmer Lake area, which is up-ice from most of the known kimberlites, and areas in the Napaktulik Lake and Point Lake regions which are not directly down-ice of large kimberlite clusters. The distribution of indicators suggests that there are more kimberlite pipes that have not yet been identified.

Regional till sampling led to the identification of the Lac de Gras dispersal plume which reflects the combined signature of many pipes in the area. Its elongate nature to the northwest corresponds to the dominant direction of glacial transport. However, sampling density was too low to resolve dispersal trains from individual pipes. A much higher sampling density is required to detect a single dispersal train of a few 100 m's to a few km's in length. The current distribution of kimberlite indicator minerals strongly suggests the existence of other kimberlites not presently recorded within the realm of public domain. More detailed information on surficial geology, methods, indicator mineral abundances and other kimberlite GSC studies can be viewed on the GSC's Web site at http://sts.gsc.nrcan.gc.ca/page1/miner/slave/index.html.

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Laboratories: Ecuador, Bolivia, Brazil, Chile, Ghana, Zimbabwe, Kazakstan, Europe and elsewhere.

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ACKNOWLEDGEMENTS

We acknowledge the high quality sample processing by Overburden Drilling Management Ltd. (Nepean, Ontario), indicator mineral picking by I. & M. Morrison Geological Services (Delta, B.C.), mineral analyses and identification by I.M. Kjarsgaard (Ottawa, Ontario), and the electron microprobe analyses by the Geological Survey of Canada. Critical review by L.H. Thorleifson improved the manuscript. Map figures were prepared by R. Knight. Thanks are also extended to Polar Continental Shelf Project for logistical support.

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Continued on Page 11

PLATE I

Scale

1 mm

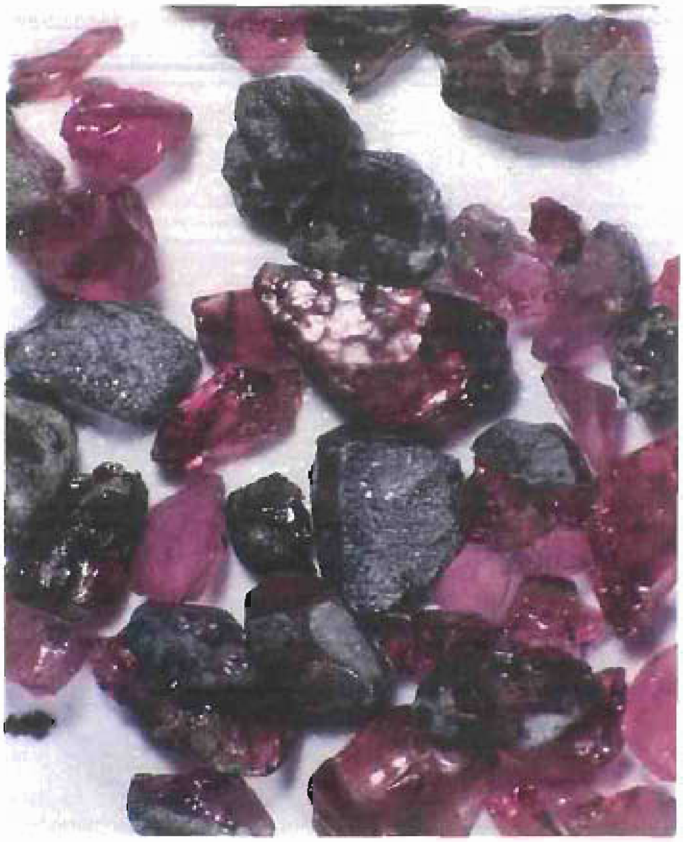

Plate I, Fig. A – Pyrope.

Plate I, Fig. B – Cr-diopside.

Plate I, Fig. C – Mg-ilmenite.

PLATE II

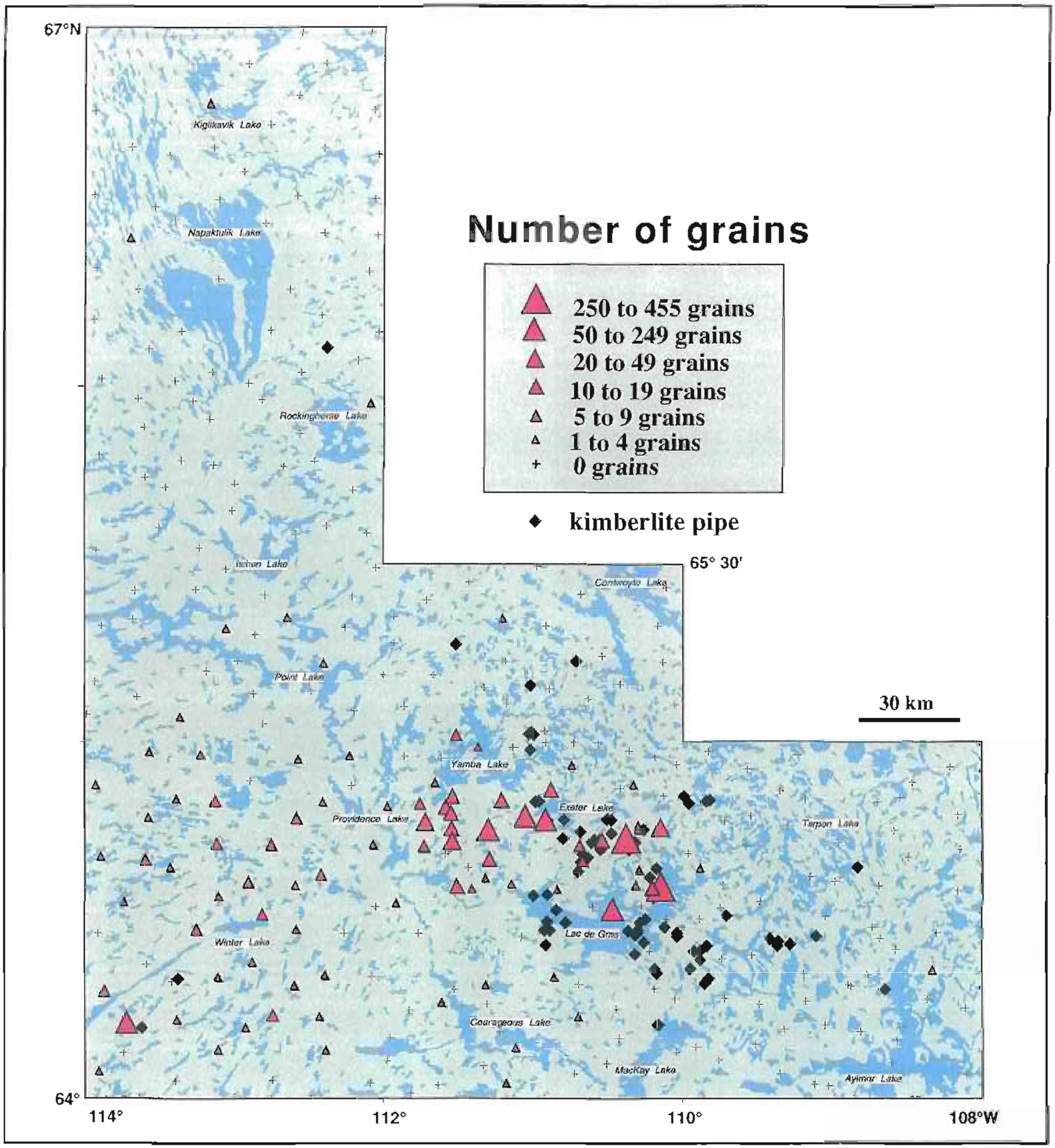

Plate II – Regional distribution of pyrope grains in 10-kg till samples and location of known kimberlite pipes in the Lac de Gras area.

Technical Note *Continued from Page 8*

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NOTES FROM THE EDITORS

You are reading the third issue of **EXPLORE** with color plates that show so well some recent advances in exploration geochemistry and presentation as color graphics. The use of color in these plates is made possible by the advertising support of Geosoft, Inc. We consider the use of color graphics to be very import for the presentation of geochemical information and hope that there will be more issues of this type in the future. We hope that advertisers will support **EXPLORE** in this endeavor. Authors wanting to participate in a future color-supported issue should contact us; regretably, we cannot promise a specific date of publication in color. We are particularly interested in geochemical maps that use color effectively, and possibly we can assist authors by offering color printing at no charge to them.

We acknowledge with thanks the continuing partnership with Geosoft, the excellent science and graphics of the authors, and the skilled work of Vivian Heggie that produces the fine printed copy.

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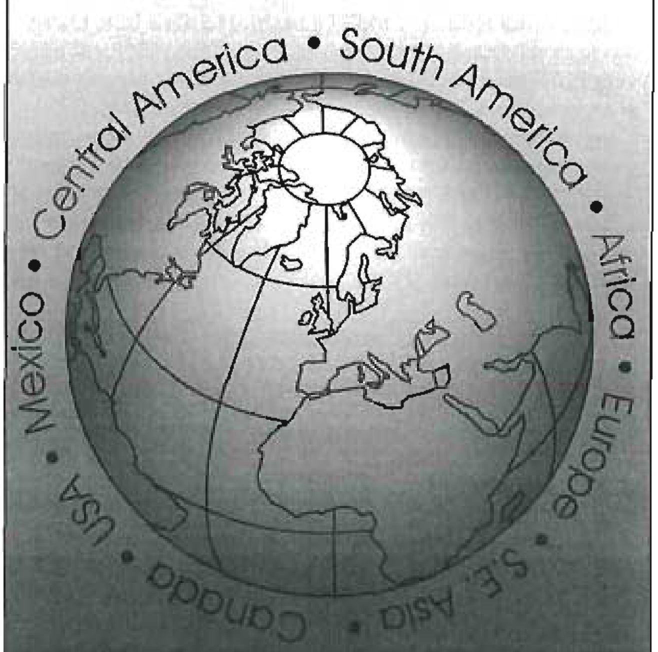

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NEWS OF MEMBERS

Sherman Marsh, long a leader in AEG as Secretary and Co-Editor of **EXPLORE**, is said to be in retirement, but is more active than ever. He spends less time at the USGS office, but devotes newly found time to consulting on geochemistry (Caribbean and Central America), golf, and travel. He has requested that he step down as Secretary of AEG, and an orderly transition is underway to the capable hands of **Dave Smith**, who quite conveniently has an office across the hall from Sherm's. Sherm will continue to be active with **EXPLORE**—thankfully, because no other person understands the nitty gritty of **EXPLORE** mailings and business like Sherm does. Enjoy your new pursuits, Sherm, but don't rub it in as to how much fun this is.

Owen Bavington of Minorco, recently promoted to Senior Vice President, Exploration, will be based in London. He will be responsible for the Minorco Group's worldwide exploration and geology activities.

Chris Oates, currently AEG's Regional Councilor for Chile, will be appointed to be Minorco's worldwide 'consulting geochemist', effectively the chief geochemist for the Minorco Group.

Note: We'd like to see more news from and about our members and fellows. Don't be bashful! In his note Owen Bavington remarked that "two fellows of the AEG will now be in very influential positions in one of the world's biggest mining companies with one of the biggest exploration budgets." Congratulations to Minorco for recognizing the talents of our colleagues Owen and Chris. This indirectly enhances the stature of AEG and is good news for friends to know. How about others out there? We'd prefer more good news, but sometimes sad news is necessary. Please include new addresses and email contacts if possible. *JTN*

UPDATE ON THE CANADIAN GEOSCIENCE COUNCIL

by Beth McClenaghan

The Association of Exploration Geochemists is one of 12 member societies of the Canadian Geoscience Council (CGC). The CGC serves the national and regional interests of all Canadians and serves the specialized disciplines of earth science practised by some 14,000 scientists in Canada. The Council represents these scientists by means of its membership of delegates from the national scientific and technical societies in the earth sciences, scientists from industry, from the universities, and from government agencies concerned with the geoscience of the natural environment of Canada and of its mineral, energy, and water resources.

The Canadian Geoscience Council:

- **Advises the general public on matters of significance to Canada and to the world that involve geoscience and geoscientists, in particular:**
  - by identifying national interests and concerns that need constructive advice from geoscience,
  - by disseminating geoscientific information and advice on national and regional issues and concerns,
  - by acting as a catalyst to increase appropriate endeavours by the national scientific and technical societies and associations;
- **Provides expert advice to governments at the federal and provincial level:**
  - by commenting on legislation and programs environmental sciences,
  - by advising on legislation to licence professional geoscientists and to accredit programs of qualification,
  - on request, by appointing and monitoring teams of experts to assist government programs;
- **Promotes scientific awareness and education in Canada and encourages talented young Canadians to consider careers in the earth sciences**
- **Organizes Canada participation in non-governmental global cooperative programs in the earth sciences**
- **Provides an accountability and reporting centre for major cooperative geoscience projects in Canada and for Canadian contributions to similar international projects.**

SOME FACTS ABOUT THE CANADIAN GEOSCIENCE COUNCIL

- CGC was a strong voice in establishing Canadian participation in the International Ocean Drilling Program, and has argued vigorously for maintenance of a strong Canadian presence in that program.
- CGC helped to preserve the "right to movement" of earth scientists under NAFTA. This now allows free-movement of professional earth scientists within North America.
- CGC appointed a Professional Registration Committee which spearheaded the registration of earth scientists in British Columbia and Newfoundland. Council has recently approved the creation of a new "Canadian Council of Professional Geoscientists" which will now assume responsibility for professional registration and associated issues.
- CGC annually has presented briefs to the Mines Ministers conferences raising matters of concern to the mining and resource-based communities.
- CGC intervention helped to preserve the Alberta Geological Survey, and assisted the USGS in resisting the threat of dissolution under proposals brought before the U.S. Congress.
- CGC has produced 3 editions of booklets entitled ìExplore Careers in Geoscienceî providing timely advice for students on careers in geological engineering and the geosciences.

Four special CGC Committees (PUBLIC AWARENESS: COOPERATION; ECONOMIC GROWTH; EARTH SYSTEM SCIENCE) have been set up to implement a series of specific projects to enhance the Geosciences in Canada over the next several years. Some of the initial Committee proposals and results to date are given below.

The **PUBLIC AWARENESS COMMITTEE** has the objective to make the public aware of the past, current and future value to Canada of the Earth Sciences. Chaired by Pierrette Tremblay, (ptremblay@gsc.NRCan.gc.ca), this group plans to direct their efforts at three levels: short-term for politicians, medium-term for the public at large, and long-term for children. They are actively gathering information on who is doing what currently in the PAS (Public Awareness of Science) field, both through school curricula and by the Earth Sciences societies.

The **COOPERATION COMMITTEE**, chaired by Jeremy Hall, (jhall@waves.esd.mun.ca), aims are to enhance the understanding, within the Earth Science community, of the challenges each segment faces, the methods that they are utilizing to solve their problems, and to provide support to reach common goals. Initial projects include initiating a debate on geoscience research directions, management of technological change, and new mega-geoscience projects (What mega-project should follow LITHOPROBE

The **ECONOMIC GROWTH COMMITTEE** is focussing on the value added by the Geosciences to the public good and economic growth of Canada. A component of this is to enhance the profile, role, and influence of the Geosciences in the political decision-making process. The Chairperson is Mary-Clare Ward (wards@ican.net). The first phases of this Committee's work involve the gathering of information on the relevance of the Geosciences to the economy of Canada. Examples of where the Geosciences have produced and will produce significant results will be gathered, and an attempt made to quantify the impact in dollar terms. The next phases include the development of a package of this material to be used by the Public Awareness Committee for dissemination.

The **EARTH SYSTEM SCIENCE COMMITTEE**, chaired by Alan Morgan (avmorgan@uwaterloo.ca), is undertaking the task of promoting the ideals of an integrated approach in the teaching and practice of the various Geoscience disciplines. Their activities will be directed toward a wide range of groups: the general public, science teachers, university departments, and practicing professionals. Their initial project is the gathering of a list of distinguished speakers chosen for their interdisciplinary backgrounds and their communication skills. Requests have been made to member societies and a list of over a dozen names and topics have been submitted to date. Topics include such titles as "Global Change and Permafrost", "Volcanism and Tectonics in Western Canada", "Groundwater", and "Megafloods and Catastrophic Events". The objectives of these CGC Distinguished Speakers will be to "spread the word" of the importance of the Earth Sciences (with special emphasis on the Earth Science System) to the public at large, to students, to peers, and to politicians. This could be accomplished through tours arranged by member societies, invitations to speak at conventions or lunches, theme sessions at meetings of learned societies, etc.

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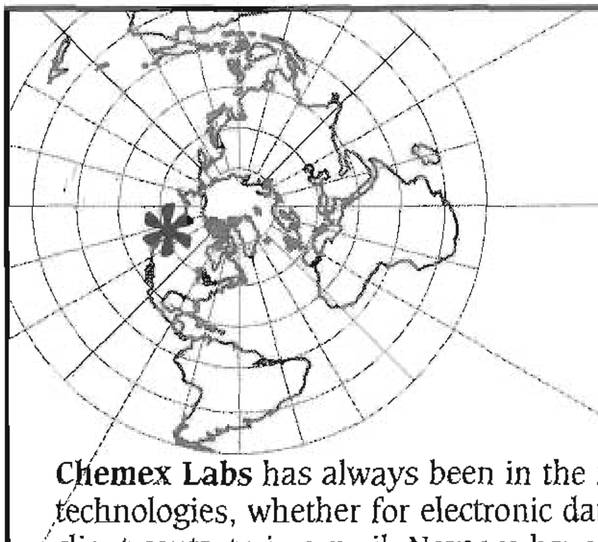

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Update *Continued from Page 13*

Member Societies of the CGC:

Association of Exploration Geochemists
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Mineralogical Association of Canada
Canadian Geophysical Union
Canadian Society of Exploration Geophysicists
Canadian Exploration Geophysical Society
Canadian Geoteehnical Society
Canadian Association of Geographers
Canadian Quaternary Association
Canadian Well Logging Society
Canadian National Chapter: International Association of Hydrogeologists

For more information about the Canadian Geoscience Council and to view the CGC newsletter NEWSNOTES, see their web site at: **http://www.science.uwaterloo.ca/earth/cgc/cgc.html**

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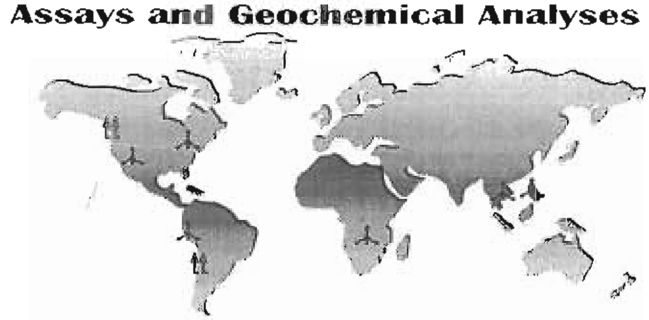

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REGOLITH '98: SUMMARY

by Leigh Bettenay

Regolith, that vexatious mask of cover and weathering products which obscures geology and mineral deposits in many of the world's prospective terrains, continues to attract attention "down under", with the advent in early May of the Third Australian Regolith Conference in Kalgoorlie. The previous events were in '94 (Broken Hill) and '96 (Brisbane).

Under the banner "**Regolith '98: New Approaches to an Old Continent**", the recent conference focussed on new aspects of regolith studies that will potentially lead to breakthroughs in scientific understanding and improved mineral exploration techniques.

Some 210 delegates attended, including about 100 from industry, and about 70 from the various nodes of Australia's forefront regolith research body CRC LEME (Cooperative Centre for Landscape Evolution and Mineral Exploration). The remaining participants comprised other Government and University researchers and students, resulting in a healthy mix of academic, pragmatic, experience and youthful exuberance.

The conference was preceded by two well-attended one-day workshops. Keith Scott, along with Ravi Anand, David Gray and Mel Lintern, conducted the one-day short course "Sampling media in various Australian regolith regimes" on both May 2-3 to a total of 36 participants. Then Ian Tapley, Steve Fraser, Mike Craig and John Wilford ran "Remote Techniques for Regolith Mapping and Characterisation" on May 3 for 25 participants.

Conference sessions ran from 4-6 May with keynote addresses from Ray Smith (CRC LEME) giving the researcher's overview, Leigh Bettenay (Inkanti Pty Ltd) providing an industry perspective, and Graham F. Taylor (CSIRO Land & Water) an environmental viewpoint. A wide variety of both oral and poster presentations followed, with strong industry and mineral exploration focus. Several discussion sessions were a particular highlight for this reviewer, with a number of sacred cows being flogged (to mix a metaphor) or at least coming under close scrutiny from the stewards. These included the veracity of the "RED" scheme in the Yilgarn and elsewhere, interpretative vs subjective regolith mapping, and the quantity and timing of erosional unroofing from the Yilgarn Craton. Other predictable squabbles concerned the definition of laterite versus ferricrete, versus ferruginous duricrust, lateritic detritus etc etc, and of whether the term calcrete should be applied to calcareous nodular materials or to all pedogenic carbonates including "dolocrete".

Two well-run field trips were organised by Ian Robertson, with assistance from other LEME stalwarts Charles Butt, Ravi Anand, Allison Britt, Mark Paine, Mel Lintern and Ken McQueen. The first was a half-day trip run as part of the main conference, with visits to several key regolith sites exposed by open pit mining operations in the immediate vicinity of Kalgoorlie including the Superpit, Mt Percy, Greenback, and True Sons sites. A post-conference field trip ventured further afield including visits to the Cawse and Mt Keith nickel deposits, the Baseline and Bronzewing gold deposits, the Mt Joel gold prospect, plus key sites for examination of regolith profiles and products including calcrete and silcrete.

Regolith '98 was sponsored by CRC LEME and organised by the Australian Mineral Foundation (AMF). Abstracts and proceedings are available from both bodies (http://

proceedings will be published in about three month's time if all goes to plan. Also of note to regolith aficionados is that proceedings for the 1996 conference "The State of the Regolith" have recently become available as Special Publication No 20 of the Geological Society of Australia. Details can be obtained from the CRCLEME web sites.

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SETTING NEW STANDARDS: AN INTERIM REPORT

Proposed Standards for Public Mineral Exploration and Mining Companies

An interim report by this title has been released by the Toronto Stock Exchange and Ontario Securities Commission 'to set standards for mineral exploration and mining companies... and how exploration programs should he carried out and the results reported and disclosed.' The 79 page report released in June will be revised later this year following input from the public. No mention is made of the Busang fiasco, but this is clearly an effort to boost investor confidence in the mineral industry. The review ranges from law enforcement to the leadership of a Qualified Person, but key parts deal with field sampling methods, assaying requirements, and quality assurance programs. The recommendations of the Task Force will have significant implications for many members of AEG. For further information contact: TSE/OSC Mining Standards Task Force, c/o Alice Janisch, Toronto, CANADA: Fax: 1.416.947.4398 E-mail: ajanisch@tse.com

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CALENDAR OF EVENTS

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

- August 9-14, 1998, **General meeting of the International Mineralogical Association,** Toronto, Canada, INFORMATION: E. Schandl, Dept. of Geology, University of Toronto, Toronto, Canada M5S 3B1. TEL 416-978-7084, FAX 416-978-3938, email: ima98@quartz.geology utoronto.ca.
- August 23-27, 1998, **American Chemical Society National Meeting,** Boston, Mass. INFORMATION: Sally Pecor, ACS News Service, 1155 16th St., NW, Washington, D.C. 20036, phone 202-872-4451, fax 202-872-4370, e-mail: s_pecor@acs.org.

Continued on Page 16

CALL FOR PAPERS / POSTERS

19TH INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM
VANCOUVER, APRIL 11-16, 1999

EXTENDED ABSTRACTS ARE REQUIRED BY OCTOBER 1, 1998.

The Technical Sessions will include the following topics but authors are encouraged to submit papers on all aspects of exploration geochemistry. Contributions from the mineral exploration industry and comparative studies of different methodologies are especially welcome.

- **Integrated exploration case histories — discoveries and disappointments**
- **Search for concealed deposits (including diamonds)**
- **New sampling methodologies at all scales**
- **Data presentation and interpretation**
- **Analytical methods (including quality control)**
- **Lithogeochemistry**
- **Envirogeochemistry related to the minerals industry.**

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Calendar of Events *Continued from Page 15*

■ August 30-Sept. 4, 1998, **Clay mineralogy and petrology,** Brno, Czech Republic, International Geological Correlation Programme Project No. 405. INFORMATION: Petr Sulovsky, Dept. of Mineralogy, Petrology, and Geochemistry, Masaryk University, Kotlarska 2, CZ 611 37 Brno, Czech Republic, FAX: 420-541211214, email: clays@sci.muni.cz.
■ September 22-25, 1998. **International Meeting of Gold Exploration and Mining in New Spain,** Oviedo, Spain. INFORMATION: Daniel Arias Priero, Facultad de Geología. Universidad de Oviedo C/Arias de Velasco s/n, 33005 Oviedo, Spain. FAX (34)8-5103087. Email: arias@asturias.geol.uniovi.es.
■ October 13-16, 1998, **III Seminario Minero Sonora 2000,** Mining development of Mexico in the XXI century, Hermosillo, Sonora, Mexico. INFORMATION: Mario Campos, Asso. Of Mining, Metalurical, and Geological Engineers of Mexico, Aldama #73, Col. San Benito, Hermosillo, Sonora, Mexico, phone: 52-62-105510, fax: 52-62-141666. E-mail: fquerol@rtn.uson.mx.
■ October 26-29, 1998, **Annual meeting of the Geological Society of America,** Toronto, Ontario, Canada. INFORMATION: Pierre Robin, Dept. of Geology, 22 Russell St., Toronto, ON M5S 3B1, Canada, TEL 416-978-3022, FAX 416-978-3938.
■ November 8-9, 1998, **Geology, mineralogy, and human welfare,** National Academy of Sciences Colloquium, Irvine, California. INFORMATION: Edward Patte, NAS-146, 2101 Constitution Ave., NW, Washington, DC 20418, 202-334-2445, fax: 202-334-2153. E-mail: epatte@nas.edu.
■ November 9 - 12, 1998, **Fifth Annual African Mining Investment Symposium, and Arab Mining Investment Symposium,** Marrakech, Morocco. Field excursions before and after. Sponsored by MIGA (World Bank). INFORMATION: Ms. L. Gorman at MIGA, Washington D.C., fax 1-202-522-2650, e-mail: lgorman@worldbank.org.
■ April 11-16, 1999, **19th International Geochemical Exploration Symposium,** Vancouver, Canada. INFORMATION: Venue West Conference Services Ltd., #645-375 Water Street, Vancouver, BC, Canada V6B5C6, TEL. 604-681-5226, FAX 604-681-2503, email: congress@venuewest.com.
■ May 26-28, 1999, **Geological Association of Canada-Mineralogical Association of Canada Joint Annual Meeting,** Sudbury, Ontario, Canada. INFORMATION: Dr. P. Copper, Dept. of Earth Sciences, Laurentian University, Sudbury, Ontario P3E 2C6, TEL. 705-675-1151 (ext. 2267), FAX: 705-675-4898, e-mail: gacmac99@nickel.laurentian,ca.
■ July 7-10, 1999, **Geocongress '98,** University of Pretoria, South Africa. INFORMATION: P.O. Box 798, Pretoria, 0001 South Africa, fax: 012-841-1221, e-mail: eaucamp@geoscience.org.za.
■ October, 25-28, 1999, **Annual Meeting of the Geological Society of America,** Denver, Colo. INFORMATION: TEL 1-800-472-1988, meetings@geosociety.org.
■ April 24-28, 2000, **5th International Symposium on Environmental Geochemistry,** Cape Town, South Africa. INFORMATION: 5ISEG, Department of Geological Sciences, University of Cape Town, Private Bag, Rondebosch, 7701, South Africa,

Continued on Page 18

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102	January 1999	November 30, 1998
103	April 1999	February 28, 1999
104	July 1999	May 31, 1999

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■ May 15-18, 2000, **Geology and ore deposits 2000: The Great Basin and beyond**, Reno/Sparks, Nevada, USA. INFORMATION: Geological Society of Nevada. 702-323-3500, ax 702-323-3599, e-mail: gsnsymp@nbmg.unr.edu.
■ August 6-17, 2000, **31st International Geological Congress**, Rio de Janeiro, Brazil. INFORMATION: Secretariat Bureau, Casa Brazil 2000, Av. Pasteur, 404 Urca, Rio de Janeiro-RJ-Brazil, CEP 22.290-240, phone 55 21 295 5847, fax: 55 21 295 8094. E-mail: 31igc@31igc.org, http: www.31igc.org.

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

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RECENT PAPERS

This list comprises titles that have appeared in major publications since the compilation in **EXPLORE** Number 100. 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). Publicarions 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**.

Andersen, J.C.O., Rasmussen, H., Nielsen, T.F.D., and Ronsbo, J.G., 1998. The Triple group and the Platinova Gold and Palladium Reefs in the Skaergaard Intrusion: Stratigraphic and Petrographic Relations. EG 93(4): 488-509.

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Cardoso-Fonseca, E. and Ferreira da Silva, E., 1998. Application of selective extraction techniques in metal-bearing phases identification: a South European case study. J. Geochem. Explor. 61: 203-212.

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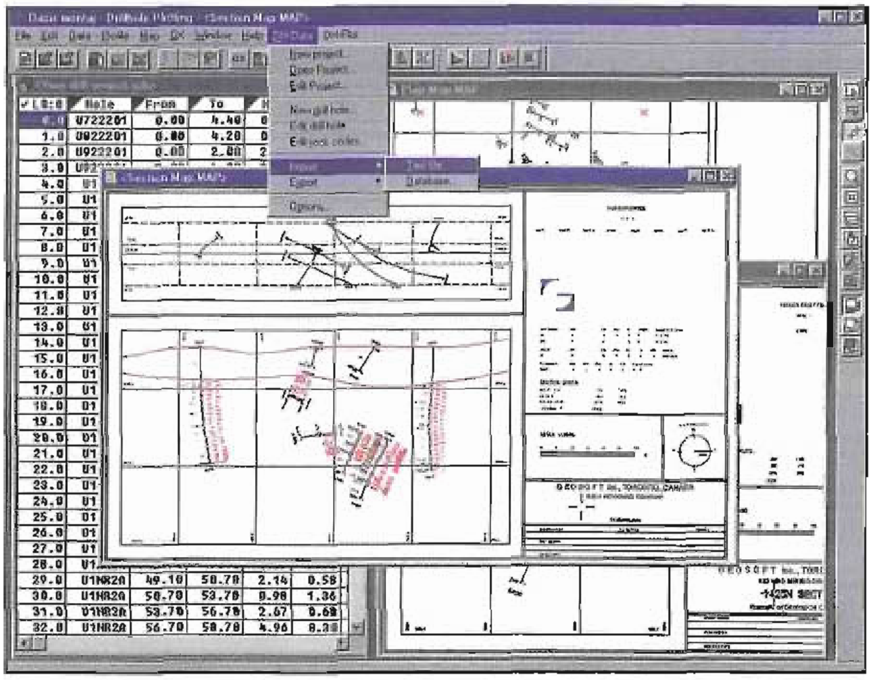

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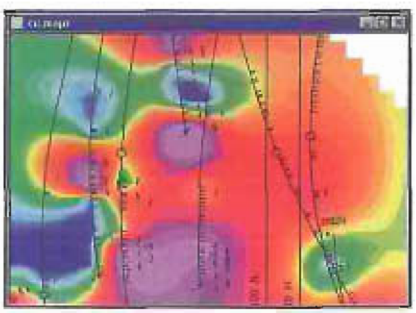

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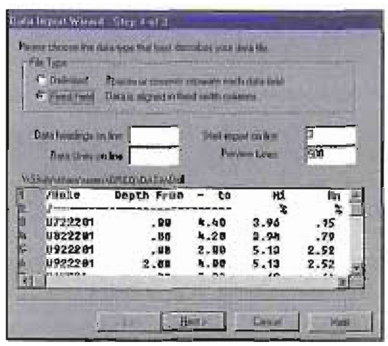

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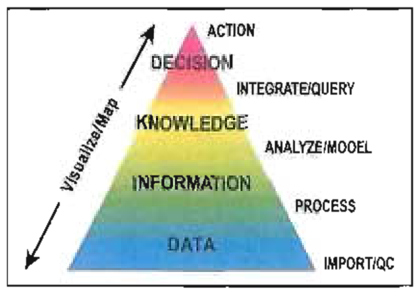

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Plate IV

Integration of Topography with Multi-element Geochemistry

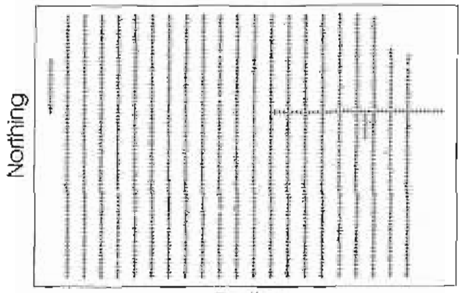

Figure 1
Soil Sample Grid, 1665 Samples
Elements: Au, Cu, Pb, Zn, As,Sb, Ba, Ca, Cd, Co, Cr, Fe, Ga, K, La, Li, Mg, Mn, Nb, Ni, Sc, Sr, Ti,V, Y, Zr, Hg

Investigate multi-element saprolite geochemistry using multivariate methods.

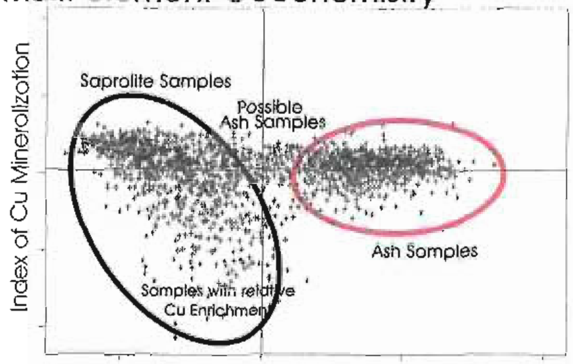

Figure 2
Identification of volcanic ash from multi-element geochemistry using multivariate methods.
Each point represents a sample

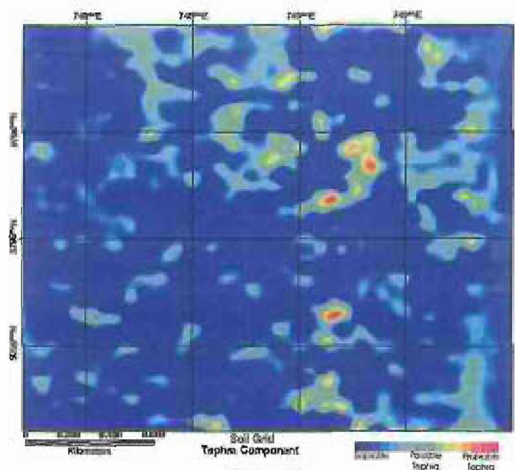

Figure 3
Interpolation and Imaging of the Index of Soil Type

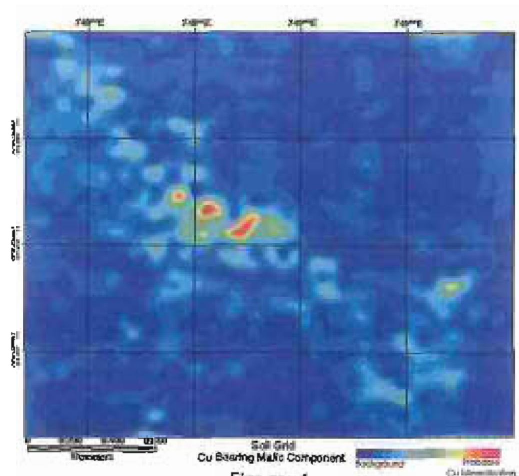

Figure 4
Interpolation and Imaging of the Index of Cu Mineralization

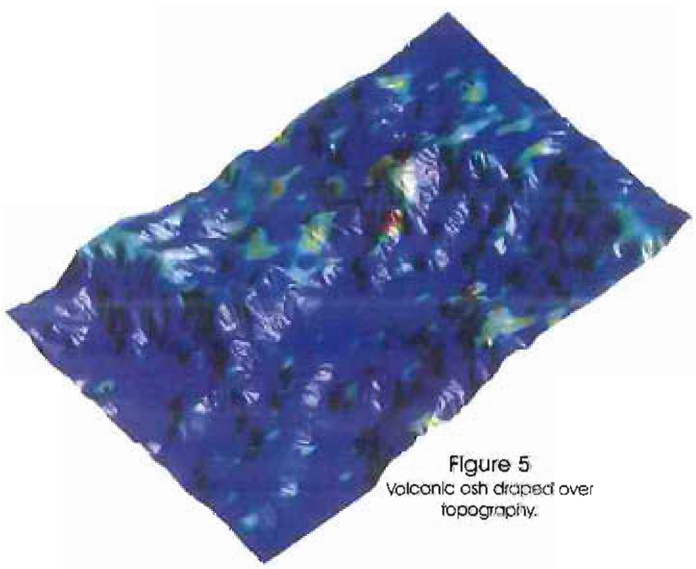

Figure 5
Volcanic ash draped over topography.

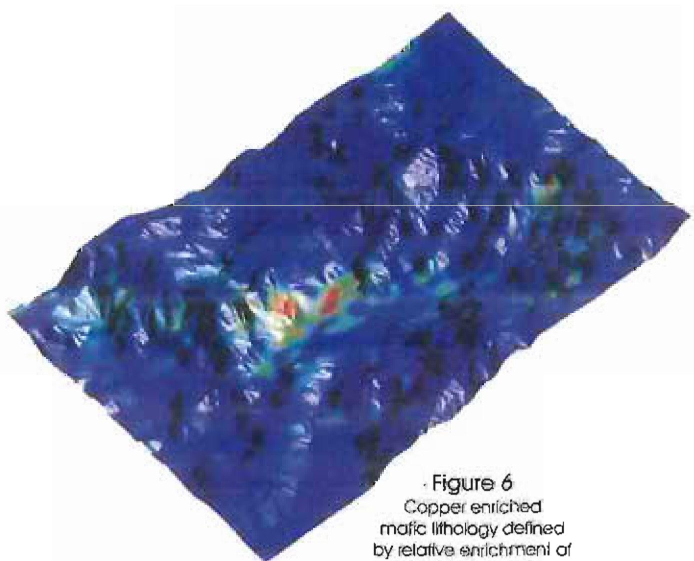

Figure 6
Copper enriched mafic lithology defined by relative enrichment of Mg, Co, Cr and Cu.

TECHNICAL NOTE

Integration of Topography with Multi-element Geochemistry

by Barry Smee and Eric Grunsky

Multi-element geochemical data can be effectively interpreted through the use of multivariate statistical techniques, imaging methods and merging with digital topographic information. This is illustrated using the results of a geochemical sampling program in Indonesia. Difficulties were encountered when the interpretation of selected elements was attempted. Patterns appeared to be discontinuous and erratic. However the application of multivariate statistical methods identified two distinct geochemical associations: recent volcanic ash, and a saprolitic soil profile containing a mineralized zone of Cu associated with mafic volcanic rocks. Maps and figures are shown on Page 20.

Figure 1 shows the soil sampling grid from which 1,665 samples were collected and analyzed for Au, Cu, Pb, Zn, As, Sb, Ba, Ca, Cd, Co, Cr, Fe, Ga, K, La, Li, Mg, Mn, Nb, Ni, Sc, Sr, Ti, V, Y, Zr, and Hg. The samples were analyzed using aqua regia digestion and an ICP-ES finish.

The results of the application of multivariate methods highlight common element associations and distinct sample populations from which an index of soil type (discrimination between saprolite and ash) and an index of potential Cu mineralization were observed. Two distinctive populations are displayed in Figure 2; one group shows a trend towards Cu enrichment along the Y-axis. Along the X-axis, another group of samples shows little dispersion relative to those samples associated with Cu-enrichment. This group represents material that is interpreted to be volcanic ash that overlies the saprolitic soils.

Figures 3 and 4 show the results of interpolating and imaging these two indices over the 1665 samples. Figure 4 shows a clear northwest trending pattern associated with Cu enrichment and mafic rocks. This pattern is coincident with the regional stratigraphy, which also trends northwesterly. Figure 3 is a plan view of the volcanic ash indices, and is difficult to interpret in the context of known stratigraphy, alteration or mineralization.

The interpretation of these images is significantly enhanced when integrated with a digital elevation model of the area. The elevation ranges from 1180 to 1350 meters. Figure 6 displays a zone of elevated Cu enrichment associated with mafic volcanic rocks trending northwesterly along the western slopes and coincident with the regional stratigraphy. Figures 5 shows that the population of samples, interpreted to be volcanic ash from the right side of figure 2, occurs along hill tops and the eastern slopes of the hills. This interpretation is supported by observations of the sampled materials and reports by geologists working in Indonesia where this phenomenon is commonly observed. The application of fractal methods also shows that the distribution of the ash represents a unique spatial pattern which is distinct from the pattern associated with the regional stratigraphy.

This example highlights the effective use of multivariate statistical methods for distinguishing between different sample media as well as the isolation of geochemical trends that define zones of possible mineralization. The use of these types of multivariate methods isolates relationships of the elements that are difficult or impossible to see by examining individual elements. The application of multivariate techniques integrated with digital elevation models provides a more effective way of visualizing and interpreting ICP produced analyses.

Additional details about the application of these methods will be made available in the future. For further information contact the authors.

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President's Message

Continued from Page 2

however, the potential rewards in dissemination of information on best practice and increased membership representation in the minerals industry are an open goal waiting to be scored.

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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 David Smith, 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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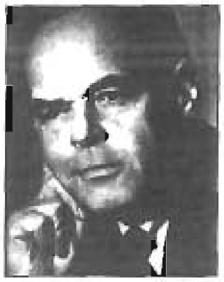

Professor Harry Warren (1904-1998)
OC, OBC, D.Sc., D. Phil., FRSC, FGSA
Founding Member of the AEG

During his richly productive 93 years, Dr. Warren had a remarkable range of interests and achievements, and his limitless enthusiasm touched and influenced many lives. In his early years he excelled in several sports, notably rugby, cricket, grass hockey and track events. As a sprinter he held track records for the 100, 220 and 440 yard events at the University of British Columbia, and went on to be a member of the Canadian track team in the 1928 Amsterdam Olympics. The same year he equaled the world record in the 100 yard dash on grass at a meeting in Dublin.

He was a Rhodes Scholar at Oxford (1926-1929), completing his doctoral disseration on lead and zinc deposits of southwestern Europe. Following a period of post-doctoral research at CalTech he joined the Department of Geology and Geography at the University of British Columbia in 1932 from where he inspired generations of students, colleagues and the many professionals with whom he came into contact for 41 years until his retirement. During his "retirement" he remained active as ever for the next 20 years as an honorary, then emeritus professor.

Harry Warren rightly became renowned as the "Father of Biogeochemistry." Many of his 198 publications described the results of a vast array of tests on the relationship between plant chemistry and mineral deposits, conducted at numerous sites across Canada. His fertile mind led to a range of rather exotic tests, like the analysis of bee pollen and trout livers to assist in locating mineral-rich areas, and the use of dogs in the bush to sniff out sulphide-rich boulders. These studies have been the inspiration for others to build on the foundation of observations and information that he laid, especially in light of the developments in low cost multi-element analytical technology.

His profound interest in the distribution of trace elements in all natural materials was not directed purely at mineral exploration, but also at the relationship between trace element concentrations and health. He was a pioneer in environmental geochemistry and was a founding member of the Society of Environmental Geochemistry and Health. In 1973 his efforts and achievements in this area resulted in his installation as an honorary member of the Royal College of General Practitioners in the United Kingdom. In his latter years he became increasingly interested in medicinal plants and their properties. On this and a wide range of biogeochemical subjects I was fortunate to have many fascinating conversations with Harry Warren — both in his office at UBC where he might demonstrate the variations in bee pollens that he had collected, and later over tea at his lovely old house close to the University where he would produce books on medicinal plants for discussion.

I have read many accounts and descriptions of Harry Warren, such as his "blazing speed" as an athlete, his "boundless energy," his "unbridled enthusiasm," his "mischievous twinkle" and his renowned sense of humor. A lasting phrase for me was when I visited him in hospital in 1997, at a time when speaking was a considerable effort for him. His response to some new developments that I had recounted was "never a dull moment". These were his last words to me, and they really epitomize the full and adventurous life of this remarkable man who has, indeed, made his permanent mark on history.

Colin E. Dunn
Geological Survey of Canada (emeritus) and Consulting Geochemist, Ottawa, Canada

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(Signature of applicant)

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(Signature of applicant)

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