



Optimised Detection Limits for Multi-Element Geochemical Analysis

A few years ago some rock samples were submitted to our laboratory by a client requiring gold analysis. We found the levels to be <1 ppb in all samples and reported them as such. The client then came back to us asking how much gold that was. Even after explaining the samples were below the detection limit, the client still replied: “Yes, I understand. But how much is there?”

The concept of a detection limit has always been difficult to explain, since it can be expressed in so many ways. It is also a somewhat controversial subject in geochemistry, as there is a commercial advantage to having lower reporting limits and seemingly offering the geologist better information about their samples. There is also the oft believed concept that a lower detection limit means that one method is ‘better’ than another one. This is not necessarily true as there are many factors that influence the efficacy of a method – sampling procedure, homogenization and digestion procedure to name but three. Nevertheless, there is a decades long trend in the geochemical laboratory industry towards reporting lower concentration levels of elements, but what is the value of these data, in terms of practical use and reliability, particularly given field sampling representation and sample homogeneity issues? Furthermore, what constitutes a method detection limit as opposed to an instrumental detection limit and what is the best way of determining it?

It is the responsibility of the analytical chemist to ensure that data are meaningful, and this becomes more important as lower element concentrations are reported. “Instruments do not write scientific papers, since they have no opinions. Scientists must give them voice.” stated Nobel laureate John Polanyi recently, adding that “truth . . . is the astonishing belief that unites us as scientists” (Polanyi 2015). It was with this goal in mind that we decided to investigate the concept of detection limit for geological analysis using inductively coupled plasma mass spectrometry (ICP-MS) and mobile metal ion (MMI®) extractions as examples of technique and methodology. The rise of ICP-MS in the past two decades, combined with advances in geochemistry that have championed the use in exploration for a large array of pathfinder elements, has resulted in laboratories offering a wide range of elements and digestion procedures. SGS Minerals Services, for example, offers standard packages for a variety of methodologies, from weak leaches through acid digests to fusion procedures that offer in excess of 55 elements reported to very low concentrations. For this study, MMI® was chosen as the methodology as it is a single pass analysis that provides data

on a wide range of elements. In addition, samples from all over the world are analysed and this variety provides a good cross-section of different terrains and soil types.

Mobile Metal Ion (MMI®) Analysis

MMI® is one of a number of weak partial extraction methods used in soil geochemistry (Mann et al. 1998). It works on the principle that mobile ions from buried ore deposits migrate to the water table and then are transported towards the surface. Over time they accumulate just below the organic layer of the soil in the active plant root zone. These mobile ions are preferentially extracted from the substrate by using a ligand based solution (MMI-M) that releases them from the soil particles. The resultant solution is then measured using ICP-MS for a wide range of elements. MMI-M has been used in a wide variety of geochemical exploration programs since 2004 due to its high selectivity, low matrix interferences and low background noise (Mann 2010). However, recent improvements in instrumentation and methodology necessitated a review of whether these reporting limits were appropriate for each element.

ICP-MS

ICP-MS offers very low detection limits for many elements, even after the typical digestion procedures required for geological samples. It can do this because of its architecture – the argon plasma is an extremely efficient heat source that can ionize elements in a solution which can then be extracted and separated by a quadrupole mass spectrometer. An electron multiplier detector allows the measurement of very low concentrations of many elements. Due to the fast scanning of the quadrupole, analysis of the majority of elements in the periodic table can be measured in a matter of a few minutes. To put the instrument sensitivity in perspective, a 0.1ppb detection limit for gold for example, is approximately the same as picking out one person from the population of the entire world. The main factors governing detection limits by ICP-MS include:

- **Ionization Potential:** the degree to which a particular ion behaves in the plasma and forms positive ions will govern the amount of signal achieved for it. For example, cobalt is 93% ionized in the plasma, whereas platinum is only 63% ionized and will give less signal for the same concentration (Houk 1986).
- **Isotopic Abundance:** Mono-isotopic elements such as cobalt at mass 59 will have a greater sensitivity than platinum with six isotopes, the largest of which is 33% abundance.

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President's Message

Welcome to 2015 and I hope that the New Year is starting well for all members of the AAG, their families, and the rest of the geochemical community. By the time you read this, we will be fast approaching our biannual conference, the International Applied Geochemistry Symposium (IAGS), which, as mentioned before, is being held in Tucson, Arizona, USA in April. Although 2014 was another difficult year in the applied geochemistry field, with the continued softness in global mineral exploration and related environmental fields, the conference is shaping up to be another great showcase for applied geochemistry. It follows on from the highly successful IAGS conference in New Zealand in 2013. As of early January, the number of registrants for the conference, field trips and workshops as well as abstracts received was progressing well. The Chair of the Local Organizing Committee, Erick Wieland, and his team have been doing an outstanding job.

The New Year brings in a new group of Association of Applied Geochemists Councillors. We welcome in particular Juan Carlos Ordóñez Calderón, who is a first time councillor, and Dave Cohen and Ray Lett, who are returning as councillors after a break of a few years. Finally, Tom Molyneaux, Peter Winterburn, and Peter Rogers were re-elected for a second two-year term. I look forward to working with all of you this year.

After fourteen outstanding years as Editor-in-Chief of our Association's journal, *Geochemistry: Exploration, Environment, Analysis* (GEEA), Gwendy Hall has retired. Taking on this important role is Kurt Kyser. The AAG and our journal are extremely fortunate to have someone of



Kurt's caliber to replace Gwendy. Gwendy has written a more complete introduction and biography of Kurt for this issue of EXPLORE and I encourage you to read it. One of the new features for GEEA that was introduced in 2014 is Online First, for papers that have been accepted and formatted, but not yet published in print. With only four issues of GEEA per year, this feature allows for more rapid dissemination of our research efforts. At the time of this writing, there are fourteen papers at the Online First site (<http://geea.geoscienceworld.org/content/early/recent>), including some papers that were presented at the 26th IAGS in Rotorua, NZ in late 2013.

In closing, I wish you all the best for 2015, and I look forward to seeing you all at the 27th IAGS in Tucson, AZ.

Matt Leybourne
President



Recent issue of Elements

Volume 10, December 2014

Graphitic carbon, with its diverse structures and unique properties, is everywhere at the Earth's surface. Strategically located at the interface between the lithosphere, biosphere, hydrosphere, and atmosphere, graphitic carbon constitutes a major terrestrial carbon reservoir. Natural and synthetic graphitic carbon is also used in a broad range of applications. Graphitic carbon has played an important role in human history (for example, coal mining) and is now a building block of nanotechnology, but this remarkable material is also an active player in geological processes.

From Beyssac and Rumble, *Elements* v. 10, p. 415-420

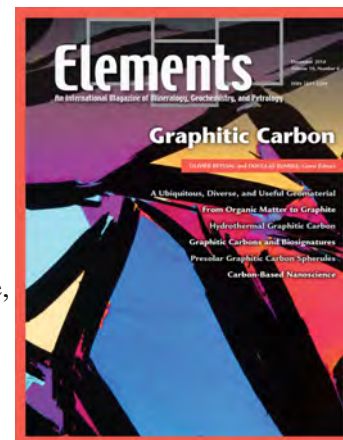


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Notes from the Editor

Happy New Year! The March 2015 issue of **EXPLORE** features one technical article about detection limits for multi-element geochemical analysis by Nick Turner. **EXPLORE** thanks all contributors and reviewers for this first issue of 2015: Steve Amor, Peter Bradshaw, Patrice de Caritat, Tony Christie, Gwendy Hall, Evan Hastie, João Larizzatti, Alex Laudadio, Ray Lett, Matt Leybourne, Ryan Noble, Nick Turner, Erick Weiland, and Peter Winterburn. I look forward to seeing you in April in Tucson at the 27th IAGS.

Beth McClenaghan, Editor



Optimised Detection Limits for Multi-Element Geochemical Analysis... *continued from page 1*

- Measurement time of the element in the solution.
- Contamination: Due to its abundant sensitivity, small traces of any element will be detected from sampling instruments, sample containers, reagents, glassware etc.
- Matrix Effects: The matrix itself can cause issues with signal suppression if it is too concentrated in the plasma.
- Interferences: Due to the high temperature of the plasma, polyatomic species from elements in the sample can be formed that interfere with the analyte, such as $^{43}\text{Ca}^{16}\text{O}$ on ^{59}Co or $^{179}\text{Hf}^{16}\text{O}$ on ^{195}Pt (May & Wiedmeyer 1998).

Thus it is important to understand what the issues are when determining a detection limit for an element in a particular matrix. Whilst the first four are somewhat constant, the last two can vary considerably from sample to sample, especially in geological samples. Matrix effects are minimized by the use of sample dilution, internal standards and matrix matched calibration standards but these approaches do have adverse effects on the detection limit for a method. Interferences are particularly difficult to deal with in geological samples compared with most other chemical analyses, because of the mineralogical variety and the subsequent changes in elements concentrations in any given sample. Whilst blood, seawater and other heavy matrices can be difficult to deal with, they are at least homogenous – you are not going to suddenly get a blood sample with 1% zirconium for instance, whereas the major elements in geological samples vary with each batch, and often dramati-

cally within a batch as well. Interferences can be corrected for mathematically or reduced using a variety of cell-based techniques. In the latter approach, a cell is placed before the quadrupole and filled with either an inert or reactive gas. The gas collides or reacts with the ions in the system, breaking up polyatomic interferences but allowing the ion of interest to exit the cell into the quadrupole (Tanner et al. 2002). Both concentration range and interferences have to be taken into consideration when determining detection limits as they affect the overall measurement uncertainty of the analytical process.

Standard Approach for Determining Detection Limits

Typically, a detection limit is based on instrument sensitivity combined with a sense of the crustal abundance of an element. This leads to several ranges of detection limits – higher levels (ppm and %) for the major elements such as Fe, Ca, Mg etc., medium levels for elements like base metals, Ba, Sr etc. (5 to 10ppb) and then low levels for elements such as precious metals (0.1 to 1ppb). This is particularly relevant in ICP-MS, where there is no point in having a very low detection limit for iron, for example, since all samples tend to contain appreciable concentrations. A common approach is to take ten method blank solutions and then measure them against the calibration. The limit of

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Optimised Detection Limits for Multi-Element Geochemical Analysis... continued from page 3

detection (L.O.D.) is defined as 3 X SD (standard deviation) of these solutions. This infers that the analyte can be detected above the background, but not necessarily quantified. A better measure is the limit of quantitation (L.O.Q.) defined as ten times the standard deviation (10 X SD) of ten method blanks measured against the calibration. Table 1 illustrates these results for several MMI-M elements. These values are then evaluated with the typical range of the elements in samples and known interference issues to arrive at values for the detection limits as shown in the table. The Pd detection limit, for instance, is significantly higher than the calculated value due to the presence of interferences from samples.

	Mn	Co	Cu	Pd	Pt	Au
Blank 1	0.05	0.23	2.64	-0.005	0.006	-0.004
Blank 2	0.03	0.14	1.58	0.009	0.029	-0.013
Blank 3	0.02	0.04	2.69	0.015	0.023	0.014
Blank 4	0.06	0.20	2.39	-0.016	0.003	-0.009
Blank 5	0.05	0.19	2.06	0.005	0.040	-0.013
Blank 6	0.02	-0.00	1.67	-0.006	0.011	-0.008
Blank 7	-0.06	0.06	2.33	0.010	0.040	-0.008
Blank 8	0.02	0.07	2.32	-0.012	0.023	-0.003
Blank 9	-0.04	0.12	2.46	-0.002	0.039	-0.016
Blank 10	-0.03	0.07	1.81	-0.007	0.028	-0.008
Average	0.013	0.113	2.193	-0.001	0.024	-0.007
SD	0.04	0.08	0.40	0.010	0.014	0.008
LOD	0.1	0.2	1.2	0.03	0.04	0.03
LOQ	0.4	0.8	4.0	0.10	0.14	0.08
Det Lt.	10	5	10	1	0.1	0.1

Table 1: An example of a common approach to the determination of the limits of detection and quantitation using 3X and 10X standard deviations (SD) of 10 method blanks for selected MMI-M elements. All results in ppb.

This approach does give justifiable detection limits but it suffers from some drawbacks:

- it is based on a single idealized test usually measured on a cleaned instrument
- there is no allowance for differences in instrument performance with time
- it does not necessarily reflect typical sample levels.

In order to address these shortcomings, a more holistic approach to the detection limit was taken by using a database of method blanks and duplicate analyses. The concept of optimising the detection limit to the levels that can both be seen and are seen in a technique, using real samples over time, was the basis of this approach, with the idea being to achieve an appropriate detection limit for each element in a methodology that would allow the geologist to use the data to its fullest extent.

Determination of Optimized Detection Limits

The long term analysis of method blanks was used to monitor the analysis over time. The use of more than 1200 randomly placed method blanks meant that all scenarios of instrument performance and sample concentrations were covered and allowed for. Here, the detection limit of an element must fall below the 95th percentile of the method blanks (Quarles et al. 2014). Furthermore, the duplicates over the same period of time were investigated to see the typical levels of elements in samples. This is invaluable as it informs whether the detection limit is appropriate for the element. As an example, the results for Cu are given in Figure 1. (See page 6.) It can be seen that the 95th percentile for the method blanks is 10 ppb which is where the detection limit is set. An analysis of the duplicates indicates that Cu tends to be relatively abundant in samples, with 90% of samples containing greater than 100 ppb. Because the lowest quartile of results is considered background in terms of anomaly determination, it can be seen that an optimised detection limit of 10 ppb will be appropriate to highlight any potential anomaly, but will not be affected by variation in the background value over time.

This approach was taken for all elements in the MMI-M scheme and example elements are given in Table 2.

	Mn	Co	Cu	Pd	Pt
No. of Method Blanks	1335	1340	2170	1257	1272
Blank: 95th Percentile	13	0.8	9.9	0.04	0.01
Current Detection Limit	10	5	10	1	1
New Detection Limit	100	1	10	1	0.1

Table 2: New reporting limits based on a combination of the LOQ, long term 95th percentile blank data and levels found in samples. All results in ppb.

It can be seen that some detection limits have been lowered, some remain the same, and Mn has increased. Cobalt for example, has been lowered from 5 ppb to 1ppb, since the 95th percentile of the blanks is 0.8 ppb. Furthermore the distribution of duplicates indicates that 50% are in the 1 to 50 ppb range. Thus 1ppb is an appropriate detection limit



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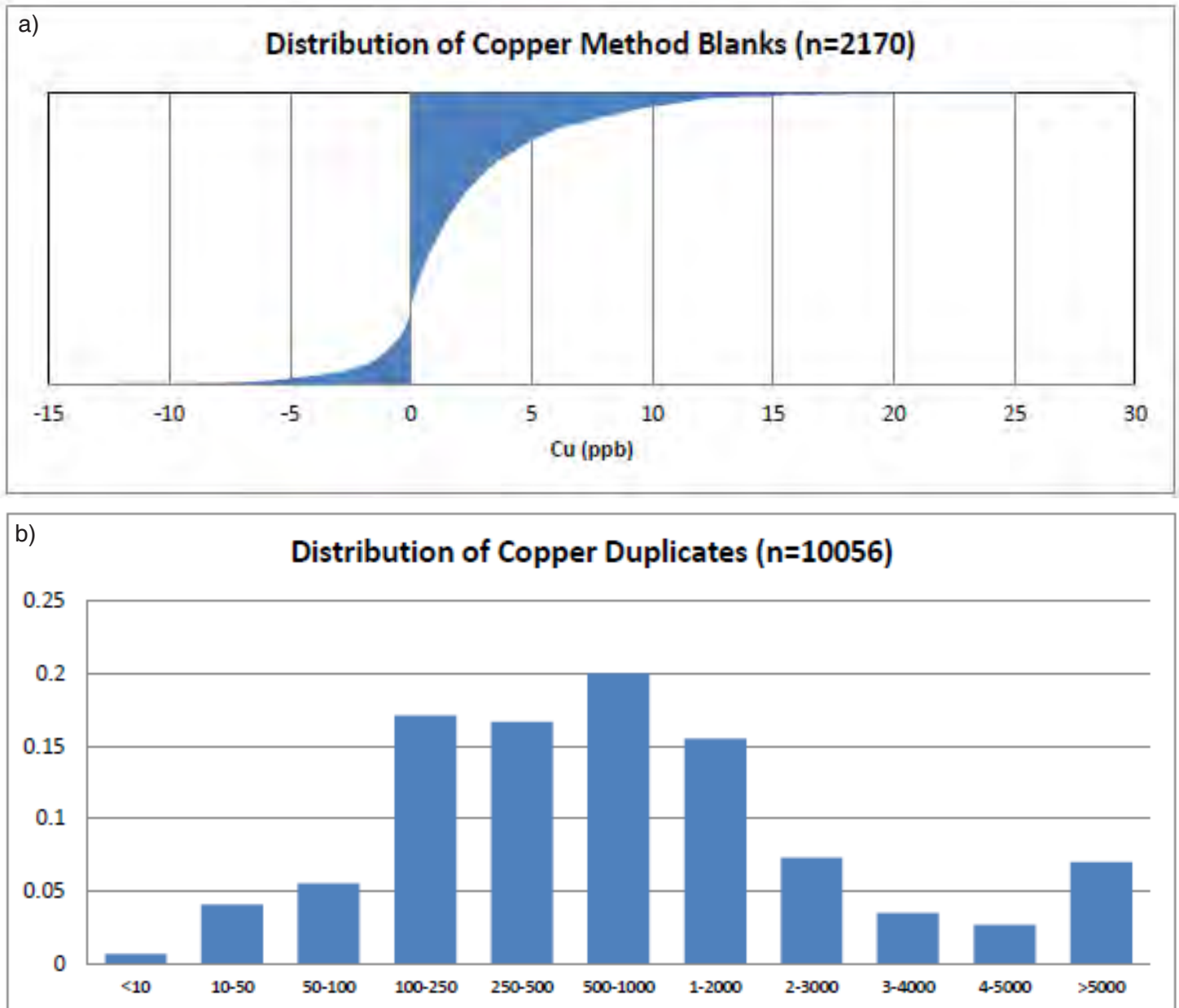


Figure 1: Analysis of long term method blank and duplicate data for Cu in order to determine the optimised detection limit. a) Method blank distribution for Cu. Bar chart illustrates the spread of 2170 method blank results around the origin. The 95th percentile value for the method blanks is 10 ppb. b) Distribution of duplicates for Cu showing that the majority of values are greater than 100 ppb in solution, indicating that the optimized detection limit is appropriate at 10ppb. Results are in ppb.

for the delineation of anomalies (Figure 2). The results for Mn illustrate that the 95th percentile method blank is at 13ppb. However, analysis of the duplicates indicates that 95% of samples are much greater than 100 ppb. Thus for Mn the detection limit has been set at 100 ppb to reflect the high levels found in all samples. This approach was applied to all elements and it was found that many elements required a lower reporting limit, based on duplicates and method blank data. Calibration ranges were also adjusted where necessary to reflect the levels found for some elements. Full results are given in Table 3 (see page 8). These

robust detection limits mean that low concentration results can be better used by the geologist for data evaluation.

A couple of important elements do not achieve reporting limits that make them particularly useful for anomaly targeting due to low concentrations found in samples, or interferences causing restrictions on reporting limit. Platinum does not show anomalies particularly well because it occurs at very low levels, has low ionization in the plasma, and has six isotopes resulting in diminished signal for each. Similarly, palladium is hard to measure at low concentrations due both to its relative insensitivity, low concentra-

Optimised Detection Limits for Multi-Element Geochemical Analysis... *continued from page 6*

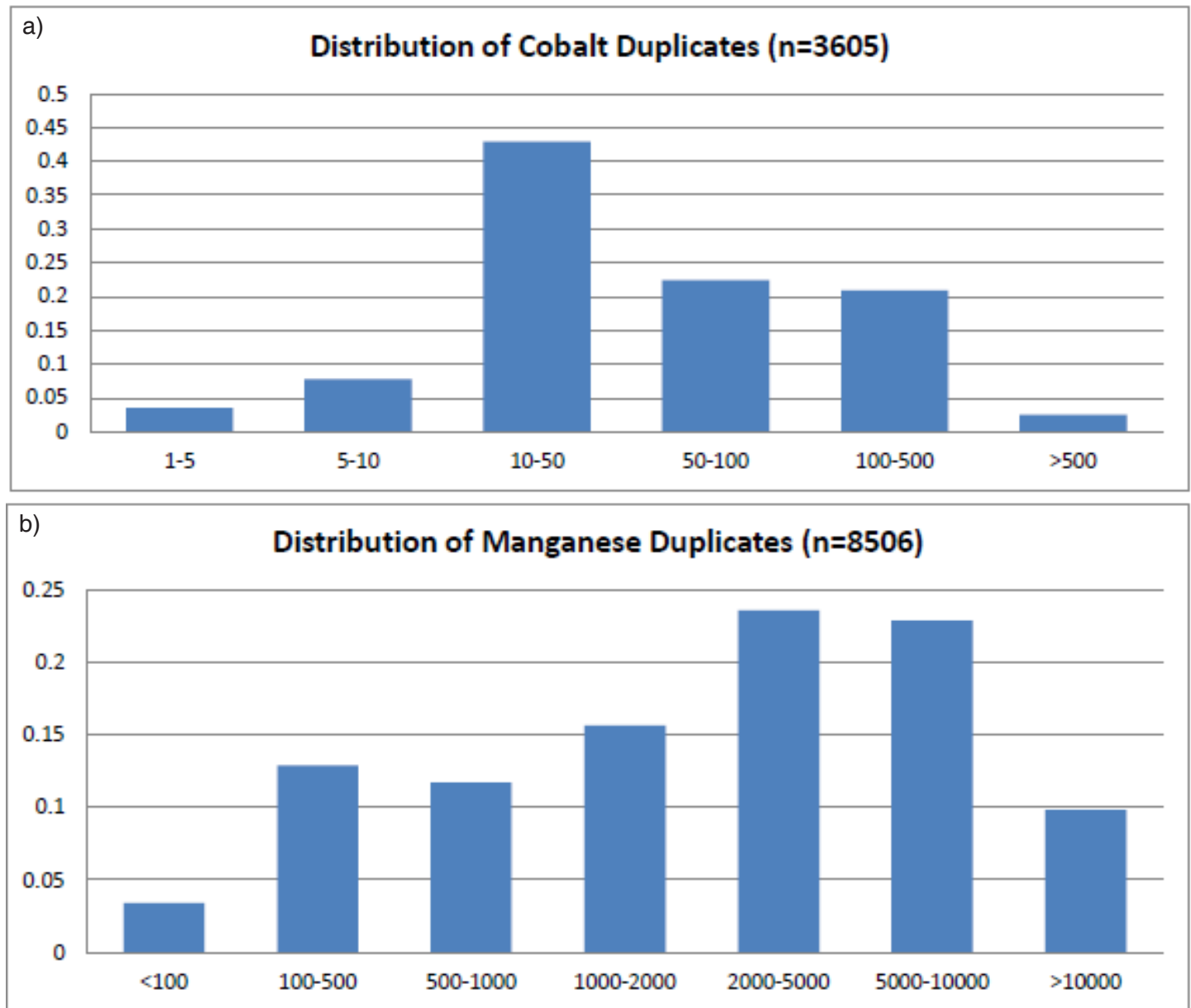


Figure 2: Analysis of long term duplicate data for Co and Mn for the determination of detection limits. a) Most Co duplicates are >10 ppb, so a detection limit lower than 1 ppb is not appropriate for detecting anomalies. b) Distribution of duplicate data for Mn, illustrating that all samples are >10 ppb initial detection limit and >95% of samples are more than 100 ppb. This indicates that the optimized detection limit should be raised to 100 ppb. Results are in ppb.

tion in samples and potential interferences from common elements such as Sr, Zr and Y. Even though the LOQ and the 95th percentile of method blanks indicate that Pd can be measured at lower detection limits, the plethora of interferences associated with the element in this method indicated that the 1 ppb detection limit was appropriate.

To address this, a separate method (MMI-MP) was developed that allowed the detection limits for these elements to be lowered to 0.1 ppb for Pd and 0.02 ppb for Pt. This was achieved through a combination of increased measurement time for the two elements and a rigorous interference correction procedure to combat effects at very low concentrations. Since ICP-MS is a sequential technique,

it is possible to measure individual masses more precisely using longer dwell times and more readings. However, this does increase the overall time of analysis and can affect the stability of the instrument due to the amount of sample passing through the spectrometer. In this case, an acceptable compromise was reached by reducing the number of elements being measured, resulting in an 11 element package focused on evaluation of precious and base metal commodity elements. This method is now being offered in Canada as an alternative to MMI-M for particular situations where palladium and platinum are required.

Optimised Detection Limits for Multi-Element Geochemical Analysis... continued from page 7

	OLD DL	NEW DL		OLD DL	NEW DL		OLD DL	NEW DL
Ag	1	0.5	Gd	1	0.5	Sb	1	0.5
Al	1	1	Hg	1	1	Sc	5	5
As	10	10	In	0.5	0.1	Sm	1	0.5
Au	0.1	0.1	K	0.1	0.5	Sn	1	1
Ba	10	10	La	1	1	Sr	10	10
Bi	1	0.5	Li	5	1	Ta	1	1
Ca	10	2	Mg	1	0.5	Tb	1	0.1
Cd	1	1	Mn	10	100	Te	10	5
Ce	5	2	Mo	5	2	Th	0.5	0.5
Co	5	1	Nb	0.5	0.5	Ti	3	10
Cr	100	100	Nd	1	1	Tl	0.5	0.1
Cs	0.5	0.2	Ni	5	5	U	1	0.5
Cu	10	10	P	0.1	0.1	W	1	0.5
Dy	1	0.5	Pb	10	5	Y	1	1
Er	0.5	0.2	Pd	1	1	Yb	1	0.2
Eu	0.5	0.2	Pr	1	0.5	Zn	20	10
Fe	1	1	Pt	1	0.1	Zr	5	2
Ga	1	0.5	Rb	5	1			

	Reporting Limit Unchanged
	Reporting Limit Lowered
	Reporting Limit Increased

Table 3: Reporting limits for the MMI-M scheme before and after the investigation. All limits in ppb except Al, Ca, Fe, K, Mg, P, which are in ppm.

Conclusions

Most approaches to the determination of detection limits for a method use a standard test of method blanks measured in a single pass. This work used long term data to calculate detection limits and resulted in:

- Detection limits that reflect technical improvements to the MMI methodology
- The use of randomized method blanks in conjunction with the common approach to detection limit calculation in order to provide true or more representative reporting limit capabilities for each element.
- Optimized detection limits related to the typical levels found in samples that are potentially more appropriate for targeting anomalies.
- The development of a new method, MMI-MP, to address the case of Pd and Pt where it was found that the MMI-M method was not sensitive enough for some situations.

Although improvements in methods, instrumentation, and sampling protocols have benefitted geochemical exploration, better handling of detection limits is important in providing high quality data for the geologist. It can be seen that the lowest detection limit is not always the best, but the use of optimized detection limits provides reliable data at low concentrations.

Acknowledgment

This article benefited from a review by Ryan Noble (CSIRO).

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AAG Website Memorial Page

The AAG website Memorials page acknowledges our friends and colleagues who have passed on and features a photo of each person and a short biography. They were leaders in the field of applied geochemistry and valued members of our Association.

<https://www.appliedgeochemists.org/index.php/memorials>

Three of the memorials do not yet have photos. If anyone can provide a photo for the memorials for Harold Bloom, Herb Hawkes, or Frank Canney, please email them to the AAG website co-ordinator, Bruno Lemiere.

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David Cohen

David has been a Fellow of AAG since 1995. He obtained a BSc (hons) in 1982 from Sydney, a MSc in 1986 from Queen's University, and a PhD in 1990 from UNSW. David has been at the University of New South Wales from 1991 to present where he is a Lecturer and researcher. Currently, he is head of the School of Biological, Earth and Environmental Sciences.

David is a former Vice President and President of the AAG and is currently the AAG's Symposia Coordinator and Chair of the AAG-SGS Student Paper Prize Committee. David has 25 years experience in exploration geochemical research and teaching, including publication of over 60 papers or major technical reports. His interests include biogeochemistry, selective extractions, geochemical mapping, and data analysis methods.



Ray Lett

Ray Lett obtained a B.Sc. from the University of London in 1968, a M.Sc. from the University of Leicester, Leicester in 1970, and a Ph.D. from the University of British Columbia in 1979. Ray has been a member of the AAG since 1972 and has been involved with the AAG as its Secretary (1980 to 1985), Councillor (1990-1992, 1999-2000, 2006-2009), and as a



Member of the AAG Education Committee (2010-2014).

His employment history includes:

- Consultant Geochemist & University Sessional Lecturer (Geochemistry, Economic Geology), Victoria, Canada, 2010 - Present.
- Laboratory Supervisor & Senior Geochemist BC Geological Survey, Victoria, BC. (1990-2010).
- Geochemist - Barringer Research/Magenta, Mississauga, Ontario, Canada (1980-1990).
- Exploration Geochemist/Geologist - Amax Exploration/Fox Geological/BP Minerals, Vancouver, BC (1970-1979).

Ray is now retired from the BC Geological Survey after 20 years with government as a geochemist. He spends his time consulting, teaching (part time) undergraduate university courses in geochemistry and economic geology and serving on various geoscience committees. Since joining the Association of Applied Geochemists in 1972, he has been able to see how it has evolved from an organization focused mainly on stimulating the use of geochemistry for mineral exploration to being a leading technical forum for a wider range of applications including environmental geochemistry and geoanalysis. Future AAG growth, he suggests, will depend on developing stronger links and lines of communication with other international geosciences organisations.



Tom Molyneux

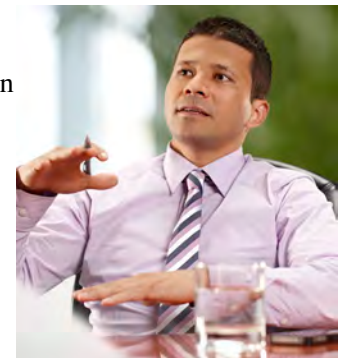
Tom Molyneux obtained BSc Honours Degree in Geology at Trinity College Dublin in 1958, a MSc in Geology at Univ. Pretoria, South Africa in 1964, and a PhD in Geology at Univ. Pretoria, South Africa in 1971. He joined Association of Exploration Geochemists in 1976.

His employment history includes:

- 1959-1961 De Beers Corp. in Tanzania
- 1961-1991 Anglo American Corp., including Bushveld Complex for TiV magnetite, tin, fluorospar, andalusite, Chromitite and Nickel, British Isles for Pb-Zn, Sn and potash, Botswana for gold, Namibia for uranium, Barberton Mountainland for base metals, Witwatersrand Basin for gold and uranium
- 1984-1985 Lectured for two semesters in Economic Geology at University of Washington, Seattle, USA
- 1991-1993 Worked for The South African Council for Geoscience(Geol. Survey) compiling mineral reserves, etc.
- 1994-present Geological and geochemical consultant from a base at Bray near Dublin in Ireland
- 2004-7 From a base at The Univ. Pretoria I compiled the surface geology of The Eastern Bushveld Complex on 1:50 000 scale with an accompanying booklet(ISBN 978-1-86854-092-3)
- 2014 Assisting in the planning and direction of an exploration project in Eastern Nevada for The Great Western Mining Company

Juan Carlos Ordóñez Calderón

Juan Carlos Ordóñez Calderón has been a Fellow of AAG since 2014. In 2001 he obtained his B.Sc. degree at the Universidad Industrial de Santander in Colombia, and graduated with the Summa Cum Laude distinction. He holds a M.Sc. and a Ph.D. degree in geochemistry and



petrology, respectively, from Shimane University (2003) in Japan and the University of Windsor (2008) in Canada. Following his Ph.D., he started an industry-oriented postdoctoral fellowship funded by NSERC, MERC-Laurentian University, The Geological Survey of Canada-TGI3 Initiative, and Hudbay. In 2010, he worked for the Ontario Geological Survey as a Precambrian Geoscientist. Later he opted for a career as a Corporate Geoscientist and since 2011 he works as an applied geochemist for Hudbay's global exploration team in Toronto. Juan Carlos unique expertise resides in the integration of geochemistry, field methods of physical volcanology and structural geology,

Councillors, 2015 ... *continued from page 10*

and statistical analysis to evaluate projects at mine to regional scale. With Hudbay he has applied field and geochemical methods in deserts and tropical rain forests along the Americas to evaluate the mineral potential of environments permissive for porphyry copper, skarn, IOCG, sediment hosted, VMS, and epithermal deposits. He has managed and mentor technical teams and has delivered several in-house and institutional workshops and lectures in applied geochemistry. Juan Carlos advocates collaborative work between industry, governments, and academia in order to solve the most immediate needs of society without leaving future generations lacking in the necessary foundations for unconceivable applications.



Peter Rogers

Peter Rogers has 40+ years of worldwide experience in economic geology, mineral exploration and environmental geochemistry. He is a Registered P.Geo with the Nova Scotia Association of Professional Geologists. His AAG experience includes 2 Council terms, the AAG New Membership Committee, Chair of the 2001 IGES

in Santiago de Chile (which made a healthy profit for AAG), and the AAG Bibliographic Committee. His AAG vision is to widen appeal in Colombia and S. America with strengthened industry participation and financing. Peter obtained a B.Sc. in 1970 from the University College London and a Ph.D. in 1974 from the University of Leicester. His work experience includes:

- 1970 diamond exploration in South Africa and Botswana.
- 1974 British Geological Survey (BGS) aggregates + Geochemist in Peru, Costa Rica, Economic Geologist to the British Antarctic Survey.
- 1982 Nova Scotia Department of Natural Resources as Province's Geochemist with many milestones include the first regional lake sediment survey for Au, application of Spans GIS to stream sediment geochemistry, background modeling and anomaly enhancement, 2-fraction stream sediment survey for coarse and fine gold, regional biogeochemistry survey, multi media deposit studies, regional multimedia surveys including water, vegetation and tills.
- 1995 private sector founding Chavin Consulting Limited. Specializations in blind prospecting deep prospecting methods in covered areas including deserts, volcanics and laterites; vegetation and heavy mineral methods. Completed hundreds of exploration projects in the many different terrains of the Americas including the Boreal glaciated forests of Canada to the Atacama high altitude desert, the high Andes to the Amazon jungles. Recently

completed projects in North and South America for Au, VMS, tailings remediation using non-toxic recovery methods and dimension stone.

- Early 2011 to June 2014 Vice President Exploration and acting CEO for Cordillera Gold Limited.
- June 2014 to present Country Manager Colombia for Cordillera Gold Limited and Managing Director Integrated Exploration Technologies Inc. (IETI), Medellin, Colombia.

Peter Winterburn

Peter graduated with a B.Sc. in Geology from Aston University, UK in 1983 and a Ph.D. from the University of Edinburgh in 1988. He relocated to South Africa initially as a Research Isotope Geochemist, later joining Anglo American in 1990 as Geochemical Database Manager, followed by Geochemical Laboratory Manager



at the Anglo Research Facilities and finally as Manager of the Geochemistry Department in Exploration. In 1999, he became the Regional Geochemist for Africa, and subsequently the Regional Geochemist for South American in 2002 based in Santiago, Chile. In 2007 he returned to South Africa as the Chief Chemist managing metal accounting and metallurgical plant auditing. Peter joined Vale (then CVRD) in 2008, as the Chief Geochemist (Global Exploration) based out of Canada. In late 2013, Peter joined MDRU at the University of British Columbia, Vancouver as the ACMELabs Research Chair in Exploration Geochemistry to facilitate a practical 3-dimensional understanding of the processes of formation and preservation of inorganic and organic geochemical anomalies over concealed mineralisation in different environments. Peter currently leads a growing research team with the ultimate objective of developing appropriate geochemical tools and applications to improve the success rates of mineral exploration under exotic cover. He is a Fellow of the AAG and was an AAG Councillor in 2013-2014.



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Regional Report from Brazil: Geochemical Surveys and Atlases in Brazil - CPRM (Geological Survey of Brazil)

by João Larizzatti

In the last two years CPRM – Geological Survey of Brazil has been conducting regional geochemical mapping surveys from Santa Catarina (South) to Roraima States (North); and from Rondônia (West) to Pernambuco (East). It is also conducting marine sediment sampling in the northeast shore of the country. The focus is on regional geochemical mapping, geochemical exploration and environmental geochemistry.

Geochemical atlases are composed from maps and databases providing regional coverages for a given sampling media (soil, stream sediment, heavy mineral concentrate, surficial water).

They often cover a large region or 1:100,000 scale map sheets. These data are available free of charge or at a low cost. Please visit www.cprm.gov.br.

Mineral Exploration and Geological/ Geochemical Mapping

During 2013 up until October 2014 4,130 soil samples and 20,523 stream sediment samples were collected in continental Brazil. During the same period of time, marine sediment samples were collected in the continental shelf. These samples were analyzed by multielement methods (XRF, ICPOES and ICPMS) using various digestion methods. CPRM also collected 19,742 heavy minerals concentrate samples; these samples were analyzed semi-quantitatively for mineralogical composition. For more details, please see Figures 1, 2 and 3.

The Brazilian government, through CPRM and its Geology and Mineral Resources Directory invested R\$ 10,657,000.00 (about US\$ 4,262,800) in sampling and R\$ 2,220,500.00 (about US\$ 888,200) in analysis for the country.

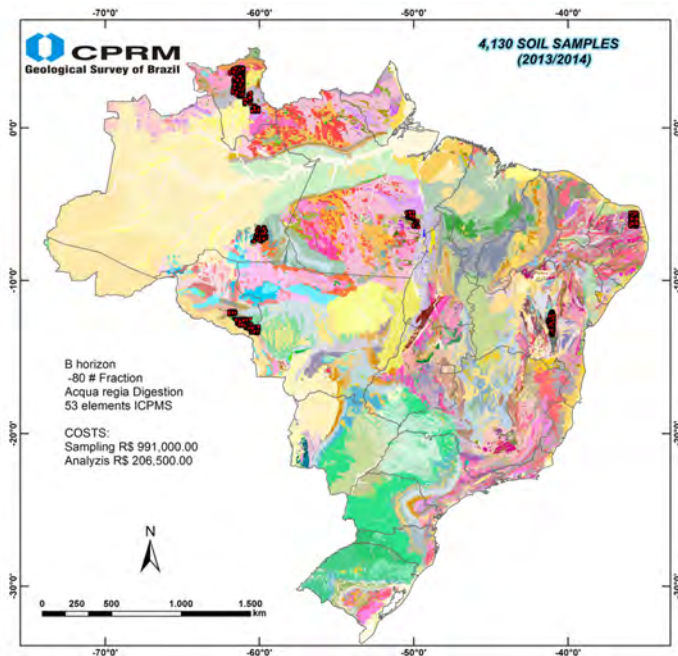


Figure 1 – Soil samples collected between 2013 and 2014 in Brazil

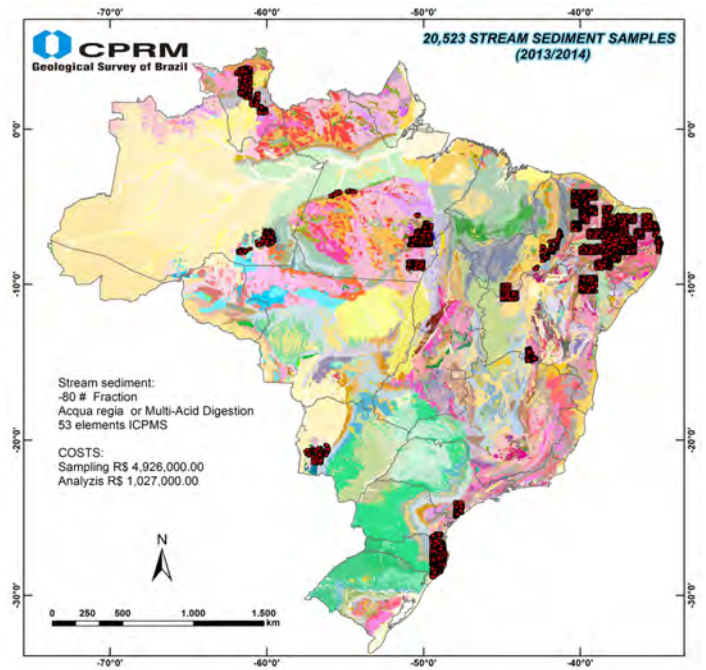


Figure 2 – Stream sediment samples collected between 2013 and 2014.

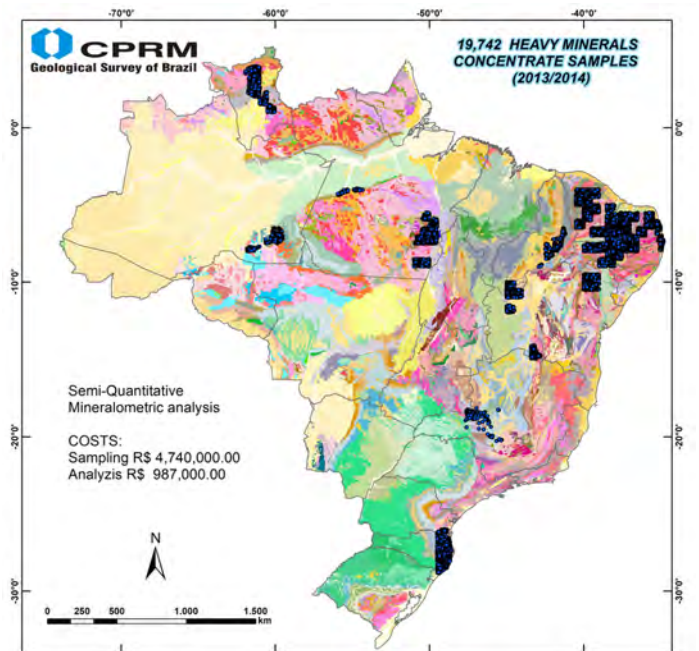


Figure 3 – Heavy minerals concentrate samples collected between 2013 and 2014.

continued on page 13

Regional Report from Brazil ...

continued from page 12

Marine Geochemistry

CPRM is investigating the mineral potential of the Brazilian continental shelf. Geological, geophysical and geochemical data are being collected and integrated. The Brazilian Navy and some Brazilian universities are working together in this project. These geological, economic and environmental data will be used by decision makers in order to develop special policies for the safe use of marine resources. See Figure 4 for details.



Figure 4 – Marine sediments collected between 2013 and 2014.

AAG “Regional Report” Australia and NZ

Ryan Noble and Tony Christie

Future mineral discoveries in Australia will most likely occur in the 80% of Australia that is covered by regolith (Figure 1). Here, traditional exploration methods are less effective as they are in outcrop areas. To address this exploration challenge an ambitious and integrated research program to enable Australia to uncover more of its mineral wealth has been proposed, and developed into the UNCOVER Initiative (Figure 2).



Figure 1: Typical landscapes with varied cover depths in out-back Australia (Rocklea Dome, Pilbara, Western Australia).

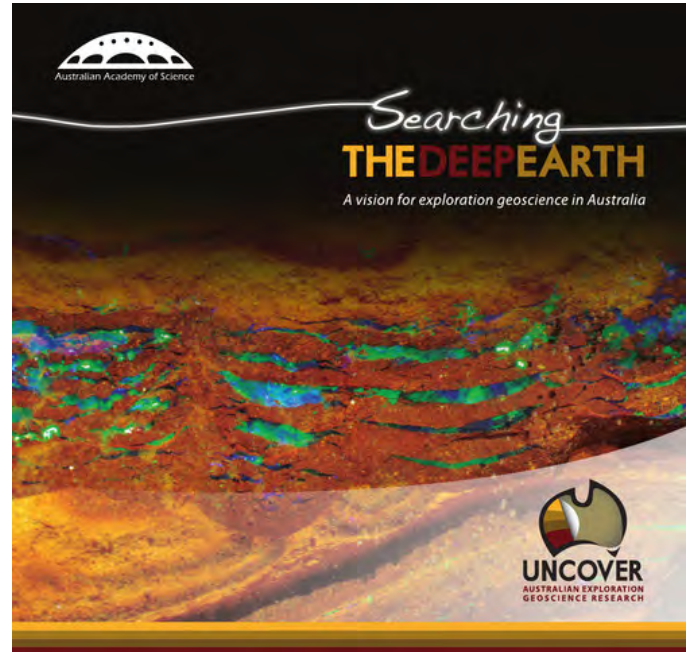


Figure 2. The initial booklet detailing the objective of UNCOVER.

As part of this initiative, the Australian state geological surveys, Geoscience Australia, CSIRO, university geoscience programs and State and Commonwealth governments will work to the same vision and strategic plan. UNCOVER has a clear and simple agenda: to identify, develop, and deliver the science necessary to improve the success rate of mineral exploration in Australia under covered areas.

Although in its infancy, already a number of programs are feeding into this plan. For example, initiatives with the Deep Exploration Technologies CRC (\$~18M p.a) undertaking research and development for rapid drilling through cover and real-time sampling analysis. The “Distal Footprints of Giant Ore Systems” is another major project (\$~4M p.a.) between core partners CSIRO, UWA/CET, Curtin University, GSWA, MRIWA and SIEF to assess broad scale geological (geochemistry/isotopes/minerals/geophysics) signatures in the Capricorn Orogen of Western Australia. Other ARC geoscience Centres of Excellence (such as the Core to Crust Fluid Systems centre) have aligned their goals to the UNCOVER vision. Additionally, a roadmap exercise project is now officially under way with industry support as the AMIRA P1162 project to clearly identify industry problems and opportunities that can practically be achieved through collaborative research. Initial implementation of UNCOVER included a comprehensive face-to-face and web-based survey of industry, the geological surveys and academia as well as a Summit held in Adelaide in early April, 2014. The summit brought together 150 delegates representing industry, academia, and government agencies from Australia and internationally. UNCOVER has four science themes:

- 1) The Cover: Characterising Australia’s cover - new knowledge to confidently explore beneath it. Depth, definition, and how we see through it and sample it for maximum benefit.

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GEOSCIENCE STUDENTS



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This symposium is the world's foremost forum for the exchange of ideas on a broad range of issues related to the use of geochemistry for the mineral resources industry, advances in geochemical analytical methods, and environmental geochemistry. The focus for the 2015 IAGS will be on ***Applied Geochemistry for: Minerals Exploration, Environmental Technologies, and Sample/Data Analysis*** having a comprehensive program with multiple keynote speakers, technical sessions, short courses, field trips, and poster sessions.

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Regional Report from Australia ...

continued from page 13

- 2) The Lithosphere: Investigating Australia’s lithospheric architecture – a whole lithosphere architectural framework for mineral systems exploration. Expanding knowledge to understand continental assembly and evolution of the deep crust and its influence on the cover.
- 3) 4D metallogenesis: Resolving the 4D geodynamic and metallogenic evolution of Australia – understanding ore deposit origins for better prediction. Predicting where going deep will be rewarded through better prediction of economically viable deposits.
- 4) Footprints: Characterising and detecting distal footprints of ore deposits – towards a toolkit for minerals exploration. Determining camp to regional to continental scale background and signatures of deposits to improve vectoring to ore bodies.

Two additional components of UNCOVER are:

- 1) A geoscience network - for improved communication and collaboration.
- 2) Education - to train the next generation of mineral explorers.

Further information on UNCOVER can be found at <https://www.science.org.au/publications/searching-deep-earth-vision-exploration-geoscience-australia>

Or the UNCOVER Roadmap project P1162 on the AMIRA website <http://www.amirainternational.com/>

Another exciting new development for geochemistry in Australia is the Advanced Resource Characterisation Facility (ARCF) that is a \$9M p.a. investment into analytical equipment capable of delivering analysis from core to atom scale. The infrastructure is funded by SIEF through UWA, Curtin University and CSIRO as partners for the National Resource Sciences Precinct in Perth, Western Australia. Preexisting facilities will be merged with a new NanoSIMS, an Atom Probe TEM and the prototype Maia mapper. This hub for geochemical characterisation will be internationally unique for the range and proximity for access to these facilities (Figures 3 and 4).

For more details see <http://www.nrsp.com.au/>
<http://www.csiro.au/Organisation-Structure/Divisions/Earth-Science—Resource-Engineering/National-Resource-Sciences-Precinct.aspx>
<http://www.csiro.au/AdvancedCharacterisationFacility>

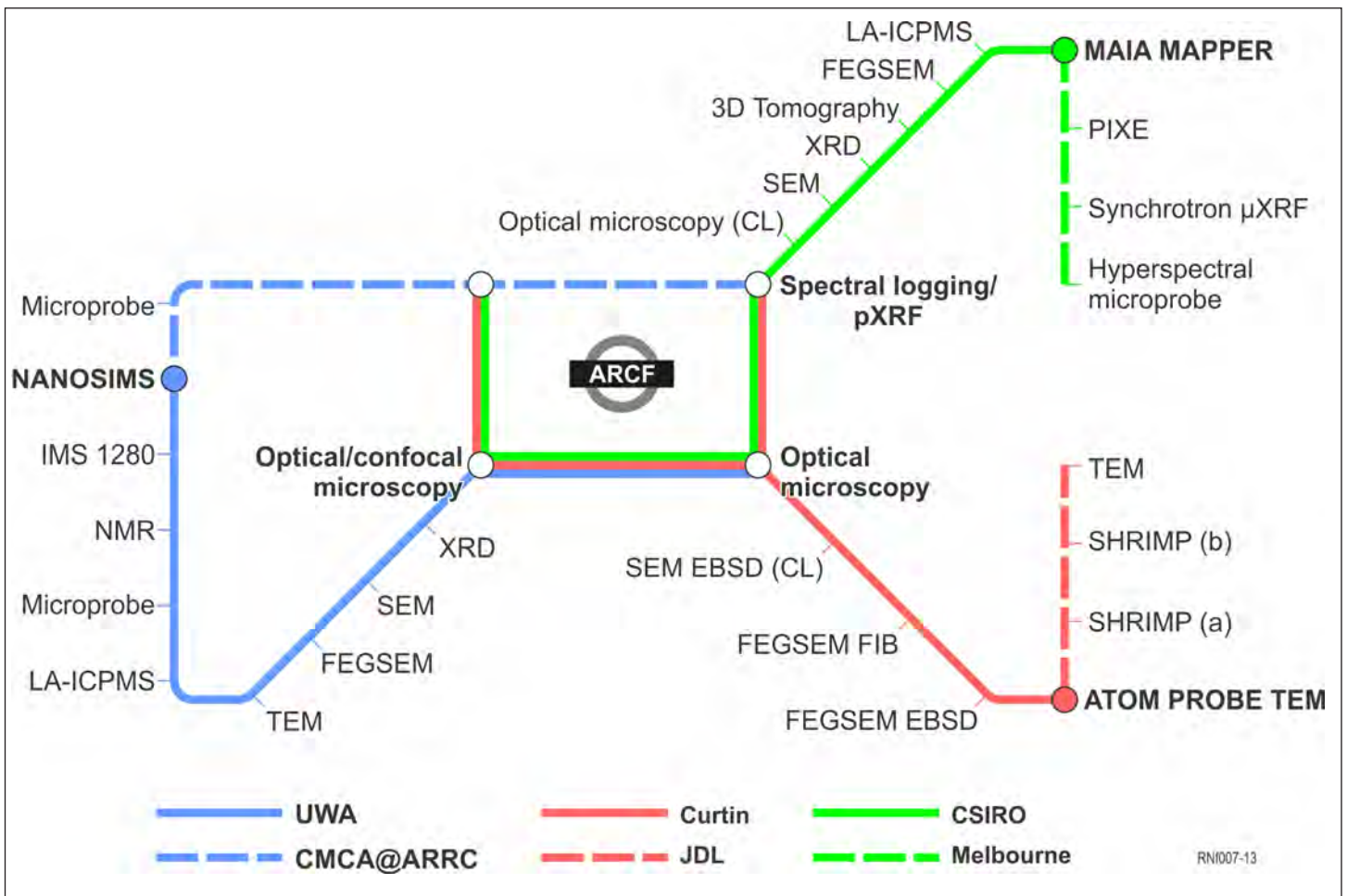


Figure 3. Equipment that will form the ARCF from the three core parties.

Regional Report from Australia and New Zealand ... *continued from page 15*

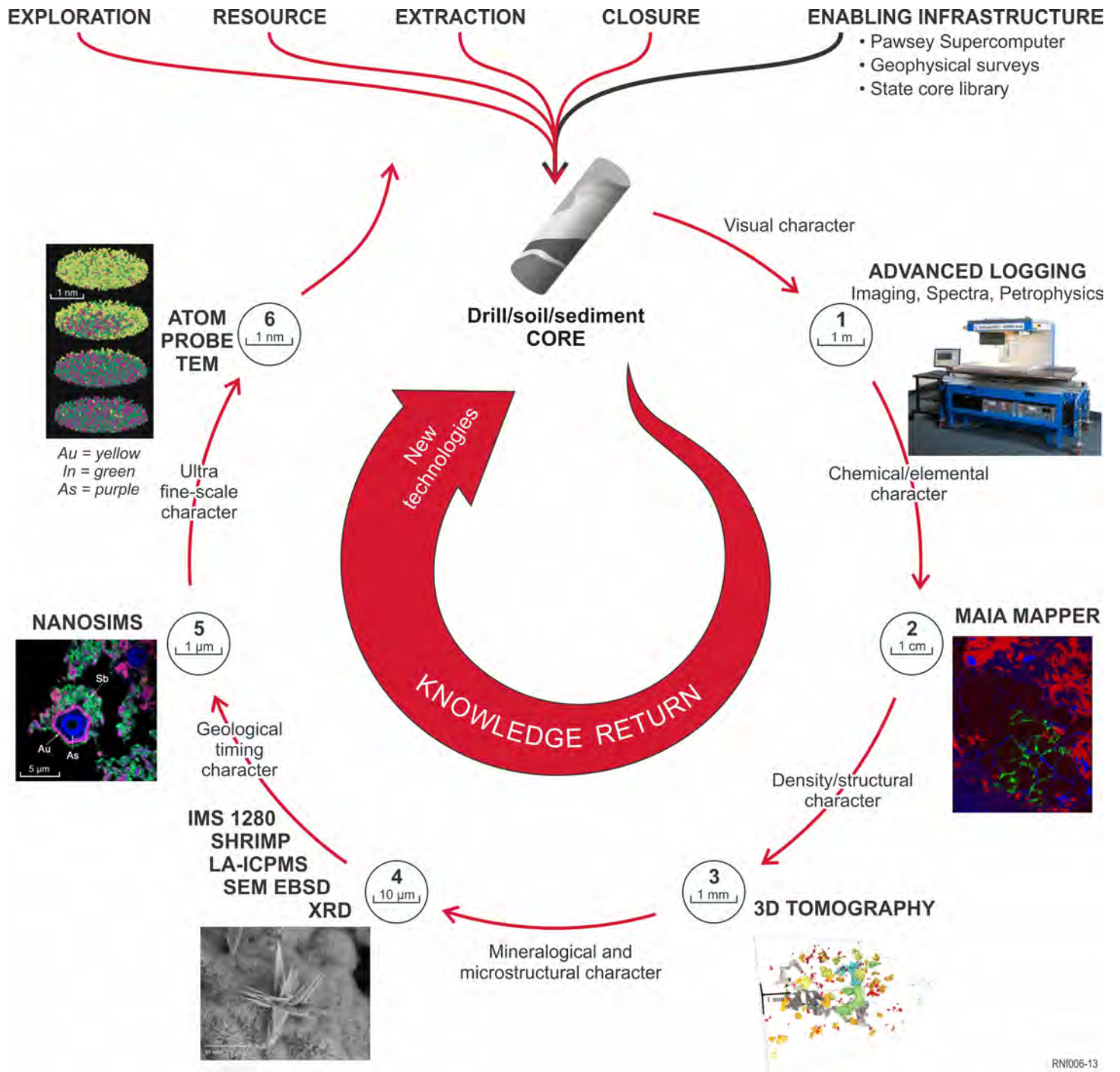


Figure 4. Work flow for characterisation from the drill core to the atom scale that will be available as part of the ARCF.

New Zealand regional multi-element geochemical baseline survey

GNS Science is undertaking a pilot regional soil geochemical survey in the southern part of the South Island to test methodologies and to provide data to help promote the concept of a national survey programme. Soil samples were collected at c. 400 sample sites spaced at 8 km centres across south Otago and Southland (Figure 5). At each site, c. 5 kg samples were taken from two depths, 0-20 cm (c. A soil horizon) and 50-70 cm (c. B soil horizon), using hand

augers (Figure 6). They were dried and sieved to provide the < 2 mm fraction that was retained and split for analysis and an archive reference collection. Sampling and QAQC protocols and methods are described by Martin et al. (2014) and Rattenbury et al. (2014), and the samples are catalogued in the national rock and geoanalytical database

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Regional Report from Australia and New Zealand ... *continued from page 16*

(pet.gns.cri.nz). It is planned to analyse the samples for more than 60 elements by pXRF, XRF and partial digest ICP-MS, all by July 2015. Some samples will also be analysed for magnetic susceptibility and for sulphur, strontium and lead isotopic compositions. The results will be used to determine the optimal “cost-benefit” sampling density for a national survey and to demonstrate to potential collaborators and funders the benefits of such a survey, particularly for environmental base lines, agricultural management and public health considerations, as well as for mineral exploration and downstream geological and geochemical research.

Martin, A.P.; Turnbull, R.E.; Rattenbury, M.S.; Strong, D.; Rieger, P. 2014: The southern South Island geochemical baseline soil survey: a progress report. Proceedings of the 47th AusIMM New Zealand Branch Annual Conference, Hamilton, pp. 363-369.

Rattenbury, M.S.; Martin, A.P.; Turnbull, R.E.; Christie, A.B. 2014: Sampling methodology for a regional multi-element geochemical baseline survey. *GNS Science Report 2014/62*. 38 p.

Figure 6. Phil Rieger auguring soil in the Waikaia area of Southland, February 2014. Photo by Adam Martin.

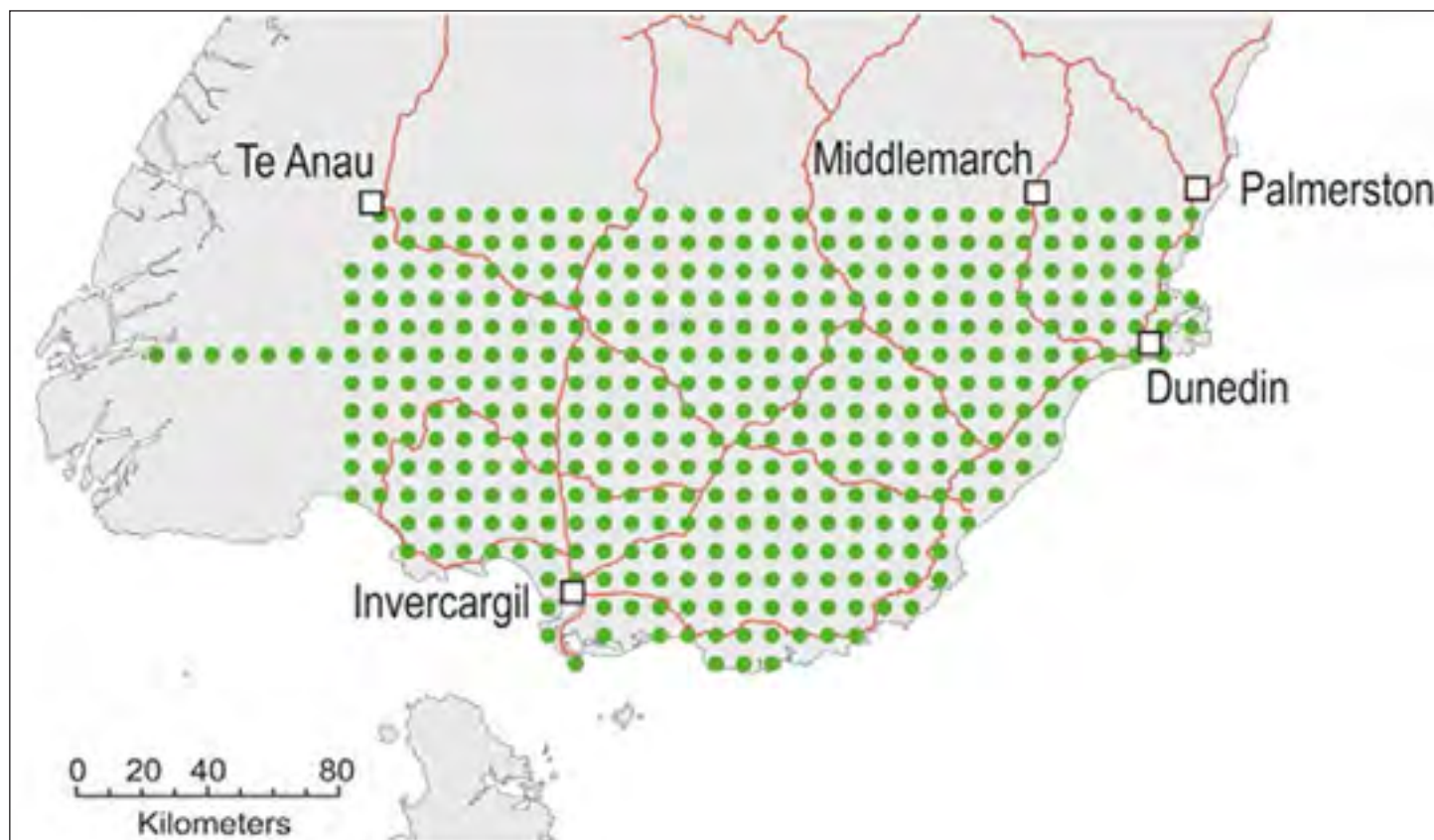


Figure 5. Southern South Island pilot soil geochemical survey sample locations based on an 8 km sampling grid (after Martin et al., 2014).



Induction into Canadian Mining Hall of Fame

Long time AAG member Peter M.D. Bradshaw was inducted into the Canadian Mining Hall of Fame on January 15, 2015. Peter has served the industry with distinction for more than 40 years as a mine finder, company builder, an advocate of collaborative research and science, and by working effectively with local and indigenous people. His early career with renowned Barringer Research gave him a global perspective on mineral exploration and the opportunity to develop and publish details of groundbreaking geochemical processes and exploration methods. In 1979, he joined Placer Development, a predecessor of Placer Dome, and helped advance several projects - most notably the high-grade VII zone at Porgera in Papua New Guinea (PNG). Bradshaw was also the force behind forming the Mineral Deposit Research Unit (MDRU) at the University of British Columbia (UBC) in Vancouver, Canada.

Among his other achievements, Peter brought expertise, integrity, and energy to the junior sector, first with Orvana Minerals, which developed the Don Mario gold-silver-copper deposit in Bolivia. Later, as co-founder and president of First Point Minerals, he helped discover and identify the commercial importance of a new type of nickel deposit in British Columbia and the Yukon, in which nickel occurs as the nickel-iron alloy, awaruite.

In 1962, Peter earned a BSc in geology from Carleton University in Ottawa, Canada and a PhD from Durham University in England (Economic Geology) in 1965. During the next decade with Barringer Research, Peter helped prove the value of advanced geochemical exploration - in particular the use of selective extractions and soil-profile sampling to improve interpretation, and enhance the signal from buried deposits.

Peter then joined Placer Development, where the greatest of many accomplishments involved the Porgera



project, which was nearly abandoned after a failed feasibility study. Convinced of the potential for a high-grade zone in the bulk-tonnage deposit, Peter launched a low-cost exploration program that led to the discovery of Zone VII, a rich and large “plum.” Porgera became a world-class mine that has produced more than 18 million oz. gold, with potential for more.

The resilience and tenacity shown by Peter at Porgera helped define his career. Still with Placer, at the Misima gold mine - also in PNG - he worked with the government to adopt a marine-tailings disposal system rather than build a tailings dam on the small, rugged and seismically active island. He worked with local leaders to prevent a mass in-migration to the island and the resulting social disruptions, as part of his long-standing commitment to work effectively with local and indigenous people. He also oversaw aspects of the final feasibility study of the Kidston gold mine in Australia, and optioned both Granny Smith in Australia and Omai in Guyana, all of which became significant producers.

Peter’s most enduring legacy is the MDRU, the highly successful industry-University of British Columbia research collaboration which he co-founded in 1989. Today MDRU is recognized internationally as a centre of excellence in mineral deposits research and training, a fitting tribute to its far-sighted and tenacious first chairman, Peter Bradshaw.

http://www.mininghalloffame.ca/inductees/a-c/peter_bradshaw





CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry. These events also appear on the AAG web page at: www.appliedgeochemists.org. Please let us know of your events by sending details to:

Steve Amor,

*Geological Survey of Newfoundland and Labrador
P.O. Box 8700, St. John's, NL, Canada, A1B 4J6
Email: StephenAmor@gov.nl.ca
709-729-1161*

12-17 April 2015. European Geosciences Union General Assembly. Vienna, Austria. Website: www.egu2013.eu/

14-17 April 2015. 24th International Mining Congress and Exhibition of Turkey. Antalya Turkey. Website: imcet.org.tr/defaulten.asp

20-24 April 2015. 27th International Applied Geochemistry Symposium. Tucson AZ USA. Website: www.27iags.com

3-7 May 2015. 14th European Workshop on Modern Developments & Applications in Microbeam Analysis. Portoroz Slovenia. Website: tinyurl.com/nlrfno

3-7 May 2015. Joint GAC-MAC-CGU-AGU Meeting. Montréal QC Canada. Website: ja.agu.org/2015

9-13 May 2015. Canadian Institute of Mining, Metallurgy, and Petroleum 2015 Conference & Exhibition. Montreal QC Canada. Website: convention.cim.org/

7-10 June 2015. 13th International Estuarine Biogeochemistry Symposium. Bordeaux France. Website: iebs2015.sciencesconf.org/

7-12 June 2015. Gordon Research Conference: Interior of the Earth. South Hadley MA USA. Website: www.grc.org/programs.aspx?id=12544

7-13 June 2015. Applied Mineralogy & Advanced Materials - International Conference. Castellaneta Marina, Italy. Website: www.amam2015.org

10-12 June 2015. World Conference on Sampling and Blending. Bordeaux France. Website: www.atout-org.com/wcsb7/

14-19 June 2015. 12th International Conference on Mercury as a Global Pollutant. Jeju Korea. Website: mercury2015.com

14-19 June 2015. Catchment Science: Interactions of Hydrology, Biology & Geochemistry. Andover NH. Website: tinyurl.com/mc2y5qm

15-19 June 2015. 6th International Limnogeology Congress. Reno NV USA. Website: ilic6.org/

22-26-June 2015. 30th European Conference of the Society for Environmental Geochemistry and Health. Bratislava Slovakia. Website: www.geology.sk/geohealth/segh-conference-2015/

22 June-2 July 2015. 26th International Union of Geodesy and Geophysics General Assembly. Prague Czech Republic. Website: www.iugg2015prague.com/

21 June-26 June 2015. Isotopes 2015. Jerusalem Israel. Website: tinyurl.com/kmu8sxe

26-28 June 2015. ECROFI23 - The Sorby Conference on Fluid and Melt Inclusions. Leeds UK. Website: www.see.leeds.ac.uk/ecrofi

29 June-2 July 2015. Conference on Mathematical and Computational Issues in the Geosciences. Stanford CA USA. Website: www.siam.org/meetings/gsl5/

12-16 July 2015. 13th International Conference on the Biogeochemistry of Trace Elements. Fukuoka Japan. Website: www.icobte2015.org

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25-29 July 2015. Annual Meeting of the American Crystallographic Association. Philadelphia PA USA. Website: tinyurl.com/3dfn8lu

26-29 July 2015. Granulites & Granulites 2015. Windhoek Namibia. Website: tinyurl.com/qg3xrwz

26-31 July 2015. Gordon Research Conference — Chemical Oceanography 2015. Holderness NH USA. Website: tinyurl.com/os2gc35

26 July-1 August 2015. 6th International Conference on Medical Geology. Aveiro Portugal. Website: medgeo15.web.ua.pt/

27-28 July 2015. Urban Geochemistry: The impact of legacy infrastructure and contaminants. Detroit MI USA. Website: www.iagc-society.org/UG.html

27 July-2 August 2015. 19th INQUA Congress (Quaternary Perspectives on Climate Change, Natural Hazards and Civilization). Nagoya, Japan. Website: inqua2015.jp

8-14 August 2015. Geoanalysis 2015. Leoben, Austria. Website: geoanalysis.info

10-12 August 2015. 12th International Congress of Applied Mineralogy. Istanbul Turkey. Website: icam2015.org/

10-12 August 2015. Microscopy & Microanalysis 2015. Portland OR USA . Website: tinyurl.com/qewvuz3

10-12 August 2015. SGA 2015. Nancy France. Website: sga2015.blog.univ-lorraine.fr/

16-21 August 2015. Goldschmidt 2015. Prague Czech Republic. Website: goldschmidt.info/2015/

17-20 August 2015. CANQUA 2015 Meeting. St. John's NL Canada. Website: www.canqua.com/meetings

23-28 August 2015. 29th Meeting of European Crystallographic Association. Rovinj, Croatia. Website: ecm29.ecanews.org/

9-11 September-2015. 8th European Conference on Mineralogy and Spectroscopy (ECMS 2015). Rome Italy. Website: www.ecms2015.eu/

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continued from page 20

13-18 September 2015. 27th International Meeting on Organic Geochemistry. Prague Czech Republic. Website: www.imog2015.org/

20-25 September 2015. 8th Hutton Symposium on Granites and Related Rocks. Florianopolis Brazil. Website: www.hutton8.com.br

21-25 September 2015. 11th meeting on Applied Isotope Geochemistry. Orléans France. Website: aig11.brgm.fr

27-30 September 2015. Society of Economic Geologists 2015 Conference: World-Class Ore Deposits: Discovery to Recovery. Hobart Australia. Website: www.seg2015.org/

28 September-2-October-2015. International Society for Environmental Biogeochemistry 22nd Symposium. Piran Slovenia. Website: www.iseb22.ijs.si

5-6 October 2015. 4th Annual International Conference on Geological & Earth Sciences. Singapore. Website: www.geoearth.org/

1-5 November 2015. GSA 2015 Annual Meeting. Baltimore MD USA. Website: www.geosociety.org/meetings/2015

3-5 November 2015. 10th Fennoscandian Exploration and Mining. Levi Finland. Website: 10times.com/fem-levi

9-13 November 2015. Introduction to Secondary Ion Mass Spectrometry in the Earth Sciences. Potsdam Germany. Website: www.gfz-potsdam.de/SIMS/short-course

18-19 January 2016. 10th International Symposium on Environmental Geochemistry. Perth Australia. Website: www.iseg10.com/

27 August – 4 September 2016. 35th International Geological Congress. Cape Town South Africa. Website: www.35igc.org

11-15 September 2016. 2nd European Mineralogical Conference. Rimini Italy. Website: emc2016.socminpet.it/

16-October 2016. Water Rock Interaction 15. Évora Portugal. Website (pdf): tinyurl.com/lch75x8



Course Review: Exploration Geochemistry (GEOL_5806)

December found me with the opportunity to take Exploration Geochemistry (GEOL_5806), offered as a modular graduate course by Laurentian University (LU) in Sudbury, Canada (<http://earthsciences.laurentian.ca>). The course ran from December 3 to 15, 2014 and was organized by Dr. Michael Lesher (Department of Earth Sciences and MERC). A total of 41 people attended the course from a range of universities and industry. Among the universities represented were: Laurentian University, University of Ottawa, Brock University, University of Toronto, University of Waterloo, and Western University. Leading us from day-to-day was a distinguished group of lecturers from academia, industry and government including: Harold Gibson, Daniel Kontak, Michael Lesher, Matt Leybourne (LU-MERC), Kurt Kyser (Queens), Tom Morris (Northern Superior Resources), Pim van Geffen (ioGlobal/REFLEX), Wayne Goodfellow, Eric Grunsky, Beth McClenaghan, Jan Peter (GSC), Marcus Burnham, Dave Crabtree, Richard Dyer, Stew Hamilton, and Jennifer Hargreaves (OGS).

The modular course started off with a very informative and hands-on tutorial in ioGAS (Pim van Geffen), a geochemical data processing and plotting program, which I found to be excellent in handling geochemical datasets. Starting the course with this tutorial was very useful as many of the labs in the course incorporated ioGAS, allowing the students to become comfortable with such a program. What followed was 7 days of intense theory in QA/QC, lithogeochemistry, indicator minerals, sediment geochemistry, alteration and mass balance, stable isotopes, and radiogenic isotopes. This was rounded off with 5 days of geochemistry as it pertains to specific deposit types: exhalites, Au, SEDEX, VMS, U, and diamonds. Lectures typically went on until early afternoon and were followed by a laboratory exercise that took up the remainder of the day and, in most cases, much of the evening. This was an intense schedule and I would recommend anyone taking the course to be organized, well prepared, and well rested. I asked some fellow students to tell me what they thought about the course and they came back with 3 similar comments generally: 1) the course was well thought out and the topics were excellent, 2) the ioGAS tutorial was extremely useful and many thought this was one of the best days, and 3) many were very tired and agreed that the course was demanding. I would agree with the above comments and add that the days I expected to be uninterested in the topic actually found me the most attentive, which is say that each and every day offered me ideas and ways of looking at geochemistry that will help me directly in my research. I thought the course was excellent and would highly recommend it to others, both in industry and at the graduate level.

Evan Hastie, PhD Candidate,
Laurentian University
Email: ehastie@laurentian.ca

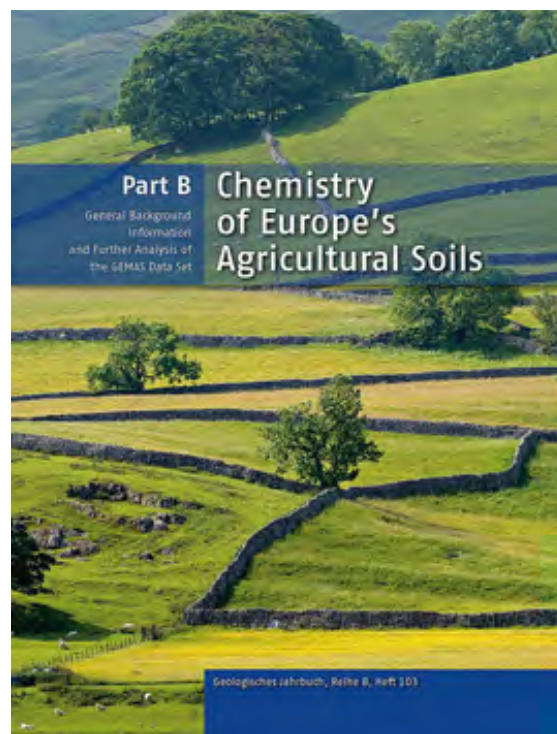
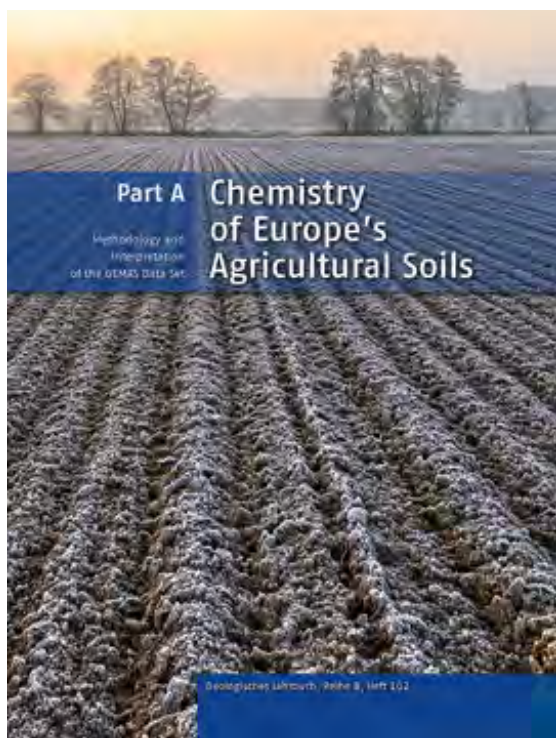


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Book Review

Chemistry of Europe's Agricultural Soils: Part A: Methodology and Part B: General Background Information and Further Analysis of the GEMAS Data Set, 2014. Eds.: C. Reimann; M. Birke; A. Demetriades; P. Filzmoser & P. O'Connor, 880 pages, 1 DVD, Language: English, (Geologisches Jahrbuch Reihe B), ISBN 978-3-510-96848-0



The publication of Chemistry of Europe's Agricultural soils represents a phenomenal achievement of collaboration, cooperation and coordination between 33 European countries covering a total area of 5.6Mkm² with 2108 samples of ploughed land and 2023 samples of grazing land. All samples were collected in 2008/2009 using identical procedures, identical quality control practices and were submitted for 52 element aqua-regia ICP-MS analysis, 41 element XRF analysis and MMI analysis (as an indicator of metal availability); in addition to C, S, TOC and Pb-Isotopes as chemical variables. Of particular note is that the complete set of 5000 samples were analysed by ICP-MS over a 3-week period, this avoiding long term batch variability. Various additional parameters such as grain size distribution, cation exchange capacity, pH and magnetic susceptibility were also routinely determined on each sample.

Part A of the 2-volume set covers the methodology and interpretation of the dataset. Following a section on the justification of the exercise with respect to the REACH program, the initial sections read almost as a guide book on how to undertake such a survey covering sample selection and collection; preparation of the samples and QA/QC materials, and in-depth details of the analytical procedures. This is followed by a series of extremely informative chapters covering the interpretation of the QA/QC data and the methodologies of data analysis. The sections on univariate and multivariate data analysis will probably be an eye opener for many readers in particular, as the inner details on the appropriateness and inappropriateness of multivariate statistics are documented

in clear and concise English. The pitfalls inherent in correlation analysis of geochemical data and how these influence a multitude of other multivariate statistical techniques such as PCA is presented with emphasis on the issues of constant sum in geochemical data. On page 87, it is noted for example that "... *the fact that certain elements jointly enter one of the components is no proof of relationship or cause....*". One of many points that are often overlooked in data manipulation and interpretation exercises. These sections lay the foundations for the subsequent detailed interpretation of the analytical data.

A brief section on supporting datasets utilized in the interpretation precedes the main body of the book. This section draws on geology, topography, parent material associations – essentially surface geology, climate, ecological zones and of importance for an assessment of this scale - areas of population density.

The main body of the text (373 pages) is a detailed account of the distribution of each element analysed presented in alphabetical order. The section starts with an assessment of the various physicochemical and physical parameters such as clay content, pH and magnetic susceptibility including some derivative data such as chemical index of alteration. Following which each of the elements determined is documented in detail typically over 3-6 pages including figures.

Each element description commences with general information on the chemistry of the element, typically mineralogical and lithological associations and ambient concentrations in different lithologies plus details on

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industrial applications of the element and biological affinities such as essentiality in plants and animals and toxicology. This portion alone will be valued as an up to date dictionary of the geochemistry of the elements. The distribution of each element as analysed by the various methods is discussed, in detail with statistical evaluation and is related to the geology, topography, anthropological information, etc. A particular observation, clearly visible in the data and which carries through much of this section is the distinction between “old” soil and “new” soil with the demarcation being the limit of the northern European ice sheet. For example, the distribution of Pb, Co, Cr, and Cs. Despite being 1 sample per 2,500km², a phenomenal amount of detail is visible in the data including the influence of major population centers and historical and current mining districts. Much to the surprise of the authors, the influence of agriculture in the data is notable by it's absence. An interesting exception being Cu, used as an insecticide in the wine industry, it is noted to clearly reflect the main wine growing districts.

Part A finishes with a discussion and conclusions section drawing together key observations from the data relating to the variation of the elements with the other key variables such as geology and climate. The complete dataset for both sample types for all methods and entities analysed is reported as excel spreadsheets on a DVD mounted in the back of the volume along with additional statistics, a full set of graphics and maps presented in addition to other maps not presented in the volume, thus allowing the reader to undertake their own evaluation of the data. This dataset is also available free to the public.

Part B provides a more detailed assessment of selected elements in particular illustrating the derivation and interpretation of the information at different scales. Additional discussion on the significance of the MMI data in terms of agricultural assessment is also made. Whilst Part A of the set provides an overview, all be it quite detailed, part B shows examples of the additional information that can be gleaned from the data by thoughtful integration with other datasets.

In summary, whilst the book may initially appear to have limited appeal to those scientists interested in the chemistry of Europe's agricultural soils, I was somewhat taken aback by the breadth and depth of the background information provided with respect to the methods, protocols, statistical methodologies and background information on the elements; all of which makes the book, even in this day of easy access to information (or perhaps information overload), a very valuable addition to the geoscientist's library. This is particularly true given the relatively low cost of the complete volumes and DVD at a list price of Euros 150.00.

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New Editor-in-Chief for the AAG's journal, GEEA



It is with great pleasure that the AAG and the Geological Society of London announce that Dr. Kurt Kyser is the new Editor-in-Chief of our journal, *Geochemistry: Exploration, Environment, Analysis (GEEA)*. Kurt, internationally well known but particularly within the AAG community, is a professor in the Department of Geological Sciences and Geological Engineering at Queen's University in Kingston, Canada. He is currently the director of Queen's Facility for Isotope Research (QFIR), the well-equipped Queen's Facility for Isotope Research which provides interdisciplinary research for university, government, industry, and private agencies on a global basis.

Kurt's research interests include isotope geochemistry, origin and chemical evolution of the earth, mass spectroscopy, evolution of fluids in basins, low-temperature geochemistry, geochronology, environmental geochemistry, and fluid-rock interactions. His work has been widely published, in, for example, ~ 300 papers in refereed journals (including GEEA of course!), 200 in conference proceedings, 50 chapters in books etc. Kurt's undergraduate and graduate teaching and supervision of numerous MSc and PhD students have provided much needed, valuable resources in the field of exploration geochemistry.

Amongst the numerous honours awarded Kurt are the Killam Research Fellowship, the Willet G. Miller Medal, the Queen's Research Chair, Fellow of the Royal Society of Canada, and the AAG Distinguished Lectureship. He has held the posts of President of the Mineralogical Association of Canada, President of Earth-Oceans-Atmosphere Sciences, and Chair of the Selection Committee on Research Grants, amongst others.

Clearly, the journal is in very capable hands and we look forward to exciting new ventures with Kurt at the helm!

Gwendy Hall





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