

MINERALS BRIEF

Regolith Science in Mineral Exploration

December 2007 Edition No 16



Wishing everyone Compliments of the season and a Happy and Prosperous New Year for 2008. I would like to take this opportunity to personally thank our industry collaborators and all our external sponsors for their continuing support of the CRC over the past year. It has been an exciting 12 months and, whilst we are now in our wind up period, we are certainly delivering in my opinion the most exciting science and end user focused outputs from the last six years. I draw your attention to the publication (with our collaborators at MERIWA, GSWA and CSIRO) of the Laterite Geochemical Atlas and Database for the Yilgarn Craton WA - LEME Open File Report 116 that has generated extraordinary exploration activity in the western Yilgarn. Likewise the publication of the Palaeodrainage and Tertiary Coastal Barriers Map of SA with our colleagues in PIRSA has led to a marked increase in exploration activity in the area.

<http://crclme.org.au/Research/researchupdates.html>
Both of these outputs are clear examples where publicly funded, pre-competitive geoscience data, expeditiously released into the public domain, can stimulate significant economic activity.

In the next six months I recommend that you keep a close eye on the CRC LEME website where we will be releasing our Explorers Guides, Thematic Volumes and Technical/Open File Reports - all of which will be available for free download as .PDF files.

<http://crclme.org.au/Pubs/Legacy%20products.html>

Steve Rogers
Chief Executive Officer

Tanami spinifex Au geochemistry mirrors hydrogeochemical response

Reid, N., Kirste, D., and Worrall, L.

One of the biggest challenges facing the mineral exploration industry in Australia is finding mineral deposits that are buried beneath transported regolith cover. A number of methodologies to see through the regolith into the bedrock are being developed and tested by CRC LEME. CRC LEME has identified specific regions of the country of interest to the minerals industry and has targeted these regions for focussed study.

The Tanami Desert in northern Australia is one such region that is being actively explored but has a significant transported regolith cover. CRC LEME in co-operation with Tanami Gold NL, Newmont Mining Corporation and Anglo American is undertaking a concerted effort to integrate geological, geophysical, geochemical,



Nathan and Tunkilla Spinifex

hydrogeochemical and biogeochemical techniques to identify mineralisation in the Tanami. Two of the techniques studied show strong correlations in this area, with preliminary work providing an indication of geochemical dispersion mechanisms. The two sampling media are spinifex and groundwater with Nathan Reid leading the study of biogeochemical signatures found in plant species and Dirk Kirste carrying out the hydrogeochemical studies.

Geochemical indicators of mineralisation can only be seen in surface sampling media if there is a suitable transport mechanism from the mineralisation to the surface. Numerous mechanisms have been postulated and identified as viable, these include: electrochemical cells driven by redox gradients, diffusion, advective transport, and migration of gases. A particular mechanism is likely to result in different element mobility and dispersion patterns so it is important to incorporate in an exploration program the geochemical exploration methods most likely to capture anomalies generated by those specific mechanisms. Part of the research program in the Tanami addresses what the mechanisms of transport in this terrain are.

Geophysical, hydrogeological and hydrogeochemical methods at the Coyote site indicate that advective transport through groundwater flow is the most likely transport mechanism. If this is the case, then deep rooted plants are potential sampling media because they access the groundwater systems. Similarly, hardpans are a likely sampling medium as they often reflect groundwater discharge points and thus carry a

chemical signature of the groundwater.

At the Coyote Prospect in Western Australia, spinifex (*Triodia pungens*) was identified as having potential in discovering buried Au mineralisation. Vegetation samples were collected at 100 m spacings across a 3 km long transect over the Coyote ore body. The spatial plots of spinifex chemistry showed that As, Au, S, Zn and REEs were directly related to mineralisation with S and Zn having a greater dispersion halo away from the ore body. Spinifex accumulates Cr at all studied sites and hence does not reflect mineralisation.

The groundwater samples were collected at a depth of 20 to 70 m with the majority at 40 m. Standing water tables ranged from 20 m to <7 m below ground surface. Groundwater samples were collected from within the area of mineralisation (8) and from all other groundwater sources in the local region (3). In general the samples were collected from bores completed in bedrock with slotted intervals at depths of up to 120 m above mineralisation. The Coyote site groundwater displays elevated Au, As and Cr contents relative to the local groundwater. At Sandpiper/Larranganni, the Au, Zn, Pb and Ni contents were higher than the regional values.

The results indicate that the spinifex roots are sampling groundwater in this region and hence could be used as a surrogate for the hydro-geochemistry in this landscape setting. Since both media were able to detect Au mineralisation within a multi-element suite, both would be useful in identifying mineralisation in areas of transported cover. Differences included the S and Zn content where neither were elevated in the groundwater at the Coyote site, but both showed highs in the Spinifex.

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Cool drink and wine could help find new mineral deposits

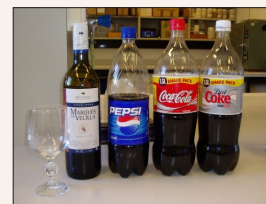
A study of traditional and novel geochemical extractions applied to a Cu-Zn soil anomaly in Victoria, Australia.

Dr Ryan Noble, a Postdoctoral Fellow with LEME/CSIRO Exploration and Mining, and Professor Cliff Stanley from Acadia University, Canada have completed an unusual project assessing the exploration accuracy and precision of traditional and novel geochemical extractions.

The study demonstrated that soft drinks and wine have the right chemistry to extract metals in soil. The chemical ingredients within these beverages have the ability to extract weakly-bound metals into solution as they contain weak organic acids such as citric acid. When the drinks are mixed with soil, these acids dissolve some of the metals in the soil, releasing them into

New Extractions

- pH and temperature controlled
- Four new extractions
 - Coke®
 - Diet Coke®
 - Pepsi®
 - Tempranillo wine
 - Marques de Velilla (Ribera del Duero, tinto joven)



solution. These positively charged mobile metals are then bound to the organic compounds to create stable, soluble metal molecules that can be easily detected in routine laboratory analysis.

The chemical ability of cool drinks and wine makes them very suitable for use as a cheap extraction tool that can be applied to mineral exploration. Their ability to mobilise metals at a range of soil pH conditions means that cool drinks and wine could be used to find out if soils contain elevated levels of metals such as silver, zinc, copper and nickel. When detected, these zones of high-metal concentrations in soils can potentially target buried mineralisation.

In many cases, the comparison of metals extracted using wine and soft drink were superior to those extracted using conventional, and much more expensive, commercial solvents.

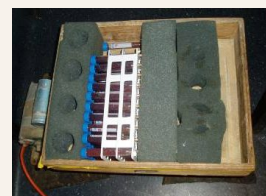
This presentation by Ryan Noble, including statistical tests, featured at the 2007 LEME Mineral Exploration Seminar. An abstract of Ryan's talk, entitled "New approaches to soil geochemical extractions" can be found on page 12 of the Abstract Volume

<http://crclleme.org.au/NewsEvents/Events/MinExp%20Abstract%20Vol%20Aug%2007.pdf>

A copy of the PowerPoint presentation is available on request. ryan.noble@csiro.au

Full disclosure...

- 0.5g soil added to 6 mL extractant in 15 mL polypropylene tube
- Shaken 2 hours
- Centrifuged 15 minutes (4500 rpm)
- Decanted and analysed by AA for Cu and Zn (SpectrAA10, Varian Instruments, Australia)
- All performed at STP, CO₂ gases equilibrated
- Extraction cost ~ \$3 (Aus) per sample in materials and analysis (not including time)



An Industry-led Bid for a New Cooperative Research Centre for Deep Exploration Technologies

As from 1st July 2008 the only two mineral exploration-focused CRC's will cease to exist:

CRC Landscape Environments and Mineral Exploration (CRC LEME) and CRC Predictive Mineral Discovery (pmd**CRC*)

Collectively these two CRCs attracted a total of AU\$38 million of funding from the Commonwealth Government which was leveraged by contributions from industry, other parts of government and by research institutions to a total spend of AU\$190 million over their seven year lifetime. CRC LEME in particular has provided explorers with hitherto unavailable expertise in understanding and sampling of the regolith and in particular is at the vanguard of developing new geochemical exploration capability particularly relevant to covered Australian terranes. The two existing CRCs combined will have produced 86 PhD and 10 MSc graduates by the time they close.

Many key exploration issues have been addressed by these CRCs, but the maturing nature of much of the Australian exploration environment, combined with the opportunities offered by the many unexplored areas with cover, require the development of new science and technology that will help fuel innovation and improve exploration success in both green fields and brown fields environments. A new Cooperative Research Centre for Deep Exploration Technologies has been proposed to develop the new science and technology.

The proposed CRC will have to focus on those areas of research that promise the greatest potential impact. Potential science & technology themes that could be considered for inclusion in the new CRC include deep targeting geophysics, deep-probing geochemistry, innovative data fusion techniques and better, safer and higher value drilling. The latter is particularly important as it is, after personnel, the single biggest cost item in exploration and a significant part of mine production costs and historically has attracted little concerted institutional research effort.

The mission of the proposed CRC is deeper discovery by opening up both the green fields and brown fields search space, through quicker, more effective exploration at depth and through cover.

A group of five companies, BHPB, Barrick, CVRD, Oxiana, Zinifex, and CSIRO is taking collective action through AMIRA International to fund the preparation of a bid for the new CRC. The companies involved, along with others that may join the initiative, will help to design the CRC by determining what the science and technology should be, who will be the research partners and what business model should be adopted. These companies will potentially be partners of the

CRC and collectively will have to commit to provide the necessary funds that the government will match.

Dr Tom Whiting has been engaged by AMIRA International to assist in the preparation of the bid. One of his key tasks is to consult with sponsors and other relevant stakeholders to define the technological challenges, the research themes and develop a suitable business model for the CRC. A critical part of this is also identifying and securing the support of suitable research partners. An Industry Steering Committee will assist in the preparation of the bid document. The application must be in by end of March 2008

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LEME Technology Transfer

This final year for LEME is all about delivery. As far as possible LEME papers and abstracts, posters and publications will be available on our web site <http://crcleme.org.au/NewsEvents/index.html> for reference and free download. We have highlighted just three recent events at which there was a major delivery of LEME regolith geoscience:

Kalgoorlie 07 Conference: Old Ground New Knowledge: 25-27 Sept 07, Kalgoorlie, WA.

The following were LEME presentations in the Landscape Evolution Session:

- **Ravi Anand. Advances in understanding regolith processes and element dispersion through transported cover, Yilgarn Craton (KEYNOTE - see below*)**
- Charles Butt. Palaeochannel uranium in southern Western Australia: déjà vu all over again
- David Gray. Yilgarn hydrogeochemistry
- Rob Hough. Gold nuggets as an indicator for exploration.
- Paul Morris (Matthias Cornelius, Ian Robertson and Amanda Cornelius). Regional geochemical patterns of the western Yilgarn
- Brad Pillans. Dating of regolith - implications for landscape evolution
- Steve Rogers. Geomicrobiology: a new perspective on regolith dispersion
- Lisa Worrall. Tertiary palaeovalley on the Yilgarn: geology and metallogenic significance

Dr Ravi Anand, LEME Program 2 Leader, delivered his presentation as part of a series acknowledging his award of the LEME/CSIRO Exploration and Mining 2006 Butt Smith Medal for 'outstanding and sustained contributions linking regolith science to mineral exploration in Australia'.

***Advances in understanding regolith processes and element dispersion through transported cover, Yilgarn Craton. Ravi Anand.**

In recent years, regolith geoscience by researchers from CRC LEME and CSIRO Exploration and Mining have

prioritised understanding of the:

1. dynamics of processes that determine the 3D structure of transported regolith, and
2. processes of metal mobility so as to make geochemistry work through transported regolith.

Reviewing some of the advances in these strategic areas, as applied to the Yilgarn Craton, the presentation covered: Multiple weathering profiles, Dating events, 3D regolith models, Objective logging of regolith, Mineral hosts for Au and trace elements, Ore grade 'laterite' deposits, Hydrogeochemistry, and Biogeochemistry.

Also, Dr Anand gave his Commemorative Address, as the 2006 Medallist, at the LEME Minerals Exploration Seminar, August 2007 "Twenty Five years of regolith geology and geochemical exploration in the Yilgarn Craton". Extended abstract on Pages 1 to 8 of the Seminar Abstract volume on the LEME web site - <http://crclleme.org.au/NewsEvents/Events/MinExp%20Abstract%20Vol%20Aug%2007.pdf>

19th International Geophysical Conference and Exhibition: Exploration and Beyond.
18–22 November 07, Perth.

LEME Program 1 Leader, Ms Lisa Worrall, received an Award from the Australian Society of Exploration Geophysicists for the BEST ENVIRONMENTAL/ GEOTECHNICAL PRESENTATION - an hour long invited keynote address entitled **Regolith Geophysics:**

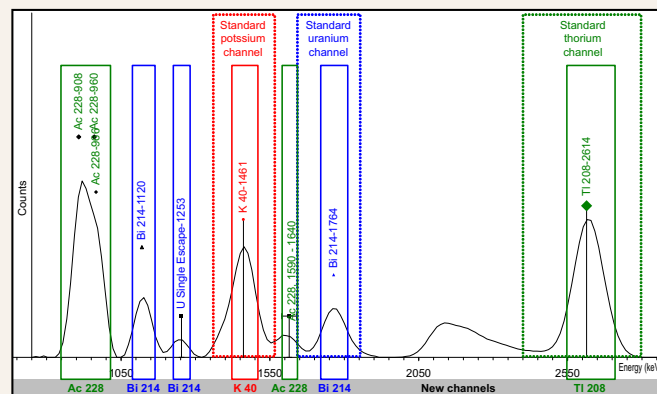
Retrospect and Prospect. This paper is available at: <http://crclleme.org.au/NewsEvents/Events/ASEG%20Nov07.html>

LEME presentations included:

- Kirsty Beckett. Mapping porosity and density changes in soil and regolith from 256-Channel Radiometric data.
- David Baker. Electromagnetic soundings of the regolith at Kalkaroo Mineral Prospect, Curnamona Province, South Australia.
- Kevin Cahill. Refined biophysical products appropriate for groundwater management - taking AEM data to the next step
- Richard Cresswell. Joining the dots: how airborne geophysics helps constrain hydrogeological models
- Andrew Fitzpatrick. Application of airborne geophysical data as a means of better understanding the efficacy of disposal basins along the Murray River
- Andrew Fitzpatrick. Determining appropriate AEM systems for groundwater exploration - a case study from the Eyre Peninsula, South Australia
- Michael Hatch. A n assessment of 'in stream' survey techniques along the Murray River, Australia
- John Joseph. Shallow geophysical and hydrogeological studies to characterise palaeochannel properties: a case study from Tanami Desert, NT
- John Joseph. Airborne measurements of natural source EM induction responses to study shallow

subsurface features: results from 3D numerical calculations

- Alan Mauger. Mapping regional alteration patterns using hyperspectral drillcore scanner
- Tim Munday. Frequency and/or time domain HEM systems for defining floodplain processes linked to the salinisation along the Murray River
- Gregory Street. Towards development of a risk management tool for roads affected by dryland salinity
- Gregory Street. Study of groundwater flow in sediments and regolith defined by airborne geophysical surveys
- Paul Wilkes. Geoscience, water and salinity in Rural Towns of Western Australia
- Lisa Worrall. Regolith Geophysics: Retrospect and Prospect
- **Kirsty Beckett. Poster: Inferring soil chemical and physical mobility using 256-Channel NAI radiometric data.** Kirsty was awarded BEST POSTER PRESENTATION by the Australian Society of Exploration Geophysicists. We are especially proud of Kirsty who recently completed her PhD at Curtin University of Technology, with a scholarship from CRC LEME. She is now employed by Rio Tinto, as Project Hydrologist. She has given permission for us to make her poster available on our website - <http://crclleme.org.au/NewsEvents/Events/ASEG%20Nov07.html> - and an extract from her poster re Multispectral Processing is shown below



MULTISPECTRAL PROCESSING

In order to extract additional information from the standard radiometric data, an alternative multispectral processing methodology was established. The objective of the multispectral processing technique was not to create an alternative method for calculating ground concentration of radionuclides, but to isolate individual gamma-ray peaks in order to assess whether a spatial relationship existed between the activity of the peak and soil type, soil properties and/or environmental conditions.

In order to separate the unwanted Compton scattered and x-ray energies from the direct emissions, a smooth

spectral 'hull' representing the bulk of the undesirable Compton scattered and x-ray energies was calculated and removed from the data, similar to the technique applied in multispectral satellite remote sensing. In this case study, the hull was defined using a simple series of constantly decreasing negative gradients bound by local lows in the spectrum. The hull for each sampled data point was determined independently and then subtracted to create a 'peak' spectrum that emphasized the energy peaks (shown previous page).

5th SPRIGG Symposium. Regolith: Mineral Deposits and Environment: 29 November 2007, The University of Adelaide

This event, hosted by the Geological Society of Australia SA Branch and sponsored by PIRSA and LEME, is held bi-annually in recognition of the remarkable contribution Dr Reginald Sprigg made to geosciences in South Australia. LEME Assistant Director Adelaide, John Keeling, was on the organising committee. It is fair to say that LEME regolith geoscience presentations from senior researchers and students from The University of Adelaide dominated the program. The PowerPoint Presentations are downloadable from the LEME web site:

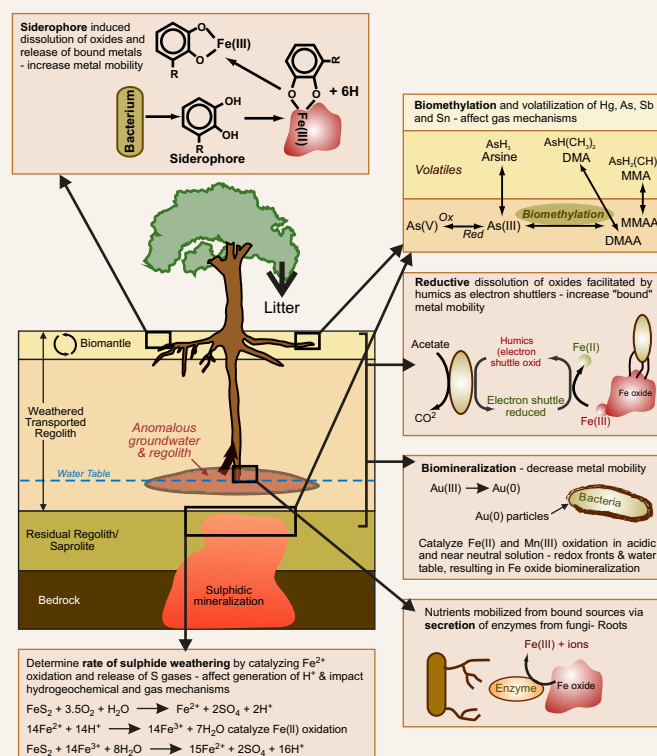
<http://crclleme.org.au/NewsEvents/Events/SpriggNov07.html>

- Aaron Brown. Soil vs biogeochemical expression of mineralisation buried by transported regolith: White Dam, Cu-Au, Curnamona Province, SA
- Barry Cooper. Sedimentary uranium. How it was first discovered in the Frome Embayment
- Robert Dart. Improving the reliability of Au-in-calcrete anomalies through the use of regolith-landform mapping and detailed assay analysis
- Jessie Davey. Incorporating surficial geology and the sedimentary record into tectonic driven landscape evolution models
- Adrian Fabris. Surface geochemical expression of bedrock beneath thick sediment cover, Curnamona Province, SA
- John Joseph. Electromagnetics for mineral exploration and environmental studies: Results from SA and NT
- John Keeling. Dr R C Sprigg - Contribution to geology and insights into landscape evolution
- Mel Lintern. Gold in calcrete - 20 years on
- Alan Mauger. Spectral mapping mineral alteration in the Central Gawler Gold province - Tarcoola case study
- Michael Neimanis. Plant biogeochemical expression of the Four Mile Uranium mineralisation - Frome Embayment, SA
- Anna Petts. Termitaria as regolith and landscape attributes: a case study from Titania Au prospect, NT
- Nathan Reid. Biogeochemical prospecting in the Tanami Desert

- Steve Rogers. Recent developments in regolith research with application to mineral exploration and environmental management (KEYNOTE)
- Malcolm Sheard. Gawler Craton regolith benchmarking: origins, types, utility and where.
- Clinton Dubieniecki. Constraints on the Four Mile uranium mineralisation resulting from neo-tectonic activity in the northern Flinders Ranges
- Deanne Gallasch. Uranium mineralisation expression and dispersion in the regolith carbonate-bedrock-plant system near the Four Mile West uranium prospect
- Andrew Hector. Upper Four Mile Creek palaeosediments and associated palaeolandscapes reconstructions, Eromanga Basin, northern Flinders Ranges, SA
- Mikaela Jennings. Biogeochemical trace element cycling over the Four Mile West uranium mineralisation by invertebrate soil biota
- Joanna McMahon. Biogeochemical and geochemical expressions of uranium prospectivity across the Four Mile Creek Catchment SA

Geomicrobial Mineralisation

Aspandiar *et al* (2006) LEME Restricted Report 230



Extract from Dr Steve Rogers' Keynote presentation - SPRIGG Symposium, 29 Nov 07

LEME Annual Report 06-07. PDF available now for download. Includes latest research highlights and advances in mineral exploration regolith geoscience.

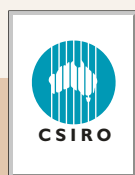
<http://crcleme.org.au/Pubs/annualreports.html>



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CRC LEME is the cooperative research centre for regolith geoscience with some 130 contributing researchers from eight Core Parties around Australia. We generate and apply regolith knowledge for mineral exploration and environmental management.



Your organisation can benefit from CRC LEME expertise.
<http://crcleme.org.au>